

FORCING OF NATURAL VENTILATION IN ELECTROLYTIC SHOPS

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ABSTRACT

The paper presents an idea for improving ventilation of big industrial units containing a large number of surface sources of acid vapors. Analysis has been made of incoming air quantities for shop ventilation, location of ventilation points, and distribution of acid vapor cresset. Parameters are explained of existing ventilation system with focus on its problems. For proper direction of contaminated air, it is appropriate to use motor-less, wind-driven roof fans, which are new in world practice. They facilitate natural convection by creating additional draught to direct contaminated air outside the shop and far from working spaces. Parameters of these fans are show and their possible applications. Comparative analysis of their efficiency is presented.

INTRODUCTION

Electrolytic shops of metallurgical works contain a number of acid vapor sources area-distributed and of significant density. These create hazards in the shop and in the working space and give rise to specific ways of their safe extraction. Because of the large emitting surface area, use of local ventilation systems presents technological difficulties for normal operation of electrolytic baths. Local exhaust ventilation adversely impacts temperature regime of electrolytic baths, particularly in cold weather. Vapor acidity requires extraction along paths that do not cross the working space or allow condensation. Such suitable passageway can be ensured along the paths of natural convective flows. However, natural ventilation depends both on specific parameters of sources and premises and of building location and weather conditions, thus not every combination of those is efficient enough.

The paper presents analysis of natural ventilation parameters at a specific site with active sources of heat and contamination, ventilation openings, convective flows and their distribution. The analysis shows that in warm weather natural convective ventilation is not efficient enough and requires significant enhancement.

One possibility of enhancement of natural ventilation whilst preserving heat flows' direction is found in the suction of air contaminated with acid vapors by means of wind-driven roof fans. Basic parameters of such facilities are presented, and their effective application field. Their efficiency is shown in directed extraction of air contaminated with sulfur acid vapors. Simultaneously, wind ventilation improves microclimatic conditions in the shop whilst avoiding additional power consumption and new sources of noise.

PROBLEM DESCRIPTION

Investigation of ventilation conditions is based on the following parameters:

- Production process analysis from the point of view of emission mechanism, propagation and carrying out of harmful substances;
- Analysis of shop geometric dimensions and of ways for fresh air intake and contaminated air extraction;
- Climatic conditions in shop location – temperatures, prevailing directions and magnitudes of air flows.

The paper presents the problems of natural ventilation and the ideas for its improvement on the example of a shop for electrolytic refining of anode copper to a purity of 99, 99%. Daily metal production is approximately 100 t with planned increase of 30%. One technological cycle lasts 21 days – removing of electrodes, draining of electrolyte, cleaning of baths and another loading.

Refining process is accompanied by emissions of vapor and gas – 2 051 m³/hour. Total evaporation area of baths is 1536 m² and this will be increased by approximately 32% on reaching design capacity. Peak values of air contaminants in the shop are, as follows:

- Moisture content – 22 g/kg;
- Sulfur acid vapors – 5 mg/ m³;
- Dust – 13 mg/ m³.

In winter, sulfur acid vapor concentration exceeds by 1.2 to 1.8 times the permissible Exposure Level (PEL) of 1 mg/m³ during the working shift. Average shift excess value for January was 1.58 ± 0.17 . In June excess over MAV during the shift at various working locations was 2.2 to 3.2 times PEL. Average shift excess is 2.7 ± 0.27 times MAV. In could be expected that during the hottest days of July and August MAV will be exceeded more than 4 times.

The shop has a typical structure – main hall and roof glass cubicle with windows located along the building length. Dimensions are, as follows:

- Length 180 m;
- Width 45 m;
- height – 20.95 m (15.50 to roof and 17.30 to cubicle).

Shop volume is 137 214 m³, which makes it a large-volume ventilation site. The openings that can be used for fresh air intake and for contaminated air extraction are located on levels 0.00, 4.50, 10.30 and 17.30. Their areas (not all of them can be opened) are, as follows:

- Doors on level 0.00 – 45.8 m²;
- Windows on level 0.00 – 315 m²;
- Windows on level 4.50 – 540 m²;
- Windows on level 10.30 – 360 m²;
- Cubicle windows on level 17.30 – 700 m².

A fact adversely impacting natural ventilation is the presence of technological openings in the floor on level 4.50 of total area 716 m².

INVESTIGATION OF NATURAL VENTILATION IN THE SHOP

Building natural ventilation parameters were investigated by series of measurements under the following three scenarios:

- Scenario 1 – current state of the building;
- Scenario 2 – partially closed windows on level +4.50;
- Scenario 3 – partially closed doors on level +0.00

Incoming fresh air quantities and extraction of contaminated air quantities for the three scenarios are presented on figures 1a, 1b and 1c, respectively.

During measurement, no changes were made in the state of active mechanical draught sources. The difference between incoming and outgoing flows on level +20.00, shown on fig. 1a, b, is due to:

- Operation of two fans in the aspiration system;
- Vapors inflow, which represents internal flow source;
- Recirculation contours between levels.

Existing situation (Scenario 1) shows that the main fresh air source is terrain level, or level +0.00. This means that, as at any ventilation entry, harmful emissions should be reduced to the technical minimum, and where this is not possible, local ventilation should be installed. Presently on level +0.00, there are zones with excessively high content of harmful emissions, mostly around electrolyte and water tanks. Air exchange in the zone from level +0.00 to level +4.50, with existing ventilation mode involving door opening on level 0.00, ensures big ventilation flow through the building. However, this flow is not properly distributed by contamination source because of structural and technological openings in the floor on level +4.50 with total area exceeding 700 m². Location of floor openings on level +4.50 opposite northern and western doors on level +0.00 causes air flow to pass along the contours “**ground atmosphere – door on level +0.00 – floor opening on level +4.50- vertical jet – window openings in roof cubicle – atmosphere around level +20.00.**” Airflows through these contours do not ventilate contamination zone where people

work. As a result of improper air distribution, huge areas wherein people move and work (between levels +4.50 and +8.40) remain insufficiently ventilated with contaminant concentrations exceeding MAV.

Changes in ventilation conditions in Scenario 2 include the following: door opening on terrain level; window closing on level +4.50. The result is increased temperature around baths with adverse effect on vapor emissions from electrolytic baths due to inhibited heat evacuation.

The essence of the changes in Scenario 3 is the regulated air intake on terrain level and increased flow from level +4.50 in intensive vapor emission zones. This scenario shows the best results for re-distribution of ventilation flows. The positive result will be enhanced further if additional draught is provided to direct flows to roof outlets. Authors suggest roof wind fans, discussed below, to serve as such additional draught.

Choice of additional means for regulation airflows in the shop should also be based on another two factors whereon intake air quantity and quality depend, namely:

- Wind speed and direction;
- Evaporation rate and expansion of evaporation cresset.

During the three measurement cycles, wind speed on the shop roof varied from 1.9 m/s to 2.6 m/s. Data submitted by nearby weather station were used to develop the wind rose (figure 2). Northeast mountain winds are the most frequent, followed by west winds. This conclusion should be taken into account in location of intake and outlet openings in the building. South and southeast winds are with the smallest frequencies and speeds. West winds have the highest speed.

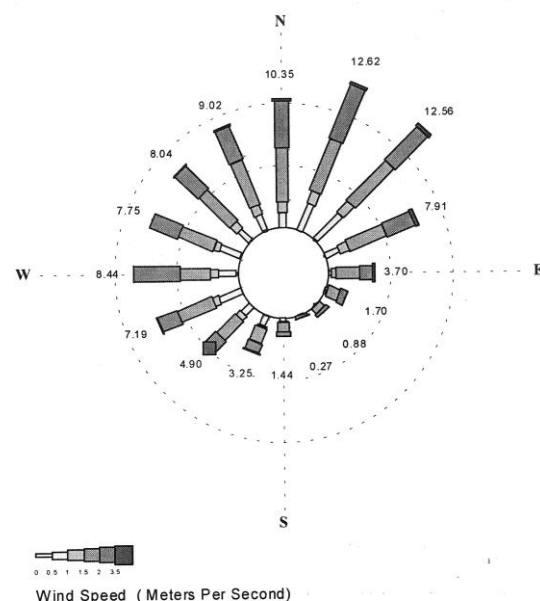


Figure 2. Wind Rose

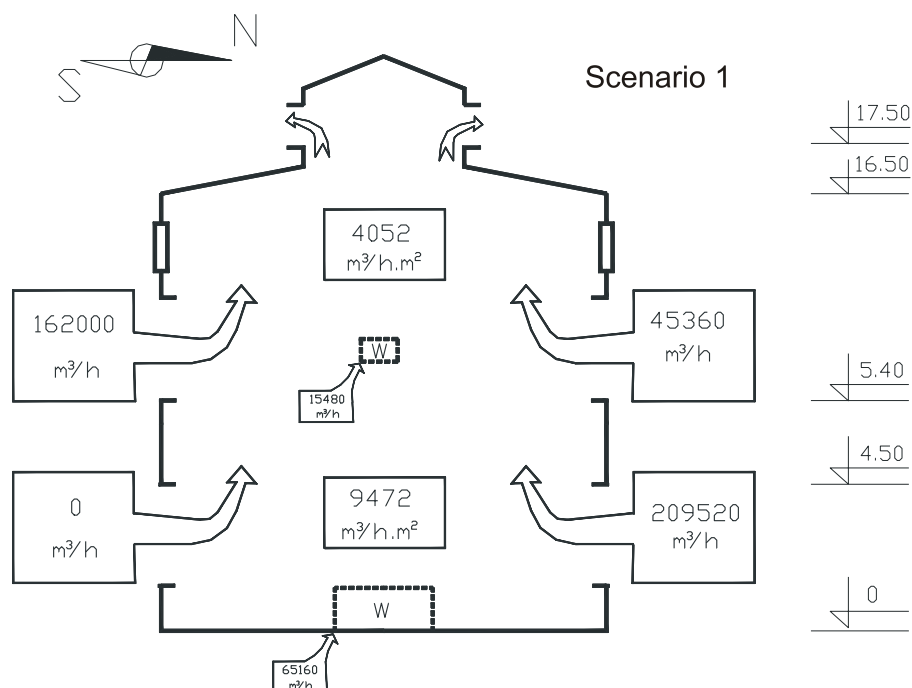
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Figure 1a.

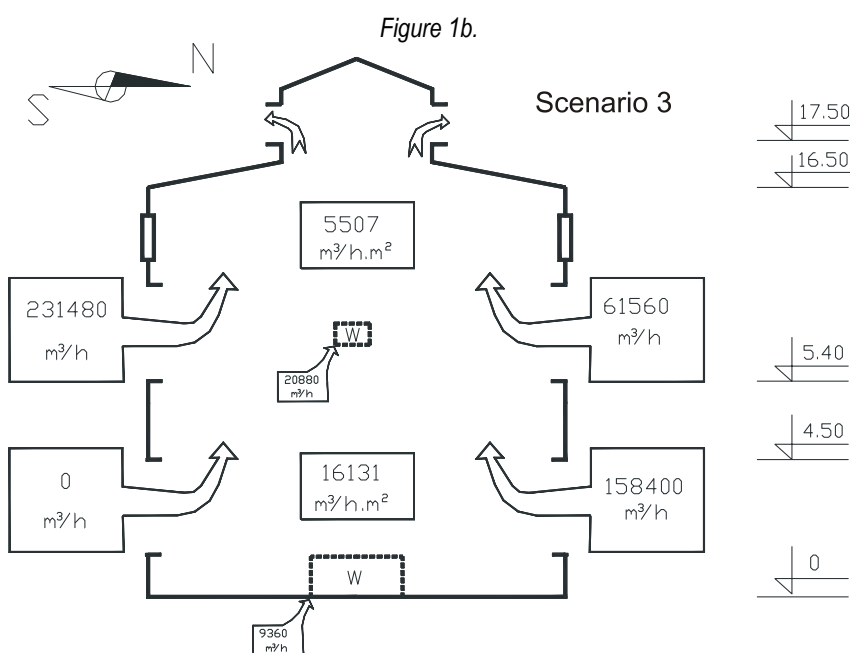


Figure 1c.

Evaporation rate can be calculated, according to [1], by the equation:

$$M = 7.4(a + 0.017V)(P_2 - P_1)101.3 \frac{A}{P_B} \quad (1)$$

where: M is evaporation rate $[kg/h]$

V – air velocity component perpendicular to evaporation, $[m/s]$

a – air mobility factor. Calculated with the help of equations shown in [1]

P_2 – pressure of saturated water vapors over fluid, κPa

P_1 – water vapor pressure over fluid, κPa

A – open surface area of fluid, m^2

P_B – barometric pressure, κPa .

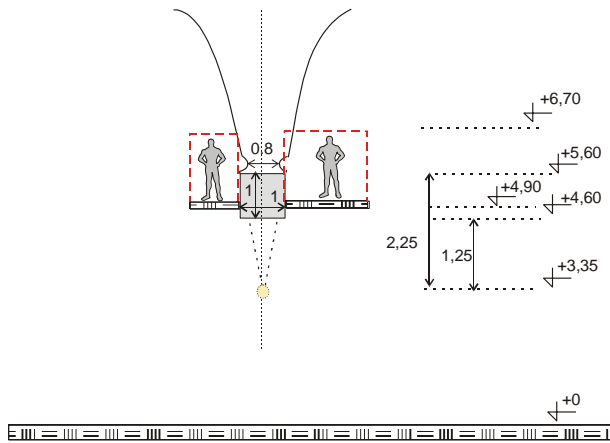


Figure 3a. Evaporation cresset at the short side of the bath

Results obtained with formula (1) and with measurement of evaporation in real conditions were quite consistent (difference 5%).

Evaporation cresset is important for the general picture of people's movement and work. Modeling was carried out using the methodology published in [1]. Worker's position at the narrow side of a single bath is shown on fig. 2a, and the position at the long bath side – on fig 3b.

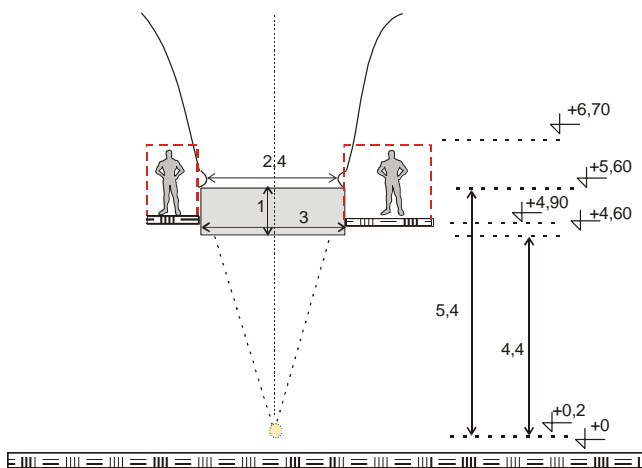


Figure 3b. Evaporation cresset at the long side of the bath

The extreme closeness of vapor cresset to the movement and work zone is clearly seen. The greater density of sulfur acid vapors and the fast cooling of in-cresset flow cause heavier vapors to flow into the work area. This picture was confirmed by smoke-tracing of flow. In order to prevent contamination of the work zone, vertical speed component should be increased in this zone or local exhaust devices should be used.

WIND DRIVEN FANS

Wind fans are turbine, motor-less devices driven by wind energy. They are mounted on the roof of the building to be ventilated. The appearance of such fan is presented on figure 4, its structure – on figure 5. The fan comprises:

- turbine;

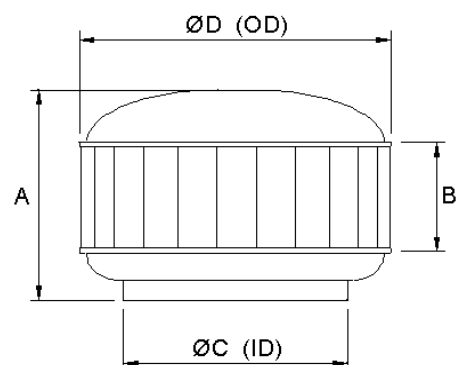
- throat ;
- a varipitch base that suits all roof slopes,
- vertical vanes for improved torque at low wind speed,
- double row ball bearing system,
- cord, remote control, manual, or electric dampers.



Figure 4. Outside view k of turbine fan

Operation is simple and sure. When the slightest breeze touches the scientific blade construction it causes the turbine to rotate. The centrifugal force caused by the revolving turbine creates a partial vacuum within the turbine. This vacuum is then replaced by a strong upward draft of air. A powerful exhaust is thus achieved. The fan works automatically, continuously and silently without operating or maintenance costs. Ball bearings are made from acetal polymer with caged 316 stainless steel precision ground ball bearings. Acetal is unique polymer that retains the lubricant within its molecular structure to ensure long life and smooth operation. Major manufacturers of such fans are shown in table 1.

Fabrication materials depend on intended application of the fan. Most often these are corrosion-proof aluminum, stainless steel or with the TGIC polyester powder coating of O'Brien Powder Products Inc., the latter, during tests, has shown resistance of 60% to sulfur acid and other harmful substances.



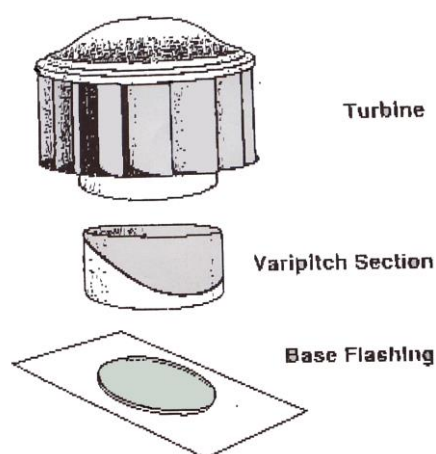


Figure 5. Structure of turbine fan

Table 1. Major manufacturers of wind driven fans

Manufacturer Country	Fan type	Wind speed [m/s]	Fan capacity [m ³ /s]
Edmonds Pty Ltd Australia [2]	H600	1.67 ÷ 3.33	0.6 ÷ 1.5
	H700	1.67 ÷ 3.33	0.85 ÷ 1.9
	H800	1.67 ÷ 3.33	1.1 ÷ 2.7
	H900	1.67 ÷ 3.33	1.55 ÷ 3.4
Metallic Products Corporation [3] USA	T500	1.8	0.8
	T600	1.8	1.1
	T900	1.8	2.1
Chin Foh Berhad Malaysia [4]	BS460	1.67 ÷ 3.33	0.4 ÷ 1.0
	BS600	1.67 ÷ 3.33	0.55 ÷ 1.35
McMaster-Carr USA [5]	1992K54	1.67 ÷ 3.33	0.4 ÷ 1.0
	1992K55	1.67 ÷ 3.33	0.6 ÷ 1.5
	1992K56	1.67 ÷ 3.33	1.05 ÷ 2.4
Ampelite Fiberglass Pty Ltd Australia [6]	AS450	1.67 ÷ 3.33	0.38 ÷ 1.0

Digits in fan names denote opening dimension - for instance H800 means Hurricane model with opening of 800 mm. McMaster Carr fans have dimensions from 500 to 762 mm. The height of fans in table 1 varies from 484 to 990 mm.

Wind roof fans are very light (their weight varies from 9 to 27 kg), but they are capable of withstanding very strong winds – of some 240 km/h. They are increasingly employed throughout the world in residential and public buildings and in industrial productions with high temperatures and contaminants. Many schools and administrative buildings in New Zealand and Australia use this type of ventilation for air conditioning. In summer the fans exhaust the hot air, and in winter they prevent condensation of hot vapors in the under-roof area. Figure 6 shows actual building equipped with wind fans.

COMPARATIVE RESULTS FROM WIND FAN OPERATION

As noted in the natural ventilation analysis and as seen from figures 1 a, b, c, ventilation and climatic conditions can be improved by increasing outlet open cross sectional area above level +15.50. This can not be accomplished solely by

adjustment of cubicle openings as additional power is required to direct airflows. Such additional power should be consistent with working conditions in the shop – release of hot acid vapors, which involve specialized requirements in respect of equipment. Therefore, the authors have chosen roof fans resistant to exhausted contaminants.

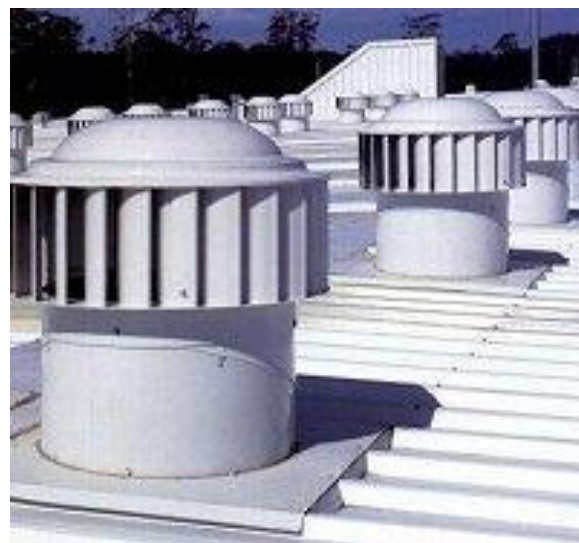


Figure 6. Actual building with roof fans

Table 2. Comparative data on additional capacity

Fan	Wind speed, m/s	Exhaust capacity (1 fan), m ³ /s	Exhaust capacity of 16 fans	Air exchange divisibility, h ⁻¹
H800	1.67	1.1	17.6	0.46
	2.22	1.4	22.4	0.59
	2.78	1.8	28.8	0.76
	3.33	2.1	33.6	0.88
1992K56	1.67	1.05	16.8	0.44
	2.22	1.3	20.8	0.55
	2.78	1.6	25.6	0.67
	3.33	1.9	30.4	0.8

Table 2 shows summary information on two proposed fans - H800 fan of Edmonds Pty Ltd and 1992K56 fan of McMaster Carr. The additional flow that will be provided by the operation of 16 fans is within the range of 16 to 34 m³/s. This means compensation of the difference between incoming and outgoing flows, with the additional capacity on level +17.30 intensifying airflows and increasing contaminant exhaust rate. This is very important in summer because temperature and air mobility are outside the admissible range for the working environment.

CONCLUSION

The above-discussed idea of forcing natural ventilation present a comparatively new approach in the world practice, the application whereof is increasing due to the following obvious advantages:

- no additional power consumption;

- can be used in various buildings – residential, public, industrial;
- can be employed in conditions of acid vapors, high temperature of exhaust gases and other contaminants;
- renewable environmentally – friendly power source;
- reliable facility with low operation costs.

REFERENCES

Industrial Ventilation – design guide book, edited by H. Goodfellow, E. Tahtii, Academic press, Hardcourt Science and Technology Company, 2001, p. 1519.

www.edmonds.com

www.mpvent.com

www.chinfor.com

www.mcmaster.com

www.apmelite.com.au

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