

# Measurement of Noise from Air-Cooled Heat Exchangers

API RECOMMENDED PRACTICE 631M  
FIRST EDITION, JUNE 1981  
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# Measurement of Noise from Air-Cooled Heat Exchangers

**Refining Department**

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## FOREWORD

This recommended practice is based on the accumulated knowledge and experience of petroleum refiners, air-cooled heat exchanger manufacturers, and engineering contractors. The objective of this publication is to provide a standard test procedure for measurement of noise emanating from air-cooled heat exchangers. Separate procedures for testing of an isolated single bay and for testing of a single bay of an installed unit are given. Testing the isolated single bay is considered a more accurate procedure.

The test procedure for installed air-cooled heat exchangers is similar to the procedure given in CONCAWEE Report Number 5/78, "Method for Determining the Sound-Power Levels of Air-Cooled (air-fin) Heat Exchangers." Comparative tests have shown that the two procedures yield similar results within  $\pm 2$  decibels.

Although it is recognized that the purchaser may desire to modify, delete, or amplify sections of the practice, it is strongly recommended that all such changes be made by supplementing this practice rather than by rewriting or by incorporating sections into another complete practice.

Suggested revisions are invited and should be submitted to the director of the Refining Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005

## CONTENTS

|                                                                                             | PAGE |
|---------------------------------------------------------------------------------------------|------|
| SECTION 1—GENERAL                                                                           |      |
| 1.1 Purpose                                                                                 | 1    |
| 1.2 Scope                                                                                   | 1    |
| 1.3 Instrumentation                                                                         | 1    |
| 1.4 Nomenclature and Definitions                                                            | 1    |
| 1.4.1 Nomenclature                                                                          | 1    |
| 1.4.2 Definitions                                                                           | 1    |
| SECTION 2—PROCEDURE FOR CONDUCTING NOISE TESTS<br>ON AN ISOLATED SINGLE BAY                 |      |
| 2.1 Procedure for Obtaining Noise Test Data                                                 | 2    |
| 2.1.1 Description of Test Set-Up                                                            | 2    |
| 2.1.2 Test Conditions                                                                       | 2    |
| 2.1.3 Location of Test Measuring Points                                                     | 2    |
| 2.1.4 Checklist                                                                             | 3    |
| 2.1.5 Recording of Data                                                                     | 4    |
| 2.2 Calculations and Interpretation                                                         | 4    |
| 2.2.1 Reducing Test Data                                                                    | 4    |
| 2.2.2 Application of Reduction Procedures                                                   | 5    |
| 2.3 Reporting of Data                                                                       | 6    |
| 2.3.1 General Requirements                                                                  | 6    |
| 2.3.2 Summary                                                                               | 6    |
| 2.3.3 Requirements for Data Sheet                                                           | 6    |
| SECTION 3—PROCEDURE FOR CONDUCTING NOISE TESTS<br>ON INSTALLED UNITS                        |      |
| 3.1 Procedure for Obtaining Noise Test Data                                                 | 6    |
| 3.1.1 Description and Requirements of Test                                                  | 6    |
| 3.1.2 Test Conditions                                                                       | 7    |
| 3.1.3 Location of Test Measuring Points                                                     | 7    |
| 3.1.4 Checklist                                                                             | 7    |
| 3.1.5 Recording of Data                                                                     | 7    |
| 3.2 Calculations and Interpretation                                                         | 8    |
| 3.2.1 Reducing Test Data                                                                    | 8    |
| 3.2.2 Application of Reduction Procedures                                                   | 10   |
| 3.3 Reporting of Data                                                                       | 11   |
| 3.3.1 General Requirements                                                                  | 11   |
| 3.3.2 Summary                                                                               | 11   |
| 3.3.3 Requirements for Data Sheet                                                           | 11   |
| APPENDIX A—MODEL FORMAT FOR NOISE TEST REPORT                                               | 13   |
| APPENDIX B—EXAMPLE NOISE TEST REPORT FOR AN ISOLATED SINGLE<br>BAY TEST                     | 21   |
| APPENDIX C—EXAMPLE NOISE TEST REPORT FOR AN INSTALLED UNIT                                  | 31   |
| LIST OF ILLUSTRATIONS                                                                       |      |
| Figures                                                                                     |      |
| 1—Isolated Single Bay Noise Measurement Points                                              | 3    |
| 2—Air-Cooled Heat Exchanger <i>SPL</i> Test Measurement Points for an Induced-Draft<br>Unit | 8    |

|                                                                                               | Page |
|-----------------------------------------------------------------------------------------------|------|
| 3—Air-Cooled Heat Exchanger <i>SPL</i> Test Measurements Points for a Forced-Draft Unit ..... | 9    |
| Tables                                                                                        |      |
| 1—Test Point Coordinates for Figure 1 .....                                                   | 2    |
| 2—Corrections for Background Noise .....                                                      | 4    |
| 3—Example of Reduction Procedures for Test on an Isolated Unit .....                          | 5    |
| 4—Example of Reduction Procedures for Test on an Installed Unit .....                         | 10   |

# Measurement of Noise from Air-Cooled Heat Exchangers

## SECTION 1—GENERAL

### 1.1 Purpose

This recommended practice establishes standard procedures for measuring and reporting sound-pressure levels (*SPL*) and sound-power levels (*PWL*) of air-cooled heat exchangers.

### 1.2 Scope

This procedure applies to air-cooled exchangers used for general refinery service, including both forced- and induced-draft type units. The procedures are based on testing complete air-cooled exchangers and are not intended for testing individual components such as fans, motors, gears, and so forth. Separate procedures are given for the following types of tests:

1. Test of an isolated single-bay air-cooled exchanger for determining sound-power levels and sound-pressure levels (Section 2).
2. Test procedures for conducting noise tests on a single bay of installed air-cooled exchangers (normally multibay installations) (Section 3).

### 1.3 Instrumentation

The following are the required instrumentation and applicable specifications to be used to perform the measurements required

| Instrument                                                | Specification           |
|-----------------------------------------------------------|-------------------------|
| Sound level meter, including microphone Type I, precision | ANSI S1.4-1971 (R1976)  |
| Octave band filter, Type E, Class II                      | ANSI S1.11-1966 (R1975) |
| Acoustic calibrator of coupler type                       | ANSI S1.4-1971 (R1976)  |
| Wind screen                                               | ANSI S1.4-1971 (R1976)  |

### 1.4 Nomenclature and Definitions

#### 1.4.1 NOMENCLATURE

The following abbreviations are used in this recommended practice.

| Abbreviation | Definition                      | Unit    |
|--------------|---------------------------------|---------|
| <i>B</i>     | Measuring distance from surface | meter   |
| <i>D</i>     | Fan diameter                    | meter   |
| <i>dB</i>    | Unit of measure for sound level | decibel |

|                      |                                                      |              |
|----------------------|------------------------------------------------------|--------------|
| <i>dB(A)</i>         | Decibel weighted to correspond to standard "A" scale | decibel      |
| <i>H</i>             | Height of geometric center                           | meter        |
| <i>hp</i>            | Horsepower                                           | —            |
| <i>Hz</i>            | Hertz, sound frequency                               | cycle/second |
| <i>L</i>             | Length of bay                                        | meter        |
| <i>N</i>             | Number of fans per bay                               | —            |
| <i>n</i>             | Number of measurement positions per source           | —            |
| <i>PWL</i>           | Sound-power level                                    | decibel      |
| <i>R</i>             | Radius of hemisphere and cyclinder                   | meter        |
| <i>S</i>             | Surface area (measuring surface)                     | square meter |
| <i>s<sub>0</sub></i> | Reference area of 1 square meter                     | square meter |
| <i>SPL</i>           | Sound-pressure level                                 | decibel      |
| $\overline{SPL}$     | Mean sound-pressure level                            | decibel      |
| <i>W</i>             | Width of one bay                                     | meter        |

#### 1.4.2 DEFINITIONS

A *bay* is one or more tube bundles served by two or more fans complete with structure, plenum, and attendant equipment

The *geometric center* is located at the center of a bay on a plane midway between the air inlet and the air outlet for both forced-draft and induced-draft units. The geometric center is also considered the acoustic center of a bay for calculations.

*Octave bands* are the preferred frequency bands.

The *sound level* is the sound-pressure level when frequency is weighted according to the standardized A, B, or C weighting used in sound-level meters. Only A weighted readings [dB(A)] are referenced in this procedure.

The *sound-power level* is ten times the logarithm to base 10 of the ratio of the total acoustic power radiated by a sound source to the reference power of  $10^{-12}$  watt.

The *sound-pressure level* is twenty times the logarithm to base 10 of the ratio of the root mean square sound pressure to the reference sound pressure of  $2 \times 10^{-5}$  newtons per square meter.

A *unit* is one or more tube bundles in one or more bays for an individual service.

NOTE: For additional definitions see API Publication EA 7301, *Guidelines on Noise*.

## SECTION 2—PROCEDURE FOR CONDUCTING NOISE TESTS ON AN ISOLATED SINGLE BAY

### 2.1 Procedure for Obtaining Noise Test Data

#### 2.1.1 DESCRIPTION OF TEST SET-UP

The more accurate noise tests on air-cooled heat exchangers are those which are performed on a single bay without interference from nearby noise or structures. Such accuracy is usually precluded on an operating installation but is attainable at the point of assembly. Units which have typical overall dimensions of from 4 to 6 meters wide, 7 to 12 meters long, and 2 to 5 meters high are discussed here.

For test, the unit should be supported above grade high enough for reasonable air access during the test. An elevation 3 to 6 meters from grade to air inlet is usually adequate to minimize ground effects. There are several optional pieces of equipment which influence noise to a negligible degree and such pieces may be omitted from the assembly for noise test purposes. Included in this category are louvers, walkways, and recirculation chambers. (The presence or absence of recirculation walls will have little effect on the total noise emitted but may cause noise to be emitted in a different direction or at a different location.)

In many cases tests will be conducted as units are completed immediately prior to shipment. However, if noise levels are critical and a large number of units are involved, consideration should be given to testing a single unit early enough to permit design changes.

#### 2.1.2 TEST CONDITIONS

The equipment should be operating as near as is practical to design fan tip speed and motor horsepower. Since most tests must be run at conditions other than design conditions, it is desirable to agree beforehand on the corrections to be made for these variables. If the customer requires, the blade angle can be set to duplicate design horsepower when temperature or elevation differs appreciably from design. Refer to 2.2.2.4 if corrections need to be made for test conditions which differ from design conditions.

#### 2.1.3 LOCATION OF TEST MEASURING POINTS

A radius of 10 meters used to define imaginary hemispherical and cylindrical surfaces surrounding the equipment to be tested is recommended. The test measuring points shall be located on this surface. There should be nine points on the hemisphere and four points on the cyl-

inder. (See Figure 1 and Table 1 for the location of these test points.)

The geometric center is located at the center of the unit on a plane midway between the air inlet and air outlet for both forced- and induced-draft units. A radius of 10 meters is recommended; however, the radius could range from 9 to 12 meters with little effect on results. The test points should be far enough from the equipment to minimize near field distortions, yet near enough to allow positioning the microphone at the various points on the imaginary enclosing surface. All fans should be running during these tests.

In addition to the above readings, which are used to calculate *PWL*, a set of readings at a single point should be taken below each fan. On forced-draft units, the point should be on a horizontal plane 1 meter below the lower edge of the fan ring. The maximum reading attainable on this plane should be taken by placing the microphone no closer than 1 meter from the motor, machinery mount, or other members. On induced-draft units, this measurement point should be on a horizontal plane 1 meter below the finned tubes. Again, the maximum reading attainable on this plane should be taken while placing the microphone no closer than 1 meter from the motor, machinery mount, or other members. [The noise meter should be reading dB(A) while finding the maximum noise point.] Again, all fans should be running during these readings. This data is taken for future reference in correlating *PWL* and sound level data and for estimating noise levels directly below the unit.

Table 1—Test Point Coordinates for Figure 1

| Position | Coordinates <sup>a</sup> |         |         |
|----------|--------------------------|---------|---------|
|          | x                        | y       | z       |
| 1        | 0                        | 0       | +1 000R |
| 2        | 0                        | +0 745R | +0 667R |
| 3        | +0 745R                  | 0       | +0 667R |
| 4        | 0                        | -0 745R | +0 667R |
| 5        | -0 745R                  | 0       | +0 667R |
| 6        | +0 689R                  | +0 689R | +0 222R |
| 7        | +0 689R                  | -0 689R | +0 222R |
| 8        | -0 689R                  | -0 689R | +0 222R |
| 9        | -0 689R                  | +0 689R | +0 222R |
| 10       | 0                        | +1 000R | -0 500H |
| 11       | +1 000R                  | 0       | -0 500H |
| 12       | 0                        | -1 000R | -0 500H |
| 13       | -1 000R                  | 0       | -0 500H |

<sup>a</sup> Coordinates x, y, and z for all positions are measured from an origin located at the geometric center of the unit.

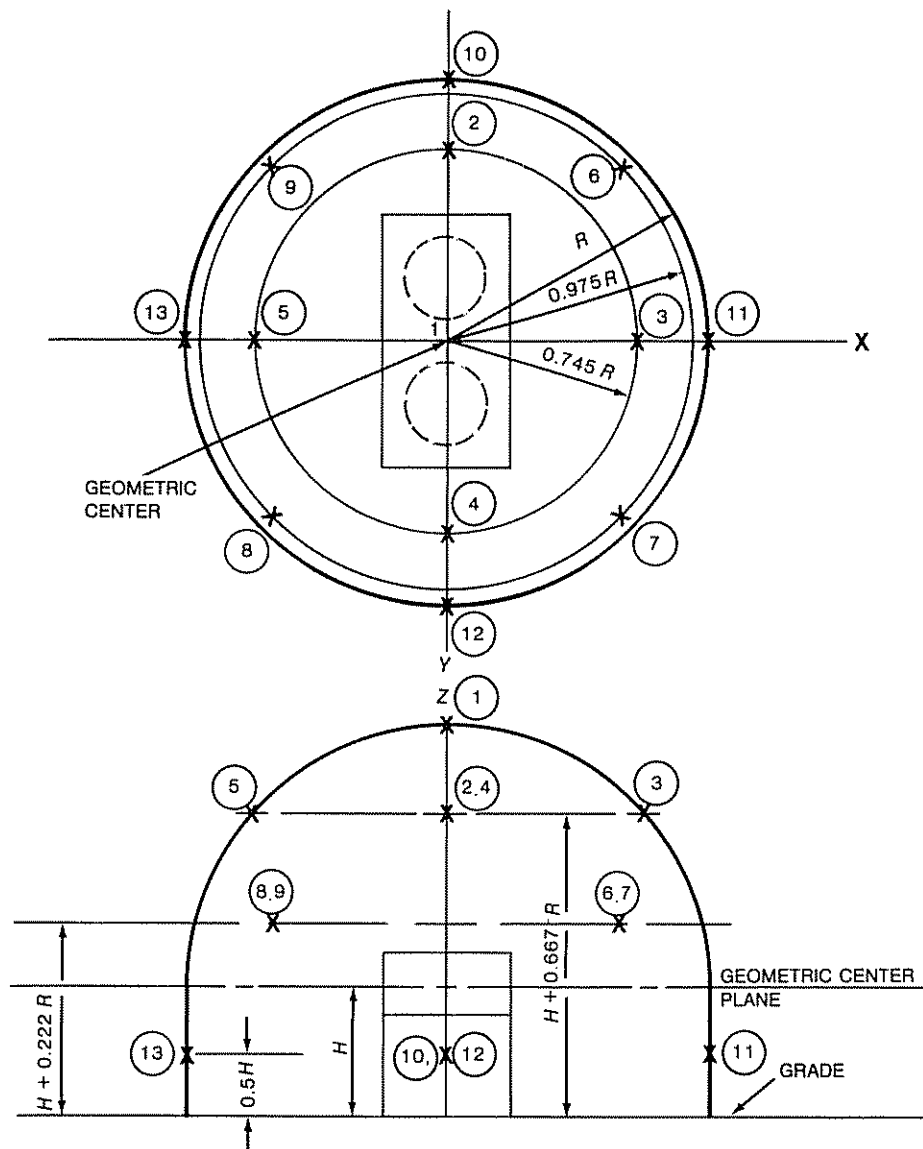


Figure 1—Isolated Single Bay Noise Measurement Points

### 2.1.4 CHECKLIST

A noise test will usually be run immediately before a unit is shipped. Therefore, all required steps must be performed and all pertinent data must be recorded, since it is impractical to recall the equipment and rerun the test at a later date. The following steps should aid operators in preparing for a test.

1. Prepare all drawings and data forms prior to the test. Lay out the test points in the x,y plane and paint spots on the working surface. Then, only the z dimension need be measured during the test.
2. Check that all noise test equipment is in working order and calibrated. A discharged battery, a faulty connection,

or similar problem has invalidated many tests.

3. Check that equipment necessary to position the microphone at all test points is on hand prior to beginning the test.
4. Check the weather forecast. The test should not be run during rain or while winds are above 10 miles per hour.
5. Do a preliminary check of motor amperes and volts to assure the operation of motors near design speed.
6. Start the unit and check it for any unusual noises or problems. Is either fan running backwards? Is there any unusual belt noise, gear noise, motor noise, or bearing noise? Are there any loose parts rattling?
7. Be aware that toothed sheaves with lobed or toothed belts create a dominant noise in the 1000 to 2000 Hz range.

## 2.1.5 RECORDING OF DATA

Prior to recording the data, a preliminary survey should be conducted with the sound level meter on the dB(A) setting. If the noise levels for either the hemisphere or cylinder differ by more than 6 dB(A), either additional measurement positions should be used or the hemisphere and cylinder radius should be increased. If the large difference results from the background noise, it may be necessary to record background noise at each measuring point. If it is not possible to measure the noise emission at a particular point because of high background noise, either the source of the background noise should be reduced or eliminated or the measurement from a similar point may be used. The latter procedure is not recommended, and any such similar point shall be noted in the test report.

Record all data as required on the data sheet (see 2.3 and Appendixes A and B). The calibration readings shall be recorded at the start and finish of a noise test. Background readings shall be taken at every fifth test point (more often if either party feels conditions warrant it). All sound level readings should be taken with the meter set to "slow" response and with a wind screen over the microphone.

## 2.2 Calculations and Interpretation

### 2.2.1 REDUCING TEST DATA

#### 2.2.1.1 Correction for Background Noise

If the test point reading exceeds the background level by more than 10 dB, no correction of the test point reading is required. When the difference between the noise level and the background is less than 3 dB, the measurements have no significance and valid test results cannot be obtained. If the difference between the test point reading and the background level is greater than 3 dB but less than or equal to

Table 2—Corrections for Background Noise

| Difference Between Total Noise Level and Background <sup>a</sup> | Decibels to be Subtracted from the Total Measured Noise Level <sup>b</sup> |
|------------------------------------------------------------------|----------------------------------------------------------------------------|
| 3                                                                | 3.0                                                                        |
| 4                                                                | 2.2                                                                        |
| 5                                                                | 1.7                                                                        |
| 6                                                                | 1.3                                                                        |
| 7                                                                | 1.0                                                                        |
| 8                                                                | 0.7                                                                        |
| 9                                                                | 0.6                                                                        |
| 10                                                               | 0.5                                                                        |
| >10                                                              | 0.0                                                                        |

<sup>a</sup> Difference is defined as the test point reading minus the background noise level.

<sup>b</sup> Correction is defined as the dB value to be subtracted from the test point reading

10 dB, the measured noise level shall be corrected according to Table 2.

#### 2.2.1.2 Determining Mean Sound-Pressure Levels

Adjust the test point readings at each location for background noise. For dB(A) plus each of the nine frequencies, determine  $\overline{SPL}$  for both the hemisphere and the cylinder. The mean sound-pressure level ( $\overline{SPL}$ ) values are determined using the following calculations.

If the maximum difference between values to be averaged is greater than 6 dB,  $\overline{SPL}$  is derived from the following equation:

$$\overline{SPL} = 10 \log \left[ \left( \frac{1}{n} \right) \left( \text{antilog} \frac{SPL}{10^1} + \text{antilog} \frac{SPL}{10^2} + \text{antilog} \frac{SPL}{10^n} \right) \right]$$

If the maximum difference between the values to be averaged is 6 dB or less,  $\overline{SPL}$  is derived from the following equation:

$$\overline{SPL} = 1/n (SPL_1 + SPL_2 + \dots + SPL_n)$$

#### 2.2.1.3 Sound-Power Level

Convert the representative  $\overline{SPL}$ s to  $PWL$ s. This is done for each of the nine frequencies plus the overall dB(A). It is done separately for the hemisphere and for the cylinder.

To convert  $\overline{SPL}$  to  $PWL$  for the hemisphere or cylinder use the following equation:

$$PWL = \overline{SPL} + \log (S/s_o)$$

Where:

$S$  = the surface area of the hemisphere or cylinder, in square meters.

$s_o$  = a reference area of 1 square meter.

$2\pi R^2$  = area of hemisphere

$2\pi RH$  = area of cylinder

$SPL_{\text{bay}}$  = sum of  $PWL$  for the hemisphere and the cylinder.

To add  $PWL$ s use:

$$PWL_{\text{bay}} = 10 \log \left( \text{antilog} \frac{PWL_{\text{cylinder}}}{10} + \text{antilog} \frac{PWL_{\text{hemisphere}}}{10} \right)$$

Sound-power level per fan can be determined as follows:

$$PWL_{\text{fan}} = PWL_{\text{bay}} - 10 \log N$$

Where:

$N$  = the number of fans per bay.

### 2.2.1.4 Design versus Test Horsepower

Since a test is seldom run with the motor at design horsepower, it is necessary to adjust test conditions to design conditions.

If a watt meter or plant power factor data are not available, the following approximation for test horsepower can be used:

$$hp_{\text{test}} = hp_{\text{nameplate}} \times \left( \frac{\text{Volts}_{\text{test}} \times \text{Amperes}_{\text{test}}}{\text{Volts}_{\text{nameplate}} \times \text{Amperes}_{\text{nameplate}}} \right)$$

To convert sound-power level calculated at test motor horsepower ( $PWL_{\text{test}}$  at  $hp_{\text{test}}$ ) to predicted sound-power level at design power ( $PWL_{\text{design}}$  at  $HP_{\text{design}}$ ) use the following equation:

$$PWL_{\text{design}} = PWL_{\text{test}} + 10 (\log hp_{\text{design}} - \log hp_{\text{test}})$$

Test horsepower should be within 15 percent of design horsepower to use this equation.

## 2.2.2 APPLICATION OF REDUCTION PROCEDURES

### 2.2.2.1 Background Noise

Adjust test point readings for background noise level. Prepare a tabulation of adjusted values for each position. The example in Table 3 illustrates the procedure.

### 2.2.2.2 Sound-Pressure Level

Consider a test in which an imaginary cylinder has the following dimensions:  $R$  equals 10 meters and  $H$  equals

4.88 meters with adjusted test point readings of 81.9, 74.8, 80.8, and 75.4 dB in one octave band and adjusted test point readings of 51.8, 53.8, 52.9, and 52.3 dB in another octave band.

In the first case, the maximum difference in values to be averaged is 7.1 (81.9 - 74.8); therefore, the representative  $SPL$  equals:

$$\begin{aligned} \overline{SPL} &= 10 \log \left[ 1/4 \left( \text{antilog} \frac{81.9}{10} + \text{antilog} \frac{74.8}{10} \right. \right. \\ &\quad \left. \left. + \text{antilog} \frac{80.8}{10} + \text{antilog} \frac{75.4}{10} \right) \right] \\ &= 10 \log [1/4 (1.5488 \times 10^8) + (.3020 \times 10^8) \\ &\quad + (1.2023 \times 10^8) + (.3467 \times 10^8)] \\ &= 79.3 \text{ dB} \end{aligned}$$

In the second case, the maximum difference in values to be averaged is 2.0 (53.8 - 51.8); therefore, the representative  $SPL$  equals:

$$\begin{aligned} \overline{SPL} &= \frac{51.8 + 53.8 + 52.9 + 52.3}{4} \\ &= 52.7 \text{ dB} \end{aligned}$$

### 2.2.2.3 Sound-Power Level

Convert representative  $SPL$  for the cylinder in the first case to  $PWL$ . From 2.2.2.2,  $SPL$  equals 79.3 dB.

$$\begin{aligned} PWL &= SPL + 10 \log (2\pi RH) \\ &= 79.3 + 10 \log (2 \times \pi \times 10 \times 4.88) \\ &= 79.3 + 10 \log 306.6 \\ &= 79.3 + 24.9 \\ &= 104.2 \text{ dB} \end{aligned}$$

Table 3—Example of Reduction Procedures for Test on an Isolated Unit

|                           | Octave Band Center Frequency |      |      |      |      |      |      |      |      |      |
|---------------------------|------------------------------|------|------|------|------|------|------|------|------|------|
|                           | dB(A)                        | 31   | 63   | 125  | 250  | 500  | 1000 | 2000 | 4000 | 8000 |
| Position 1                |                              |      |      |      |      |      |      |      |      |      |
| Test Value                | 77                           | 82   | 83   | 80   | 79   | 75   | 72   | 68   | 62   | 56   |
| Background                | 68.5                         | 76   | 75   | 71   | 69   | 67   | 62   | 61   | 51   | 44   |
| Difference                | 8.5                          | 6    | 8    | 9    | 10   | 8    | 10   | 7    | 11   | 12   |
| Correction                | -0.7                         | -1.3 | -0.7 | -0.6 | -0.5 | -0.7 | -0.5 | -1.0 | 0.0  | 0.0  |
| Adjusted Test Point Value |                              |      |      |      |      |      |      |      |      |      |
| Position 1                | 76.3                         | 80.7 | 82.3 | 79.4 | 78.5 | 74.3 | 71.5 | 67.0 | 62.0 | 56.0 |

Determine the sound-power level per bay, assuming that the hemispherical *PWL* equals 106 and the cylindrical *PWL* equals 104.2.

$$\begin{aligned} PWL_{\text{bay}} &= 10 \log \left( \text{antilog} \frac{106}{10} + \text{antilog} \frac{104.2}{10} \right) \\ &= 10 \log (6.6114 \times 10^{10}) \\ &= 10 \times 10.82 \\ &= 108.2 \text{ dB} \end{aligned}$$

Determine the sound-power level per fan in a two fan bay if the *PWL* per bay is 108.2

$$\begin{aligned} PWL &= 108.2 - 10 \log 2 \\ &= 108.2 - 3 \\ &= 105.2 \end{aligned}$$

#### 2.2.2.4 Design versus Test Horsepower

If nameplate horsepower is 25, nameplate voltage is 460, nameplate amperage is 31, test voltage is 470, and test amperage is 27, then—

$$\begin{aligned} hp_{\text{test}} &= 25 \times \frac{470}{460} \times \frac{27}{31} \\ &= 22.3 \end{aligned}$$

If design horsepower is 23.7, test horsepower is 22.3, and test *PWL* per fan is 105.2 dB, determine adjusted *PWL* per fan at design horsepower.

$$\begin{aligned} PWL_{\text{design}} &= 105.2 + 10 (\log 23.7 - \log 22.3) \\ &= 105.2 + 10 (1.3747 - 1.3488) \\ &= 105.2 + (10 \times 0.0264) \\ &= 105.5 \text{ dB} \end{aligned}$$

## 2.3 Reporting of Data

### 2.3.1 GENERAL REQUIREMENTS

The noise test report shall include a summary sheet with

the main results, a description of the equipment tested, and the noise test data. Appendix A provides a model format for noise test reports. Appendix B provides a completed noise test report for a noise test conducted on an isolated single bay.

### 2.3.2 SUMMARY

The summary shall make reference to this API recommended practice.

The principal results of the test are to be reported on one sheet. These results are to be supported by the test data, calculations, and sketches which follow. All calculations and interpretation of data shall be in accordance with 2.2. The calculations shall be appended to the noise test report.

The test results shall include the following:

1. The overall sound power levels and the octave band sound power levels shall be tabulated.
2. Measurements taken at special locations for future reference in correlating sound-power level and sound level data and for estimating noise levels below the unit shall be shown separately. Corrected and uncorrected noise levels shall be reported.

### 2.3.3 REQUIREMENTS FOR DATA SHEET

1. A sketch of the test layout and microphone locations shall be provided. Special measuring locations shall be noted on the sketch.
2. A description of the equipment tested and its operating conditions shall be provided.
3. Details of the measuring equipment including make, model, and serial number shall be recorded.
4. A tabulation of all test data [dB(A) and octave band sound pressure levels] shall be provided, which includes:
  - a. Sound level measurements at each test point.
  - b. Background sound level measurements at selected points.
  - c. Sound level measurements at special locations.

## SECTION 3—PROCEDURE FOR CONDUCTING NOISE TESTS ON INSTALLED UNITS

### 3.1 Procedure for Obtaining Noise Test Data

#### 3.1.1 DESCRIPTION AND REQUIREMENTS OF TEST

This section covers procedures for noise testing on installed units. However, it should be noted that a more accurate test procedure for the determination of noise levels of air-cooled heat exchangers is given in Section 2. The Section 2 procedure would not usually be satisfactory for

application on installed air-cooled heat exchangers in operating plants.

The test procedure outlined in Section 2 is ideally suited for shop test situations and employs measurements of sound pressure levels of an imaginary hemisphere and cylinder having a radius of about 10 meters. This large measuring distance, 10 meters, would be impractical for installed exchanger situations and would yield inaccurate results because of noise interference from other operating