Ventilation Investigations in Factory Buildings

by

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The paper describes findings of a ventilation survey carried out in factory buildings employing various types of ventilation systems. It is found that shortage of power in summer prevents the continuous running of cooling plants. These are either shut down or run intermittently. Consequently, uncomfortable environment is created and natural ventilation sought for to ameliorate the indoor conditions. Provision of ceiling fans is advantageous for enhancing air motion in all types of buildings including those employing evaporative cooling system. Forge and foundry shops should be provided with air douches for spot cooling. Buildings which rely only on natural ventilation should have openings of appropriate sizes in walls and roof as well. Arrangement for adequate natural ventilation should also be made in buildings fitted with forced ventilating system, and because of the uncertainty of the power supply, total reliance should not be placed on mechanical ventilation.

Introduction :

Ventilation is the most commonly adopted method for control of contaminants and indoor thermal environment in industrial buildings. Better control and greater reliability have led to the preference of mechanical to natural ventilation system. However, the inherent problem in the adoption of mechanical systems lies in the occasional shut down of electrical power. It is also desirable to check the wasteful consumption of power in the operation of air moving appliances and to explore the feasibility of employing natural ventilation to avoid unnecessary expenditure. With this in view, ventilation systems employed in several factories with different types of industrial processes were examined to evaluate the resulting indoor conditions. The findings of the survey together with suggestions for improvement are presented in this paper.

Scope of Survey :

The factory buildings covered in the survey can be broadly divided into three categories; (i) Light industries manufacturing electronic goods (ii) Medium industries manufacturing light mechanical gadgets, (iii) Heavy industries producing large electrical appliances. Each factory comprised of several shops for carrying out different processes, like foundry, forging, electroplating, spray painting, electronic assembly, machining etc. Data on the sizes and location of ventilation openings and also details of ventilation system in use in various shops were collected. Dry bulb temperature, wet bulb temperature and air velocities were measured at several points in the normal working zones indoors. Simultaneous measures of the outdoor climatic conditions were also made. The survey was carried out in hot dry, and rainy seasons. The results are summarised in Table 1.

Results and Discussion

(a) Forge and Foundry Shops:

The common enclosures for forge and foundry shops have pitched roofs with openings in their monitors, and partly covered walls. The ventilation is usually natural. However, at few places pedestal fans are also provided for local air movement. It is observed that when openings are provided only on one wall (S. No. 1.1) the indoor air motion varies from 0.05 to 0.15 m/sec. Thus the air is almost still and the high indoor air temperature (41°C) makes the ambient conditions far from satisfactory. It is also noted that when large size openings are provided on walls and roof (S. No. 1.2 & 1.3) wind speeds varying from 0.13 to 2 m/sec are induced in the working zone. This enhances the cooling effect and consequently indoor conditions are considerably ameliorated. Wind speeds measured at roof openings vary from 0.35 to 1.5 m/sec. (S. No. 1.2 & 1.3). This causes 7 to 23 air changes per hour in the shops and contributes significantly to the removal of heat from the forging and foundry processes. A comparison of data collected in various shops (S. No. 1.1, 1.2, 1.3, 1.4 & 1.5) indicates that provision of ample natural ventilation through suitably designed walls and roof openings[10] is needed for extracting heat and inducing air motion for thermal comfort in forge and foundry shops. In the summer season the indoor temperatures are very high and general natural ventilation may not suffice for the comfort of workers. This may possibly be accomplished by the use of air douches.

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TABLE I

S. No.	Name of the Building	Type of roof	Size of Building	Location of Openings	Size of Openings	Systems of ventilation	Outdoor conditions: Wind speed/ direction (m/sec.)	Outdoor conditions: Temperature °C	Outdoor conditions: Relative humidity (percent)	Indoor conditions: Wind speed m/sec.	Indoor conditions: Temperature °C	Indoor conditions: Relative humidity (percent)
1.1	Foundry and	Sawtooth roof	180x16x6.9m	Wall Roof	Door on one wall only. 0.7m high fitted with S type louvers	Natural	1.0-2.0/ oblique to the wall openings	40	41	0.05-0.15	41	[illegible]
1.2	Forge Shops	Pitched roof	180x16x6.9m	Wall Roof	Doors on Opposite walls one of the longer walls is partially open 0.5 m high	Natural	1.0-2.0/ oblique to the wall openings	40	41	0.4-1.75	40	[illegible]
1.3		Pitched roof	180x16x6.9m	Wall Roof	Fully open on one side 1.4 m high	Natural	1.0-2.0 oblique to the wall openings	40	41	0.4-2.5	40	38
1.4		Pitched roof	48x45.5x155x25 m	Wall Roof	Openings fitted with inclined louvers are provided over the entire longer walls up to a height of 2.3 m above the floor. 2.7 m high	Natural	0.5-1.5 Parallel to the wall openings	32	66	0.2-1.0	32	68
1.5		Pitched roof	168x80x22.5m	Wall Roof	276 m² on each of the shorter walls. One longer side fully open. 2.7 m high	Natural	0.5-1.5 perpendicular to wall openings	32	66	0.2	30.5	72
2	Electroplating shop	Pitched type roof fitted with false ceiling	25.5x25.5x4m	Wall Roof	Door 10.5 m² in size on one wall only. NIL	10 exhaust fans for general ventilation & 9 exhaust fans for local extraction	0.5-2.4	36	47	0.1-0.2	32	45
3	Machine shop	Pitched roof	18 bays each of size 18x.2x18x6.4m	Wall Roof	3 windows each 1.5x1.2 m size (closed) located in each bay. 0.9 m high along half the bay depth	Forced Draft Ventilation	1.0-2.0	40	41	0.1-2.0	35	68
4.1	Electronics Shops	Folded plate type roof	64x48x5m	Wall Roof	Windows with 1.0 5 m height (closed) are provided on an exposed wall covering half of wall width. NIL	Forced Draft Ventilation	2.0	38	40	0.1-0.2	32.5	70
4.2		Folded plate type roof	50x40x5 m	Wall Roof	Windows with 1.0 5 m height covering about the half wall width are provided on opposite walls. 4 exhaust fans are fitted on one of the side wall	Natural	0.2 parallel to the wall openings	38	40	0.05-0.1	35	54
4.3		Pitched type roof fitted with false ceiling	50x30x4m	Wall Roof	8 windows with 1.2x1.2 m size are provided on one of the shorter wall and 5 exhaust fans are provided on other of the shorter wall. NIL	Forced Draft Ventilation	0.5-2.4	36	47	0.15-0.5	32.5	45

(b) [illegible] Electroplating Shops :

[illegible] electroplating shop with 625 m² floor area is provided with dual ventilation system. Rim exhaust is [illegible] for removal of contaminants given off from [illegible] used for hot dipping, electroplating, [illegible] etc. The process baths are not enclosed in ventilating chambers and extraction is carried out with the help of nine exhaust fans (900 mm size). [illegible] exhaust fans (900 and 600 mm size) are also [illegible] on exposed wall for the general ventilation of the shop. On an adjacent wall close to the [illegible] large door (3 x 3.5 m²) is provided to facilitate [illegible] into the shop. (S. No. 2). Thus ventilation is [illegible] mainly by exhaust fans without making [illegible] provision for natural inlets. A visual [illegible] of the shop revealed that the working space was filled with obnoxious vapours. Obviously, the ventilating system in use is not sufficient to [illegible] amounts of vapours liberated indoors. The concentration of contaminants in the working [illegible] be reduced by cutting down the amount of [illegible] evaporating from the surface of the baths. This can be accomplished by providing adjustable covers on the baths and thereby reducing the exposed [illegible] area of the solution to the minimum required [illegible] sizes. Furthermore, inlets with free area approximately three times the total area of exhaust [illegible] should be so provided that the fresh air admitted for the replacement of extracted air is drawn across the entire working zone.

(c) [illegible] Painting Shops :

[illegible] Spray painting is carried out in enclosures which are isolated from other parts of the factory. The chambers in use may broadly be divided into two types viz, (i) completely enclosed and (ii) bounded by side walls but open on top. The former type is [illegible] the spray painting is done on very small components while the latter type is employed for [illegible] whose transportation requires travelling [illegible] Both types of chambers are provided with an [illegible] water tank covered with a grating of [illegible] metallic bars. During spraying, the work [illegible] are placed on the grating. The paint laden [illegible] air [illegible] down into the water and thus prevented from [illegible] the extraction system.

[illegible] air of the chamber is extracted by means of [illegible] fans. In closed type enclosures the extraction is carried out from the top while enclosures [illegible] are ventilated through extraction openings located under the grating. An examination of the extraction system revealed that some paint also settles on the surface of the extraction grills. This indicated that the paint particles were not completely removed from the air before it entered the extraction system. This creates an apprehension of damaging the fan due to the deposition of paint particles thereon. However, an enquiry from the operators of the plant revealed that the system was in use for more than a decade without showing any fault therein.

(d) Machine Shops :

An enclosure having eighteen bays, each measuring about 185 x 18 meter high forms the main plant of a factory manufacturing light mechanical gadgets (S. No. 3). Each bay is provided with three windows 1.5 x 1.2 m in size. Openings of about 0.9 m high are provided in the roof monitors over half of the bay lengths. The roof openings are fitted with louvers to protect against rain penetration. All the windows are kept closed, and except the entry doors, there are no openings on the walls to allow the flow of natural wind indoors. Forced draft ventilation is employed for cooling the entire working area. Air coolers are located in each bay on the two larger sides of the building but because of power shortage only alternate coolers are put into operation. The air is distributed through main ducts running above the working level. The supply grills are located at about 2 m above the floor. The air speed in the vicinity of the grills is about 2.5 m/sec and at a distance of about 0.6 m from the grill, it is 0.3 m/sec. At farther distances the air is almost calm. The temperature and relative humidity in the working zone are 35°C and 68 per cent respectively. Obviously, the conditions are outside thermal comfort limits[4]. The air velocity at roof openings varies from 0.35 to 0.7 m/sec, producing thereby about 5 air changes per hour. This shows that roof openings play significant role in inducing air changes in factory buildings.

(e) Electronic Shops:

Buildings employed for manufacturing electronic equipments are provided with openings covering 1/3 to 1/2 of wall width (S. No. 4.1 & 4.2). The highest of openings is around 1.1 m. Exhaust fans are also provided in alternate bays on one of the exposed walls of the buildings. No roof light is provided and cooling is accomplished by evaporative cooling. The height of the supply grills varies from 3 m in buildings provided with false ceiling to 5 m in buildings without false ceiling. In the later case, with the cooling system in operation, average air speed in the working zone is about 0.2 m/sec and and temperature and relative humidity 32.5°C and 70 percent respectively. However, with the cooling plant off, the respective values are 0.05 m/sec, 35°C and 54 percent. This indicates that use of evaporative cooling (in forced draft ventilation) reduces the air temperature by about 2.5°C. However, the system did not induce higher air motion, and due to increased relative humidity cooling was not effective to the desired extent.

The survey conducted during post-monsoon season revealed that water spraying system is put out of operation and ventilation is carried out by the forced draft system as employed for summer cooling. Two blowers consuming about 135 kw hour are used for blowing dry filtered air in the factory building covering about 1500 m² of floor area (S. No. 4.3). The indoor temperature and relative humidity are 32.5°C and 45 percent respectively. The air speed in the working zone varies from 0.1 to 0.5 m/ sec. The higher air motion is attributable to the lower height (3 m) of supply grills.

Thus, it is seen that factories employing 'Forced Draft Ventilation' (F.D.V.) have lower indoor air temperature. However, because of the high location of supply grills, the air motion in most of the occupied zone is too low and conditions are not quite comfortable. As air motion is an important contributor to the thermal comfort of workers, the indoor conditions can be improved by enhancing air motion with the help of ceiling fans. During the post-monsoon season when evaporative cooling is not effective, air motion for comfort may be further induced by the ceiling fans and the huge power consumed in running F.D.V. plant may be economised upon. The survey has also revealed that the cooling plants of the factories have to be shut down or run intermittently because of the power shortage during peak summer season when ventilation is not needed. Thus the plants are not utilized to the fullest capacity. Consequently, the indoor conditions become uncomfortable and workers prefer to keep the windows open for achieving natural breeze. THEREFORE, FACTORIES EMPLOYING FORCED DRAFT VENTILATION SYSTEM SHOULD HAVE PROVISION FOR NATURAL VENTILATION AS WELL. Walls and roofs should have openings of appropriate sizes so that indoor environment may be ameliorated during the hours of power shortage or non-operation of cooling plant due to some other unavoidable reasons. However, this should be accomplished without prejudice to the requirements of the industrial process.

Incidentally, a practical problem is noticed in the operation of a typical F.D.V. plant. The controls for water supply pumps are mounted on the floor of a chamber located on the downstream side of the blower from where the main supply duct for the cool air starts. In the running condition of the blower, opening of the door of the chamber is likely to cause accident and as such it is not possible to check the water level in the spray tank and control the flow at the desired rate. THE OBVIOUS REMEDY IS TO LOCATE THE PUMP CONTROLS OUTSIDE THE BLAST OF THE FAN. IN THE EXISTING SITUATION IT MAY BE ACCOMPLISHED BY PROVIDING A FALSE CEILING ABOVE THE CONTROLS SUCH THAT THE FAN OUTLET IS CONNECTED DIRECTLY WITH THE OUTLET DUCT.

Conclusion

(1) Total reliance should not be placed on mechanical ventilation and provision should be made for natural ventilation as well unless the industrial processes otherwise demand conditioning of the incoming air.

(2) For adequate natural ventilation sufficient openings (outlets) should be provided in the roof with inlet openings on walls at about 1.1 m above the floor.

(3) Ceiling fans should also be provided in factories using forced draft ventilation for cooling purposes.

(4) Factories employing exhaust system of ventilation should be provided with inlets on the walls opposite the fans. The inlet should never be provided close to the fans.

(5) In forge and foundry shops, air douches should be made use of for creating local comfort for workers.

(6) Control of pumps etc. of FDV plants should be located outside the blast of the blower.

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