inter•noise 83

FLEXIBLE BLANKETS FOR NOISE CONTROL INSULATION

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INTRODUCTION

Flexible blankets, produced with glass or ceramic fiber insulation and custom fabricated for equipment such as pumps, turbines, and valves, are commonly used to control heat loss. They can be made to be durable, easy to reinstall, attractive, and reasonably priced. These thermal blankets typically have a 1-in.-thick or thicker inner layer of glass or ceramic fiber insulation covered with glass fiber cloth and/or stainless steel mesh. Blankets usually are custom fabricated for each machine in much the same way that a suit is custom tailored for a person. Individual blanket parts for a machine are installed and laced together using stainless steel hog ties and tie wire. This insulation is much easier and less expensive to remove and reinstall during maintenance and inspections than most other insulations. Figure 1 shows a typical application of flexible blanket thermal insulation on a steam turbine to control heat loss. The TVA-sponsored study summarized here has shown that thermal blanket insulation can be designed to provide significant noise attenuation.

As part of an insulation development and demonstration program we prepared a mathematical model of the acoustic performance of blanket insulation installed on a vibrating metal surface such as the casing of a boiler feed pump. This model highlighted the important parameters related to improved sound attenuation. We also met with insulation vendors to discuss the fabrication and installation requirements for flexible blankets used in industrial applications. In addition, we tested and evaluated the noise reduction performances of typical and specially constructed insulation samples in a laboratory test rig.

MATHEMATICAL MODEL

The simplest mathematical model considers a representative portion of the vibrating machine surface to act like a piston which sets the air adjacent to it in motion and thus produces sound much like a loudspeaker membrane. By considering a double-layer blanket that includes a resilient (springy) element and a heavy outer layer (mass) the sound attenuation that results at a frequency f, which is considerably higher than the spring-mass resonance frequency of the blanket, is approximately given by

$$\text{Atten (dB)} = 20 \log \left[(2\pi f)^2 \, m/k\right] \tag{1}$$

where m denotes the mass per unit area of the covering layer and k the dynamic stiffness (at frequency f) of unit area of the blanket. The logarithm here is to the base 10.

This relation applies for any set of consistent units. In English (engineering) units this becomes

$$\begin{aligned}\text{Atten (dB)} &= 40 \log [f(\text{Hz})] + 20 \log [m \ (\text{lb/ft}^2)] \\ &\quad - 20 \log [k \ (\text{lb/in./ft}^2)] - 20 \quad .\end{aligned} \tag{2}$$

This simple expression is particularly useful for indicating trends to be expected from parameter changes. For example, a given configuration may be expected to produce greater attenuation at higher frequencies, and greater attenuation may be obtained by use of heavier cover layers and/or softer blankets.

This expression represents only the simplest possible physical situation. It does not apply at frequencies below the simple resonances of the lumped-parameter spring-mass system consisting of the blanket and heavy layer. It also does not apply at high frequencies, where the blanket strain is not uniform throughout the blanket's thickness. A more complete mathematical model was developed that accounts for these affects, as well as for the realistic variation of the blanket's dynamic stiffness with frequency, static compression, and amplitude.

LABORATORY MEASUREMENTS

We built a test rig to simulate a portion of the vibrating boiler feed pump surface. Our tests involved vibrating the rig surface at discrete frequencies between 250 and 4000 Hz at controlled (and monitored) amplitudes by means of a shaker, and measuring the sound levels near the rig surface with and without the blanket samples installed. The difference between the two sound pressure levels at any frequency then corresponds directly to the sound attenuation provided by the test blanket at that frequency.

Engineers of Eastern Refractories Company (ERCO), Belmont, Mass., manufacturers of high-quality flexible blankets for thermal insulation, collaborated in the development of alternative blanket designs with enhanced acoustic properties. ERCO also fabricated sample blankets of each promising design for acoustic testing. The upper two curves in Fig. 2 illustrate the sound attenuation measured for two specially designed 1-in.-thick blankets made of needled fiber mat insulation that has a dynamic spring constant of about 7.6 lb per inch per square inch (or psi/in.). Also shown is the approximate sound attenuation achieved by use of a 1-in.-thick conventional thermal blanket. The specially designed blankets provide up to 10 to 20 dB greater sound attenuation at frequencies between 250 and 4000 Hz.

Two-in.-thick blankets that included a 1-in.-thick layer of light density insulation were also tested. These were found to provide up to 10 dB more attenuation than the 1-in.-thick blankets.

The test data are generally consistent with the mathematical models mentioned previously. As one might expect, a simple lumped-parameter model is adequate for the lower frequency range and for general estimation purposes, and a more complex distributed-parameter model generally is more accurate for higher frequencies. Both the test data and the analyses have proven useful for designing blankets with enhanced high-frequency attenuation for equipment such as valves or with enhanced mid-frequency attenuation for equipment such as pumps, compressors, and turbines.

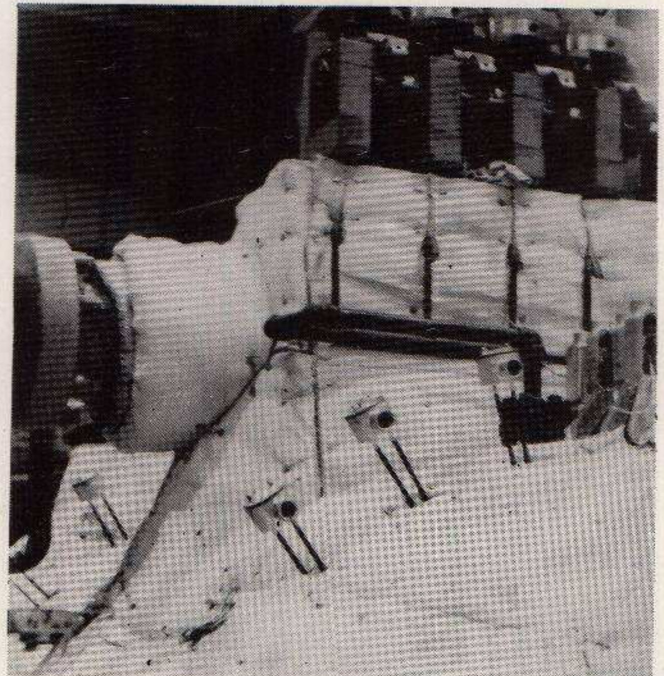

FIG. 1. THERMAL BLANKET INSULATION INSTALLED ON STEAM TURBINE.

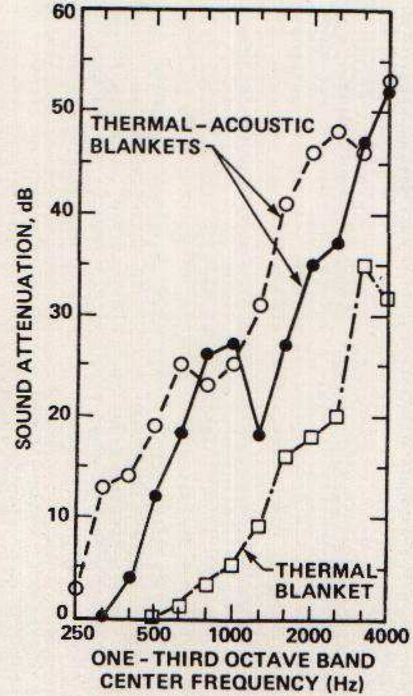

FIG. 2. SOUND ATTENUATION MEASURED FOR THREE 1-IN. THICK BLANKETS.