A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

BUILDING SCIENCE SERIES 27

Performance of Louvered Devices as Air Mixers

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

Announcing—The Building Science Series

The "Building Science Series" disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

These publications, similar in style and content to the NBS Building Materials and Structure Reports (1938–59), are directed toward the manufacturing, design, and construction segments of the building industry, standards organizations, officials responsible for building codes, and scientists and engineers concerned with the properties of building materials.

The material for this series originates principally in the Building Research Division of the NBS Institute for Applied Technology. Published or in preparation are:

- BSS0. Building Research at the National Bureau of Standards. (In Press)
- BSS1. Performance of Buildings—Concept and Measurement. Man and His Shelter. $2.75
- BSS2. Interrelations Between Cement and Concrete Properties: Part 1, Materials and Techniques, Water Requirements and Trace Elements. 35 cents.
- BSS3. Doors as Barriers to Fire and Smoke. 15 cents.
- BSS4. Weather Resistance of Porcelain Enamels: Effect of Exposure Site and Other Variables After Seven Years. 20 cents
- BSS5. Interrelations Between Cement and Concrete Properties: Part 2, Sulfate Expansion, Heat of Hydration, and Autoclave Expansion. 35 cents.
- BSS6. Some Properties of the Calcium Aluminoferrite Hydrates. 20 cents
- BSS7. Organic Coatings. Properties, Selection, and Use. $2.50
- BSS8. Interrelations Between Cement and Concrete Properties: Part 3, Compressive Strengths of Portland Cement Test Mortars and Steam-Cured Mortars. 55 cents
- BSS9. Thermal-Shock Resistance for Built-Up Membranes. 20 cents
- BSS10. Field Burnout Tests of Apartment Dwelling Units. 25 cents
- BSS11. Fire Resistance of Steel Deck Floor Assemblies. 25 cents
- BSS12. Performance of Square-Edged Orifices and Orifice-Target Combinations as Air Mixers. 15 cents
- BSS13. Shrinkage and Creep in Prestressed Concrete. 15 cents
- BSS14. Experimental Determination of Eccentricity of Floor Loads Applied to a Bearing Wall. 15 cents
- BSS15. Interrelations Between Cement and Concrete Properties: Part 4, Shrinkage of Hardened Portland Cement Pastes. 75 cents
- BSS16. Techniques for the Survey and Evaluation of Live Floor Loads and Fire Loads in Modern Office Buildings. 40 cents
- BSS17. Causes of Variation in Chemical Analyses and Physical Tests of Portland Cement. 40 cents
- BSS18. Smoke and Gases Produced by Burning Aircraft Interior Materials. 35 cents
- BSS19. A Study of the Variables Involved in the Saturating of Roofing Felts. 30 cents
- BSS20. Proceedings of a Seminar on the Durability of Insulating Glass. 75 cents
- BSS21. Algorithms for Psycrometric Calculations. 55 cents
- BSS22. Investigation of Performance Characteristics for Sanitary Plumbing Fixtures. 70 cents
- BSS23. Hail Resistance of Roofing Products. 25 cents
- BSS24. Natural Weathering of Mineral Stabilized Asphalt Coatings on Organic Felt. 30 cents
- BSS25. Structural Performance Evaluation of a Building System. $1.25
- BSS26. Radiation Errors in Air Ducts Under Nonisothermal Conditions Using Thermocouples, Thermisters, and a Resistance Thermometer. 25 cents

Send orders with remittance to: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. Remittances from foreign countries should include an additional one-fourth of the purchase price for postage.

[See mailing list announcement on last page.]

UNITED STATES DEPARTMENT OF COMMERCE • Maurice H. Stans, *Secretary*
NATIONAL BUREAU OF STANDARDS • Lewis M. Branscomb, *Director*

Building science series, 27.

Performance of Louvered Devices as Air Mixers

T. K. Faison, Jr., J. C. Davis, and P. R. Achenbach

Building Research Division
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 27, 22 pages (Mar. 1970)
CODEN: BSSNB

Issued March 1970

For sale by the Superintendent of Documents, U.S. Government Printing Office Washington, D.C. 20402. (Order by SD Catalog No. C 13.29/2:27). Price, 30 cents

Contents

Library of Congress Catalog Card No. 73–603859

Performance of Louvered Devices as Air Mixers

T. K. Faison, Jr., J. C. Davis, and P. R. Achenbach

As part of a study of evaluating methods for reducing thermal gradients within the cross section of an air stream, three louvered mixing devices were investigated. Each of these devices was found to be capable of reducing the cross-sectional nonuniformity of air temperature to a few percent of the entering value. The three devices covered in this report contain combinations of louvers (directing vanes) and baffles as mixing elements. Two of the devices were designed at the National Bureau of Standards; the third was a modification of a previous design. The three mixers (the louvered strip, the concentric louvers, and the louvered-baffle) required 4.75, 3.8, and 3.0 duct diameters, respectively, to reach a mixing effectiveness level of 97 percent. The mixing effectiveness of the louvered strip and concentric louver models was independent of the approach velocity, whereas the effectiveness of the louver-baffle model was somewhat dependent on the approach velocity. The pressure drops accompanying air flow through the mixers, expressed as multiples of the velocity head of the entering air, were approximately 7, 5, and 38 for the louvered strip, concentric louver, and louver-baffle mixers, respectively.

Key words: Effectiveness; forced mixing; mixing device; pressure drop; temperature; uniformity.

1. Introduction

The lack of uniformity of temperature within the cross section of air streams has long posed a problem to investigators trying to make accurate measurements of air-stream temperature. Several mixing devices have been developed and many rather complicated designs have been devised to promote uniformity of temperature, although the literature contains little information of a quantitative nature on their effectiveness. Each of the methods seems to have its own particular drawback—too complicated to use, the pressure drop too high, the length for mixing too long, etc.

A recent study [1] [1] at the National Bureau of Standards showed that thermal gradients within the cross section of an air stream can be effectively diminished through forced mixing. With the removal of the undesirable condition of temperature nonuniformity, the average temperature of the air stream can be more accurately obtained and air stream temperature-dependent properties, such as enthalpy, can be determined with greater precision.

Several types of air mixing devices were evaluated in the laboratory but evalutations of only three types are presented here; louvered strip, louvered-baffle combination, and concentric louvers. The performance of each is given for various initial conditions of nonuniformity. The names given these mixers tend to describe the geometric configuration of each. The authors have previously described the apparatus in which the devices were evaluated and discussed the performance of the orifice as a mixer for removing thermal gradients in an air stream [1, 2]. The three types presented here and the orifices previously reported [1] were studied in detail. Several other designs, which were not as effective, were evaluated only qualitatively.

2. Apparatus and Test Procedure

The test appartus [2] was designed to produce in a 24-in-diam duct a condition (nonuniformity of temperature in the air stream) that might be commonly encountered in heating and air conditioning systems and laboratory applications. A schematic of the apparatus is shown in figure 1. Figure 2 is a photograph of the apparatus. A detailed description of the apparatus, the instrumentation, and procedure is given in reference [2]. Briefly, the apparatus functioned as follows: Air preconditioned and maintained at a constant temperature was drawn into the inlet blower at a controlled rate. Downstream from the blower, just

[1] Figures in brackets indicate the literature references at the end of this paper.

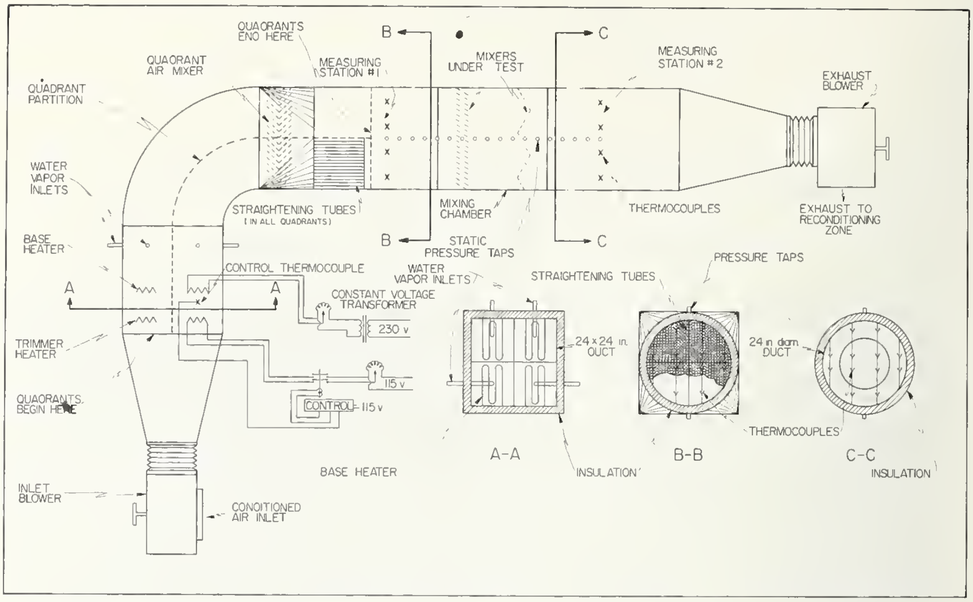


FIGURE 1. *A sketch of the mixing apparatus used to produce the test condition and house the mixing devices to be evaluated.*

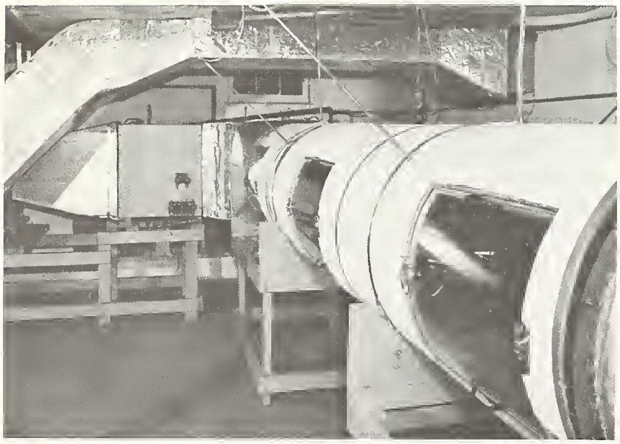


FIGURE 2. *Overall view of assembled test apparatus.*

after an enlarging transition, the duct cross-sectional area was divided into four equal 1-ft squares (sect. A-A, fig. 1). The dividing partitions were made to extend from beginning of the 24-in square conditioning portion of the apparatus on through a portion of the round duct and terminated at a position a short distance upstream from the section shown as B-B in figure 1. The partitions in the circular duct divided the duct space or air stream into four equal pie-shaped quadrants. The portions of the apparatus immediately upstream and downstream of section A–A in figure 1 contained electrical resistance heaters in each of the spaces to produce and maintain selected conditions of temperature.

Immediately following the conditioning section of the apparatus, a measuring station was positioned for determining the temperature pattern of the air prior to its entering the mixing device to be tested. From the first measuring station, the air passed through the mixing device and along the duct to a second measuring station. The second station could be repositioned along the length of the duct to determine the uniformity of the air stream at different locations downstream from the mixing device. The air was then passed from the apparatus through the exhaust blower. The two blowers, the supply and exhaust, were dampered to control both the flow rate and the static pressure within the apparatus.

Temperature patterns shown in figure 3 were used to evaluate the performance of the mixing devices. These patterns indicate distinct differences in temperature within the cross section of air streams prior to entering a device under test. The cases shown in the center and left part of the figure might represent situations where two streams of fluid merge together and form patterns of nonuniformity. The case shown at the right in the figure illustrates a situation where air flows for a distance in a duct located in an ambient temperature that is higher or lower than the initially uniform temperature in the duct, thus causing the temperature near the wall of the duct to be different from that at the center of the stream. These patterns are fairly common in practice and should give meaningful information on the ability of a mixing device to promote mixing and thus produce a homogeneous stream.

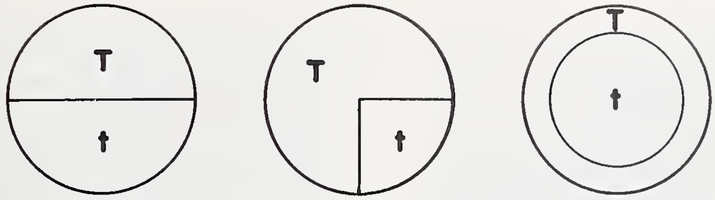


FIGURE 3. *Patterns of temperature distribution within the cross section of the test stream.*

2.1. Instrumentation

Temperature measurements were made at each of two stations. Measuring station No. 1 (see fig. 1) was located just downstream from the termination of the quadrant partitions, where the nonuniform temperature pattern of the air was measured as it existed prior to passing through the mixing device. The second measuring station was used to make measurements of the temperature distribution at selected points along the duct length as the mixing progressed. Both stations were constructed having the same physical pattern as shown in figure 1, with the only difference being that the upstream station was stationary and the downstream station was movable. At each station an array consisting of 24 copper-constantan thermocouples constructed of 30 gage (A.W.G.) wire was used. Thermocouples were calibrated at the National Bureau of Standards and were manually read on a precision-type potentiometer capable of direct reading to 1.0 μV (0.05 deg F for the wire used) with interpolation to 0.1 μV. A zone box [3] was used in the thermocouple circuit to permit the use of a common ice reference junction and all switching was accomplished in the copper portion of the thermocouple circuit.

From time to time comparison tests to determine the magnitude of variations amongst the 24 thermocouples at each station were made by immersing all of the thermocouples in a Dewar containing room-temperature water. The difference between any two of the 24 thermocouples was always less than 0.7 μV (0.03 deg F).

2.2. Conditioning and Control

Air flow rate in the test apparatus was controlled by varying adjustable dampers at the inlet of the first blower and at the exhaust downstream from the second blower. By proper adjustment of these two dampers, the pressure inside the apparatus was maintained at a positive level to prevent leakage of unconditioned air into the system from the room. Flow rates through the four quadrants were approximately equal. The volume rate of air flow was determined by using pitot-static tubes to measure the velocity head at 18 positions in the cross-sectional area of the rectangular inlet duct. The duct had a straight length of 8 ft ahead of the station of measurement. The pressures from the pitot-static tubes were measured with a Hook gage, which could be read to the nearest 0.001 in of vertical water column. Using potentiometer-type thermostat controllers and manually operated base heaters, air temperature was maintained constant at preselected temperature levels in the apparatus. The major increase of the air temperature was obtained from base heaters. Final control was obtained by thermostatic operation of trimmer heaters of smaller capacity. Each of the four quadrants was individually controlled to provide flexibility in selection of temperature patterns. Electrical resistance heaters positioned in a circular pattern around the periphery of the duct near the duct wall were used to produce concentric temperature patterns.

3. Description of Mixing Devices

In this study, three types of mixers were investigated: louvered strip, a louver-baffle combination, and concentric louvers. These mixers were designed with the objective of obtaining a satisfactory combination of mixing effectiveness, pressure drop, and space requirements for their use. The design and construction of the three types of mixers are described in the following sections.

3.1. Louvered Strip

In designing the louvered strip mixer, the area enclosed by a circular band 24 in in diameter was divided into 6 horizontal strips, each 4 in high, as shown in figure 4, left view. The areas bounded by the strips were fitted with vertical louvers for deflecting the air from its normal path. Louvers were designed so that

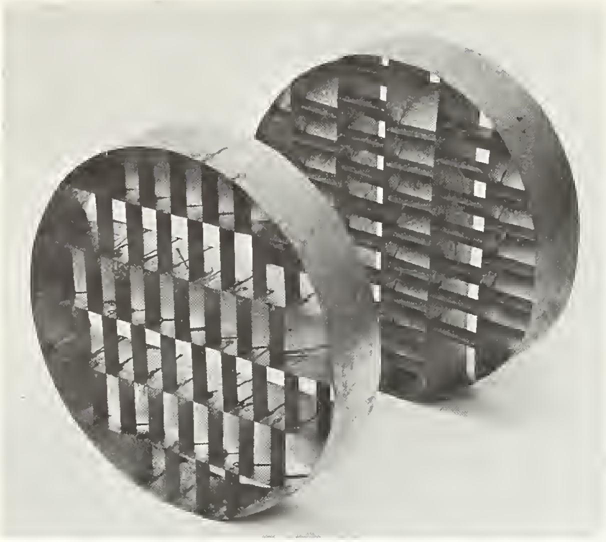


FIGURE 4. *A view of the louvered strip mixing device showing the two elements in series.*

the air passing through any two adjacent louvered areas was deflected through equal and opposing angles from its normal path. For example, the air passing through one area was deflected left by the louvers and in the adjacent area the deflection of the air was to the right. The air streams issuing through adjacent louvered strips moved in opposing directions, thus creating a shearing action between the streams at their interface. Both the forces generated by the shearing action and the resistance set up by opposing flow caused the formation of a highly turbulent field downstream from the mixing device.

Two louvered strip mixers of this construction were placed in series for this study. The first mixer provided shearing action in the horizontal plane. The second, rotated 90° in respect to the first mixer and located downstream, provided shearing action in the vertical plane (see fig. 4).

3.2. Louver-Baffle

The louver-baffle mixing device, as shown in figure 5, is a modification of one developed by Wile [4]. It was modified to fit into a round duct rather than a square or rectangular duct. For this mixer, the circular area was divided into six vertical strips each 4 in wide (left, fig. 5). One-half of the area of each strip was completely covered by a fixed metal baffle, thus making up a pattern of staggered baffles and openings over the large circular area. Behind the opening in each strip a set of louvers was attached to direct the flow of air from one side of the duct to the other. By blocking half of the total cross section of the duct, the set of

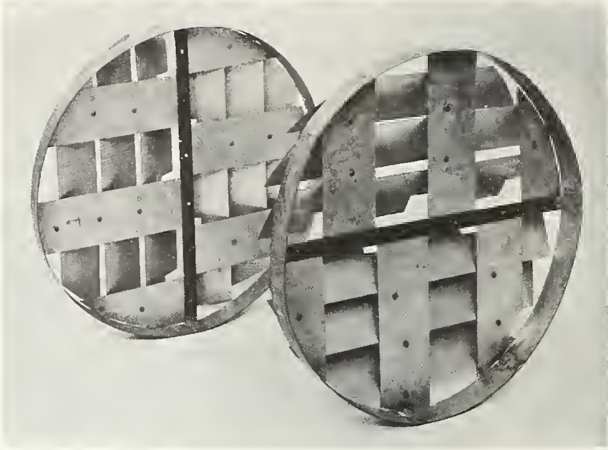


FIGURE 5. *A view of the louver-baffle mixing device showing the two elements in series.*

baffles approximately doubled the average air velocity in the plane of each mixing element. The baffles created in their wake, low-pressure regions into which the deflected air could flow. A pattern of turbulence was set up by the action of the adjacent layers of air moving in opposing directions. Two of the louver-baffle elements were used in series. Through the first element the air stream was deflected vertically and in the second element a horizontal deflection was achieved by rotating the element 90° from the first.

3.3. Concentric Louver

Shown in figure 6 is a set of two concentric louver elements which were placed in series.

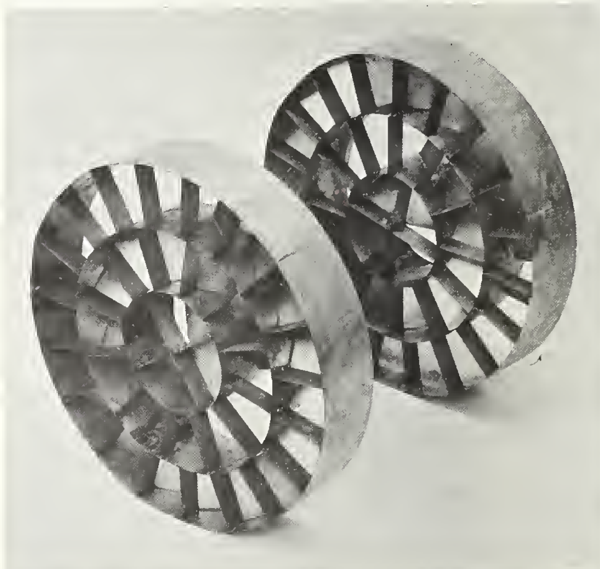


FIGURE 6. *A view of the concentric louver mixing device showing the two elements in series.*

The large circular area was divided by three concentric bands of 4 in in radial width. The two outer annular areas and the central circular area were fitted with louvers, which deflect these streams of air in a clockwise or counterclockwise direction. Because of counterrotation of the adjacent annular air streams, turbulence was generated at the interface of the annuli downstream from the mixing element. Through the shearing movement of the rotating air streams, a general condition of mixing or energy transfer was developed. As shown, a second set of concentric louvers caused the air to be directed in a direction opposite to that of the corresponding areas of the first set of concentric louvers.

4. Performance

For each of the three mixers, tests were conducted to determine how a variation of each of the following parameters would affect mixer performance.

1. Temperature pattern
2. Initial temperature nonuniformity
3. Distance between mixing elements
4. Overall distance required for mixing
5. Air flow rate
6. Deflection angle.

In each test, temperature values were recorded for each of the 24 thermocouple positions at the upstream and downstream measuring stations. A statistical analysis was made of the temperature values of the two stations. Five sets of temperature measurements were made for each test, and standard deviations of the upstream and downstream distribution were made for each set. An average upstream standard deviation and an average downstream standard deviation were obtained from the five sets. A value of effectiveness, which would give an indication of mixing capability, was calculated by subtracting from unity the ratio of downstream to upstream standard deviations. The mathematical relationships used for determining both the standard deviation and the effectiveness are defined by eqs (1) and (2).

$$\text{S.D.} = \left[\frac{1}{n-1}\sum(x_i - \bar{x})^2\right]^{1/2} \qquad (1)$$

$$\text{Effectiveness}_{\text{S.D.}} = \left(1.0 - \frac{\overline{\text{S.D.}}_{\text{DS}}}{\overline{\text{S.D.}}_{\text{US}}}\right) \times 100\% \qquad (2)$$

where:

n = number of measurements,
x_i = individual measurements,
$\bar{x}$ = arithmetic mean,
$\overline{\text{S.D.}}_{\text{DS}}$ = average standard deviation downstream,
$\overline{\text{S.D.}}_{\text{US}}$ = average standard deviation upstream.

The range of values was also found for the sets of upstream and downstream temperatures. An alternate value for effectiveness, based on range, was calculated by subtracting from unity the ratio of the average downstream to upstream ranges. This relationship is shown in eq (3):

$$\text{Effectiveness}_{\text{(Range)}} = \left(1.0 - \frac{\overline{\text{Range}}_{\text{DS}}}{\overline{\text{Range}}_{\text{US}}}\right) \times 100\% \qquad (3)$$

where:

$\overline{\text{Range}}_{\text{DS}}$ = average $(x_{max} - x_{min})$ downstream
$\overline{\text{Range}}_{\text{US}}$ = average $(x_{max} - x_{min})$ upstream.

This latter method of determining effectiveness, based on the range, is much simpler to calculate but could be more influenced by a single temperature value. If, for instance, either the maximum or minimum value were in error or differed considerably from the average value, then the effectiveness based upon the range would reflect this one value to a greater extent than would the method based upon standard deviation.

Since the air flow was in the turbulent region for these tests, it was of interest to determine to what extent the air was mixed during the simple process of flowing along the duct with no mixing device in the duct. Earlier tests [1] with no mixing device in the duct showed that mixing caused by the inherent turbulence and duct configuration was less than 7 percent when calculated by the range method of determining effectiveness. When calculated by the standard deviation method, a higher value of 17 percent was obtained for the natural mixing because this method takes into account all of the observed values. Some mixing, which is not indicated by the range method, does occur at the interface between streams of different temperature air.

4.1. Louvered Strip

Table 1 is a summary compilation of all of the tests conducted on the louvered strip mixing device and gives details of the test conditions and resulting performance at these conditions. In all illustrations which relate effec-

TABLE 1. *Summary of test conditions and performance of the louvered strip mixer.*

Test No.	Flow Rate	Pressure Drop Across Mixer	Distance Between Mixing Elements		Distance from 2nd Element to Down-stream Meas. Station		Overall Distance		Temperature Conditions at Mixer Inlet		Effectiveness	
									Temp. Diff.	Temp. Pattern*	Range	Std. Dev.
	CFM	in. W.G.	in.	Duct Diam.	in.	Duct Diam.	in.	Duct Diam.	deg F		%	%
1	1400	0.07	12	0.50	102	4.25	114	4.75	3.6		90.1	92.5
2	1400	0.07	24	1.00	90	3.75	114	4.75	3.6		91.5	93.9
3	1400	0.07	36	1.50	78	3.25	114	4.75	3.7		94.5	96.1
4	1400	0.07	48	2.00	66	2.75	114	4.75	3.6		95.1	96.2
5	1400	0.07	60	2.50	54	2.25	114	4.75	3.6		94.7	96.3
6	1400	0.07	72	3.00	42	1.75	114	4.75	3.6		93.8	96.2
7	1400	0.07	48	2.00	48	2.00	96	4.00	3.6		94.0	95.6
8	1400	0.07	48	2.00	36	1.50	84	3.50	3.6		93.0	94.9
9	1400	0.07	48	2.00	24	1.00	72	3.00	3.6		90.6	93.5
10	1400	0.07	48	2.00	66	2.75	114	4.75	4.2		98.3	99.0
11	1400	0.07	48	2.00	66	2.75	114	4.75	6.5		97.6	98.7
12	1400	0.07	48	2.00	66	2.75	114	4.75	15.5		98.8	99.2
13	1400	0.07	48	2.00	48	2.00	96	4.00	4.3		97.3	98.5
14	1400	0.07	48	2.00	24	1.00	72	3.00	4.2		94.5	96.6
15	1400	0.07	48	2.00	66	2.75	114	4.75	3.5		84.2	90.2
16	1875	0.15	48	2.00	66	2.75	114	4.75	4.8		97.4	98.5
17	1875	0.15	48	2.00	66	2.75	114	4.75	3.8		93.8	95.6
18	1000	0.04	48	2.00	66	2.75	114	4.75	3.5		94.9	96.5
19	1000	0.04	48	2.00	66	2.75	114	4.75	4.7		98.4	98.9
20	500	0.01	48	2.00	66	2.75	114	4.75	4.4		97.8	98.5
21	500	0.01	48	2.00	66	2.75	114	4.75	3.5		94.2	95.6

* Shaded area represents a temperature different from the unshaded area.

To assist readers interested in making use of the coherent system of SI units, the exact conversion factors to be used with the above table are

Length	1 inch = 0.0254 meter
Temperature difference	1 deg F = 5/9 deg C = 5/9 K
Pressure	1 inch of water = 2.488×10^2 newton/meter^2
Flow rate	1 cubic foot/minute = 4.719×10^{-4} meter^3/second

tiveness to some other parameter, the standard deviation method of determining effectiveness was used.

Three patterns of temperature nonuniformity were used to determine how mixer effectiveness was influenced by variation of the initial temperature distribution. The temperature patterns are shown in figure 7. The right and left patterns in figure 7 represent situations where a maximum nonuniformity of 50 percent warm and 50 percent cool air occurs. A pattern, which might be more common, of one-

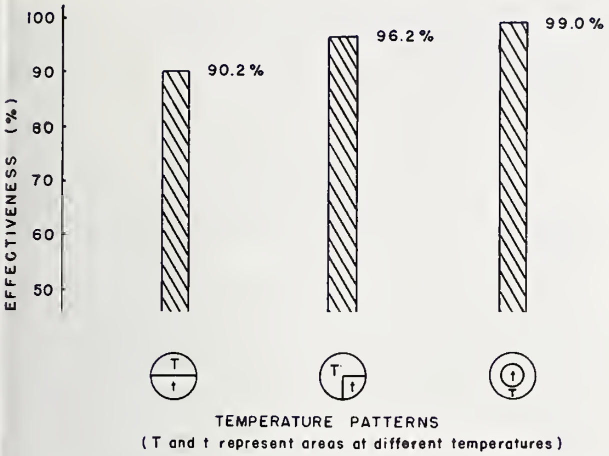


FIGURE 7. *Effectiveness of the louvered strip mixing device for selected temperature patterns.*

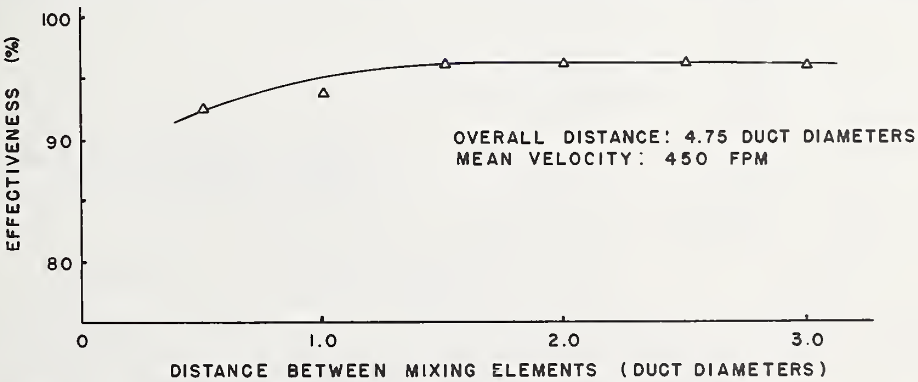
fourth of the stream at a different temperature than the remaining three-fourths is shown in the center of figure 7. From the results shown by the three bar graphs in figure 7, it is evident that the lowest effectiveness occurred for a pattern composed of 50 percent warm air and 50 percent cool air with the interface along the diameter of the duct. The next most difficult pattern of nonuniformity to mix was that of three-fourths of the stream at a different temperature than the remaining one-fourth. The easiest pattern of nonuniformity to mix was that of a concentric distribution. With the concentric pattern, the 99.0 percent effectiveness of the mixer approached very nearly the limitation of the temperature-measuring system.

It was also of interest to determine how the magnitude of an initial temperature difference might affect the value of effectiveness. Tests using the concentric temperature pattern were made by varying the temperature difference between the warm and cool portions of the air stream. Observations of temperature differences between portions of the unmixed stream of 4.0, 6.5, and 15.5 deg F revealed no change in the percentage effectiveness of the mixer. In studying all other parameters, a temperature difference in the unmixed air stream of approximately 3 to 4 deg F was used for all mixers.

Using two mixing elements in series, it was desirable to know at what position the elements should be located with respect to each other for best mixing. Tests were made to determine the optimum placement by varying the location of the second element with respect to the first element. Figure 8 shows a curve of effectiveness as the distance between the mixing elements was changed. As a result of space limitations, the overall distance from the inlet of the mixing device to the downstream measuring station was confined to 4.75 duct diameters. Because of the space limitation, the distance from the second mixing element to the downstream measuring station varied as the distance between mixing elements varied. Under the conditions of the tests, the effectiveness increased gradually from 92.5 to 96.1 percent as the spacing was increased from 0.5 to 1.5 duct diameters; it remained constant at spacings greater than 1.5 duct diameters.

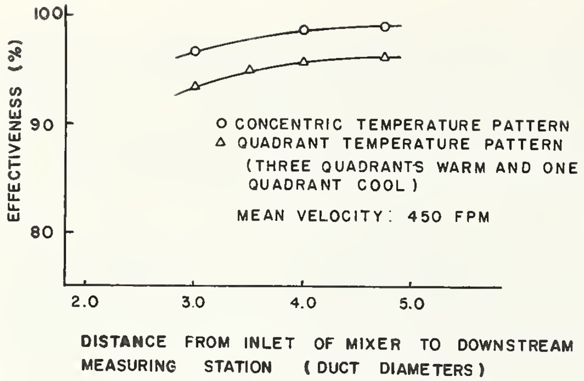
Figure 9 presents the effectiveness as a function of overall distance between the first mixer element and the downstream measuring station with the spacing between mixing elements held constant at 2.0 duct diameters. Presented in the figure is the performance of the mixer for two temperature patterns, the concentric distribution and the quadrant distribution. As can be seen, mixing effectiveness for the concentric pattern was consistently the higher of the two.

Measurements were made over a selected range of air flow corresponding to average air stream velocities ranging from 150 to 600 fpm. Figure 10 illustrates the negligible effect upon the effectiveness of mixing as the flow or mean velocity was varied over the above range.



The overall distance of 4.75 duct diameters from the inlet of the mixing device to the downstream station was held constant.

FIGURE 8. *Effectiveness of the louvered strip mixing device relative to the spacing between mixing elements.*



The distance between the mixing elements was held constant at 2.0 duct diameters.

FIGURE 9. *Effectiveness of the louvered strip mixing device as the overall distance from the inlet of the mixing device to the downstream measuring station was varied.*

Measurements were also made to compare the effectiveness of the mixer at two different louver angle positions. The results illustrated in figures 7 to 10 inclusive are for a position of 60° from the normal path of flow along the axis of the duct. Using the quadrant temperature distribution pattern, the effectiveness decreased from 96 to 93 percent for the respective settings of 60° and 45° from the normal path of flow. For the comparative tests, the flow rate was 1400 cfm, the spacing between mixing elements was 2.0 duct diameters, and the downstream measuring station was 4.75 duct diameters from the first mixing element.

The loss of static head due to the presence of a mixing device in the duct system was of interest because of the energy required and size of equipment needed to move the air through such devices. The pressure loss from the louvered strip mixer was relatively low, as is shown in the plot of figure 11. When the loss in static pressure head is expressed in terms of equivalent multiples of velocity head, the static pressure drop is equivalent to approximately seven velocity heads. For the other two mixers, the louver-baffle and the concentric louver, the equivalent velocity head multiples are 38 and 5, respectively.

4.2. Louver-Baffle

A summary of the test conditions and performance of the louver-baffle mixer is given in table 2.

The same three temperature patterns as previously described, having quadrant and annular distributions, were used in evaluating the performance of the louver-baffle mixing device. Shown in figure 12 are bar graphs which compare the performance for the three temperature patterns. By comparing figures 6 and 12, it is seen that the effectiveness of this mixer is not as much affected by temperature distribution as was that of the louvered strip mixer.

From the curve of figure 13, it is seen that there was little change in effectiveness beyond the 3 deg F level of temperature difference. It is possible that the computed values of effectiveness for temperature differences of less than 3 deg F at the mixer inlet (0.6 and 1.7 deg F) could have been influenced by the instrument error, since the ratio of the instrument error to the temperature gradient increases as the temperature gradient gets smaller. At the downstream measuring station, an error of 0.01 deg F for an initial temperature difference of 0.5 deg F between quadrants would cause an error of 2 percent in effectiveness. To reduce the influence of instrument error upon the observed effectiveness, all other tests were conducted at a temperature difference of 3 deg F or higher.

Tests were conducted to determine at what distance the two elements should be placed with respect to each other and at what overall length the mixer would be highly effective (97% or higher). Figures 14 and 15, respectively, show the effect when the distance between elements is varied, and the effectiveness

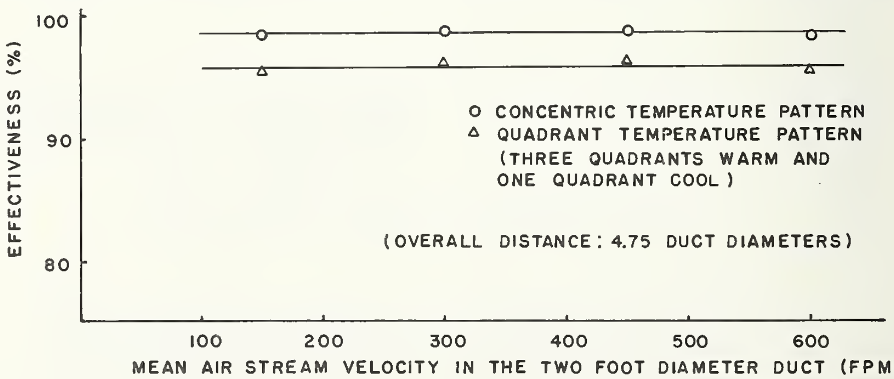


FIGURE 10. *Relation of mixer inlet velocity to effectiveness for the louvered strip mixing device.*

TABLE 2. *Summary of test conditions and performance of the louver-baffle mixer.*

Test No.	Flow Rate	Pressure Drop Across Mixer	Distance Between Mixing Elements		Distance from 2nd Element to Down-stream Meas. Station		Overall Distance		Temperature Conditions at Mixer Inlet		Louver Angle	Effectiveness	
									Temp. Diff.	Temp. Pattern*		Range	Std. Dev.
	Cfm	in. W.G.	in.	Duct Diam.	in.	Duct Diam.	in.	Duct Diam.	deg F		Degree	%	%
1	1400	0.71	14	0.58	46	1.92	60	2.50	3.3		60	94.6	95.5
2	1400	0.71	18	0.75	42	1.75	60	2.50	3.3		60	95.9	96.7
3	1400	0.71	22	0.92	38	1.58	60	2.50	3.6		60	96.4	97.1
4	1400	0.71	26	1.08	34	1.42	60	2.50	3.5		60	95.4	96.4
5	1400	0.71	22	0.92	38	1.58	60	2.50	0.6		60	93.0	95.0
6	1400	0.71	22	0.92	38	1.58	60	2.50	1.7		60	94.6	96.0
7	1400	0.71	22	0.92	38	1.58	60	2.50	10.8		60	96.2	97.1
8	1400	0.71	22	0.92	38	1.58	60	2.50	20.7		60	95.2	96.5
9	1400	0.71	6	0.25	42	1.75	48	2.00	3.6		60	91.5	93.8
10	1400	0.71	30	1.25	42	1.75	72	3.00	3.8		60	95.2	96.6
11	1400	0.17	22	0.92	38	1.58	60	2.50	3.5		0	57.6	63.7
12	1400	0.25	22	0.92	38	1.58	60	2.50	3.5		30	57.8	67.6
13	1400	0.45	26	1.08	34	1.42	60	2.50	3.2		45	83.3	88.2
14	1400	0.46	22	0.92	38	1.58	60	2.50	3.2		50	92.1	93.6
15	1400	0.54	22	0.92	38	1.58	60	2.50	3.3		55	92.5	94.6
16	1400	0.80	22	0.92	38	1.58	60	2.50	3.5		65	94.4	95.6
17	300	0.02	22	0.92	38	1.58	60	2.50	3.6		60	92.9	93.9
18	1000	0.21	22	0.92	38	1.58	60	2.50	5.1		60	94.3	95.3
19	1400	0.71	22	0.92	26	1.08	48	2.00	3.7		60	89.6	92.6
20	1400	0.71	22	0.92	30	1.25	52	2.17	3.7		60	91.6	93.5
21	1400	0.71	22	0.92	34	1.42	56	2.34	3.7		60	94.0	95.0
22	1400	0.71	22	0.92	38	1.58	60	2.50	3.3		60	94.3	95.3
23	1400	0.71	22	0.92	42	1.75	64	2.67	3.9		60	96.3	97.0
24	1400	0.71	22	0.92	46	1.92	68	2.84	4.1		60	96.4	96.9
25	1400	0.71	22	0.92	50	2.08	72	3.00	3.6		60	95.5	96.7
26	1400	0.71	22	0.92	54	2.25	76	3.17	3.8		60	96.1	97.2
27	1400	0.71	22	0.92	12	0.50	34	1.42	3.5		60	75.8	83.3
28	1400	0.71	22	0.92	12	0.50	34	1.42	4.3		60	93.7	96.1
29	1400	0.71	22	0.92	24	1.00	46	1.92	4.3		60	97.4	98.3
30	1400	0.71	22	0.92	38	1.58	60	2.50	4.4		60	98.4	98.9
31	1400	0.71	22	0.92	60	2.50	82	3.42	4.3		60	98.3	99.0
32	1400	0.71	22	0.92	84	3.50	106	4.42	4.4		60	98.9	99.3
33	1400	0.71	22	0.92	38	1.58	60	2.50	3.7		60	95.5	96.9
34	1400	0.71	34	1.42	42	1.75	76	3.17	3.7		60	95.2	96.3
35	1400	0.71	26	1.08	42	1.75	68	2.84	3.6		60	94.6	95.7
36	1400	0.71	10	0.42	42	1.75	52	2.17	3.5		60	91.3	93.6

* Shaded area represents a temperature different from the unshaded area.

To assist readers interested in making use of the coherent system of SI units, the exact conversion factors to be used with the above table are:

Length	1 inch = 0.0254 meter
Temperature difference	1 deg F = 5/9 deg C = 5/9 K
Pressure	1 inch of water = 2.488×10^2 newton/meter^2
Flow rate	1 cubic foot/minute = 4.719×10^{-4} meter^3/second

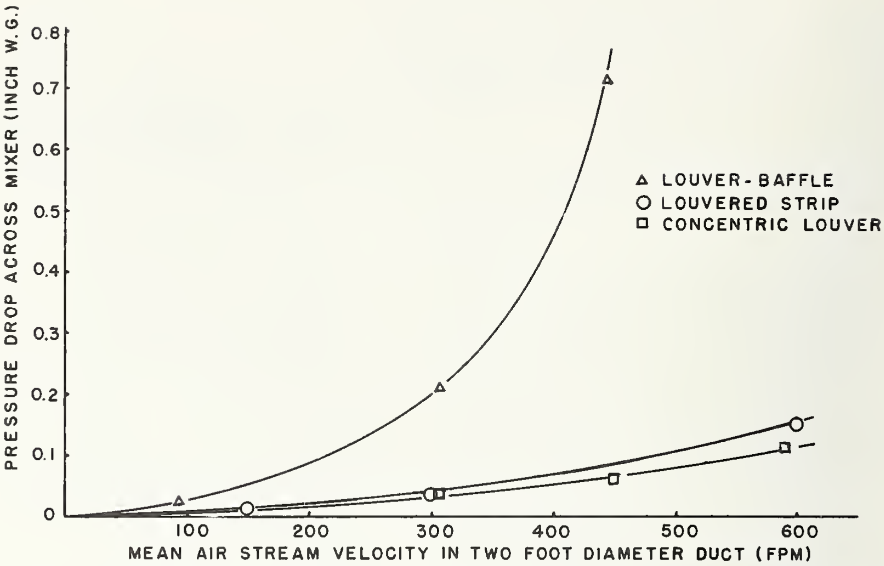


FIGURE 11. *Observed pressure drop for each of the three mixing devices for a range of air flow.*

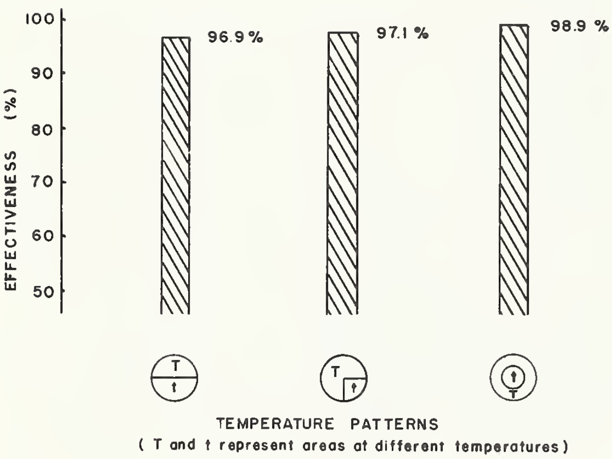


FIGURE 12. *Effectiveness of the louver-baffle mixing device for selected temperature patterns.*

at various downstream locations after the air stream has passed through the mixer. From the data shown in figure 14, it was found that a distance of 0.92 duct diameter between elements provided sufficient spacing to accomplish good mixing. With the elements located 0.92 duct diameter apart, measurements were taken to determine mixer performance as the overall distance varied. For temperature patterns of concentric and quadrant distributions, it was found that, for overall distances greater than 2.5 duct diameters from the first mixing element to the downstream measuring station, little improvement in mixing was accomplished. The maximum observed mixing effectiveness for the quadrant temperature pattern and the concentric temperature pattern was about 97 and 99 percent, respectively, for the test conditions shown in figure 15.

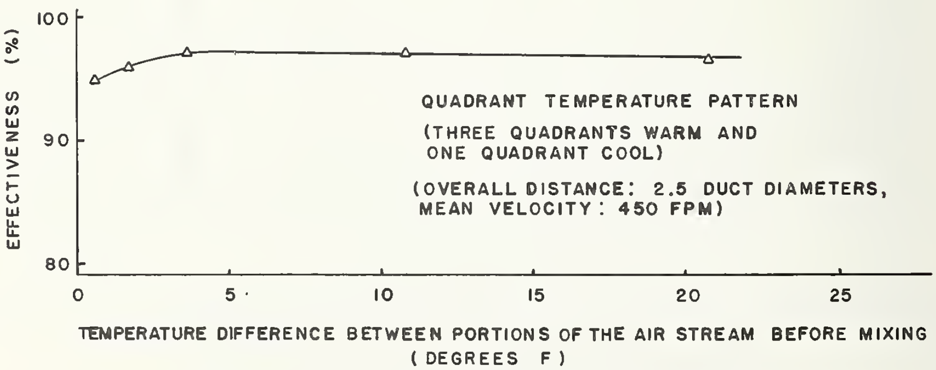
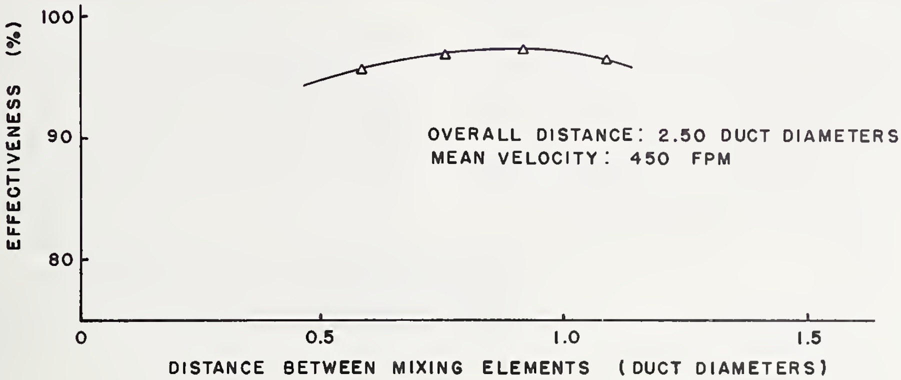
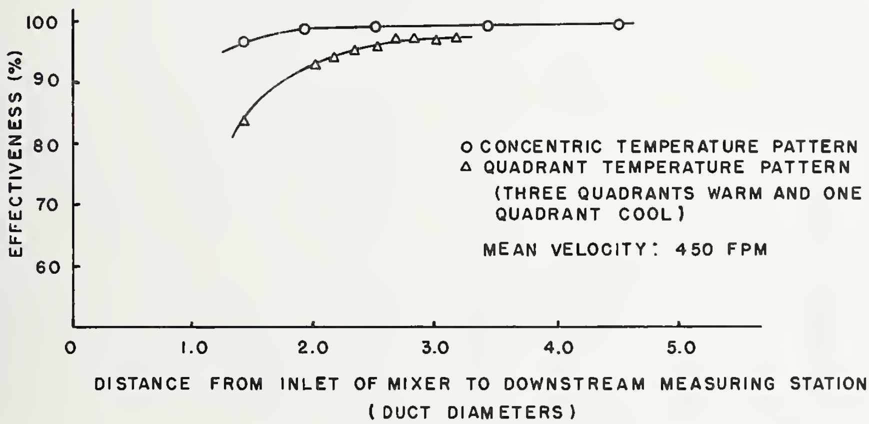


FIGURE 13. *Effect of air temperature difference at mixer inlet upon the effectiveness of the louver-baffle mixing device.*



The overall distance of 2.5 duct diameters from the inlet of the mixing device to the downstream measuring station was held constant.

FIGURE 14. *Effectiveness of the louver-baffle mixing device relative to the spacing between mixing elements.*



The distance between the mixing elements was held constant at 0.92 duct diameter.

FIGURE 15. *Effectiveness of the louver-baffle mixing device as the overall distance from the inlet of the mixing device to the downstream measuring station was varied.*

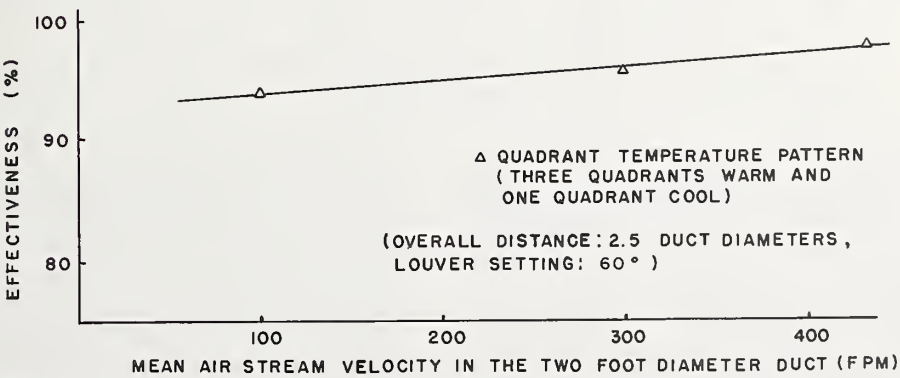


FIGURE 16. *Relation of mixer inlet velocity to effectiveness for the louver-baffle mixing device.*

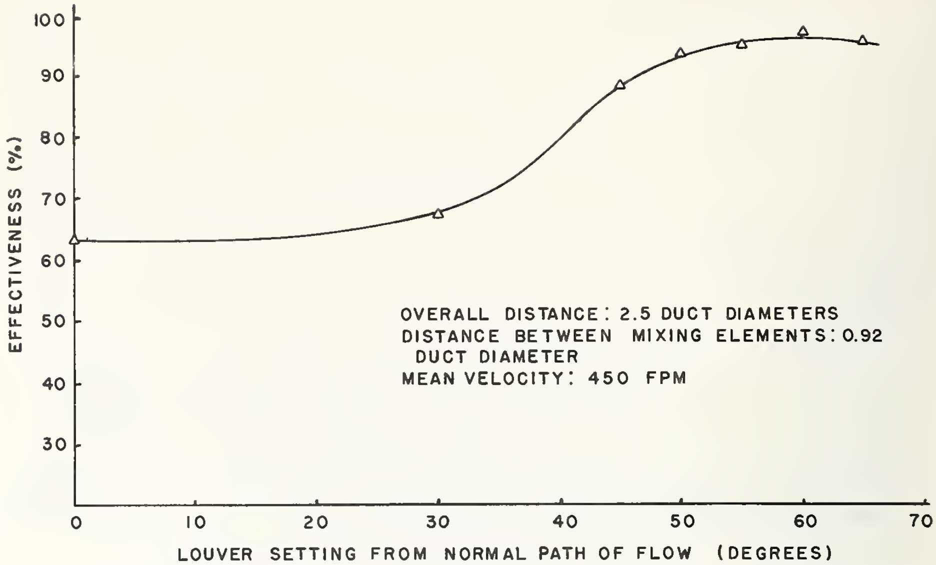


FIGURE 17. *Relation of the louver angle to effectiveness for the louver-baffle mixing device.*

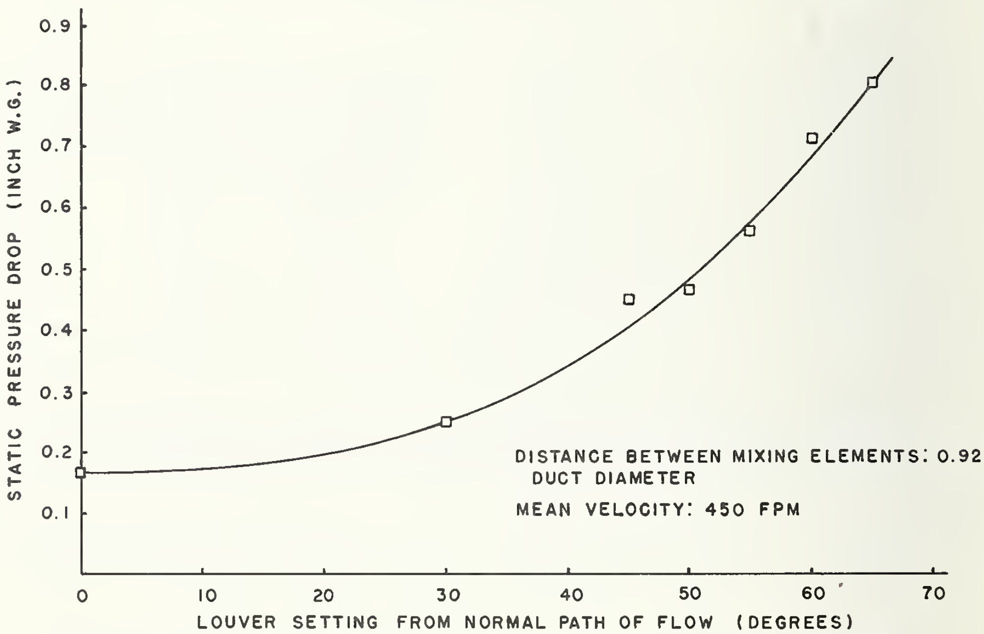


FIGURE 18. *Pressure drop for the louver-baffle mixing device at selected louver settings.*

The louver-baffle mixer was found to be slightly more sensitive to variation of flow rate than the louvered strip mixer. Over the velocity range from 100 to 450 fpm, as shown in figure 16, the effectiveness increased approximately 3 percent as the mean stream velocity was increased over this range.

Along with placement of elements, temperature patterns, etc., tests to determine how the effectiveness would change were made by varying the angular deflection of the air as it passed through the mixer. Tests were made at various louver angle positions from 0°, or along the axis of the duct, to 65° from the axis. As shown in figure 17, the observed effectiveness was maximum at a setting of 60°. Beyond 60° the pressure drop became prohibitively high without an increase in effectiveness. Figure 18 shows a plot of the pressure drop across the mixing device as the louver angle was changed while the flow rate remained constant.

4.3. Concentric Louver

For the concentric louver mixing device, the angular setting of the louvers in the outermost area was selected to be 60° from the normal path of flow. At the 60° louver angle setting, the pressure drop was determined for a given rate of air flowing through the outer area. Then with the same flow rate,the angular setting of the louvers in the two inner areas was adjusted to give a matching pressure drop for the two inner areas and the outer area. The resulting angular setting for the two inner areas was 49° from the normal path of flow. All test were conducted at these louver angle settings. A summary of test conditions and performance of the concentric louver mixer is given in table 3.

TABLE 3. *Summary of test conditions and performance of the concentric louver mixer.*

Test No.	Flow Rate	Pressure Drop Across Mixer	Distance Between Mixing Elements		Distance from 2nd Element to Down-stream Meas. Station		Overall Distance		Temperature Conditions at Mixer Inlet		Effectiveness	
									Temp. Diff.	Temp. Pattern*	Range	Std. Dev.
	CFM	in. W.G.	in.	Duct Diam.	in.	Duct Diam.	in.	Duct Diam.	deg F		%	%
1	1400	0.06	12	0.5	102	4.25	114	4.75	3.7		85.9	90.0
2	1400	0.06	24	1.0	90	3.75	114	4.75	3.7		93.8	96.0
3	1400	0.06	36	1.5	78	3.25	114	4.75	3.8		95.8	97.1
4	1400	0.06	48	2.0	66	2.75	114	4.75	3.7		97.1	98.0
5	1400	0.06	60	2.5	54	2.25	114	4.75	3.9		95.4	97.0
6	1400	0.06	72	3.0	42	1.75	114	4.75	3.7		93.1	96.1
7	1400	0.06	48	2.0	60	2.50	108	4.50	3.7		96.2	97.3
8	1400	0.06	48	2.0	48	2.00	96	4.00	3.8		95.2	96.8
9	1400	0.06	48	2.0	36	1.50	84	3.50	3.8		94.9	96.5
10	1400	0.06	48	2.0	24	1.00	72	3.00	3.7		93.2	95.1
11	1400	0.06	48	2.0	12	0.50	60	2.50	3.6		87.2	91.9
12	1850	0.11	48	2.0	60	2.50	108	4.50	5.8		97.8	98.8
13	1850	0.11	48	2.0	36	1.50	84	3.50	5.9		97.5	98.4
14	1850	0.11	48	2.0	12	0.50	60	2.50	5.9		92.9	94.9
15	1000	0.04	48	2.0	60	2.50	108	4.50	3.8		96.0	96.8
16	1850	0.11	48	2.0	60	2.50	108	4.50	3.7		95.0	96.4
17	500	----	48	2.0	60	2.50	108	4.50	4.0		96.9	97.7
18	1400	0.06	48	2.0	60	2.50	108	4.50	3.7		95.2	97.1
19	1400	0.06	48	2.0	60	2.50	108	4.50	4.1		97.8	98.8
20	1400	0.06	48	2.0	60	2.50	108	4.50	5.8		98.5	99.1
21	1400	0.06	48	2.0	60	2.50	108	4.50	13.1		98.8	99.3
22	500	----	48	2.0	60	2.50	108	4.50	5.6		98.4	99.1

* Shaded area represents a temperature different from the unshaded area.

To assist readers interested in making use of the coherent system of SI units, the exact conversion factors to be used with the above table are:

Length	1 inch = 0.0254 meter
Temperature difference	1 deg F = 5/9 deg C = 5/9 K
Pressure	1 inch of water = 2.488×10^2 newton/meter^2
Flow rate	1 cubic foot/minute = 4.719×10^{-4} meter^3/second

The concentric louver mixer was subjected to air streams having the same nonuniform temperature distributions at the inlet as for the other two mixing devices. The results of this study are shown in figure 19. The bar graphs, which relate the effectiveness of the mixer to the three temperature patterns, show that the effectiveness is only slightly affected by the temperature pattern of the air stream.

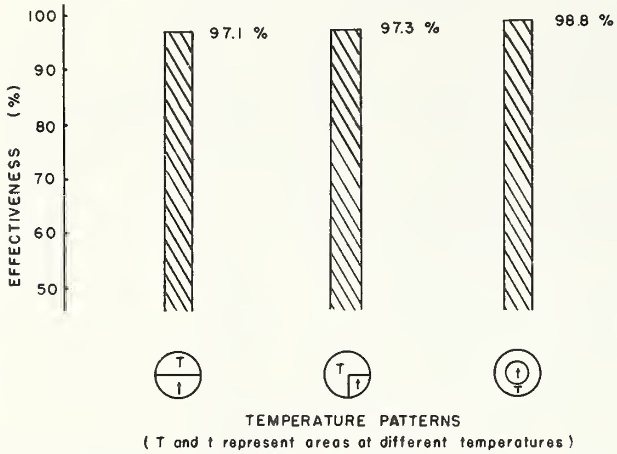


FIGURE 19. *Effectiveness of the concentric louver mixing device for selected temperature patterns.*

Using the temperature pattern shown in the center of figure 19, tests were made to determine the effect of increasing the magnitude of the temperature difference between portions of the cross section of the air stream over the range from 4 to 13 deg F. Results shown in figure 20 indicate that there was no change in performance within this range.

As in the case of the other mixers, which have two elements in series, it was necessary to determine at what distance, with respect to each other, the mixing elements would best perform. For this determination, the downstream measuring station was held in a fixed position and the location of the second mixing element with respect to the first was varied. The results illustrated in figure 21 show that effective mixing was gained when the elements were placed approximately two duct diameters apart, but that very little mixing would be lost by reducing the spacing down to one duct diameter. Tests using a spacing of two duct diameters between mixing elements showed that the overall distance from the first mixing element to the point of maximum observed uniformity was 4.75 duct diameters. Figure 22 shows how the effectiveness varied as the overall distance was changed.

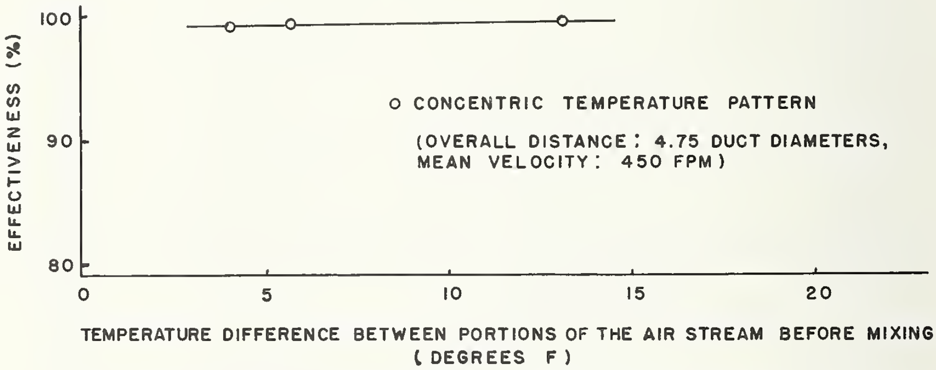


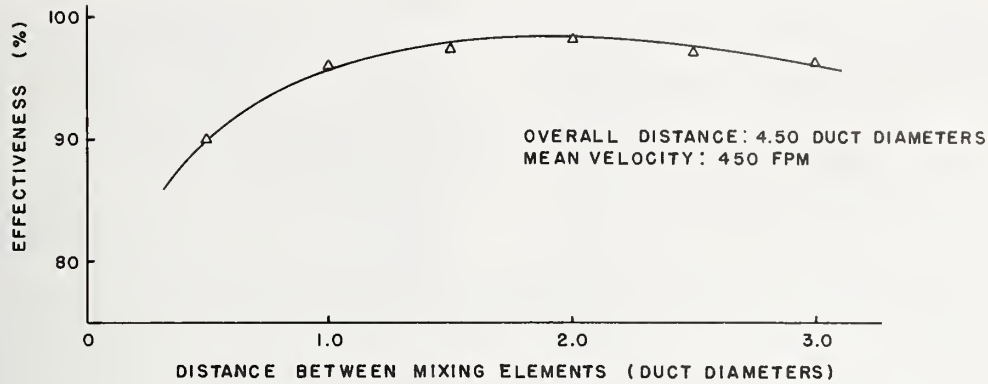
FIGURE 20. *Effect of air temperature difference at mixer inlet upon the effectiveness of the concentric louver mixing device.*

The effect of velocity upon the mixing process was determined by varying the average speed of the air stream over the range from 150 fpm to 600 fpm. The results plotted in figure 23 show that the effectiveness of the concentric louver mixer is relatively unaffected by the speed of the air stream.

4.3.1. Applications of the Concentric Louver Mixer

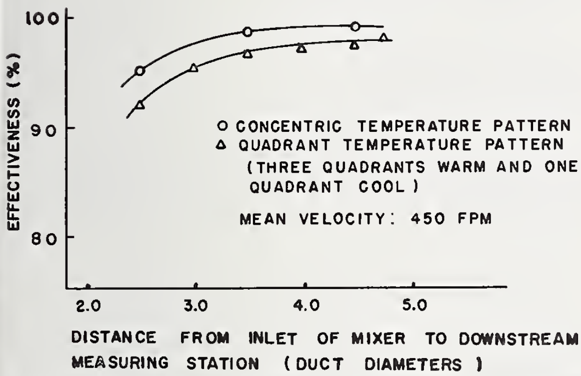
The concentric louver mixer has been used successfullv in several test apparatuses at the National Bureau of Standards in which uniformity of temperature of an air stream greatly facilitated the purpose of the investigation. In one case it was used to mix the air stream leaving a coil being tested in a psychrometric calorimeter apparatus for measurement of the heat transfer characteristics of cooling coils. After determining that the uniformity of temperature downstream from the mixer was good, only three thermocouples were used to obtain a representative sampling of the air stream for the psychrometric determinations.

In the second case the mixer was used, in a study of the effect of thermal radiation upon temperature-measuring sensors, to obtain a condition of reasonably uniform air tempera-



The overall distance of 4.5 duct diameters from the inlet of the mixing device to the downstream measuring station was held constant.

Figure 21. *Effectiveness of the concentric louver mixing device relative to the spacing between mixing elements.*



The distance between the elements was held constant at 2.0 duct diameters.

Figure 22. *Effectiveness of the concentric louver mixing device as the overall distance from the inlet of the mixing device to the downstream measuring station was varied.*

ture at all points within the cross section of the air stream prior to entering the heated portion of the duct. Figure 24 is a drawing of the heated wall apparatus showing the mixer, measuring stations, probe location, and heating elements. The study was made by locating the sensors in a duct whose wall was heated to a higher temperature than the air which surrounded the sensors. Heat was applied to the duct walls and, as the air passed downstream, an approximately symmetrical pattern of temperature from the duct wall to the sensors was achieved. At the point where the sensors were placed there existed a flow of air in which temperature fluctuations were very small. Error of measurement for temperature sensors of thermocouples, a thermistor and a resistance thermometer, due to the radiation from the heated walls, was then determined

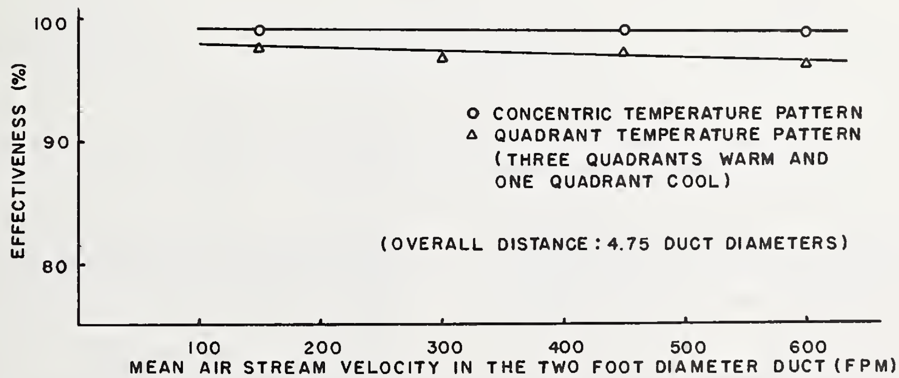
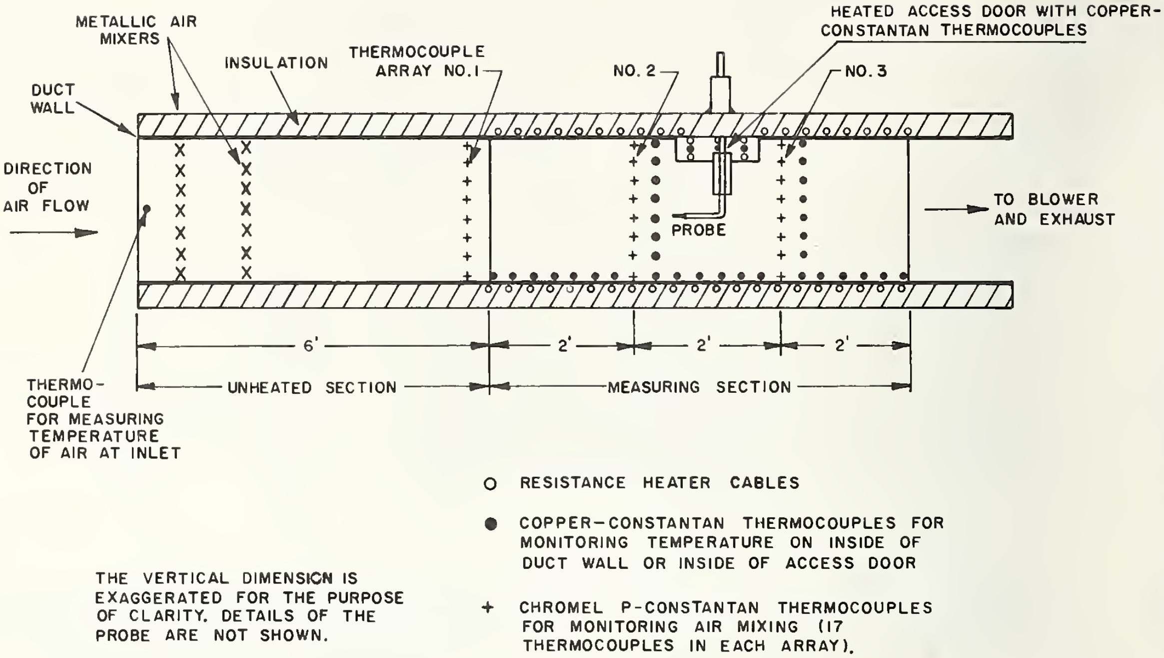
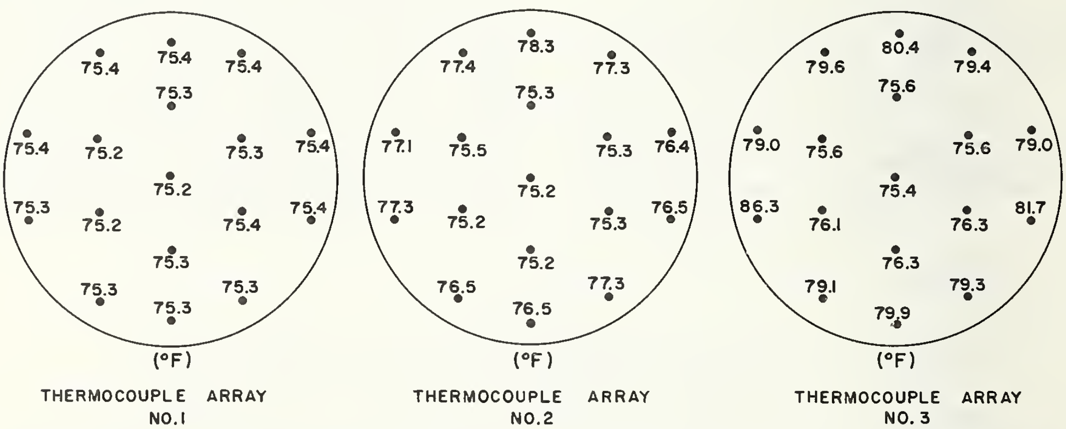


Figure 23. *Relation of mixer inlet velocity to effectiveness for the concentric louver mixing device.*



The performance of three types of air temperature sensing devices encased in the probe was evaluated using this heated wall apparatus. The air mixer location can be seen at the left of the illustration.

FIGURE 24. *A sketch of an apparatus in which the concentric louver mixing device was used to produce a uniform temperature in an air stream.*



Due to the heat applied to the wall of the measuring section, the temperature of the air at measuring stations 2 and 3 was higher near the duct wall than at the center

FIGURE 25. *Temperature patterns at the three measuring stations in the heated wall apparatus, shown in figure 24.*

through an extensive investigation. Figure 25 shows temperature profiles at the three measuring stations when the duct wall at stations 2 and 3 was 50 deg F higher than the air stream at the center of the duct.

Recently one of the mixers described in this paper, the concentric louver, was proposed as a recommended mixing device in the ASHRAE Standard 41–66 [5], Section on Temperature Measurement of the Standard Measurements Guide, Part I. The recommendation has been incorporated in the new issue of the standard. An appendix is included at the end of the paper which gives detailed drawings of the three mixing devices and discusses techniques helpful in construction of the mixers.

4.4. Comparison of Other Air Mixer Designs

In the previous investigation on orifices and orifice-target combinations [1], it was determined that an orifice having a diamter ratio (ratio of the orifice throat diameter to the duct diameter) of approximately 0.33 was consistently more effective in reducing the thermal differences in an unmixed air stream than orifices having diameter ratios of 0.50 and 0.67. However, the mixing process was accompanied by a high pressure drop across the mixer. If the pressure drop can be tolerated, temperature nonuniformity could be reduced to 3 or 4 percent of its original value, at a distance of approximately 4.5 duct diameters downstream from the orifice. The study indicated that diameter ratio was the most important parameter affecting the mixer effectiveness, but that the interface area between cold and warm elements of the air stream and size of the nonisothermal elements also had a bearing on the mixing process. The performance of the orifice-target combinations showed no improvement over the plain orifice even when using a target as large as two-thirds of the duct diameter.

During the course of the investigation of mixing devices, a number of designs (including the three reported herein) were evaluated using the flow visualization technique for observing the flow pattern, with smoke used as the indicator. Although observation of flow patterns is qualitative, good correlation between flow visualization and quantitative method of evaluation using temperature patterns was gained. This correlation indicates that flow visualization is a rather good but coarse method of evaluation. Listed below are a number of designs which revealed relatively poor mixing characteristics.

1. *Screens.* Layers of flat wire screen, having approximately 50 percent free area, placed in series over the area of the duct, through which the air could flow, showed very little effect upon the air stream with respect to mixing. (Velocity profiles taken before and after a number of layers of screen showed a distinct improvement in the uniformity of the velocity within the cross-sectional plane of the duct.)

It should be mentioned that for a temperature distribution having many small variations, the screen might be more effective, as the flow through the screen is in the form of many small jets. For the distribution as described in this report, one quadrant different from the other three, for example, screens provide little displacement of flow from one part of the stream to another; thus, the general effectiveness for screens was very limited.

2. *Baffles.*

a. Semicircular baffles were placed in series approximately one duct diameter apart in such a way that one-half of the area of the round duct was blocked off by the first baffle. One duct diameter downstream, the second baffle was placed in a position corresponding to the space not occupied by the first baffle; thus, the air would pass through the restricted opening of the first baffle and strike the second baffle before passing through the second opening. This method proved unsatisfactory (but better than screens). It was evident that the patterns were not being fully broken up.

b. Single slats one-third of a duct diameter in width were placed along the diameter of the duct and used as baffles. The baffles were installed in series, the first horizontal and the second vertical, approximately one duct diameter apart. The mixing was comparable to that of the semicircular baffles but was not considered good.

c. Quartered baffles were used and showed some improvement over the above two types. These baffles consisted of openings in the first and third quadrants through which the air could pass, while the second and fourth quadrants were blocked off with metal plates. Approximately one duct diameter downstream, another baffle was fixed with openings in the second and fourth quadrants and the first and third blocked off. Still the mixing was not considered good, but an improvement.

3. *Fans.*

a. A multi-blade fan was placed in the air stream and allowed to rotate as the air passed through it. This method did not produce mixing, as the air was not displaced but traveled essentially along its original path.

b. The same multi-blade fan was held in a stationary position and the air was forced through the openings between blades and again little mixing occurred. The resulting action was that of swirling as the air moved downstream. The pattern remained essentially the same; there was simply an angular displacement as the air passed downstream.

c. Powered fans were not tested because of the difficulty of mounting a moving mechanism in the duct and because of the introduction of unwanted heat.

Table 4. *Comparative performance of mixing devices*

		Louvered Strip	Louver-Baffle	Concentric Louver	Orifice* (0.5 diam. ratio)	Orifice* (0.33 diam. ratio)
Range of mixing effectiveness for different temperature patterns (percent)		90–99	97–99	97–99	85–97**	95–99**
Minimum distance between mixing elements (duct diameters)		1.5	0.92	2.0	----	----
Distance required to obtain indicated effectiveness (duct diameters)	97%	4.75	3.0	3.8	***	4.1
	95%	3.5	2.3	3.0	4.2	3.3
Change in effectiveness for range of velocity tested (percent)		1	3.2	1.3	3.3	1.4
Pressure drop through mixer (number of equivalent velocity heads)		7	38	5	43	166

*Reported in a previous publication (ref. [1]).
**The concentric temperature pattern was not considered in the evaluation of the orifice.
***An effectiveness of 97 percent was not achieved in the available length, 4.75 duct diameter, test duct.

5. Summary

Table 4 is a simplified presentation of comparative performance of the three mixers described in this paper plus the orifice as described in a previous publication [1]. From these studies on mixing devices it was shown that a poor distribution of temperature could be effectively improved by either the louvered strip, the louver-baffle, the concentric louver, or the 0.33-diameter ratio orifice. Each possesses good features and each has shortcomings. Consequently tradeoffs must be considered when selecting a mixer for a particular application. The concentric louver, the louver-baffle, and the 0.33-diameter ratio orifice were relatively unaffected by temperature pattern, whereas the louvered strips showed some sensitivity to temperature pattern. As shown in table 4, the resistance to flow for the louvered strip and the concentric louver when described in multiples of velocity head was 7 and 5, respectively, as compared to 38, 43, and 166 for the louver-baffle, 0.50-, and 0.33-diameter ratio orifices. The overall distance required to attain an effectiveness level of 95 percent ranged from 2.3 to 4.2 duct diameters. A 97 percent effectiveness was obtained by all of the mixers with the exception of the 0.50-diameter ratio orifice. Through reference to table 4, it can be seen that the change in effectiveness from 95 to 97 percent was accomplished in 0.7 to 0.8 duct diameter for the louver-baffle, the concentric louver, and the 0.33-diameter ratio orifice. The louvered strip mixer was less responsive to the change and required a distance of 1.25 duct diameters for the 2.0 percent increase in effectiveness.

Overall, the louver-baffle and the concentric louver mixers were comparable in their mixing effectiveness, with the tradeoffs being pressure drop and distance required for mixing. The mixing distance of the louver-baffle is approximately 0.8 of that required for the concentric louver, but the pressure drop is some seven times as high for the louver-baffle when compared to the concentric louver.

For all of the mixing devices, the magnitude of the temperature differences in the cross section of the air stream does not seem to affect the mixing effectiveness a great deal. As a word of caution, careful consideration should be given in determining the average temperature of the mixed air stream when large temperature differences are encountered prior to mixing. With large initial temperature differences, even with a high effectiveness, the temperature differences in the mixed portion of the air stream could be significant in some applications.

6. References

[1] Faison, T. K., Jr., Davis, J. C., and Achenbach, P. R., Performance of square-edged orifices and orifice-target combinations air mixers, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 12 (Nov. 1967).

[2] Faison, T. K., Jr., Davis, J. C., and Achenbach, P. R., A test apparatus for the study of forced air-mixing devices, J. Res. Nat. Bur. Stand. (U.S.), 70C (Eng. and Instr.), No. 1 (Jan.-Mar. 1966).

[3] Temperature: Its Measurement and Control, Thermoelectric Thermometry 1, 202 (Reinhold Publ. Corp., 1941).

[4] Wile, D. D., Air flow measurement in the laboratory, Refrigerating Engineering 53, No. 6, 515 (June 1947).

[5] ASHRAE Standard 41–66, Part I, Standard measurements guide, section on temperature measurements.

7. Appendix. Construction Techniques for Fabrication of Mixing Devices

Louvered Strip. This mixer was made of (24 gage) sheet metal and attachments between members were made by soldering or with screws. It is important that the outer band of the mixer be very nearly circular. This was accomplished by cutting a circular groove in a flat sheet of plywood into which could be fitted a metal band to form the outer edge of the mixing element. A metal strap approximately $d/6$* wide and πd long was fitted into the groove in the plywood and soldered to form the circular band. Five additional grooves were cut in the plywood to accept metal dividers which ran parallel to and along the diameter. Four dividers were fitted at equal distances parallel to the one along the diameter, thus cutting the circle into six parallel strips. Into each of these strips was fitted louvers, set at 60° from the axis of the duct on the downstream side but alternately, in adjoining strips, directing the flow upward or downward. The louvers were metal members, shaped to fit between the dividing strips. In figure 26 details are shown for both the louvers and the band with its dividing strips.

Two similar elements are required and are installed 90° out of phase; thus, if the first element directs the air vertically, the second element would direct the air horizontally.

*Since the mixers evaluated in this paper were 24 in in diameter, the dimensions referred to, if in inches, will be based on this particular size, if a function of d, will be based on duct diameter, d (any size).

Louver-Baffle. Again the circular band was made and held into place by a groove in the sheet of plywood. Along the diameter of the circle formed by the band, a metal strip was attached. The strip was attached at both ends to the circular band and was used to anchor the baffles. Metal strips of $d/6$ width were cut and served as the baffles. The baffles were attached to the metal strip along the diameter of the circle. The baffles were fitted so that they extended orthogonally from the strip to the band in an alternate fashion first to the right, then to the left; thus, six baffles were fitted onto the circular band covering approximately one-half of the area. Metal louvers were made of sheet metal and fitted onto the baffles in the positions as shown in figure 27. Small metal tabs were used to attach the louvers to the baffles and were made of a heavier metal to assure that the proper angle setting of the louvers was maintained. Louvers were fixed over each half of the circular area to direct the air flow to the other side of the duct 60° from its normal path. The two louvers nearest the center of each element were notched to permit flow of air through the center region with no greater restriction than that required for the other areas. The notched areas are shown in the rear view of the element in figure 27. Two similar elements are required and installed 90° out of phase; thus, if the first element directs the air horizontally, the second element would direct the air vertically.

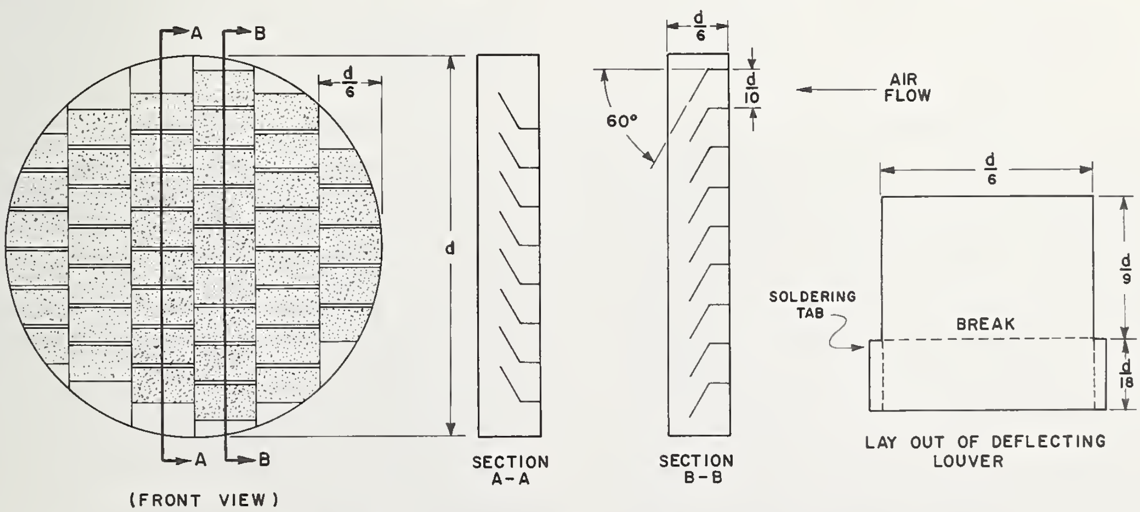


FIGURE 26. *A detail of the construction of the louvered strip mixing device.*

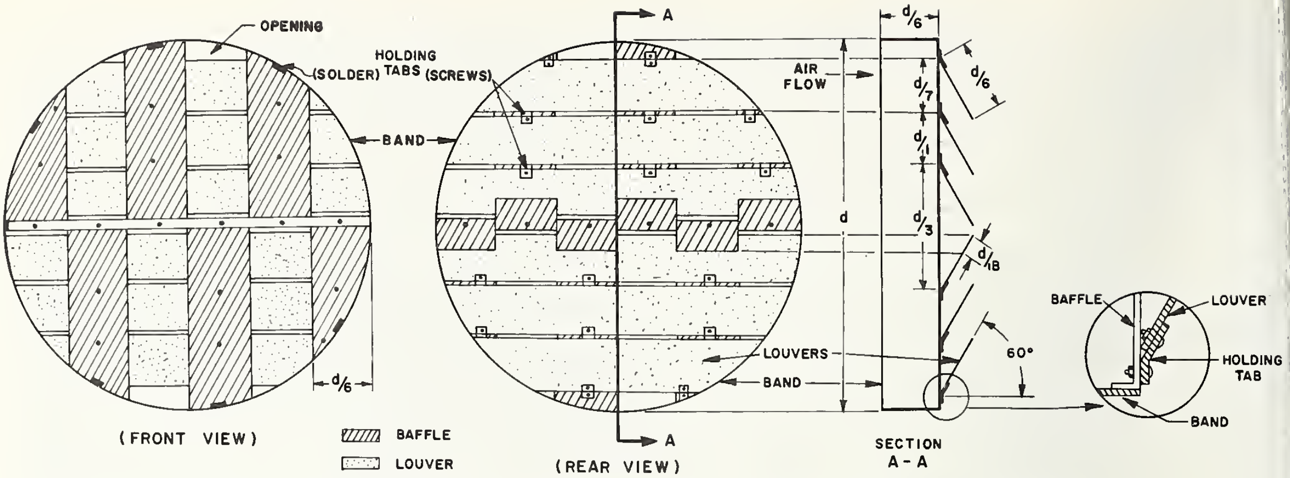


FIGURE 27. *A detail of the construction of the louver-baffle mixing device.*

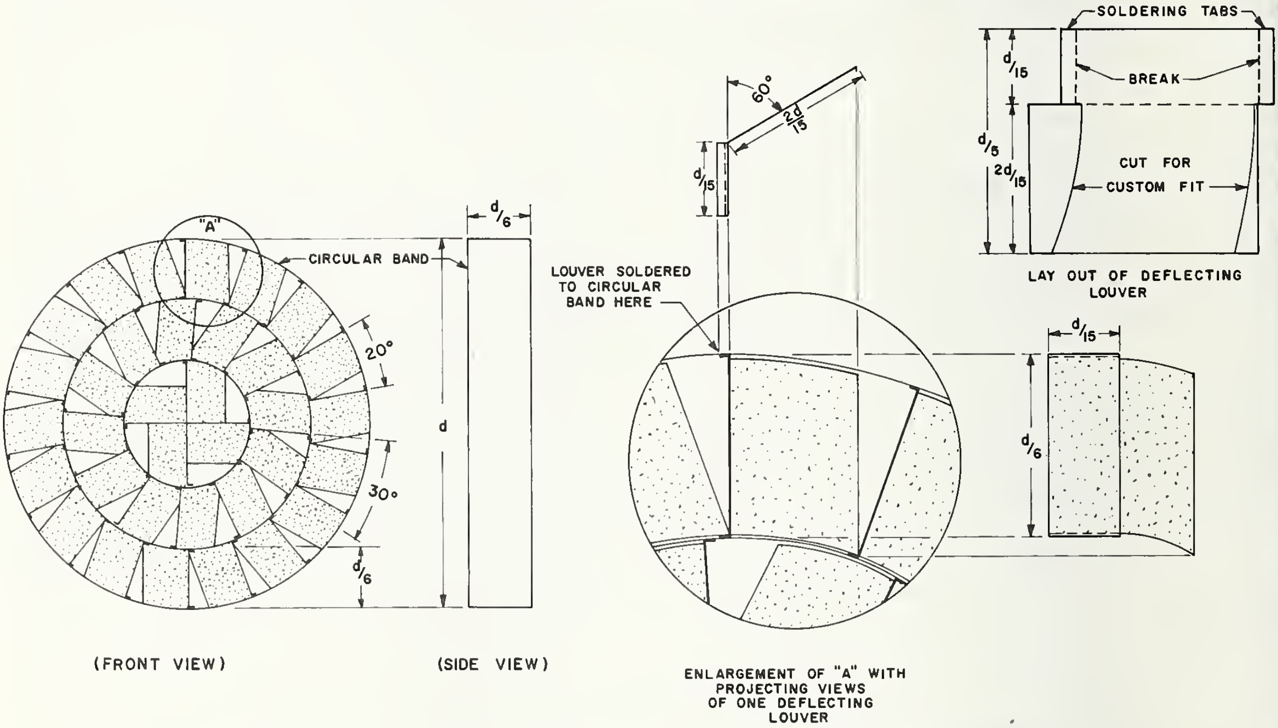


FIGURE 28. *A detail of the construction of the concentric louver mixing device.*

Concentric Louver. For this mixer three grooves are needed to accept the three bands having diameters of d, $2d/3$, and $d/3$ concentrically spaced; thus, providing a distance between bands of $d/6$. The spaces between bands were fitted with louvers which direct the air flow along the desired course. In the outer area, the louvers were set at an angle of 60° from the normal path of flow and caused the air to rotate around the axis of the duct in a clockwise or counterclockwise direction depending upon the louver setting. The adjoining area was fitted with louvers set at an angle of 49° from the normal path and caused a rotation in the opposite direction from that in the outer area. The central area is composed of four louvers with the same angle setting of 49°, but in the same direction as those of the outer area. The outer area was divided into 18 equal areas with the divisions being along the radius. The adjacent area toward the center was divided into 12 equal areas and the central portion divided into four parts. Figure 28 shows a detail of the concentric areas, divisions, and a louver pattern. The louvers are made from sheet metal and are custom shaped for each of the three areas. The louvers should not be made to fit too tightly between the bands as the angle may have to be adjusted after fabrication.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1970 O—373-166

(cut here)

Announcement of New Publications in Building Science Series

Superintendent of Documents,
U.S. Government Printing Office,
Washington, D.C., 20402

Dear Sir:

Please add my name to the announcement list of new publications to be issued in the series: National Bureau of Standards Building Science Series.

Name ______________________________

Company ______________________________

Address ______________________________

City ______________ State ______________ Zip Code ________

(Notification key N-339)

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards [1] was established by an act of Congress March 3, 1901. Today, in addition to serving as the Nation's central measurement laboratory, the Bureau is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. To this end the Bureau conducts research and provides central national services in four broad program areas. These are: (1) basic measurements and standards, (2) materials measurements and standards, (3) technological measurements and standards, and (4) transfer of technology.

The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Radiation Research, the Center for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of an Office of Measurement Services and the following technical divisions:

> Applied Mathematics—Electricity—Metrology—Mechanics—Heat—Atomic and Molecular Physics—Radio Physics [2]—Radio Engineering [2]—Time and Frequency [2]—Astrophysics [2]—Cryogenics.[2]

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to improved methods of measurement standards, and data on the properties of well-characterized materials needed by industry, commerce, educational institutions, and Government; develops, produces, and distributes standard reference materials; relates the physical and chemical properties of materials to their behavior and their interaction with their environments; and provides advisory and research services to other Government agencies. The Institute consists of an Office of Standard Reference Materials and the following divisions:

> Analytical Chemistry—Polymers—Metallurgy—Inorganic Materials—Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations in the development of technological standards, and test methodologies; and provides advisory and research services for Federal, state, and local government agencies. The Institute consists of the following technical divisions and offices:

> Engineering Standards—Weights and Measures — Invention and Innovation — Vehicle Systems Research—Product Evaluation—Building Research—Instrument Shops—Measurement Engineering—Electronic Technology—Technical Analysis.

THE CENTER FOR RADIATION RESEARCH engages in research, measurement, and application of radiation to the solution of Bureau mission problems and the problems of other agencies and institutions. The Center consists of the following divisions:

> Reactor Radiation—Linac Radiation—Nuclear Radiation—Applied Radiation.

THE CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in the selection, acquisition, and effective use of automatic data processing equipment; and serves as the principal focus for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Center consists of the following offices and divisions:

> Information Processing Standards—Computer Information — Computer Services — Systems Development—Information Processing Technology.

THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System, and provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world. The Office consists of the following organizational units:

> Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—Office of International Relations.

---

[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

U.S. DEPARTMENT OF COMMERCE
Washington, D.C. 20230

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE