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# HELICOPTER NOISE ANALYSIS -- ROUND-ROBIN TEST


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15. Supplementary Notes

16. Abstract


This report documents the results of an international Round Robin Test on the analysis of helicopter noise. Digital spectral noise data of a 3.5-second simulated helicopter flyover and identical analog test tapes containing helicopter noise data, reference signals, test tones and time code signals were sent to 13 participating organizations. The purpose of the test was to evaluate data reduction systems and procedures; to determine the magnitude of the variability between representative systems and organizations; and to identify potential causes and assist in establishing recommended procedures designed to minimize the variability.


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# PREFACE

A round-robin test was conducted to promote uniformity in the analysis of data for describing helicopter noise for international helicopter certification standards. Identical analog tape recordings containing helicopter noise data, and reference and test signals were sent to 13 acoustic-analysis laboratories around the world. Seven of the 13 organizations responded and supplied test data reduced from the tapes. These data plus the TSC data are tabulated and discussed in this report. Data from three additional organizations, which were received late, are tabulated in the report without comment. Since this was a completely voluntary test, the time and effort of the respondents are acknowledged with appreciation.

The following members of the Noise Measurement and Assessment Laboratory of the Transportation Systems Center contributed to the preparation of this report: A. Dahlgren, A. DiTomaso, J. Hickey, R. Quinn and N. Rice.

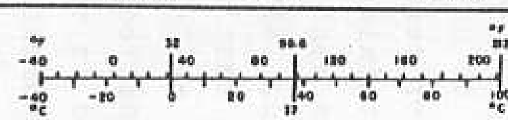
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | 2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | | **MASS (weight)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| Tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | | **TEMPERATURE (exact)** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | | **MASS (weight)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | | **TEMPERATURE (exact)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



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SUMMARY

The results of an international Round-Robin Test on the Analysis of Helicopter Noise data are reported. Seven of thirteen participating organizations, who received identical copies of a test tape containing calibration signals, reference signals, and noise data from four helicopter flyover operations, responded by returning processed results from the test tape using instructions and procedures provided. As part of the test, digital tabulations for 3.5 seconds of a simulated helicopter flyover were also provided in an attempt to isolate computational or procedural variations between participants. To preserve anonymity of the participants no means is provided to identify respondents.

The results of the computations on the digital data showed good procedural application of the Annex 16 methodology for computation of noise indexes, such as PNL and PNLT. In addition, calculated adjustments for distance and meteorological conditions were in excellent agreement.

The results of the reductions and analyses of the analog tape showed an exceptionally small within-organization variability (standard deviation of 0.2 dB or less for the measured noise indexes). The organization-to-organization variability was 0.5 dB or less. A variability of 0.7 dB or less was achieved for the test run No. 13 (level helicopter flyover) which contained signals with the most rapid transient changes.

Although the data set for this test was small (eight organizations, including TSC), a grouping of the data could be seen. A close grouping (variability 0.2 dB) was formed from data by respondents who used instrumentation from a single manufacturer and external computer averaging with an effective RC time constant of 750 milliseconds. A second group (variability 0.5 dB) was formed by respondents who used commercially packaged systems of two manufacturers (3 types of equipment) set to an effective RC time

constant of 1000 milliseconds. Data from three additional organizations, which were received late, have been included in the tables and figures of the report without comment.

# 1. INTRODUCTION

At the October 1979 meeting of the International Civil Aviation Organization, Committee on Aircraft Noise (ICAO/CAN), Working Group B, it was proposed that a round-robin test be conducted to promote uniformity in the analysis of data for describing helicopter noise for international helicopter certification standards.

The U.S. DOT/Transportation Systems Center (TSC) Kendall Square, Cambridge, MA was requested by the Federal Aviation Administration/Office of Energy and Environment, who sponsored the test, to act as the focal point for the definition of the test procedure, and for the subsequent collection and evaluation of results generated by the nations and organizations participating. Accordingly, TSC generated seventeen identical helicopter-noise test-recordings, identified procedures for their reduction, and distributed them to thirteen acoustic analysis laboratories around the world. Seven out of the thirteen organizations responded by returning test data reduced from the tapes. Since labor and materials for this test were supplied voluntarily, the efforts are acknowledged with appreciation.

Test tapes and procedures were sent to the following:

The de Havilland Aircraft of Canada Ltd.
Downsview, Ontario

Direction des Transports Aerieane
Paris, France

Societe Nationale Industrielle Aerospatiale
Marignane, France

Federal Ministry of Transport
Civil Aviation Department
Federal Republic of Germany

Costruzioni Aeronautiche
Giovanni Agusta
Gallarate, Italy (two tapes)

Kawasaki Heavy Industries, Ltd
Aircraft Manufacturing Division
GIFU, Japan

Department of Industry
London, England

Westland Helicopters
United Kingdom

Bell Helicopter Company
Fort Worth, Texas

Boeing-Vertol Company
Philadelphia, Pa. (two tapes)

FAA Noise Monitoring Lab
Washington, D.C.

Sikorsky Aircraft
Stratford, Connecticut (two tapes)

Commission USSR for ICAO
Moscow, USSR.

In order to preserve anonymity, the eight participants are not identified, nor does the reference number assigned reflect the above ordering.

Note: Three additional organizations responded late, their data are included in the figures and tabulations of this report without comment.

## 2. GENERAL

The complexity of helicopter flyby noise, which contains non-stationary random noise, fluctuating periodic signals and impulsive signals, in combination with a variety of noise measurement and data processing systems and procedures could result in a variation of derived flyby noise levels and descriptors measured for the same type aircraft. The purpose of this round-robin test is to evaluate data reduction systems and procedures to determine the magnitude of the variability among representative systems and organizations, and to identify potential causes, and therefore assist in establishing recommended procedures designed to minimize the variabilty.

As part of the evaluation, an analog test tape was generated containing helicopter noise data, reference signals, test tones and time-code signals. Seventeen copies of tape recordings were carefully made for distribution to the round-robin test participants. Prior to shipment, each tape was processed and analyzed using the TSC analysis system to insure uniformity of the data on each tape.

The participants were requested to process the data from the tapes using the instructions provided and the procedures outlined in the ICAO International Standards and Recommended Practices on Aircraft Noise, Annex 16, Third Edition, July 1978 (Reference 1). At present Annex 16 does not apply to helicopters but will when the recommendations of CAN 6 for helicopter standards are incorporated as an amendment. The procedures of the Third Edition supplemented by the appropriate CAN 6 recommendations were to be used in this test as specified in the supplied test instructions. (Appendix A)

Digital tabulations of one-third octave sound pressure levels for seven consecutive 0.5-second periods around PNLTM for a simulated helicopter flyover were also provided for evaluation in an attempt to isolate possible computational or procedural variations between participants, and to evaluate the techniques used to apply atmospheric and distance corrections to the data.

The data submitted by eight respondents (including TSC) is summarized and tabulated in this report. To preserve anonymity of the respondents, no means is provided to identify participants from the numeric code used in summarizing data.

## 3. EXPERIMENTAL APPROACH

Each participant in the test was provided with:

1) A test tape recording consisting of calibration and reference signals and noise data from three helicopter flyovers and one helicopter flypast.
2) Digital tabulations of one-third-octave-band sound-pressure levels of seven consecutive 0.5-second increments around PNLTM for a simulated flyover.
3) A set of instructions and standard data reporting forms. (Appendix A)

### 3.1 ANALOG TAPE RECORDING

A master analog test tape recording was generated on a two-track NAGRA® IVSJ recorder with a Cue Track at a speed of 7-1/2 inches per second. Seventeen identical copies were made also using NAGRA IVSJ recorders operating at 7-1/2 inches per second in the copying process.

To insure that all copies were identical, each tape was reduced on the TSC analysis system (GenRad® 1921) before distribution to the participant. The reduced data were stored on computer disc for further evaluation if the need arose. A tape was rejected if a variation in either OASPL, PNL, PNLT, EPNL was found to be greater than 0.1 dB from the average of all tapes.

The contents of the test tape are summarized below.

| Test Run | Data: (Channels 1 & 2) | Time Code (Cue Track) |
|---|---|---|
| 1 | Playback Reference Tone, 1000 Hz | ---------- |
| 2 | Frequency Response Signal, Pink Noise | 00:02:04.0 |
| 3 | Amplitude Calibration, 250 Hz, 94 dB | 00:03:20.0 |
| 4 | Amplitude Calibration, 500 Hz, 94 dB | 00:04:21.0 |
| 5 | Amplitude Calibration, 1000 Hz, 94 dB | 00:05:39.0 |

| Test Run | Data: (Channel 1 & 2) | Time Code (Cue Track) |
|---|---|---|
| 6 | Linearity Test Tone, 1000 Hz, 84 dB | 00:06:56.0 |
| 7 | Linearity Test Tone, 1000 Hz, 74 dB | 00:08:16.0 |
| 8 | Linearity Test Tone, 1000 Hz, 64 dB | 00:09:32.0 |
| 9 | Linearity Test Tone, 1000 Hz, 54 dB | 00:10:50.0 |
| 10 | Detector Test, 1000 Hz tone bursts | 00:12:25.0 |
| 11 | Helicopter Flyover, Approach centerline | 00:14:50.0 |
| 12 | Helicopter Flyover, Takeoff centerline | 00:15:42.0 |
| 13 | Helicopter Flyover, Level Flight centerline | 00:16:40.0 |
| 14 | Helicopter Flypast, Level Flight sideline | 00:17:31.0 |
| 15 | Playback Reference Tone, 1000 Hz | ---------- |

Note: Channel 1 and 2 contain identical data.

### 3.1.1 Reference Tones

The signals of test runs 1 and 15 were to be used to adjust the electronics of the reproduce/analysis systems to full scale, thus insuring that the test signal would not overload the amplifiers in the analysis system. A measurement of the frequency of these signals by the respondents provides a measure of the accuracy of the speed of the tape recorder used to reproduce the data.

### 3.1.2 Pink Noise

A pink noise signal, provided in test run 2, was to be used to correct for the spectral irregularities of the respondents' reproduce/analysis systems. Twenty seconds of pink noise data were to be energy averaged and referenced back to the frequency band of the chosen amplitude reference tone.

### 3.1.3 Calibration Signals

Absolute calibration of the analysis system was provided through the use of the 250-, 500-, or 1000-Hz amplitude reference tone, test runs 3, 4, and 5. A respondent could use the calibration frequency of his choice with the stipulation that the spectral corrections should be referenced back to the particular frequency band of the reference tone.

### 3.1.4 Linearity Test Tones

The 1-kHz tones of runs 6, 7, 8,and 9 in conjunction with that of test run 5, provided a measure of the linearity of the respondent's reproduce/analysis systems at 1 kHz, and at four levels over the upper 40 dB of the system's dynamic range. Systems with a single detector would be checked at 1 kHz while only the detector in the 1-kHz band would be checked on systems with multiple detectors.

### 3.1.5 Detector Dynamics

Test run 10 consists of a constant-level 1-kHz tone followed by 1-kHz tone bursts which were to be used to obtain the dynamic detector characteristics of the respondent's analysis system at 1 kHz. Tone bursts in lengths of 1/4, 1/2, and 2 seconds were provided, five each.

The start of each pulse was staggered in time (i.e., 100 msec was added to the start of consecutive pulses) such that when the test sequence was started as prescribed, an appropriate alignment would be assured for at least one pulse in those systems whose detector mode of operation used a 0.5-second integration time followed by computer smoothing. The resulting measured levels could then be used to assess the dynamic rise and fall characteristics of the detectors in all systems. This was not an all inclusive test but would provide a good measure of the detector characteristics.

3.1.6 Helicopter Noise Data

Noise data from helicopter approach, take-off and level flyover and level flypast were selected for inclusion in this test. These events were selected to include impulsive noise (blade slap), pure tones, band-sharing, broadband noise and psuedotones. The original recordings were made with the microphone at 1.2 meters over grass and located as follows:

Run 11, (Approach) directly under the approach flight path. (10-dB-down duration, 16.5 seconds)

Run 12, (Takeoff) directly under the takeoff flight path. (10-dB-down duration, 9.5 seconds)

Run 13, (Level Flyover) directly under the flight path. (10-dB-down duration 6.0 seconds)

Run 14, (Level Flypast) 150 meters to the side of the flight path. (10-dB-down duration, 17.0 seconds)

Because of the wide dynamic range of the spectral levels, of helicopter noise, and the limitation in dynamic range characteristics of present day tape recorders, it was necessary to "shape" the low frequencies of the helicopter noise, to insure that the complete flyover noise history could be recorded on a single recorder channel unaffected by the electronic noise-floor of the record/reproduce recorders. No instructions were given to the participants to correct for this shaping, nor was it necessary because all participants would be working with the same "shaped" spectra.

3.2 DIGITAL TABULATIONS ONE-THIRD OCTAVE SPECTRA

One-third octave digital sound pressure level data of a simulated flyover for seven consecutive 0.5-second periods around PNLTM was supplied. Participants were instructed to calculate indexes from these spectra using the same computer processing technique which was used for the analog tapes. These results would provide an insight into possible variations in final results between respondents because of calculation, procedural differences, or even computer roundoff techniques.

In addition, methodology for correcting data for atmospheric absorption by both the "10-meter" and "layered" technique would be compared. A flight-path profile and temperature/humidity-data-versus-altitude were supplied (see Appendix A, Figure 4.1 and Table 4.2 ), with instructions to adjust the PNLTM spectra for positional and meteorological correction by both the "10-meter" and "layered" procedures.

The equations of SAE-ARP-866A (3/15/75) were to be used for computing the atmospheric absorption corrections. The data was to be corrected back to the reference meteorological condition of Annex 16 (25°C and 70% relative humidity).

The "ten-meter" procedure assumes constant temperature/humidity conditions versus altitude, based on meteorological measurement made 10 meters above the ground. Although not specified, a microphone height of 0.0 feet (flush or ground level) was to be assumed with the aircraft in level flight.

The following steps were to be used for the layered procedure:

a) Divide the sound-propagation path into increments of 30 meters in altitude.

b) Determine the average temperature and relative humidity in each 30-meter altitude increment.

c) Calculate the atmospheric-attenuation rate in each one-third-octave band in each altitude increment.

d) The mean atmospheric-attentuation rate over the complete propagation path for each one-third-octave band must be computed and used to calculate the corrections required.

## 3.3 INSTRUCTIONS

A set of instructions, which take into account the latest proposed changes to Annex 16,were provided (See Appendix A). It was requested that deviation from the procedures be minimized, and where absolutely necessary a description of the deviation be supplied. Standard data sheets were provided for reporting all information requested for comparison purposes. (See Appendix A).

Each test was to be replicated four times to obtain a measure of the variation within an organization. Specific data was requested from the respondents to be used to identify data analysis variations. Specific start times were specified for each test utilizing the IRIG-B time code signal provided on the CUE track, to minimize resultant variation from irregular start times.

# 4. RESULTS

## 4.1 SUMMARY RESPONDENT INFORMATION

Eight participants, including TSC, responded by submitting data generally in the manner requested. Table 1 summarizes some of the important differences and similarities noted between respondents.

Note that all but two respondents utilized analog 1/3-octave band filters in their analysis system. One used Fast Fourier Transform Techniques (FFT) to form sets of 1/3-octave band data. In the second, the digital 1/3-octave filters were an integral part of the commercial analysis package. Four of the eight used systems with a single detector working in conjunction with a multiplexer to sample the output of all filter bands (GenRad® 1921 Real-time Analyzer). The FFT system also used a single detector. The remaining three respondents used systems with multiple detectors (e.g., GR 1995, B & K 2131, B & K 2130).

The time constant for those systems with multiple detectors (nominally 1 second) is front panel controlled and uses internal analog circuitry or a combination of internal analog detectors and microprocesser averaging. The remaining systems, including the FFT system, used external computer smoothing to arrive at appropriate time constants and averaging times to meet the conditions of Annex 16. (More will be said on detectors in a later section.)

Four respondents used the 250-Hz amplitude calibration reference tone, and four used the 1000-Hz tone. It was found, after the fact at TSC, that the amplitude of the 250-Hz tone in conjunction with the pink noise signal in the 250-Hz band introduced an error in the resultant analysis. This characteristic was traced back to the master tape and would thus be inherent in all tapes. Data, for all tapes, stored in computer disc memory at TSC was reprocessed using both the 250-Hz and 1000-Hz amplitude reference. It was determined that using the 250-Hz reference

## TABLE 1. RESPONDENT SUMMARY INFORMATION

Helicopter Noise Analysis - Round Robin Test

| | 3 | 7 | 9 | 10 | 15 | 16 | 17 | 18 | 1* | 2* | 6* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Filters: 1/3 Octave | | | | | | | | | | | |
| Analog (A) Digital (D) | D | A | A | D | A | A | A | A | A | A | D |
| Detector | | | | | | | | | | | |
| Single (S)/Multiple (M) | M | S | M | S | M | S | S | S | S | M | M |
| Time Constant or Integrating Time (Seconds) | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | * | 1.0 |
| Computer Smoothing | No | Yes | No | Yes | No | Yes | Yes | Yes | Yes | No | No |
| Calibration Frequency (Hz) | 250 | 250 | 1000 | 250 | 250 | 1000 | 1000 | 1000 | 250 | 1000 | 250 |
| Band Share Correction Procedure | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | No | No | No |
| Tone Correction to 50 Hz | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Atmospheric Corrections | | | | | | | | | | | |
| 10 Meter | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | No | No |
| Layered | Yes | Yes | Yes | Yes | No | No | Yes | Yes | No | No | No |
| Recorder Speed Accuracy | -0.1% | -0.2% | -0.3% | -0.2% | -0.3% | - | - | +0.1% | 0% | +0.2% | -0.2% |
| Time Code Reader Used | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | No | No |

NOTE: Respondents identified by numeric code

* Data submitted indicates respondent may have used "fast" detector characteristic to process data instead of "slow" response.

resulted in levels 0.4 dB lower than those obtained using the 1000 Hz tone. This difference was taken into account in the comparison of respondents' data in later sections of this report.

All respondents used NAGRA® recorders which have an accuracy and stability specification for speed of ± 0.2%. The results of test runs 1 and 15 indicate the speed of the respondents' recorders were within an acceptable range (+0.1% to -0.3%).

4.2 SYSTEM FREQUENCY RESPONSE

The pink noise data of test run 2, processed by the test respondents, provides a measure of the deviation from "flat" frequency response of the respondent's reproduce/analysis system. The deviation from flat response as determined by this test was to be applied by the respondents as corrections to processed helicopter noise data of test runs 11 through 14.

A comparison of the corrections supplied (not part of this report) indicate marked differences in the frequency response of the respondent's systems, and reinforces the need for the pink noise correction process to account for frequency response variation in the data gathering system on through to the reproduction and analysis systems.

4.3 LINEARITY TEST

Figure 1 shows the result of the linearity test using the data from test runs 5 through 9. The measurement range is referenced to the amplitude of the 1000-Hz calibration signal test run 5 (94 dB). The error shown is over the upper 40 dB of range of the measurement system. Thus, it can be seen that respondent 15, for example, can expect the SPL readings which are obtained 40 dB down from the reference, i.e. at the 54-dB level, to be low by 1.2 dB. In a like manner, respondent 17 would expect SPL readings at the 74-dB level (i.e., 20 dB down from the reference) to be low by 0.5 dB. The deviations shown in all cases are within the limits as specified in Annex 16, Appendix 2,

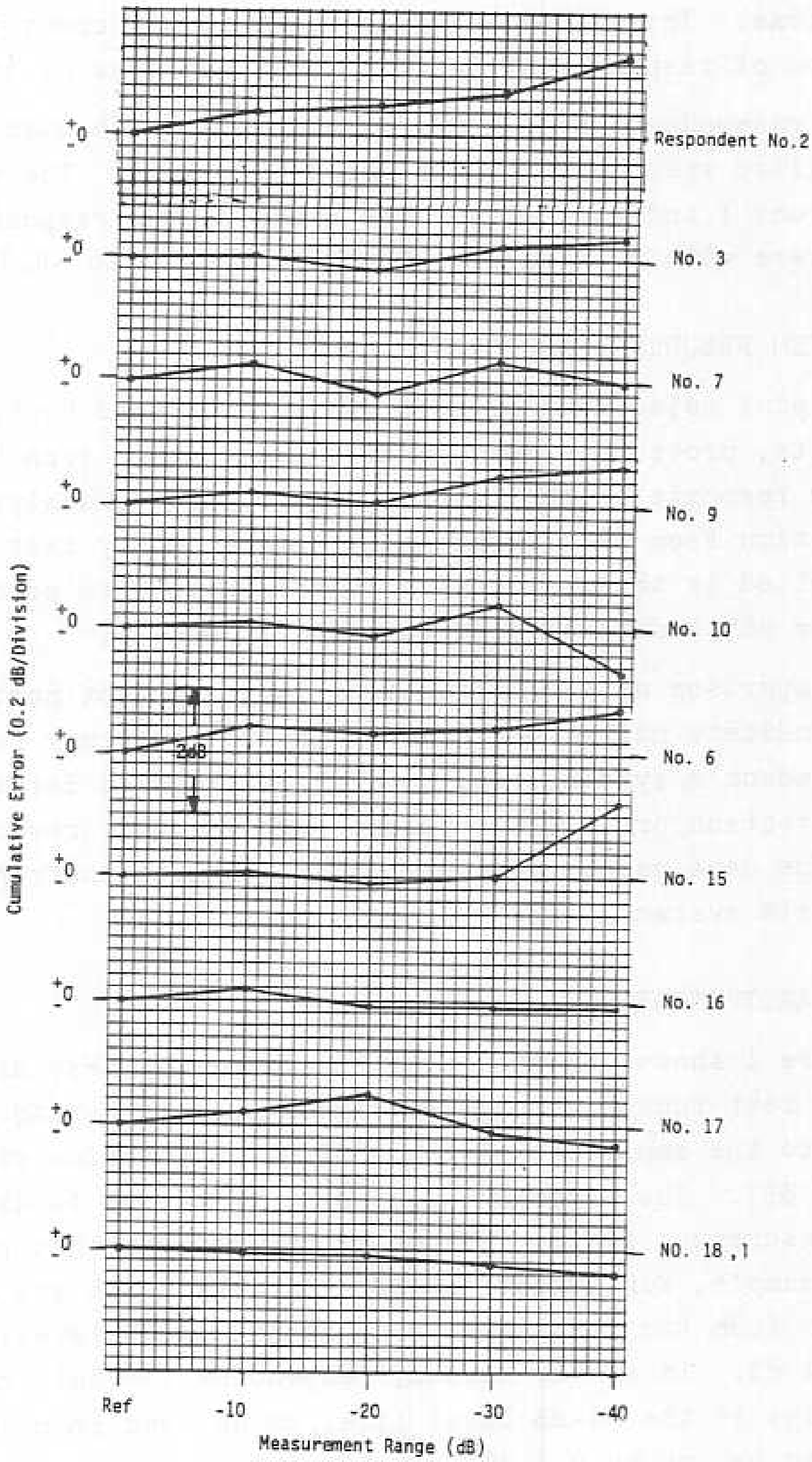



FIGURE 1. SYSTEM LINEARITY TEST AT 1 kHz

paragraph 3.4.3.

## 4.4 DETECTOR TRANSIENT RESPONSE

Figure 2 depicts the detector dynamic response characteristics of the respondent's analysis system as obtained from the results of test run 10. As shown, the results were grouped into three distinct characteristic-curves which differ slightly both in rise and fall characteristics. They however, meet the dynamic detector specifications of Annex 16, Appendix 2, Section 3.4 which have been included in Figure 2 as vertical bars. The specifications of IEC-651 (Reference 3) for type 0 sound level meters are also included.

Respondents 7, 10, 16, 17, and 18 used a sliding-window or running-logarithmic average procedure, with data from three consecutive 0.5-second integration periods, to achieve the dynamic response shown. The actual calculation procedure used by respondents 17 and 18 differ slightly from that used by respondents 7, 10, 16, in that more "weight" is given to the later of the three 0.5-second samples of data. The following relationship was used to calculate the "weighted" logarithmic average:

$$SPL_{i,averaged} = 10 \log_{10}\left[0.2\left(10^{0.1SPL_{i-2}}\right) + 0.35\left(10^{0.1\,SPL_{i-1}}\right) + 0.45\left(10^{0.1SPL_{i}}\right)\right],$$

where i represents the sample number. The detector dynamic curve of Figure 2 for respondents 17 and 18 can be characterized as that of an exponential function with a nominal 750 millisecond RC time constant.

Respondents 7, 10, and 16 applied equal weight to each of the three 0.5-second samples of data; hence an unweighted logarithmic average according to the following relationship:

$$SPL_{i,averaged} = 10 \log_{10}\left[0.33\left(10^{0.1SPL_{i-2}}\right) + 0.33\left(10^{0.1SPL_{i-1}}\right) + 0.33\left(10^{0.1SPL_{i}}\right)\right].$$

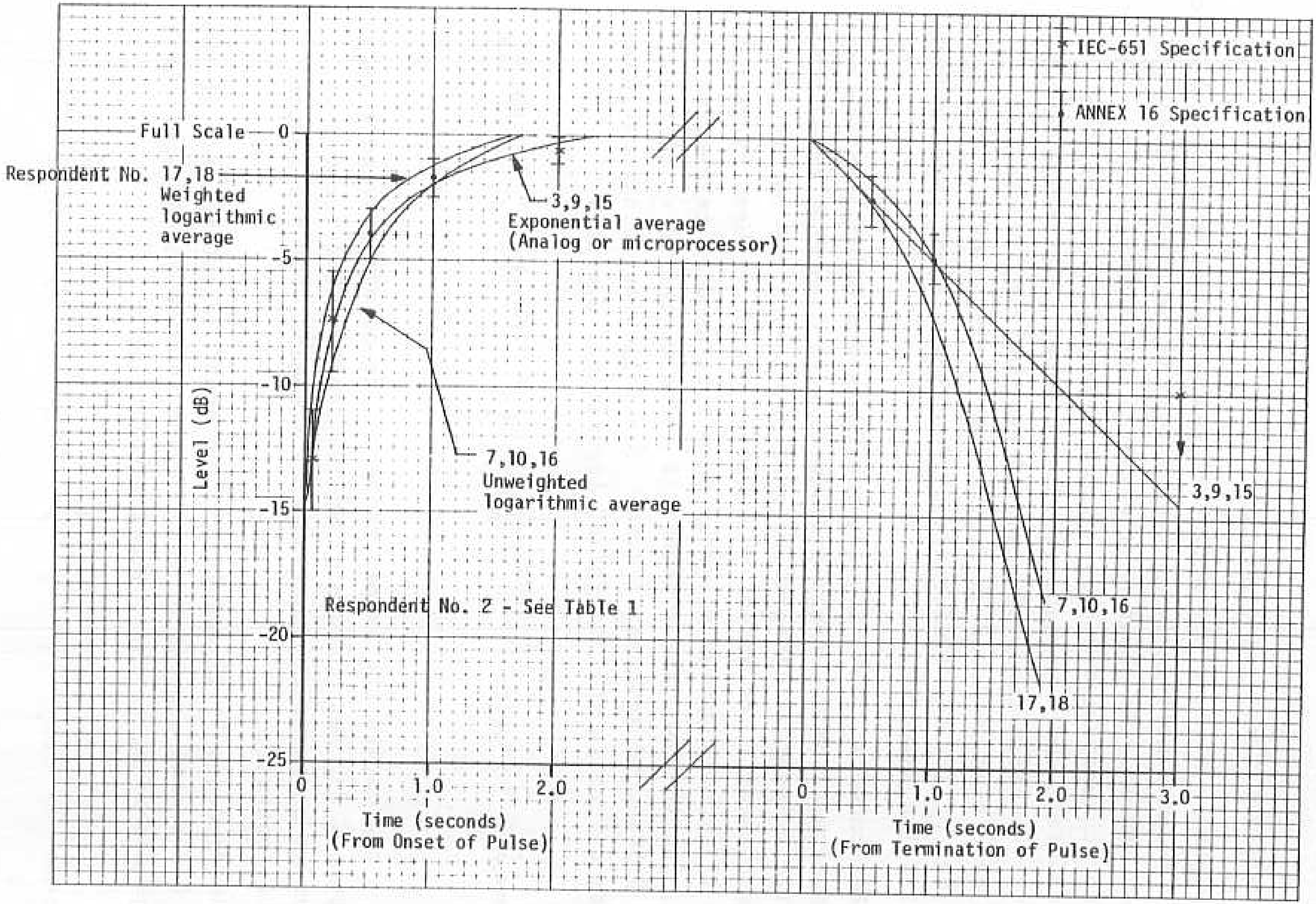



FIGURE 2. DETECTOR TRANSIENT RESPONSE

The curve of Figure 2 for respondents 7, 10, and 16 can be characterized as a quasi-exponential function with a nominal 750-millisecond RC time constant.

The dynamic detector characteristics for the remaining three systems are obtained internally in the commercially packaged systems (in one case by strictly analog circuitry; in a second case, by a combination of an analog detector and continuous exponential averaging using microprocessor techniques; and, in the third case, by digital and microprocessor techniques). The results obtained for respondents 3, 9, and 15 are characterized by the exponential curve depicted in Figure 2 with a nominal 1000-millisecond RC time constant.

An inspection of Figure 2 shows that the three curves meet the Annex 16 requirements, however, only the exponential curve with the 1000-msec RC time constant meets the 2.0-second sound level meter specification of IEC 651. This long slow rise and fall characteristic can result in slightly lower levels measured for transient signals.

TSC has been experimenting with a 4-sample, weighted logarithmic average procedure to achieve an exponential detector characteristic with an effective RC time constant of 1000 milliseconds; thus approximating the dynamic detector curve of respondents 3, 9, and 15. The following equation was used:

$$SPL_{i,ave.} = 10 \log_{10} \left[ 0.13 \left( 10^{0.1SPL_{i-3}} \right) + 0.21 \left( 10^{0.1SPL_{i-2}} \right) + 0.27 \left( 10^{0.1SPL_{i-1}} \right) + 0.39 \left( 10^{0.1SPL_{i}} \right) \right].$$

Reprocessing digital data stored on computer disk for test runs 11 through 14 using the TSC 4-sample, weighted logarithmic averaging procedure (2.0 seconds averaging time) produced results (PNL, PNLT) for test runs 11, 12, and 14 which were 0.1 to 0.2 dB lower than those obtained using the same digital data and the above 3-sample weighted procedure (1.5-second averaging time) while results of 0.6 dB lower were calculated for test run 13 which contained signals with the most rapid transient changes.

## 4.5 HELICOPTER NOISE DATA -- TEST RUNS 11, 12, 13, 14

Tables 2, 3, 4 and 5 summarize the results of respondents processing the helicopter noise of test runs 11, 12, 13 and 14 respectively. Included (column 1) is a measure of the uniformity of all seventeen tapes prior to shipment. The seventeen tapes were analyzed at TSC using a GenRad® 1921 Real-Time Analyzer set to integrate over 0.5-second periods. External computer smoothing was used to achieve the dynamic detector requirements of Annex 16.

The tabulated respondents' data is the mean and standard deviations of four replications. (No adjustments have been made to this data.) An inspection of Tables 2 through 5 show, in general, a standard deviation of 0.2 dB or less was achieved by each respondent, indicating a good within-organization repeatability. Two exceptions are noted, respondent 15, test run 11, and respondent 16, test runs 11, 12, 13,and 14. An examination of the data submitted by respondent number 15 showed an apparent "noise spike" in the third replication of test run number 11, affecting in particular the tone correction calculation and the PNLTM value. Excluding data from the third replication would have reduced the standard deviation for test number 11 to 0.2 dB or less, which is more in line with the rest of respondent 15's submissions. Respondent 16 indicated he did not use the time code signal provided to start the analyses. The non-standard start times and a recorder amplitude instability problem, as indicated by other data supplied by number 16, could account for the high variability noted.

The average and standard deviation of the mean values submitted by all respondents are tabulated in column 10 of Tables 2 through 5. Note that those respondents who used the 250-Hz calibration tone (respondents 3, 7, 10,and 15) reported consistently lower results than those who used the 1000-Hz calibration tone. As noted in Section 4.1, because of the manner in which the raw data is stored on computer disc at TSC, it was possible to reprocess the stored data referencing either calibration tone. It was found that a -0.4 dB discrepancy was associated with the

TABLE 2. ANALYSIS SUMMARY, RUN NO. 11--APPROACH CENTERLINE

Levels - dB re 20 micro-Pa

| NOISE INDEX | | (1) | 3 | 7 | 9 | 10 | 15 | 16 | 17 | 18 | AVERAGE | 1(3) | 2(3) | 6(3) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EPNL | AVG. | - | 98.9 | 98.8 | 98.8 | 99.4 | 97.9 | 100.2 | 99.1 | 99.2 | 99.0 | 98.7 | 98.9 | 98.9 |
| | STD. DEV. | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 | 0.2 | 0.1 | 0.1 | 0.6 | 0.1 | 0.3 | 0.1 |
| PNLT(M) | AVG. | - | 100.5 | 100.2 | 100.2 | 101.0 | 99.7 | 102.0 | 100.7 | 100.8 | 100.6 | 100.1 | 101.2 | 100.2 |
| | STD. DEV. | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.3 | 0.2 | 0.1 | 0.1 | 0.7 | 0.1 | 1.2 | 0.1 |
| PNL(M) | AVG. | - | 100.0 | 99.7 | 99.6 | 100.3 | 99.0 | 101.1 | 100.2 | 100.0 | 100.0 | 99.5 | 100.4 | 99.7 |
| | STD. DEV. | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.6 | 0.1 | 0.0 | 0.6 | 0.1 | 1.2 | 0.1 |
| OASPL(M) | AVG. | - | 91.9 | 91.6 | 91.6 | 91.9 (2) | 91.1 | - | 91.8 | 91.8 | 91.7 | 91.3 | 91.8 | 92.4 |
| | STD. DEV. | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | - | 0.1 | 0.1 | 0.3 | 0.2 | 0.7 | 0.1 |
| TONE CORR. | AVG. | - | 0.6 | 0.5 | 0.6 | 0.7 | 0.7 | 0.9 | 0.7 | 0.6 | 0.6 | 0.6 | 0.9 | 0.5 |
| | STD. DEV. | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 |
| DURATION (Seconds) | AVG. | - | 16.5 | 16.5 | 17.0 | 16.5 | 15.1 | 15.0 | 15.5 | 16.0 | 16.0 | 16.5 | 15.7 | 16.0 |
| | STD. DEV. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.7 | 0.0 | 0.0 | 0.7 | 0.0 | 0.3 | 0.0 |
| TIME AT PNLT(M) (min:sec) | | - | 15:05.75 | 15:05.25 | 15:05.0 | 15:06.0 | 15:06.0 | - | 15:05.25 | 15:05.25 | | - | - | - |

(1) Standard deviation of indexes as measured at TSC for all 17 tapes prior to shipment to participants.
(2) OASPL reported "FAST" response. Not included in average.
(3) Late Submittal-Not included in Average.
NOTE: Respondents indentified by numeric code.

TABLE 3. ANALYSIS SUMMARY, RUN NO. 12--TAKEOFF CENTERLINE

Levels - dB re 20 micro Pa

| NOISE INDEX | | (1) | 3 | 7 | 9 | 10 | 15 | 16 | 17 | 18 | AVERAGE | 1(3) | 2(3) | 6(3) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EPNL | AVG. | - | 99.9 | 99.7 | 99.5 | 99.9 | 98.9 | 100.7 | 99.8 | 100.0 | 99.8 | 99.3 | 99.3 | 99.6 |
| | STD. DEV. | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.1 | 0.5 | 0.1 | 0.1 | 0.1 |
| PNLT(M) | AVG. | - | 102.5 | 103.3 | 102.5 | 103.4 | 102.2 | 104.3 | 103.6 | 103.6 | 103.2 | 102.1 | 104.0 | 102.6 |
| | STD. DEV. | 0.1 | 0.0 | 0.2 | 0.1 | 0.1 | 0.0 | 0.2 | 0.2 | 0.1 | 0.7 | 0.1 | 1.1 | 0.2 |
| PNL(M) | AVG. | - | 101.5 | 101.6 | 101.6 | 102.2 | 100.8 | 103.0 | 102.0 | 102.0 | 101.8 | 101.1 | 102.7 | 101.5 |
| | STD. DEV. | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 | 0.3 | 0.1 | 0.1 | 0.6 | 0.1 | 1.4 | 0.2 |
| OASPL(M) | AVG. | - | 92.7 | 92.9 | 92.6 | 92.9 (2) | 92.2 | - | 92.9 | 92.8 | 92.7 | 92.3 | 92.5 | 93.5 |
| | STD. DEV. | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | - | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 | 0.1 |
| TONE CORR. | AVG. | - | 1.0 | 1.9 | 1.0 | 1.3 | 1.4 | 1.4 | 1.7 | 1.6 | 1.4 | 1.2 | 1.3 | 1.1 |
| | STD. DEV. | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.2 | 0.0 | 0.1 | 0.3 | 0.3 | 0.2 | 0.2 |
| DURATION (Seconds) | AVG. | 0.3 | 11.5 | 9.5 | 10.5 | 10.0 | 9.8 | 9.6 | 8.5 | 9.5 | 9.9 | 10.5 | 8.5 | 10.0 |
| | STD. DEV. | | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.5 | 0.8 | 0.0 | 0.9 | 0.4 | 1.0 | 0.0 |
| TIME AT PNLT(M) (min:sec) | | - | 15:52.25 | - | - | - | 15:52.5 | - | 15:51.75 | 15:51.75 | | - | - | - |

(1) Standard deviation of indexes as measured at TSC for all 17 tapes prior to shipment to participants.

(2) OASPL reported "FAST" response. Not included in average.

(3) Late Submittal-Not included in Average

NOTE: Respondents identified by numeric code.

TABLE 4. ANALYSIS SUMMARY, RUN NO. 13--FLYOVER CENTERLINE

Levels - dB re 20 micro Pa

| NOISE INDEX | | (1) | 3 | 7 | 9 | 10 | 15 | 16 | 17 | 18 | AVERAGE | 1 (3) | 2 (3) | 6 (3) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EPNL | AVG. | - | 99.2 | 99.2 | 99.3 | 99.9 | 98.6 | 100.4 | 99.7 | 99.7 | 99.5 | 98.8 | 99.5 | 99.3 |
| | STD. DEV. | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.3 | 0.1 | 0.1 | 0.5 | 0.1 | 0.4 | 0.1 |
| PNLT(M) | AVG. | - | 104.2 | 104.8 | 104.4 | 105.5 | 103.9 | 106.8 | 105.7 | 105.5 | 105.1 | 103.8 | 106.8 | 104.3 |
| | STD. DEV. | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.2 | 0.4 | 0.1 | 0.1 | 1.0 | 0.3 | 1.1 | 0.1 |
| PNL(M) | AVG. | - | 103.0 | 103.4 | 103.3 | 104.2 | 102.4 | 105.5 | 104.2 | 104.0 | 103.8 | 102.7 | 105.5 | 103.3 |
| | STD. DEV. | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.2 | 0.1 | 0.1 | 0.9 | 0.2 | 1.3 | 0.1 |
| OASPL(M) | AVG. | - | 92.8 | 93.3 | 93.1 | 94.4 (2) | 92.3 | - | 93.8 | 93.7 | 93.3 | 92.6 | 94.4 | 94.3 |
| | STD. DEV. | 0.1 | 0.1 | 0.2 | 0.0 | 0.1 | 0.0 | - | 0.1 | 0.1 | 0.7 | 0.8 | 0.9 | 0.2 |
| TONE CORR. | AVG. | - | 1.3 | 1.5 | 1.5 | 1.3 | 1.6 | 1.4 | 1.5 | 1.5 | 1.5 | 1.4 | 1.2 | 1.2 |
| | STD. DEV. | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 | 0.1 | 0.2 | 0.4 | 0.2 |
| DURATION (Seconds) | AVG. | - | 7.0 | 6.0 | 6.5 | 6.0 | 6.5 | 5.8 | 5.0 | 6.0 | 6.1 | 6.1 | 4.6 | 6.0 |
| | STD. DEV. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.6 | 0.3 | 0.3 | 0.0 |
| TIME AT PNLT(M) (min:sec) | | - | 16:47.25 | - | - | - | 16:47.5 | - | 16:47.25 | 16:47.25 | - | - | - | - |

(1) Standard deviation of indexes as measured at TSC for all 17 tapes prior to shipment to participants.
(2) OASPL reported "FAST" response. Not included in average.
(3) Late Submittal-Not included in Average
NOTE: Respondents identified by numeric code.

TABLE 5. ANALYSIS SUMMARY, RUN NO. 14--FLYPAST CENTERLINE

Levels - dB re 20 micro Pa

| NOISE INDEX | | (1) | 3 | 7 | 9 | 10 | 15 | 16 | 17 | 18 | AVERAGE | 1(3) | 2(3) | 6(3) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EPNL | AVG. | - | 106.1 | 105.9 | 106.1 | 106.3 | 105.3 | 107.1 | 106.3 | 106.3 | 106.2 | 105.9 | 105.7 | 106.0 |
| | STD. DEV. | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.2 | 0.0 | 0.1 | 0.5 | 0.1 | 0.1 | 0.2 |
| PNLT(M) | AVG. | - | 108.0 | 107.7 | 107.6 | 108.0 | 107.1 | 109.1 | 108.2 | 108.1 | 108.0 | 107.4 | 108.6 | 107.5 |
| | STD. DEV. | 0.2 | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 | 0.4 | 0.1 | 0.2 | 0.6 | 0.2 | 0.6 | 0.1 |
| PNL(M) | AVG. | - | 106.1 | 106.0 | 106.1 | 106.6 | 105.2 | 107.7 | 106.5 | 106.3 | 106.3 | 105.9 | 106.2 | 105.9 |
| | STD. DEV. | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.4 | 0.1 | 0.1 | 0.7 | 0.2 | 0.6 | 0.2 |
| OASPL(M) | AVG. | - | 95.3 | 95.3 | 95.4 | 95.4 (2) | 94.5 | - | 95.5 | 95.5 | 95.3 | 95.0 | 96.1 | 96.3 |
| | STD. DEV. | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.1 | 0.3 | 0.1 | 0.6 | 0.0 |
| TONE CORR. | AVG. | - | 1.9 | 1.8 | 1.6 | 1.4 | 1.9 | 1.5 | 1.8 | 1.7 | 1.7 | 1.5 | 1.4 | 1.6 |
| | STD. DEV. | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.2 | 0.1 | 0.8 | 0.0 |
| DURATION (Seconds) | AVG. | - | 17.0 | 16.5 | 17.0 | 16.5 | 16.5 | 14.1 | 14.5 | 16.9 | 16.1 | 16.8 | 15.5 | 16.5 |
| | STD. DEV. | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.3 | 1.2 | 0.3 | 0.4 | 0.0 |
| TIME AT PNLT(M) (min:sec) | | - | 17:43.5 | - | - | - | 17:44.0 | - | 17:42.75 | 17:42.75 | | - | - | - |

(1) Standard deviation of indexes as measured at TSC for all 17 tapes prior to shipment to participants.

(2) OASPL reported "FAST" response. Not included in average.

(3) Late Submittal-Not included in Average

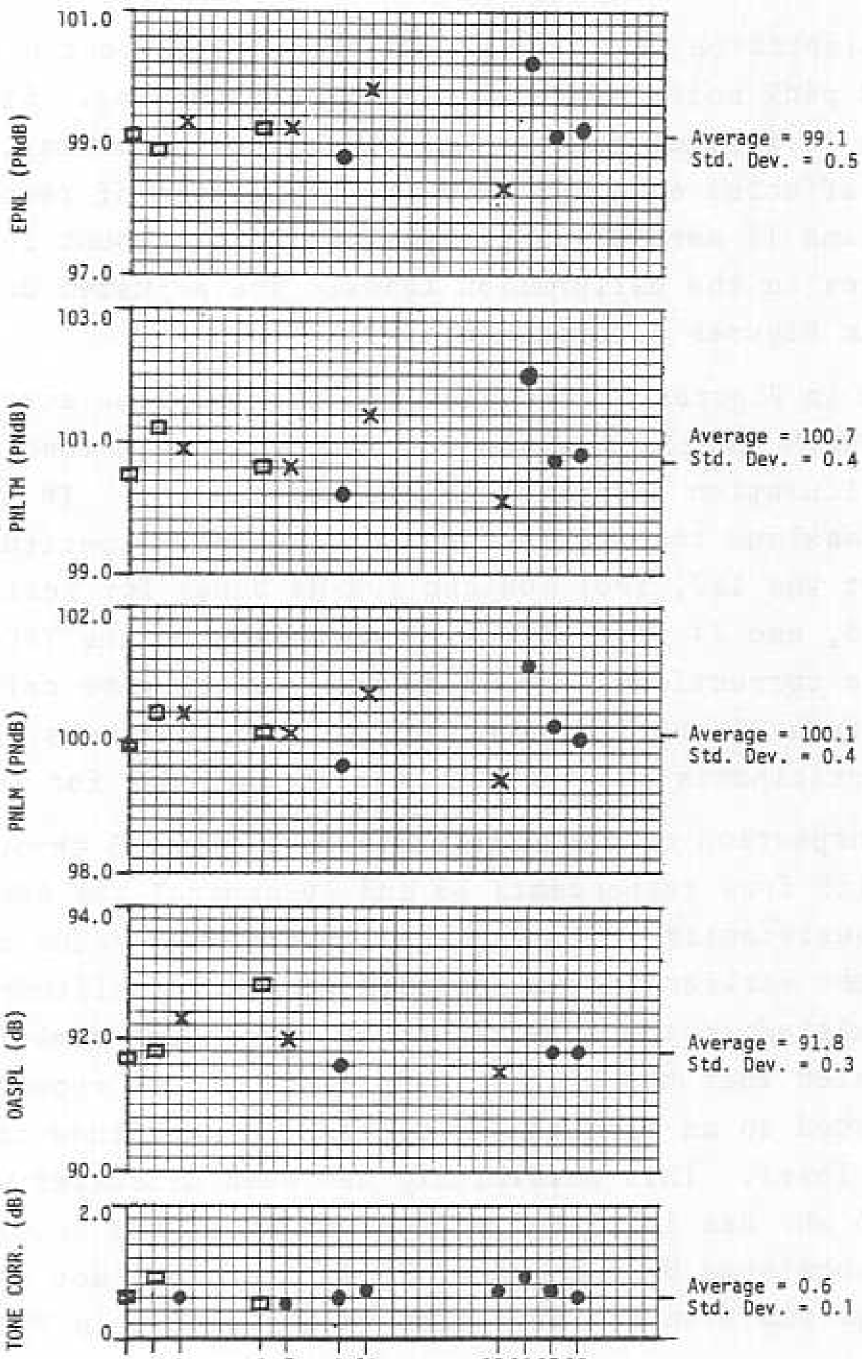
NOTE: Respondents identified by numeric code.

250-Hz calibration tone. This was traced back to the reference tones and pink noise of the master tape-recording. Since the deviation is a fixed function of the master recording, all tapes would be affected equally; thus the submission of respondents 3, 7, 10,and 15 were adjusted by +0.4 dB to account for amplitude differences in the calibration tones. The adjusted data were plotted in Figures 3 through 6.

Note in Figures 3 through 6,the plotted tone corrections at the time of PNLTM indicate a good correspondence in tone-correction-factor calculation technique by all respondents. It is noted that the maximum tone correction for the PNLTM spectrum was calculated at the 160, 100, 100,and 100-Hz bands for test run numbers 11, 12, 13, and 14 respectively. According to the TSC procedure, band-share corrections of 0.18 dB and 0.07 dB were calculated for test runs 11 and 13 respectively. This data was not requested of the participants and the TSC data is included for information.

An inspection of the data plots of Figures 3 through 6 shows that results from respondents 15 and 16 control the spread of data by consistently affecting the low and high value data points. It was noted earlier that a possible recorder amplitude instability problem existed in the submissions by respondent number 16. It is speculated that the higher-than-normal values reported by 16 may be traced to an erroneously reproduced amplitude calibration reference level. This possibility has been discussed with respondent 16 who has initiated an evaluation of the recorder used. The data submitted by respondent 16 is therefore not included in the average and standard deviation values listed in Figures 3 through 6.

Nothing obvious was found from the data submitted by respondent number 15 to indicate why his results were consistently lower than the average. It is, however, noted in Figure 2, that respondent 15 along with respondents 3 and 9 processed data in systems with a nominal one-second exponential time constant. A close examination of the data in Figures 3 through 6 showed that

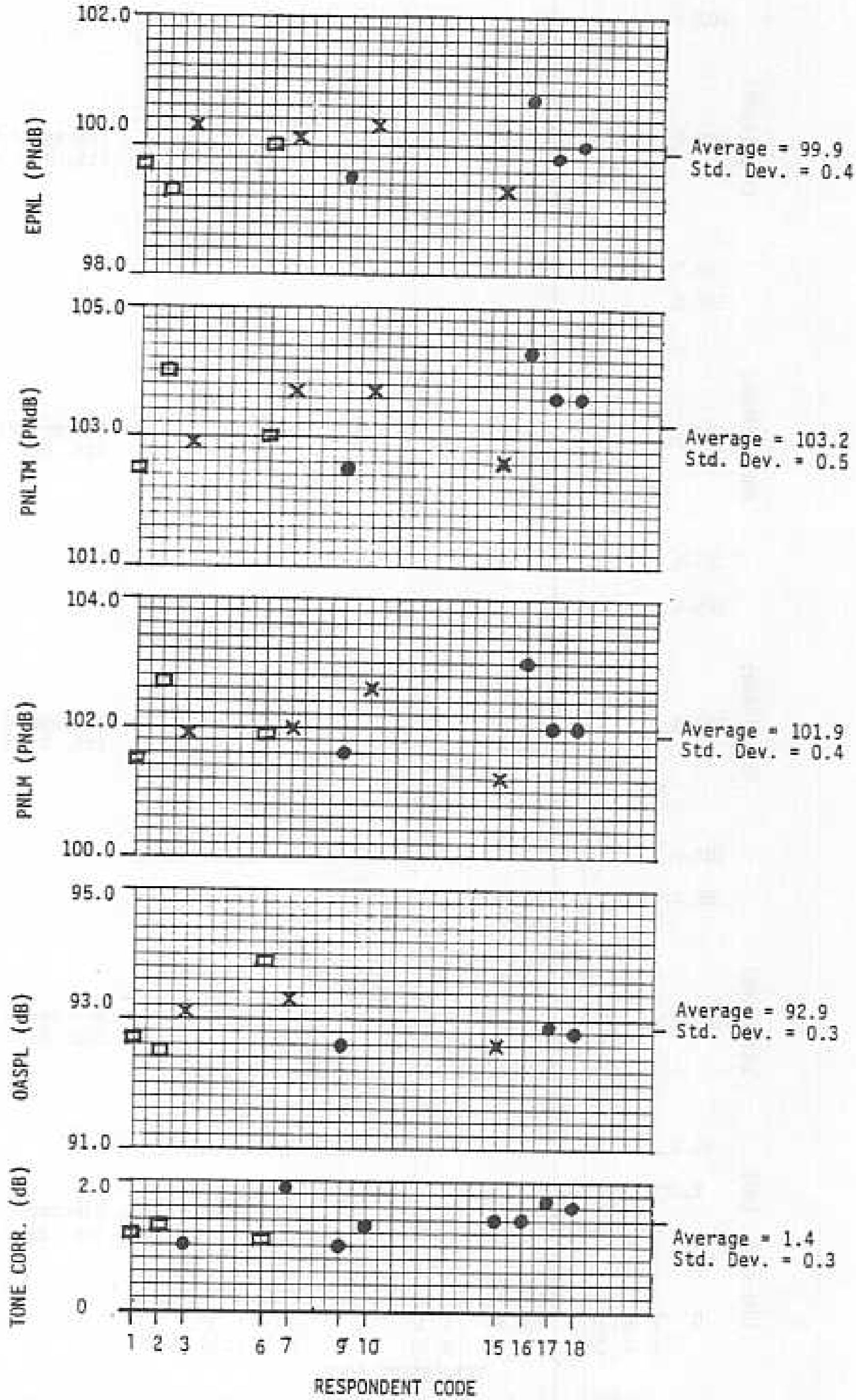



NOTE: Data from Respondent 16 not included in average values

(X)Respondent used 250-Hz calibration tone.
Data submitted was adjusted by +0.4 dB.

□ Late submittal-not included in average

FIGURE 3. SUMMARY DATA,
RUN NO. 11 -- APPROACH CENTERLINE

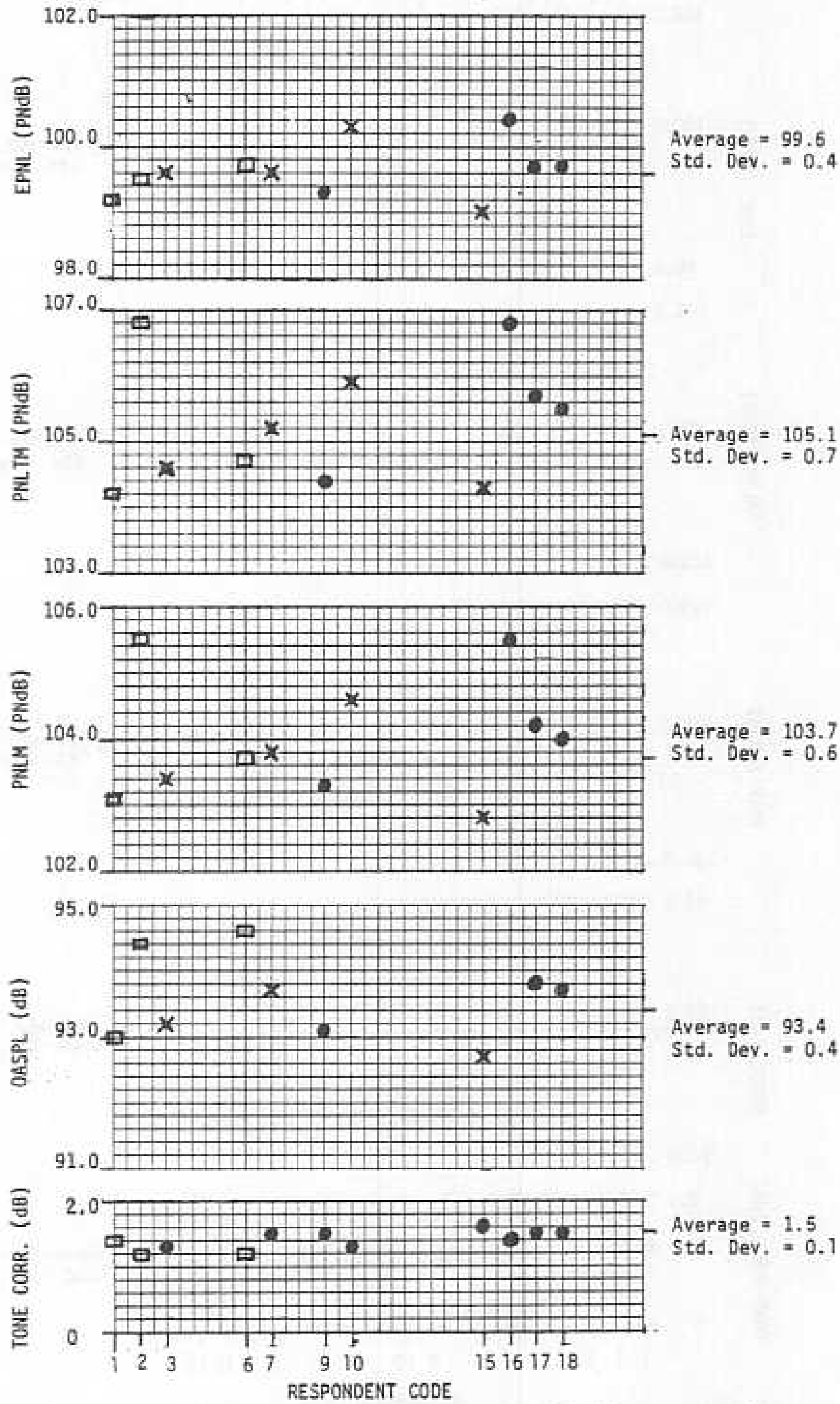



NOTE: Data from Respondent 16 not included in average values

(X)Respondent used 250-Hz calibration tone.
Data submitted was adjusted by +0.4 dB.

□ Late submittal-not included in average

FIGURE 4. SUMMARY DATA,
RUN NO. 12 -- TAKEOFF CENTERLINE




NOTE: Data from Respondent 16 not included in average values.

(X)Respondent used 250 Hz calibration tone.
Data submitted was adjusted by +0.4 dB.

☐ Late submittal - not included in average

FIGURE 5. SUMMARY DATA,
RUN NO. 13 -- FLYOVER CENTERLINE

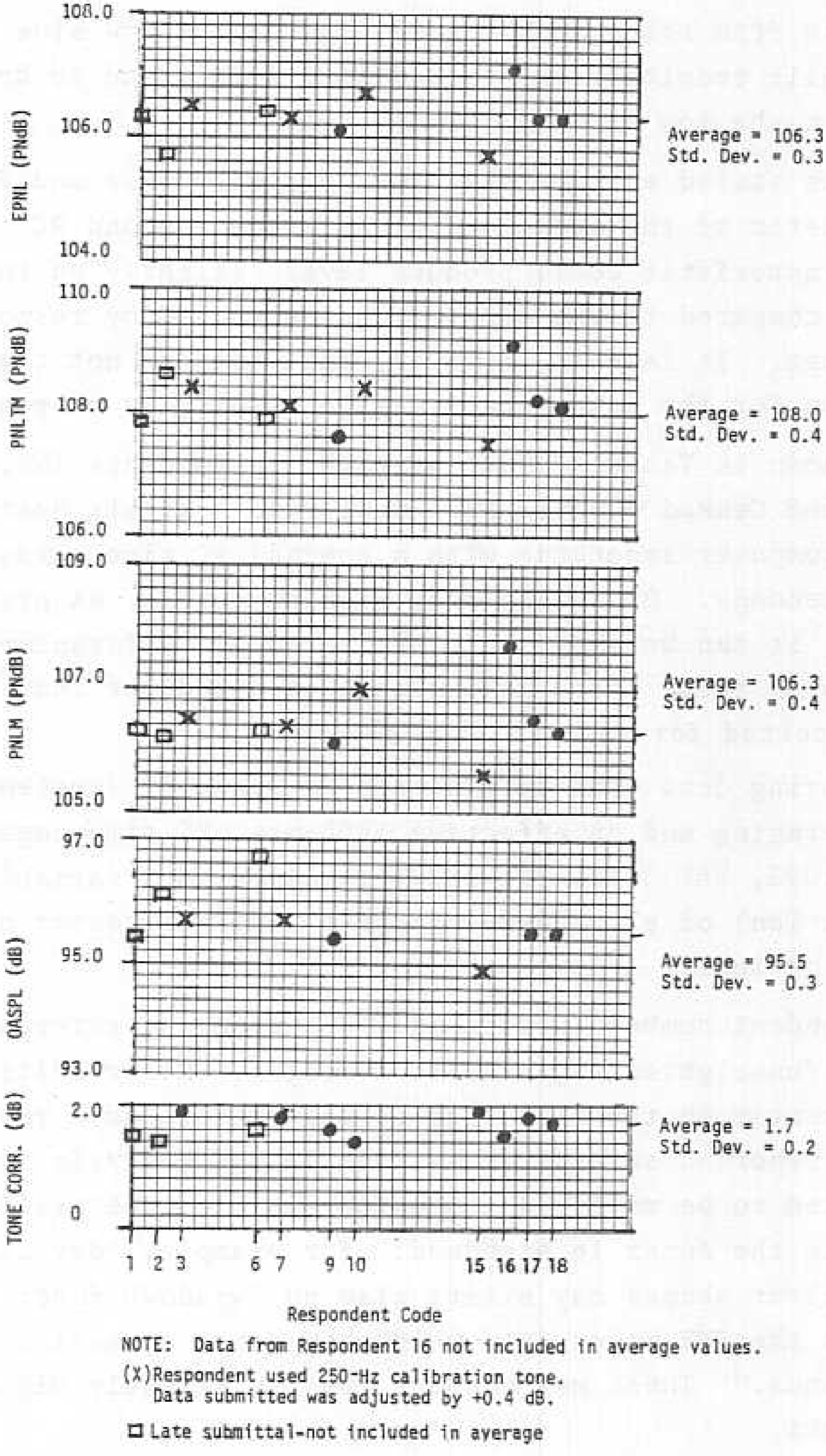



FIGURE 6. SUMMARY DATA,
RUN NO. 14 -- FLYPAST CENTERLINE

the results from respondent 9 were also on the low side of the average while results from respondent 3 were found to be at or slightly on the low side of the average.

It was stated earlier that the long slow rise and fall characteristic of the detectors with the one-second RC time constant characteristic could produce levels slightly on the low side when compared to the other techniques used by respondents in this test. It is felt, however, that this is not the complete explanation for the lower-than-average reading by respondent 15.

As shown in Table 1, four of eight respondents (No.'s 7, 16, 17, 18) used GenRad® Model 1921 Real-Time Analysis System and external computer smoothing with a nominal RC time constant of 750 milliseconds. Excluding data from number 16, as previously mentioned, it can be shown that the variability (standard deviation) between these three respondents is 0.2 dB or less for all indexes reported for runs 11 through 14.

Comparing data from respondents 3, 9,and 15 (system with internal averaging and an effective 1000-msec RC time constant, GenRad® 1995, B&K 2131, B&K 2130) resulted in a variability (standard deviation) of all indexes for the four helicopter noise tests of 0.5 dB or less.

Respondent number 10 used an FFT system and external computer smoothing (unweighted logarithmic average). His results seem to be consistently on the high side of the average data reported. Number 10 reported several deviations in his analysis system which was reported to be modified to conform as close as practicable (at present) to the Annex 16 standard: for example, "deviation in digital filter shapes may exist; also no "window" function was applied to the FFT input data which can cause excessive leakage between bands." These may account for the slightly higher-than-average data.

The overall organization-to-organization variability (standard deviation) is seen to be 0.5 dB or less for the noise indexes of test runs 11, 12,and 14;and 0.7 dB or less is noted for test run

13 (center-line flyover), the test signal with the most rapid transient changes.

The time reported for the PNLTM spectrum (Table 2) ranges over a full second between respondents (test run number 11). The PNLTM time was not reported by all respondents for the other test runs. However, considering that each of these respondents used the time code signal to start the analysis, and the consistency of other data submitted (including PNL and PNLT time histories), it is felt that closer agreement should have been achieved. The reason for the disparity is seen to be the method by which time is assigned to a particular measurement sample. For example, respondents 7, 17, and 18 assigned time as follows: A moving-window technique is used to accomplish the averaging required. The first three consecutive 0.5-second integration periods, which form the first averaged sample, are assigned a time which is the mid-point of the 1.5-second period, or 0.75 seconds after the start of the analysis ($T_o$). The time of each averaged sample thereafter is incremented by 0.5 seconds; thus the time at the Nth sample is:

$$T_N = T_o + 0.75 + \frac{N-1}{f_s},$$

where N = sample number,

$f_s$ = sampling rate = 2 samples per second,

$T_o$ = start time

On the other hand, respondent number 10, who also used the three 0.5-second-sample,moving-window technique, assigned a time at the end of the first averaged sample; that is, 1.5 seconds after the start of the analysis. Thus, the time of respondent 10's Nth sample is:

$$T_N = T_o + 1.5 + \frac{N-1}{f_s}.$$

The remaining three respondents appear to have assigned time to the Nth sample according to the following relationship:

$$\text{Respondent No. 3:} \quad T_N = T_o + 0.25 + \frac{N-1}{f_s},$$

Respondent No. 9: $T_N = T_o - 0.5 + \frac{N-1}{f_s}$,

Respondent No. 15: $T_N = T_o + \frac{N-1}{f_s}$.

Appendix 2, paragraph 3.4.7 of Annex 16 states in part that "the instant in time a readout is characterized shall be the mid-point of the averaging period." The PNLTM times submitted by the respondents indicate several possibilities; that is, (1) the above specification was not complied with; (2) the system readout introduced a positive or even negative timing error; or (3) the "averaging period" of the above specification needs clarification.

In analog exponential averaging using RC networks, the averaging period (the time required for the network to charge to 87 percent or 0.6 dB of its final value) is defined as 2 times the RC time constant of the network. It was shown in Section 4.4 that the RC time constant was 750 milliseconds for the system used by respondents 7, 10, 16, 17, and 18; and 1000 millisecond for the systems used by respondents 3, 9, and 15. By the above definition the averaging period would be 1.5 seconds and 2.0 seconds respectively. The above averaging times and the individual system output delay characteristics should be taken into account in time-of-day assignments.

An additional subtle point in timing would be to be sure to account for the time delay between the reproduced data and the time code signal. For the NAGRA® recorder used in this test, the reproduced data lags 0.25 seconds behind a time code signal reproduced from a CUE channel because of physical alignment of the record and reproduce heads. None of the respondents accounted for this delay.

## 4.6 DIGITAL DATA

Only two respondents used computer smoothing of the digital data (respondents 7, 10). Both used a running-average technique applying equal weighting (unweighted logarithmic average) to each of the three 0.5-second data samples making up the average. In order to provide a more consistent comparison between respondents, the data submitted by respondents 7 and 10 were adjusted, based on TSC's computations on un-averaged data and on data averaged using the unweighted logarithmic procedure.

The summary results (unaveraged data) for time period No. 4, (see Table 4.1, Appendix A) are tabulated in Table 6. Excellent consistency of results is shown, with minor deviations resulting from computer round-off procedures. Also it was noted that several respondents used the present Appendix 2 formula for the computations of PNL with a constant of 33.2. Others used the constant 33.22 which is presently being proposed for Annex 16. This variation in constants results in the 0.03 dB difference in the PNL values tabulated in Table 6 which could change the round-off by 0.1 dB.

Two exceptions to the consistency of results are noted. Respondent number 16 made an error in entering the 250-Hz digital level into his computer, resulting in an erroneous PNLM and PNLTM calculation. Respondent 3 appears to have made an error in the tone-correcting calculations for the PNLTM spectrum; however, the PNL/PNLT calculations, by respondents 3 and 15 for the remaining six 0.5-second intervals of data show excellent agreement with the other respondents. Respondent 3 also shows a 0.4-dB band share correction for the PNLTM spectrum based on tones at the 315-Hz band. However, TSC's tone correction computation shows the maximum tone correction for the PNLTM spectrum occurred at the 630-Hz band, with no apparent band-sharing present. It is true that had the tone correction at PNLTM occurred at the 315-Hz band, the Doppler shift of the tone could have indicated band sharing in the vicinity of the 315-Hz band. Although this test was set up by TSC to force a band-share condition at 315 Hz, based on Doppler shift, an error in the initial TSC calculations failed to show the 630-Hz tone correction. This oversight effectively negated the band-sharing portion of this test.

## TABLE 6. DIGITAL DATA SUMMARY *

Helicopter Noise Analysis - Round Robin Test

LEVEL - dB re 20 micro Pa

| NOISE INDEX | 3 | 7 (2) | 9 | 10 (2) | 15 | 16 | 17 | 18 | AVERAGE / STD. DEV. | 1 (5) | 2 (5) | 6 (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dBA | 86.4 | 86.4 | 86.41 | - | 86.41 | - | 86.41 | 86.41 | 86.5<br>0.0 | - | 86.4 | |
| OASPL | 91.8 | 91.8 | 91.79 | - | 91.79 | - | 91.79 | 91.79 | 91.8<br>0.0 | - | 91.7 | |
| PNL | 99.6 | 99.7 | 99.63 | 99.7 | 99.63 | 99.1 (1) | 99.67 | 99.66 | 99.7<br><0.1 | 99.66 | 99.9 | 99.7 |
| PNLT(M) | 100.6 (3) | 100.5 | 100.41 | 100.5 | 100.42 | 102.4 (1) | 100.46 | 100.45 | 100.5<br><0.1 | 100.45 | 99.9 | 100.5 |
| BAND SHARE CORRECTION | 0.4 (4) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| TONE CORRECTION | 1.0 (3) | 0.8 | 0.78 | 0.8 | 0.79 | 3.3 (1) | 0.79 | 0.79 | 0.8<br>0.1 | 0.79 | 0 | 0.8 |
| ATMOSPHERIC/ DISTANCE CORRECTION<br>10 Meter<br>Layered | +0.7<br>+0.9 | +0.7<br>+0.9 | +0.5<br>+1.0 | +0.7<br>+1.2 | -1.5<br>- | +0.7<br>- | +0.7<br>+0.9 | +0.7<br>+0.9 | -<br>- | -<br>- | -<br>- | -<br>- |

(1) Error made by respondent in entering 250-Hz digital number into computer. Not included in average.
(2) Respondent used computer averaging of data. Submitted data was corrected based on TSC's averaged vs. non-averaged data for consistency with other respondents.
(3) Calculation of tone correction by respondent appears to be incorrect since the value reported included a 0.4-dB band share correction.
(4) Respondent calculated band-sharing for tone in 315-Hz frequency band. Maximum tone correction however, occurs in 630-Hz band at PNLT(M), negating band-sharing of tone at 315 Hz.
(5) Late Submittal-Not included in Average

* Time Period No 4 See Table A-4.1 Appendix A

4.7 ATMOSPHERIC/DISTANCE CORRECTIONS

Corrections to the PNLTM spectrum based on distance and meteorological conditions by the "10-meter" and the "layered" procedures are tabulated in Table 6. The "10-meter" corrections to PNLTM show a good correspondence between respondents, except for respondents 9 and 15.

An inspection of the "10-meter" correction by frequency band, Table 7, shows that respondent 15 obtained the proper correction for each frequency band, but somehow applied them to the PNLTM spectrum incorrectly, thus obtaining an incorrect "10-meter" correction to PNLTM. Respondent 9 is seen to have made the distance correction properly (0.74 dB) but computed an erroneous set of atmospheric corrections.

The layered-atmosphere corrections to PNLTM in Table 8 shows that respondent 9 and 10 deviate from the results of the remainder of the respondents. An inspection of the "layered" corrections by frequency band, Table 8, shows that their deviation is not minor but results in a large deviation especially in the 10-kHz band.

It is impossible to speculate as to the cause of the deviations noted in the atmospheric correction although a computation at TSC showed that respondent 9 may be using the geometric mean frequency, for the last four frequency bands (5000, 6300, 8000, and 10,000 Hz), in the computation of atmospheric attenuation instead of the lower band edge frequencies (4500, 5600, 7100, and 9000 Hz) as specified in ARP-866A. After discussions with respondent 9 about the suspected problem, an updated submission was provided. The corrected data (not included in this report) for both the "10-meter" and "layered" procedures are now in agreement with the majority of the respondents.

With the one exception noted above, the computed distance and meteorological corrections provided by all respondents were in good agreement. Minor differences resulted from computer round-off techniques.

# TABLE 7. ATMOSPHERIC/DISTANCE CORRECTIONS, 10-METER PROCEDURE

| 1/3 OCTAVE BAND CENTER FREQUENCY | CORRECTIONS - dB re 20 micro-Pa | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 7 | 9 | 10 | 15 | 16 | 17 | 18 | 1 | 2 | 6 |
| 25 Hz | 0.74 | 0.74 | 0.74 | 0.0 | - | - | 0.74 | 0.74 | | | |
| 31.5 Hz | 0.74 | 0.74 | 0.74 | 0.0 | - | - | 0.74 | 0.74 | | | |
| 40 Hz | 0.74 | 0.74 | 0.74 | 0.0 | - | - | 0.74 | 0.74 | | | |
| 50 Hz | 0.74 | 0.74 | 0.74 | 0.8 | 0.74 | 0.7 | 0.74 | 0.74 | | | |
| 63 Hz | 0.74 | 0.74 | 0.74 | 0.7 | 0.74 | 0.7 | 0.74 | 0.74 | | | |
| 80 Hz | 0.74 | 0.74 | 0.73 | 0.8 | 0.74 | 0.7 | 0.74 | 0.74 | | | |
| 100 Hz | 0.73 | 0.73 | 0.73 | 0.8 | 0.73 | 0.7 | 0.73 | 0.74 | | | |
| 125 Hz | 0.73 | 0.73 | 0.73 | 0.7 | 0.73 | 0.7 | 0.73 | 0.73 | | | |
| 160 Hz | 0.73 | 0.73 | 0.72 | 0.7 | 0.73 | 0.7 | 0.73 | 0.73 | | | |
| 200 Hz | 0.72 | 0.72 | 0.72 | 0.7 | 0.72 | 0.7 | 0.73 | 0.73 | | | |
| 250 Hz | 0.72 | 0.72 | 0.71 | 0.7 | 0.72 | 0.7 | 0.72 | 0.72 | | | |
| 315 Hz | 0.71 | 0.71 | 0.70 | 0.8 | 0.71 | 0.7 | 0.71 | 0.72 | | | |
| 400 Hz | 0.71 | 0.71 | 0.69 | 0.7 | 0.71 | 0.7 | 0.71 | 0.71 | | | |
| 500 Hz | 0.70 | 0.70 | 0.68 | 0.7 | 0.70 | 0.7 | 0.70 | 0.70 | | | |
| 630 Hz | 0.69 | 0.69 | 0.66 | 0.7 | 0.69 | 0.7 | 0.69 | 0.69 | | | |
| 800 Hz | 0.67 | 0.67 | 0.65 | 0.7 | 0.67 | 0.7 | 0.67 | 0.67 | NO DATA | NO DATA | NO DATA |
| 1 kHz | 0.65 | 0.65 | 0.65 | 0.7 | 0.65 | 0.7 | 0.65 | 0.65 | | | |
| 1.25 kHz | 0.63 | 0.63 | 0.66 | 0.7 | 0.63 | 0.6 | 0.63 | 0.63 | | | |
| 1.6 kHz | 0.60 | 0.60 | 0.74 | 0.6 | 0.60 | 0.6 | 0.60 | 0.60 | | | |
| 2 kHz | 0.56 | 0.56 | 0.84 | 0.6 | 0.56 | 0.6 | 0.56 | 0.56 | | | |
| 2.5 kHz | 0.55 | 0.55 | 1.11 | 0.6 | 0.55 | 0.5 | 0.55 | 0.55 | | | |
| 3.15 kHz | 0.59 | 0.59 | 1.56 | 0.6 | 0.59 | 0.6 | 0.59 | 0.60 | | | |
| 4 kHz | 0.70 | 0.70 | 2.25 | 0.6 | 0.70 | 0.7 | 0.69 | 0.70 | | | |
| 5 kHz | 0.83 | 0.83 | 3.28 | 0.9 | 0.83 | 0.8 | 0.82 | 0.83 | | | |
| 6.3 kHz | 1.21 | 1.21 | 4.82 | 1.2 | 1.22 | 1.2 | 1.20 | 1.21 | | | |
| 8 kHz | 1.84 | 1.84 | 7.00 | 1.9 | 1.84 | 1.8 | 1.84 | 1.85 | | | |
| 10 kHz | 2.81 | 2.81 | 9.86 | 2.8 | 2.82 | 2.8 | 2.80 | 2.81 | | | |

NOTE: Respondent identified by numeric code

TABLE 8. ATMOSPHERIC/DISTANCE CORECTIONS, LAYERED PROCEDURE

| 1/3 OCTAVE BAND CENTER FREQUENCY | CORRECTIONS - dB re 20 micro-Pa | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 7 | 9 | 10 | 15 | 16 | 17 | 18 | 1 | 2 | 6 |
| 25 Hz | 0.74 | 0.74 | 0.74 | 0.0 | | | 0.74 | 0.74 | | | |
| 31.5 Hz | 0.74 | 0.74 | 0.74 | 0.0 | | | 0.74 | 0.74 | | | |
| 40 Hz | 0.74 | 0.74 | 0.74 | 0.0 | | | 0.74 | 0.74 | | | |
| 50 Hz | 0.74 | 0.74 | 0.74 | 0.8 | | | 0.74 | 0.74 | | | |
| 63 Hz | 0.74 | 0.74 | 0.74 | 0.7 | | | 0.74 | 0.74 | | | |
| 80 Hz | 0.73 | 0.73 | 0.73 | 0.8 | | | 0.74 | 0.74 | | | |
| 100 Hz | 0.73 | 0.73 | 0.73 | 0.8 | | | 0.73 | 0.73 | | | |
| 125 Hz | 0.73 | 0.73 | 0.73 | 0.7 | | | 0.73 | 0.73 | | | |
| 160 Hz | 0.73 | 0.73 | 0.73 | 0.7 | | | 0.73 | 0.73 | | | |
| 200 Hz | 0.72 | 0.72 | 0.72 | 0.7 | | | 0.72 | 0.72 | | | |
| 250 Hz | 0.72 | 0.72 | 0.72 | 0.7 | | | 0.72 | 0.72 | | | NO DATA |
| 315 Hz | 0.71 | 0.71 | 0.71 | 0.8 | | | 0.71 | 0.71 | | NO DATA | |
| 400 Hz | 0.70 | 0.70 | 0.70 | 0.7 | | | 0.70 | 0.70 | NO DATA | | |
| 500 Hz | 0.69 | 0.69 | 0.69 | 0.7 | | NO DATA | 0.69 | 0.69 | | | |
| 630 Hz | 0.67 | 0.67 | 0.67 | 0.7 | NO DATA | | 0.67 | 0.68 | | | |
| 800 Hz | 0.66 | 0.66 | 0.66 | 0.7 | | | 0.66 | 0.66 | | | |
| 1 kHz | 0.64 | 0.64 | 0.64 | 0.7 | | | 0.64 | 0.64 | | | |
| 1.25 kHz | 0.62 | 0.62 | 0.62 | 0.7 | | | 0.62 | 0.62 | | | |
| 1.6 kHz | 0.62 | 0.61 | 0.61 | 0.7 | | | 0.61 | 0.62 | | | |
| 2 kHz | 0.63 | 0.63 | 0.63 | 0.8 | | | 0.63 | 0.64 | | | |
| 2.5 kHz | 0.71 | 0.70 | 0.71 | 1.0 | | | 0.71 | 0.71 | | | |
| 3.15 kHz | 0.88 | 0.88 | 0.87 | 1.3 | | | 0.88 | 0.89 | | | |
| 4 kHz | 1.23 | 1.22 | 1.22 | 1.9 | | | 1.23 | 1.23 | | | |
| 5 kHz | 1.49 | 1.48 | 1.79 | 2.3 | | | 1.50 | 1.50 | | | |
| 6.3 kHz | 2.23 | 2.21 | 2.73 | 3.4 | | | 2.22 | 2.23 | | | |
| 8 kHz | 3.34 | 3.32 | 4.07 | 4.9 | | | 3.36 | 3.34 | | | |
| 10 kHz | 4.94 | 4.90 | 5.90 | 7.0 | | | 4.97 | 4.93 | | | |

NOTE: Respondent identified by numeric code

## 5. CONCLUSIONS

1. Computations utilizing the digital data (3.5 seconds of a simulated flyover) show excellent agreement among participants, thus indicating good procedural application of the Annex 16 methodology for computation of noise indexes, such as PNL and PNLT. A previous test on aircraft noise analysis (Reference 5) concluded "a large part of the variations in results among organizations was due to procedures" and therefore recommended changes to be instituted.

2. With one exception, the computation of distance and meteorological corrections based on the "10-meter" and more complex "layered" procedures were also in excellent agreement.

3. Band-sharing methodology (identification and adjustment for important tones recorded in two adjacent 1/3-octave levels) was not effectively tested with the digital data, however, a common procedure for this adjustment should be specified by ICAO. The FAR Part 36 Noise Standard, Reference 2, specifies a band-sharing detection and adjustment procedure utilizing the Doppler-shift phenomena. This procedure is used at TSC.

4. An inconsistent methodology was apparent in assigning time-of-day to a sample of data. Time assigned is important since it affects the apparent emission angle and noise propagation path length, thus affecting the test-day-to-reference-day and position corrections.

5. Although the transient response characteristics measured (Figure 2) can be shown to meet the specifications of Annex 16 (Appendix 2 Section 3.4), the three typical curves shown are uniquely different and the systems from which they were obtained can respond differently under a variety of input noise situations. In spite of the small data set of this test, grouping of the results can be seen. One group (variability 0.2 dB or less) was formed by the data from respondents 7, 10, 16, and 18, who used external computer averaging with an effective RC

time constant of 750 milliseconds. A second group, although not closely aligned (variability of 0.5 dB or less), was formed by the data from respondents 3, 9, and 15, whose commercially packaged systems were set to an effective RC time constant of 1000 milliseconds. A tighter specification by ICAO for the detector characteristics is necessary.

6. The within-organization variability for the results of test runs 11-14 (EPNL, PNL, PNLT) was shown to be 0.2 dB or less. A reasonable organization-to-organization variability of 0.5 dB or less was obtained for test runs 11, 12 and 14 and 0.7 dB or less for test run 13 which contained signals with the most rapid transient changes.

Appreciation is again expressed to the participating organizations. It is hoped that these results will serve to compensate for the significant time expenditure volunteered for the conduct of this Round-Robin Test.

# APPENDIX A

## TEST PROCEDURE
## AND
## SAMPLE DATA-REPORTING SHEETS

(Note: certain data sheet page numbers have been omitted because they were duplicates of pages shown.)

# HELICOPTER NOISE ANALYSIS
# ROUND ROBIN TEST PROCEDURE

Edward J. Rickley

January 1980

U.S. DEPARTMENT OF TRANSPORTATION
Research and Special Programs Administration
Transportation Systems Center
Environmental Technology Branch
Cambridge, MA 02142

CONTENTS

# 1. INTRODUCTION

At the October 1979 meeting of the International Civil Aviation Organization, Committee on Aircraft Noise (ICAO/CAN), Working Group B, it was proposed that a round-robin test be conducted to promote uniformity in the analysis of data for describing helicopter noise for international helicopter certification standards.

The U.S. DOT/Transportation Systems Center (TSC) Kendall Square, Cambridge, MA was requested by the Federal Aviation Administration Office of Energy and Environment to act as the focal point for the definition of the test procedure and for the subsequent collection and evaluation of results generated by the nations and organizations participating. Accordingly TSC will generate a set of identical helicopter noise test recordings, identify procedures for their reduction, and distribute them to the participants for the conduct of the test.

The test, sponsored by the Federal Aviation Administration, Office of Energy and Environment, and proposed by the, International Civil Aviation Organization, Committee on Aircraft Noise, is to promote uniformity in the analysis of data for describing helicopter noise for international certification standards.

## 2. GENERAL

The complexity of helicopter flyby noise, which contains non-stationary random noise, fluctuating periodic signals and impulsive signals, in combination with a variety of noise measurement and data processing systems and procedures could result in a variation of flyby noise levels and descriptions measured for the same type aircraft. The purpose of this round robin test is to evaluate the data reduction systems and procedures to determine the magnitude of the variability between systems and organizations, identify potential causes and assist in establishing recommended practices to minimize the differences.

Each participant in the test will be provided with:

1) A test tape recording consisting of calibration and reference signals and noise data from three helicopter flybys and one helicopter flypast.
2) Digital tabulations of one-third-octave band sound pressure levels in 0.5 second increments around PNLTM for a simulated flyover.
3) A set of instructions and standard data reporting forms.

The participants will process the data using the instructions provided and the procedures outlined in the ICAO International Standards and Recommended Practices on Aircraft Noise, Annex 16, Third Edition, July 1978. At present Annex 16 does not apply to helicopters until the recommendations of CAN 6 for helicopter standards are incorporated as an amendment. The procedures of the Third Edition supplemented by the appropriate CAN 6 recommendations will however be used in this test as specified in these test instructions.

### 2.1 TEST TAPE

The test tape recording contains noise data from three helicopter flyovers and one flypast. Events were selected to include pure tones, impulsive noise, broadband noise and psuedotones. Included on the test recording are the following reference and calibration signals for proper adjustment and calibration of the data reduction system: a 1000 Hz pure tone signal provided at four levels to determine the linearity of the data reduction system; a series of tone bursts to obtain a measure of detector dynamic characteristics at 1000 Hz; and a standard IRIGB time code signal recorded on a separate channel to provide exact synchronization of measurement periods. The contents of the test tape are summarized below:

| Run | Data (Channel 1) | Time Code Channel 2 |
|---|---|---|
| 1 | Playback Reference Tone, 1000-Hz | |
| 2 | Frequency Response Signal, Pink Noise | |
| 3 | Amplitude Calibration, 250 Hz, 94dB | |
| 4 | Amplitude Calibration, 500 Hz, 94dB | |
| 5 | Amplitude Calibration, 1000 Hz, 94dB | |
| 6 | Linearity Test Tone, 1000 Hz, 84dB | |
| 7 | Linearity Test Tone, 1000 Hz, 74dB | |
| 8 | Linearity Test Tone, 1000 Hz, 64dB | |
| 9 | Linearity Test Tone, 1000 Hz, 54dB | |
| 10 | Detector Test, 1000 Hz tone burst | |
| 11 | Helicopter Flyover, Approach centerline | |
| 12 | Helicopter Flyover, Takeoff centerline | |
| 13 | Helicopter Flyover, Level Flight centerline | |
| 14 | Helicopter Flypast, Level Flight sideline | |
| 15 | Playback Reference Tone, 1000 Hz | |

The master tape and the fifteen identical duplicate tapes were recorded at a speed of 7 1/2 inches per second on a two track NAGRA IVSJ recorder with Cue track. To insure that all copies were identical, each tape was analyzed on the TSC analysis system (GenRad 1921) before distribution to the participants.

## 2.2 DIGITAL TABULATIONS ONE-THIRD OCTAVE SPECTRA

One-third-octave digital sound pressure level data of a simulated flyover for seven consecutive 0.5 second periods around PNLTM is supplied to each participant for processing through his computer program that calculates PNL and PNLTM.

Processing of this digital data will allow investigation of the possibility that variations in final results between participants in the analysis of the test tapes can be attributed to calculation procedural differences, i.e., interpretation of defined procedures or perhaps computer roundoff techniques.

## 2.3 INSTRUCTIONS

A set of instructions, including consideration of the latest proposed changes to Annex 16 are provided. Deviation from the procedures must be minimized and where absolutely necessary a description of the deviation must be supplied. Standard data sheets are provided for reporting all information requested for comparison purposes. Any other pertinent data that may influence the results should be reported.

# 3. TEST PROCEDURE

## 3.1 ANALYSIS SYSTEM

The entire analysis system consisting of hardware and software should comply with the requirements of the ICAO International Standards and Recommended Practices on Aircraft Noise, Annex 16, Appendix 2. One exception is noted, namely, the corrections for spectral irregularities in Appendix 2, Paragraph 4.3 shall start at 50 Hz instead of 80 Hz. Fill in the required information data sheet pages 1 and 2. If "OTHER" was checked in box 4 or 5 on page 1, explain fully on page 21. Explain any other special characteristics of your analysis system that may not be adequately covered by pages 1 and 2.

## 3.2 TAPE RECORDER

Using appropriate procedures set up channel 1 and 2 of the tape recorder for correct playback of the direct recorded signal at a recorder speed of 7 1/2 inches per second. Run 1 playback reference tone, should be used to adjust channel 1 and 2 of the recorder electronics to full scale meter indication.

## 3.3 SYSTEM CALIBRATION

3.3.1 Playback the first reference tone (Run 1, channel 1). Measure the frequency and level of reference tone. Signal should be 1.0 ± 0.1 volt and 1000 ± 10 Hz. Run 15 is a repeat of the reference tone. Playback run 15 and measure the frequency and voltage of reference tone. Tabulate voltage and frequency of runs 1 and 15 on the data sheet page 3.

3.3.2 Using the reference tone (Run 1, channel 1), adjust electronics of analysis system for approximately full scale indication.

3.3.3 Run 3, 4, and 5 are acoustic calibration tones with a sound pressure level of 94 dB re 20 micro Pascal at 250 Hz, 500 Hz, and 1000 Hz respectively with 0 dB gain. No gain or range corrections are required with this tape. Playback the acoustic calibration signal with the frequency that best suits you and adjust the absolute calibration level of your system using the energy average of twenty consecutive 1/2 second integration periods. Starting at times indicated on data sheet, record the frequency of the calibration signal used on the data sheet page 3.

### 3.4 LINEARITY TEST

Runs 5, 6, 7, 8, and 9 will be used to determine system linearity. The energy average of twenty consecutive 1/2 second integrations periods should be determined. Playback runs 5, 6, 7, 8, and 9 and start analysis at times indicated on data sheet.

Record the energy average at each level on the data sheet provided page 3.

### 3.5 DETECTION TEST

To test the dynamic response characteristics at 1000 Hz of each participant's detection system a constant sinusoidal signal followed by a series of tone bursts at 1000 Hz are provided as part of Run 10. The digital time history (consecutive 1/2 second dB values) of the RMS level of the 1000 Hz one-third octave band is required from your analysis system. It is understood that some systems require additional computer smoothing or averaging of the analyzer output to conform to the dynamic response requirements of Appendix 2, Paragraph 3.4.5. The digital history to be provided must be processed in this manner.

3.5.1 Set the time constant or integration time of the analysis system to the desired value. Playback the recorded signal of Run 10 and start the analysis at time 00:12:25 for a total of 86 seconds duration. Record the 172 consecutive digital outputs (one for each 1/2 second) on the data sheet provided page 4. Also record time constant or integration time. If computer smoothing was used, explain the procedure employed on page 21.

3.6 PINK NOISE CALIBRATION

3.6.1 The pink noise signal (Run 2) should be processed through the analysis system starting at time 00:02:04 for 40 consecutive 1/2 second integrations. A single value of the RMS level for each of 24 one-third-octave bands (50 Hz-10kHz) should be obtained by energy averaging the 40 sets of data. Tabulate the one-third-octave-band levels in dB on the supplied data sheet page 5.

3.6.2 Assuming a 0 dB correction for the one-third-octave band with a center-frequency to match the calibration signal used (section 3.3.3), determine the corrections to be applied to each one-third-octave-band to give a flat frequency response. Tabulate the corrections on the data sheet page 5. These corrections must be applied to the data of the following operations.

3.7 DATA ANALYSIS

3.3.3 With the system calibrated as in section 3.2 and the one-third-octave band corrections determined as in section 3.6, the four recorded helicopter noise signals (Runs 11, 12, 13, 14) will be processed through the calibrated analysis system and calculation of noise descriptors performed. Since the noise signals are recorded at the same gain as the acoustic calibration, no gain corrections are required. Do not make any corrections for background noise.

3.7.1 Integration Time Set the time constant or integration time to the value in section 3.5. Record time constant or integration time and computer smoothing procedure employed on data sheet page 6.

3.7.2 Start Times and Duration Playback the signals of Runs 11, 12, 13, 14. The start time and duration of the analysis is as follows:

| Run | Start Time | Duration (seconds) |
|---|---|---|
| 11- Approach centerline | 00:14:50 | 25 |
| 12- Takeoff centerline | 00:15:42 | 20 |
| 13- Flyover centerline | 00:16:40 | 20 |
| 14- Flypast centerline | 00:17:31 | 35 |

Each event is to be analyzed over the total period given.

3.8 CALCULATIONS

The procedures of latest version of Section 4 Appendix 2 of Annex 16 must be used to determine EPNL and associated noise indexes. All indexes will be calculated using the corrected 24 one-third-octave bands of sound pressure levels.

For these computations it is to be assumed that actual and reference flight tracks are the same and that the reference meteorological conditions (25°C, 70% RH) apply to produce a set of "As Measured" indexes. The following information is required on the data sheet pages 6-17 for Runs 11, 12, 13 and 14.

a) Time constant or integration time used.

b) Computer smoothing used, yes or no.

c) Start time and duration of data analysis

d) EPNL calculated in accordance with Annex 16, Appendix 2 procedures. (EPNdB)

e) Time of maximum PNLT (PNLTM) - (hr:min:sec).

f) Overall SPL for each 0.5 second interval (dB).

g) Perceived Noise Level (PNL) for each 0.5 second interval (PNdB).

h) Tone corrected Perceived Noise Level (PNLT) for each 0.5 second interval (PNdB).

i) One-third octave band SPL's for the 0.5 second interval at the time of PNLTM (dB).

## 3.9 REPEATABILITY OF ANALYSIS SYSTEM

The test procedure section 3 should be performed four times to obtain a measure of the variance within each organization.

All data should be recorded in the data sheets provided indentifying the repetition number.

# 4. DIGITAL TABULATIONS

Digital one-third-octave-band sound pressure level tabulations of seven consecutive 0.5 second periods of data around PNLTM for a portion of a simulated flyover are supplied in Table 4.1. These data should be manually input and processed through each participants computer program. These digital data are to be considered the data that would be input to the computer from your analysis system; therefore, if computer averaging is normally used to obtain the required system dynamic response it should be applied to these data as well. No gain corrections, frequency response corrections, or background noise corrections should be applied to this digital data.

## 4.1 COMPUTER AVERAGING

Apply computer averaging to the digital data as required. The averaged data should be tabulated in the data sheet supplied (page 18) along with a short discussion of averaging or smoothing technique employed.

## 4.2 AS MEASURED PNL, dBA, OASPL

Utilizing the procedures of Annex 16, and the averaged data of Section 4.1 calculate the perceived noise level (PNL). Also calculate the "A" weighted level (dBA) and the overall sound pressure levels (OASPL) for each 0.5 second period. Tabulate the calculated data on the data sheet provided page 19.

## 4.3 AS MEASURED PNLT AND PNLTM

Corrections as appropriate should be calculated to account for pronounced spectral irregularities (e.g. the maximum discrete frequency component or tone) for each 0.5 second period and applied to the PNL calculations to determine the tone corrected perceived noise level (PNLT). Record data on the data sheet provided. Identify the maximum PNLT (PNLTM), test for band sharing and apply the necessary band sharing correction. Record data on the data sheet provided page 19.

4.4 CORRECTION TO REFERENCE CONDITIONS

Utilizing the flight track conditions as specified in Figure 4.1 (where point Q is the aircraft position, in retarded time, at the time of PNLTM) and the temperature humidity profile of Table 4.2, the 1/3-octave spectra at PNLTM should be corrected for the effects of atmospheric absorption and deviation from reference flight track. The atmospheric attenuation of sound in air shall be determined in accordance with the curves presented in SAE-ARP-866A (3/15/75) the meteorological reference conditions are 25°C, 70% RH).

4.4.1 Ten Meter Corrections Atmospheric absorption corrections and distance correction should be calculated assuming the ten meter meteorological data provided are constant throughout the propagation path of the sound. Record data in the data sheet page 20.

4.4.2 Layered-Atmosphere Corrections The layered-atmosphere procedure to correct the data for sound propagation in air using SAE-ARP-866A is as follows:

a) Divide the sound propagation path into increments of 30 meters in altitude.

b) Determine the average temperature and relative humidity in each 30 meter altitude increment.

c) Calculate the atmospheric attenuation rate in each one-third-octave-band in each altitude increment.

d) The mean atmospheric attenuation rate in each one-third-octave-band over the complete propagation path must be computed and used to calculate the corrections required.

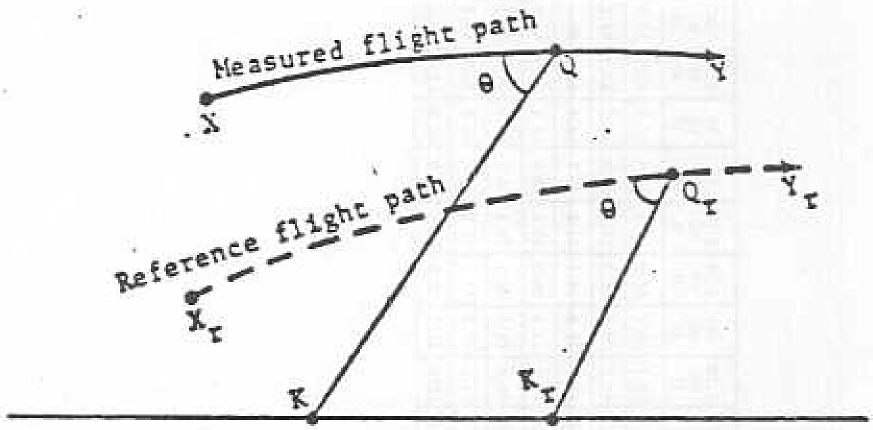
Record atmospheric absorption and distance correction on data sheet provided page 20.

## 5. DATA REPORTING

Fill out the data sheets reporting all information requested for data comparison purposes. Any other pertinent data should be reported if said data influences the data comparison between analysis systems being employed by the various participants taking part in the round robin test. All data should be mailed to:

Edward J. Rickley (Code DTS-331)
U.S. Department of Transportation
Research and Special Programs Administration
Transportation Systems Center
Kendall Square
Cambridge MA USA 02142
Tel 617-494-2053

Participant organizations are not required to identify themselves. All identities will be treated with the highest degree of confidentiality.




$K_rQ_r$ = 106.3 Meters

$\theta = 110^\circ$

KQ = 115.8 Meters

FIGURE 4.1 Flight path profile

TABLE 4.1

| TIME PERIOD | 25 HZ 14 | 31.5 HZ 15 | 40 HZ 16 | 50 HZ 17 | 63 HZ 18 | 80 HZ 19 | 100 HZ 20 | 125 HZ 21 | 160 HZ 22 | 200 HZ 23 | 250 HZ 24 | 315 HZ 25 | 400 HZ 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 76.5 | 72.7 | 83.1 | 86.9 | 85.8 | 78.0 | 78.3 | 81.3 | 77.5 | 76.8 | 76.6 | 84.0 | 78.0 |
| 2 | 76.1 | 72.6 | 82.7 | 86.3 | 84.4 | 75.4 | 75.6 | 80.6 | 77.7 | 77.6 | 79.7 | 84.7 | 79.4 |
| 3 | 75.0 | 71.8 | 81.5 | 85.0 | 81.3 | 73.3 | 73.2 | 78.6 | 77.1 | 78.3 | 83.0 | 84.0 | 77.2 |
| 4 | 74.5 | 70.5 | 80.0 | 83.2 | 78.2 | 70.0 | 73.5 | 75.9 | 77.1 | 80.9 | 84.0 | 84.0 | 74.2 |
| 5 | 72.3 | 68.3 | 78.2 | 80.6 | 78.6 | 70.1 | 73.7 | 71.7 | 76.4 | 79.4 | 83.7 | 82.4 | 71.4 |
| 6 | 72.5 | 68.0 | 78.2 | 80.6 | 80.2 | 70.6 | 74.4 | 71.6 | 75.3 | 78.6 | 83.6 | 79.1 | 69.8 |
| 7 | 72.3 | 68.3 | 78.0 | 80.4 | 80.9 | 70.7 | 74.2 | 66.3 | 74.0 | 80.3 | 83.1 | 77.6 | 69.6 |

| TIME PERIOD | 500 HZ 27 | 630 HZ 28 | 800 HZ 29 | 1K HZ 30 | 1.2K HZ 31 | 1.6K HZ 32 | 2K HZ 33 | 2.5K HZ 34 | 3.1K HZ 35 | 4K HZ 36 | 5K HZ 37 | 6.3K HZ 38 | 8K HZ 39 | 10K HZ 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 79.0 | 77.7 | 77.7 | 74.3 | 73.0 | 69.7 | 68.2 | 67.2 | 67.1 | 65.4 | 64.8 | 62.5 | 57.1 | 52.7 |
| 2 | 79.4 | 78.7 | 77.5 | 76.2 | 74.3 | 71.5 | 70.3 | 71.3 | 71.2 | 67.9 | 66.3 | 63.9 | 59.2 | 54.9 |
| 3 | 76.3 | 78.5 | 75.8 | 76.3 | 76.0 | 73.4 | 71.9 | 74.1 | 73.2 | 70.7 | 67.3 | 64.4 | 59.7 | 55.4 |
| 4 | 75.0 | 76.9 | 73.7 | 76.4 | 76.6 | 74.4 | 73.3 | 75.0 | 73.8 | 70.9 | 67.4 | 64.3 | 59.9 | 55.2 |
| 5 | 76.0 | 73.7 | 73.7 | 75.7 | 76.0 | 74.4 | 73.1 | 74.1 | 72.9 | 70.5 | 67.6 | 64.1 | 59.7 | 55.1 |
| 6 | 76.3 | 73.6 | 75.2 | 75.0 | 74.7 | 73.5 | 72.3 | 72.1 | 71.0 | 68.9 | 66.8 | 63.9 | 59.3 | 55.1 |
| 7 | 75.1 | 72.6 | 74.6 | 73.8 | 73.6 | 72.6 | 71.3 | 70.4 | 69.6 | 67.8 | 65.9 | 63.4 | 58.5 | 54.8 |

TABLE 4.2

| ALTITUDE METERS | TEMPERATURE °C | HUMIDITY % |
|---|---|---|
| 10 | 12.0 | 90.0 |
| 30 | 11.2 | 85.6 |
| 60 | 10.0 | 79.0 |
| 90 | 8.8 | 72.4 |
| 120 | 7.6 | 65.8 |
| 150 | 6.4 | 59.2 |
| 180 | 5.2 | 56.2 |

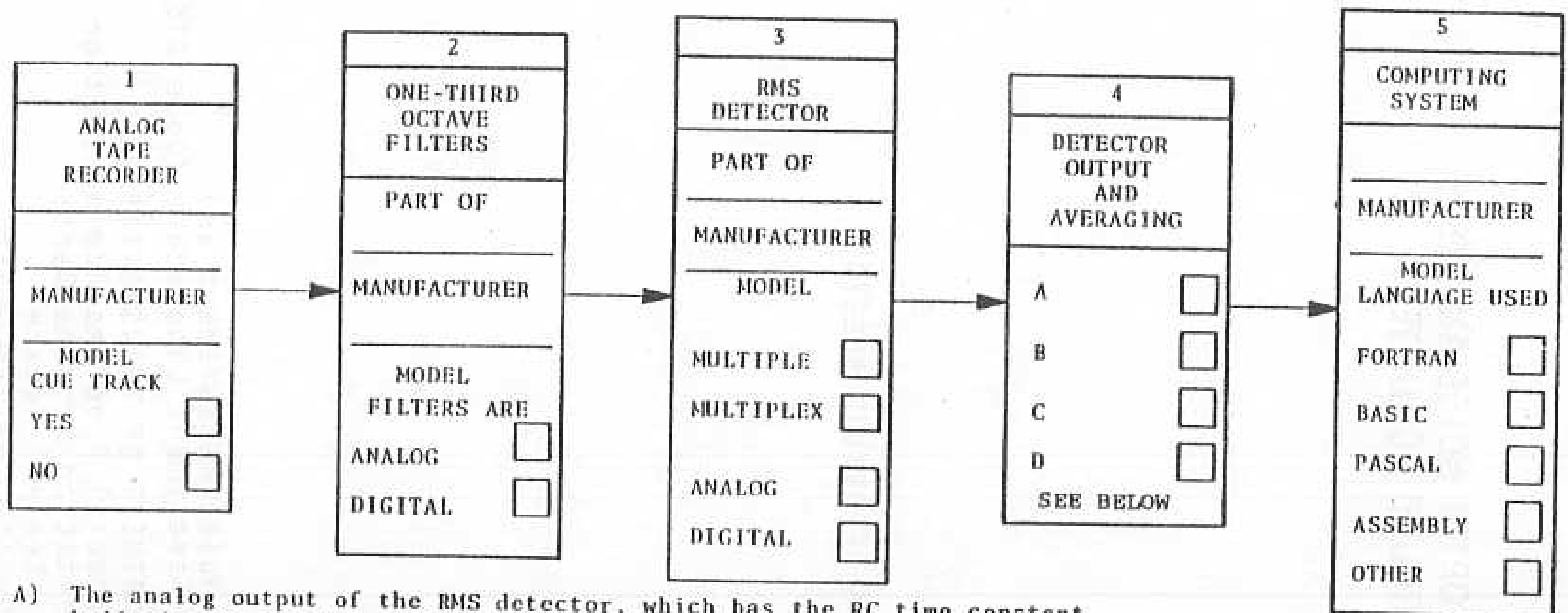
# HELICOPTER NOISE ANALYSIS
# ROUND ROBIN TEST

## DATA REPORTING SHEETS

Mail to: Noise Measurement and
Assessment Laboratory (Code DTS-331)

U.S. DEPARTMENT OF TRANSPORTATION
Research and Special Programs Administration
Transportation Systems Center
Kendall Square
Cambridge, MA USA 02142

## BLOCK DIAGRAM OF ANALYSIS SYSTEM




A) The analog output of the RMS detector, which has the RC time constant built in, is sampled at the 0.5 second rate.
B) The digital RMS detector integrates for 0.5 second. Averaging is accomplished in computer software.
C) The analog output of the RMS detector is averaged by computer software or firmware. (explain on page 21).
D) Other. (explain fully on page 21).

## DATA SHEET

Please indicate whether or not your data analysis system complies with the following requirements of Annex 16, Appendix 2 and other special requirements listed below.

| | Requirement | YES | NO |
|---|---|---|---|
| a) | Dynamic characteristics of the RMS detector for rise and fall times of all one-third octave filters. | ☐ | ☐ |
| b) | 0.5 second intervals must be 0.5 seconds ± 0.01 second. | ☐ | ☐ |
| c) | In cases where dead time occurs during readout and integrator reset, the loss shall not exceed 1% of the total data. | ☐ | ☐ |
| d) | The levels from all 24 one-third-octave bands must be obtained within a 50 ms period. | ☐ | ☐ |
| e) | The resolution of the digitizing system output shall be equal to or better than 0.25 dB. | ☐ | ☐ |
| f) | The detector must perform as a true mean square device with range and accuracies in agreement with Annex 16 Appendix 2-3.4.3. | ☐ | ☐ |
| g) | Tone correction procedures must be extended to include all bands from 50 Hz to 10 KHZ. | ☐ | ☐ |
| h) | Tones that are recorded in two adjacent one-third octave bands must be compensated for. | ☐ | ☐ |

Explain the details of any checks in the "No" column on page 21.

Para. 3.3.1 run 1 & 15 — Enter the voltage and frequency of the reference tone.

| REPETITION NO. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| VOLTAGE RUN 1 | | | | |
| VOLTAGE RUN 15 | | | | |
| FREQUENCY RUN 1 | | | | |
| FREQUENCY RUN 15 | | | | |

Para. 3.3.3 run 3-5 — Check which calibration frequency was used. Energy average for 10 seconds after starting time.

| REPETITION NO. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 250 Hz. Start - 00:03:20 | | | | |
| 500 Hz, Start - 00:04:21 | | | | |
| 1000 Hz. Start - 00:05:39 | | | | |
| | | | | |

Para. 3.4 Run 5-9 — Enter the measured RMS levels of the six 1000 HZ. calibration signals. Energy average for 10 seconds after starting time.

| REPETITION NO. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| RUN 5 Start - 00:05:39 | | | | |
| RUN 6 Start - 00:06:56 | | | | |
| RUN 7 Start - 00:08:16 | | | | |
| RUN 8 Start - 00:09:32 | | | | |
| RUN 9 Start - 00:10:50 | | | | |

# DATA SHEET

Para. 3.5.1 run 10

Record the digital time history of the 1000 Hz one-third octave band (band 30) for the 86 second duration of that run.

REPETITION NO. 1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
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Time constant or integration time used. ☐

Smoothing used? YES ☐ NO ☐

(explain pg. 21)

# DATA SHEET

Para. 3.6 run 2 — Tabulate the one-third octave sound pressure levels and corrections.

| REPETITION NO. | 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| FREQ. | SPL | CORRECTION | SPL | CORRECTION | SPL | CORRECTION | SPL | CORRECTION |
| 50 HZ | | | | | | | | |
| 63 HZ | | | | | | | | |
| 80 HZ | | | | | | | | |
| 100 HZ | | | | | | | | |
| 125 HZ | | | | | | | | |
| 160 HZ | | | | | | | | |
| 200 HZ | | | | | | | | |
| 250 HZ | | | | | | | | |
| 315 HZ | | | | | | | | |
| 400 HZ | | | | | | | | |
| 500 HZ | | | | | | | | |
| 630 HZ | | | | | | | | |
| 800 HZ | | | | | | | | |
| 1 KHZ | | | | | | | | |
| 1.2 KHZ | | | | | | | | |
| 1.6 KHZ | | | | | | | | |
| 2 KHZ | | | | | | | | |
| 2.5 KHZ | | | | | | | | |
| 3.1 KHZ | | | | | | | | |
| 4 KHZ | | | | | | | | |
| 5 KHZ | | | | | | | | |
| 6.3 KHZ | | | | | | | | |
| 8 KHZ | | | | | | | | |
| 10 KHZ | | | | | | | | |

# DATA SHEET

## RUN 11

Para. 3.7&3.8 Run 11

Time constant or integration time used.

Repetition No. 1 [ ]

Repetition No. 2 [ ]

Repetition No. 3 [ ]

Repetition No. 4 [ ]

Smoothing used ?

Repetition No. 1 YES [ ] NO [ ]

Repetition No. 2 YES [ ] NO [ ]

Repetition No. 3 YES [ ] NO [ ]

Repetition No. 4 YES [ ] NO [ ]

Start time and duration of the run.

Start Repetition No. 1 __:__:__. for_____sec.

Start Repetition No. 2 __:__:__. for_____sec.

Start Repetition No. 3 __:__:__. for_____sec.

Start Repetition No. 4 __:__:__. for_____sec.

Calculated Effective Perceived Noise Level ( EPNL ).

Repetition No. 1 [ ]

Repetition No. 2 [ ]

Repetition No. 3 [ ]

Repetition No. 4 [ ]

The time of maximum Tone Corrected Perceived Noise Level is:

Repetition No. 1 [ ]

Repetition No. 2 [ ]

Repetition No. 3 [ ]

Repetition No. 4 [ ]

# DATA SHEET

## RUN 11

Para. 3.8 Run 11 — Tabulate the Overall Sound Pressure Level ( OASPL ), Perceived Noise Level ( PNL ), and Tone Corrected Perceived Noise Level ( PNLT ).for the entire run. Column headings 1 through 4 refer to the repetition no.

| OASPL | | | | PNL | | | | PNLT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| | | | | | | | | | | | |
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Continued on Pg. 7b

Para. 3.8 Run 11 Tabulate the one-third octave band levels at PNLTM time.

| FREQ | 1 SPL | 2 SPL | 3 SPL | 4 SPL |
|---|---|---|---|---|
| 50 HZ | | | | |
| 63 HZ | | | | |
| 80 HZ | | | | |
| 100 HZ | | | | |
| 125 HZ | | | | |
| 160 HZ | | | | |
| 200 HZ | | | | |
| 250 HZ | | | | |
| 315 HZ | | | | |
| 400 HZ | | | | |
| 500 HZ | | | | |
| 630 HZ | | | | |
| 800 HZ | | | | |
| 1 KHZ | | | | |
| 1.2 KHZ | | | | |
| 1.6 KHZ | | | | |
| 2 KHZ | | | | |
| 2.5 KHZ | | | | |
| 3.1 KHZ | | | | |
| 4 KHZ | | | | |
| 5 KHZ | | | | |
| 6.3 KHZ | | | | |
| 8 KHZ | | | | |
| 10 KHZ | | | | |

Para. 4.1 If computer smoothing was used on the digital data from table 1, tabulate the resulting averaged data.

| FREQ | TIME INTERVAL 1 | TIME INTERVAL 2 | TIME INTERVAL 3 | TIME INTERVAL 4 | TIME INTERVAL 5 |
|---|---|---|---|---|---|
| 50 HZ | | | | | |
| 63 HZ | | | | | |
| 80 HZ | | | | | |
| 100 HZ | | | | | |
| 120 HZ | | | | | |
| 160 HZ | | | | | |
| 200 HZ | | | | | |
| 250 HZ | | | | | |
| 315 HZ | | | | | |
| 400 HZ | | | | | |
| 500 HZ | | | | | |
| 630 HZ | | | | | |
| 800 HZ | | | | | |
| 1 KHZ | | | | | |
| 1.2 KHZ | | | | | |
| 1.6 KHZ | | | | | |
| 2 KHZ | | | | | |
| 2.5 KHZ | | | | | |
| 3.1 KHZ | | | | | |
| 4 KHZ | | | | | |
| 5 KHZ | | | | | |
| 6.3 KHZ | | | | | |
| 8 KHZ | | | | | |
| 10 KHZ | | | | | |

Provide a short discussion of averaging or smoothing employed.

Para. 4.2 Tabulate the calculated "A" Weighted SPL (dBA), Overall SPL (OASPL), Perceived Noise Level (PNL), Tone Corrected Perceived Noise Level (PNLT), and identify the Maximum PNLT (PNLTM).

| TIME INTERVAL | dBA | OASPL | PNL | PNLT | CHECK PNLTM |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |

## DATA SHEET



Para. 4.4 Tabulate the corrections applied to the one-third octave band SPL's as a result of atmospheric absorption and distance correction using the 10 meter method and using the layered atmosphere method.

| FREQ | 10 METER | LAYERED ATMOS. |
|---|---|---|
| 50 HZ | | |
| 63 HZ | | |
| 80 HZ | | |
| 100 HZ | | |
| 120 HZ | | |
| 160 HZ | | |
| 200 HZ | | |
| 250 HZ | | |
| 315 HZ | | |
| 400 HZ | | |
| 500 HZ | | |
| 630 HZ | | |
| 800 HZ | | |
| 1 KHZ | | |
| 1.2 KHZ | | |
| 1.6 KHZ | | |
| 2 KHZ | | |
| 2.5 KHZ | | |
| 3.1 KHZ | | |
| 4 KHZ | | |
| 5 KHZ | | |
| 6.3 KHZ | | |
| 8 KHZ | | |
| 10 KHZ | | |

The corrected PNLTM is: ____________

# DATA SHEET

# REFERENCES

1. The International Standard and Recommended Practice, Aircraft Noise, Annex 16 to the Convention on International Civil Aviation, Third Edition, July 1978. The International Civil Aviation Organization (ICAO), Montreal, Canada.

2. The US/DOT/FAA Federal Aviation Regulations Part 36, Noise Standards: Aircraft Type and Airworthiness Certification (continuously amended). The Superintendent of Documents, U.S. Government Printing Offices, Washington, DC 20402, USA.

3. Publication 651, Instruments for the Measurement of Sound Level (Sound Level Meters), 1st Edition 1979, The International Electrotechnical Commission, Geneva, Switzerland.

4. Aerospace Recommended Practice (ARP) 866A, Standard Value of Atmospheric Absorption as a Function of Temperature and Humidity, Society of Automotive Engineers (SAE), Warrendale, PA 15096, USA.

5. AIAA Paper No. 76-589, "Evaluation of Proposed Standards for Aircraft Flyover Noise Analysis Systems," Stouder, D.J. and McCann, J.C., American Institute of Aeronautics and Astronautics (AIAA), New York, NY 10019, USA.

450 copies

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1. ICAO, International Standards and Recommended Practices, Aircraft Noise, Annex 16 [illegible] Civil Aviation, ICAO [illegible] Aviation Organization [illegible]

2. [illegible] Aircraft [illegible] [illegible] from the [illegible] (Provisionally Amended). The [illegible] U.S. Government Printing Office [illegible]

3. [illegible], Instructions for [illegible] (Revised [illegible]), [illegible] Electrotechnical Commission, Geneva, Switzerland.

4. Aerospace Recommended Practice [illegible] of Atmospheric Absorption as a Function of Temperature and Humidity, Society of Automotive Engineers [illegible] PA [illegible]

5. NASA Report No. [illegible] Aircraft Flyover Noise [illegible] Measured [illegible] [illegible] [illegible] [illegible], New York, [illegible]