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ADDRESSING DISCOMFORT AND DISSATISFACTION IN A WINDOWLESS SCHOOL

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The occupants of a 40-classroom, windowless secondary school in Toronto, Canada, have complained of poor thermal comfort and poor indoor air quality for the past 12 years. Modifications to the heating and ventilation systems have been made to provide more outdoor air, and better air circulation. Heating stacks have been raised to avoid boiler effluent contaminations, heat exchangers installed for energy conservation and better thermal control, and a new humidification system installed.

Indoor air quality tests in December 1988 confirm comfort guidelines were being achieved, yet approximately 30% of the occupants continue to complain of poor thermal comfort and/or poor air quality.

SCHOOL BOARD RESOLUTIONS

The Toronto School Board in 1989 passed the following resolutions:

(a) That windows that open and are of an appropriate size be used in all new school construction.

(b) That mechanical air handling systems shall be properly designed to provide a clean, healthy school environment.

(c) That mechanical air handling systems be maintained and operated to design specifications at all times.

(d) That pollutants within school buildings be eliminated where possible or controlled to acceptable environmental standards.

(e) That educational programs be instituted to ensure that building occupants and school plant personnel share the responsibility for the internal environment and contribute to its improvement and upkeep at all times.

(f) That the above recommendations apply to all new school construction and/or major renovations.

INTRODUCTION AND HISTORY

The Toronto School Board in 1971 built a three-storey school, West Toronto Secondary School, for 1200 students. All classrooms are located in the interior space of each floor. Corridors with windows separate classrooms from the outside. This was the era when many educators thought windowless classrooms were better, as students would not be distracted from their studies. Architects and engineers liked the design as environmental conditions could be more easily controlled.

The building's heating and ventilating system was designed to maintain year-round thermal comfort with individual room control. Design criteria was minimum fresh air of 6 1/s per person.

When complaints were received, various attempts were made to repair and adjust the heating/cooling system. However, complaints continued and by the early 1980's a special task force was formed to do a full investigation.

In July 1985 they reported "poor ventilation" and "poorly controlled temperatures" in some rooms; "low humidity" and "deficient quantity of return air" throughout.

Various repairs were carried out with some success. The task force also recommended engaging an independent consultant "to review the problem and recommend various solutions regarding improving classroom ventilation".

Dr. F.C. Hooper of the University of Toronto was engaged to investigate the ventilation system, especially in relation to the complaints of poor air quality. Dr. Hooper used gas tracer techniques to determine actual rates of air change and air circulation within the building. He investigated the building for construction discrepancies and, aided by Board psychologists, studied the psychological effects of light, colour and space. Investigations and tests were done in August 1985.

Dr. Hooper's testing determined the ventilation efficiencies to be relatively high, 70 to 90 percent, "indicating fairly good mixing of the supply air and room air, and they do not suggest that there is much room for improvement, in the type or location of the diffuser grilles". However, teachers often left doors open and efficiencies were noted to be less than 50%.

In order to meet the criteria of 1000ppm CO2 or less, Dr. Hooper determined 100 percent outdoor air was required for most classrooms. The height of the boiler stacks indicated a high probability of downwash occurring under certain meteorological conditions, resulting in high concentrations of CO2 entering the classroom ventilation systems. The intakes and exhaust locations were adjacent to each other, resulting in high amounts of re-entrainment occurring.

The Board psychologists found the lighting adequate but with the unitary room colour the overall effect was monotony. They found the occupants had no sense of control in the rooms. They suggested that complaints might continue even after the

ventilation problems were corrected. They recommended teachers and students be involved with other Board personnel in developing and implementing physical changes.

Dr. Hooper made the following recommendations:

1. That the ventilation system be operated in the 100% fresh air mode whenever the building is under normal occupation.

2. That the classroom exhaust air vents on the east and west walls be ducted upward to roof level to eliminate cross-over mixing.

3. That the air circulation rate be increased by approximately 10% by increasing the speeds of fans numbers 1, 2, 7, and 8, and by opening additional parallel return ducts to compensate for the obstructions in the present return air passages.

4. That the boiler flues be raised to put the outlets at least 22 feet above the roof surface, and that any caps or other rain shedding devices used not be of a design that would deflect the gases downward.

5. That attention be directed to evaluating the advantages of heat recovery heat exchangers between the classroom area exhaust air stream and the fresh air stream.

6. That action to reduce the oppressiveness of the classrooms and workrooms be taken where possible, through wisely chosen colours or designs, differentiated lighting or by other devices which will relieve the stresses felt by some people in windowless spaces and which may also reduce the tendency to leave classroom doors open.

ACTION TAKEN

Work commenced in early 1986 in stages to carry out the corrective action. Recommendations 1 to 5 were completed by mid 1989. No action has been taken on recommendation 6. During the installation of the first of two heat exchangers in the fall of 1988 the ventilation fans were shut down for a short period of time on a regular school day. This precipitated a large number of air quality complaints. Teaching staff at the school expressed doubt that air quality conditions had improved at all even though most modifications had been completed.

Following meetings with school staff, it was agreed to engage an independent consultant to carry out indoor air quality tests. Goodfellow Consultants Inc. was engaged in December 1988. A full range of testing was carried out December 13, 14 and 15, 1988 during school hours, with the following results:

	Measured Level	Comfort Level
Carbon Dioxide	420-800 ppm (outdoor level was 350-400 ppm)	below 1000 ppm

	Measured Level	Comfort Level
Total Suspended Particulates	- 60 ug/cu.m. (outdoor level was 120 ug/cu.m.)	below 100 ug/cu.m.
Volatile Organic Compounds	145-270 (outdoor level was 148-215)	not specified
Bacterial/ Mold Contents	120 cfu/cu.m. maximum	750 cfu/cu.m.
Temperature	20.0-22.5 degrees C (room 336 was 24.8 degrees C)	20-24 degrees C
Humidity	12-47.7%	25-60%

The levels of airborne contaminants were generally below the accepted comfort levels. One exception was the relative humidity. Low levels (as low as 10%) were detected on a day when the outside air was cold and dry.

Ventilation Rates

Two methods were used to measure the ventilation rate and both measurements concluded that the ventilation rate was adequate.

Method	Measurement*	Recommended Criteria
Direct air volume measurement	10-130 l/s/ person	8 1/2/person
Tracer gas decay method	5.4-11.1 ACH	4.5 ACH

*Remark When the damper was switched to maximum RA, the measurement was ranged from 4 to 130/person.

Dr. Goodfellow notes 12% and 26% of exhaust air were re-entrained by the intakes for the "East" and "West" systems. (The "East" system had the exhaust and intakes separated.) Dr. Goodfellow agreed the higher boiler stacks were sufficient to avoid any downwash. However, poor thermal control on the "West" unit and poor air motion was noted due to side wall-mounted supply grilles. Dr. Goodfellow noted "the characteristics of the wall-mounted supply grilles, including location, long throw and low air induction and temperature equilibrium rates amplifies the problem".

Dr. Goodfellow made the following recommendations:

1. It is necessary to ensure that the system is balanced according to the occupancy.

2. There is no additional recommendation to remove the pollutants.

3. It is recommended to have a control expert to inspect, test, calibrate or replace the individual room thermostat. Its location should also be reviewed.

4. Install a pre-heat system for the "West" system.

5. It is suggested to increase the air induction and thermal equilibrium rates of the supply air.

6. An operator must be fully trained in the operation of the air handling system and must be instructed to:

   - set the recirculation damper at "min RA" when the building is occupied
   - check the damper positions regularly
   - inspect and replace filter regularly.

7. The conversion of the "West" system to 100% fresh air is not justified.

8. An HVAC specialist should inspect the humidification system to ensure that it is working properly and that it has sufficient humidification capacity on days when the outside air is cold and dry.

PRESENT SITUATION

Further steps have been taken to improve the environment, i.e. replace blank thermostat covers with thermometers, installation of the "West" heat exchanger, a fully trained operator in attendance, and repair of the humdifiers. A full air balance is still required, however complaints mainly of overheating in the spring and fall continue.

CONLUSIONS

1. Good thermal comfort and air quality is required at all times in windowless classrooms.

2. Building operators need to be well trained in the operation of heating and cooling systems for windowless schools.

3. Continued liaison between occupants and building operators is required.

4. Repairs must be carried out quickly.

5. Further consultation with students and staff is necessary to determine what additional steps are necessary for a satisfactory indoor environment.

6. The construction of windowless schools should be avoided.