Noise Reduction in Vane-axial Fan-burner Units Used for Drying Peanuts

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ABSTRACT

Methods were investigated for reducing the sound-pressure level (SPL) of vane-axial fan-burner units used for drying peanuts. Straight-through mufflers 61-cm (24-in.) long with 10-cm (4-in.), fiber-glass-lined walls were evaluated. In the first setup, one muffler on the fan inlet reduced the average SPL 9.9 dBA. The second setup, a muffler on inlet and exhaust reduced the SPL 13.4 dBA. In the third setup, a redesigned housing incorporating absorption areas on inlet and exhaust but allowing a shorter overall length, reduced SPL by 13.5 dBA. With an absorptive insert equal in diameter to the fan hub installed in the inlet side of the fan, the average SPL was reduced by 8.6, 17.3, and 18.1 in the first, second, and third setups, respectively. The effect of the treatments on airflow rate was negligible. Costs of the treatments are discussed.

Peanuts are generally harvested at moisture-content levels that are too high for safe storage and must be artificially dried soon after harvest. Most peanuts are placed in metal bins and dried with heated air forced through a perforated false floor in the bottom of the bin. Commonly, these bins are mobile trailers or wagons that are also used to transport the crop. Upon harvesting, the peanuts are moved to the drying area where the wagons are connected by canvas ducts to a source of heated air.

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Vane-axial fan-burner units are used extensively to supply the heated air to the wagon dryers. These units are compact and efficient; however, they have an inherent drawback—they are excessively noisy. The excessive noise levels of the fans are objectional for two reasons. First, communications, worker morale and efficiency, and product quality are generally affected adversely in noisy environments (1, 5). Also, public awareness of environmental noise is increasing, and vigorous community action against industrial noise is increasing. Measurements made prior to initiating this research revealed noise levels in commercial drying areas that would restrict workers to an exposure of 2 hours per day, or less, under existing occupational laws. Noise levels created by the fans were high enough in surrounding areas to cause serious objections by residents.

Criteria for any method or equipment for reducing SPL should include: The magnitude of SPL reduction to be attained, the cost, and the effects of the modifications on performance, accessibility of internal parts of the unit, size, and weight. An absolute decision concerning the SPL reduction to be attained cannot always be made. Generally, a compromise must be made between the amount of reduction desired and the sacrifice that can be sustained in the other factors. The cost and inconvenience of reduction will almost

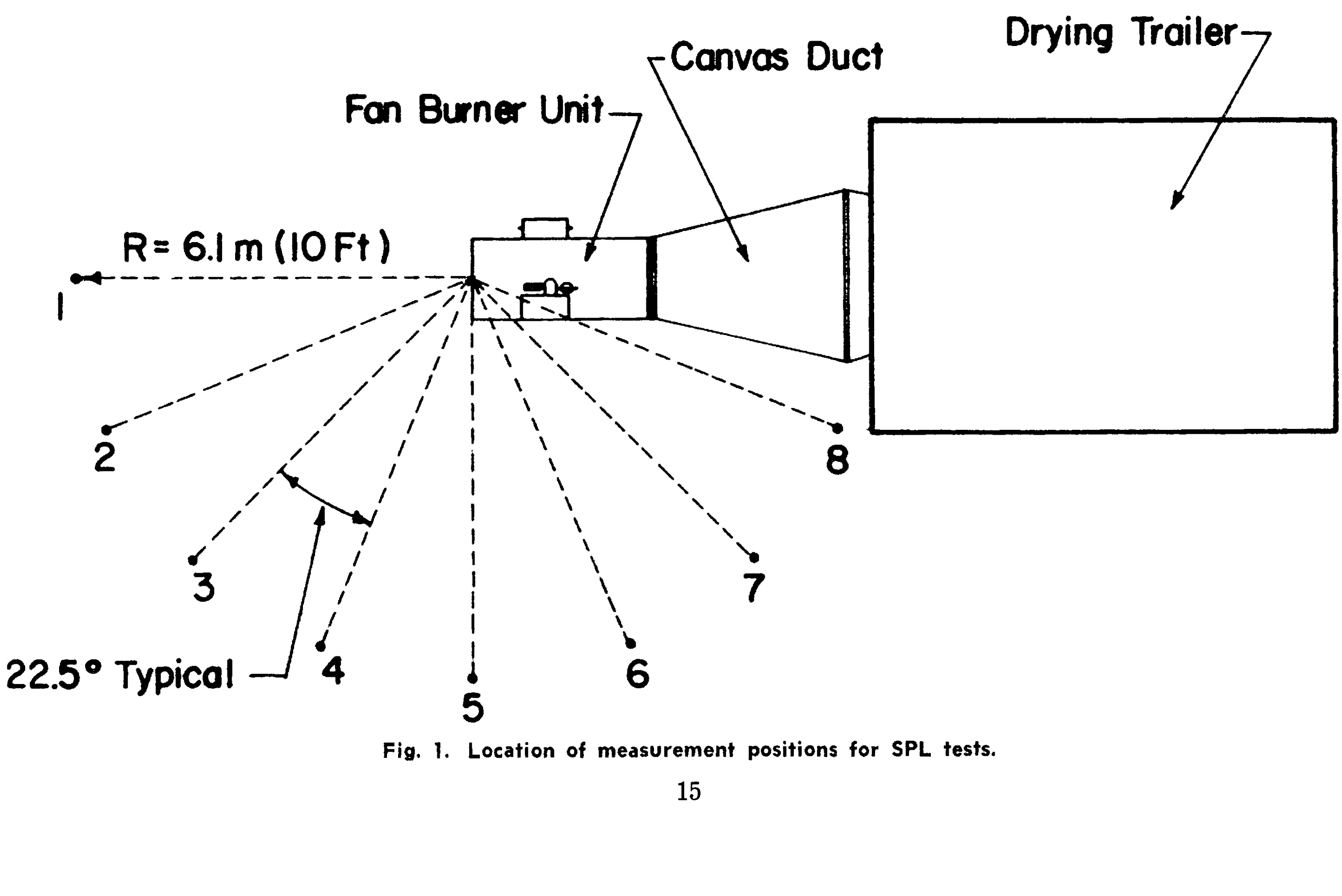

Fig. 1. Location of measurement positions for SPL tests.

always increase as reduction increases.

The purpose of the work reported here was to develop a practical method of modifying the vane-axial fan-burner units used for drying peanuts to reduce the SPL of the units without significantly reducing their performance.

Materials and Methods

The drying unit used for the developmental work was a commercial, 56-cm (22-in.)-dia. vane-axial fan with integral gas burner. The impeller had a 30-cm (12-in.)-dia. hub and four 13-cm (5-in.) air-foil blades. The fan was direct driven by a 5-hp motor at 3,450 rpm.

The SPL was evaluated while the fan-burner unit was connected to a wagon loaded with peanuts to duplicate actual operating conditions. The entire system was placed in an open, grassy area away from any obstructions. SPL was measured with a General Radio Model 1933[2] precision sound-level meter equipped with a microphone wind screen. The instrument was calibrated at regular intervals with a sound-level calibrator. Measurements were made at 1.2-m (4-ft)-high levels at positions 22.5° apart on a 3-m (10- ft) radius from the fan blade, as shown in Fig. 1. Values for 10-octave bands having center frequencies from 31.5 to 16,000 Hz were recorded, along with A-weighted values. The A value, which can also be calculated from the octave band values, is the most commonly accepted single measurement of SPL for hearing-conservation purposes and was used primarily in evaluating results. However, for additional information, SPL data are reported for all octave bands for two locations in the appendix table.

To test the effect of the modifications on airflow rate, we connected the fan-burner unit to a plenum 1.2 m x 1.2 m x 6.1 m (4 ft x 4 ft x 20 ft). The exit of the plenum was sized to produce a static pressure similar to that found in normal applications. To determine average velocity and, subsequently, flow rate, we made a series of 20 measurements with a pitot tube in a section of straight pipe downstream from the plenum. Each measurement location represented an equal area, and was located in accordance with recommendations of the Air Moving and Conditioning Association. We used a section of hardware cloth to assure accurate and repeatable location of the pitot tube. Pressure readings were made with an inclined manometer having graduations of 0.02 in. of water (5 Pa). In addition to making pitot-tube measurements, we determined the average static pressure produced in the plenum for each test from a manifold connected to pressure taps around the perimeter of the plenum. These values also allowed comparisons of the effects of the modifications.

Results and Discussion

A study of the literature and commercially available products indicated that a reasonable decrease in SPL could be obtained with a simple, straight-through muffler without unreasonable sacrifices in the other evalution criteria. Selection of a course of action for modifying the drying unit was based, primarily, on work by Ige and Finner (*2*). They evaluated mufflers 46- and 91-cm (18- and 36-in.) long, with 5- and 10-cm (2- and 4-in.)-thick shells, on the inlet of axial-flow fans. They tested the mufflers with two sizes of conical end baffles and with no baffle. Attenuation increased with increased length, thickness, and baffle size.

Based on their data, material availability, cost, size considerations, and other design data, we selected a muffler 61 cm (24 in.) long and 10 cm (4 in.) thick for use in our tests with the peanut drying unit. We constructed a muffler of this configuration by forming an interior shell of flattened expanded metal (having 56% open area) of the same diameter as the fan housing and covering it with a 10-cm (4-in.)-thick layer of fiber glass (about 4 kgm/m^3 (2.5 lb/ft^3) and a solid outer housing attached concentrically to the inner shell with metal spacers. (Perforated metal of any configuration is suitable for the interior shell if the open area exceeds 25 percent.) Figure 2 shows the muffler installed on a fan-burner unit in position for testing. Figure 3 shows SPL around the fan with and without the muffler installed on the inlet and with an absorptive insert installed in the inlet side of the fan. The insert, which was a right circular cylinder of the same diameter as the fan hub and of the same length as the inlet absorptive area, was made of perforated metal, filled with fiber glass, and mounted concentrically within the muffler with metal brackets in an attempt to reduce the SPL around the inlet of the fan. Ige and Finner discovered high SPL in this area and resorted to large, absorptive, conical baffles placed away from the fan inlet to block the line of sight. These baffles added considerably to the bulkiness of the unit and were considered a major hindrance to the peanut-drying process. The insert provided more absorptive area within the muffler, some blockage of the line of sight to the blades, and a reduction in air passage size, but no reduction of the cross-sectional area available for airflow. The importance of a reduced air passage size is discussed by Ingard and Maling (*3*). The insert decreased SPL around the inlet area of the fan; however, additional turbulence was apparently created downstream of the blade, because SPL was higher at all other locations. Thus, the insert was not effective for a muffler on the fan inlet only.

The results shown in Fig. 3 indicated that sound was being transmitted through the canvas duct and that attenuation on the exhaust side of

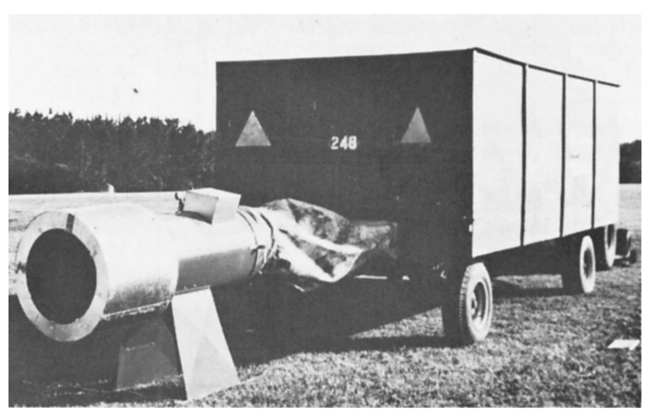

Fig. 2. Muffler mounted on inlet of fan-burner unit in position for SPL tests.

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[2]Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may be suitable.

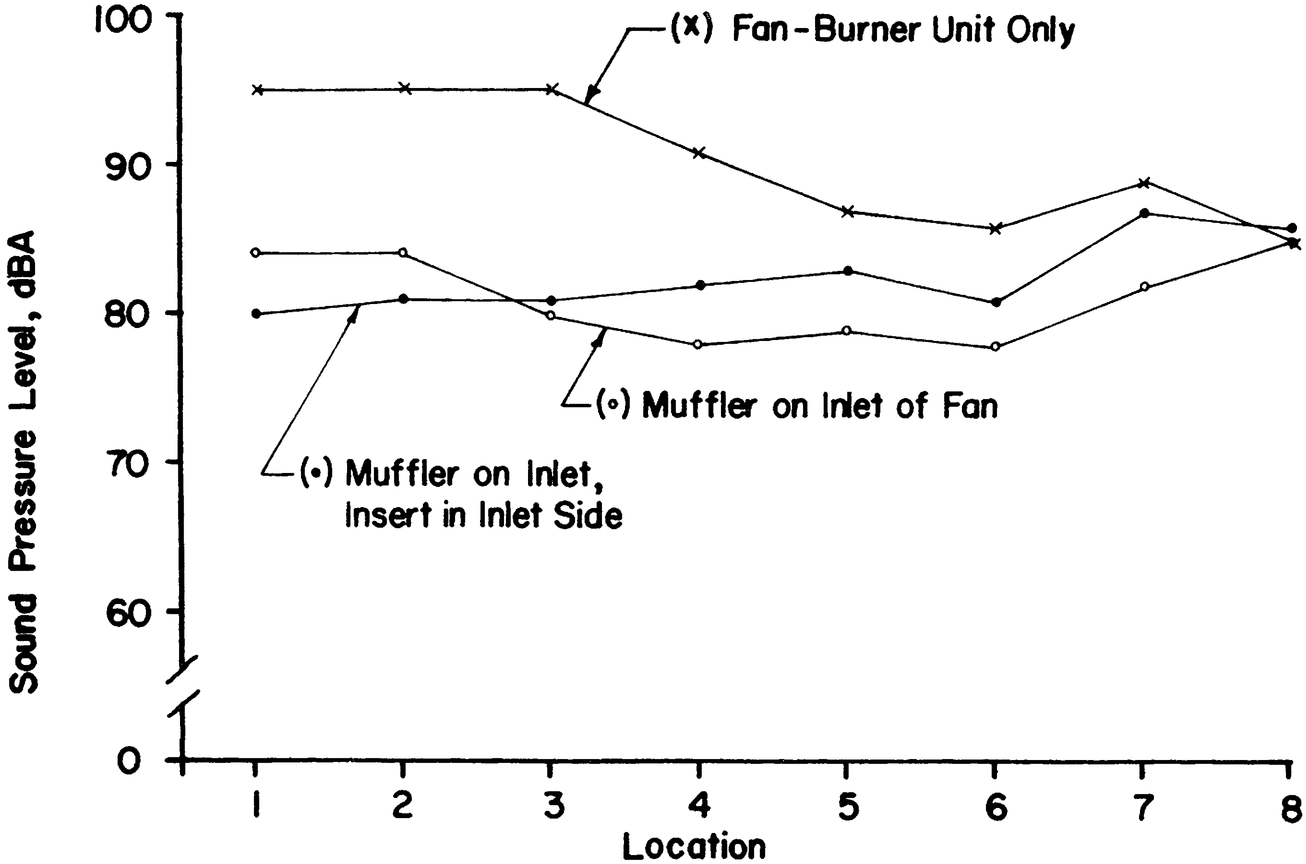

Fig. 3. Sound-pressure levels after inlet of fan-burner unit received acoustic treatment.

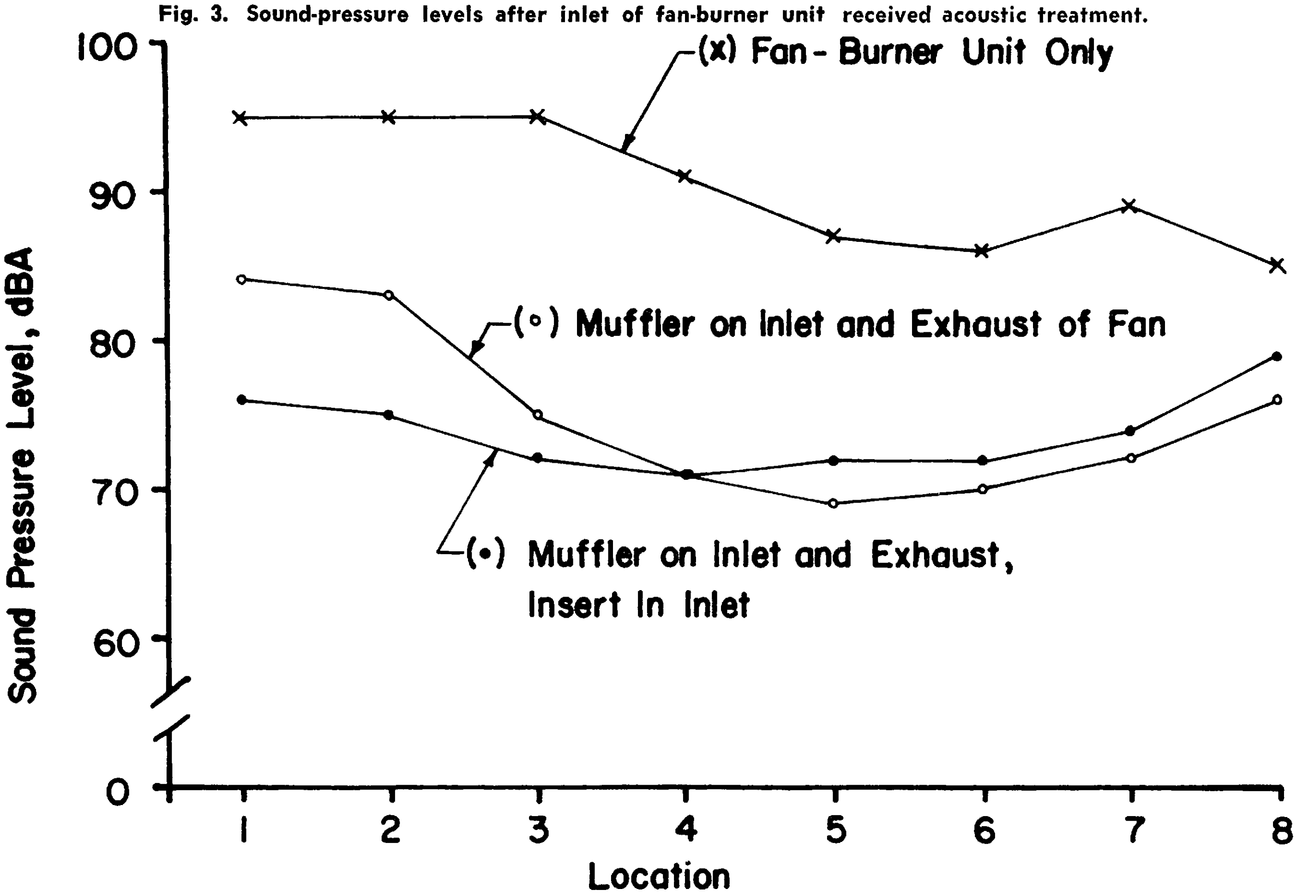

Fig. 4. Sound-pressure levels after inlet and exhaust of fan-burner unit received acoustic treatment.

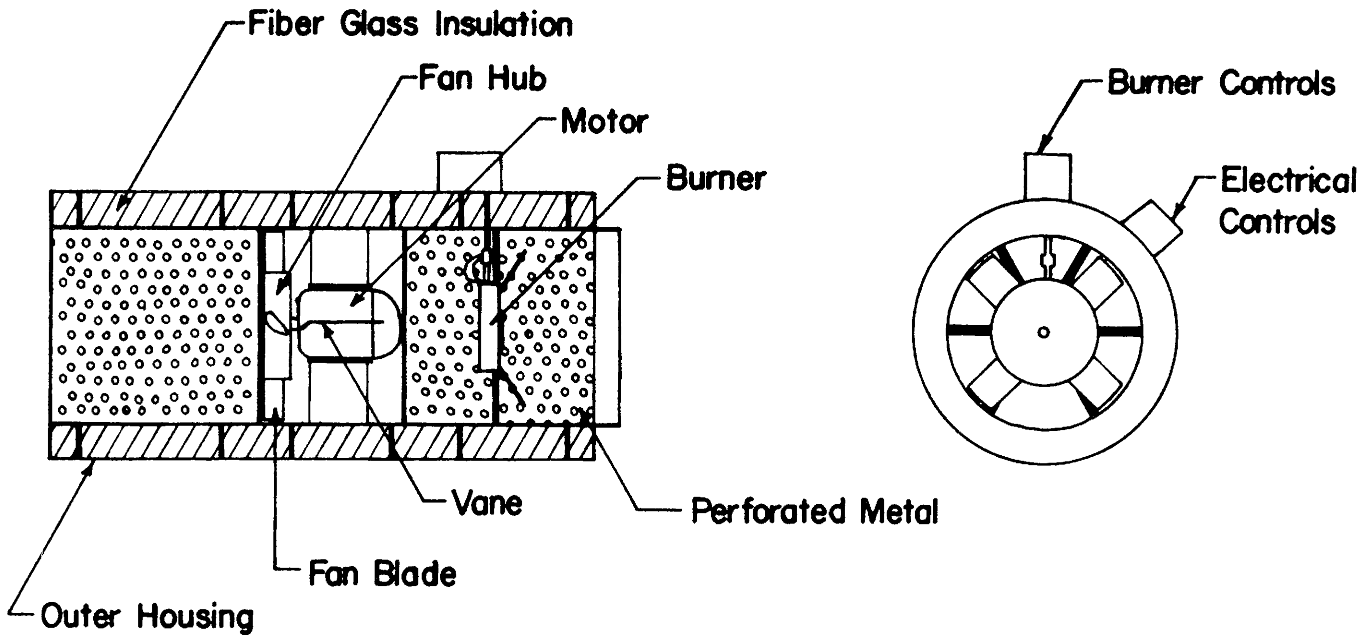

Fig. 5. Redesigned fan-burner unit.

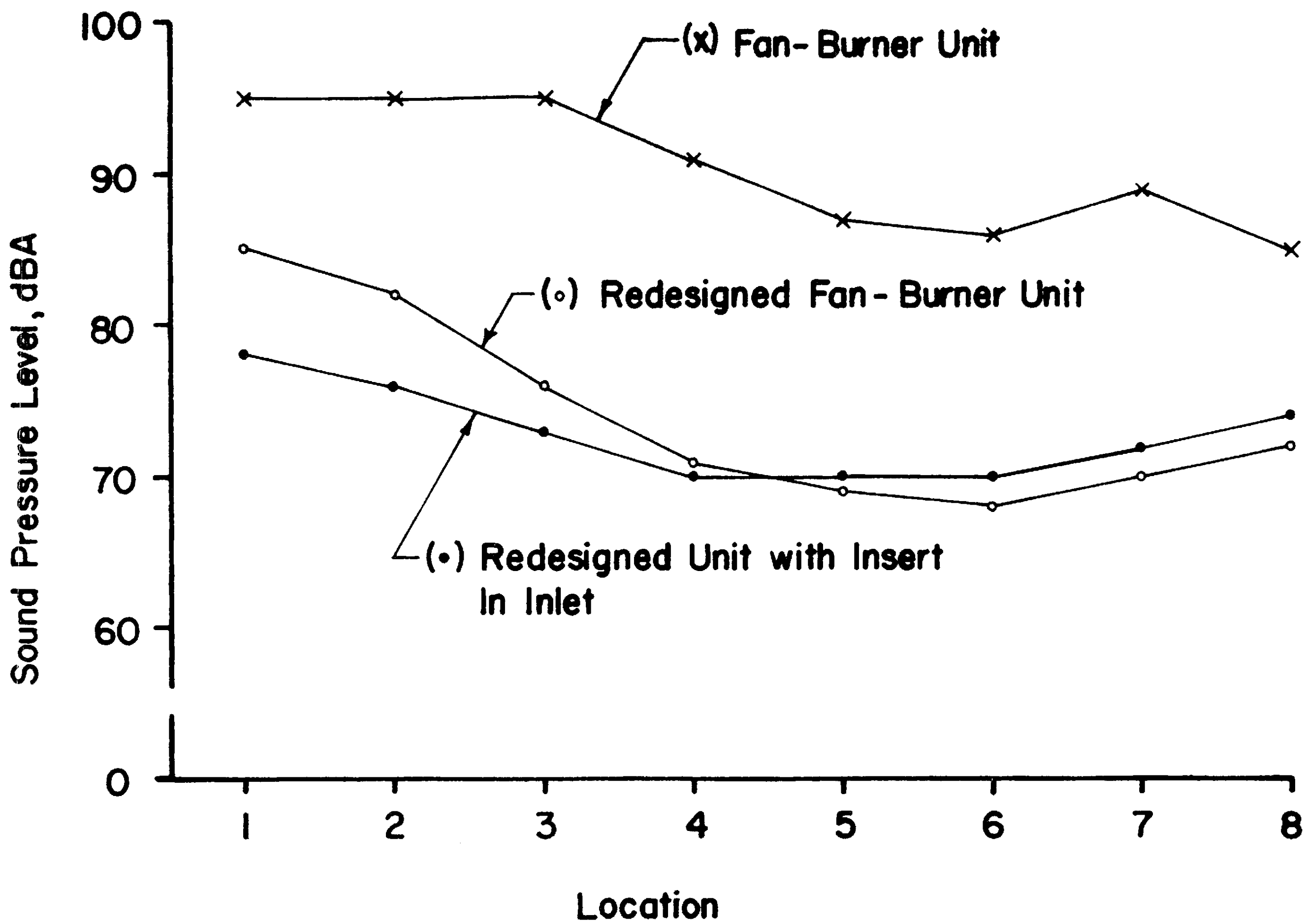

Fig. 6. Sound-pressure levels with redesigned fan housing with and without insert in inlet.

the fan was needed. Thus, a muffler identical to the other one was installed on the fan outlet. The performance of the system with both mufflers in place, with and without the insert in the inlet side, is shown in Fig. 4. Performance of the unit was considerably improved over that with the single muffler. The insert reduced the SPL considerably around the inlet, and the SPL increased only slightly in the other locations.

Thus, the data now indicated the need for mufflers on both the fan inlet and exhaust. However, the length of the unit with two mufflers was considered excessive, and redesign of the entire system seemed appropriate.

In the redesign, we shortened the fan housing and used the muffler area to contain the burner. We enclosed the fan-housing in the insulated area of the mufflers to eliminate sound transmission through the housing. The redesigned fan-burner unit is shown in Fig. 5. The redesigned unit, in addition to being shorter, reduced the SPL's slightly beyond that of the unit with individual mufflers on each end. The sound-pressure levels with the redesigned fan, both with and without the insert in place, are shown in Fig. 6.

The effects of all the treatments on length and average SPL of the fan-burner unit are summarized in Table 1. The average SPL at a commercial drying location using similar, untreated equipment was about 99 dBA throughout the area. The effect of the additional units in the area was an increase of about 7 dBA to the SPL above that of the single-unit average when measured at the 3 m (10 ft) radius. Thus, an estimate of the SPL in an area using multiple units of the type tested, all treated in the same manner, can be obtained by adding 7 dBA to the values in Table 1. Any of the treatments shown, except the single muffler with insert installed, should provide an average SPL below 90 dBA, the maximum allowed for 8 hours of exposure under current occupational laws. Of course, this estimate would not hold true for all conditions because of the variations in fan units, arrangements, surroundings, and other variables.

The three muffler modifications were slightly beneficial (about 2%) to the airflow rates of the fan-burner units. This effect was predictable from fan design information on fan-blade location relative to the fan inlet (*4*). The installation of the insert into the inlet was slightly detrimental (about 3%) to the airflow rate.

As a final step in evaluation of the modifications, a solid cylindrical-pipe, equal in diameter to the fan housing and the same length as the mufflers, was attached to the inlet of the fan. The resulting reduction in SPL was negligible, indicating that the absorptive areas of the mufflers were essential to their effectiveness.

Summary and Conclusions

Sound-pressure level was measured around a single vane-axial fan-burner unit used for drying peanuts. These values, and airflow rates, were compared with those obtained after making several treatments to the unit to reduce SPL. Treatments included installation of a muffler on inlet, installation on inlet and exhaust, and redesign of

Table 1. The effects of acoustic treatments on length and average SPL of fan-burner unit.

Noise-control description	Length	Average SPL 1/	Attenuation effect
	In.	dBA	dBA
None	45	92.0	---
Muffler on inlet, with insert	69	83.4	8.6
Muffler on inlet, no insert	69	82.1	9.9
Muffler on inlet and exhaust, no insert	93	78.6	13.4
Redesigned fan-burner, no insert	64	78.5	13.5
Muffler on inlet and exhaust, with insert	93	74.7	17.3
Redesigned fan-burner, with insert	64	73.9	18.1

1/ Calculated by power ratio method as described in Handbook of Noise Measurement (5).

the fan-burner unit to incorporate absorption area integral to the unit. An absorptive insert was also installed in the fan inlet and evaluated separately with each of the treatments.

Information provided in the figures and tables herein should provide guidance for reducing SPL of vane-axial fan-burner units under various situations. The redesigned fan-burner unit offers the best overall performance because of its shorter length. For existing situations in which fan length is not critical, mufflers on the inlet and exhaust of the fan-burner unit are recommended. Although not nearly as effective, one muffler on the fan inlet certainly provides a worthwhile benefit.

The absorptive insert on the inlet side of the fan provided a worthwhile benefit, except when only one muffler was used, and caused only a minor reduction in airflow rate. If space is not critical, a similar effect can be obtained by the use of large, conical, absorptive baffles as used by Ige and Finner (2). In some situations baffles may be incorporated within the surrounding structure of the drying area and thus eliminate the need for further attachments to the fan-burner unit.

Presence of the mufflers has little effect on the accessibility of the internal parts of the unit, since the mufflers can be easily removed and reinstalled. The redesign of the fan-burner unit complicated accessibility somewhat; however, some thoughtful design of motor and burner installation methods could minimize this problem. Fabrication of the mufflers was straight-forward, requiring only limited equipment and skill of sheet-metal forming. Total cost of materials for each muffler was about $40. The author feels that the total cost (labor and material) of mufflers of the type used in our research can be kept within $100 if existing facilities and labor are used. Commercial model mufflers of comparable diameter, but longer and more complicated, are available for less than $225.

The redesigned fan-burner unit, if adopted for manufacture, could be built at a cost lower than that of the fan and two mufflers; however, conversion of an existing fan-burner unit to this design is not recommended unless length is critical.

Acknowledgment

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Table 2. Octave-band and A-scale sound-pressure levels (dB) at two locations for all tests.

Test description	Location [1/]	A weighting	Octave band center frequency, Hz 31.5	63	125	250	500	1000	2000	4000	8000	16,000
Fan-burner unit only	1	95	65	68	68	76	89	91	90	86	74	61
	5	87	66	70	69	78	82	82	81	74	65	55
Muffler on inlet, with insert	1	80	70	70	67	75	74	76	71	71	67	59
	5	83	67	80	65	69	82	81	75	63	54	46
Muffler on inlet, no insert	1	84	64	70	68	74	80	82	78	70	64	57
	5	79	69	84	66	68	77	76	70	59	50	44
Muffler on inlet and exhaust, no insert	1	84	65	67	67	74	78	81	77	69	62	56
	5	69	66	77	65	66	70	65	62	56	48	40
Redesigned fan-burner unit, no insert	1	85	65	69	70	74	82	81	78	75	65	57
	5	69	66	68	65	67	67	65	58	50	42	38
Muffler on inlet and exhaust, with insert	1	76	64	66	67	74	72	70	67	69	65	56
	5	72	64	78	64	68	69	67	64	56	49	46
Redesigned fan-burner unit, with insert	1	78	64	68	68	72	77	73	67	69	66	57
	5	70	64	68	64	64	70	66	59	51	43	34

1/ Location is described in figure 1 of text.