This translation is posted with the kind permission of the author of the study, Mr. Réal Dugas, engineer, Groupe-Conseil TDA. The original French title is “Ventilation des bouilloires servant à la cuisson du crabe en milieu industriel.”

This translation is intended only to provide information to those concerned with occupational asthma related to work in crab-processing plants. *SafetyNet* has not done any experimental testing to verify the recommendations of this study and thus cannot formally endorse it.

C.L.S.C. AND CENTRE D'HÉBERGEMENT DE MANICOUAGAN

VENTILATION OF CRAB COOKING BOILERS IN AN INDUSTRIAL SETTING

File: 98-2616

CONSULTANT'S REPORT

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1.0 INTRODUCTION

On February 13th, 1998, the C.L.S.C and the Centre d'hébergement de Manicouagan commissioned us to carry out an expert appraisal regarding the ventilation above crab cooking boilers in the seafood processing plants in Chute-aux-Outardes and in Baie-Trinité.

According to current knowledge, crab cooking steam found in the air creates asthma problems for workers. The present study, therefore, aims to propose solutions and to come up with typical installations that will perhaps be able to be used as a basis for setting up complete ventilation systems.

2.0 DESCRIPTION OF THE PROBLEM

The problem is due specifically to the methods of cooking crab, which consist briefly of the following steps:

- The crab is placed in baskets and cooked in small boilers raised to high temperatures. These boilers consist of stainless steel basins filled with water and closed with a cover.
- At the end of the cooking process, the boiler operator removes the cover. This operation lets an enormous amount of steam out into the building.
- With the aid of a hoist, the operator has to retrieve the basket and transfer it into a basin of cold water in order to proceed to the first rinsing and cooling of the crab. During the entire process of transferring the basket, a significant amount of steam is let out into the building.

The steam contains proteins that spread out into the workplace. Sooner or later, employees working in such an environment are at risk of developing occupational asthma.

3.0 GOAL OF THE STUDY

It is possible to significantly decrease the amount of steam inside the premises and improve ambient air quality, thus reducing the workers' exposure.

The goal of the present study is to propose various exhaust systems that will make it possible to remove the steam.

In order to carry out this study, we planned the following steps:

- Analysis of operating principles, by making a visit to the plants in Chute-aux-Outardes and Baie-Trinité
- Research into ventilation documents and standards
- Analysis of proposed solutions
- Drafting of a study report
- An estimated budget of the costs of carrying out the chosen solutions

4.0 VENTILATION

4.1 VENTILATION PRINCIPLES

The recommended exhaust system will have to capture the air in the space occupied by each boiler, thus avoiding the spread of steam to the operator. When the source of the contamination is localized, the exhaust grille must be nearby in order to be totally efficient. An efficient exhaust grille can take in air up to about one metre away.

When a boiler is opened at the end of the cooking process, a significant amount of steam escapes and disperses into the premises. If the steam is not captured at the source, it will have time to spread throughout the entire room before a wall- or ceiling-mounted exhaust system can take it in. As well, while the crab is being carried over to the basin, a significant amount of water evaporates and thus increases the amount of protein in the air. As much as possible then, it is important to avoid the accumulation of steam by capturing it at the source, as near as possible to where it is being produced.

As well, for an exhaust system to be efficient, it must be counter-balanced with fresh air. If we consider, for example, a closed room from which we are continuously removing air, the exhaust system will gradually become less and less efficient as the negative pressure in the room increases. If we want to preserve the efficiency of the exhaust system then, there has to be as much air going into the building as there is leaving it. Given that plants are usually in operation from the month of April until the month of September, the outside temperature will be warm enough that this air can brought into the plant without being heated. After discussing this issue with plant owners, we understand that it would be possible to work with the doors to the building continuously open to allow the exhaust air to be replaced. If this is not possible, openings (shutters) should be planned to let in the required replacement air for the exhaust system.

5.0 PROPOSED SOLUTIONS

5.1 BOILER VENTILATION

In order to improve the ventilation of this equipment, we suggest installing a ventilation hood. It would not be sufficient to install a hood above the equipment because the steam has to be taken up before it is breathed in by the workers. Therefore, we suggest installing a wall-mounted hood such as the one shown in Sketch M1 of Appendix B. This hood has the advantage of only using a very small amount of space behind the boilers. However, the existing covers will have to be modified. At present, the cover must be removed from front to back, which would obstruct the hood's ventilating process.

Consequently, we propose halving the covers so that they can be opened laterally. Moreover, to prevent the accumulation of steam in the boiler during the cooking process, we suggest making an opening in two sections of the cover near the hood. In this way the steam will be drawn away by the hood throughout the cooking process, thus limiting the surplus steam that could escape the hood when the boiler is opened (see Sketch M1).

For the design of these hoods, we used the standards described in the document 'Industrial Ventilation'. You will find a number of relevant excerpts in Appendix A.

These standards explain how to determine the flow of exhaust air that is to be recommended for each type of boiler. The dimensions of the boilers and the position of the hood in relation to the boiler are important elements of the hood design. Taking into account the fact that the product to be removed is water vapour, and with the goal of retrieving as much of it as possible, the standards stipulate that the velocity of the steam uptake must be 75 feet/minute at the furthest point of the hood.

Now, in order to determine the exhaust flow required for the uptake velocity of 75 feet/minute, the horizontal surface area of the boiler (square feet) must be found. Next, the width/length ratio must be found, and finally, with the help of Table 5.5.4 in Appendix A, it is necessary to ascertain the required flow in cubic feet per minute (CFM) per square foot of the boiler. For example, taking a boiler with a width of 36 inches and a length of 48 inches, we get a surface area of 12 square feet and a ratio (36/48) of 0.75. Thus, in Table 5.5.4, a value of 130 cubic feet per minute per square foot is found.

In Table 1 you will find a few typical cases representing the dimensions encountered in plants on the Côte-Nord.

Table 2 explains how to proceed to the manufacturing of each type of hood according to the required flow. To help to understand this procedure, it is important first of all to consider that to capture steam efficiently, a speed of 2000 feet/minute is required at the entry point of the hood. Thus, the flow in cubic feet per minute divided by the velocity gives us the surface area in square feet required by the opening in the hood. Knowing the required hood width, we are able to determine the height of the opening. The only thing that remains is to determine the number of openings judged to be suitable for the particular case. However, there is no doubt that if more than one opening is planned (for example, three vertical openings one over the other), it is three times more likely that all of the steam will be captured. Finally, Table 2 also shows the size of the exhaust conduit that is recommended to circulate the steam in the hood over to the fan..

TABLE #1: EXHAUST FLOW

BOILER TYPE	Width (w) (inches)	Length (L) (inches)	Surface area (square feet)	Ratio (W/L)	Flow (cubic feet/ min/ square foot)	Calculated hood flow: cubic foot/ min
1	36	36	9,0	1,0	150	1350
2	36	40	10,0	0,9	130	1 300
3	36	44	11,0	0,81	130	1 430
4	36	48	12,0	0,75	130	1 560
5	36	52	13,0	0,69	130	1 690
6	36	56	14,0	0,64	130	1 820
7	36	60	15,0	0,60	130	1 950
8	40	36	10,0	1,11	150	1 500
9	40	40	11,1	1,0	150	1 665
10	40	44	12,2	0,90	130	1 586
11	40	48	13,3	0,83	130	1 729
12	40	52	14,4	0,77	130	1 872
13	40	56	15,5	0,71	130	2 015
14	40	60	16,7	0,67	130	2 171
15	44	36	11,0	1,22	150	1 650
16	44	40	12,2	1,10	150	1 830
17	44	44	13,4	1,0	150	2 010
18	44	48	14,7	0,92	130	1 911
19	44	52	15,9	0,84	130	2 067
20	44	56	17,1	0,78	130	2 223
21	44	60	18,3	0,73	130	2 379
22	48	36	12,0	1,33	150	1 800
23	48	40	13,3	1,2	150	1 995
24	48	44	14,7	1,09	150	2 205
25	48	48	16,0	1,0	150	2 400
26	48	52	17,3	0,92	130	2 249
27	48	56	18,7	0,86	130	2 431
28	48	60	20,0	0,8	130	2 600

TABLE 2: HOODS

Hood type	Flow (cubic feet per minute)	Velocity at opening (feet per min)	Calculated surface area of opening (sq.inch)	Boiler width (inches)	Boiler and hood length (inches)	Required height of opening (inches)	Number & height of openings (inches)		Pipe diameter (inches)
1	1 350	2 000	97,2	36	36	2,70	3	$^{3}/_{4}$	12
2	1 300	2 000	93,6	36	40	2,34	3	$^{3}/_{4}$	12
3	1 430	2 000	103,0	36	44	2,34	3	$^{3}/_{4}$	12
4	1 560	2 000	112,3	36	48	2,34	3	$^{3}/_{4}$	12
5	1 690	2 000	121,7	36	52	2,34	3	$^{3}/_{4}$	14
6	1 820	2 000	131,0	36	56	2,34	3	$^{3}/_{4}$	14
7	1 950	2 000	140,4	36	60	2,34	3	$^{3}/_{4}$	14
8	1 500	2 000	108,0	40	36	3,00	3	1	12
9	1 665	2 000	120,0	40	40	3,00	3	1	12
10	1 586	2 000	114,2	40	44	2,60	3	$^{7}/_{8}$	14
11	1 729	2 000	124,5	40	48	2,60	3	$^{7}/_{8}$	14
12	1 872	2 000	134,8	40	52	2,60	3	$^{7}/_{8}$	14
13	2 015	2 000	145,1	40	56	2,60	3	$^{7}/_{8}$	14
14	2 171	2 000	156,3	40	60	2,60	3	$^{7}/_{8}$	14
15	1 650	2 000	118,8	44	36	3,30	4	$^{13}/_{16}$	12
16	1 830	2 000	131,8	44	40	3,30	4	$^{13}/_{16}$	14
17	2 010	2 000	144,7	44	44	3,29	4	$^{13}/_{16}$	14
18	1 911	2 000	137,6	44	48	2,87	3	$^{15}/_{16}$	14
19	2 067	2 000	148,8	44	52	2,86	3	$^{15}/_{16}$	14
20	2 223	2 000	160,0	44	56	2,86	3	$^{15}/_{16}$	15
21	2 379	2 000	171,3	44	60	2,85	3	$^{15}/_{16}$	15
22	1 800	2 000	129,6	48	36	3,60	4	$^{7}/_{8}$	14
23	1 995	2 000	143,6	48	40	3,59	4	$^{7}/_{8}$	14
24	2 209	2 000	158,8	48	44	3,60	4	$^{7}/_{8}$	14
25	2 400	2 000	172,8	48	48	3,60	4	$^{7}/_{8}$	16
26	2 249	2 000	161,9	48	52	3,11	4	$^{3}/_{4}$	15
27	2 431	2 000	175,0	48	56	3,13	4	$^{3}/_{4}$	15
28	2 600	2 000	187,2	48	60	3,12	4	$^{3}/_{4}$	15

After determining the size of the exhaust hoods, it is important to assess the position of the equipment in order to design the most symmetrical exhaust system possible. Among other things, this will allow for equal flow to each of the hoods.

5.2 EXHAUST AT THE SOURCE DURING TRANSFER OF CRAB BASKETS

It has also been noted that while baskets of crab are being transferred from the boiler over to the cooling basin, there is a significant loss of steam that it would be wise to remove. As previously described, it would be more efficient to design an exhaust system at the source. Since this part of the equipment is mobile, it is more difficult to plan this type of exhaust system.

In this case, we suggest installing a mobile hood connected to a flexible conduit, which could be attached directly to the hoist transferring the crab cages. This system would allow us to take up a great deal of the steam and remove it directly to the outside of the building. However, we understand that the dimensions of the hood will have to be limited, since they must not hinder the operation of the hoist.

Normally, a hood is constructed in such a way that it covers the entire surface of the equipment that is to be ventilated. In conventional practice, the hood size must be larger than that of the equipment to be ventilated by about 6 inches around the entire perimeter of the equipment. In the case that concerns us, we estimate that the dimensions must be limited to a mobile hood of about 36 inches by 24 inches. This will permit the removal of almost all of the steam that escapes from the baskets.

The method used to design these hoods is as follows: the flow corresponds to 1.4 * the perimeter of the basket * the distance between the hood and the crab baskets * the uptake velocity. According to the literature, when removing steam of this type, the uptake velocity is calculated to be 50 feet/minute. The following table summarizes the results of typical calculations.

TABLE 3: VENTILATION FLOW REQUIRED DURING TRANSPORT

Hood type	Crab basket length (inches)	Crab basket width (inches)	Height between hood & basket (inches)	Basket perimeter (inches)	Uptake velocity (feet per minute)	Calculated flow (cubic feet per min)
1	36"	24"	24"	10	50	1 400
2	36"	36"	24"	12	50	1 680
3	36"	24"	36"	10	50	2 100
4	36"	36"	36"	12	50	2 520
5	36"	24"	48"	10	50	2 800
6	36"	36"	48"	12	50	3 360
7	42"	24"	24"	11	50	1 540
8	42"	36"	24"	13	50	1 820
9	42"	24"	36"	11	50	2 310
10	42"	36"	36"	13	50	2 730
11	42"	24"	48"	11	50	3 080
12	42"	36"	48"	13	50	3 640
13	48"	24"	24"	12	50	1 680
14	48"	36"	24"	14	50	1 960
15	48"	24"	36"	12	50	2 520
16	48"	36"	36"	14	50	2 940
17	48"	24"	48"	12	50	3 360
18	48"	36"	48"	14	50	3 920

The results obtained in Table 3 show that at heights greater than 24 inches between the top of the crab basket and the beginning of the hood, the necessary flow is so large that it will be difficult to design a system under these conditions.

As the hood is mobile and it must consequently be attached to a flexible hose, we will have to limit the flow to an exhaust conduit of 12 inches in diameter, since this value corresponds to the maximum acceptable size for a flexible pipe used in food service.

Finally, for a group of hoods linked in a network, these figures allow for the evaluation of the overall system to be installed, particularly for the capacities of the fans and the exhaust equipment.

Given that this equipment is used mainly to ventilate food products, you will understand that the standards require that all of the equipment, air ducts, etc. be made of stainless steel.

6.0 **COST ESTIMATES**

In our role as consultants, we are putting forward our opinion on the probable construction costs at the pre-project level for several examples of common conditions. In Appendix C you will find a detailed ventilation *(sic)* of the costs. This is submitted with all due reserve, and must only be used to give to give a rough estimate of the construction costs. This opinion does not in any way constitute a guarantee that the actual costs of construction will not exceed the sum of our estimates.

The costs are expressed in 1998 Canadian dollars. Any undertaking at a later date must entail a revision of the probable costs to take into account the inflation of the cost of materials, of labour and of changes in market trends.

Common examples:

Estimate #1: One boiler hood, 1,950 cubic feet/minute, conduits, fan, and accessories, see Sketch M3.

Estimate #2: A group of two boiler hoods, 1,950 cubic feet/minute, each connected by a network of piping and accessories to a common fan, see Sketch M4.

Estimate #3: A group of three boiler hoods, 1,950 cubic feet/minute, each connected to a network of piping and accessories to a common fan, see Sketch M5.

Estimate #4: A group of four boiler hoods, 1,950 cubic feet/minute, each connected by a network of piping and accessories to a common fan, see Sketch M6.

Estimate #5: One mobile crab basket hood, 1,400 cubic feet/minute, piping, accessories, and fan, see Sketch M7.

7.0 CONCLUSION

The pre-project study of boiler ventilation presented here has made possible the description of a typical installation and several design parameters that could be used in various similar plants. Depending on the placement of the equipment, the number, the choice of fans and the length of piping may certainly differ. The estimate and choice of exhaust equipment will thus have to be adapted to the actual plant encountered.

In a second phase, we will be happy to help you with preparing plans and estimates in order to carry out the work described in this study.

Respectfully submitted,

Groupe-conseil TDA

APPENDIX A

REFERENCE DOCUMENTS

Section 4

HOOD DESIGN DATA

Introduction

Proper design of exhaust hoods is necessary if a local exhaust system is to effectively control atmospheric contamination at its source with a minimum air flow and power consumption. The theory of capture velocity depends on the creation of air flow past the source of contaminant sufficient to remove the highly contaminated air around the source or issuing from that source and to draw the air into an exhaust hood.

It can be shown that dust particles in the small micron sizes, even if impelled at extremely high original velocities, travel a very short distance in air--a matter of a few inches at the most (References 7, 16). Thus the fine dust particles of health significance follow the air currents and are often referred to as "air-borne dust." The same considerations apply to mists and fumes. Vapors and gases, of course, mix intimately with air and follow the air currents.

Larger dust particles released at high velocities (example, the larger particles from grinding) do have an appreciable trajectory or "throw" in air. These larger particles cannot be captured unless directed into the hood. Scattering can also be prevented by properly placed barriers. It is desirable to collect this dust as well as the truly air-borne dust and thus utilize the exhaust ventilation to improve the housekeeping and maintenance situation in the plant.

Principles of Hood Design

Basically, hood design requires sufficient knowledge of a process or operation so the most effective hood or enclosure can be installed to provide minimum exhaust volumes for effective contaminant control. The more complete the enclosure, the more economical and effective the installation will be. Many designers develop their hoods by mentally enclosing the operation completely, from there providing access and working openings as indicated. From this complete enclosure concept, familiar hood shapes like booths, side or down-draft hoods with or without side shields are developed. All openings are kept to a minimum and located away from the natural path of the contaminant travel wherever possible. Inspection and maintenance openings are provided with doors whenever practicable.

Local hoods that do not enclose or confine the contaminant are recommended only as a last resort because exhaust volumes are large and control can be so easily upset by cross drafts in the area.

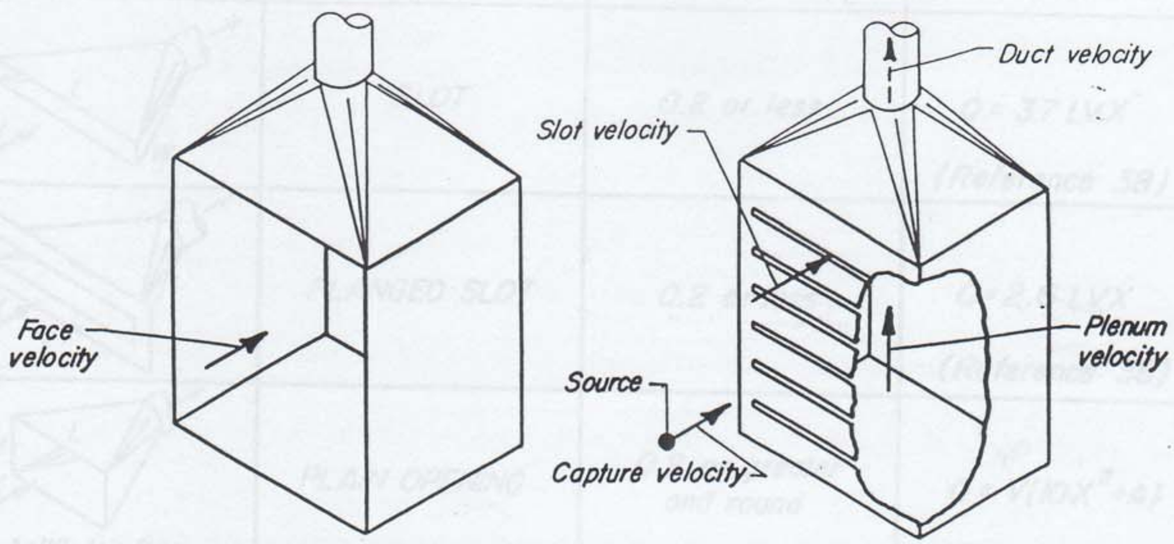
Canopy hoods are effective for the control of hot processes and for those operations which release sudden surges of hot gases and vapors. Canopies should not be used where men must work directly over the operation as in the case of plating tanks and cementing tables since the flow of air passes the worker's breathing zone and can increase his exposure to toxic materials.

Exhaust duct takeoffs will be located, when possible, to be in the line of normal contaminant travel and will be arranged so desired distribution of exhaust air flow is attained. In the case of large shallow hoods, the air movement tends to concentrate in front of the duct opening. Satisfactory air distribution can be attained by using multiple takeoffs or by installing interior baffles or filter banks.

Effects of Flanging

Wherever possible, flanges should be provided to eliminate air flow from ineffective zones where no contaminant exists. Increasing the hood effectiveness in this manner can reduce air requirements by as much as 25% (See Figures 4-2, 4-3 and 4-4.) For most applications the flange width should be equal to the hood diameter or side to be effective.

It is only after the hood design has been determined that exhaust volume requirements can be calculated. With enclosures, volumes are calculated from the known open area of the hood and the selection of the capture or indraft velocity sufficient to prevent outward escapement. Where enclosure of the process is impracticable, air flow pattern in front of the hood must be such that selected capture velocities will be maintained in the area of generation, conveying the contaminant to the hood opening.



Capture Velocity – *Air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.*

Face Velocity – *Air velocity at the hood opening.*

Slot Velocity – *Air velocity through the openings in a slot-type hood, fpm. It is used primarily as a means of obtaining uniform air distribution across the face of the hood.*

Plenum Velocity – *Air velocity in the plenum, fpm. For good air distribution with slot-types of hoods, the maximum plenum velocity should be 1/2 of the Slot Velocity or less.*

Duct Velocity – *Air velocity through the duct cross section, fpm. When solid material is present in the air stream, the duct velocity must be equal to the Minimum Design Duct Velocity.*

Minimum Design Duct Velocity – *Minimum air velocity required to move the particulates in the air stream, fpm.*

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
PRINCIPLES OF EXHAUST HOODS	
DATE *1-76*	*Fig. 4-1*

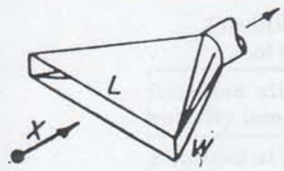
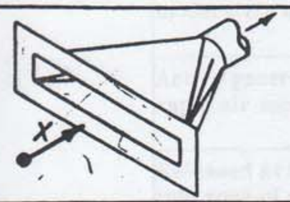
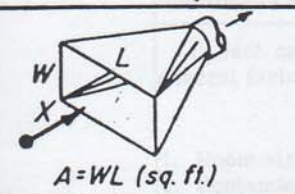
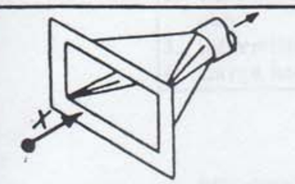
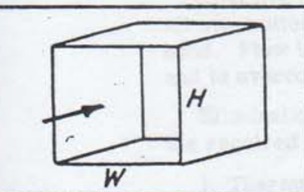
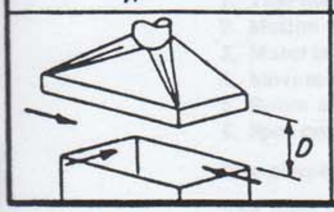
HOOD TYPE	DESCRIPTION	ASPECT RATIO, $\frac{W}{L}$	AIR VOLUME
	SLOT	0.2 or less	$Q = 3.7\,LVX$ (Reference 38)
	FLANGED SLOT	0.2 or less	$Q = 2.6\,LVX$ (Reference 38)
	PLAIN OPENING	0.2 or greater and round	$Q = V(10X^2 + A)$ (Reference 9)
	FLANGED OPENING	0.2 or greater and round	$Q = 0.75\,V(10X^2 + A)$ (Reference 9)
	BOOTH	To suit work	$Q = VA = VWH$
	CANOPY	To suit work	$Q = 1.4\,PDV$ See VS-903 P = perimeter of work D = height above work

Fig. 4-4

Capture Velocities

Capture velocity is the velocity at any point in front of the hood necessary to overcome opposing air currents and to capture the contaminated air by causing it to flow into the exhaust hood.

Exceptionally high volume hoods (example, large side-draft shakeout) require less air volume than would be indicated by the capture velocity values recommended for small hoods. This phenomenon is ascribed to: be indicated by the capture velocity values recommended for small hoods. This phenomenon is ascribed to:

1. **The presence of a large air mass moving into the hood.**
2. **The fact that the contaminant is under the influence of the hood for a much longer time than is the case with small hoods.**
3. **The fact that the large air volume affords considerable dilution as described above.**

Table 4-1 offers capture velocity data. Additional information is found in Section 5, Table 5-9-2.

TABLE 4-1

RANGE OF CAPTURE VELOCITIES (7,24)

Condition of Dispersion of Contaminant	Examples	Capture Velocity, fpm
Released with practically no velocity into quiet air.	Evaporation from tanks; degreasing, etc.	50-100
Released at low velocity into moderately still air.	Spray booths; intermittent container filling; low speed conveyor transfers; welding; plating; pickling	100-200
Active generation into zone of rapid air motion	Spray painting in shallow booths; barrel filling; conveyor loading; crushers	200-500
Released at high initial velocity into zone of very rapid air motion.	Grinding; abrasive blasting, tumbling	500-2000

In each category above, a range of capture velocity is shown. The proper choice of values depends on several factors:

Lower End of Range	Upper End of Range
1. Room air currents minimal or favorable to capture.	1. Disturbing room air currents.
2. Contaminants of low toxicity or of nuisance value only.	2. Contaminants of high toxicity.
3. Intermittent, low production.	3. High production, heavy use.
4. Large hood—large air mass in motion.	4. Small hood—local control only.

Hood Design Procedure

Effective control of a contaminant producing process is brought about by first eliminating or minimizing all air motion about the process and then capturing the contaminated air by causing it to flow into the exhaust hood. Flow toward the suction opening must be sufficiently high to maintain the necessary capture velocity and to overcome opposing air currents.

Elimination of sources of air motion as a first step in hood design is an important factor in cutting down the required air volume and the corresponding power consumption. Important sources of air motion are:

1. Thermal air currents, especially from hot processes or heat-generating operations.
2. Motion of machinery, as by a grinding wheel, belt conveyor, etc.
3. Material motion, as in dumping or container filling.
4. Movements of the operator.
5. Room air currents (which are usually taken at 50 fpm minimum and may be much higher).
6. Spot cooling and heating equipment.

The shape of the hood, its size, location and rate of air flow are important design considerations.

The hood should enclose the operation as much as possible. If enclosure is not practicable, the hood should be located as close as possible to the source and shaped to control the area of contamination.

Flanges should be used whenever possible to eliminate exhausting air from ineffective areas (see page 4-1) and also to decrease the hood entry loss.

Hood Entry Coefficient and Static Pressure

If by creating suction air enters an opening, a typical flow pattern results as shown in Figure 4-2. Maximum convergence of the air stream occurs at a short distance downstream at the plane of the vena contracta where the diameter of the jet is smaller than the diameter of the duct.

The formation of the vena contracta is accompanied by a conversion of static pressure to velocity pressure and from velocity pressure back to static pressure. A loss of about 2% in static pressure results from the conversion of static to velocity pressure and a much greater loss in static pressure results from the conversion of velocity pressure at the vena contracta to static pressure as the air fills the duct. The area of the air stream at the vena contracta will vary with the shape of the hood or duct opening and for most hood shapes will range from 70% to 100% of the duct area.

It is, therefore, desirable to minimize the air stream contraction which occurs at the vena contracta zone by suitable hood design. Figure 4-8 illustrates the effect of hood design on the entry coefficient and on the entry loss in terms of velocity head in the connecting duct, the latter being another way of expressing hood entry loss.

Minimum Design Duct Velocity

For systems handling particulate, a minimum design velocity is required to prevent settling and plugging of ductwork. On the other hand, excessively high velocities are wasteful of power and may cause rapid abrasion of ductwork (Ref. 7, 57, 91, 118, 119, 120, 121, 122). Minimum design velocities are higher than theoretical and experimental values to protect against various practical contingencies such as:

1. Plugging or closing one or more branch will reduce the total volume in the system and correspondingly will reduce the velocities in at least some sections of the duct system.
2. Damage to ductwork, by denting for example, will increase the resistance and decrease the volume and velocity in the damaged leg of the system.
3. Leakage of ductwork will increase volume and velocity downstream of the leak but will decrease upstream and in other legs of the system.
4. Corrosion or erosion of the fan wheel or even slipping in a fan belt drive will reduce volumes and velocities.
5. Velocities must be adequate to pick up or re-entrain dust which may have settled due to improper operation of the exhaust system.

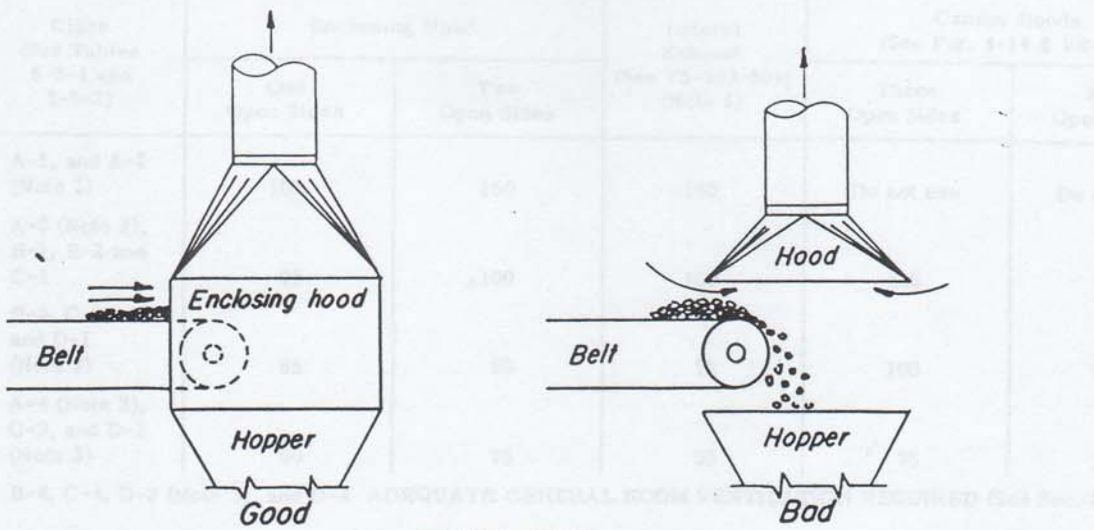
The designer is cautioned that for some conditions such as sticky materials, condensing conditions in the presence of dust, strong electrostatic effects, etc., velocity alone may not be sufficient to prevent plugging and other special measures may be necessary.

TABLE 4-2. RANGE OF DESIGN VELOCITIES

Nature of Contaminant	Examples	Design Velocity
Vapors, gases, smoke	All vapors gases and smokes	Any desired velocity (economic optimum velocity usually 1000-1200 fpm)
Fumes	Zinc and aluminum oxide fumes	1400-2000
Very fine light dust	Cotton lint, wood flour, litho powder	2000-2500
Dry Dusts and powders	Fine rubber dust, Bakelite molding powder dust, jute lint, cotton dust, shavings (light), soap dust, leather shavings	2500-3500
Average industrial dust	Sawdust (heavy and wet), grinding dust, buffing lint (dry), wool jute dust (shaker waste), coffee beans, shoe dust, granite dust, silica flour, general material handling, brick cutting, clay dust, foundry (general), limestone dust, packaging and weighing asbestos dust in textile industries	3500-4000
Heavy dusts	Metal turnings, foundry tumbling barrels and shakeout, sand blast dust, wood blocks, hog waste, brass turnings, cast iron boring dust, lead dust	4000-4500
Heavy or moist dusts	Lead dust with small chips, moist cement dust, asbestos chunks from transite pipe cutting machines, buffing lint (sticky), quick-lime dust	4500 and up

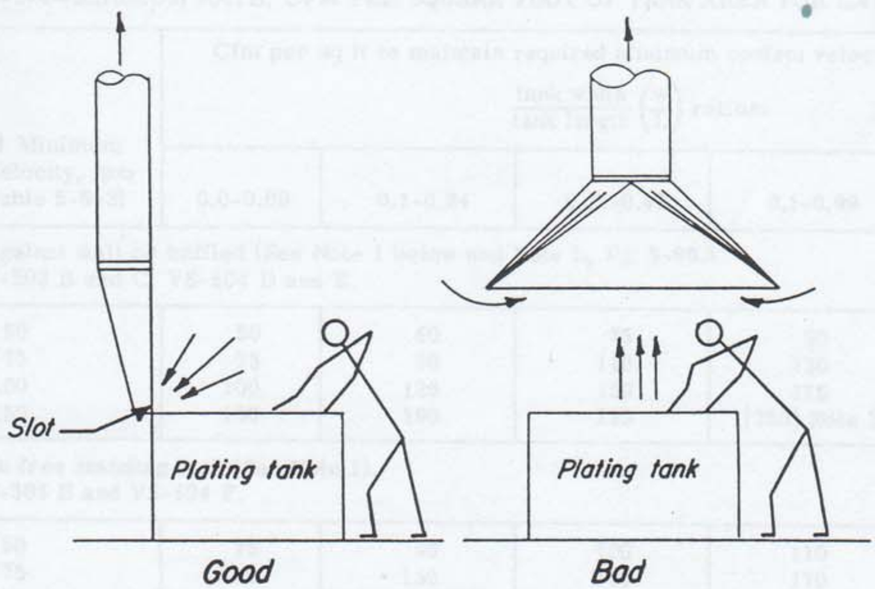
Example Problem I

Considering the grinding wheel hood shown in Figure 4-8, some typical calculations are as follows:



ENCLOSE

Enclose the operation as much as possible. The more completely enclosed the source, the less air required for control.



DIRECTION OF AIR FLOW

Locate the hood so the contaminant is removed away from the breathing zone of the worker.

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PRINCIPLES OF EXHAUST HOODS

DATE 1-64 | Fig. 4-10

TABLE 5-5-3—MINIMUM CONTROL VELOCITY (FPM) FOR UNDISTURBED LOCATIONS

Class (See Tables 5-5-1 and 5-5-2)	Enclosing Hood		Lateral Exhaust (See VS-503-504) (Note 1)	Canopy Hoods (See Fig. 4-14 & VS-903)	
	One Open Sides	Two Open Sides		Three Open Sides	Four Open Sides
A-1, and A-2 (Note 2)	100	150	150	Do not use	Do not use
A-3 (Note 2), B-1, B-2 and C-1	75	100	100	125	175
B-3, C-2, and D-1 (Note 3)	65	90	75	100	150
A-4 (Note 2), C-3, and D-2 (Note 3)	50	75	50	75	125
B-4, C-4, D-3 (Note 3), and D-4 ADEQUATE GENERAL ROOM VENTILATION REQUIRED (See Sec. 2)					

Notes: 1. Use aspect ratio to determine air volume, see Table 5-5-4 for computation.
2. Do not use canopy hood for Hazard Potential A processes.
3. Where complete control of hot water is desired, design as next highest class.

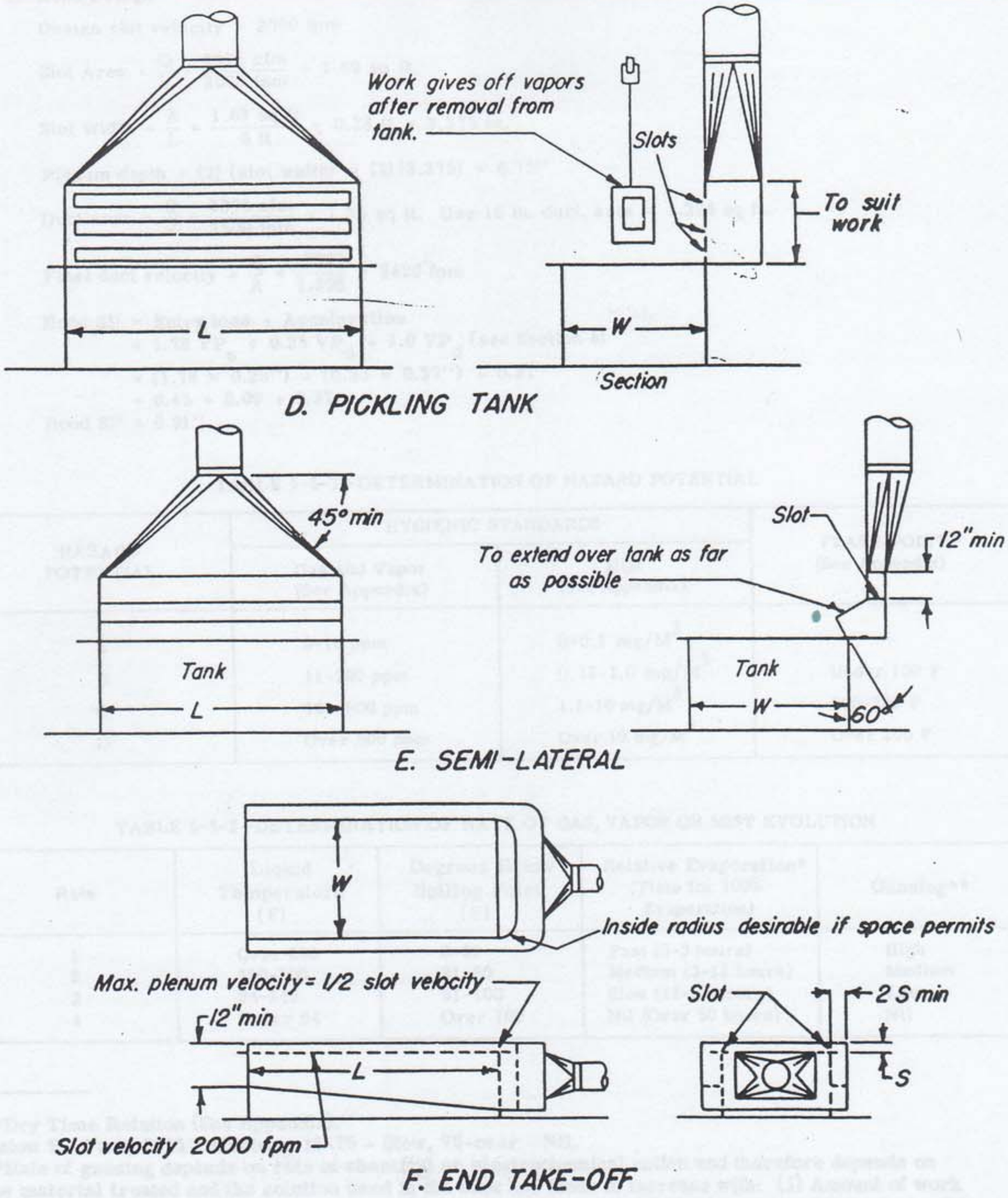
TABLE 5-5-4—MINIMUM RATE, CFM PER SQUARE FOOT OF TANK AREA FOR LATERAL EXHAUST

Required Minimum Control Velocity, fpm (From Table 5-5-3)	Cfm per sq ft to maintain required minimum control velocities at following $\frac{\text{tank width}}{\text{tank length}}\left(\frac{W}{L}\right)$ ratios.				
	0.0-0.09	0.1-0.24	0.25-0.49	0.5-0.99	1.0-2.0 Note 2
Hood against wall or baffled (See Note 1 below and Note L, Pg. 5-66.) See VS-503 B and C, VS-504 D and E.					
50	50	60	75	90	100
75	75	90	110	130	150
100	100	125	150	175	200
150	150	190	225	[250] Note 3	[250] Note 3
Hood on free standing tank (See Note 1). See VS-503 B and VS-504 F.					
50	75	90	100	110	125
75	110	130	150	170	190
100	150	175	200	225	250
150	225	[250] Note 3	[250] Note 3	[250] Note 3	[250] Note 3

Notes: 1. Use W/2 as tank width in computing W/L ratio for hood along centerline or two parallel sides of tank. See VS-503 B and VS-504 F.

2. See Notes F and G. Pg. 5-66.

3. While bracketed values may not produce 150 fpm control velocity at all aspect ratios, the 250 cfm/ft^2 is considered adequate for control.



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OPEN SURFACE TANKS

DATE	1-66	VS-504

SEE NOTICE OF INTENDED CHANGE

c. Hood Design

Design slot velocity = 2000 fpm

Slot Area = $\frac{Q}{V} = \frac{3375 \text{ cfm}}{2000 \text{ fpm}} = 1.69$ sq ft.

Slot Width = $\frac{A}{L} = \frac{1.69 \text{ sq ft}}{6 \text{ ft}} = 0.28$ ft = 3.375 in.

Plenum depth = (2) (slot width) = (2)(3.375) = 6.75''

Duct area = $\frac{Q}{V} = \frac{3375 \text{ cfm}}{2500 \text{ fpm}} = 1.35$ sq ft. Use 16 in. duct, area = 1.396 sq ft.

Final duct velocity = $\frac{Q}{A} = \frac{3375}{1.396} = 2420$ fpm

Hood SP = Entry loss + Acceleration
= $1.78\ VP_s + 0.25\ VP_d + 1.0\ VP_d$ (see Section 4)
= (1.78 × 0.25'') + (0.25 × 0.37'') + 0.37''
= 0.45 + 0.09 + 0.37
Hood SP = 0.91''

TABLE 5-5-1—DETERMINATION OF HAZARD POTENTIAL

HAZARD POTENTIAL	HYGIENIC STANDARDS		FLASH POINT (See Appendix)
	Gas and Vapor (See Appendix)	Mist (See Appendix)	
A	0-10 ppm	0-0.1 mg/M^3	—
B	11-100 ppm	0.11-1.0 mg/M^3	Under 100 F
C	101-500 ppm	1.1-10 mg/M^3	100-200 F
D	Over 500 ppm	Over 10 mg/M^3	Over 200 F

TABLE 5-5-2—DETERMINATION OF RATE OF GAS, VAPOR OR MIST EVOLUTION

Rate	Liquid Temperature (F)	Degrees Below Boiling Point (F)	Relative Evaporation* (Time for 100% Evaporation)	Gassing**
1	Over 200	0-20	Fast (0-3 hours)	High
2	150-200	21-50	Medium (3-12 hours)	Medium
3	94-149	51-100	Slow (12-50 hours)	Low
4	Under 94	Over 100	Nil (Over 50 hours)	Nil

***Dry Time Relation (See Appendix).**
Below 5 - Fast, 5-15 - Medium, 15-75 - Slow, 75-over - Nil.
****Rate of gassing depends on rate of chemical or electrochemical action and therefore depends on the material treated and the solution used in the tank and tends to increase with: (1) Amount of work in the tank at any one time; (2) Strength of the solution in the tank; (3) Temperature of the solution in the tank; and (4) Current density applied to the work in electrochemical tanks.**

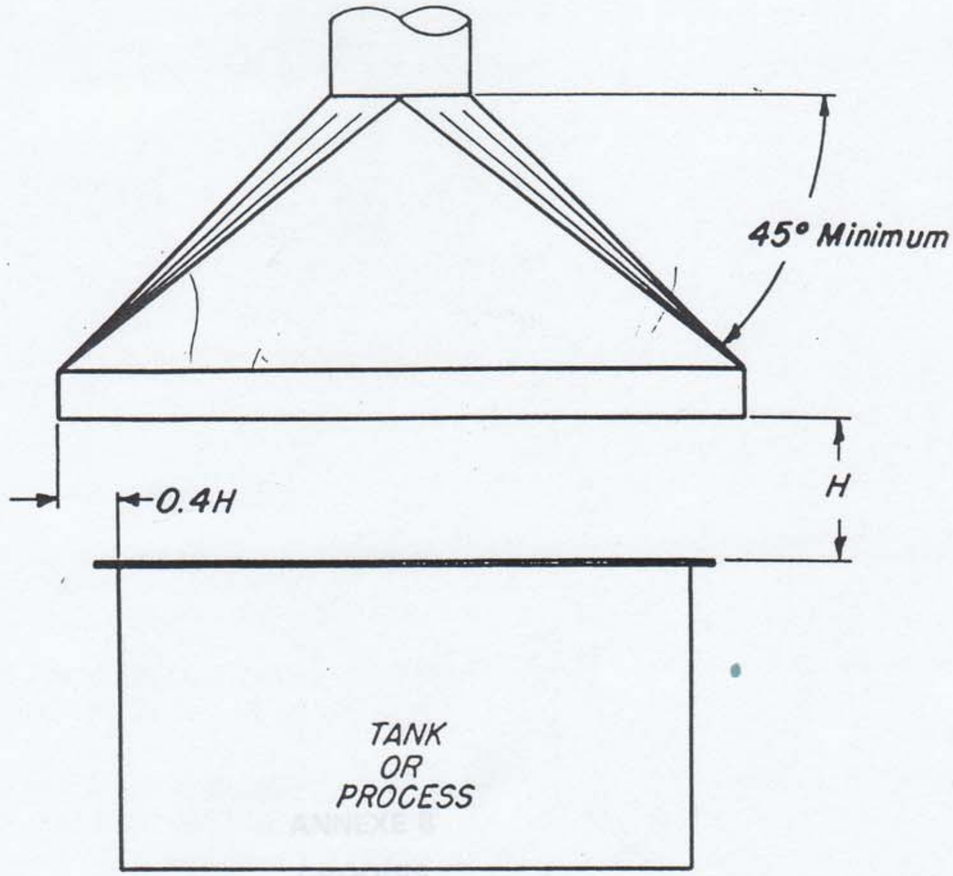
TABLE 5-5-5
Typical Processes
MINIMUM CONTROL VELOCITY (fpm) FOR UNDISTURBED LOCATIONS

Operation	Contaminant	Hazard	Contaminant Evolution	Lateral Exhaust Control Velocity See VS-503-504	Collector Recommended
Anodizing Alum.	Chromic-Sulf. Acids	A	1	150	X
Alum. Bright Dip	Nitric+Sulf. Acids	A	1	150	X
	Nitric+Phosphoric Acids	A	1	150	X
Plating -					
Chromium	Chromic Acid	A	1	150	X
Copper Strike	Cyanide Mist	C	2	75	X
Metal Cleaning (Boiling)	Alkaline Mist	C	1	100	X
Hot Water (If Vent Desired)					
Not Boiling	Water Vapor	D	2	50*	
Boiling		D	1	75*	
Stripping -					
Copper	Alkaline-Cyanide Mists	C	2	75	X
Nickel	Nitrogen Oxide Gases	A	1	150	X
Pickling - Steel	Hydrochloric Acid	A	2	150	X
	Sulfuric Acid	B	1	100	X
Salt Solution (Bonderizing & Parkerizing)					
Not Boiling	Water Vapor	D	2	50*	
Boiling		D	1	75*	
Salt Baths (Molten)	Alkaline Mist	C	1	100	X

* Where complete control of water vapor is desired, design as next highest class.

TABLE 5-5-6—AIRBORNE CONTAMINANTS RELEASED BY METALLIC SURFACE TREATMENT, ETCHING, PICKLING, ACID DIPPING AND METAL CLEANING OPERATIONS

Process	Type	Notes	Component of Bath which May be Released to Atmosphere (13)	Physical and Chemical Nature of Major Atmospheric Contaminant	Class (12)	Usual Temp. Range-F
Surface Treatment	Anodizing Aluminum		Chromic-Sulfuric Acids	Chromic Acid Mist	A-1	95
	Anodizing Aluminum		Sulfuric Acid	Sulfuric Acid Mist	B-1	60- 80
	Black Magic		Conc. Sol. Alkaline Oxidizing Agents	Alkaline Mist, Steam	C-1	260-350
	Bonderizing	1	Boiling Water	Steam	D-2,1 (14,15)	140-212
	Chemical Coloring		None	None	D-4	70- 90
	Descaling	2	Nitric-Sulfuric, Hydrofluoric Acids	Acid Mist, Hydrogen Fluoride Gas, Steam	B-2,1 (15)	70-150
	Ebonol		Conc. Sol. Alkaline Oxidizing Agents	Alkaline Mist, Steam	C-1	260-350
	Galvanic-Anodize	3	Ammonium Hydroxide	Ammonia Gas, Steam	B-3	140
	Hard Coating Aluminum		Chromic-Sulfuric Acids	Chromic Acid Mist	A-1	120-180
	Hard Coating Aluminum		Sulfuric Acid	Sulfuric Acid Mist	B-1	120-180
	Jetal		Conc. Sol. Alkaline Oxidizing Agents	Alkaline Mist, Steam	C-1	260-350
	Magcote	4	Sodium Hydroxide	Alkaline Mist, Steam	C-3,2 (15)	105-212
	Magnesium Pre-Dye Dip		Ammonium Hydroxide-Ammonium Acetate	Ammonia Gas, Steam	B-3	90-180
	Parkerizing	1	Boiling Water	Steam	D-2,1 (14,15)	140-212
	Zincete Immersion	5	None	None	D-4	70- 90



Not to be used where material is toxic and worker must bend over tank or process.
Side curtains are necessary when extreme cross-drafts are present.

Q = 1.4PHV	for open type canopy. P= perimeter of tank, feet. V= 50-500 fpm. See Section 4
Q =(W+L)HV	for two sides enclosed. W & L are open sides of hood. V = 50-500 fpm. See Section 4
Q = WHV or LHV	for three sides enclosed. (Booth) V= 50-500 fpm. See Section 4

Entry loss= .25 duct VP
Duct velocity=1000-3000 fpm

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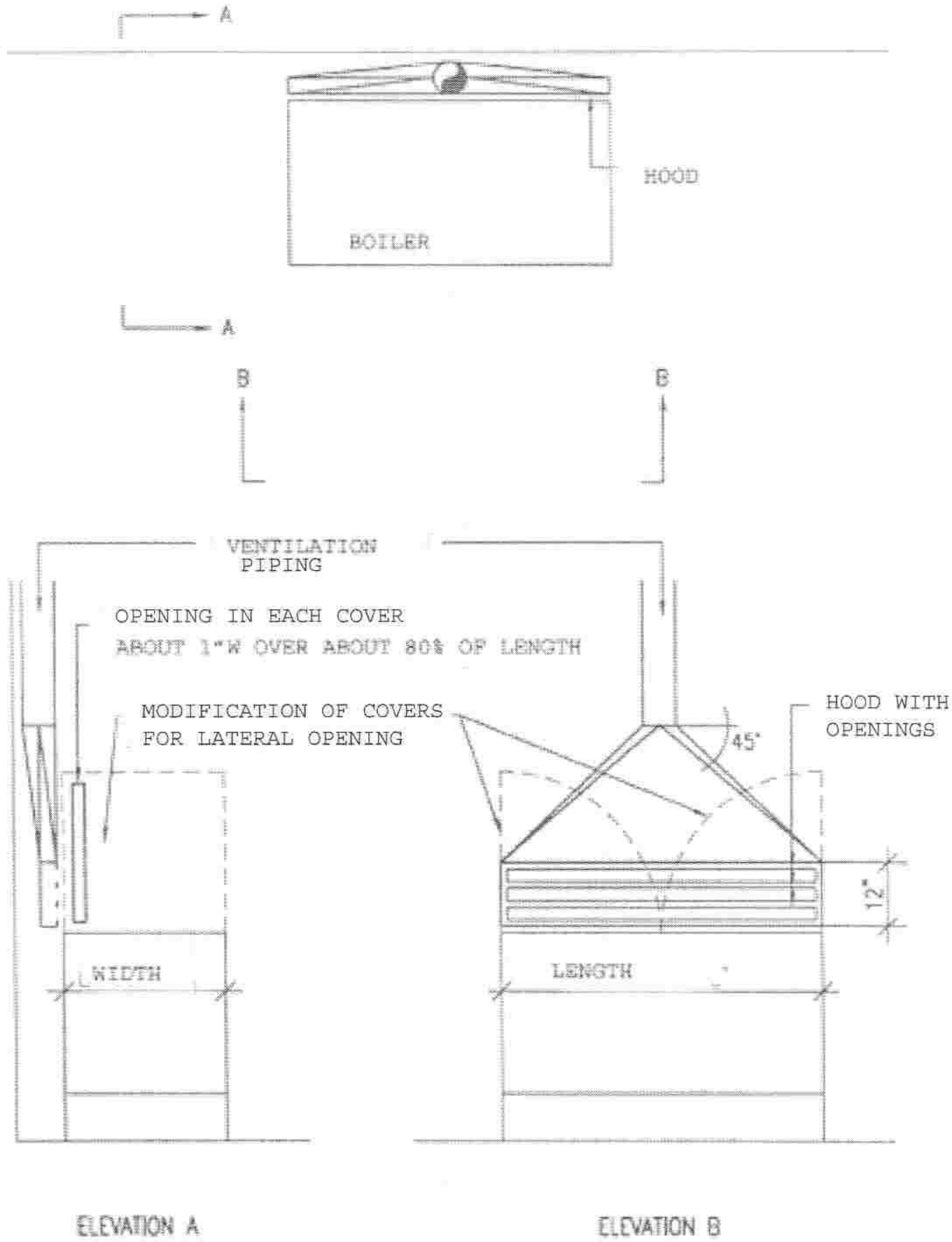
CANOPY HOOD

DATE 1-70 | VS-903

APPENDIX B
SKETCHES

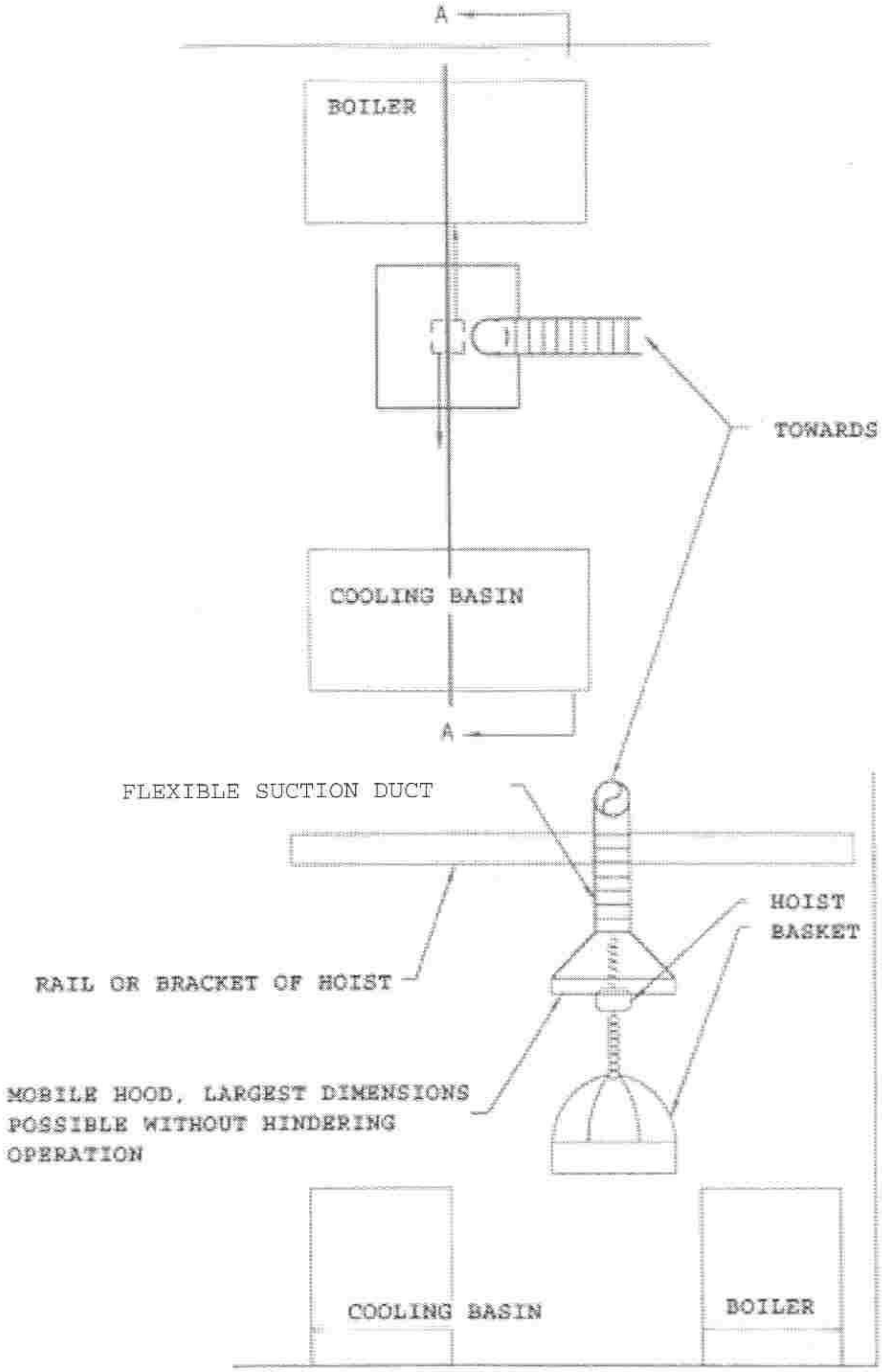


2616RAP3

Design:
STEAM UPTAKE
FIXED HOOD
TYPICAL MANUFACTURING DETAIL DRAWING

Groupe conseil TDA

Designed by:	Approved by:	Date:	Scale:	File:	
G.BOUCHARD	R.DUGAS	FEB. 98	NONE	98-2616	M1/7

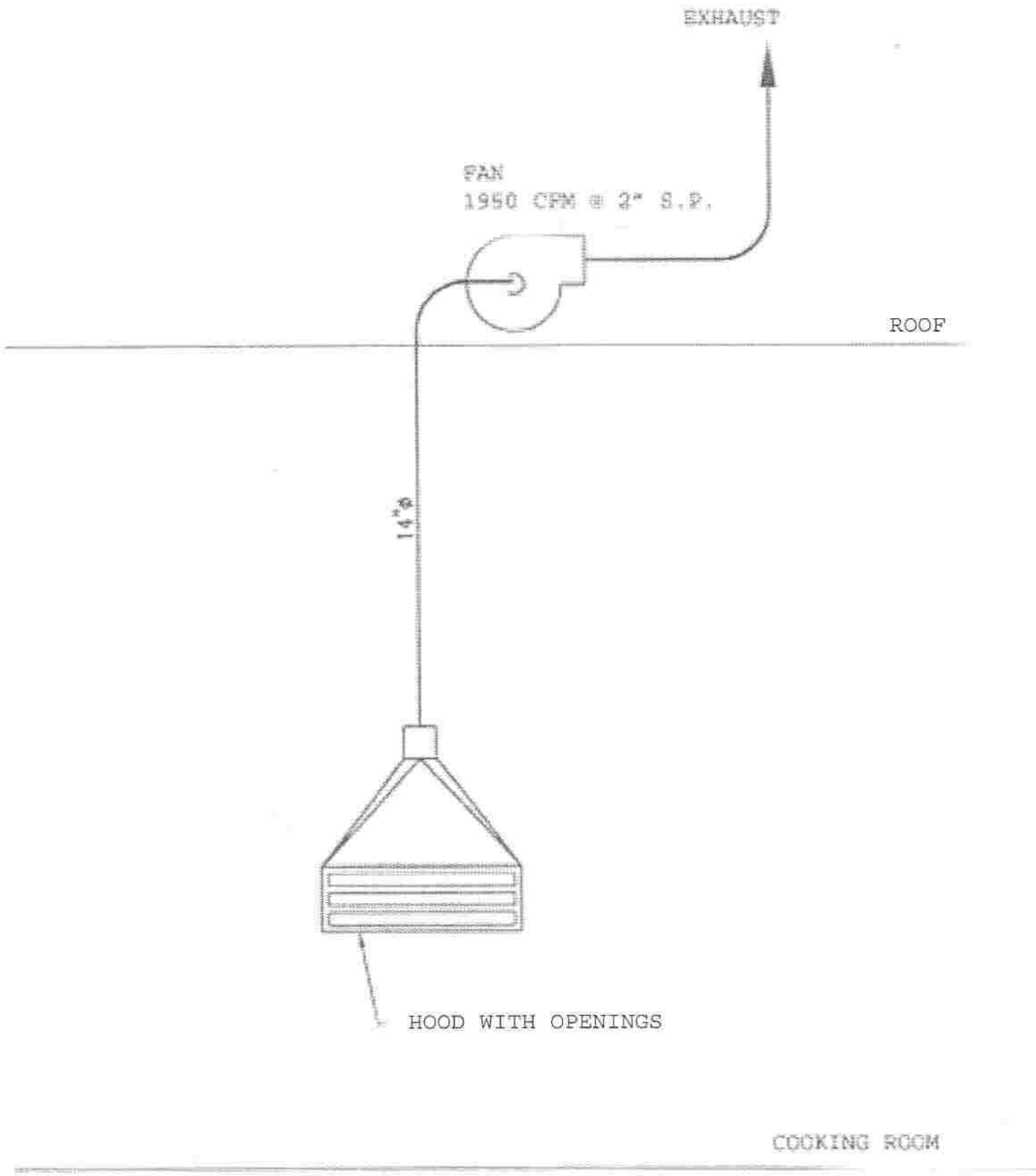


ELEVATION A

2616RAP4

Design: STEAM UPTAKE MOBILE HOOD TYPICAL MANUFACTURING DETAIL DRAWING	Groupe conseil TDA

Designed by:	Approved by:	Date:	Scale:	File:	
G.BOUCHARD	R.DUGAS	FEB. 98	NONE	98-2616	M2/7



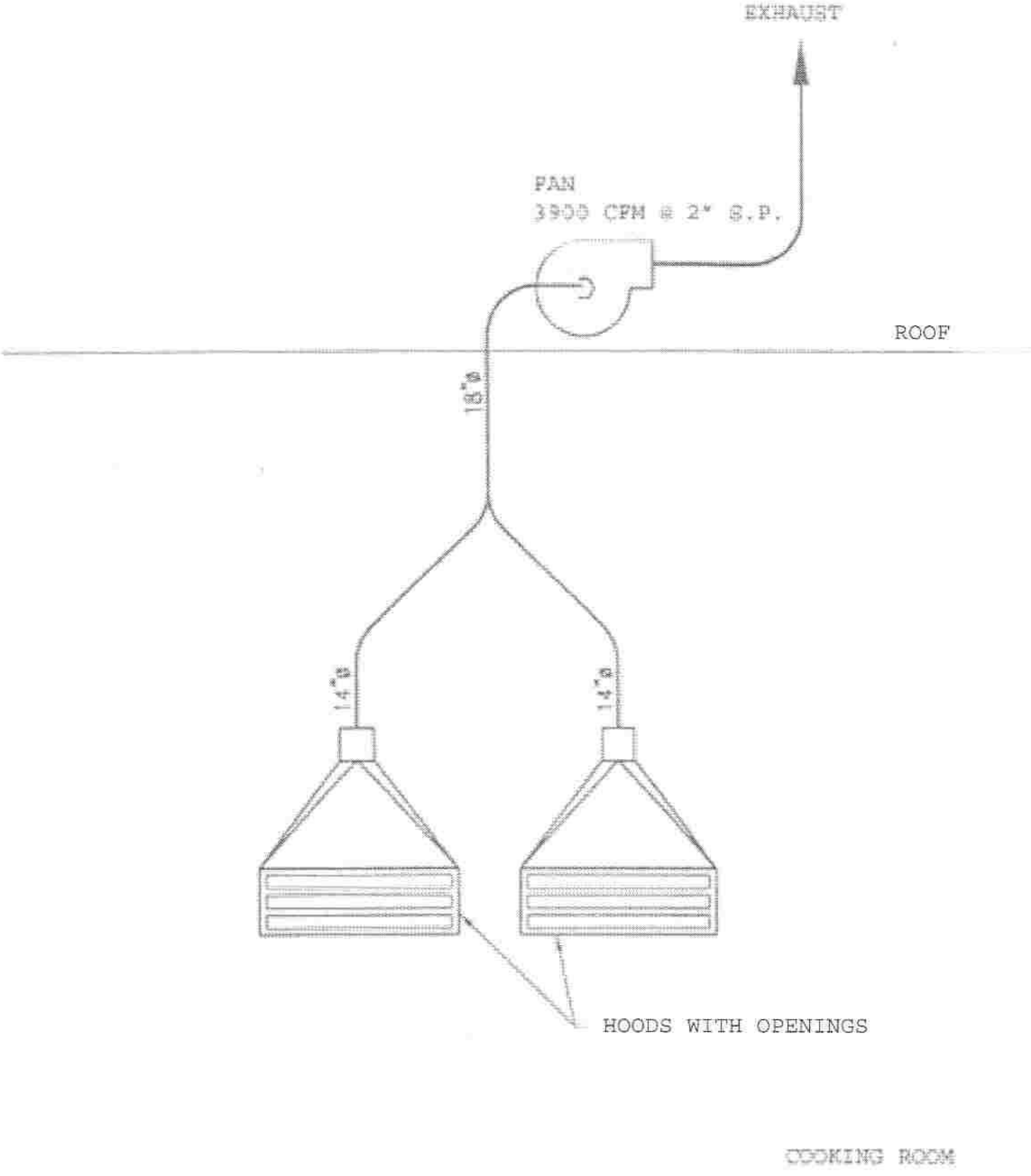
2616RA10

Design:

STEAM UPTAKE
TYPICAL INSTALLATION
1 FIXED HOOD 1950 CFM

Groupe conseil TDA

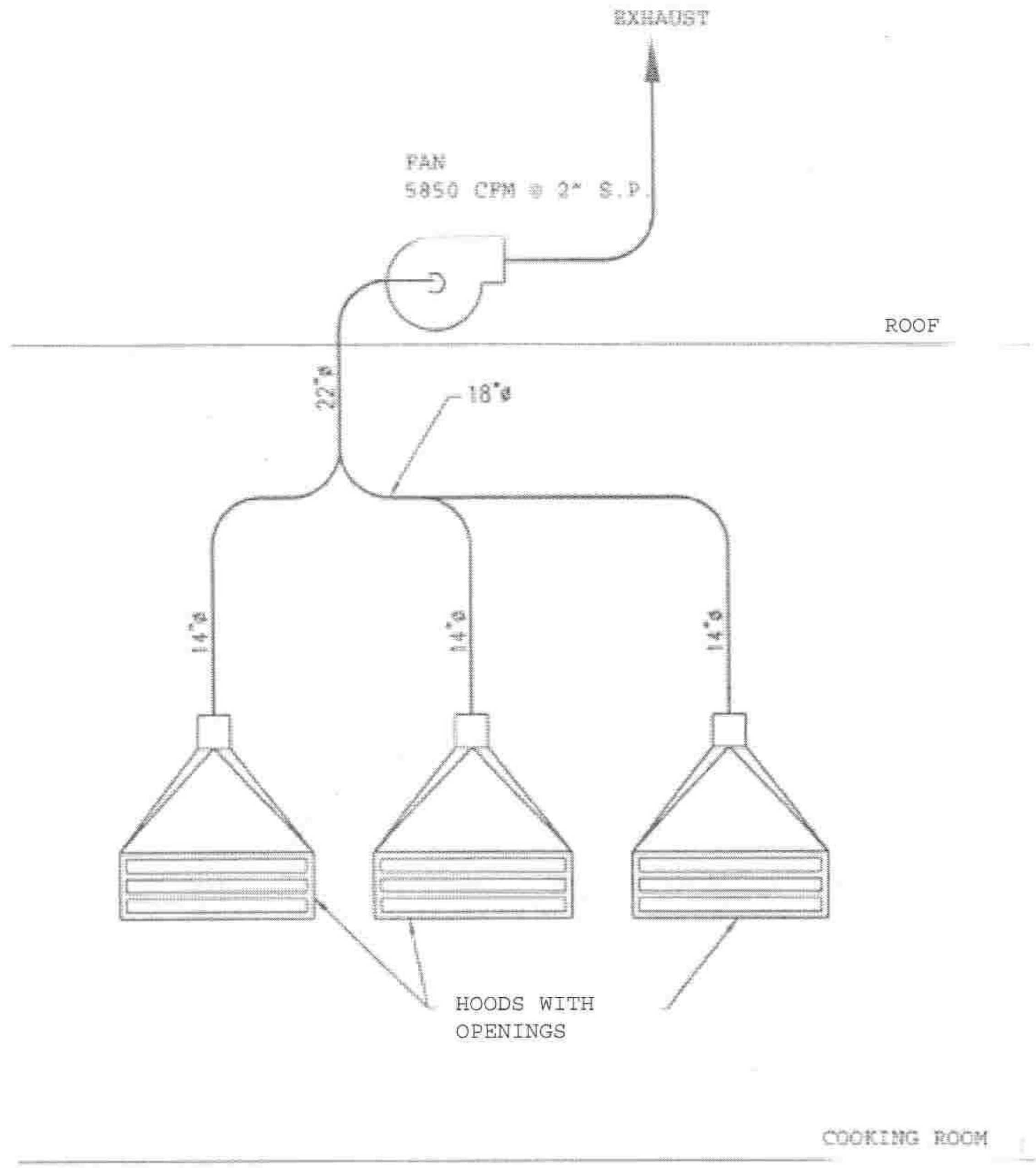
Designed by:	Approved by:	date:	Scale:	File:	
G.BOUCHARD	R.DUGAS	FEB. 98	NONE	98-2616	M3/7



2616RAP7

Design:	
STEAM UPTAKE TYPICAL INSTALLATION 2 FIXED HOODS 3900 CFM	Groupe conseil TDA

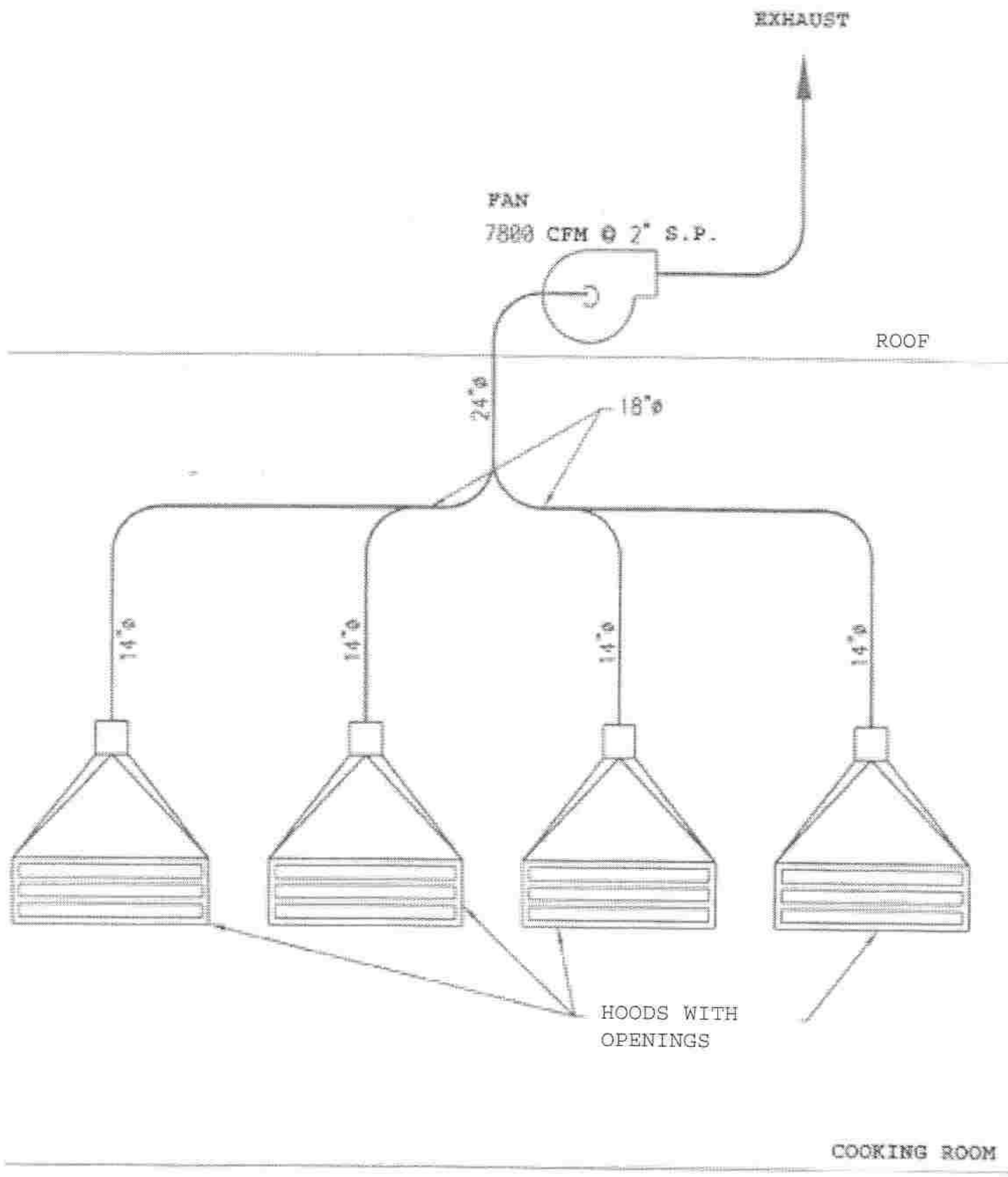
Designed by:	Approved by:	date	Scale:	File:	
G.BOUCHARD	R.DUGAS	FEB. 98	NONE	98-2616	M4/7



2616RAP8

Design:	
STEAM UPTAKE TYPICAL INSTALLATION 3 FIXED HOODS 5850 CFM	Groupe conseil TDA

Designed by:	Approved by:	date:	Scale:	File:	
G.BOUCHARD	R.DUGAS	FEB. 98	NONE	98-2616	M5/7



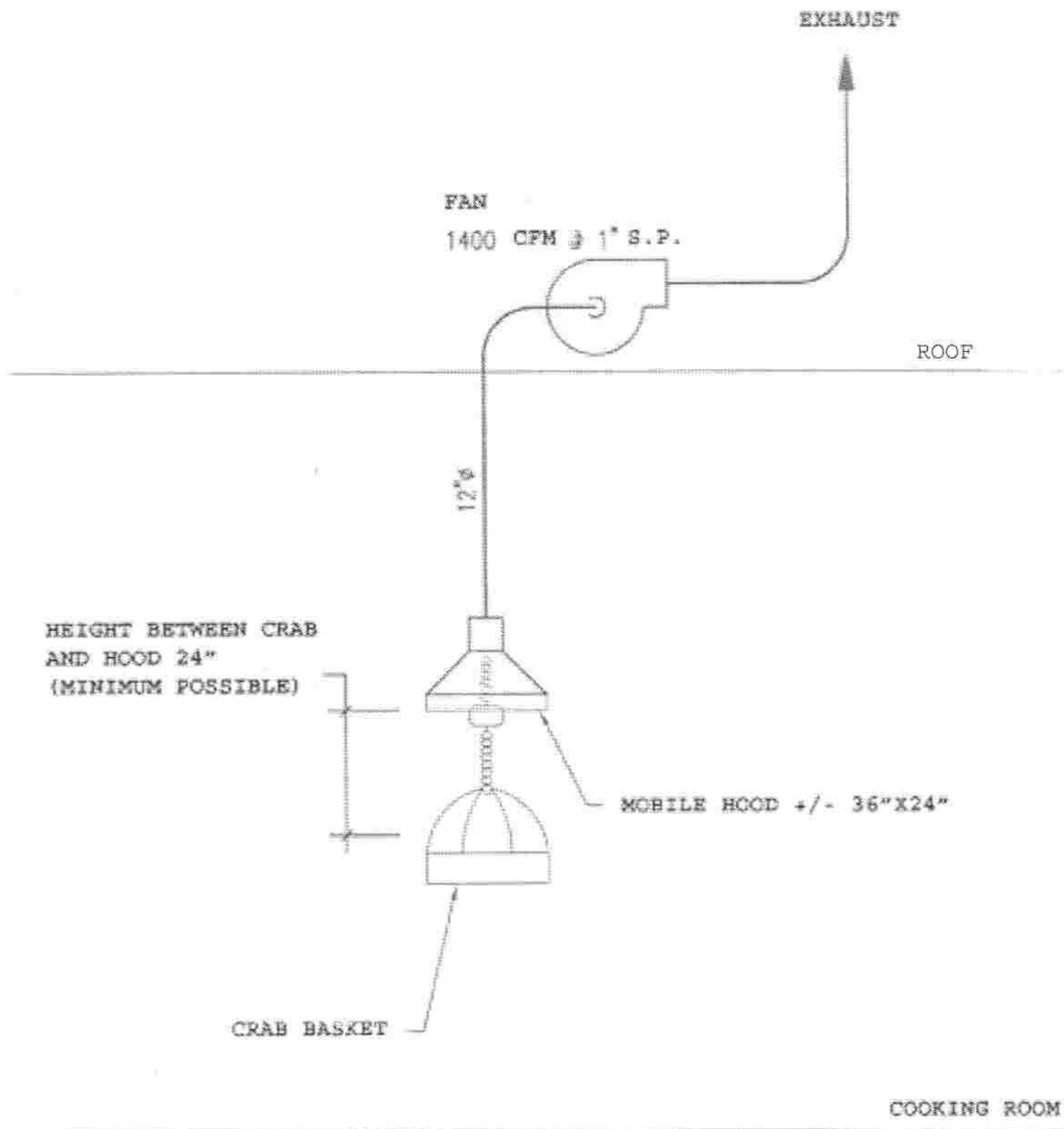
2616RAP9

Design:

STEAM UPTAKE
TYPICAL INSTALLATION
4 FIXED HOODS 7800 CFM

Groupe conseil TDA

Designed by:	Approved by:	Date:	Scale:	File:	
G.BOUCHARD	R.DUGAS	FEB. 98	NONE	98-2616	M6/7



2616RA11

Design:

STEAM UPTAKE
TYPICAL INSTALLATION
1 MOBILE HOOD 1400 CFM

Groupe conseil TDA

Designed by:	Approved by:	Date:	Scale:	File:	
G.BOUCHARD	R.DUGAS	MAY 03	NONE	98-2616	M7/7

APPENDIX C

PROBABLE COST ESTIMATES

PROBABLE COST ESTIMATES AT THE PRE-PROJECT LEVEL
DESCRIPTION

ESTIMATE #1 - One boiler hood

1,950 cubic feet/minute fan at 2" S.P. (1)	$1,900
Piping, accessories, supplies, manufacturing and installation (2)	$3,600
Total without taxes	$5,500

ESTIMATE #2 – Two boiler hoods, 1,950 cubic feet/minute

3,900 cubic feet/minute fan at 2" S.P. (1)	$2,500
Piping, accessories, supplies, manufacturing and installation (2)	$5,500
Total without taxes	$8,000

ESTIMATE #3 – Three boiler hoods, 1,950 cubic feet/minute

5,850 cubic feet/minute fan at 2" S.P. (1)	$3,000
Piping, accessories, supplies, manufacturing and installation (2)	$6,500
Total without taxes	$9,500

ESTIMATE # 4 – Four boiler hoods, 1,950 cubic feet/minute

7,800 cubic feet/minute fan at 2" S.P. (1)	$3,700
Piping, accessories, supplies, manufacturing and installation (2)	$7,800
Total without taxes	$11,500

ESTIMATE #5 – One mobile crab basket hood, 2000 cubic feet/minute

2,000 cubic feet/minute fan at 1" S.P. (1)	$1,800
Flexible conduit accepted for food service (1) $27 per foot	$325
Piping, accessories, supplies, manufacturing and installation (2)	$4,375
Total without taxes	$6,500

(1) Supplies only.

(2) Purchase of stainless sheet steel at about $3.25 per pound

Baie-Comeau, March 10, 1998

APPENDIX D
CASE STUDY:
CHUTE-AUX-OUTARDES PLANT

D.1 PROJECT DESCRIPTION

In order to facilitate the installation of 2 fixed hoods, it is necessary to relocate the boilers from one side to the other, positioned against the same wall as shown in Sketch C-1.

An assembly of 2 fixed hoods attached to a common fan (3,300 cubic feet/minute), as well as a mobile hood (1,500 cubic feet/minute) attached independently to its own fan, will have to be installed (see Sketch C-2). In order to minimize the discharge of cooking odours circulated by the fans, the pipes will be attached to the existing chimney already installed by the owner. Planning 2 independent fans, one for cooking (fixed hood) and one for transfer (mobile hood), makes it possible to limit the operating time of each fan.

D.2 PROBABLE COST ESTIMATES

Fixed hoods, one group of two	$8,000
Single mobile hood	$6,500
Miscellaneous 10%	$1,500
Total without taxes	$16,000

D.3 EXCLUDED WORK

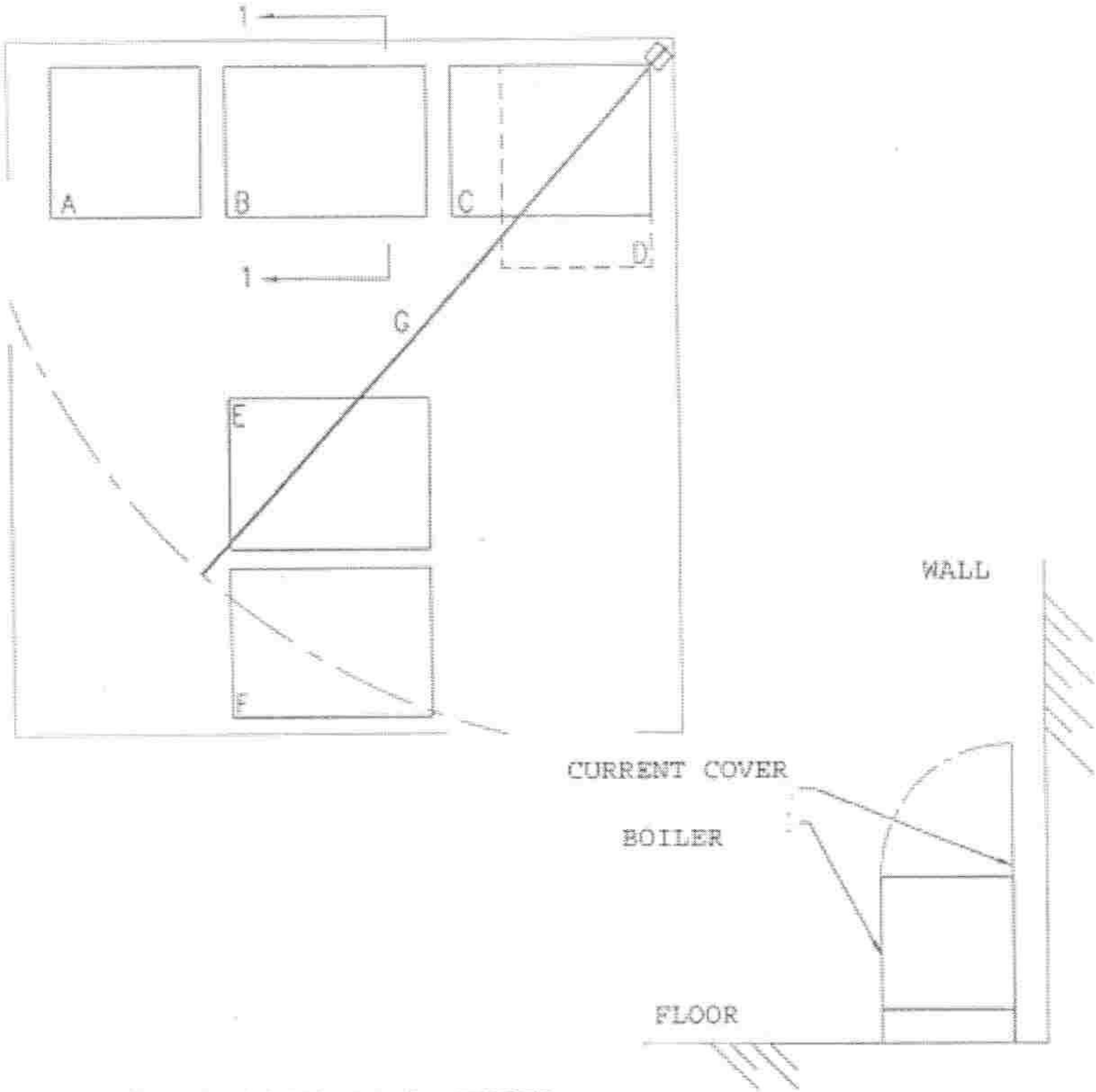
- Reorganization of the workplace, such as relocating the boilers to make the uptake process efficient
- Modification of the boiler covers

- Modification of the hoist to enable the installation of the mobile hood

- Relocating any water and propane pipes, etc., that hinder the installation of the hoods

D.4 **CONCLUSION**

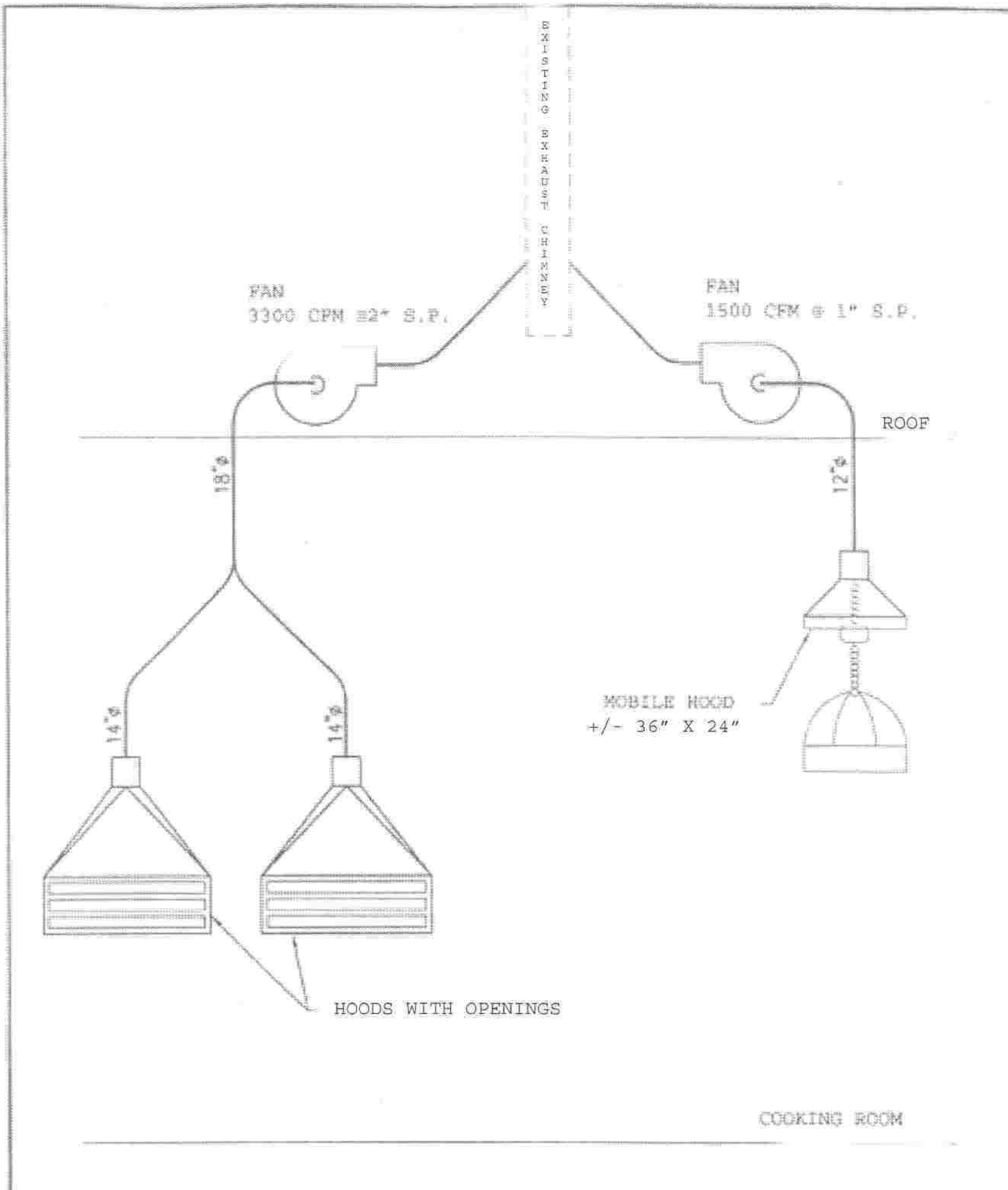
Completely carrying out the modifications described above will considerably improve the ventilation of the work sites. In order to improve the chances of success of such a project, we recommend that you consult our company to check the work that you are planning on the basis of the concepts explained in this report.



A: BOILER #1 30"wX30"lX30"d, UNUSED
B: BOILER #2 51"wX36"lX30"d, CURRENT POSITION
C: BOILER #3 51"wX36"lX30"d, SUGGESTED POSITION
D: BOILER #3 51"wX36"lX30"d, CURRENT POSITION
E: COLD WATER BASIN 51"wX36"lX30"d, FIRST COOLING,
STEAM UNTIL IMMERSION
F: COLD WATER BASIN 51"wX36"lX30"d, LAST COOLING, NO STEAM
G: BRACKET & HOIST FOR TRANSPORTING CRAB BASKETS

2616RAP1

Design: CRAB COOKING COOKING ROOM CURRENT & PROPOSED ARRANGEMENT CHUTE-AUX-OUTARDES		Groupe conseil TDA			
Designed by: G.BOUCHARD	Approved by: R.DUGAS	date: FEB. 98	Scale: NONE	File: 98-2616	C1 / 2



2616RAP5

Design:

STEAM UPTAKE
PROPOSED INSTALLATION
CHUTE-AUX-OUTARDES

Groupe conseil TDA

Designed by:	Approved by:	Date	Scale:	File:	
G.BOUCHARD	R.DUGAS	FEB. 98	NONE	98-2616	C2/2