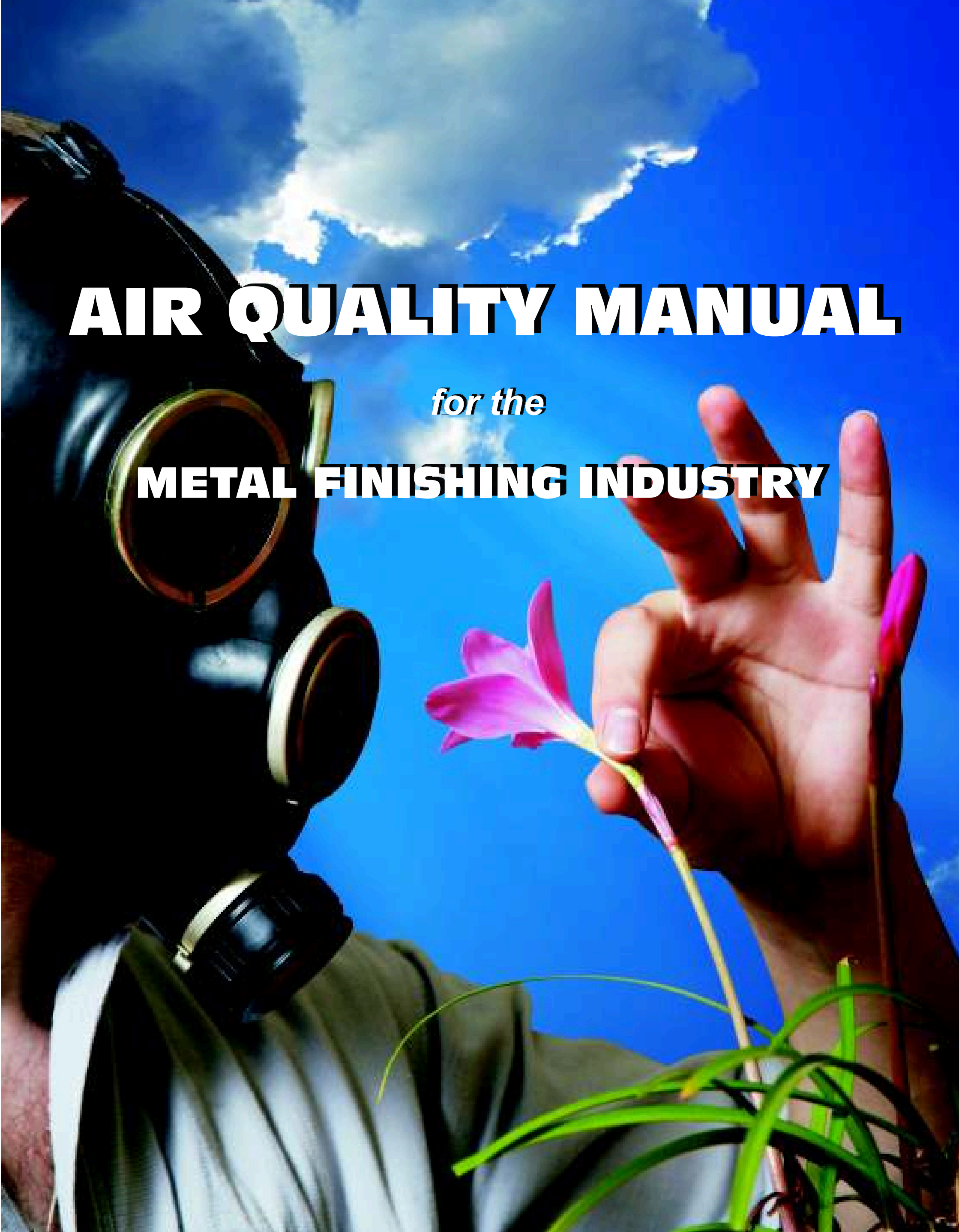
AIR QUALITY MANUAL

for the

METAL FINISHING INDUSTRY



A DANIDA sponsored SAMFA initiative in collaboration with VJL Technologies

VJL TECHNOLOGIES (PTY) LTD

FOREWORD

A brief explanation by
Tony van der Spuy

Air quality has always been an issue in the metal finishing industry and particularly in electroplating.

There are not many workshops that an outsider can enter without immediately becoming aware of unpleasant emissions to air from the various processes.

Workers and managers in this environment become accustomed to the situation and soon become complacent about the long-term threat to health and safety. Some may believe that they have become immune to the dangers, but this is patently not so.

For the past two years DANIDA funding has been used to highlight these issues and to seek methods to improve working conditions wherever possible. As one of the final outputs of this programme, this manual has been compiled to help operators to have a better grasp of the issues involved. It seeks to provide technical input that will allow those with in-house capabilities to construct functional extraction systems for their process lines.

For those who need to look to professional plant builders for their needs, it helps the manager to understand the requirements and to approach the subject from a more informed perspective.

Special thanks go to Johan Vermeulen of VJL Technologies, who has compiled this manual as a service to the industry.

If only one worker in the industry gains from healthier and safer working conditions as a result of this effort, it will have been more than worth it!

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AIR QUALITY MANAGEMENT IN METAL FINISHING

A practical hands-on guide developed as part of the DANIDA sponsored OHS programme

Contributed by Johan Vermeulen
CEO of the VJL Group

1. INTRODUCTION

From the outset, the design of any chemical process plant must consider environmental issues for the immediate operator working environment and prevention of potential pollution of the atmosphere.

A typical metal finishing plant utilises a wide variety of chemistries, most of which are potentially hazardous, ranging from mild alkaline and acidic solutions to chemistry containing strong acids, e.g. chromic, hydrofluoric, hydrochloric, nitric and sulphuric acids as well as cyanide based plating solutions.

This manual serves as a guide for the DIY Plant owner and professional plant builders alike to offer practical advice for the design and construction of fume abatement systems on existing and new chemical surface treatment plants.

2. TYPES OF VENTILATION

Industrial ventilation of chemical process plants can be mainly categorised in two groups:

(i) General extraction and dilution
(ii) Localised extraction

The former type functions by causing sufficient air to pass through the room or shop to dilute the contaminated air to a safe level by mixing with the fresh uncontaminated air entering the space from the outside. Window fans, roof fans, central ventilation systems, etc, accomplish general ventilation. Local exhaust ventilation, on the other hand, functions by capturing the contaminant or contaminated air as close to its source or point of release as possible and conveying it to the outside either directly or after passing through air pollution control devices where necessary. Slot-type exhaust hoods on tanks, hoods for grinding and buffing wheels and canopy-type hoods above tanks are examples of local exhaust hoods. Even though the design, construction and arrangement of the ventilation equipment indicate generally whether the effect produced is general or local exhaust ventilation, the deciding criteria is the relationship between the concentration of air contaminant in the room air and that in the exhaust air before cleaning. Therefore, if the concentration of contaminant in the exhaust air is essentially the same as or only slightly higher than in the room air, the ventilation is general; whereas, if the concentration of contaminant in the air exhausted is much greater than in the general room air, the ventilation principle should be local extraction.

As a general rule, local extraction ventilation is preferred to general ventilation in the control of air contamination. In fact, there are many operations in the electroplating industry for which local extraction must be used to prevent the creation of a health hazard. If the sources or areas of escape of the contaminant are defined and if the volume of contaminant escaping from such sources is considerable, no reasonable general ventilation rate will suffice to dilute the contaminant to a safe level before it reaches the breathing zone of the operators. Local exhaust ventilation may be employed to prevent the escape of huge volumes of contamination by capturing it at the points or areas of escape, and frequently comparatively low ventilation rates will suffice. For this reason, and possibly because the basic concepts of local exhaust ventilation are not generally understood, emphasis in this guide will be placed on the principles governing the design of local exhaust systems.

General ventilation will be considered, but only in its proper perspective.

Fortunately, most operations involved in the electroplating industry may be categorised into one type as far as ventilation is concerned, namely, open-tank type operations.They include alkaline cleaning, solvent cleaning, pickling, plating, rinsing, electropolishing, anodising and others which are carried out in tanks.

2.1 General Ventilation

For non-hazardous chemical applications, i.e. mild alkaline cleaners and heated tanks general room ventilation might be considered as adequate to improve the working environment, humidity levels and general housekeeping. With reference to figure 1, the room air changes are calculated at 20 – 50 air changes / hour. Fresh dilution air is pulled into the building through filtered louvers on the operator side and exhausted again through windows mounted extraction fans on the opposite side.

The total combined extraction fan capacity would be calculated as follows:

Q = L x W x H x Extraction rate

Where:

Q = air extraction volume (m^3 / h)

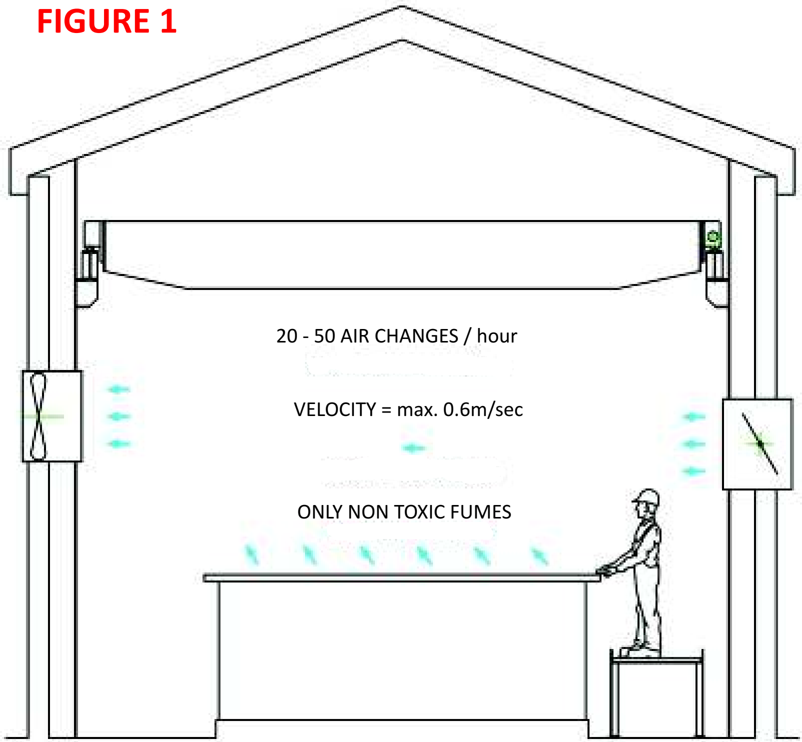
L = length of building (m)

W = width of building (m)

H = height of building (m)

Extraction rate = air changes / h (20 – 50)

FIGURE 1



TYPICAL SECTION
GENERAL INDUSTRIAL VENTILATION

2.2 Open-surface tank Extraction

Local extraction may be applied to tanks in any of three different ways, and the ventilation rate to accomplish adequate control of the contamination varies considerably. These different types of hoods/ plenums are

(i) enclosing hoods

(ii) canopy hoods

(iii) lateral exhaust plenums

The characteristics of these different hoods are as follows:

(i) Enclosing Hoods

This hood design does not need to enclose the tank completely. Any hood which projects over the entire tank and encloses it on at least two sides falls in this category. It is the intent when employing hoods of this kind that the workers will have their heads outside the hoods at all times except possibly when repairs or adjustments are necessary. Control is affected by moving air through the hood at such rate that its velocity into all openings in the hood will prevent the escape of mist or gas. As a rule, an average air velocity into the hood openings of 0.5 m/sec is adequate to prevent escape of the contaminant.

(ii) Canopy Hoods

This is the most uncommon localized extraction system currently employed as this hampers the ergonomics or material handling through the plant. Figure 2 illustrates the design parameters of this concept.

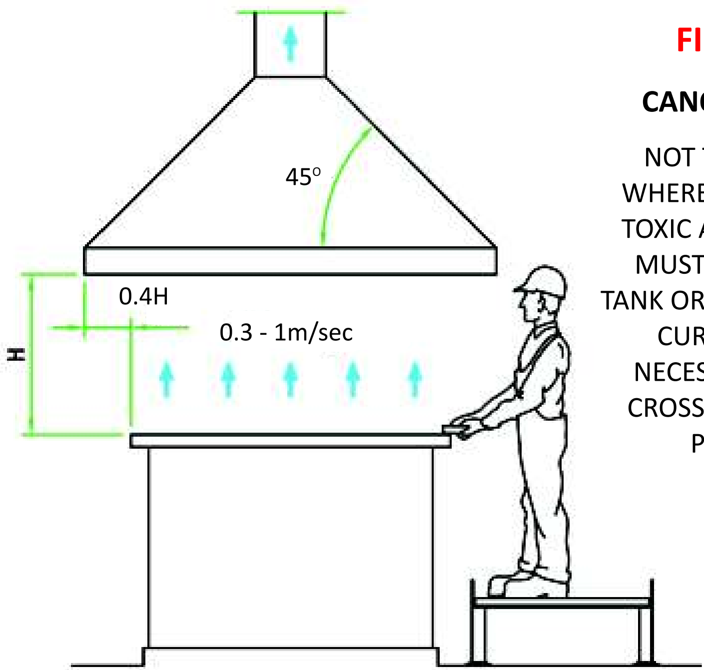


FIGURE 2

CANOPY HOOD

NOT TO BE USED WHERE MATERIAL IS TOXIC AND WORKER MUST BEND OVER TANK OR PROCESS. SIDE CURTAINS ARE NECESSARY WHEN CROSS-DRAFTS ARE PRESENT

Hoods of this design should extend beyond the edges of the tanks in all directions. They are not recommended for operations which require workers to be in attendance at one or more sides of the tanks because the contaminated air rising towards the hood passes through the breathing zones of the workers. The mist and gas must be prevented from escaping into the workroom air by maintaining a curtain of air flowing into the hood through all openings or the entire open are between the top edges of the tank and the lower edges of the hood.

(iii) Lateral Extraction plenums

The most basic principle is illustrated in figure 3 and offers limited operator protection for smaller tank sizes up to 1000 mm in width. The vertical extraction plenums on the far side of the operator also assist in the removal of fumes from the hot component as it is lifted from the solution.

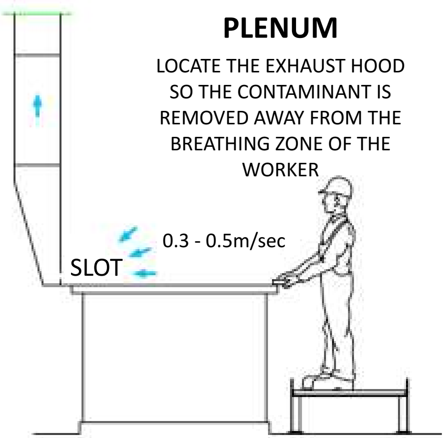


FIGURE 3

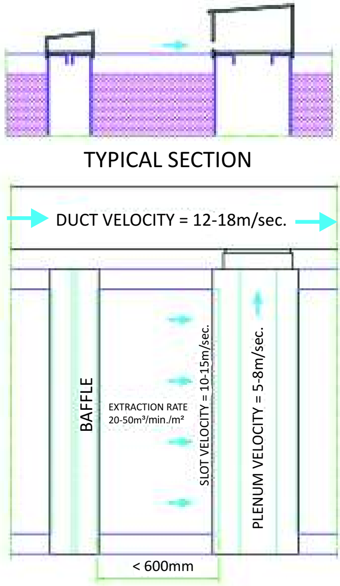
Lip extraction Plenum design (Recommended)

This is by far the most proven and effective localised extraction principle widely applied.

Fumes emitted from the open surface of the bath are extracted through the extraction plenums mounted on one, two or three sides of the tank (depending on tank size) to ensure that the fumes do not escape to atmosphere. The plenum design however is critical and predetermined minimum velocity rates have to be applied to ensure effectiveness.

Small sized tanks (<600 mm width)

For open tanks with a width of less than 600 mm one single lip extraction plenum mounted on the side of the tank would suffice. Refer to Figure 4 on the right.



TYPICAL SECTION
LIP EXTRACTION PLENUM
FOR TANK WIDTH <600mm

FIGURE 4

Plenums would normally be manufactured by plant builders in chemical corrosion resistant polypropylene or UPVC using well equipped thermoplastic workshops fitted with the appropriate welding equipment. For the DIY plant builder these plenums could also be manufactured from readily available UPVC pipe spanning the length of the tank with extraction slots cut at a width of 30 – 40 mm along the length of the pipe. The end of this pipe can then be closed with a standard pipe end-cap with the other end joined into the extraction duct (also pipe in the case of a DIY job) using PVC cement.

The calculation of the pipe / plenum size can be determined as follows:

Tank extraction volume = Q = L x W x Extraction Rate, where:

Q = Tank Extraction volume (m^3 / min)

L = Tank inside length

W = Tank inside width

Extraction rate = 20 – 50 m^3 / min / m^2 (Refer Table 3)

Using Table 1, at the top of page 9, the pipe size can then be determined comparing the extraction rate with the permissible plenum velocity.

Medium sized tanks (< 1500 mm width)

Open tanks larger than 600 mm but smaller than 1500 mm in width would require two lateral lip extraction plenums on either side of the tank as detailed in Figure 5 on page 10.

The plenum calculations would remain the same as above with the total extraction rate divided by two plenums.

Table 1 - Plenum Pipe Size Selection

Pipe Diameter	Cross Section Area	Max. Permissible Airflow [m3/min]	
mm	**m^2**	**5 m/s**	**8 m/s**
160	0.0201	6.03	9.65
200	0.0314	9.42	15.08
250	0.0491	14.73	23.56
315	0.0779	23.38	37.41
400	0.1257	37.70	60.32
500	0.1963	58.90	94.25
630	0.3117	93.52	149.63
800	0.5027	150.80	241.27

Large sized tanks

As lip extraction from one side of the tank is only effective up to 500 – 750 mm from the plenum (depending on the velocities) the larger tanks are normally fitted with a combination of:

(i) two long horizontal lip extraction plenums on the long sides of the tank;

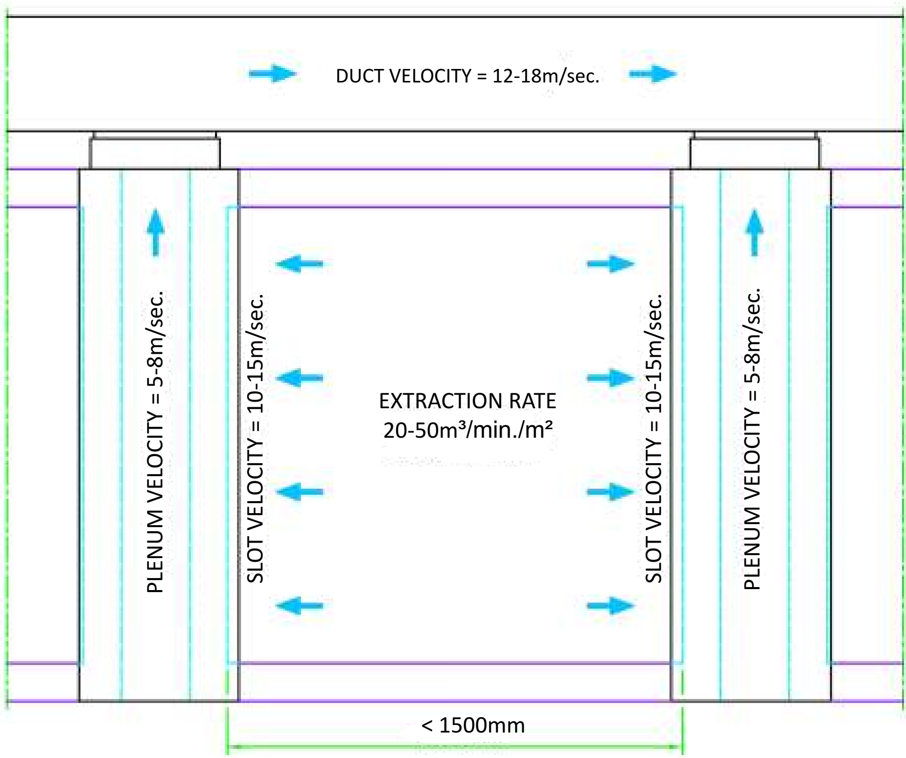
(ii) one vertical extraction plenum with multiple slots on the far side of the tank joining the two horizontal plenums together; one blow plenum on the operator side of the tank introducing fresh dilution air and forming a protective air curtain to create a clean healthy environment for the operator.

This is commonly referred to as a push-pull extraction system and would normally be designed by recognised plant builders.

Refer to figures 6 & 7 on pages 11 & 12 respectively for design parameters.

FIGURE 5

TYPICAL SECTION



TYPICAL SECTION
TWO UP EXTRACTION PLENUMS
FOR TANK WIDTH < 1500mm

3. EXTRACTION RATES

When setting out to design a new extraction system for a metal finishing line each process tank has to be individually assessed at first. Table 3 on page 16 is a useful tool to establish the individual extraction rates and total extraction volumes.

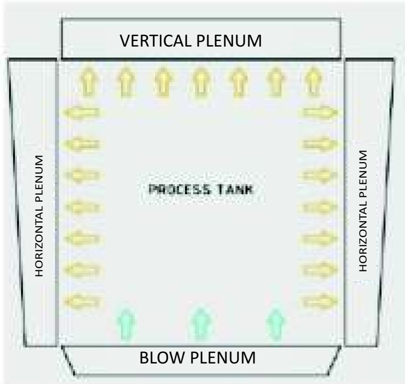


ILLUSTRATION OF PUSH-PULL EXTRACTION SYSTEM

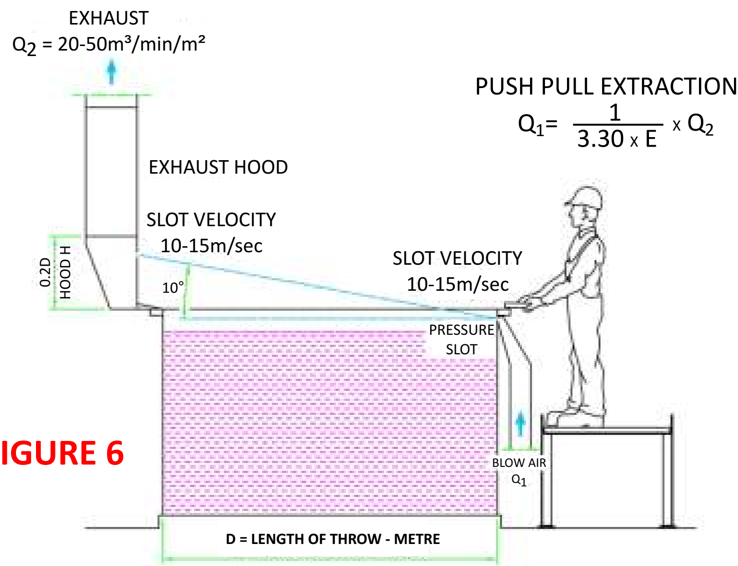
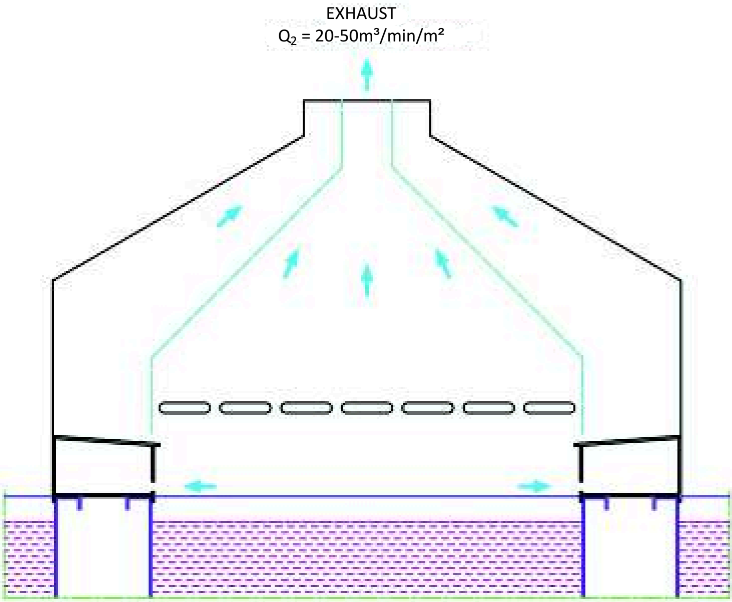


FIGURE 6



TYPICAL SECTION

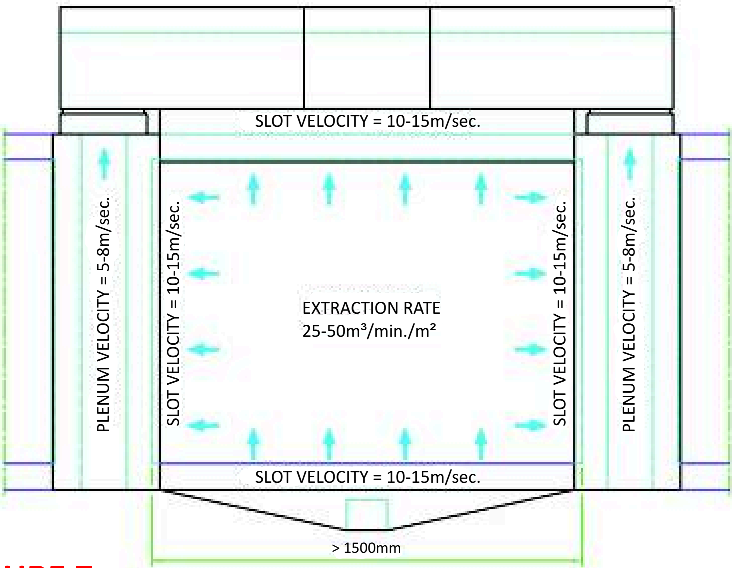


FIGURE 7

TYPICAL SECTION
PUSH PULL EXTRACTION
+ TWO LIP EXTRACTION PLENUM (OPTIONAL)
FOR TANK WIDTH >1500mm

The extraction rate per tank is calculated by the open surface area (L x W) multiplied by the extraction rate relevant for the chemical composition of the tank. Table 3 on page 16 is indicative of extraction rates ($m^3 / m^2 / min$) for different type of tank compositions which are then applied to the relevant open tank surface area and added to determine the total extraction rate.

Care should be taken not to mix extraction air flows of cyanide containing liquids with acidic air streams. These should be completely separately extracted to prevent the formation of HCN gas.

4. EXTRACTION DUCTING DESIGN

The various extraction plenums on the plant are joined into a common extraction duct (with the exception of incompatible air streams as described under section 3) to feed into one of the following:

(i) Directly into an extraction fan

(ii) Through a dry demister and extraction fan

(iii) Through a wet scrubber and extraction fan

The total air volumes from Table 3 are now applied to determine the ducting size. Using table 2 on page 14 the ducting size can be determined. Care should be taken not to undersize the ducting (pipe) diameter as this would result into too high friction losses rendering the extraction inefficient.

5. SCRUBBER DESIGN

Hazardous and toxic fumes cannot be released into atmosphere and have to be cleaned before exhausted outside the building.

Fume scrubbers are designed to absorb toxic particles from the air streams using water or appropriate chemical reagents to scrub the air. The scrubber liquor contacts the particles in the air flow by means of counter flow and enlarged surface area principles.

A final dry demister stage removes the liquid from the air stream.

Scrubbers and Demisters are normally custom built for these applications and can be sourced from a number of local plant designers and fabricators. For academic reasons Figure 8 on page 15 details the basic design parameters of a typical vertical fume scrubber.

Pipe Diameter mm	Cross Section Area m^2 *put line*	Max. Permissible Airflow [m^3/min]	
		12 m/s	18 m/s
160	0.0201	14.48	21.71
200	0.0314	22.62	33.93
250	0.0491	35.34	53.01
315	0.0779	56.11	84.17
400	0.1257	90.48	135.72
500	0.1963	141.37	212.06
630	0.3117	224.44	336.66
800	0.5027	361.91	542.87

Table 2 - Ducting Vent Pipe Size Selection

6. GENERAL

6.1 Pro-Active Measures

Since adequate ventilation is seldom inexpensive, it is advisable to keep to a minimum the capacity of such equipment required by employing other means of controlling the air contamination using overall and practical measures. For example, inhibitors of various sorts are available for use in acid pickling baths, many of which decrease the amount of acid mist escaping into the air. Plastic chips or balls, surface-foam type inhibitors, and surface-tension depressive agents decreasing the mist escaping from plating and processing tanks are extensively used. A number of different degreasing or cleaning solvents are available which are low in order of toxicity and volatility to meet operational requirements. It is therefore recommended to give careful thought to other steps which might be taken with the objective to minimising the problem at source.

Cyanide based electrolytes were traditionally used for reasons that they are

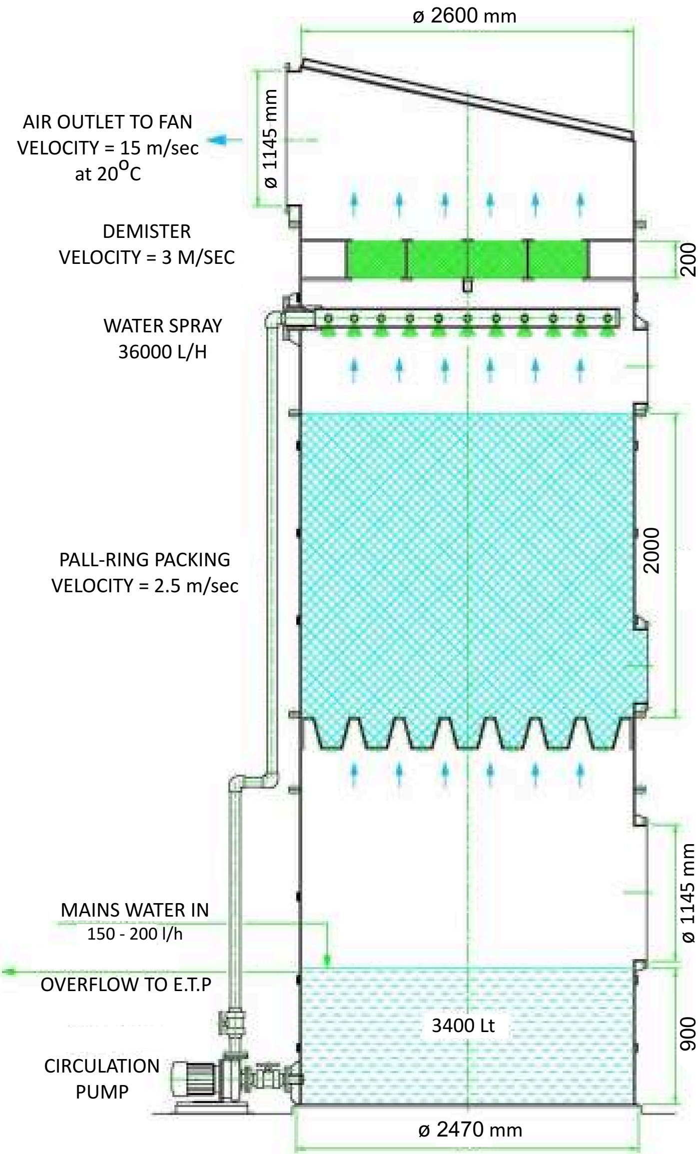


FIGURE 8

SCRUBBER

Automotive regulations and increasing environmental pressures are driving alkaline cyanide free technologies and field proven environmentally friendly alternative processes are available for almost all cyanide-based solutions.

Chrome VI free chemistry has also now become mandatory in many industries.

TABLE 3

Process No.	Process description	Working Temp [℃]	Extraction Required		
			Scrubber	Demister	None
1	Soak Cleaner	70-90		Yes	
2	Electro Cleaner	40-70		Yes	
3	Rinse	Ambient			None
4	Rinse	Ambient			None
5	Hydrochloric Acid	Ambient	Yes		
6	Rinse	Ambient			None
7	Rinse	Ambient			None
8	CN Copper plate	60-70	Yes		
9	Drag-out	Ambient			None
10	Rinse	Ambient			None
11	Rinse	Ambient			None
12	Acid Activation	Ambient	Yes		
13	Rinse	Ambient			None
14	Nickel Plate	50-60	Yes		
15	Drag-out	Ambient			None
16	Rinse	Ambient			None
17	Rinse	Ambient			None
18	Chrome Activation	Ambient	Yes		
19	Chrome Plate	40	Yes		
20	Drag-out	Ambient			None
21	Chrome Neutraliser	Ambient		Yes	
22	Rinse	Ambient			None
23	Rinse	Ambient			None
24	Hot Rinse / Dry	60-70		Yes	
Scrubber Air Total					
Demister Air Total					

TYPICAL FUME EXTRACTION SCHEDULE

Tank Length [m]	Tank Width [m]	Tank Height [m]	Vol [L*W*H] [l]	Area [L * W] [m^2]	Extraction Rate [$m^3/min/m^2$]	Extraction [m^3/min]	
						Scrubber	Demister
1.2	0.7	1	0.84	0.84	35	-	29
1.2	0.8	1	0.96	0.96	35	-	34
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72	40	29	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.8	1	0.96	0.96	40	38	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72	35	25	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.8	1	0.96	0.96	40	38	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72	40	29	-
1.2	0.8	1	0.96	0.96		0	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72	35	-	25
1.2	0.6	1	0.72	0.72		-	-
1.2	0.6	1	0.72	0.72		-	-
1.2	0.7	1	0.84	0.84	30	-	25
						160	
							113

6.2 Ventilation of applications other than open-surface Tanks.

Allied operations sometimes conducted as part of the electroplating process include abrasive blasting, grinding, buffing and polishing. These operations seldom create a health hazard unless performed on rather toxic materials such as cadmium or lead. Abrasive blasting will create a serious health hazard if sand is used as the blasting medium. However, if steel grit or other material low in free silica is used, the safety-hazard as well as the house-keeping problem far outweigh health considerations.

Abrasive Blasting

If blast cleaning is done, it should be carried out in properly ventilated equipment which has been designed for the purpose. There are many kinds of such equipment available commercially, including blasting rooms, blasting cabinets, blasting tables and blasting barrels. The characteristics of the work to be done govern to a large extent which type of equipment if preferred. All such equipment requires proper ventilation. Most blasting rooms are so constructed that make-up air enters at or near the roof and is exhausted through a grill-type floor. The recommended minimum ventilation rate for blasting with friable abrasives (including sand) is 0.21 $m^3/min/m^2$ of cross sectional plan area. If a non-friable abrasive (such as steel shot) is used, and if the material being blasted is not coated with sand or a coating contains toxic components (such as lead), this rate may be cut in half. For rooms designed to be ventilated horizontally, the recommended minimum rate is 0.26 $m^3/min/m^2$ of cross sectional area in a plane at right angles to the direction of the air flow if a friable abrasive is used and one-half this value if a non-friable abrasive is used and the material being blasted is not coated with sand or a toxic coating. Abrasive blasting cabinets should be ventilated at such rates that the air flow into the cabinet through all openings (excluding curtains) is not less than 2.54 m/s. Rotary abrasive blasting tables should be enclosed or baffled as effectively as possible and should be ventilated at such rates as to produce a velocity of air into all openings of 1.27 m/s (based on free openings without baffles or curtains). Blasting barrels also should be ventilated at a rate capable of producing an air flow into the mill of 2.54 m/s through all openings.

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