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Westinghouse Astronuclear Laboratory

TEST CELL "A" NARROW BAND DATA ACQUISITION
ACCURACY TEST EVALUATION

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February 1966

TEST CELL "A" NARROW BAND DATA ACQUISITION
ACCURACY TEST EVALUATION

Submitted By

Westinghouse Electric Corporation
Astronuclear Laboratory
P. O. Box 10864, Pittsburgh, Pa., 15236

Prepared by

W. H. Horton
Product Assurance P. Blau
Instrument Systems Engineering

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Approved by

R. F. Roller, Supervisor
Instrument Systems Engineering
Instrumentation and Control R. W. Kaisner, Manager
Instrumentation Systems and Facilities Support
Instrumentation and Control

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1.0 INTRODUCTION

1.1 PURPOSE

This report presents the results, and a description of how they were obtained, of an accuracy test of the narrow band data acquisition system at Test Cell "A".

The test was proposed because the quality of the NRX vehicle design and performance is dependent on the knowledge of the accuracy of the test measurements. Prior to this test conflicting opinions existed as to the accuracy of the Test Cell "A" data system.

The final revision of the test plan, WANL-TME-1161, incorporated both the statistical and technical approach to the method of testing the data acquisition system. The test plan was reviewed and agreed upon by SNPO, AGC, EG&G, NTO, and WANL. Detailed test procedures and test operations were produced and conducted by EG&G personnel and monitored by WANL and NTO personnel. Additional details are covered in the references and the Appendixes.

1.2 SUMMARY TEST DESCRIPTION

From over three hundred narrow band diagnostic NRX-A3 data channels, ten basic transducer channel configurations were present. For each configuration, four identical channels were selected for the accuracy test. These 40 channels were maintained as they were used during the NRX-A3 test runs to enable a comparison of the accuracy test data with the NRX-A3 data.

For the test runs, a known simulated transducer output was provided to duplicate each of the ten basic NRX-A3 transducer configurations. These simulated signals were used as parallel inputs for each set of four identical channels.

Twenty-eight separate test runs during three different time periods were made to determine linearity, drift, crosstalk, and frequency response. By changing certain data components between these time periods, component contributions to channel inaccuracy were to be evaluated.

2.0 TEST OBJECTIVES

The accuracy test was designed to investigate the following objectives.

2.1 BASIC ACCURACY TEST OBJECTIVES

- 2.1.1 Determine overall channel accuracy (error band limits).
- 2.1.2 Determine channel linearity, drift, noise, zero offset.
- 2.1.3 Determine channel frequency response.
- 2.1.4 Determine channel crosstalk.
- 2.1.5 Determine the contribution of data instrument component error (amplifier, etc.) to channel inaccuracy.
- 2.1.6 Provide data that would permit component error contribution isolation if large errors were encountered.

2.2 ADDITIONAL ACCURACY TEST OBJECTIVES

Certain additional evaluations were required by WANL-TME-1161 and are covered by this report. These are:

- 2.2.1 An evaluation of the quick-look system (Sanborn recordings).
- 2.2.2 A comparative analysis for the same channels between the CAL-COMP plots of the accuracy test and the NRX-A3 calibrations.
- 2.2.3 An evaluation of the NRX-A3 ambient run data for the same channels used in the accuracy test.
- 2.2.4 A comparative analysis for the same channels between the N3 tape values of the accuracy test and the NRX-A3 calibrations.
- 2.2.5 An evaluation of changes in channel accuracy due to the installation of new data amplifiers and multiplexers.
- 2.2.6 An evaluation of the manually recorded data.

3.0 SUMMARY OF TEST RESULTS

3.1 BASIC ACCURACY TEST RESULTS (Statistical Evaluation)

The statistical summary of the data for the basic accuracy test is tabulated below according to configuration-multiplexer type. The values listed are the channel accuracies (99% confidence*, $\pm$ limits, % of full scale), and represent (1) the accuracy test data resulting from inserting inputs at the car plug through the acquisition and reduction systems, and (2) the calibration data resulting from inserting inputs at the signal conditioner through the acquisition and reduction systems.

The tabulated accuracy values are configuration-multiplexer oriented because channel configurations have different accuracy values when used with different multiplexers. A complete data analysis presentation is given in section 6.0.

<u>Configuration</u>	<u>Multiplexer</u>	<u>Type</u>	<u>Input at Test Car Plug</u>	<u>Input at Signal Conditioner</u>
1	H01	EG&G	1.64	.439
2	H01	EG&G	.645	.484
3	H01	EG&G	1.03	.416
1	H02	EG&G	1.06	.673
2	H02	EG&G	2.12	1.27
3	H02	EG&G	2.34	.676
4	H04	EG&G	2.12	1.14
4	H05	EG&G	1.80	1.08
8	L09	SEL	1.42	.598
9	L09	SEL	1.37	.595
9	L02	SEL	1.48	1.76
10	L02	SEL	1.16	1.66
8	L10	SEL	2.07	1.34
10	L10	SEL	3.95	1.30

*99% confidence signifies that there is a 99% assurance that any single observation, plus and minus the stated limits, will contain the true value.

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<u>Configuration</u>	<u>Multiplexer</u>	<u>Type</u>	<u>Input at Test Car Plug</u>	<u>Input at Signal Conditioner</u>
5	L03	BEN	2.73	2.25
5	L04	BEN	2.00	1.85
6	L05	BEN	1.58	1.14
7	L05	BEN	1.84	1.21
6	L06	BEN	2.39	1.28
7	L06	BEN	2.58	1.25

3.2 BASIC ACCURACY TEST RESULTS (Engineering Evaluation)

The following tabulation is an engineering interpretation of the statistical summary data presented in sections 3.1 and 6.0 organized on two bases:

- a) Maximum channel accuracy values oriented by multiplexer type. Such accuracy figures may be used for estimating accuracy for specific channels, rather than the data system as a whole.
- b) One overall channel accuracy value for general use, and applying to the entire data system.

3.2.1 NRX-A3 MAXIMUM CHANNEL ACCURACY VALUES BY MULTIPLEXER TYPE (99% Confidence, $\pm$ Limits for Percentage of Full Scale)

<u>Multiplexer</u>	<u>Input at Test Car Plug</u>	<u>Input at Signal Conditioner</u>
EG&G	2.34	1.27
SEL (prior to NRX/EST)	3.95	1.76
Bendix	2.73	2.25
Linearity	= Insignificant	
Drift	= 0% to 2.66%	
Noise	= .096% to 1.85%	
Sanborn Recording Readability	= 1.89%	

CAL-COMP plot readability is dependent on transducer range as indicated on Table XVIII, and therefore one overall value is not obtainable. (See section 6.7)

3.2.2 NRX/EST CHANNEL ACCURACY VALUES (99% Confidence, $\pm$ Limits for Percentage of Full Scale)

Because of the improvement shown in the channel calibration accuracies after installation of the new data amplifiers and multiplexers (the Bendix and older SEL multiplexers have been removed), the following values should be used for NRX/EST.

<u>Multiplexer</u>	<u>Input at Test Car Plug</u>	<u>Input at Signal Conditioner</u>
EG&G	2.34	1.27
SEL	2.07*	1.95*
Linearity	=	Insignificant
Drift	=	0% to 2.22%
Noise	=	0.096% to 1.34%
Sanborn Recording Readability	=	1.89%

3.2.3 Accuracy values are used for two reasons, (1) analytical evaluations and (2) general communication purposes. NRX-A3 channel accuracy evaluations should be based on the values given in section 3.2.1.

*The 2.07% value is an overall channel accuracy estimate for the new SEL multiplexers. After installation of the new SEL multiplexers, the NTO time schedule permitted only a voltage calibration and not a signal insertion test from the test car plug. The 2.07% value was obtained from Table XI and section 3.1 for SEL multiplexer L10, configuration 8. This selection is based on the observation that the accuracy test (old) SEL multiplexer channel values were not greater than 2.07% with the 3.95% value considered unrealistic because the Table XI maximum drift and bias values underlined (for 3.95) are abnormally high in comparison to all the other underlined values for bias and drift. Furthermore, this value is obtained on multiplexer L10 with configuration 10, and on this same multiplexer with configuration 8, the maximum channel accuracy value is 2.07; the other maximum accuracy values for the SEL multiplexers are below 2%. The 1.95% calibration estimate is obtained from the maximum noise variance of 0.0266 from Table XVI for the new SEL multiplexer L06 and the maximum drift variance of 0.3446 from Table XII for the old SEL multiplexer 9-L02. The voltage calibration tests on the new SEL multiplexers did not produce a drift value; therefore, the accuracy test (old SEL) drift values were used. The sum of the standard deviations for these values is 0.75; multiplying by 2.6 results in the 99% confidence $\pm$ limit of 1.95%.

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3.2.3.1 NRX/EST and future TCA channel accuracy predictions should be made on a channel-by-channel basis as shown in section 3.2.2.

3.2.3.2 OVERALL CHANNEL ACCURACY OF THE DATA SYSTEM

The accuracy of the data system, when referred to as an entity, may be termed as $\pm 2.3\%$.

3.2.4 Channel frequency response has been grossly determined, and is described in section 6.2.5.

3.2.5 Channel crosstalk has been considered from its effect on other parameters. (See section 6.1.5)

3.2.6 Interchange of amplifiers or signal conditioners had no effect on channel inaccuracy. Multiplexer effects on channel inaccuracy were quite significant and varied widely, causing the differences noted in section 3.2.1.

3.2.7 No large errors associated with components were encountered.

3.3 ADDITIONAL ACCURACY TEST OBJECTIVE RESULTS

3.3.1 Data on Sanborn recordings were read within $\pm 1.89\%$ of full scale by different readers. An analysis indicated that the V_4 full scale and zero voltages (which are amplifier outputs, and consequently the inputs to the Sanborns) were read in the ELR on digital voltmeters to within $\pm 0.34\%$ of the actual readings. (See section 6.8)

3.3.2 A comparison of CAL-COMP plots made from NRX-A3-EPI and accuracy test data revealed significant differences. NRX-A3 plots without exception had higher error values; however these were made prior to the use of the new NDRS computer program.

3.3.3 Analysis of the ambient run data from NRX-A3-EP5 for the same channels indicated that the transducer ambient noise contribution ranged from 0% to 0.924%.

3.3.4 A comparative analysis for the same channels between NRX-A3 and accuracy test voltage calibrations yielded values of the same order of magnitude as seen in Table XIII.

3.3.5 An improvement in channel calibration inaccuracies (as much as 50%) because of installation of the new data amplifiers and multiplexers was observed.

3.3.6 Evaluation of the manually recorded linearity run data indicated that a comparison with the accuracy test linearity run data was not plausible.

3.3.7 An evaluation of the data system by statistical analysis of the pre- and post-voltage calibrations should yield a good estimate of the channel noise, and possibly drift. Such calibrations ignore cable and transducer effects, and therefore may not be predictive of overall channel error.

4.0 DATA COLLECTION AND PRELIMINARY DATA REDUCTION

Activation of a transducer during a reactor test, or activation of a programmable power supply during calibration, produces an analog signal conditioned by the data acquisition channel components. This signal is recorded on an analog tape, designated the N1 tape. The analog data are then digitized by the Astrodata PAM telemetry digital decommutator under the control of the CDC 160-A computer over specific time intervals and at specific sampling rates (controlled by input cards and manual switches) to produce a digitized tape, designated N2. Data on this digitized tape are then processed by an IBM 704 computer to yield an additional digitized tape, designated N3. N3 tape data are always expressed in engineering units; such data are generated by considering both the channel voltage calibration and the transducer conversion.

In processing data from a standard calibration run, digitized data on N2 tapes can be converted to percentage of full scale values on N3 tapes in the following manner: all count data on N2 tapes are put into a one-to-one relationship with the voltage steps taken during the calibration run; a "best" linear fit to the count data versus steps as percentage of full scale is computed by the least squares method; the resulting expression, relating counts to percentage, is used as the channel voltage calibration. Insertion of a dummy transducer conversion allows the data on the N3 tape to be expressed as percentage of full scale.

For data other than that from a standard calibration run (i.e., reactor test data or that data generated for this accuracy study), coefficients for the expression obtained for the appropriate channel voltage calibration run are used to adjust all N2 count data in converting these data to engineering units on N3 tapes. Thus, the process of fitting a linear relationship to the standard calibration data establishes the full scale through zero count values for all subsequent data and may reflect values different from those specified as nominal for the channel.

The N3 tape may be further processed on the IBM 704 computer to obtain a tape, designated N4, for plotting of time-versus-function (voltage) curves by California Computer Corporation (CAL-COMP) plotters. Also, during reactor test or during calibration, data can

be observed via the quick-look system. This system takes a voltage signal from the data channel amplifier directly into the input of Sanborn recorders. The resulting data are plots of time-versus-voltage as a percentage of full scale.

4.1 N3 TAPE DATA

For the most part, the analysis and results reported herein will be concerned with N3 tape data, where such data were processed as percentage of full scale values, using dummy transducer conversions.

4.1.1 BASIC ACCURACY TEST DATA

4.1.1.1 CHANNEL SELECTION

As described in WANL-TME-1161, the basic accuracy test was to consider 10 basic channel configurations as covering most of the diagnostic measurement possibilities.

For each configuration, four identical channels were selected with, in each case, two of the four channels as inputs to one multiplexer and the other two, as inputs to a second multiplexer. Data were to be obtained on the 40 channels so represented during three test phases. Phase I specified that the 40 channels for this test were to be as connected for NRX-A3 test runs. Phase II specified the interchange of amplifier or signal conditioner for the pairs of channels having the same configuration and multiplexer. Phase III specified an interchange of multiplexers by pairs for the same configuration with amplifiers or signal conditioners the same as found in Phase I. (See Appendix A for further detail on channel configuration and description.)

4.1.1.2 CONDITION OF OTHER TEST CELL EQUIPMENT DURING TEST

The 40 channels tested represented the diagnostic acquisition system under typical operating conditions; however, certain controls in effect should be noted. The wide band, neutronics, and controls system channels were not energized. A printed circuit board was used in conjunction with the program patchboard to facilitate the various

crosstalk tests. All unused multiplexer inputs were shorted by use of jumpers on the printed circuit board. Forty resistance thermometer signal conditioner modules were used to simulate transducer inputs and impedances. Further details are available in sections 5.3 and 5.5 of EG&G Procedure No. AD.3 and section 3.2.3 of WANL-TME-1161.

4.1.1.3 DATA TAKEN AND MODE OF HANDLING

During each phase, data corresponding to standard calibration, AC frequency response, AC and DC crosstalk, and special linearity runs were to be obtained. The specific sequence of data runs can be seen in Table I. A detailed description of these test runs may be found in Appendix A and EG&G Detailed Procedure No. AD.3. For any one step of these test runs, data were to be generated for at least 10 seconds. If the test run did not involve discrete steps (i.e., AC frequency response and some crosstalk runs), data were generated for at least 100 seconds. In converting the N1 analog tape data to N2 digitized tape data, a sampling rate of 5 data points per second was used. Referring to Table I, data corresponding to items (2) through (10) were adjusted by data system calibration 1 (step 1). Data corresponding to items 12 through 17 were adjusted by data system calibration 2 (step 11). Data corresponding to items 19 through 29 were adjusted by data system calibration 4 (step 18). Dummy transducer conversions were used such that the data on N3 tapes were expressed as percentage of full scale. The total number of data points was approximately 1.9 million. As N3 tape data, this number was to be further reduced by additional computer programming and handling.

4.1.2 NRX-A3 CALIBRATION DATA (See Section 2.2, "Additional Objectives")

WANL-TME-1161 required a comparative analysis for the same channels between the data system calibrations as recorded on the N3 tapes for the accuracy test, and for the NRX-A3 test. Data system calibrations number 2 (time 84320 to 84430) and 3 (time 39190 to 39300) for Phase I of the accuracy test were compared with the pre- and post-calibrations of the NRX-A3-EP5 run (times 34590 to 34700 and 41030 to 41140).

4.1.3 NRX-A3 AMBIENT DATA (See Section 2.2, "Additional Objectives")

The accuracy test plan required an evaluation of the ambient run data from NRX-A3 in order to establish the transducer contribution. Since the accuracy test was performed under controlled conditions by simulating transducer output signals at ambient conditions, a comparison with the ambient run data from NRX-A3 for the same channels would enable an evaluation of the noise level of the transducers. NRX-A3 ambient data evaluated were from EP5. For this report, transducer contribution is defined as the noise level associated with the portion of the channel on the test car; i.e. transducer, cabling, terminal board, and test car plug.

4.1.4 NEW EQUIPMENT DATA (See Section 2.2, "Additional Objectives")

New Neff amplifiers and low level SEL multiplexers were installed in the narrow band data channels after the accuracy test was completed. An N3 tape (in percentage of full scale value) was made of two data system calibrations (at two different times). Table II is a list of forty channels and associated multiplexers selected for evaluation. These new equipment data were compared with accuracy test data system calibrations numbers 2 and 3 of Phase I.

4.2 SANBORN DATA (See Section 2.2, "Additional Objectives")

WANL-TME-1161 required an evaluation of the data obtained by Sanborn recordings. Data from the accuracy test data system calibration number 2 of Phase I (time 84320 to 84430) and data system calibration number 3 of Phase III (time 47510 to 47620) were used for this evaluation. The following nine channels were randomly selected for these accuracy test runs and recorded on the Sanborn recorders.

T-607	T-663	P-124
T-763	T-602	P-210
T-601	T-139	PD-203

These Sanborn recordings were made during the system calibrations while the data were also being recorded on the N1 tapes.

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4.3 CAL-COMP DATA (See Section 2.2, "Additional Objectives")

WANL-TME-1161 required a comparative analysis for the same channels between the CAL-COMP plots of the accuracy test calibrations and the NRX-A3 calibrations.

Data from the accuracy test data system calibration number 2 of Phase I (time 84320 to 84430) and data system calibration number 3 of Phase I (time 39190 to 39300) were used.

Data from the NRX-A3-EP1 pre- and post-system calibrations (times 4650 to 4760 and 49510 to 49620) were used.

The following ten channels were randomly selected for this analysis:

T-603	DP-049	M-254
T-601	T-245	T-216
P-124	T-856	T-854
		P-406

4.4 BASIC ACCURACY TEST MANUAL DATA

Table I also indicates that a number of manual measurements were required in each phase of the basic accuracy test. The measurement points are identified in the block diagrams of the channel configurations in Appendix A. An analysis was made of the manually recorded linearity run and V4 voltage data.

5.0 SECONDARY DATA REDUCTION

As indicated in section 4.0, channel signals result in either Sanborn plots, CAL-COMP plots or N3 tapes. Data reported by any one of these modes must be further reduced if an analysis is to be made.

5.1 N3 TAPE DATA REDUCTION

All N3 tape data, expressed as percentage of full scale values, were reduced by computer program to yield two values for all time periods (generally 10 seconds duration) for which the data were consistent. Frequency response and AC crosstalk data runs did not have a consistent time base and were not reduced in this manner. (For further details see Appendix B.)

The two values computed were the average ($\bar{X}$) and a variance estimate (s^2) based upon the first 40 readings for the time period. The average value was computed by summing the first 40 values and dividing this sum by 40. The variance estimate was computed by summing the squares of the deviations of the first 40 values from the average of these values and dividing this sum by 39. Algebraically:

$$\bar{X} = \frac{\sum_{i=1}^{40} X_i}{40}, \text{ and } s^2 = \frac{\sum_{i=1}^{40} (X_i - \bar{X})^2}{39}$$

5.2 SANBORN AND CAL-COMP DATA REDUCTION

Ten people of varying experience in reading plotted data were randomly selected as data readers from WANL Instrumentation, Systems Analysis, Reactor Analysis, and Mechanical Design groups. All were given the same instructions and forms for recording their observations.

For the Sanborn recordings, each reader wrote down his observations of maximum and minimum values for the full scale and zero limits. The Sanborn recordings of calibrations are plotted data in percentage from full scale to zero.

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The same ten people also read the CAL-COMP plots. Since CAL-COMP plots have a larger Y-axis scale than Sanborn recordings, each reader recorded maximum and minimum peak values, plus a nominal value for each full scale, midpoint, and zero level as plotted.

Sanborn plots used by the readers were Xerox reproductions of the accuracy test originals. The CAL-COMP plots used by the readers were made as follows: (1) NRX-A3 plots were Xerox copies of reproductions from 16mm microfilm negatives of original NTO plots, (2) accuracy test plots were Xerox copies of original accuracy test blue-lines.

6.0 DATA ANALYSIS

With the data in reduced form, formal analyses may be completed to define those parameters affecting the determination of an accuracy value for a data channel. Naturally, the format (i.e., percentage of full scale value, Sanborn recordings, or CAL-COMP plot) of the data may affect the accuracy value; thus, separate accuracy values must be determined for each data type.

6.1 DEFINITION OF ACCURACY PARAMETERS

Although WANL-TME-1161 defined the accuracy parameters and the methods by which these were to be evaluated, subsequent examination of the N3 tape, Sanborn, and CAL-COMP outputs revealed that more meaningful and more rigorous definitions and methods should be used. The accuracy parameters used in the data analysis are as follows.

6.1.1 NOISE

Noise is defined as an evaluation of the random fluctuations in signal output as compared to the average of the output. For the N3 tape data, noise is determined by the variance estimates described in section 5.1. For the Sanborn and CAL-COMP plotted data, noise is determined by a somewhat more complicated technique subsequently described in section 6.6.

6.1.2 LINEARITY

Linearity is defined as an evaluation of the deviations from a fitted linear relationship compared to the random fluctuations in the data, i.e., compared to the noise in the data. Thus, linearity is truly an evaluation of the non-linearity of the data. For all data for which there was a step function introduced (e.g. voltage calibrations on N3 tapes or CAL-COMP plots), a linear relationship was fitted to the data by the least squares method and deviations from this "best" fit compared to the noise for the same data.

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6.1.3 DRIFT

For a full scale input voltage applied at several distinctly separate times, some variation in N3 indicated voltages can be expected. This variation represents (primarily) full scale drift (or gain stability) 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 should 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. Thus, drift is obtained by comparing the linearity curves taken at several separate time intervals.

6.1.4 BIAS AND STATISTICAL BIAS

While not explicitly covered in WANL-TME-1161 as an accuracy component, bias definitely can contribute to the data channel output inaccuracy. Bias may be defined as the disagreement between common signal input and average signal output for computer processed data or as the disagreement among different readers observing the same point on plotted data. For computer processed data bias is quite similar to full scale drift (gain stability) and zero offset drift as discussed in WANL-TME-1161.

In addition, the disagreement between pairs of channels having the same configuration, processed through the same multiplexer and activated under the same conditions indicates a parameter of accuracy not covered by any of the previous definitions. A measure of this disagreement has been called statistical bias and is evaluated for all N3 tape data.

6.1.5 CROSSTALK

Crosstalk, per se, is not an accuracy parameter but is an evaluation of the previously defined parameters in the presence of coupling. Thus, crosstalk must be considered in terms of its effect on the parameters of noise, linearity, drift, and bias.

6.1.6 FREQUENCY RESPONSE

Frequency response is the fidelity of the data system in reproducing signals of varying frequency. Distortion of signals by active components, such as amplifiers, results in degraded frequency response.

6.2 BASIC ACCURACY TEST DATA ANALYSIS

With the basic data in reduced form (averages and variances of forty readings as described in section 5.1 and Appendix B) individual accuracy parameters can be evaluated. The basic test plan enumerated ten channel configurations that were thought to be significantly different, such that distinct accuracy values for each of these might be derived. Thus, all analyses were performed with these configurations as of primary interest; however, in reducing the basic data further, multiplexer and type of test run are seen to be the areas towards which accuracy values should be oriented. This is to say that channel configurations have separate accuracy values when these have different multiplexers. In addition, an individual configuration could have more than one accuracy value with the number dependent upon the number of different multiplexers used with the configuration.

A discussion of the accuracy parameters as defined in section 6.1 and in accordance with the preceding comments now follows.

6.2.1 NOISE

In section 6.1.1, noise was defined as an evaluation of the random fluctuations in signal output as compared to the average of the output with the value for noise to be estimated by a variance (s^2). The reduced data resulted in approximately 25,000 variance estimates describing noise.

These estimates were analyzed by the techniques described in Appendix B to assess whether or not the differences in these estimates could be attributable to any consistent or systematic effects. Differences were found to be randomly oriented insofar as discrete steps in a test run, and test run to test run within a phase, were concerned. To rationalize these differences would present a virtually impossible task; thus the noise estimates were

averaged for each of the 40 test channels for each test run for each phase. Noise estimates so averaged are presented in Tables III and IV. In considering these values, it must be realized that the values presented are optimistic, in that both maximum and minimum estimates are hidden in the averaging process. The loss of the minima is not serious but the loss of the maxima does result in an optimization.

Two tables are presented to divorce those readings taken from the source signal conditioners as a part of the accuracy test from those readings taken during the test following the standard calibration procedure. The estimates found in these tables will be combined with other accuracy parameters in a subsequent section.

6.2.2 LINEARITY

In section 6.1.2 linearity was defined as an evaluation of the deviations from the "best" linear relationship for a set of data as compared to the noise for the same set.

The reduced data resulted in approximately 25,000 averages. Analyses of these data using the techniques described in Appendix B enable not only the assessment of the linearity parameters but also the assessment of the parameters, drift, and statistical bias. As discussed in Appendix B, the first analyses were configuration oriented. Subsequently, analyses were made on pairs of channels of the same multiplexer configuration combination.

Of the 180 analyses for which the data had discrete steps (i.e., data were in the standard calibration form from 100 to 0 percent in eleven steps) only one analysis resulted in a significant linearity parameter estimate. This implies that the non-linearity of data channels is not of sufficient magnitude to contribute significantly to data channel inaccuracy.

6.2.3 DRIFT

Drift, as defined in section 6.1.3, is a comparison of the linearity curves taken at several separate time intervals. In essence, drift is a comparison of the differences in these curves versus the random differences expected in the data and as measured by the variance for these differences, or noise. Since, as discussed in section 6.2.2, there were

not significant non-linearities, any difference between distinct data points taken at several separate time intervals would also enable an evaluation of data channel drift.

In performing the analyses as described in Appendix B, the first approach to an evaluation of drift was as implied in WANL-TME-1161, that is, to determine at least short term and long term drift and possibly a relationship of drift as a function of time. These analyses indicated that, in this data system, drift cannot be considered as a definitive function of time or as different between short and long term periods. In other words, differences between linearity curves taken at several separate time intervals vary randomly such that the degree of drift from one interval to the next is predictable only as a variance estimate reflecting random differences. It is possible that a time-dependent drift trend could have been observed if the system had not been warmed up prior to the test. However, such useage would not be ordinary for the data system, and has been ignored.

Tables V and VI give the variance estimate of drift for the basic accuracy test data. Both tables present drift parameter estimates derived for the data obtained during each phase of the accuracy test. Table V contains those values for the data from the source signal conditioners, and Table VI, those values for the data obtained during calibration runs made with the data signal conditioners. Both tables are multiplexer-configuration organized.

The data presented in these tables reflect the difficulty experienced in deriving a single drift estimate for any particular combination and further indicate the "true" randomness of the drift parameter. As may be seen in these tables, the contribution of drift to data channel inaccuracy may be zero (not significantly greater than noise) or relatively large. In Table V, the variance estimate of 1.0467 for 10-L10; DC-1, 2, 5 and 6 crosstalk runs, Phase I, seems unusually large with respect to the remaining entries in this table. However, no explanation as to the cause of its occurrence can be given.

6.2.4 BIAS

Section 6.1.4 defined statistical bias as the disagreement between data for pairs of channels having the same configuration, processed through the same multiplexer and

activated under the same conditions. Variance estimates for this parameter were determined as described in Appendix B and are presented in Tables VII and VIII.

The data presented in these tables indicate that statistical bias (differences between pairs of channels) has the characteristics of a random parameter with the contribution of this parameter to data channel inaccuracy varying from zero to relatively large values. In Table VII the variance estimates of 1.0475 for 10-L10 and 1.6442 for 7-L06 seem unusually large with respect to the remaining entries in this table. No explanation for the channel differences can be given for 10-L10; however, the manual recordings for the two channels for 7-L06 indicate this difference was present in the input signals.

Tables IX and X present components of bias similar to full scale drift (gain stability) and zero offset drift. These tables contain averages of data for pairs of channels for the 100% and 0% settings. The small (in most cases) differences between the nominals of 100% and 0%, and the average outputs for the calibration runs are probably associated with the determinations of the linear relationships as described in section 4.0. These differences were not used in this report. The differences in the average outputs between the calibration runs, and the linearity and crosstalk runs (averages between these are the values most realistically compared) for the most part are slightly larger than the differences between nominal and average calibration outputs. Again these may be reflections of the determination of the linear relationship, or possibly a result of the two different input sources. However, a comparison of the crosstalk and linearity averages would seem to discount the latter. The unusually low linearity and crosstalk full scale values for 4-H04 do agree with the manual inputs, as do the two low full scale values for 7-L06.

6.2.5 FREQUENCY RESPONSE AND DATA ALIASING

The question of the error contribution of the data system that is associated with frequency response must be handled separately from all other considerations, because the frequency content of the data signal may vary over a large range. Tests were made as described in WANL-TME-1161 to determine the fidelity of the Test Cell "A" narrow band system in reproducing signals of varying frequency content. Test signals of 100% full scale amplitude

were inserted in all channels, at frequencies of 0.1, 1.0, 5.0, and 10.0 Hertz. Results have pointed out that two decidedly separate phenomena may be observed.

1. The sampling rate of the narrow band system multiplexer produces a cutoff frequency above which signals will be aliased.
2. Regardless of the sampling frequency of the multiplexer system itself, the sampling frequency of the computer reduction and plotting routine also produces a cutoff frequency above which aliasing may be observed.

Thus, to report the findings of the frequency response analysis the subject must be broken into two subheadings: normal frequency response, and aliased data. These two subjects will be treated as follows:

1. Normal frequency response will be considered as applicable to all signals that fall below the so-called foldover frequency (less than half of the sampling rate). The effect of distortion by the sampling system and the plotting system will be studied.
2. Signals whose frequencies are above the foldover frequency for the data system and/or data reduction system will be treated as if aliasing has occurred. This phenomenon will be explained in detail and proof that aliasing does occur in the data system will be given.

No attempt will be made to analyze aliased data, since the phenomenon of aliasing cannot be prevented in the present data system.

6.2.5.1 ANALYSIS OF NON-ALIASED DATA

Data frequency content and data system fidelity in reproducing this content are of significant interest to the data user; however, it is difficult to evaluate the effect of distortion on the accuracy of a data system. In any sampled-data system the fidelity of reproduction of a given signal depends upon the frequency content of the signal itself; usually the fidelity of various amplifiers and signal-passing components is negligible with respect to the sampling error. Thus, to evaluate the effect of the frequency response on the channel itself, it is necessary to know the frequency content of the data as they exist.

This information is not usually available, and indeed, if any aliasing is present, an erroneous interpretation of the frequency content can be derived. Data systems employ DC amplifiers with bandwidths of at least 50 cycles per second; the distortion levels not related to sampling involved in signals below this frequency are very small, and are negligible when compared with the overall accuracy of the data system. Since aliasing occurs in the Test Cell "A" data system for any frequency in excess of 2.5 Hertz (if the usual data reduction methods are employed), it may be assumed that the signal passing components exclusive of the multiplexer may be considered as not contributing to data inaccuracy. Thus, all observed inaccuracies have to do with the actual sampling of the waveform rather than with non-linear amplification of it.

It is obvious that the number of samples taken per cycle of the stimulus waveform will influence the fidelity of the output from a sampled data system. (See Figure 1.) The maximum distortion will occur when the sampling rate is exactly twice the frequency of the maximum signal component present. In the NRDS data system, the minimum sampling rate for either the data acquisition or the data reduction components is presently 5 samples-per-second. In reducing these data, sample data points are connected by straight lines, and thus a 2.5 Hertz waveform would be reproduced approximately as Figure 2 indicates. In a more practical sense, data in excess of 1.0 Hertz should not be considered as valid in a 5 sample-per-second data system. A 1.0 Hertz wave sampled at 5 samples-per-second is reconstituted as shown in Figure 3.

The frequencies utilized in the test setup that will appear as non-aliased data are 0.1 Hertz and 1.0 Hertz at the 5 sample-per-second rate first utilized in reduction. A 0.1 Hertz waveform, when sampled at 5 samples-per-second theoretically will produce a waveform as shown in Figure 4. Figures 5 and 6 illustrate data taken at 5 samples-per-second of waveforms of the frequencies described. It is to be noted that the output waveform closely matches the anticipated output waveform as shown in Figures 3 and 4. It may thus be assumed that the distortions present in the waveform are (as predicted) those associated with the sampling of the data. The 1.0 Hertz waveform of Figure 6 also clearly

shows the effect of the 0.1 Hertz power supply modulation observed while the test was being taken.

If the sampling rate is increased to 40 samples-per-second, no data taken in the test will be aliased. Distortions of a 10.0 Hertz waveform sampled at 40 samples-per-second will be quite similar to those observed for a 1.0 Hertz waveform sampled at 5 samples-per-second, since the ratio of the frequency to the sampling rate is approximately the same in both cases. Examples of such results are shown in Figure 7, where a 5.0 Hertz waveform has been sampled at 40 samples-per-second. No attempt has been made to factor the percentage distortion observed into the accuracy calculations for the channels tested, since the frequency content of the data cannot be pre-determined.

6.2.5.2 DATA ALIASING

The phenomenon of data aliasing is apparent in the plotted results of the frequency response check. An explanation of this aliasing and its effect on data will now be given.

A fundamental law in sampling of data, commonly referred to as the Hartley-Shannon Law, states that the sampling frequency must be at least twice the maximum signal frequency in any noise-free system, to properly reproduce the signal waveform.

$$f_d \geq 2 f_s \quad (1)$$

where f_d = sampling frequency of data system, and f_s = signal frequency.

To illustrate the effect of sampling, consider the waveform of Figure 8a, which has been arbitrarily chosen to be a pure 3.0 Hertz wave. From Equation (1), sampling must be performed at a rate of excess of 6 samples-per-second. In Figure 8b, the output waveform is given, assuming that sampling is set for 6 samples-per-second. It should also be noticed that the exact sampling point in the cycle has been carefully determined; if it had not been, it would be possible to sample exactly on the zero-crossing points, and no output could be observed. Normally, f_d is held to approximately $10 f_s$ to eliminate possible problems such as this.

In Figure 9 the same 3.0 Hertz waveform has been sampled at 4 samples-per-second, which is insufficient by Equation (1). The result may be seen to be a frequency which was not present in the original signal waveform. This "fake" 1.0 Hertz signal cannot be distinguished from valid data at this frequency, and would be directly added to any valid data which might exist. It is even possible that aliasing can produce a DC level. In Figure 10, for example, a 5.0 Hertz waveform is sampled at 5 samples-per-second and an apparent DC output results.

All of the above considerations have assumed a noise-free data system, which is unrealistic at best. In an actual situation, it is desirable that sampling be accomplished at least 10 times the maximum signal component present in order to prevent aliasing. It should be pointed out that the sampling rate of the multiplex data system is not the only consideration. For example, if data are sampled at 40 points per second the output signal should be easily capable of sensing the 5.0 Hertz frequency called out in the narrow band system. However, these data are in turn reduced at 5 points per second through the CDC 160-A CAL-COMP system unless it is specifically requested that a higher rate be used, and aliasing will result.

The usual method of eliminating aliasing in a data system is to include low-pass filters, set for $1/2$ of the sampling frequency or less, in all data channels ahead of the multiplexing system. Such filters either do not exist at NRDS or are too high in frequency to prevent aliasing, and therefore it is expected that aliasing of all data of frequencies higher than the so-called Nyquist frequency will be observed. It should further be pointed out that aliasing of noise is possible in the NRDS system. Any random signal which exists will be sampled by the multiplexer and may appear as valid data and be misinterpreted by the data user.

The waveforms from the 5.0 Hertz frequency response test exhibit major aliasing as shown in Figure 11 when sampled at 5 samples-per-second. It may safely be stated that 100% of these data are aliased and appear at a frequency less than actual frequency. From the frequency observed (about 0.07 Hertz) it is evident that: (1) either the signal generator was not exactly at 5.0 Hertz, differing by approximately 0.07 Hertz, or

(2) that the sampling rate was not exactly 5 samples-per-second. Therefore, the output waveform appears to be approximately 0.07 Hertz although such a component did not exist in the input waveform. When these data were later plotted with a higher sampling rate no aliasing was evident, as shown in Figure 7. As a result of this, the following conclusions have been reached:

1. Sampling should be performed at as high a rate as possible, and the data plotted with the maximum plotting speed consistent with cost.
2. If any suspicion exists that data may have been aliased, the data should be replotted at a higher rate, up to the maximum sampling rate of the multiplexer used when taking the data.
3. Both of the above are temporary solutions. A far more lasting solution would be the addition of data filtering prior to the multiplexer.

It is evident that some severe aliasing are present in the TCA data system.

6.2.6 SUMMARY OF BASIC ACCURACY TEST DATA

Tables XI and XII summarize the data found in Tables III through VIII. Table XI presents, for each configuration-multiplexer pair of channels, the maximum variance estimates (s^2) for each accuracy parameter as observed during both the linearity runs and the crosstalk runs. Table XII presents similar data observed for the calibration runs made during the basic accuracy test runs. In preparing Table XI, the unusually high value of 1.6442 for 7-L06 from Table VII was not entered for the reasons given in section 6.2.4.

Referring to Table XI, variance totals ($\sum s^2$) were obtained by adding the maximum variances (s^2) for each of the accuracy parameters. Standard deviations corresponding to the variance totals were obtained by taking the square root of the totals; and 99% confidence,

$\pm$ limits for each standard deviation were obtained by multiplying the standard deviation by ± 2.6 , approximately equal to the normal deviate and the appropriate value for the number of observations for the study.

Variance totals, standard deviations, and 99% confidence limits were also obtained for the data summarized in Table XII. Comparing the limits for these two tables (XI and XII), differences may be noted. However, these differences occur because of the low drift and statistical bias estimates for the calibration runs. These naturally should approach zero because the calibration data are adjusted to themselves, whereas the linearity and cross-talk data uses the calibration data as a reference.

6.3 NRX-A3-EP5 CALIBRATION DATA ANALYSIS

Table XIII summarizes the data for the pre- and post-NRX-A3 calibrations and compares these with the calibration data for the same channels of the accuracy test. The data shown for each parameter of the accuracy test were taken from Table XII.

Although there were fewer values to yield the NRX-A3 data of Table XIII (a total of 616 for the NRX-A3 calibrations versus 7920 for the accuracy test calibrations), there are some comparisons that are valid. Noise estimates are directly comparable; and, as seen in Table XIII, the NRX-A3 noise estimates agree reasonably well with the accuracy test noise estimates. With only two calibrations from NRX-A3-EP5, as contrasted to eighteen runs for the accuracy test, estimates for drift and statistical bias are quite likely to be minimum; thus these should be, for the most part, less than those estimates from the accuracy test calibrations, and these are.

In summary, the accuracy test calibration runs were probably as good as the calibration runs of NRX-A3-EP5 for determination of accuracy of the system.

6.4 NRX-A3 AMBIENT DATA ANALYSIS

Table XIV presents the noise data from the NRX-A3-EP5 ambient runs and the basic accuracy test runs. Since the accuracy test was performed under controlled conditions by simulating transducer output signals at ambient conditions, an analysis of the NRX-A3 ambient

data for the same channels may determine the transducer noise contribution. A total of 432 averages and variances from the NRX-A3 ambient runs were analyzed.

The underlined variance values, s^2 , in columns 1 and 2 are the maximum noise values for the accuracy test as shown in Table XI. The standard deviations in column 3 are the square roots of the underlined values. Multiplying the values in column 3 by 2.6 results in the noise values in column 4.

Column 7 contains the noise values for the same channels as determined from the NRX-A3 ambient runs. The values in column 7 are obtained from columns 5 and 6 similar to those in column 4.

Column 8 shows the differences between the NRX-A3 ambient noise and the accuracy test noise. Six of the differences are positive (indicating possible transducer contribution) and six are negative (indicating possibly a better impedance match between simulator and channel than between calibrator and channel).

Table XV presents the noise data from the NRX-A3-EP5 calibration and ambient runs. These two sets of data were previously shown in Table XIII and XIV respectively. As may be seen upon comparing Tables XIV and XV, the comparisons made in these two tables lead to essentially the same conclusions.

6.5 NEW EQUIPMENT DATA ANALYSIS

After the accuracy test was completed, new Neff amplifiers and low level SEL multiplexers were installed in some narrow band data channels. The multiplexer and channel configurations maintained for the NRX-A3 and accuracy tests were changed for the NRX/EST test series; therefore, there are no direct comparisons.

Table II contains a list of 40 channels and fifteen associated multiplexers selected for limited comparisons with the accuracy test channels and multiplexers. A total of 836 averages and variances were obtained from two calibrations of eleven steps each (data for two channels were not available).

Table XVI presents the summary of the new equipment data analysis. As is indicated in the columns for the parameters linearity and drift, many of the values determined were negligible as would be expected from the number of data points available.

Table XVII allows a comparison of the 99% confidence limits for the calibration runs for the accuracy test, NRX-A3-EP5, and NRX/EST. High level multiplexer values agree reasonably well and low level multiplexer values show considerable improvement as a result of the use of the new SEL multiplexers, this improvement being as much as 50% for some of the accuracy values.

6.6 SANBORN DATA ANALYSIS

As described in sections 4.2 and 5.2, Sanborn data were obtained and resulted in 1440 observations (4 calibration plots for 9 channels, read at maximum and minimum for full scale and zero settings by 10 readers).

These data were investigated using the analysis of variance technique as described in Appendix B. The primary interest in this analysis is that of estimating the inaccuracy of Sanborn plots as affected by noise and bias between readers. In other words, the interest in the analysis of these data centers in how well a point on the Sanborn plot can be read.

The analysis revealed that, in addition to the basic random variation in the data (or noise) as determined from the analyses, there is a natural difference between the maximum and minimum values, as expected, and that this difference is affected by the reader.

Variance estimates reflecting these differences were derived from the analysis and summed to give a total variance ($\sum s^2$) equal to 0.5292. Multiplying the standard deviation ($\sqrt{0.5292} = 0.727$) by ± 2.6 gives the 99% confidence limits of $\pm 1.89\%$. Thus, this means that a single point on the Sanborn plot can be read within $\pm 1.89\%$ of full scale, 99% of the time.

6.7 CAL-COMP DATA ANALYSIS

As described in sections 4.3 and 5.2, CAL-COMP data were obtained and resulted in 3600 observations (4 calibration plots for 10 channels, read at maximum, nominal, and minimum for full scale, midpoint and zero settings by 10 readers).

Since CAL-COMP plots are in engineering units versus time as opposed to Sanborn plots of percentage of full scale value versus time (the engineering scale varying for the 10 channels selected), an analysis of variance combining the calibration data from NRX-A3-EPI and the calibration data from Phase I of the basic accuracy test runs were completed for each channel. These 10 analyses revealed that the data from these two sets of calibration runs were not homogeneous. Thus, the data were analyzed by the analysis of variance technique as described in Appendix B, the data being separated into two sets of 180 observations for each channel, to give 20 separate analyses.

The primary interest in each of these analyses is that of estimating the inaccuracy of the CAL-COMP plots as affected by noise and bias between readers. These effects must be evaluated before a comparative evaluation of the CAL-COMP plots of the NRX-A3 calibrations and accuracy test calibrations can be made.

Table XVIII summarizes the data from the CAL-COMP plots for the 10 channels for the two sets of calibration runs. As may be seen in this table, average full scale, midpoint and zero values, variances totals (reflecting noise and reader bias) and standard deviations are given in engineering units.

The standard deviations were converted to percentage of full scale limits by dividing the deviations by the full scale values and multiplying the quotients by ± 2.6 . The first point to be noted is the large differences between the NRX-A3 limits and the accuracy test limits. Data used to generate the NRX-A3 limits were from NRX-A3-EPI CAL-COMP plots. Subsequent to these plots, changes were made in the IBM 704 computer program such that the differences shown are a reflection of the improvement in the processing of data system data.

The second, and perhaps more important, point to be made with respect to the limits given in Table XVIII is concerned with the differences in these limits from channel to channel.

These differences indicate that the ability to read a single data point on a CAL-COMP plot is a function of at least two factors in addition to the data channel inaccuracy. These are: (1) the engineering scale used and the range of this scale; and (2) the transducer conversion as it is used to convert signal output to engineering units. For example, a comparison of channels T-245 and T-216 in Table XVIII (both channels having essentially the same scale and range) reveals a difference in limits of approximately 2 to 1. On the other hand, channels T-603 and T-601, both channels having essentially the same limits, have widely different scales.

In summary, the preceding comments indicate the difficulty to be experienced in setting limits for CAL-COMP plots, since such limits can be expected to be different for each transducer output. In addition, individual limits for particular channels would be more a function of the data system and transducer accuracies than the ability to read CAL-COMP plots.

6.8 MANUALLY RECORDED DATA ANALYSIS

Table XIX presents the summary of the manually recorded linearity run data analysis for 22 channels. (Manual data recorded for 4 runs in each of 3 phases, at 6 voltage steps for each run.)

Column 1 lists the variances and column 2 the standard deviations. Column 3 values are obtained by dividing column 2 values by the full scale values for each channel. Column 4 values in percentage of full scale are obtained by multiplying column 3 by 2.6 and 100.

A comparison of the manually recorded linearity run data with the accuracy test linearity data is not plausible for the same reasons as discussed in section 4.0. Manual data were taken for back-up information in case taped data were lost; however, because of the adjustments made during data processing, such data could only be used for gross error evaluation.

The V_4 voltages listed in Table I were evaluated as an additional part of the analysis of the Sanborn recordings. The Sanborn analysis indicated that a reader could determine the value of a single point on the recordings to within $\pm 1.89\%$ of full scale. The inputs to the Sanborns are the V_4 voltages which were manually recorded in the ELR by reading the digital voltmeters (the accuracy of the DVM measurement is 0.1%). As shown on figures 1b, 2b, and

3b of Appendix A, the V_4 voltages are the amplifier (for NRX-A3, Offner 190A) outputs. There were 72 observations (9 channels for each of 2 phases and 2 calibrations, at 2 voltage levels), and the analysis indicated that these voltages were read within $\pm 0.34\%$ of the actual readings.

NOTE:

The authors wish to acknowledge the contribution of the large number of people who participated in the data gathering, reduction, and reporting phases of this document. If the contribution of everyone who helped was acknowledged, this report could nearly double in size; therefore a limited acknowledgement is necessary, but the contributions of all are appreciated. In particular our thanks are expressed to Mr. D. Swartz for his many pertinent comments and his expeditious review; to Messrs. L. Rizzola and P. Sutton for their thoughtful criticism and helpful suggestions; Mr. C. R. Dippel for his help in expediting all phases of the work; Mr. B. Auxer for his data handling and his helpful suggestions; Mr. R. Roller for his contribution in the writing of the section on Frequency Response and Data Aliasing; and to Mr. L. Kristoff for his help in preparing the data.

Many others have aided materially; the authors wish to thank them for their efforts on behalf of this program

TABLE I
SEQUENCE OF DATA RUNS FOR BASIC ACCURACY TEST
(REPEATED FOR EACH PHASE)

	Manual Measurements Recorded	Manual Measurements Evaluated
** (1) Data System Calibration 1		
(2) AC-1 Frequency Response at 0.1 cps	40 V1	
(3) AC-2 Frequency Response at 1.0 cps	40 V1	
(4) AC-3 Frequency Response at 5.0 cps	40 V1	
(5) AC-4 Frequency Response at 10.0 cps	40 V1	
(6) AC-5 Crosstalk (13 channels)	52 V1, V2, V3, V4	
(7) DC-1 Crosstalk	40 V1	
(8) DC-2 Crosstalk	---	
(9) DC-3 Crosstalk	---	
(10) DC-4 Crosstalk	---	
** (11) Data System Calibration No. 2	266 V1A, V1, V2, V3, V4	V4
(12) Linearity Run A at 0 hours	66 F	
(13) Linearity Run B at 0 + 2 hours	240 V1	V1
(14) Linearity Run C at 0 + 4 hours	240 V1	V1
(15) Linearity Run D at 0 + 8 hours	240 V1	V1
(16) Data System Calibration No. 3	266 V1A, V1, V2, V3, V4; 66 F	V4
(17) Linearity Run E at 0 + 16 hours	240 V1	V1
** (18) Data System Calibration No. 4	---	
(19) DC-5 Crosstalk	40 V1	
(20) DC-6 Crosstalk	---	
(21) DC-7 Crosstalk	---	
(22) DC-8 Crosstalk	---	
(23) AC-6 Frequency Response at 0.1 cps	40 V1	
(24) AC-7 Frequency Response at 1.0 cps	40 V1	
(25) AC-8 Frequency Response at 5.0 cps	40 V1	
(26) AC-9 Frequency Response at 10.0 cps	40 V1	
(27) AC-10 Crosstalk (13 channels)	52 V1, V2, V3, V4	
(28) Data System Calibration No. 5	---	
* (29) Linearity Run F at 0 + 32 hours		

*Applies to Phase III test runs only.

**Voltage calibrations used in adjusting basic accuracy test data.

TABLE II
NRX/EST CHANNELS AND ASSOCIATED MULTIPLEXERS
EVALUATED AFTER INSTALLATION OF
NEW NEFF AMPLIFIERS AND S.E.L. MULTIPLEXERS

T-601	HL01	T-361	LL01
T-616	HL01	T-368	LL01
T-617	HL02	M-203	LL02
T-632	HL02	M-205	LL02
P-034	HL03	T-852	LL02
P-152	HL03	T-862	LL02
T-101	HL04	T-360	LL03
T-107	HL04	T-365	LL03
T-401	HL05	T-245	LL04
T-603	HL05	T-246	LL04
T-403	HL06	M-220	LL04
T-705	HL06	M-240	LL04
T-103	HL07	T-212	LL05
T-108	HL07	T-218	LL05
P-112	HL08	P-214	LL05
P-601	HL08	P-804	LL05
		T-207	LL06
		T-213	LL06
		PD-117	LL06
		PD-125	LL06
		T-856	LL07
		T-866	LL07
		T-261	LL08
		T-324	LL08

Note: These channel designations are not the same designations used in the basic accuracy test.

TABLE III
AVERAGE NOISE ESTIMATES (VARIANCES) FOR
BASIC ACCURACY TEST DATA

(Values are logarithmic averages and are expressed in terms of percentage of full scale.)

PHASE Configuration, Multiplexer & Bit	Linearity Runs			DC-1, 2, 5 & 6 Crosstalk Runs			DC-3, 4, 7 & 8 Crosstalk Runs		
	I	II	III	I	II	III	I	II	III
1-H0124	.0181	.0129	.0180	.0103	.0107	.0163	.0132	.0118	.0204
1-H0134	.0188	.0144	.0181	.0093	.0113	.0167	.0140	.0203	.0179
2-H0122	.0186	.0131	.0200	.0108	.0117	.0162	.0133	.0119	.0198
2-H0133	.0201	.0158	.0182	.0132	.0137	.0204	.0134	.0119	.0184
3-H0103	.0200	.0141	.0194	.0223	.0114	.0158	.0151	.0128	.0212
3-H0110	.0200	.0146	.0201	.0102	.0115	.0146	.0279	.0117	.0204
1-H0203	.0236	.0240	.0226	.0268	.0271	.0299	.0328	.0253	.0331
1-H0205	.0252	.0268	.0243	.0313	.0311	.0261	.0327	.0247	.0327
2-H0222	.0242	.0239	.0250	.0192	.0298	.0227	.0352	.0250	.0277
2-H0213	.1068	.0609	.0496	.0195	.0258	.0199	.2338	.1920	.2932
3-H0204	.0344	.0262	.0271	.0243	.0228	.0195	.0346	.0255	.0348
3-H0209	.0239	.0245	.0224	.0211	.0262	.0206	.0344	.0226	.0323
4-H0431	.4562	.4995	.4876	.0201	.0132	.0221	.4526	.4882	.4789
4-H0432	.4691	.5168	.4867	.0156	.0122	.0186	.4717	.5089	.4755
4-H0502	.0940	.1563	.1241	.0383	.0279	.0359	.1076	.1517	.1306
4-H0503	.0886	.1527	.1364	.0320	.0205	.0233	.1142	.1505	.1467
5-L0316	.0423	.0203	.0343	.0159	.0143	.0391	.0366	.1839	.1221
5-L0320	.0436	.0190	.0418	.0154	.0161	.0950	.0186	.1797	.1749
5-L0416	.0584	.0321	.0305	.0286	.0471	-	.0379	.0494	-
5-L0420	.0455	.0332	.0275	.0283	.0875	-	.0248	.0607	-
6-L0528	.0262	.0308	.0231	.0178	.0135	.0216	.0319	.0141	.0279
6-L0530	.0315	.0246	-	.0216	.0132	.0196	.0297	.0150	.0252
7-L0516	.0312	.0283	.0336	.0274	.0146	.0242	.0420	.0232	.0234
7-L0517	.0282	.0267	.0255	.0239	.0144	.0189	.0272	.0183	.0222

(continued)

-Data missing.

TABLE III (Continued)

PHASE	Linearity Runs			DC-1, 2, 5 & 6 Crosstalk Runs			DC-3, 4, 7 & 8 Crosstalk Runs		
	I	II	III	I	II	III	I	II	III
<u>Configuration, Multiplexer & Bit</u>									
6-L0628	.0257	.0228	.0216	.0454	.2351	.0284	.0395	.0598	.0217
6-L0629	.0228	.0228	.0206	.0197	.0134	.0166	.0366	.0216	.0217
7-L0615	.0789	.0276	.0227	.0435	.3074	.0283	.3726	.0489	.0311
7-L0616	.0418	.0225	.0210	.0230	.0129	.0198	.1189	.0250	.0288
8-L0936	.0447	.0494	.0317	.0523	.0356	.0282	.0867	.1625	.1283
8-L0937	.0625	.0542	.0312	.0544	.0406	.0387	.0992	.1578	.1412
9-L0935	.0513	.0533	.0331	.0486	.0427	.0388	.0852	.1620	.1518
9-L0938	.0446	.0432	.0337	.0467	.0320	.0317	.0832	.1449	.1494
8-L1010	.1788	.1291	.2093	.1707	.1038	.1947	.0978	.0550	.0994
8-L1011	.1844	.1278	.2651	.1596	.1339	.2633	.1076	.0632	.1238
10-L1019	.1210	.0824	.2282	.1067	.0732	.2292	.0765	.0419	.1049
10-L1030	-	.0677	.1471	.0864	.0621	.1641	.0603	.0422	.0932
9-L0230	.0643	.0594	.0229	.0566	.0557	.0252	.0507	.0324	.0184
9-L0231	.0798	.0714	.0270	.0598	.0836	.0248	.0585	.0433	.0209
10-L0220	.0731	.0543	.0311	.0666	.0541	.0328	.0523	.0359	.0243
10-L0221	.0799	.0592	.0448	.0578	.0585	.0467	.0522	.0437	.0329

-Data missing.

TABLE IV
AVERAGE NOISE ESTIMATES (VARIANCES) FOR
BASIC ACCURACY TEST DATA

(Values are logarithmic averages and are expressed in terms of percentage of full scale.)

(Calibration Runs)

PHASE	<u>I</u>	<u>II</u>	<u>III</u>		<u>I</u>	<u>II</u>	<u>III</u>
Configuration, Multiplexer & Bit				Configuration, Multiplexer & Bit			
1-H0124	.0143	.0116	.0182	6-L0528	.0215	.0248	.0251
1-H0134	.0139	.0127	.0179	6-L0530	.0263	.0224	-
2-H0122	.0138	.0127	.0195	7-L0516	.0300	.0222	.0226
2-H0133	.0147	.0236	.0185	7-L0517	.0305	.0203	.0189
3-H0103	.0154	.0131	.0206				
3-H0110	.0139	.0119	.0202	6-L0628	.0473	.0225	.0172
				6-L0629	.0481	.0186	.0181
1-H0203	.0257	.0215	.0383	7-L0615	.0814	.0647	.0192
1-H0205	.0257	.0196	.0255	7-L0616	.0558	.0190	.0211
2-H0222	.0243	.0236	.0284				
2-H0213	.0887	.1553	.2157	8-L0936	.0471	.0429	.0322
3-H0204	.0279	.0213	.0405	8-L0937	.0420	.0337	.0310
3-H0209	.0233	.0219	.0308	9-L0935	.0471	.0452	.0345
				9-L0938	.0379	.0371	.0355
4-H0431	.1826	.0818	.0676				
4-H0432	.1906	.0866	.0705	8-L1010	.2008	.1226	.2075
				8-L1011	.2063	.1279	.2672
4-H0502	.1129	.0876	.0934	10-L1019	.1121	.0775	.2510
4-H0503	.1070	.0846	.1040	10-L1030	.0991	.0795	.1520
5-L0316	.0584	.1427	.0873	9-L0203	.0924	.0548	.0221
5-L0320	.0469	.1794	.0817	9-L0231	.1151	.0742	.0287
				10-L0220	.1061	.0634	.0317
5-L0416	.0612	.0458	.0261	10-L0221	.1134	.0600	.0530
5-L0420	.0488	.0365	.0309				

-Data missing.

TABLE V
VARIANCE ESTIMATES FOR DRIFT FOR
BASIC ACCURACY TEST DATA

(Values expressed in terms of percentage of full scale.)

PHASE	Linearity Runs			DC-1, 2, 5 & 6 Crosstalk Runs			DC-3, 4, 7 & 8 Crosstalk Runs		
	I	II	III	I	II	III	I	II	III
**Configuration-Multiplexer									
1-H01	.0074	.0017	.0012	.0165	0	.0336	.1170	*	0
2-H01	.0050	.0066	0	.0054	0	0	.0045	.0238	0
3-H01	*	.0011	.0018	.0285	0	.0113	.1285	0	.0619
1-H02	.0131	.0129	0	.0231	.0465	0	.0183	.0175	0
2-H02	.0079	0	.0051	.1721	.3180	0	0	0	0
3-H02	.0088	.0118	.0053	0	.7206	0	.0093	.0634	0
4-H04	0	0	0	.1506	.0495	0	.1100	0	0
4-H05	.0311	0	0	0	0	.1791	0	0	.3183
5-L03	.0966	.0074	.0228	.1530	0	.6748	.0607	.6364	.5039
5-L04	.0653	.0651	.0123	.1509	.0808	-	.0287	.0892	-
6-L05	.0259	.0048	0	.2741	0	.0267	.1908	.3008	0
7-L05	.0291	.0058	.0130	.2599	0	.3715	.1494	.2029	.0904
6-L06	.1205	.0081	.0062	0	.3275	.1154	0	.0718	.0668
7-L06	*	.0030	0	0	.3538	.1942	0	.1321	.0250
8-L09	0	0	0	0	.0581	.1194	0	0	.0480
9-L09	.0074	.0044	.0071	0	.0342	.0609	0	0	0
8-L10	0	0	0	.3250	.0363	.0909	.1020	0	.0550
10-L10	0	0	0	1.0467	.0936	0	.1354	0	0
9-L02	.1363	.0055	0	.0776	0	.0259	.2072	.0190	.0314
10-L02	.0694	.0051	.0087	0	.0308	.0950	.0355	0	0

*Erratic data.

**Two channels for each configuration-multiplexer.

-Data missing.

TABLE VI
VARIANCE ESTIMATES FOR DRIFT FOR
BASIC ACCURACY TEST DATA
(Values expressed in terms of percentage of full scale.)
(Calibration Runs)

PHASE	I	II	III
<u>**Configuration-Multiplexer</u>			
1-H01	.0051	*	.0017
2-H01	.0077	.0056	.0040
3-H01	.0042	0	0
1-H02	.0288	.0070	.0091
2-H02	.0141	.0060	.0092
3-H02	.0273	.0095	.0073
4-H04	0	0	0
4-H05	.0594	.0174	.0154
5-L03	.5628	0	.0566
5-L04	.4177	.0566	.0049
6-L05	.1656	0	0
7-L05	.1859	.0078	.0077
6-L06	.0680	.1939	.0046
7-L06	.0547	.1492	0
8-L09	.0049	.0058	0
9-L09	.0053	0	0
8-L10	0	0	0
10-L10	0	0	0
9-L02	.3446	0	0
10-L02	.2957	0	0

*Erratic data.

** Two channels for each configuration-multiplexer.

TABLE VII
VARIANCE ESTIMATES FOR STATISTICAL BIAS FOR
BASIC ACCURACY TEST DATA

(Values expressed in terms of percentage of full scale.)

PHASE	Linearity Runs			DC-3, 4, 7 & 8 Crosstalk Runs		
	I	II	III	I	II	III
<u>**Configuration-Multiplexer</u>						
1-H01	.2157	.0946	.0892	.2592	*	.1611
2-H01	.0172	.0051	.0068	.0039	0	.0012
3-H01	*	.0030	0	*	.0043	0
1-H02	.0613	.0308	.0771	.0172	.0879	.0047
2-H02	.0023	.0073	0	0	.0531	.0202
3-H02	.0077	.0020	.0042	.0567	.0215	.0295
4-H04	0	0	0	0	0	0
4-H05	.0045	0	0	0	0	0
5-L03	0	.2504	.0040	.0049	.1686	0
5-L04	0	.0201	.3556	.0307	0	-
6-L05	.0036	.0343	-	.0009	.0230	.0122
7-L05	0	0	.0878	.0267	.0088	.0576
6-L06	.0310	.2259	.3145	.1606	.4043	.4252
7-L06	*	0	.1196	1.6442	0	.1098
8-L09	.0043	.0119	.0173	.0145	0	.0085
9-L09	0	.0550	.0127	.0296	.0522	.0508
8-L10	0	0	0	.0420	.0199	0
10-L10	-	0	1.0475	0	0	.9201
9-L02	.0055	0	0	.0348	.0338	.0311
10-L02	.0159	.0015	.0090	0	.0231	0

*Erratic data.

**Two channels for each configuration-multiplexer.

-Data missing.

TABLE VIII
VARIANCE ESTIMATES FOR STATISTICAL BIAS FOR
BASIC ACCURACY TEST DATA

(Values expressed in terms of percentage of full scale.)

(Calibration Runs)

PHASE	I	II	III
<u>**Configuration-Multiplexer</u>			
1-H01	.0052	*	0
2-H01	.0014	.0033	0
3-H01	.0009	0	0
1-H02	0	0	0
2-H02	0	.0080	0
3-H02	0	0	0
4-H04	0	0	0
4-H05	0	0	0
5-L03	.0033	.0063	0
5-L04	.0251	.0015	.0073
6-L05	.0010	.0016	-
7-L05	0	0	0
6-L06	0	0	0
7-L06	0	0	0
8-L09	0	0	0
9-L09	0	0	0
8-L10	0	0	0
10-L10	0	0	0
9-L02	0	0	0
10-L02	0	0	0

*Erratic data.

**Two channels for each configuration-multiplexer.

-Data missing.

TABLE IX
AVERAGE FULL SCALE VALUES FOR
BASIC ACCURACY TEST DATA

(Values are averages of at least 300 data points, in percentage of full scale.)

PHASE	Linearity Runs			Calibration Runs			DC-3, 4, 7 & 8 Crosstalk Runs		
	I	II	III	I	II	III	I	II	III
**Configuration-Multiplexer									
1-H01	100.4	100.1	100.5	100.0	100.0	100.0	99.8	93.4*	100.6
2-H01	100.1	100.0	100.2	100.0	100.0	100.0	99.2	99.2	99.7
3-H01	99.2	99.8	100.0	100.0	99.9	100.0	99.3	99.1	99.5
1-H02	100.7	100.0	100.4	100.2	99.9	100.1	99.8	99.6	99.6
2-H02	100.4	99.6	100.4	100.1	100.0	100.1	99.3	99.3	99.4
3-H02	100.7	100.0	100.5	100.1	99.9	100.1	99.8	99.7	99.8
4-H04	96.8	96.8	97.1	99.8	99.9	100.0	96.7	97.0	96.9
4-H05	100.0	99.7	99.7	100.1	100.0	100.2	99.1	99.2	99.5
5-L03	100.1	99.7	100.0	100.0	100.1	99.9	99.5	100.0	99.8
5-L04	100.4	99.9	100.2	100.4	100.0	99.9	100.5	100.5	-
6-L05	99.1	99.6	99.8	99.8	100.0	99.9	100.0	99.7	99.7
7-L05	98.7	99.4	100.2	99.7	99.9	100.0	99.8	99.9	100.0
6-L06	100.1	99.5	99.5	99.8	100.1	99.9	100.0	100.0	99.7
7-L06	97.2	99.5	99.7	99.9	100.1	100.0	97.5	100.3	100.0
8-L09	99.9	100.0	100.2	99.9	99.9	99.9	100.2	100.2	100.4
9-L09	99.8	100.1	100.2	100.0	99.9	99.9	100.2	100.1	100.4
8-L10	100.3	99.9	99.9	100.1	100.0	99.9	100.0	100.0	100.0
10-L10	100.4	100.0	100.0	99.9	100.0	100.0	99.8	99.8	99.9
9-L02	100.2	99.8	100.0	100.1	99.9	100.0	99.8	99.8	99.9
10-L02	100.2	100.0	100.0	100.2	99.9	99.9	100.0	99.9	100.0

*Improper full scale setting for one channel.

**Two channels for each configuration-multiplexer.

-Data missing.

TABLE X
AVERAGE ZERO VALUES FOR
BASIC ACCURACY TEST DATA

(Values are averages of at least 300 data points, in percentage of full scale.)

PHASE	Linearity Runs			Calibration Runs			DC-3, 4, 7 & 8 Crosstalk Runs		
	I	II	III	I	II	III	I	II	III
<u>**Configuration-Multiplexer</u>									
1-H01	0.0	-0.1	-0.1	0.1	0.0	-0.1	-0.4	-0.5	-0.4
2-H01	-0.1	0.0	0.0	0.0	0.0	0.0	-0.5	-0.6	-0.4
3-H01	-0.1	0.0	0.0	0.0	0.0	0.0	-0.5	-0.6	-0.3
1-H02	-0.2	-0.2	-0.1	0.1	0.0	-0.1	-0.5	-0.5	-0.6
2-H02	-0.2	-0.1	0.0	0.0	0.1	0.0	-0.4	-0.5	-0.6
3-H02	-0.2	-0.2	-0.1	0.0	0.0	-0.2	-0.5	-0.6	-0.7
4-H04	0.3	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.0
4-H05	0.9	0.2	0.1	0.3	0.1	-0.1	0.1	-0.1	-0.2
5-L03	0.8	-0.3	0.0	0.3	-0.2	-0.1	-0.5	-0.5	-0.4
5-L04	1.0	0.1	0.3	0.4	0.0	-0.3	0.3	0.6	-
6-L05	-1.4	-0.2	-0.4	0.4	0.0	-0.1	0.1	-0.2	-0.3
7-L05	-1.4	-0.2	0.2	-0.3	0.0	0.0	0.0	0.1	0.2
6-L06	-1.2	-0.5	-0.5	-0.4	0.2	-0.1	-0.2	-0.3	-0.4
7-L06	-2.1	-0.3	-0.1	-0.3	0.1	-0.1	-1.8	0.7	-0.1
8-L09	0.1	-0.1	0.0	0.0	-0.1	-0.1	0.2	0.1	0.0
9-L09	0.1	0.0	0.0	0.0	-0.1	-0.1	0.3	0.2	0.2
8-L10	0.5	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1
10-L10	0.2	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.2
9-L02	1.1	-0.1	-0.3	0.6	0.0	-0.1	0.0	-0.2	-0.1
10-L02	1.0	0.0	0.0	0.6	0.0	0.0	-0.2	-0.1	0.1

**Two channels for each configuration-multiplexer.

-Data missing.

TABLE XI
SUMMARY DATA OF ACCURACY PARAMETERS FOR BASIC TEST DATA

(Values expressed in terms of percentage of full scale.)

	Noise (From Table III)		Drift (From Table V)		Statistical Bias (From Table VII)		Variance Totals	Standard Deviations	99% Confidence ± Limits
	Linearity	Crosstalk	Linearity	Crosstalk	Linearity	Crosstalk			
**Configuration-Multiplexer									
1-H01	.0188	<u>.0204</u>	.0074	<u>.1170</u>	<u>.2157</u>	<u>.2592</u>	.3966	.630	1.64
1-H02	.0268	<u>.0331</u>	.0131	<u>.0465</u>	<u>.0771</u>	<u>.0879</u>	.1675	.409	1.06
2-H01	.0201	<u>.0204</u>	.0066	<u>.0238</u>	<u>.0172</u>	.0039	.0614	.248	.645
2-H02	.1068	<u>.2932</u>	.0079	<u>.3180</u>	<u>.0073</u>	<u>.0531</u>	.6643	.815	2.12
3-H01	.0201	<u>.0279</u>	.0018	<u>.1258</u>	.0030	<u>.0043</u>	.1580	.398	1.03
3-H02	.0344	<u>.0348</u>	.0118	<u>.7206</u>	<u>.0077</u>	<u>.0567</u>	.8121	.901	2.34
4-H04	<u>.5168</u>	.5089	0	<u>.1506</u>	0	0	.6674	.817	2.12
4-H05	<u>.1563</u>	<u>.1517</u>	.0311	<u>.3183</u>	<u>.0045</u>	0	.4791	.692	1.80
5-L03	.0436	<u>.1839</u>	.0966	<u>.6748</u>	<u>.2504</u>	.1686	1.1091	1.05	2.73
5-L04	.0584	<u>.0875</u>	.0653	<u>.1509</u>	<u>.3556</u>	.0307	.5940	.771	2.00
6-L05	.0315	<u>.0319</u>	.0259	<u>.3008</u>	<u>.0343</u>	.0230	.3670	.606	1.58
6-L06	.0257	<u>.2351</u>	.1205	<u>.3275</u>	<u>.3145</u>	<u>.4252</u>	.9878	.994	2.58
7-L05	.0336	<u>.0420</u>	.0291	<u>.3715</u>	<u>.0878</u>	.0576	.5013	.708	1.84
7-L06	.0789	<u>.3726</u>	.0030	<u>.3538</u>	<u>.1196</u>	.1098	.8460	.920	2.39
8-L09	.0625	<u>.1625</u>	0	<u>.1194</u>	<u>.0173</u>	.0145	.2992	.547	1.42
8-L10	<u>.2651</u>	<u>.2633</u>	0	<u>.3250</u>	0	<u>.0420</u>	.6321	.795	2.07
9-L02	.0798	<u>.0836</u>	.1363	<u>.2072</u>	.0055	<u>.0348</u>	.3256	.571	1.48
9-L09	.0533	<u>.1620</u>	.0074	<u>.0609</u>	<u>.0550</u>	<u>.0522</u>	.2779	.527	1.37
10-L02	<u>.0799</u>	.0666	.0694	<u>.0950</u>	.0159	<u>.0231</u>	.1980	.445	1.16
10-L10	<u>.2282</u>	<u>.2292</u>	0	<u>1.0467</u>	<u>1.0475</u>	<u>.9201</u>	2.3234	1.52	3.95

**Two channels for each configuration-multiplexer.

TABLE XII
SUMMARY DATA OF ACCURACY PARAMETERS FOR CALIBRATION RUNS

(Values expressed in terms of percentage of full scale.)

<u>**Configuration- Multiplexer</u>	<u>Noise (From Table I)</u>	<u>Drift (From Table VI)</u>	<u>Statistical Bias (From Table VIII)</u>	<u>Variance Totals</u>	<u>Standard Deviations</u>	<u>99% Confidence ± Limits</u>
1-H01	.0182	.0051	.0052	.0285	.169	.439
1-H02	.0383	.0288	0	.0671	.259	.673
2-H01	.0236	.0077	.0033	.0346	.186	.484
2-H02	.2157	.0141	.0080	.2378	.488	1.27
3-H01	.0206	.0042	.0009	.0257	.160	.416
3-H02	.0405	.0273	0	.0678	.260	.676
4-H04	.1906	0	0	.1906	.437	1.14
4-H05	.1129	.0594	0	.1723	.415	1.08
5-L03	.1794	.5628	.0063	.7485	.865	2.25
5-L04	.0612	.4177	.0251	.5040	.710	1.85
6-L05	.0263	.1656	.0016	.1935	.440	1.14
6-L06	.0481	.1939	0	.2420	.492	1.28
7-L05	.0305	.1859	0	.2164	.465	1.21
7-L06	.0814	.1492	0	.2306	.480	1.25
8-L09	.0471	.0058	0	.0529	.230	.598
8-L10	.2672	0	0	.2672	.517	1.34
9-L02	.1151	.3446	0	.4597	.678	1.76
9-L09	.0471	.0053	0	.0524	.229	.595
10-L02	.1134	.2957	0	.4091	.640	1.66
10-L10	.2510	0	0	.2510	.501	1.30

**Two channels for each configuration-multiplexer.

TABLE XIII
COMPARISON OF ACCURACY PARAMETERS FOR CALIBRATION RUNS
BETWEEN ACCURACY TEST AND NRX-A3-EP5

(Values expressed in terms of percentage of full scale.)

	Noise		Drift		Statistical Bias		Variance Totals		Standard Deviations		99% Confidence ± Limits	
	Accuracy	NRX	Accuracy	NRX	Accuracy	NRX	Accuracy	NRX	Accuracy	NRX	Accuracy	NRX
**Configuration- Multiplexer												
1-H01	.0182	.0226	.0051	0	.0052	0	.0285	.0226	.169	.150	.429	.390
1-H02	.0383	.0257	.0288	.0108	0	0	.0671	.0365	.259	.191	.673	.497
2-H01	.0236	.0270	.0077	0	.0033	0	.0346	.0270	.186	.164	.484	.426
2-H02	.2157	.1006	.0141	0	.0080	0	.2378	.1006	.488	.317	1.27	.824
3-H01	.0206	.0220	.0042	.0059	.0009	0	.0257	.0279	.160	.167	.416	.435
3-H02	.0405	.0243	.0273	.0240	0	0	.0678	.0483	.260	.220	.676	.572
4-H04	.1906	.2340	0	0	0	0	.1906	.2340	.437	.548	1.14	1.43
4-H05	.1129	.1166	.0594	.0444	0	0	.1723	.1610	.415	.401	1.08	1.04
5-L03	.1794	.0404	.5628	.0721	.0063	.0101	.7485	.1226	.865	.350	2.25	.910
5-L04	.0612	.0313	.4177	.0468	.0251	0	.5040	.0771	.710	.278	1.85	.724
6-L05	.0263	.0207	.1656	.0071	.0016	0	.1935	.0278	.440	.167	1.14	.434
6-L06	.0481	*	.1939	*	0	*	.2306	*	.480	*	1.28	*
7-L05	.0305	.0239	.1859	.0889	0	0	.2164	.1128	.465	.336	1.21	.874
7-L06	.0814	*	.1492	*	0	*	.2306	*	.480	*	1.25	*
8-L09	.0471	*	.0058	*	0	*	.0529	*	.230	*	.598	*
8-L10	.2672	*	0	*	0	*	.2672	*	.517	*	1.34	*
9-L02	.1151	.0796	.3446	0	0	0	.4597	.0796	.678	.282	1.76	.734
9-L09	.0471	*	.0053	*	0	*	.0524	*	.229	*	.595	*
10-L02	.1134	.0914	.2957	0	0	0	.4091	.0914	.640	.302	1.66	.785
10-L10	.2510	*	0	*	0	*	.2510	*	.501	*	1.30	*

*Missing data on N3 tape.

**Two channels for each configuration-multiplexer.

TABLE XIV
AN EVALUATION OF THE AMBIENT RUN DATA FOR TRANSDUCER NOISE CONTRIBUTION FOR
THE SAME CHANNELS USED IN ACCURACY TEST
(Values expressed in terms of percentage of full scale.)

**Configuration- Multiplexer	ACCURACY TEST NOISE DATA				AMBIENT RUN NOISE DATA NRX-A3-EP5			Difference Between Ambient Noise and Accuracy Test Noise
	Variance (s ²) (From Table XI)		Standard Deviation	Noise 99% Confidence ± Limits	Variances (s ²)	Standard Deviation (s)	Noise 99% Confidence ± Limits	
	Linearity	Crosstalk						
	1	2	3	4	5	6	7	
1-H01	.0188	.0204	.143	.372	.0348	.187	.486	.114
1-H02	.0268	.0331	.182	.473	.0379	.195	.507	.034
2-H01	.0201	.0204	.143	.372	.0338	.183	.476	.114
2-H02	.1068	.2932	.542	1.41	.0326	.181	.471	- .939
3-H01	.0201	.0279	.167	.434	.0307	.175	.455	.021
3-H02	.0344	.0348	.187	.486	.0294	.172	.447	- .041
4-H04	.5168	.5089	.713	1.85	.0387	.197	.512	-1.34
4-H05	.1563	.1517	.390	1.01	.1038	.322	.837	-1.73
5-L03	.0436	.1839	.429	1.12	.0541	.233	.606	- .514
5-L04	.0584	.0875	.295	.767	.0216	.147	.382	- .385
6-L05	.0315	.0319	.179	.465	*	*	*	*
6-L06	.0257	.2351	.485	1.26	*	*	*	*
7-L05	.0336	.0420	.205	.533	*	*	*	*
7-L06	.0789	.3726	.610	1.59	*	*	*	*
8-L09	.0625	.1625	.403	1.05	*	*	*	*
8-L10	.2651	.2633	.513	1.30	*	*	*	*
9-L02	.0798	.0836	.289	.751	.1335	.365	.949	.198
9-L09	.0533	.1620	.402	1.05	*	*	*	*
10-L02	.0799	.0666	.258	.671	.2627	.513	1.33	.659
10-L10	.2282	.2292	.479	1.25	*	*	*	*

*Missing data on N3 tape.

**Two channels each for configuration-multiplexer.

TABLE XV

AN EVALUATION OF AMBIENT RUN DATA FOR TRANSDUCER NOISE CONTRIBUTION FOR
THE SAME CHANNELS OF NRX-A3-EP5 CALIBRATION AND AMBIENT RUNS

(Values expressed in percentage of full scale.)

**Configuration- Multiplexer	Noise NRX-A3-EP5 Calibration			Noise NRX-A3-EP5 Ambient			Transducer Noise Contribution (2 minus 1)
	Variances (s ²)	Deviation (s)	Noise 99% Confidence ± Limits	Variances (s ²)	Deviation (s)	Noise 99% Confidence ± Limits	
			1			2	
1-H01	.0226	.150	.390	.0348	.187	.486	.096
1-H02	.0257	.160	.416	.0379	.195	.507	.091
2-H01	.0270	.164	.426	.0338	.183	.476	.050
2-H02	.1006	.317	.824	.0326	.181	.471	-.353
3-H01	.0220	.148	.385	.0307	.175	.455	.070
3-H02	.0243	.156	.406	.0294	.172	.447	.041
4-H04	.2340	.484	1.26	.0387	.197	.512	-.748
4-H05	.1166	.342	.889	.1038	.322	.837	-.052
5-L03	.0404	.201	.523	.0541	.233	.606	-.083
5-L04	.0313	.177	.460	.0216	.147	.382	-.078
6-L05	.0207	-	-	*	*	*	*
6-L06	*	*	*	*	*	*	*
7-L05	.0239	-	-	*	*	*	*
7-L06	*	*	*	*	*	*	*
8-L09	*	*	*	*	*	*	*
8-L10	*	*	*	*	*	*	*
9-L02	.0796	.282	.733	.1335	.365	.949	.134
9-L09	*	*	*	*	*	*	*
10-L10	.0914	.302	.785	.2627	.513	1.33	.263
10-L10	*	*	*	*	*	*	*

*Missing data on N3 tape.

**Two channels for each configuration-multiplexer.

-Calculations not required.

TABLE XVI

SUMMARY DATA OF NEFF/SEL CALIBRATION RUNS

 (Values expressed in percentage of full scale.)

	<u>Noise</u>	<u>Linearity</u>	<u>Drift</u>	<u>Variance Totals</u>	<u>Standard Deviations</u>	<u>99% Confidence ± Limits</u>
H01	.0642	0	0	.0642	.254	.661
H02	.0279	0	0	.0279	.167	.435
H03	.0331	0	0	.0331	.182	.474
H04	.0140	0	.0037	.0177	.133	.346
H05	.0123	0	0	.0123	.111	.289
H06	.0165	0	0	.0165	.128	.333
H07	.0156	0	0	.0156	.125	.325
H08	.0192	0	0	.0192	.139	.362
L01	.0195	0	0	.0195	.139	.362
L02	.0119	0	0	.0119	.109	.284
L02	.0117	0	0	.0117	.108	.281
L03	.0109	0	0	.0109	.104	.271
L04	.0118	0	.0030	.0148	.122	.318
L04	.0122	0	0	.0122	.111	.289
L05	.0109	.0065	0	.0174	.132	.344
L05	.0095	.0052	0	.0147	.121	.315
L06	.0238	0	0	.0238	.154	.395
L06	.0266	0	0	.0266	.163	.425
L08	.0095	0	.0072	.0167	.129	.336

TABLE XVII
COMPARISON OF THE
CALIBRATION RUNS BETWEEN ACCURACY TEST,
NRX-A3-EP5, AND NRX/EST
(99% Confidence, $\pm$ Limits)

<u>**Configuration- Multiplexer</u>	Accuracy	NRX A3-EP5	NRX/EST (With Neff/SEL Change)	
			<u>**Multiplexer[†]</u>	
1-H01	.439	.390	H01	.661
2-H01	.484	.426	H02	.435
3-H01	.416	.435	H03	.474
1-H02	.673	.497	H04	.346
2-H02	1.27	.260	H05	.289
3-H02	.676	.572	H06	.333
4-H04	1.14	1.43	H07	.325
4-H05	1.08	1.04	H08	.362
5-L03	2.25	.910	L01	.362
5-L04	1.85	.724	L02	.284
6-L05	1.14	.434	L02	.281
7-L05	1.21	.874	L03	.271
6-L06	1.28	*	L04	.318
7-L06	1.25	*	L04	.289
8-L09	.598	*	L05	.344
9-L09	.595	*	L05	.315
8-L10	1.34	*	L06	.395
9-L10	1.30	*	L06	.425
9-L02	1.76	.734	L07	.336
10-L02	1.66	.785		

*Missing data on N3 tape.

**Two channels for each configuration-multiplexer or multiplexer.

[†]Not same channel designations as basic accuracy test.

TABLE XVIII
COMPARISON OF CAL-COMP PLOTS FOR CALIBRATIONS RUNS
OF THE ACCURACY TEST AND NRX-A3-EP1

Channel	Full Scale (Eng. Units)		Mid-Point (Eng. Units)		Zero (Eng. Units)		Variance Totals (Eng. Units)		Standard Deviations (Eng. Units)		99% Confidence ± Limits (% of Full Scale)	
	NRX-A3	Acc.	NRX-A3	Acc.	NRX-A3	Acc.	NRX-A3	Acc.	NRX-A3	Acc.	NRX-A3	Acc.
T-245	656.43	657.95	433.17	440.52	47.97	61.70	361.74	79.16	19.02	8.89	7.53	3.51
T-216	659.93	655.15	434.95	437.77	44.95	34.63	137.18	21.98	11.71	4.69	4.62	1.86
T-856	850.75	849.42	672.87	671.67	500.23	497.50	7.09	2.33	2.66	1.52	.81	.47
T-854	1498.88	1500.80	979.13	985.85	502.93	510.63	157.61	32.38	12.55	5.69	2.18	.99
T-603	1984.08	1979.00	1121.72	1125.90	156.25	139.63	133.87	89.79	11.57	9.48	1.52	1.25
T-601	4983.78	5056.23	2745.05	2766.48	645.58	443.53	1812.03	900.21	42.57	30.00	2.22	1.54
DP-049	100.08	100.70	50.26	50.15	0.02	0.02	0.61	0.46	0.78	0.68	2.03	1.76
P-406	875.17	806.78	443.95	408.80	2.68	12.27	314.98	41.40	17.75	6.43	5.27	2.07
P-124	1001.40	1201.82	500.38	601.43	-0.38	-1.23	19.68	7.17	4.44	2.68	1.15	.58
M-254	3516.17	3491.75	5.17	-24.33	-3504.33	-3542.42	1417.56	941.65	37.65	30.69	2.78	2.28

TABLE XIX
AN EVALUATION OF MANUALLY RECORDED DATA

Channel	Variance (mv) ² 1	Standard Deviation (mv) 2	Avg. Full Scale Value, mv (12 V1 sets) 3	Standard Deviation Full Scale 4	99% Confidence ± Limits (% of Full Scale) 5
T-603	.0107	.1034	33.2	.00311	.81
T-607	.0145	.1204	33.1	.00364	.91
T-613	.0159	.1261	33.4	.00378	.98
T-763	.0185	.1360	33.1	.00411	1.07
T-601	.0038	.0616	40.0	.00154	.40
T-663	.0012	.0346	40.0	.00087	.23
T-602	.0020	.0447	39.9	.00112	.29
T-139	.0201	.1418	36.7	.00386	1.00
P-124	.0083	.0911	24.3	.00374	.97
PD-401	.0695	.2636	21.6	.01220	3.17
P-210	.0306	.1749	20.2	.00866	2.25
PD-203	.0026	.0509	22.0	.00231	.60
T-246	.2389	.4877	3.8	.12834	33.4
T-434	.0652	.2553	2.6	.09819	25.5
M-254	.2847	.5336	19.9	.02681	6.97
M-255	.1516	.3894	19.6	.01987	5.17
T-226	.0180	.1342	3.7	.03627	9.43
T-360	.0453	.2128	12.9	.01650	4.29
T-854	.0009	.0300	151.0	.00020	.05
T-784	.0015	.0387	10.0	.00387	1.01
P-406	.6084	.7800	19.8	.03939	10.24
P-308	.0129	.1136	19.8	.00574	1.49

TABLE XX
TABULATION OF 99% CONFIDENCE $\pm$ LIMITS
GROUPED ACCORDING TO MULTIPLEXER TYPE

(Values are percentage of full scale.)

<u>**Configuration- Multiplexer</u>	<u>Multiplexer Type</u>	<u>Accuracy Test</u>	<u>Calibration</u>
1-H01	EG&G	1.64	.439
2-H01	EG&G	.645	.484
3-H01	EG&G	1.03	.416
1-H02	EG&G	1.06	.673
2-H02	EG&G	2.12	1.27
3-H02	EG&G	2.34	.676
4-H04	EG&G	2.12	1.14
4-H05	EG&G	1.80	1.08
8-L09	SEL	1.42	.598
9-L09	SEL	1.37	.595
9-L02	SEL	1.48	1.76
10-L02	SEL	1.16	1.66
8-L10	SEL	2.07	1.34
10-L10	SEL	3.95	1.30
5-L03	BEN	2.73	2.25
5-L04	BEN	2.00	1.85
6-L05	BEN	1.58	1.14
7-L05	BEN	1.84	1.21
6-L06	BEN	2.39	1.28
7-L06	BEN	2.58	1.25

**Two channels for each configuration-multiplexer.

WANL-TME-1372

FIG. 1 - EFFECT OF VARYING SAMPLING RATE

WANL-TME-1372

FIG. 3 - 1.0 HERTZ SAMPLED AT 5 PPS

610792-5B

610792-4B

FIG. 4 - 0.1 HERTZ SAMPLED AT 5 PPS

FIGURE 9 - ALIASED WAVEFORM FROM WAVE OF FIG. 8

610972-1B

610972-2B

FIG. 10 - DC ALIASING

WANL-TME-1372

APPENDIX A

WANL - TME - 1161

TITLE: PLAN FOR TEST CELL "A" NARROW BAND DATA ACQUISITION

ACCURACY TEST

DATE: Initial Issue May 12, 1965
Final Revision June 25, 1965

AUTHOR(S): P. Blau
P. Blau, Instrument Systems Engineering

APPROVED BY: R. F. Roller
R. F. Roller, Supervisor
Instrument Systems Engineering
Instrumentation Systems and Facilities Support
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PROJECT NE-3630

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1.0 INTRODUCTION

Accuracy tests performed to date on the Test Cell "A" Data Acquisition System have resulted in differing accuracy values.

Meetings have been held (Reference (1) NTO-M-2775, dated March 5, 1965; (2) NTO-M-3976, dated May 5, 1965; (3) WANL-TR-4529 (ISFS-973), dated May 11, 1965) to resolve these inconsistencies and it was agreed:

- a. That a narrow band accuracy test should be performed at the end of the NRX-A3 tests.
- b. That the plan and procedure for this test should be reviewed and agreed upon by all parties concerned.
- c. That the statistical method of selecting channels and analyzing data, and the tests employed should result in an accuracy value for each of the ten possible channel configurations and that these accuracy values will be used by all parties concerned.
- d. That while the tests shall be performed on specific channels typical of NRX-A3 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:

- 2.1 Overall channel accuracy (error band limits).
- 2.2 Channel linearity, drift, noise, zero offset.
- 2.3 Channel frequency response.

WANL-TME-1161

2.4 Channel crosstalk.

2.5 Contribution of data instrument component error to channel (amplifier, etc.) inaccuracy.

2.6 Provide data that would permit component error contribution isolation if large errors are encountered.

3.0 TEST DESCRIPTION AND PLAN

3.1 System Description

The narrow band data acquisition system at Test Cell "A" consists of a high-level and a low-level Pulse Amplitude Modulated-Frequency Modulated (PAM/FM) system. The high-level system accepts input signals in the 0 to 5 volt range. These signals are derived either from high-level transducer outputs or from amplified low-level transducer outputs. Input analog signals are sampled at 40 samples per second by solid-state (EG&G) high-level multiplexers. 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 Pulse Amplitude Modulated (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.

The low-level system functions the same as the high-level system using appropriate low-level components such as low-level multiplexers. Both 40 sample-per-second solid-state (SEL) and 10 sample-per-second mechanical (Bendix) multiplexers are used in the low-level system. Each signal conditioner contains resistance networks which are used to range or scale the transducer output voltage for input to the rest of the system.

Figures 1A through 10A indicate the 10 basic channel configurations found on NRX-A3 high and low-level measurements. These 10 basic channel configurations are typical and cover most of the NRX-A3 diagnostic measurement possibilities. Figures 1A through 4A are the high-level configurations; Figures 5A through 10A are low-level configurations. The configurations covered are:

- Figure 1A - Thermocouple (Ch/A) Measurement - High-Level,
With Reference Well (EG&G Multiplexer).
- Figure 2A - Thermocouple (W/W) Measurement - High-Level,
Without Reference Well (EG&G Multiplexer).
- Figure 3A - Strain Gage Measurement - High-Level (EG&G Multiplexer).
- Figure 4A - Swept Pot Measurement - High-Level (EG&G Multiplexer).
- Figure 5A - Thermocouple (C/C) Measurement - Low-Level
With Reference Well (Bendix Multiplexer).
- Figure 6A - Temperature (RTT) Measurement - Low-Level
Without Reference Well (Bendix Multiplexer).
- Figure 7A - Strain Gage Measurement - Low-Level (Bendix Multiplexer).
- Figure 8A - Thermocouple (C/C) Measurement - Low-Level
With Reference Well (SEL Multiplexer).
- Figure 9A - Temperature (RTT) Measurement - Low-Level
Without Reference Well (SEL Multiplexer).
- Figure 10A - Strain Gage Measurement - Low Level (SEL Multiplexer).

3.2 Test Description

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 each phase. Also, before Linearity Run A; and before and after Linearity Run E.

3.2.2 Frequency Response Tests

A signal generator may be used to activate the amplifier sections of the power supplies permitting AC signals to be applied for the frequency response test, conducted at 0.1, 1.0, 5.0 and 10 cps. The accuracy of the frequency response measurements should be within 0.1 per cent. All test instruments used in this test shall be laboratory calibrated prior (within 2 weeks) to this test.

3.2.3 Crosstalk Tests

Determination of the level of cross talk will be accomplished by setting channels up as follows:

- (1) DC-1 Crosstalk (13 data channels at full scale input while the 27 remaining data channels are also at full scale)
- (2) DC-2 Crosstalk (13 data channels at zero level input while the 27 remaining data channels are at full scale)
- (3) DC-3 Crosstalk (the 40 test channels will have full scale to zero input in 11 steps while all unused multiplexer inputs are at 75% of full scale)
- (4) DC-4 Crosstalk (the 40 test channels will have full scale to zero input in 11 steps while all unused multiplexer inputs are at 200% of full scale)
- (5) AC Crosstalk (13 data channels at zero level input while the 27 remaining data channels are at full scale 1 cps)

The chart which follows indicates the multiplexers and the total number of bits which are involved in this crosstalk test with channels as wired for NRX-A3.

Multiplexer	HL1	HL2	HL4	HL5	LL2	LL5	LL6	LL9	LL10	Total
Data Channel Bits	33	03, 05	31	02	30, 20	16	15, 28	35, 37	10	(13)
Adjacent Channel Bits	34	04	32	03	31, 21	17	16, 29	36, 38	11	(12)

The channels are preselected (see section 8.0) and the programmable power supply system is wired to the mating car plug (at the Test Cell wall) from the ELR. Care should be taken to account for line drop in this cabling.

All NRX-A3 channel hook-ups shall remain intact after completion of the NRX-A3 tests. None of the channels indicated herein will be disconnected; these tests are to be performed on the indicated channels as wired for NRX-A3 (see Table I).

3.2.4 Linearity Tests

The programmable power supply system will be used to insert test signals in ten 10 per cent steps from zero to full scale through a "patch-plug" type arrangement at the test cell plug. A brief description of this EG&G set-up is covered in section 5.0. In providing the 10 per cent steps the power supplies will provide data needed to fulfill the linearity, drift, noise, and zero offset test objectives.

The linearity, frequency response, and crosstalk tests as indicated in section 3.5.1 will constitute a complete test cycle for each of the three phases described in the following sections.

3.2.5 Phase I

Figures 1B through 10B are block diagrams indicating the ten basic channel configurations repeated for four identical channel measurements. The same signal source levels (except for the crosstalk test) will be inserted simultaneously into these four channels. Each of

the two multiplexers will receive inputs from two channels. These forty channels will be sampled at time intervals of 0, 2, 4, 8 and 16 hours (16 hour total). These time intervals will be designated Test Runs A, B, C, D, and E.

3.2.6 Phase II

For the Phase II tests, amplifiers A and B are interchanged in the block diagram of each test setup. For example, in Figure 1B, amplifier A_1 is connected with multiplexer bit H0134 and A_2 is connected to H0124. With the amplifiers interchanged, the same 40 channels will be sampled again, for additional time intervals of 0, 2, 4, 8 and 16 hours. Where amplifiers cannot be interchanged, signal conditioners will be interchanged.

3.2.7 Phase III

For Phase III, the amplifiers are reconnected in their original positions but the multiplexers are interchanged. For example, in Figure 1B, multiplexer A will now be connected with inputs B_1 and B_2 , while multiplexer B is connected with inputs A_1 and A_2 . The same 40 channels (with multiplexers interchanged) are again sampled at the same time intervals as before. This will now provide a total of 120 channels of sampled data taken over a span of 16 hours each. If time permits, another data sample (run F) should be taken after an additional 16 hours; a final data sample (run G) is then taken after another 16-hour period. Specified time intervals for drift tests may be modified in order that normal working schedules can be maintained. However, this modification should remain consistent throughout all phases of the test.

3.3 Components Test

A cross check on the data instrument components in the above manner is an essential part of this test. The common methods of adding the certified accuracies of all the components, or even calculating the square root of the sum of the squares of the accuracies of all the components does not always result in realistic estimates. When a number of

instruments are grouped to perform a single overall function, their individual errors may become combined in such a way that the error of the whole group is largely random. If statistical methods can be used to evaluate the entire system, the contribution of each part can be determined. The system error can then be considered as a statistical combination of the errors of the parts.

3.4 Test Measurements and Setup

Refer to Figure 2B as a typical block diagram. The following voltage and frequency measurements are to be manually recorded as indicated under 3.5.1:

- V_1 - at the test car wall plug
- V_2 - at signal conditioner input
- V_3 - at signal conditioner output
- V_4 - at amplifier output
- F - output frequency of the VCO
- V_{1A} - at power supply output bus. (Note: this bus is the input to the source signal conditioners which is the EG&G system for transducer simulation. This circuit is not shown on the attached block diagrams.)

In addition, the calibration voltage to the VCO's, as well as the frequency shifts associated with this voltage, are to be recorded. All voltage measurements are to be made with digital voltmeters within 0.1 per cent. The frequency measurement is to be made with the Hewlett-Packard frequency counter within 0.1 per cent.

To provide four channels each for Figures 6B and 9B, three simulated temperature channels (identified as T-XXX-1, -2 and -3) were added.

3.5 Test Procedure

3.5.1 Each of the three phases will consist of the following 28 separate runs:

Manual Measurements

(1) Data System Calibration 1	
(2) AC-1 Frequency Response at 0.1 cps	40 V1
(3) AC-2 Frequency Response at 1.0 cps	40 V1
(4) AC-3 Frequency Response at 5.0 cps	40 V1
(5) AC-4 Frequency Response at 10.0 cps	40 V1
(6) AC-5 Crosstalk (13 channels)	52 V1, V2, V3, V4
(7) DC-1 Crosstalk	40 V1
(8) DC-2 Crosstalk	---
(9) DC-3 Crosstalk	---
(10) DC-4 Crosstalk	---
(11) Data System Calibration No. 2	266 V1A, V1, V2, V3, V4
(12) Linearity Run A at 0 hours	66 F
(13) Linearity Run B at 0 + 2 hours	240 V1
(14) Linearity Run C at 0 + 4 hours	---
(15) Linearity Run D at 0 + 8 hours	---
(16) Data System Calibration No. 3	266 V1A, V1, V2, V3, V4; 66 F
(17) Linearity Run E at 0 + 16 hours	---
(18) Data System Calibration No. 4	---
(19) DC-5 Crosstalk	40 V1
(20) DC-6 Crosstalk	---
(21) DC-7 Crosstalk	---
(22) DC-8 Crosstalk	---
(23) AC-6 Frequency Response at 0.1 cps	40 V1
(24) AC-7 Frequency Response at 1.0 cps	40 V1
(25) AC-8 Frequency Response at 5.0 cps	40 V1
(26) AC-9 Frequency Response at 10.0 cps	40 V1
(27) AC-10 Frequency Response at 10.0 cps	52 V1, V2, V3, V4
(28) Data System Calibration No. 5	---

3.5.2 Recording

3.5.2.1 Tape Signals

The programmable power supply system will be stepped off in ten 10 per cent 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 28 runs indicated on 3.5.1 will be recorded on tape for each phase. The time code generator will be running during the entire test; and a log recorded of the test portion being conducted and the time.

NOTE: Do not operate tape recorder while V_1 signals are being measured, because of loading effects.

3.5.2.2 Digital Signals (Manual Measurements)

The voltage and frequency measurements specified in section 3.4 will be manually recorded for each of the 16 separate runs indicated in section 3.5.1. The specified voltages can be measured with the Electro-Instruments voltmeter in the Transducer Test Equipment if desired.

3.5.3 Quick-Look System

The quick-look system will be checked by comparing all V_3 voltages (signal conditioner outputs for configurations typical of Figure 6B), or all V_4 voltages (amplifier outputs for configurations typical of Figure 1B) with the recordings made on the Sanborns. Admittedly, only gross errors can be determined by this visual procedure.

4.0 STATISTICAL BASIS FOR TEST PLAN

4.1 Since the primary objective of this experiment is to estimate the accuracy of data channels, it would seem that a simple experimental plan involving repeated tests of

several channels would be sufficient. However, the circuitry of these channels varies with the type of input being observed and thus the accuracy of measurements transmitted would not necessarily be independent of the type of channel (channel configuration), nor necessarily independent of the components of the circuit for a particular configuration. Then too, if the accuracy as determined from a simple experiment differs substantially from the expected, an indication as to what configuration or what components may be at fault cannot be easily obtained. Thus, it is necessary to perform tests which help to pinpoint individual component errors, rather than solely system error limits.

4.2 Section 3.0, Test Description and Plan, contains a description of a plan considering ten channel configurations with two multiplexers per configuration and two channels (different amplifiers or signal conditioners) per multiplexer, for a total of 40 channels for Phase I. Phases II and III also consider 40 channels using the same test conditions with an interchange of multiplexers and/or signal conditioners and/or amplifiers occurring between each phase. In each phase the parameters of interest are to be measured at 0, 2, 4, 8 and 16 hours with the possibility of two additional sets of measurements after an additional 16 and 32 hours in Phase III.

4.3 Following the plan as described in section 3.0, a total of 200 measurements for each parameter in each phase will be obtained. These data will be analyzed using the Analysis of Variance technique and should yield a valid estimate of the accuracy of a data channel. Furthermore, by combining data from Phase I and Phase II, an estimate of the effect of amplifiers and/or signal conditioners on the accuracy estimate will be derived; by combining the data from Phase I and Phase III, an estimate of the effect of multiplexers on the accuracy estimate will be obtained; and finally, by combining the data of Phase II and Phase III, estimates of possible interaction effects will be evaluated. Additional analyses using the Analysis of Variance technique will be made to derive correlations between the parameters of interest, primarily to determine weighing factors (if these exist) for combining variance (accuracy) estimates from all parameters. The Plan described in section 3.0 was established to yield valid

estimates associated with the overall accuracy of data channels. It was established with the Analysis of Variance technique considered as the statistical tool to be used to obtain these valid estimates. The tests were established to obtain maximum information (configuration, multiplexer, amplifier, signal conditioner, time, and their interaction effects) for a minimum experimental effort.

4.4 Test data taken in the program described are to be analyzed using analysis of variance techniques, as described in the following references 1 and 3. The additional references describe techniques of lesser importance which will be utilized as needed.

1. Chew, V.
Experimental Designs in Industry
John Wiley and Sons, New York City
2. Cochran, W. G., and Cox, G. M.
Experimental Designs
John Wiley and Sons, New York City
3. Davies, O. L.
Design and Analysis of Industrial Experiments
Hafner Publishing Company, New York City
4. Fisher, R. A.
Design of Experiments
Hafner Publishing Company, New York City
5. Kempthorne, O.
Design and Analysis of Experiments
John Wiley and Sons, New York City

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4.5 Source of Analysis Data

The analysis will be done from the digital (N_3) tapes and separate values will be reported for the CAL COMP plotter and non-linear calibrations. A comparative analysis will be made (for the same channels) between the CAL COMP PLOTS of this test and those from the calibrations on NRX-A3.

4.5.1 Use of NRX-A3 Data in Verification of Derived Values

A comparison of the ambient run data from NRX-A3 will be made of the channels under test in the accuracy test plan in order to establish the transducer contribution to the inaccuracy. Such transducer contribution should be helpful, especially in the determination of noise.

4.5.1.1 The end-to-end stimulus test from NRX-A3 data will also be considered as a possible addition to the analysis data. (It should be noted that the mechanical commutators were not running at this time, and some reduction of noise will be observed because of this.)

4.5.1.2 NRX-A3 data from the test channels specified in the test plan will be analyzed and compared with the results of the accuracy test. Check values for linearity and long term drift (approximately 13 hours) can be evaluated from the pre- and post-voltage calibrations of NRX-A3. Also, a quasi-crosstalk measurement (considering the multiplexer component only, and disregarding cable and connector contributions) from the signal conditioners to the recorders can be obtained from these NRX-A3 calibrations, and used to check crosstalk figures obtained by the analysis technique.

4.6 Reports

The final analysis report will include samples of CAL Comp plots, Sanborn charts, and a description of the data reduction and analysis techniques used in determining the accuracy values. If possible, the analysis report will indicate the separate inaccuracy contributions for the transducer, the data acquisition and the data reduction systems.

5.0 SIMULATION OF TRANSDUCER OUTPUTS

The programmable power supplies will remain in and be used from the ELR, thus keeping the ambient temperature of the power supplies well controlled. These supplies (in conjunction with 40 source signal conditioners) will be used with the channel signal conditioners as follows:

5.1 EG&G will hook up the power supplies and source signal conditioners to provide the correct signal levels and simulated transducer impedances, route a cable from the ELR to the test pad, and connect the cable to the test car plug. These signals will permit the accomplishment of the linearity test (section 3.2.4) objective of section 2.2.

5.2 Channel crosstalk (section 3.2.3) will be accomplished by routing signals from a separate power supply to the test car plug in order to supply the required two signals.

5.3 EG&G will provide a function generator and read out equipment required to accomplish the frequency response test (section 3.2.4) objectives.

6.0 DATA REDUCTION AND PRESENTATION METHOD

6.1 Data Reduction

The PAM/FM data recorded on magnetic tape for this test will be decommutated, digitized by the CDC160-A computer, reduced to engineering units by an IBM-704 computer, formatted for plotting by the CD160-A computer and plotted as time versus function (voltage) curves by California Computer Corporation (CAL COMP) plotters.

A portion of the data will be reduced twice. This will be done for the purpose of checking any errors resulting from the making of tape copies.

6.2 Figure 11 shows a flow chart of the data flow through the data reduction system. The operations shown are:

1. Digitization: Under control of input cards (I) and manual switches data (A) is digitized over specific time intervals and at specific sampling rates.
2. Reduction: The data on the N2 tape (B) is reduced to engineering units via a calibration (C) in the form of straight line segments approximating the transducer calibration curve to within 0.1 per cent. Data is reduced from channels as specified on the patch panel tape (D) over time intervals as specified by the input cards (J). All data will be reduced linearly for direct comparison with the manually recorded data. In addition, all linear data for Phase I will be processed to generate CAL COMP plots similar to NRX-A3 calibration data. These CAL COMP plots will include both voltage calibrations and transducer conversion data associated with particular channels. (NOTE: Transducer conversion is defined as the reduction process of converting the transducer calibration to engineering units. Since Phase I of this test is wired as it was during NRX-A3, CAL COMP plots for Phase II and III will not include the transducer conversion.) To evaluate the accuracy of the CAL COMP plots in general, and not those associated with transducer conversion inaccuracies, CAL COMP plots of all the linearly reduced data will be made.
3. Formatting: The data in engineering units contained on the N3 tape (E) is formatted for the plotters and written on the N4 tape (G).
4. Plotting: Plots (H) are prepared under control of the CDC160-A computer.

7.0 CHANGES TO SYSTEM CONFIGURATION - NEW EQUIPMENT

When new components are substituted in the data system, it is not necessary to perform the entire system check again. The following procedure shall be observed.

7.1 Bench test values for linearity, crosstalk, drift, frequency response and noise for any new component shall be used to calculate a new expected channel accuracy value based on one of the correct channel configurations.

7.2 An end-to-end channel check shall then be performed to confirm the predicted channel accuracy. This is done by applying known voltages at the test car plug and noting the frequency shift at the output of the VCO. Also, the output shall be recorded on the N3 tape, and this N3 tape compared with the N3 tape made with previous (NRX-A3) equipment.

7.3 If this new accuracy value is not within ± 0.5 per cent of the predicted channel configuration accuracy value, then a complete Phase II or Phase III (depending upon the type of component) test shall be performed as described in section 3.2.5 or 3.2.6 to determine the reasons for the lack of estimated accuracy.

8.0 DETAILS OF CHANNEL SET-UP AIDS

8.1 Table I shows the channels which will be used during the accuracy tests. The column headings are defined as follows:

<u>Column</u>	<u>Description</u>
1	System measurement types, as given previously (Figure 1B through Figure 10B).
2	Channels for which signals will be simulated.
3	Transducer type being simulated.
4	Full scale signal for that channel.
5	Band width of this type of measurement.
6	Multiplexer and bit position for that multiplexer for the channel indicated.
7	Multiplexer type.
8	Zero calibration offset signal required.

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8.2 Table II describes the signal insertion points for each channel measurement at the master plug. (Note: Signals for Figure 4B will be inserted at the most convenient terminal boards located in the ELR, FCR, or RER.)

9.0 DATA ANALYSIS AND COMPUTATION METHOD

9.1 Linearity

Linearity is determined by defining a function such that $V_i = f[V_i^1]$

where: V_i = the computer calculated output voltage

V_i^1 = the input voltage as recorded at the TCA

i = 1 to 11 voltage calibration steps

Therefore linearity is defined as the maximum of the absolute difference $[V_i^1 - \bar{V}_i]$, where $\bar{V}_i$ is the measured output voltage as read from the N3 tape.

This, linearity for the entire system includes the data reduction system linearity correction capability as well as the data system contribution. The maximum deviation on any single step of the eleven step calibration signal then becomes the defining system linearity.

9.2 Drift

9.2.1 Full Scale Drift (Gain Stability)

For a full scale input voltage applied at several distinctly separate times, some variation in N3 indicated voltages can be expected. This variation represents (primarily) full scale drift (or gain stability) in the channel.

9.2.2 Zero Offset Drift

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.

9.2.3 Determination of Drift

Full scale drift and zero offset drift as described in paragraphs 9.2.1 and 9.2.2 should 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 maximum deviation between these curves over the zero to full scale span. This deviation should be expressed as a percent of full scale per hour.

9.3 Noise

Noise will be determined by using the N3 peak-to-peak values. From these values, the standard deviation for the eleven steps, (each being a 10 second data sample period) will be determined. Noise will be expressed as a percentage of the full scale input.

For each step, the maximum difference of the peak-to-peak values will be determined and compared with the standard deviation to ascertain the presence of spurious signals.

9.4 Crosstalk

Crosstalk will be defined as the maximum coupling (expressed as a percentage of full scale signal on the test channel) observed in any of the tests described in section 3.2.3.

9.5 Channel Accuracy

The accuracy of some systems have commonly been computed by taking the variances of the data runs for each parameter (linearity, drift, noise, etc.), then adding the sum of the square of the variances and extracting the square root. This method may be realistic if the parameters are independent.

For this accuracy tests, the subsequent analysis of the data may indicate that some of the parameters under test are not independent. Therefore, weighing factors will be

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developed from the analyses, and will be appropriately assigned for computing the channel accuracy. An equation cannot be given at this time, except to state that it will generally follow the form of the root mean square formula.

NOTE: The writer acknowledges the contribution of all who have participated in the preparation and review of this test plan, especially Mr. W. Horton (WANL, Reliability) for preparing section 4.0 "Statistical Basis for Test Plan," and Mr. M. Vuckovich (WANL, Instrumentation Systems and Facilities Support) for technical contributions.

FIG. 1,A THERMOCOUPLE MEASUREMENT THROUGH HIGH LEVEL SYSTEM/USING REFERENCE WELL (EG&G MULTIPLEXER)

605352A

*ONLY USED WITH EG & G MULTIPLEXERS

605353A

FIG. 2.A THERMOCOUPLE MEASUREMENT THROUGH HIGH LEVEL SYSTEM WITHOUT A REFERENCE WELL (EG&G MULTIPLEXER)

FIG. 3.A STRAIN GAGE MEASUREMENT THROUGH HIGH LEVEL SYSTEM (EG&G MULTIPLEXER)

*ONLY USED WITH EG & G MULTIPLEXERS

605355A

FIG. 4.A SWEEP POT MEASUREMENT THROUGH HIGH LEVEL SYSTEM. (EG&G MULTIPLEXER)

FIG. 5.A THERMOCOUPLE MEASUREMENT THROUGH LOW LEVEL SYSTEM USING REFERENCE WELL. (BENDIX MULTIPLEXER)

605356A

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FIG. 6.A TEMPERATURE MEASUREMENT THROUGH LOW LEVEL SYSTEM WITHOUT REFERENCE WELL. (BENDIX MULTIPLEXER)

605357A

WALT-TME-1161

FIG. 7.A STRAIN GAGE MEASUREMENT THROUGH LOW LEVEL SYSTEM. (BENDIX MULTIPLEXER)

605358A

WALT-TME-1161

FIG. 8. A TEMPERATURE MEASUREMENT THROUGH LOW LEVEL SYSTEM USING REFERENCE WELL (SEL MULTIPLEXER)

605359A

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FIG. 9.A TEMPERATURE MEASUREMENT THROUGH LOW LEVEL SYSTEM WITHOUT REFERENCE WELL (SEL MULTIPLEXER)

605378A

WANT-ME-1161

605379A

FIG. 10.A STRAIN GAGE MEASUREMENT THROUGH LOW LEVEL SYSTEM (SEL MULTIPLEXER)

FIGURE 1B - (CH/A) T/C MEASURE THROUGH HIGH LEVEL SYSTEM WITH
REFERENCE JUNCTION (EC&G MULTIPLEXER)

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FIGURE 2B - (W/N) T/C MEASUREMENT THROUGH HIGH LEVEL SYSTEM
WITHOUT A REFERENCE WELL (EG&G MULTIPLEXER)

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FIGURE 3B - STRAIN GAGE MEASUREMENT THROUGH HIGH LEVEL SYSTEM (EQ&G MULTIPLEXER)

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FIGURE 4B - SWEPT POT MEASUREMENT THROUGH HIGH LEVEL SYSTEM (EG&G MULTIPLEXER)

FIGURE 5B - (C/C) T/C MEASUREMENT THROUGH LOW LEVEL SYSTEM WITH REFERENCE JUNCTION
(T/C MULTIPLEXER.)

FIGURE 6B - (RTT) TEMPERATURE MEASUREMENT THROUGH LOW LEVEL SYSTEM WITHOUT REFERENCE JUNCTION (BENDIX MULTIPLEXER)

FIGURE 7B - STRAIN GAGE MEASUREMENT THROUGH LOW LEVEL SYSTEM (BENDIX MULTIPLEXER)

FIGURE 8B - (C/C) T/C MEASUREMENT THROUGH LOW LEVEL SYSTEM WITH
REFERENCE JUNCTION (SEL MULTIPLEXER)

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FIGURE 9B - (RTT) TEMPERATURE MEASUREMENT THROUGH LOW LEVEL SYSTEM WITHOUT REFERENCE JUNCTION (SEL MULTIPLEXER)

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FIGURE 10B - STRAIN GAGE (PRESSURE) MEASUREMENT THROUGH LOW LEVEL SYSTEM (SEL MULTIPLEXER)

FIGURE 11 DATA FLOW THROUGH DATA REDUCTION SYSTEM

TABLE I

<u>Fig.</u>	<u>Channel</u>	<u>Descrip.</u>	<u>F.S.</u>	<u>B/W</u>	<u>Mplx.</u>	<u>Type</u>	<u>Z Cal.</u>
1. B	T-603-3A	C/A	40 mv	5	H0203	EG&G	+5.714
	T-607-3A	C/A	40 mv	5	H0205	EG&G	+5.714
	T-613-3A	C/A	40 mv	5	H0124	EG&G	+5.714
	T-763-3A	C/A	40 mv	5	H0134	EG&G	+5.714
2. B	T-601-3A	W/W	40 mv	5	H0122	EG&G	0
	T-663-3A	W/W	40 mv	5	H0133	EG&G	0
	T-602-3A	W/W	40 mv	5	H0222	EG&G	0
	T-139-3A	W/W	40 mv	5	H0213	EG&G	0
3. B	P-124-3A	SG PS	20 mv	5	H0103	EG&G	0
	PD-401-3A	SG PS	20 mv	5	H0110	EG&G	0
	P-210-3A	SG PS	20 mv	5	H0204	EG&G	0
	PD-203-3A	SG PS	20 mv	5	H0209	EG&G	0
4. B	DP-XXX-1	Pot.	10 v	5	H0431	EG&G	0
	DP-049B-K	Pot.	10 v	5	H0432	EG&G	0
	DJ-011-G	Pot.	10 v	5	H0502	EG&G	0
	DJ-XXX-2	Pot.	10 v	5	H0503	EG&G	0
5. B	T-245-3A	C/C	10 mv	1	L0316	Ben.	+6.155
	T-433-3A	C/C	10 mv	1	L0320	Ben.	+6.125
	T-246-3A	C/C	10 mv	1	L0416	Ben.	+6.155
	T-434-3A	C/C	10 mv	1	L0420	Ben.	+6.125
6. B	T-856-3A	RTT	40 mv	1	L0528	Ben.	-55.253
	T-866-3A	RTT	40 mv	1	L0530	Ben.	-39.173
	T-860-3A	RTT	40 mv	1	L0628	Ben.	-76.708
	T-XXX-1	RTT	40 mv	1	L0629	Ben.	-55.253
7. B	M-254-3A	SG	40 mv	1	L0516	Ben.	+20.00
	M-256-3A	SG	40 mv	1	L0517	Ben.	+20.00
	M-253-3A	SG	40 mv	1	L0615	Ben.	+20.00
	M-255-3A	SG	40 mv	1	L0616	Ben.	+20.00
8. B	T-216-3A	C/C	10 mv	5	L0936	SEL	+6.155
	T-226-3A	C/C	10 mv	5	L0937	SEL	+6.155
	T-360-3A	C/C	10 mv	5	L1010	SEL	+6.066
	T-361-3A	C/C	10 mv	5	L1011	SEL	+6.066

TABLE I (Cont'd)

<u>Fig.</u>	<u>Channel</u>	<u>Descrip.</u>	<u>F.S.</u>	<u>B/W</u>	<u>Mplx.</u>	<u>Type</u>	<u>Z Cal.</u>
9.B	T-854-3A	RTT	100 mv	5	L0230	SEL	-51.147
	T-864-3A	RTT	100 mv	5	L0231	SEL	-51.147
	T-XXX-2	RTT	100 mv	5	L0935	SEL	-51.147
	T-XXX-3	RTT	100 mv	5	L0938	SEL	-51.147
10.B	P-406-3A	SG PS	20 mv	5	L0220	SEL	0
	P-500-3A	SG PS	20 mv	5	L0221	SEL	0
	P-305-3A	SG PS	20 mv	5	L1019	SEL	0
	P-308-3A	SG PS	40(20)mv	5	L1030	SEL	0

TABLE II

<u>Fig.</u>	<u>Channel</u>	<u>Type</u>	<u>Wire Code</u>	<u>Master Plug</u>	<u>Mplx.</u>
1.B	T-603-3A	CH/A	CH	J15-88	H0203
			AL	J15-89	
			SH	J15-90	
	T-607-3A	CH/A	CH	J15-98	H0205
			AL	J15-97	
			SH	J15-96	
	T-613-3A	CH/A	CH	J17-1	H0124
			AL	J17-2	
			SH	J17-3	
	T-763-3A	CH/A	CH	J17-19	H0134
			AL	J17-20	
			SH	J17-21	
2.B	T-601-3A	W/W	BLK	J9-1	H0122
			WHT	J9-2	
			SH	J9-3	
	T-663-3A	W/W	BLK	J11-82	H0130
			WHT	J11-81	
			SH	J11-80	
	T-602-3A	W/W	BLK	J9-4	H0222
			WHT	J9-5	
			SH	J9-6	
	T-139-3A	W/W	BLK	J-28-91	H0213
			WHT	J-28-92	
			SH		
3.B	P-124-3A	SG PS	BLK-7	J22-19	H0103
			WHT	J22-20	
			BLK-8	J22-22	
			WHT	J22-23	
			SH	J22-33	
	PD-401-3A	SG PS	BLK-24	J30-70	H0110
			WHT	J30-71	
			BLK-25	J30-73	
			WHT	J30-74	
			SH	J30-75	

TABLE II (Cont'd)

<u>Fig.</u>	<u>Channel</u>	<u>Type</u>	<u>Wire Code</u>	<u>Master Plug</u>	<u>Mplx.</u>
3.B (Cont'd)	P-210-3A	SG PS	BLK-9	J23-32	H0204
			WHT	J23-31	
			BLK-10	J23-29	
			WHT	J23-28	
			SH	J23-27	
	PD-203-3A	SG PS	BLK-5	J23-8	H0209
			WHT	J23-7	
			BLK-6	J23-16	
			WHT	J23-17	
			SH	J23-18	
4.B	DP-XXX-1	Pot.		J-14-70	H0431
				J-14-71	
	DP-049B-K	Pot.		J-14-76	H0432
				J-14-77	
	DJ-011-G	Pot.		J-14-82	H0502
				J-14-81	
	DJ-XXX-2	Pot.		J-14-88	H0503
				J-14-89	
5.B	T-245-3A	C/C	CU BLK-19	J28-55	L0316
			CN WHT	J28-56	
			SH	J28-57	
	T-433-3A	C/C	CU BLU-4	J16-11	L0320
			CN RED	J16-10	
			SH	J16-9	
	T-246-3A	C/C	CU BLK-20	J28-58	L0416
			CN WHT	J28-67	
			SH	J28-66	

TABLE II (Cont'd)

<u>Fig.</u>	<u>Channel</u>	<u>Type</u>	<u>Wire Code</u>	<u>Master Plug</u>	<u>Mplx.</u>
5.B (Cont'd)	T-434-3A	C/C	CU BLU-5 CN RED SH	J16-8 J16-7 J16-15	L0420
6.A	T-856-3A	RTT	BLK-24 WHT BLK-25 WHT SH	J29-70 J29-71 J29-73 J29-74 J29-75	L0528
	T-866-3A	RTT	BLK-17 WHT BLK-18 WHT SH	J30-44 J30-43 J30-52 J30-53 J30-54	L0530
	T-860-3A	RTT	BLK-28 WHT BLK-29 WHT SH	J29-82 J29-81 J29-79 J29-78 J29-87	L0628
	T-XXX-1	RTT	BLK WHT	J24-22 J24-23	L0629
7.B	M-254-3A	SG	BLK-1 WHT BLK-2 WHT SH	J30-1 J30-2 J30-4 J30-5 J30-6	L0615
	M-256-3A	SG	BLK-5 WHT BLK-6 WHT SH	J30-8 J30-7 J30-16 J30-17 J30-18	L0517

TABLE II (Cont'd)

<u>Fig.</u>	<u>Channel</u>	<u>Type</u>	<u>Wire Code</u>	<u>Master Plug</u>	<u>Mplx.</u>
7.B (Cont'd)	M-253-3A	SG	BLK-32	J23-94	L0615
			WHT	J23-100	
			BLK-33	J23-98	
			WHT	J23-97	
			SH	J23-96	
	M-255-3A	SG	BLK-3	J30-14	L0616
			WHT	J30-13	
			BLK-4	J30-11	
			WHT	J30-10	
			SH	J30-9	
8.B	T-216-3A	C/C	CU BLK-12	J27-34	L0936
			CN WHT	J27-35	
			SH	J27-36	
	T-226-3A	C/C	CU BLK-14	J27-40	L0937
			CN WHT	J27-41	
			SH	J27-42	
	T-260-3A	C/C	CU BLU-13	J8-37	L1010
			CN RED	J8-38	
			SH	J8-39	
	T-361-3A	C/C	CU BLU-14	J8-40	L1011
			CN RED	J8-41	
			SH	J8-42	
9.B	T-854-3A	RTT	BLK-22	J29-62	L0230
			WHT	J29-61	
			BLK-23	J29-59	
			WHT	J29-68	
			SH	J29-69	
	T-864-3A	RTT	BLK-32	J29-94	L0231
			WHT	J29-100	
			BLK-33	J29-98	
			WHT	J29-97	
			SH	J29-96	

TABLE II (Cont'd)

<u>Fig.</u>	<u>Channel</u>	<u>Type</u>	<u>Wire Code</u>	<u>Master Plug</u>	<u>Mplx.</u>
9.B (Cont'd)	T-XXX-2	RTT	BLK-17	J29-44	L0935
			WHT	J29-43	
			BLK-18	J29-52	
			WHT	J29-53	
			SH	J29-54	
	T-XXX-3	RTT	BLK-19	J29-55	L0938
			WHT	J29-56	
			BLK-20	J29-58	
			WHT	J29-67	
			SH	J29-66	
10.B	P-406-3A	SG PS	BLK-10	J14-29	L0220
			WHT	J14-28	
			BLK-11	J14-26	
			WHT	J14-25	
			SH	J14-24	
	P-500-3A	SG PS	BLK-16	J14-47	L0221
			WHT	J14-46	
			BLK-17	J14-44	
			WHT	J14-43	
			SH	J14-51	
	P-305-3A	SG PS	BLK-6	J14-16	L1019
			WHT	J14-17	
			BLK-7	J14-19	
			WHT	J14-20	
			SH	J14-21	
	P-308-3A	SG PS	BLK-8	J14-22	L1030
			WHT	J14-23	
			BLK-9	J14-32	
			WHT	J14-31	
			SH	J14-30	

APPENDIX B

METHOD OF DATA REDUCTION AND ANALYSIS

Data from the basic accuracy test as described in WANL-TME-1161 were recorded on N3 tapes as percentage of full scale values. For this study a total of 33 tapes (one tape per multiplexer per test phase) were derived. These tapes were forwarded to WANL from the Test Site for further data reduction and analysis. This appendix is to describe in more detail the methods used to reduce the data for analytical determinations and the technique used to analyze the reduced data.

For any one step of the test runs required by the basic accuracy test plan, data were to be generated for at least 10 seconds. If the test run did not involve discrete steps such as performed in the linearity and calibration runs, data were generated for at least 100 seconds. For all data generated, a sampling rate of 5 data points per second was used in creating the N3 tapes. Table B-1 contains typical data as found on the N3 tapes and gives that data for the four channels on multiplexer LL02 for the 100 and 99% steps of linearity run A during Phase I.

As may be seen in Table B-1, approximately 50 values were obtained for both the 100% and 90% steps. These data are typical of almost all data recorded on the N3 tapes (notable exceptions were the frequency response and AC crosstalk data).

N3 tape data were further processed on the IBM 7094 computer at WANL with a program to yield two values. The two values computed were the average ($\bar{X}$) and a variance estimate (s^2) based upon the first 40 readings for a specified set of conditions (e.g., a voltage step of a calibration run). Basically the program read the N3 tape, established a set of limits for the subsequent data, checked the subsequent data to assure that the data point fell within these limits, and, if 40 values falling within these limits were found before there were eight values outside these limits, computed the two values.

For example, referring to the data in Table B-1, the first value for channel T.854.3A030 is 100.0171. The computer program established the limits from a table by determining that the value 100.0171 fell between 95.0 and 104.9 (if the value were approximately 90, the limits would be 85.0 and 94.5, and so forth). The program then checked the subsequent data

such that the first 40 data points within these limits would be used. An erroneous data point such as that seen in Table B-1 for the 90% step for channel P.500.3A021 (value = 134217727.0000) would be rejected. Eight erroneous values before 40 acceptable data points would reject the complete set.

As stated earlier, the first 40 values meeting the previous criteria were used to compute an average ($\bar{X}$) and a variance estimate (s^2). The average ($\bar{X}$) was determined by summing the first 40 values and dividing this sum by 40. The variance estimate (s^2) was computed by summing the square of the deviations of the first 40 values from the average ($\bar{X}$) and dividing this sum by 39. Algebraically, these values are:

$$\bar{X} = \frac{\sum_{i=1}^{40} X_i}{40}, \text{ and}$$

$$s^2 = \frac{\sum_{i=1}^{40} (X_i - \bar{X})^2}{39} = \frac{\sum_{i=1}^{40} X_i^2 - (\sum_{i=1}^{40} X_i)^2 / 40}{39}.$$

As these values were computed, an IBM card was punched so as to record the date, time, multiplexer, channel, average, and variance estimate. Reduced data recorded in this manner were to be those data used in the analyses subsequently described.

For example, Table B-2 contains the reduced data ($\bar{X}$'s and s^2 's) for the five linearity runs of Phase I for the two LL02 channels of configuration 9. The first two averages and variance estimates for each channel could be derived from the data given in Table B-1.

The first analyses made were analyses of variance for the variance estimates. (The analysis of variance will be explained in more detail further on in this appendix.) A basic assumption of the analysis of variance is that the data being analyzed are normally distributed. Variance estimates per se would not be normally distributed; in fact, it is known that variances follow a logarithmic distribution. For this reason, the analyses made were on the logarithms

of the variance estimates to satisfy the normality assumption. The results of these analyses centered in the randomness of the differences found in these estimates and led to the determination of logarithmic averages of the variance estimates and the subsequent acceptance of these averages as the estimates of the noise for the data channels under different conditions. The primary disadvantage to this approach is perhaps a somewhat optimistic estimate for this accuracy parameter.

Analyses of variance for the averages were also made with those averages corresponding to the 10 channel configurations and the other test condition combined in sets of analyses for each configuration. These analyses indicated that the grouping of channel data on a configuration basis was misleading with the effects of the test difficult to assess and interpret. These analyses further indicated that the data were more properly oriented by multiplexer. For these reasons, additional analyses were made with Table B-3 reflecting the variables, their levels, total combinations per analysis, total analyses and total data (in this case, total averages and total variance estimates) used in deriving the accuracy parameters given in the body of the report.

Table B-3 says that the analyses of variance of averages were made on pairs of channels having the same multiplexer configuration history. Table B-3 also reveals that data from each phase of the test, as well as data for the linearity runs, calibration runs, and the two types of crosstalk runs were analyzed separately, yielding a total of 240 analyses of variance for the averages computed from the N3 tapes.

The analysis of variance is a statistical technique whereby the total variation in a set of data from a properly designed experiment can be partitioned into those variations assignable to the variables considered in the design and their joint affects or interactions. For the most part, the analyses made for this study were to yield variance estimates to be associated with the accuracy parameters of interest and as such were analyses for which the components of variance model was assumed. Detailed discussion of this model and the computational methods may be found in reference (1). For this appendix, it should be sufficient to give an example analysis, some discussion of its purpose and additional comments as to the estimates derived from the analysis.

Table B-4 contains the analysis of variance of the averages for the Phase I linearity runs made on the two channels of multiplexer LL02-configuration 9. Data for this analysis are given in Table B-2. Referring to Table B-4, the sources of variation in the data given in Table B-2 were the 11 linearity steps, the 5 linearity runs, the 2 channels and their interactions. Associated with each of these possible effects were the sums of squares as partitioned from the total sums of squares. Dividing each of the sums of squares by its corresponding number of degrees of freedom gives the values shown in the mean squares column. These mean squares are evaluated by means of the F-ratio and a comparison of the computed ratio to standard values of the F-distribution. As may be seen in Table B-4, the deviations from linearity and the interactions between variables were not significant when compared to the variance attributable to noise. Differences between linearity runs (termed drift) and between channels (termed bias) were significant and variance estimates reflecting these differences were computed.

The analysis of variance of Table B-4 is typical of the analyses made for all the conditions enumerated in Table B-3, with a total of 240 analyses made for the basic accuracy test data. Analyses made for data from Sanborn and CAL-COMP plots, as well as analyses made for data from the NRX-A3 calibration runs, the new equipment calibrations runs, and the manual recordings of the basic accuracy test plan, were all quite similar to the typical analysis of Table B-4. Each analysis was concerned with a factorial components of variance analysis as discussed in more detail in reference (1).

Variance estimates derived from these analyses are given in the body of this report and, from the standpoint of the number of observations involved, should be realistic and valid estimates. Combining the estimates for noise, drift, and bias to give an overall variance estimate for accuracy is also realistic and valid. After the overall variance estimates were obtained, 99% $\pm$ limits were derived by taking the square root of the variance estimates and multiplying by ± 2.6 . These limits are 99% confidence limits and imply that 99% of the intervals computed by adding these limits to an observation, will contain the "true" value. In other words, there is 99% confidence that an observation, plus and minus the stated limits, will contain the "true" value. Such limits are given in the body of this report and are those required by this study.

Reference:

- (1) Anderson, R. L., and Bancroft, T. A., "Statistical Theory in Research," McGraw-Hill Book Company, Inc., 1952.

TABLE B-1
TYPICAL N3 TAPE DATA

Data are percentage of full scale values for the four channels of multiplexer LL02 for the 100% and 90% steps of linearity run A of Phase I.

<u>Time</u>	<u>Channel P. 406. 3A020</u>	<u>Channel P. 500. 3A021</u>	<u>Channel T. 854. 3A030</u>	<u>Channel T. 864. 3A031</u>
6750. 0049	100. 4311	99. 9588	100. 0171	100. 1503
6750. 2050	100. 1011	99. 7409	99. 9092	100. 1503
6750. 4050	100. 1011	100. 0678	100. 0171	99. 6040
6750. 6050	100. 4311	99. 9588	100. 0171	99. 6040
6750. 8050	99. 9911	100. 1767	99. 8013	99. 4948
6751. 0049	100. 4311	100. 0678	99. 4775	100. 2596
6751. 2050	100. 6511	100. 2857	99. 6933	99. 9318
6751. 4050	100. 2111	99. 3051	99. 6933	99. 6040
6751. 6050	100. 1011	99. 5230	100. 1250	99. 6040
6751. 8050	99. 7710	99. 5230	99. 9092	99. 6040
6752. 0049	100. 4311	100. 0678	99. 6933	100. 0411
6752. 2050	100. 2111	99. 8499	100. 0171	99. 7133
6752. 4050	99. 9911	99. 4140	99. 9092	100. 3688
6752. 6050	99. 6610	99. 8499	100. 1250	100. 0411
6752. 8050	100. 2111	99. 8499	99. 9092	99. 9318
6753. 0049	100. 5411	99. 6319	99. 4775	100. 0411
6753. 2050	99. 8811	99. 9588	99. 8013	100. 3688
6753. 4050	100. 5411	99. 9588	100. 1250	100. 2596
6753. 6050	100. 2111	100. 0678	100. 0171	99. 7133
6753. 8050	100. 1011	99. 6319	99. 8013	99. 6040
6754. 0049	100. 4311	99. 5230	99. 5854	100. 0411
6754. 2050	99. 8811	99. 7409	99. 9092	100. 0411
6754. 4050	99. 7710	99. 9588	99. 9092	99. 8225
6754. 6050	99. 9911	99. 6319	99. 6933	100. 4781
6754. 8050	100. 5411	99. 8499	99. 6933	99. 9318
6755. 0049	100. 3211	99. 6319	100. 0171	99. 4948
6755. 2050	99. 9911	99. 7409	99. 5854	99. 9318
6755. 4050	100. 2111	99. 6319	99. 8013	100. 0411
6755. 6050	99. 8811	99. 8499	100. 1250	100. 1503
6755. 8050	99. 8811	99. 5230	99. 9092	99. 8225
6756. 0049	100. 3211	99. 4140	100. 0171	99. 8225
6756. 2050	100. 1011	99. 6319	100. 1250	100. 1503
6756. 4050	99. 7710	99. 9588	99. 9092	99. 8225

(continued)

TABLE B-1 (continued)

<u>Time</u>	<u>Channel P. 406. 3A020</u>	<u>Channel P. 500. 3A021</u>	<u>Channel T. 854. 3A030</u>	<u>Channel T. 864. 3A031</u>
6756.6050	100.3211	99.6319	100.2329	99.8225
6756.8050	99.6610	99.7409	99.9092	99.9318
6757.0049	100.1011	99.9588	99.9092	100.2596
6757.2050	100.3211	99.9588	99.8013	99.8225
6757.4050	99.9911	100.1767	99.9092	99.8225
6757.6050	100.1011	99.4140	100.0171	100.6966
6757.8050	100.1011	99.7409	99.6933	100.3688
6758.0049	100.2111	99.9588	99.6933	100.3688
6758.2050	99.8811	99.9588	99.9092	100.0411
6758.4050	100.5411	100.2857	99.9092	100.2596
6758.6050	100.1011	99.4140	99.9092	99.9318
6758.8050	100.4311	99.8499	99.8013	99.9318
6759.0049	99.8811	99.9588	100.0171	100.0411
6759.2050	99.9911	99.9588	100.0171	100.1503
6759.4050	100.1011	99.6319	99.9092	100.1503
6759.6050	99.8811	99.9588	100.0171	99.9318
6759.8050	100.1011	100.2857	100.2329	99.8225
6760.0049	100.1011	100.1767	99.8013	99.8225
6760.2050	100.1011	99.7409	100.0171	100.2596
6760.4050	100.4311	99.8499	100.2329	99.9318
6760.6050	99.9911	99.6319	100.0171	100.3688
6760.8050	99.8811	100.0678	99.6933	99.9318
6761.0049	100.2111	99.7409	99.9092	100.0411
6761.2050	90.3100	90.2616	89.6567	90.5358
6761.4050	90.4200	90.0436	90.0884	90.0987
6761.6050	90.5300	90.0436	89.9804	89.5525
6761.8050	90.5300	90.2616	89.9804	90.2080
6762.0049	90.5300	89.8257	89.7646	89.9895
6762.2050	90.4200	89.9347	90.1963	90.2080
6762.4050	90.4200	90.1526	90.0884	89.6617
6762.6050	90.2000	90.1526	90.0884	90.2080
6762.8050	90.2000	90.0436	90.1963	90.3172
6763.0049	90.4200	89.9347	89.8725	90.0987
6763.2050	89.9799	89.8257	90.6280	89.9895
6763.4050	90.3100	90.0436	89.6567	89.9895
6763.6050	89.8699	90.2616	90.0884	90.0987
6763.8050	90.4200	89.6078	89.5487	89.9895

(continued)

TABLE B-1 (continued)

<u>Time</u>	<u>Channel P. 406. 3A020</u>	<u>Channel P. 500. 3A021</u>	<u>Channel T. 854. 3A030</u>	<u>Channel T. 864. 3A031</u>
6764. 0049	90. 3100	90. 0436	90. 1963	89. 8802
6764. 2050	90. 0899	90. 2616	90. 5200	90. 0987
6764. 4050	89. 9799	90. 1526	89. 8725	90. 2080
6764. 6050	90. 4200	90. 0436	90. 3042	90. 3172
6764. 8050	90. 5300	90. 2616	89. 7646	90. 4265
6765. 0049	90. 2000	90. 1526	90. 0884	89. 7710
6765. 2050	90. 4200	89. 2809	89. 9804	90. 4265
6765. 4050	90. 0899	89. 4989	90. 0884	89. 9895
6765. 6050	90. 2000	89. 8257	89. 8725	89. 9895
6765. 8050	89. 9799	89. 6078	89. 5487	90. 4265
6766. 0049	90. 5300	89. 4989	89. 9804	90. 4265
6766. 2050	90. 2000	90. 2616	90. 1963	90. 0987
6766. 4050	90. 3100	89. 9347	89. 7646	90. 5358
6766. 6050	90. 4200	89. 9347	89. 9804	90. 5358
6766. 8050	89. 9799	90. 1526	89. 9804	90. 4265
6767. 0049	90. 2000	89. 8257	89. 5487	90. 0987
6767. 2050	89. 9799	90. 0436	89. 9804	89. 9895
6767. 4050	90. 3100	89. 6078	89. 5487	89. 9895
6767. 6050	89. 8699	89. 6078	89. 7646	90. 2080
6767. 8050	90. 0899	90. 4795	89. 7646	90. 2080
6768. 0049	90. 3100	89. 6078	89. 6567	90. 5358
6768. 2050	90. 2000	90. 4795	89. 8725	90. 2080
6768. 4050	89. 8699	90. 0436	89. 8725	89. 8802
6768. 6050	90. 2000	90. 0436	89. 6567	90. 3172
6768. 8050	90. 5300	90. 5884	90. 1963	90. 4265
6769. 0049	90. 4200	89. 8257	89. 7646	90. 2080
6769. 2050	90. 3100	134217727. 0000	89. 9804	90. 2080
6769. 4050	90. 4200	90. 0436	89. 5487	90. 3172
6769. 6050	90. 2000	90. 0436	89. 8725	89. 9895
6769. 8050	90. 3100	89. 7168	90. 1963	90. 2080
6770. 0049	90. 0899	90. 1526	89. 8725	90. 3172
6770. 2050	90. 4200	90. 0436	89. 7646	90. 2080
6770. 4050	89. 7599	89. 9347	89. 8725	90. 2080
6770. 6050	90. 2000	90. 3705	90. 0884	90. 0987
6770. 8050	90. 2000	89. 9347	89. 7646	89. 8802
6771. 0049	90. 2000	90. 1526	90. 4121	90. 4265

TABLE B-2
TYPICAL DATA REDUCED FROM N3 TAPES

Data are averages and variance estimates for two of the four LL02 multiplexer channels for the five linearity runs of Phase I.

<u>Date</u>	<u>Time</u>	<u>Multiplexer</u>	<u>Channel</u>	<u>Percentage of Full Scale</u>	
				<u>Average</u>	<u>Variance</u>
650622	6750.	LL02	T.854. 3A030	99.88	0.035657
650622	6761.	LL02	T.854. 3A030	89.94	0.066206
650622	6771.	LL02	T.854. 3A030	79.96	0.045873
650622	6781.	LL02	T.854. 3A030	70.16	0.052294
650622	6791.	LL02	T.854. 3A030	60.23	0.063151
650622	6801.	LL02	T.854. 3A030	50.40	0.050255
650622	6811.	LL02	T.854. 3A030	40.40	0.045523
650622	6821.	LL02	T.854. 3A030	30.57	0.046136
650622	6831.	LL02	T.854. 3A030	20.72	0.056196
650622	6841.	LL02	T.854. 3A030	10.71	0.062132
650622	6851.	LL02	T.854. 3A030	0.84	0.049268
650622	13540.	LL02	T.854. 3A030	99.97	0.074619
650622	13551.	LL02	T.854. 3A030	90.09	0.044171
650622	13561.	LL02	T.854. 3A030	80.19	0.042919
650622	13571.	LL02	T.854. 3A030	70.27	0.037360
650622	13581.	LL02	T.854. 3A030	60.38	0.048427
650622	13591.	LL02	T.854. 3A030	50.34	0.050506
650622	13601.	LL02	T.854. 3A030	40.46	0.036909
650622	13611.	LL02	T.854. 3A030	30.57	0.046124
650622	13621.	LL02	T.854. 3A030	20.72	0.135767
650622	13631.	LL02	T.854. 3A030	10.64	0.078956
650622	13641.	LL02	T.854. 3A030	0.74	0.054830
650622	20750.	LL02	T.854. 3A030	100.70	0.031751
650622	20761.	LL02	T.854. 3A030	90.82	0.032252
650622	20771.	LL02	T.854. 3A030	80.84	0.036709
650622	20781.	LL02	T.854. 3A030	70.99	0.039063
650622	20791.	LL02	T.854. 3A030	61.08	0.041416
650622	20801.	LL02	T.854. 3A030	51.09	0.066757
650622	20811.	LL02	T.854. 3A030	41.34	0.090645
650622	20821.	LL02	T.854. 3A030	31.24	0.070438
650622	20831.	LL02	T.854. 3A030	21.40	0.069330
650622	20841.	LL02	T.854. 3A030	11.40	0.097691
650622	20851.	LL02	T.854. 3A030	1.41	0.074182

(continued)

TABLE B-2 (continued)

<u>Date</u>	<u>Time</u>	<u>Multiplexer</u>	<u>Channel</u>	<u>Percentage of Full Scale</u>	
				<u>Average</u>	<u>Variance</u>
650622	20869.	LL02	T.854.3A030	100.34	0.096454
650622	35471.	LL02	T.854.3A030	90.37	0.044571
650622	35481.	LL02	T.854.3A030	80.55	0.056591
650622	35491.	LL02	T.854.3A030	70.69	0.058694
650622	35501.	LL02	T.854.3A030	60.81	0.073217
650622	35511.	LL02	T.854.3A030	50.77	0.073443
650622	35521.	LL02	T.854.3A030	40.99	0.067358
650622	35531.	LL02	T.854.3A030	31.16	0.069060
650622	35541.	LL02	T.854.3A030	21.26	0.111773
650622	35551.	LL02	T.854.3A030	11.41	0.088046
650622	35561.	LL02	T.854.3A030	1.55	0.066829
650622	39349.	LL02	T.854.3A030	99.71	0.167167
650622	64201.	LL02	T.854.3A030	89.72	0.048377
650622	64211.	LL02	T.854.3A030	79.92	0.047827
650622	64221.	LL02	T.854.3A030	70.01	0.072716
650622	64231.	LL02	T.854.3A030	60.20	0.093600
65-622	64241.	LL02	T.854.3A030	50.34	0.056691
650622	64251.	LL02	T.854.3A030	40.42	0.067445
650622	64261.	LL02	T.854.3A030	30.43	0.085938
650622	64271.	LL02	T.854.3A030	20.61	0.038123
650622	64281.	LL02	T.854.3A030	10.76	0.106295
650622	64291.	LL02	T.854.3A030	0.75	0.089323
650622	6750.	LL02	T.864.3A031	99.96	0.083333
650622	6761.	LL02	T.864.3A031	90.16	0.059095
650622	6771.	LL02	T.864.3A031	80.18	0.079928
650622	6781.	LL02	T.864.3A031	70.28	0.077011
650622	6791.	LL02	T.864.3A031	60.31	0.071264
650622	6801.	LL02	T.864.3A031	50.42	0.051583
650622	6811.	LL02	T.864.3A031	40.54	0.056340
650622	6821.	LL02	T.864.3A031	30.72	0.069962
650622	6831.	LL02	T.864.3A031	20.84	0.077292
650622	6841.	LL02	T.864.3A031	10.74	0.065139
650622	6851.	LL02	T.864.3A031	0.92	0.101127
650622	13540.	LL02	T.864.3A031	100.21	0.060897
650622	13551.	LL02	T.864.3A031	90.19	0.081631
650622	13561.	LL02	T.864.3A031	80.38	0.053536
650622	13571.	LL02	T.864.3A031	70.42	0.101162
650622	13581.	LL02	T.864.3A031	60.60	0.086839

(continued)

TABLE B-2 (continued)

<u>Date</u>	<u>Time</u>	<u>Multiplexer</u>	<u>Channel</u>	<u>Percentage of Full Scale</u>	
				<u>Average</u>	<u>Variance</u>
650622	13591.	LL02	T.864.3A031	50.63	0.109150
650622	13601.	LL02	T.864.3A031	40.62	0.038186
650622	13611.	LL02	T.864.3A031	30.70	0.103328
650622	13621.	LL02	T.864.3A031	20.83	0.055151
650622	13631.	LL02	T.864.3A031	10.74	0.083074
650622	13641.	LL02	T.864.3A031	0.78	0.063044
650622	20750.	LL02	T.864.3A031	100.90	0.097256
650622	20761.	LL02	T.864.3A031	90.93	0.049980
650622	20771.	LL02	T.864.3A031	81.00	0.070613
650622	20781.	LL02	T.864.3A031	71.12	0.066106
650622	20791.	LL02	T.864.3A031	61.21	0.067708
650622	20801.	LL02	T.864.3A031	51.30	0.065480
650622	20811.	LL02	T.864.3A031	41.31	0.073618
650622	20821.	LL02	T.864.3A031	31.38	0.078438
650622	20831.	LL02	T.864.3A031	21.44	0.101487
650622	20841.	LL02	T.864.3A031	11.29	0.087180
650622	20851.	LL02	T.864.3A031	1.51	0.090713
650622	20869.	LL02	T.864.3A031	100.47	0.101563
650622	35471.	LL02	T.864.3A031	90.66	0.078325
650622	35481.	LL02	T.864.3A031	80.68	0.080829
650622	35491.	LL02	T.864.3A031	70.75	0.044421
650622	35501.	LL02	T.864.3A031	60.95	0.105769
650622	35511.	LL02	T.864.3A031	51.01	0.086639
650622	35521.	LL02	T.864.3A031	41.06	0.080704
650622	35531.	LL02	T.864.3A031	31.22	0.074419
650622	35541.	LL02	T.864.3A031	21.35	0.104736
650622	35551.	LL02	T.864.3A031	11.37	0.085682
605622	35561.	LL02	T.864.3A031	1.48	0.117158
650622	39349.	LL02	T.864.3A031	99.72	0.140925
650622	64201.	LL02	T.864.3A031	89.94	0.080729
650622	64211.	LL02	T.864.3A031	80.06	0.116436
650622	64221.	LL02	T.864.3A031	70.18	0.067708
650622	64231.	LL02	T.864.3A031	60.34	0.059195
650622	64241.	LL02	T.864.3A031	50.43	0.133889
650622	64251.	LL02	T.864.3A031	40.53	0.061073
650622	64261.	LL02	T.864.3A031	30.62	0.092485
650622	64271.	LL02	T.864.3A031	20.69	0.078037
650622	64281.	LL02	T.864.3A031	10.76	0.060120
650622	64291.	LL02	T.864.3A031	0.87	0.073451

TABLE B-3
CONDITIONS FOR ANALYSES OF VARIANCE OF AVERAGES
DERIVED FROM N3 TAPES

Phase	<u>Linearity Runs</u>			<u>Calibration Runs</u>			<u>DC-1, 2, 5 & 6 Crosstalk Runs</u>			<u>DC-3, 4, 7 & 8 Crosstalk Runs</u>		
	<u>I</u>	<u>II</u>	<u>III</u>	<u>I</u>	<u>II</u>	<u>III</u>	<u>I</u>	<u>II</u>	<u>III</u>	<u>I</u>	<u>II</u>	<u>III</u>
Channels	2	2	2	2	2	2	2	2	2	2	2	2
Runs	5	5	6	7	6	5	4	4	4	4	4	4
Voltage Steps	11	11	11	11	11	11	-	-	-	11	11	11
Duplicates	-	-	-	-	-	-	10	10	10	-	-	-
Total Combinations	110	110	132	154	132	110	80	80	80	88	88	88
Total Analyses	20	20	20	20	20	20	20	20	20	20	20	20

(Analyses were made on pairs of channels having the same multiplexer-configuration history)

The total number of averages used in the analyses was 25,040. Similarly there were the same number of variance estimates computed; these variance estimates averaged logarithmically to yield a different noise estimate corresponding to each of the 240 analyses of variance of averages.

TABLE B-4
TYPICAL ANALYSIS OF VARIANCE

Data analyzed are the averages from the Phase I linearity runs for the two channels of multiplexer LL02-configuration 9 and are the data given in Table B-2.

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F-Ratio ⁽¹⁾	Components of Variance
Linearity Steps (L)	108003.421875	10	10800.34219		
Linear Fit	108003.333984	1	10800.33340		
Deviations	0.087891	9	0.00977	N.S.	$\sigma_N^2 + \sigma_{LRC}^2 + c \sigma_{LR}^2 + r \sigma_{LC}^2 + rc \sigma_L^2$
Linearity Runs (R)	12.285581	4	3.07140	42.6***	$\sigma_N^2 + \sigma_{LRC}^2 + c \sigma_{LR}^2 + l \sigma_{RC}^2 + lc \sigma_R^2$
Channels (C)	0.377029	1	0.37700	5.23*	$\sigma_N^2 + \sigma_{LRC}^2 + r \sigma_{LC}^2 + l \sigma_{RC}^2 + lr \sigma_C^2$
L X R	0.533906	40	0.01335	N.S.	$\sigma_N^2 + \sigma_{LRC}^2 + c \sigma_{LR}^2$
L X C	0.079628	10	0.00796	N.S.	$\sigma_N^2 + \sigma_{LRC}^2 + r \sigma_{RC}^2$
R X C	0.012504	4	0.00313	N.S.	$\sigma_N^2 + \sigma_{LRC}^2 + l \sigma_{RC}^2$
L X R X C	0.095036	40	0.00238	N.S.	$\sigma_N^2 + \sigma_{LRC}^2$
Total	108016.802724	109			

(1) F-Ratios determined by using s_N^2 estimating $\sigma_N^2 = 0.07202$ with 110 degrees of freedom.

N.S. - Not significant.

* Probability of so large a ratio occurring by chance alone less than 0.05 (1 in 20).

*** Probability of so large a ratio occurring by chance alone less than 0.001 (1 in 1000).

$$s_R^2 = \frac{3.07140 - 0.07202}{22} = 0.1363 = \text{drift parameter}$$

$$s_C^2 = \frac{0.37700 - 0.07202}{55} = 0.0055 = \text{statistical bias parameter}$$