#6261

EVALUATION OF SMOKING LOUNGE AIR DISTRIBUTION

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INTRODUCTION

The purpose of this study was to determine the most effective way to apply ANSI/ASHRAE Standard 62-1989 (1) to the practical design of smoking lounges. ASHRAE recommends ventilation rates and maximum occupancy but not the best way to distribute air within the room to maximize air quality. Different air distribution arrangements were tested in a full size smoking lounge using smokers to occupy and then evaluate each system. Temperatures and air motion were recorded for each arrangement. The measure of acceptability of the air quality was determined with a simple questionnaire administered to the smokers.

EXPERIMENTAL

Test Facility

A test room, 13' 11" by 19' 4" by 9' ceiling with a raised computer room type floor was built adjacent to an office/laboratory facility in Richardson, TX.

The room was ventilated by exhausting 60 CFM per person and supplying both cooling air and transfer to equal the exhaust. All supply came from adjacent offices thus no outside air was supplied. Figure 1 illustrates the general arrangement with fans, dampers and flow cross measuring stations.
Supply air was conditioned by cooling coils which were controlled by room thermostat. DDC controls (direct digital controls) regulated dampers equipped with multi point averaging sensors (flow crosses) to control air flows. Air flows were monitored by computer. The controls were calibrated to insure that the set points and air flows were accurate. In addition, a standard measuring hood was used to check the air flows before and after each test at all supply, transfer, and exhaust openings .

Air motion in the room was tested during unoccupied times by generating smoke with a smoke gun at points throughout the room and recording the movement.

Test Arrangements

Four physical air distribution arrangements were built as shown in Figure 2. Six variations on the arrangements were tested. All arrangements except 2R were tested at 60 CFM/occupant.

Arrangement 1 was a conventional diffusion type air distribution system using 2 four-way blow supply diffusers. Ceiling grilles near the north and south walls provided transfer air and exhaust, respectively.

In arrangement 2, the four-way blow diffusers were replaced with one-way blow diffusers discharging toward the east and west walls. For arrangement 2R, the exhaust volume was reduced to 30 CFM per occupant. Cooling air volume remained constant therefore transfer air volume was reduced to maintain air balance.

Arrangement 3, used four 4-ft linear diffusers in the ceiling at the center of each wall, discharging supply air at low velocity down each wall. Four grilles, near the floor in the north and south walls, supplied transfer air to the room. This arrangement was designed to approximate a displacement system.

In arrangement 4, to create a true displacement system, 45 (75%) of the solid floor tiles were replaced with perforated tiles In arrangement 4R the number of perforated floor tiles was reduced to 18 (30% of the floor area). Air flow quantities were not reduced. Cooling supply and transfer air were supplied to the room from the plenum space beneath the floor; the exhaust was located in the ceiling in the center of the room.

Analytical Measurements
Real time and integrated average measurements were obtained for a number of analytes including CO, CO_2, respirable suspended particles, nicotine, and 3-ethenyl pyridine. The results of these analyses are described elswhere (4). Analyte levels were typically low; for example CO_2 remained below 1000 ppm in all tests and average CO levels ranged between 1 and 1.5 ppm for the lounges ventilated at 60 CFM per person.

Smokers
Fourteen smokers, recruited for the study by a marketing research firm, smoked an average of 3.3 cigarettes per hour determined by counting cigarette butts (partially smoked cigarettes were counted as being completely smoked). They sat in chairs around the perimeter of the room during each test run. A television, for entertainment, was installed behind a window in the north wall.

Testing Procedure
Number of occupants (14) was based on ASHRAE Standard 62-1989 (1) of 7 people per 100 ft² net usable floor area. Net floor area was 200 ft². The exhaust rate was 840 CFM based on 60 CFM/person. Cooling air was 350 CFM at temperatures down to 52° F. Neither the supply nor the transfer air was filtered during the tests. Three replicate runs were performed for each of the six test arrangements.

For each experiment, air from the transfer air duct was sampled for ten minutes. Air was then sampled from the test room for ten minutes. Twenty minutes into the experiment, the smokers were instructed to begin smoking simultaneously. After the first cigarette, they smoked at will for the remainder of a 50-minute smoking period. At the 70-minute time point, the smokers were instructed to extinguish all cigarettes and exit the test room.

RESULTS AND DISCUSSION

Ballots

To assess air quality, ASHRAE Standard 62-1989 (1) recommends the use of a subjective ballot. For this investigation, the smokers were asked to indicate their satisfaction with air quality on a ballot as they exited the test room at the end of each experiment. The ballot consisted of a single statement, "The air quality in the smoking lounge was acceptable to me. : True or False?". Three replicate experiments (14 ballots) were performed for each condition which resulted in a total of 42 ballots being collected for each arrangement tested.

The results are given here in Table 1. The highest ratings of air quality satisfaction were obtained for arrangements 1&2. Assuming 80% satisfaction as a minimum level of acceptability, the two conventional air distribution system, Arrangements 1 & 2, and Arrangement 4R will provide acceptable air quality for smoking lounges. Under maximum usage conditions, reducing the ventilation to 30 CFM per smoker had a detrimental impact on air quality in a smoking lounge as indicated by reduced occupant satisfaction.

	Arr. 1	Arr. 2	Arr. 4R	Arr. 3	Arr. 2R	Arr. 4
Ballots - % Acceptance	93	88	81	79	69	45

Table 1. Percent of respondents who agreed with the statement "The air quality in the smoking lounge was acceptable to me" for each test room arrangement.

Air Distribution

Air patterns are graphically illustrated in Figures 3-7. Table 2 details air flow rates, temperatures, and the ADPI index for each test. Generalizations about comfort and air quality can be drawn from this information. Temperature and air velocity was measured in the test rooms at various heights in five locations. Four of the locations are marked on Figure 2 as A, B, C, and D. The remaining measurement was obtained in the center of the room. ASHRAE 62-1989 (1) refers to ANSI/ASHRAE 55-1981 (2) for acceptable environmental conditions. All temperature measurements taken at the 4 ft level fell within the recommended range of 72.5 to 76.5° F. The cooling system was able to control the room temperature during the test within 1° F . The exceptions to this were the tests of Arrangements 4 and 4R. In these tests the supply and transfer air was introduced under the floor and the thermostat was unable to attain the same level of control. Between the 4 in. and 4 ft level, the temperature variation did not stray beyond the recommended value of 5° F in any configuration.

The air diffusion performance index (ADPI) is a method for evaluating comfort based upon local air velocities and temperature differences from the reference room temperature (3). Calculating the ADPI using test data for each run yields results over 80 (indicating 80% of the occupants rating the air as comfortable) for each arrangement tested with the exception of Arrangement 2. The Arrangement 2 data contain a large number of points with velocities over 70 FPM which are greater than the comfort limit for calculating ADPI.

This conflict between the ADPI and ballot ratings of air quality may be clarified by a review of the air patterns in Figures 3 through 7. The velocity approach to the exhaust in Figure 3 shows a portion of a hemispherical air pattern to the exhaust inlet. This is a typical pattern around an exhaust or return intake. When the outer circle of air velocity is only about 20 FPM, air streams of slightly higher velocity can move past this circle without being drawn into it. Figure 4 shows that in Arrangement 2, the air thrown toward the East wall moved down the wall and toward the floor and the north and south walls. Air throughout the room, and especially at the ceiling, was moving to be induced into the supply and transfer air jets. In this pattern the transfer air jet was a major factor in the results. Transfer air was supplied at 514 CFM and a 480 FPM jet velocity was projected straight down to the floor. Air near the ceiling was induced into the jet and a well mixed air pattern in the room was produced. The south wall air pattern shows that the jets from the one-way diffusers followed along the wall downward toward the floor. The majority of smokers sat along the South wall to watch the television located behind the North wall partition. This allowed a clear movement of their smoke up toward the exhaust and contributed to their satisfaction with the air quality.

In Arrangement 2R the transfer air flow was reduced to 76 CFM. At this lower flow, mixing was not as effective. The combination of higher smoke concentrations and poorer mixing may have led to the low acceptance ratings shown in Table I. These results demonstrate that a relatively high velocity jet with high induction projected down to the floor would be desirable.

The air flow patterns in Arrangement 1 were similar to those in Arrangement 2. An exception was that air was projected across the ceiling in 4 directions. That portion of the air which flowed down the South wall, passed by the smokers along this wall and carried contaminants to the center of the room. This movement of smoke away from the smokers may have helped to increase the acceptability rating.

In arrangement 3 the four linear diffusers carried the smoke away from the smokers toward the center of the room. The linear diffusers were selected to produce a relatively low velocity with the intent to discharge the air to the floor and let it react like a displacement ventilation system. Displacement ventilation was not achieved with this system. The air quality acceptability was judged just short of 80% .

Stratification occurred in Arrangement 4 (Figure 6) - a dense layer of smoke which hovered 2 - 3 ft above the floor was bounded on the top and bottom by relatively clear air. This resulted in nearly all of the contaminants remaining in the vicinity of the smokers. Cooling effect was lost because the main cooling remained near the floor. Air quality was judged poor in comparison to Arrangements 1, 2, 3, and 4R.

Arrangement 4R (Figure 7) resulted in a stratification layer at about the same level as the sampling tube, about 4'. A smoke check of this air flow showed a solid layer of smoke that gradually moved toward the walls. At the walls the stratification layer joined with air from under the layer then moved up the walls toward the ceiling and the exhaust inlet. Despite this air flow pattern, the air quality in this Arrangement was rated as acceptable.

CONCLUSIONS

The most acceptable level of satisfaction of indoor air quality at the ASHRAE Standard 62-1989 (1) levels of ventilation, as described by occupant ratings, can be attained in a smoking lounge using conventional air distribution designs which maximize the mixing of air within the lounge and which move smoke away from occupants. Under the occupancy and airflows used for this test, the vertical velocity of air in the displacement configurations was not great enough to rapidly move smoke away from the occupants.

Results obtained in this study demonstrate that conventional air distribution and the use of transfer air will provide acceptable air quality at minimal construction and energy costs.

Several smoking lounges have been successfully built using the recommendations of this study. One large lounge used a fan powered box to introduce not only the cooling air but also the transfer air through the ceiling diffusers. Exhaust exceeds supply by 10% which maintains a negative pressure in the lounge relative to adjacent spaces. Results have been very satisfactory. Further testing of this application is planned.

REFERENCES

1. ***ANSI/ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality***, Atlanta: American Society for Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

2. ***ANSI/ASHRAE Standard 55-1981, Thermal Conditions for Human Occupancy***, Atlanta: American Society for Heating, Refrigerating, and Air- Conditioning Engineers, Inc.

3. **1981 ASHRAE Handbook--Fundamentals**, Atlanta: American Society for Heating, Refrigerating, and Air- Conditioning Engineers, Inc., Ch. 32.6.

4. P.R. Nelson, R.B. Hege, J.M. Conner, G.B. Oldaker,III, and H.E. Straub; ***Effects of Ventilation on Smoking Lounge Air Quality***, in Proceedings of the 1992 EPA/A&WMA International Symposium on Measurement of Toxic and Related Air Pollutants, Air and Waste Management Association, Pittsburgh, In Press.

CFM, TEMPERATURE, AND VELOCITY READINGS

ARR.1	RUN 1		RUN 2		RUN 3		ELEV	CTR		A		B		C		D	
	CFM	TEMP	CFM	TEMP	CFM	TEMP		V	T	V	T	V	T	V	T	V	T
SUPP	350	55.2	350	54.1	350	58.9	8'	-	73.2	25	72.3	35	72.7	40	71.6	45	71.9
EXH	866	78.3	850	78.2	866	77.2	6'	-	72.6	35	72.4	35	72.9	30	71.4	65	71.5
TRAN	500	77.2	500	77.5	500	77.0	4'	-	73.1	35	72.4	25	72.6	30	72.0	50	71.1
ROOM		73.1		74.1		73.2	2'	-	73.4	40	72.7	30	73.0	25	72.5	40	71.6
ADPI	= 94						4"	-	74.4	55	72.9	40	72.7	40	72.3	60	72.6

ARR.2	RUN 1		RUN 2		RUN 3		ELEV	CTR		A		B		C		D	
	CFM	TEMP	CFM	TEMP	CFM	TEMP		V	T	V	T	V	T	V	T	V	T
SUPP	344	57.9	350	56.8	354	57.7	8'	-	74.0	25	73.7	60	73.5	40	73.5	25	73.1
EXH	849	77.5	849	75.2	849	76.1	6'	-	73.8	25	74.0	30	74.1	40	73.5	30	73.0
TRAN	514	77.4	514	75.2	514	76.1	4'	-	74.1	60	73.5	25	73.7	30	73.1	65	72.1
ROOM		74.1		73.1		73.1	2'	-	74.4	100	73.5	25	73.5	40	73.1	100	72.4
ADPI	= 56						4"	-	75.1	75	73.1	75	72.3	85	72.9	120	71.6

ARR2R	RUN 1		RUN 2		RUN 3		ELEV	CTR		A		B		C		D	
	CFM	TEMP	CFM	TEMP	CFM	TEMP		V	T	V	T	V	T	V	T	V	T
SUPP	340	59.2	354	59.4	350	60.0	8'	-	74.7	25	74.0	20	73.6	25	73.7	25	74.0
EXH	433	76.6	433	78.4	433	79.8	6'	-	74.1	25	73.7	20	73.2	30	73.7	30	73.4
TRAN	76	82.9	76	84.4	76	85.0	4'	-	74.4	20	72.9	30	73.0	30	72.9	25	72.9
ROOM		73.4		74.4		75.4	2'	-	74.0	80	72.4	45	72.5	50	72.7	30	72.4
ADPI	= 82						4"	-	74.3	75	72.2	25	72.0	30	72.4	25	72.2

ARR3	RUN 1		RUN 2		RUN 3		ELEV	CTR		A		B		C		D	
	CFM	TEMP	CFM	TEMP	CFM	TEMP		V	T	V	T	V	T	V	T	V	T
SUPP	344	58.4	356	56.8	352	57.4	8'	60	76.0	25	75.6	20	74.8	25	75.0	20	75.4
EXH	857	76.4	857	72.9	857	74.0	6'	25	75.7	24	74.3	20	74.3	30	74.3	25	74.8
TRAN	487	79.4	492	77.1	496	85.0	4'	30	76.0	30	73.7	25	73.7	35	73.6	25	74.3
ROOM		76.1		73.3		74.2	2'	30	75.4	30	73.5	30	72.9	30	74.0	25	73.4
ADPI	= 100						4"	25	74.3	75	72.2	25	72.0	30	72.4	25	72.2

ARR4	RUN 1		RUN 2		RUN 3		ELEV	CTR		A		B		C		D	
	CFM	TEMP	CFM	TEMP	CFM	TEMP		V	T	V	T	V	T	V	T	V	T
SUPP	349	55.5	349	55.1	354	55.5	8'	65	74.5	20	73.8	<10	74.2	<10	73.9	<10	74.0
EXH	839	74.0	839	75.1	839	74.4	6'	20	74.4	<10	73.7	<10	74.0	<10	74.0	<10	74.0
TRAN	492	79.1	492	78.9	492	78.8	4'	<10	74.3	<10	73.2	<10	73.5	<10	73.6	<10	73.6
ROOM		74.3		75.0		74.4	2'	<10	72.9	<10	72.8	<10	72.7	<10	73.2	<10	73.1
ADPI	= 100						4"	<10	73.0	<10	71.1	<10	71.9	<10	71.7	<10	72.1

ARR4R	RUN 1		RUN 2		RUN 3		ELEV	CTR		A		B		C		D	
	CFM	TEMP	CFM	TEMP	CFM	TEMP		V	T	V	T	V	T	V	T	V	T
SUPP	352	52.9	349	50.2	349	51.3	8'	65	75.7	-	-	-	-	-	-	-	-
EXH	857	76.5	840	74.6	857	75.2	6'	<10	75.0	-	-	-	-	-	-	-	-
TRAN	492	80.9	489	79.5	482	81.1	4'	<10	74.8	-	-	-	-	-	-	-	-
ROOM		74.8		74.8		75.2	2'	<10	73.0	-	-	-	-	-	-	-	-
ADPI	= 100						4"	<10	72.9	-	-	-	-	-	-	-	-

SUPP - Supply Air, EXH - Exhaust Air, TRAN - Transfer Air, V - Velocity in FPM, T - Temperature in °F., Elev - Elevation in Ft. or In.
CTR, A, B, C, D, - Measuring points.

Table 2. Airflows (±25 CFM), temperatures (± 1°F.), velocities (± 5 FPM), and ADPI determined for each of the ventilation arrangements tested. Temperature and velocity readings were obtained at the measuring points indicated in the Arrangement 1 drawing in Figure 2.

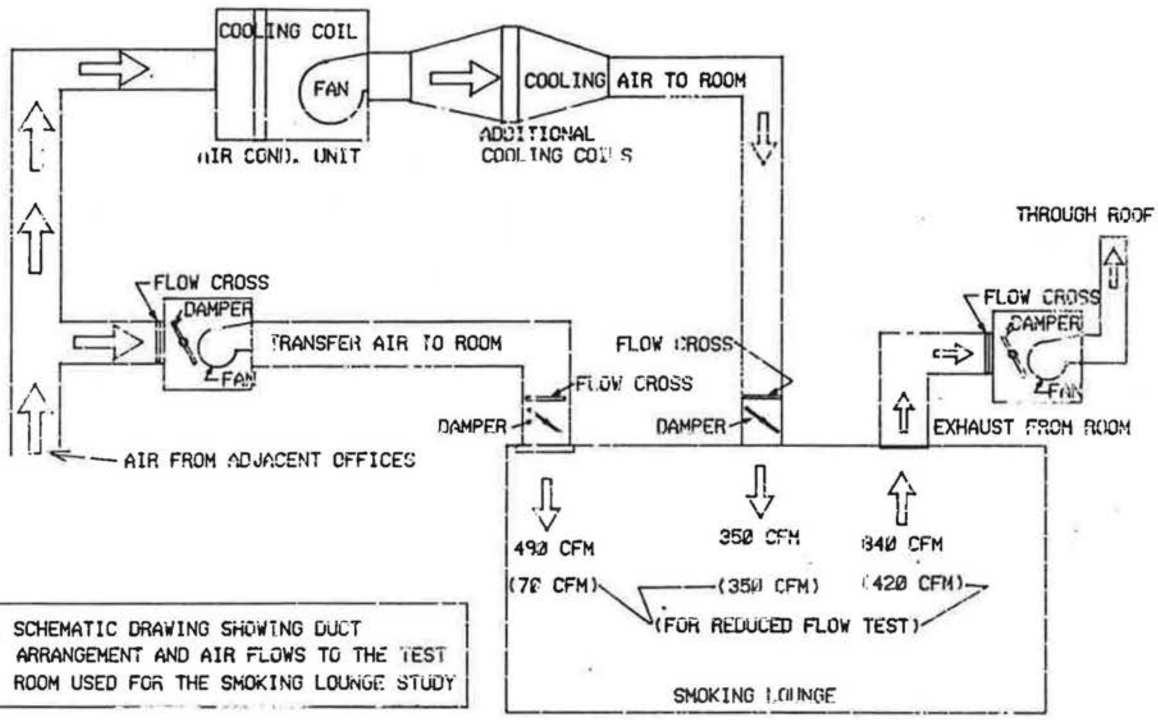


FIGURE 1. SCHEMATIC DRAWING SHOWING DUCT ARRANGEMENT AND AIR FLOWS TO THE TEST ROOM USED FOR THE SMOKING LOUNGE STUDY

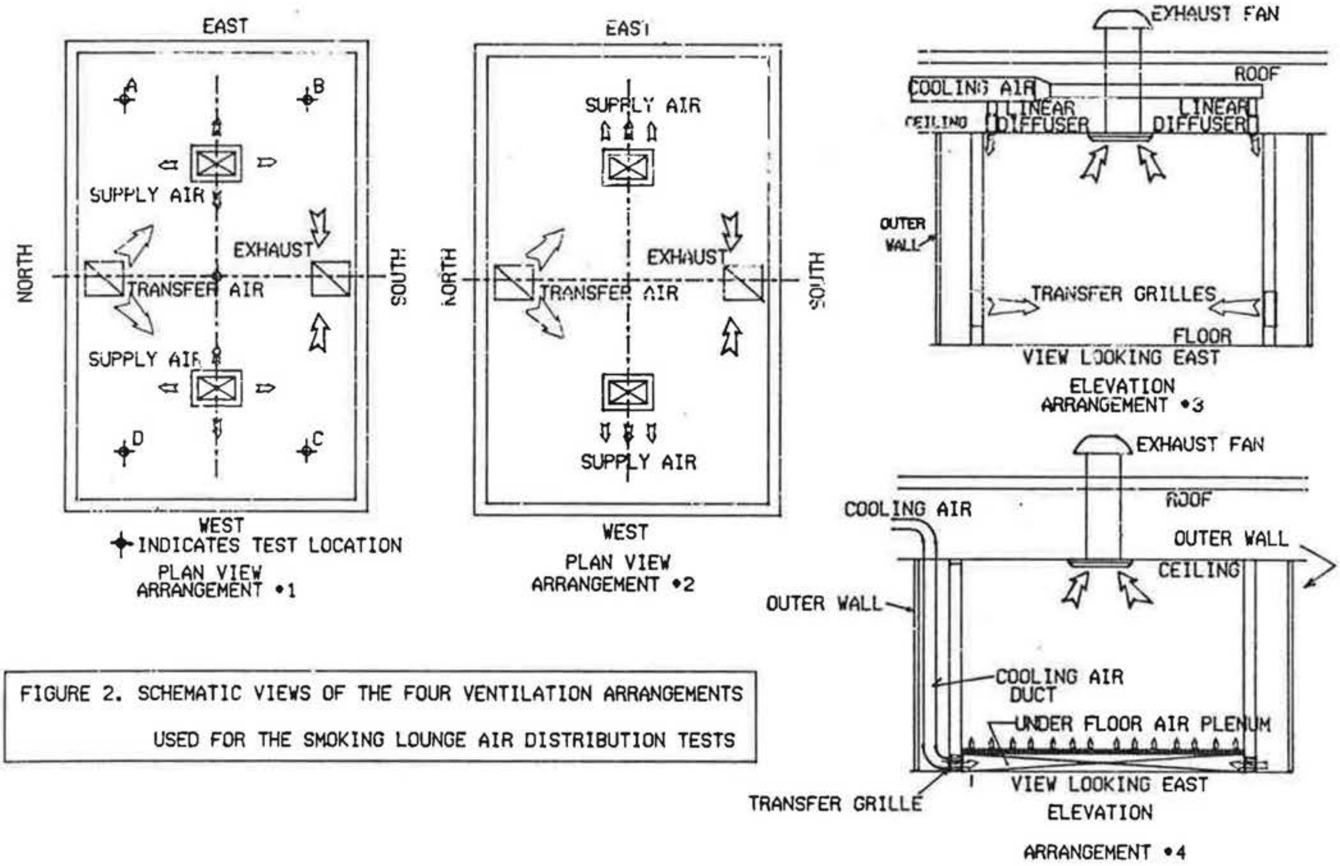


FIGURE 2. SCHEMATIC VIEWS OF THE FOUR VENTILATION ARRANGEMENTS USED FOR THE SMOKING LOUNGE AIR DISTRIBUTION TESTS

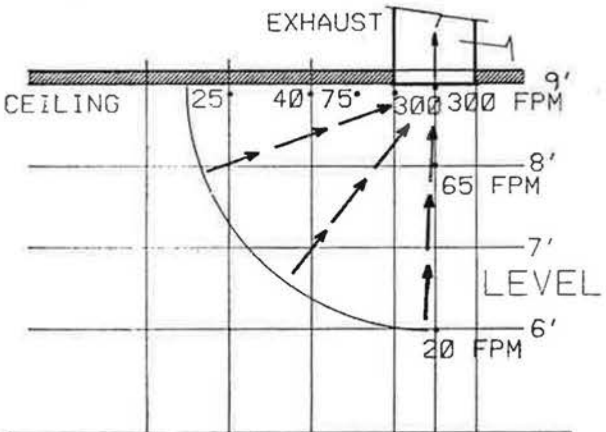
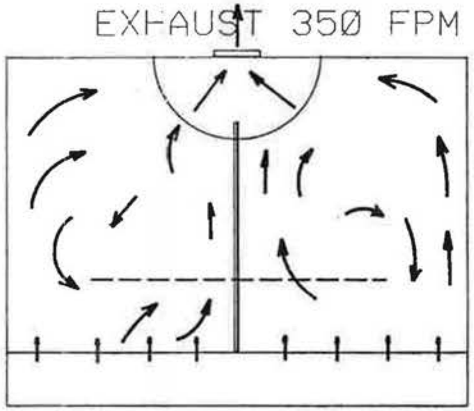
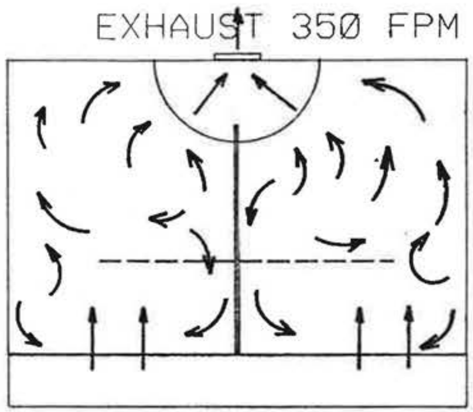


FIG 3. AIR FLOW VELOCITIES IN VICINITY OF TEST ROOM EXHAUST



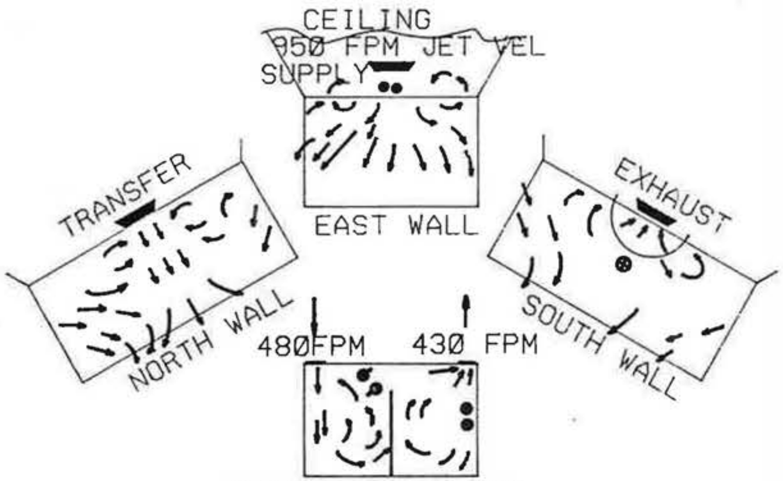
CENTER ELEVATION
45 PERF. FLOOR TILES
20 FPM/HOLE

FIG 6. AIR FLOW PATTERNS IN TEST ROOM - ARR. 4



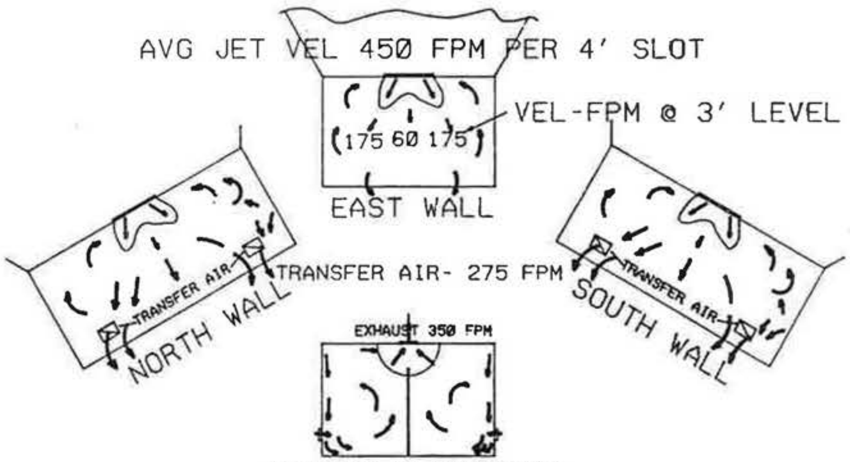
CENTER ELEVATION
18 PERF. FLOOR TILE
80 FPM/HOLE

FIG 7. AIR FLOW PATTERNS IN TEST ROOM - ARR. 4R



CENTER ELEVATION

FIGURE 4. AIR FLOW PATTERNS IN THE TEST ROOM OPERATED IN ARR 2



CENTER ELEVATION

FIGURE 5. AIR FLOW PATTERNS IN THE TEST ROOM OPERATED IN ARR 3