

**MANUAL FOR THE CONSTRUCTION OF A
MERCURY CAPTURE SYSTEM FOR USE IN
GOLD PROCESSING SHOPS**

By:

Argonne National Laboratory

For:

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MANUAL FOR THE CONSTRUCTION OF A MERCURY CAPTURE SYSTEM FOR USE IN GOLD PROCESSING SHOPS

OVERVIEW

This manual provides detailed information on the construction, operation and maintenance of the Mercury Capture System (MCS), a device for the collection of mercury emitted from gold shops that process mercury-gold amalgam. This amalgam, which typically contains 5-40% mercury, is commonly referred to as dore. It is produced by artisanal and small-scale gold miners who use the mercury amalgamation method to separate gold from ore or alluvial deposits. Gold shops heat the dore to a high temperature to vaporize the mercury and refine the gold to a pure state. An MCS unit that is constructed, operated, and maintained in accordance with this manual should capture at least 80% of the mercury emitted in gold shop dore processing and significantly reduce personal inhalation exposure.

Part A is the base design for a system utilizing a fan with a 500 mm diameter, which is the maximum that can be accommodated in the drum housing the system. When this size fan is used the hood should have a face area (opening) of 0.25 m², which will provide a face velocity 0.4 m/sec into the hood, as is required to protect the operator from inhaling toxic mercury fumes. The 500 mm diameter baffle plates are designed to provide the optimal collection efficiency at the resulting volumetric flow rate of (0.25 x 0.4) = 0.1 m³/sec.

Part B describes recommended changes in system dimensions for different hood and mercury collection system configurations.

Part C provides illustrations for various installation configurations.

Part D provides recommendations to ensure best performance. IT IS IMPORTANT TO FOLLOW THESE RECOMMENDATIONS. More details provided in part D.



IMPORTANT RECOMMENDATIONS FOR BEST PERFORMANCE

Installation:

- Orient MCS, preferably vertically, to minimize air flow leakage and maximize collection of mercury;
- Position MCS to minimize heat from hood and blow torch and for easy access to the spigot for mercury flasking.

Operation:

- Drain and flask mercury daily into plastic or steel containers;
- Only run exhaust fans during and shortly after amalgam burning.

An **Addendum** gives the basis for calculation of dimensions for alternate system configurations.

This construction manual can be used in conjunction with the report:

Technology Demonstration for Reducing Mercury Emissions from Small-Scale Gold Refining Facilities, ANL/EVS/TM/08-6, Argonne National Laboratory, USA, February 2008.

Available at: <http://www.ipd.anl.gov/anlpubs/2008/06/61757.pdf>

For more information contact:

Primary Point of Contact: Loren Habegger
Argonne National Laboratory
Lemont, IL 60439
lhabegger@anl.gov

OR

Marilyn Livingood or Marianne Bailey
U.S. Environmental Protection Agency
Office of International and Tribal Affairs
Washington, DC 20460

Livingood.marilyn@epa.gov
Bailey.marianne@epa.gov

Part A: Base system design

Parts Listing

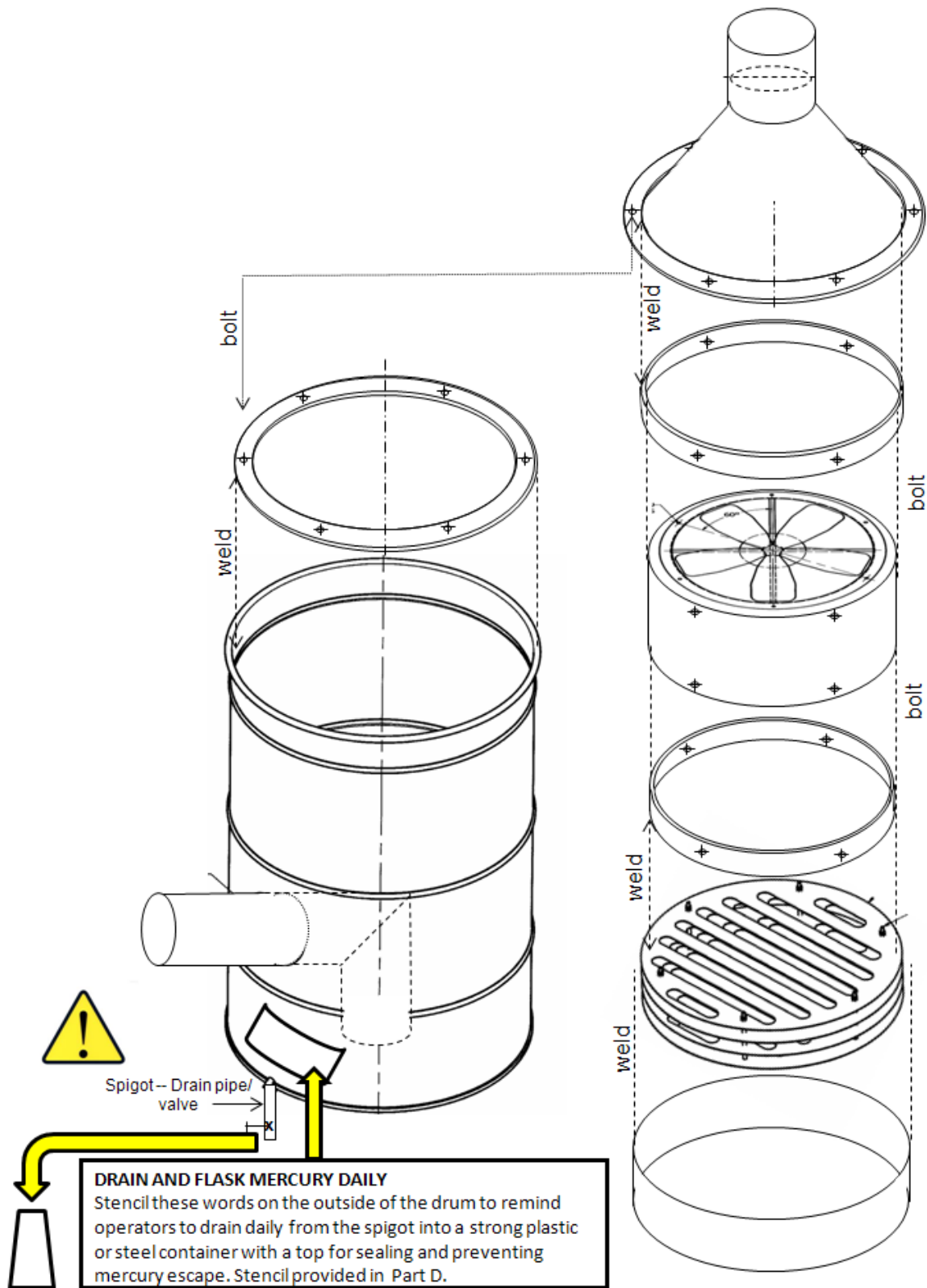
Dimensions are millimeter (mm), unless otherwise noted; t=thickness; dia=diameter. Some dimensions may need to be adjusted for specific applications and depending on the local availability of materials.

Item	Quantity	Description	Construction Notes
1	1	200-liter drum	Top and 150-mm inlet opening cut out
2	1	Drum top mounting ring; outer dia matches drum dia; 4-mm t; cover topside with gasket material	Drill 6 holes for bolting to cover; weld bolt nuts to underside of holes
3	1	L-shaped inlet pipe; 3-mm t	Weld to drum
4	1	Small dia tube with valve for mercury drain	Weld to drum; use locally available tubing
5	1	Deflector plate; semi-circular disc; 3-mm t	Bottom inlet only; dia adjusted for welding to inside drum
6	1	Flow control damper; 150 dia x 2-mm t; optional	Welded to bolt penetrating exhaust pipe
7	1	Exhaust pipe; 150 dia x 3-mm t	Length adapted to application
8	1	Conical outlet hood; 3-mm t	
9	1	Flat hood supporting ring, 4-mm t	Drill 6 holes to match Item 2
10	1	Trapezoidal flow smoothing plenum; 2-mm t	Welded to inside of Item 8
11	1	Cylindrical upper fan support ring; 4-mm t	Sized to fit outside of fan; drill 6 holes for attaching to fan
12	1	Fan; 500-mm dia; 3600 rpm	
13	4–6	Baffle plate support ring; 3-mm t	
14		Metal baffle plate strips; 9 per plate; 2-mm t	Cut to length for welding to support ring
15	4–6	Reinforcing bar; one per plate; 3-mm t	Spot weld to baffle metal strips and supporting ring
16	1	Cylindrical baffle assembly cover; 2-mm t	
17	1	Cylindrical lower fan support ring; 4-mm t	Sized to fit inside of fan; drill 6 holes for attaching to fan

NOTES:

- All surfaces to be coated with lead-free, rust-inhibiting paint.
- Total weight is approximately 45 kg.
- Larger number of plates is to ensure higher collection efficiencies for designs without sufficient mixing volume preceding the collector.
- Figure 1 illustrates an expanded view of the complete system.

Fig. 1 Expanded view of complete system



Drum, upper mounting ring, and gas inlet

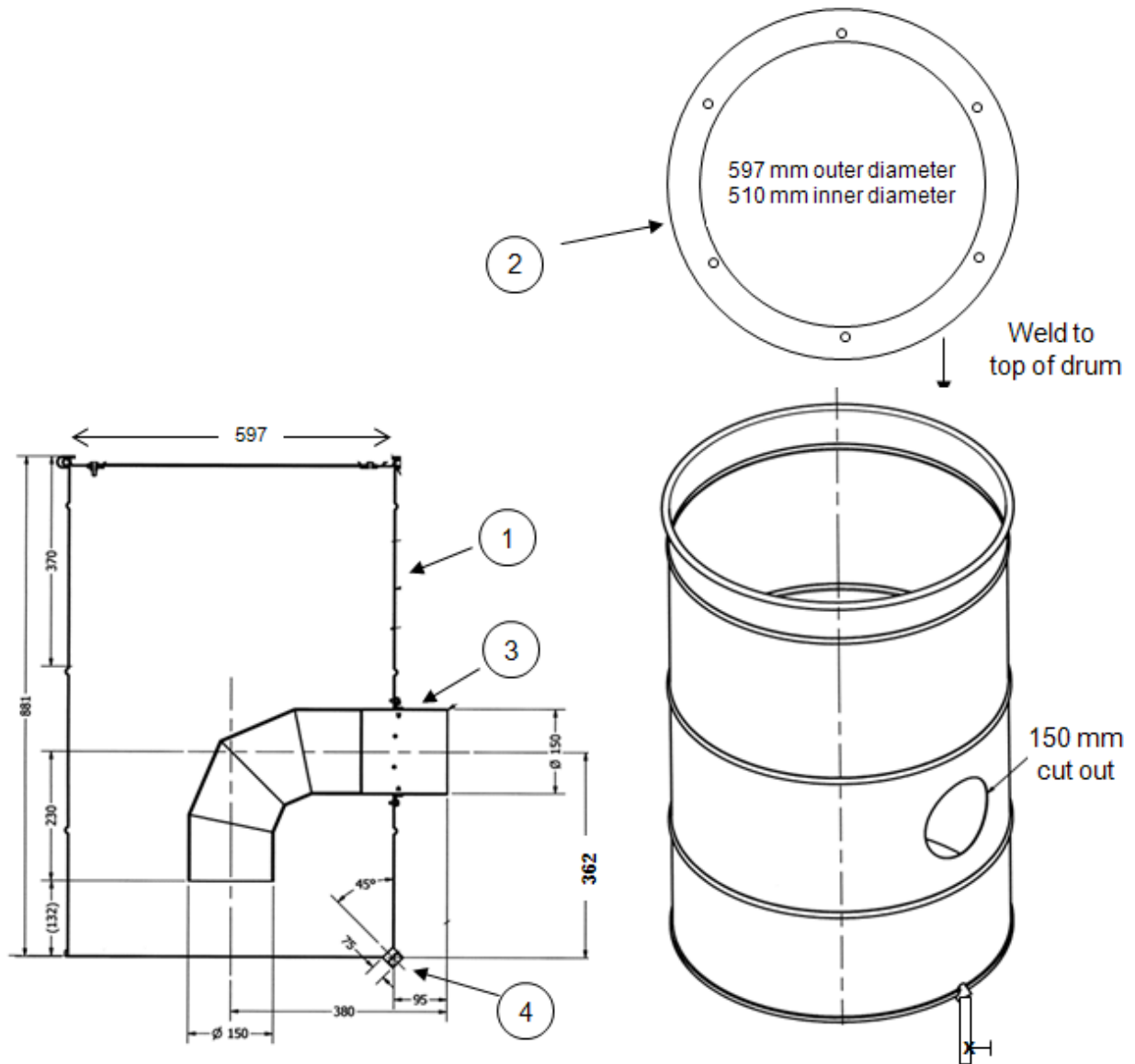
- A standard 200 liter steel drum is used to house the mercury collection system.
- A clean, new or used drum in good condition without leaks is required.
- Approximate dimensions: 600 mm diameter and 880 mm height.
- The cover of the drum is removed and a flat ring is welded to the top for bolting the internal assembly in place.
- The inside of the drum and other internal surfaces should be coated with lead-free rust-inhibiting paint.
- Holes for bolt fasteners are drilled into the ring, and the bolt nuts are welded below the ring because after the assembly is attached, there will no longer be access below the ring to hold the nuts.
- A mercury drainage spigot is positioned at the bottom of the drum, with open and closed positions, from which mercury should be drained daily and flaked.
- In order to decrease the amount of mercury building up on the inside walls of the MCS, consider using stainless steel drums.
- Figure 2 shows the drum, upper mounting ring, and gas inlet.



WELDING

Welding torches or hot sparks from grinding should not be allowed in the vicinity of partially closed drums because the drums could explode if they had formerly been used to contain flammable materials.

Fig. 2 Drum, upper mounting ring, and gas inlet



Alternate gas inlet configuration

The location of the gas inlet into the drum can be at the side or bottom of the drum so that the gas is directed either toward the bottom of the drum as shown in Figure 3a, or toward a baffle plate as shown in Figure 3b. This ensures mixing of the gas to promote mercury cooling and coagulation. Also, directing the inlet gas toward the steel plate will cause some of the mercury droplets to be collected on the steel surfaces. Figures 3a and 3b illustrate the side and bottom entry and flow into the gas inlet. Figure 4 shows photographs of the drum, upper mounting ring, and gas inlet.

Fig. 3a Side Entry and Flow

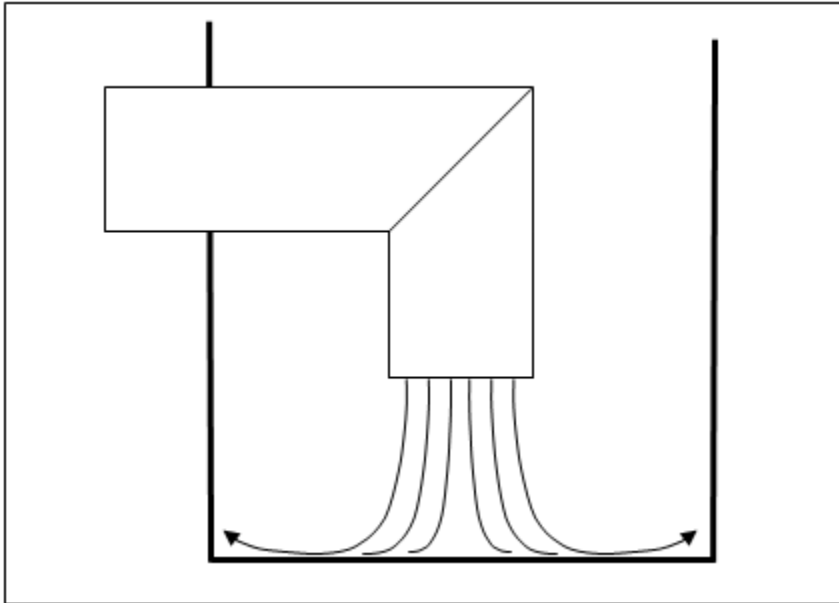


Fig. 3b Bottom Entry and Flow

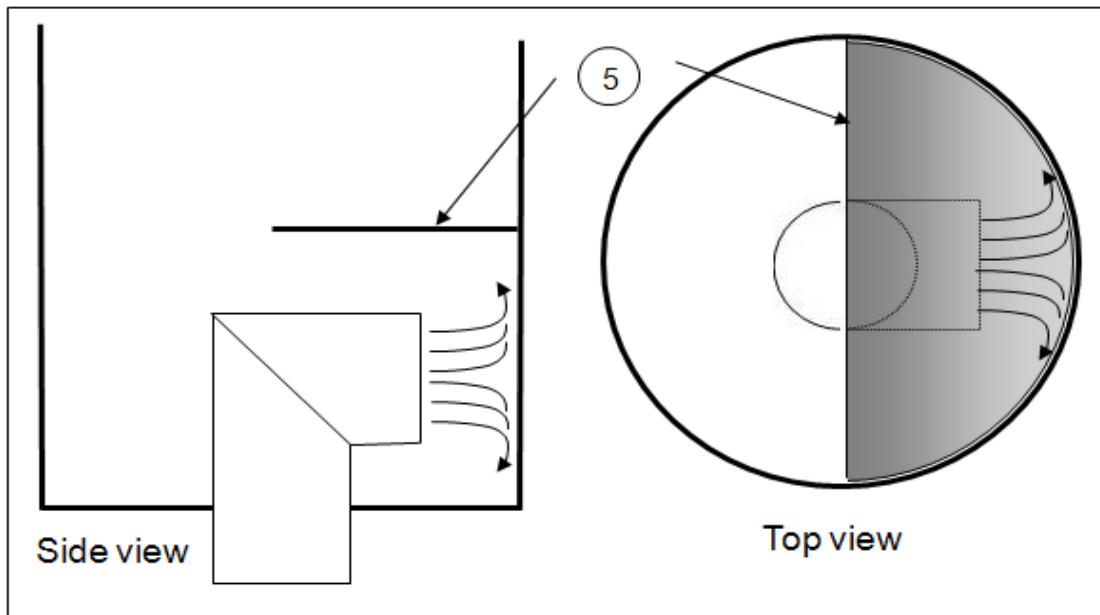


Fig. 4 Photographs of drum, upper mounting ring, and gas inlet



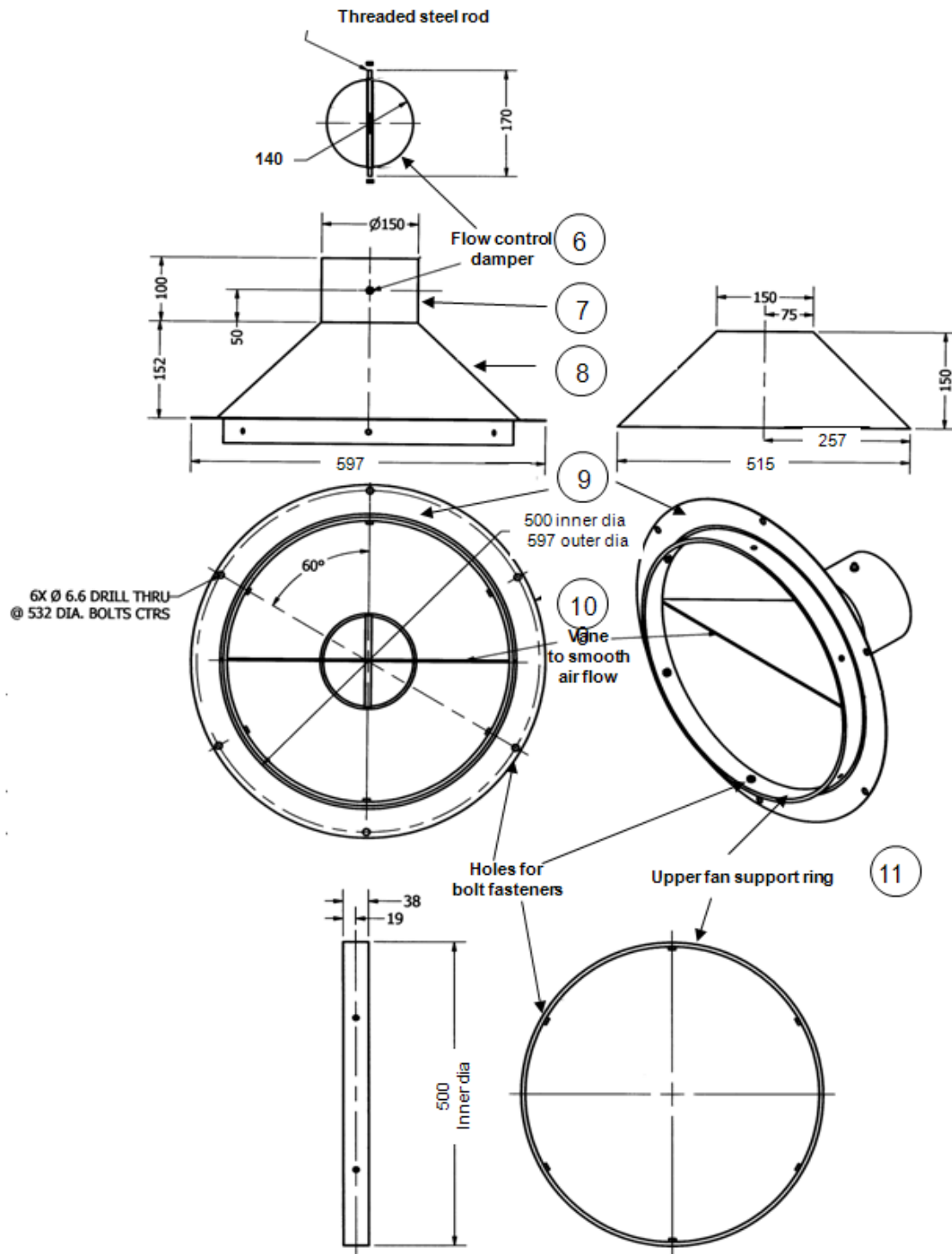
Upper plenum

- The drum cover is a cone-shaped plenum that is welded to a flat ring with bolt holes that match the upper ring on the drum. (A pyramid-shaped plenum could be used to facilitate this part of the construction.)
- Inside the plenum is a vertical vane (Item 10) that is necessary to prevent fan-induced rotational flow that will inhibit upward flow.
- A section of pipe is attached to the top of the cone for connecting to the duct that leads to the outside of the gold shop.
- A valve for regulating flow is shown (Item 6), although for some applications there may not be a need to regulate flow.
- Below the cone, a ring (Item 11) is welded for attaching this component to the upper part of the fan housing.

Fig. 5 Photograph of upper plenum assembly



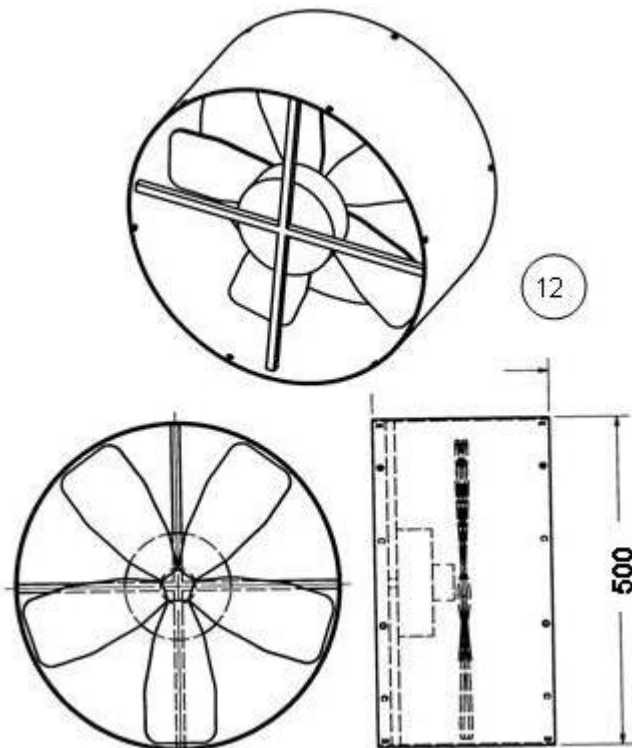
Fig. 6 Upper plenum assembly



Fan

- A 500 mm diameter fan (Item 12) is connected at the top to the ring welded to the cone assembly (Item 9), and at the bottom to the ring welded to the baffle assembly (Item 17).
- A 3,600 rpm fan produces the recommended flow rate of approximately 0.1 m³/s.
- Some adaptation may be required depending on fan availability. The flow of air into the hood opening (the face velocity) should be at least 0.4 m/s to prevent toxic mercury fumes from escaping from the hood. This face velocity can be controlled by changing the area of the hood face. At a flow rate of 0.1 m³/s, a hood face of 0.25 m² will give the minimum face velocity of 0.4 m/s.
- The electrical wiring from the fan is drawn through a hole in the conical plenum. Where it passes through the hole, this electrical wire should be wrapped with a protective insulation such as electrical tape.
- Figure 7 illustrates the fan.
- Figure 8 illustrates the measurement of face velocity with a wind speed monitor.

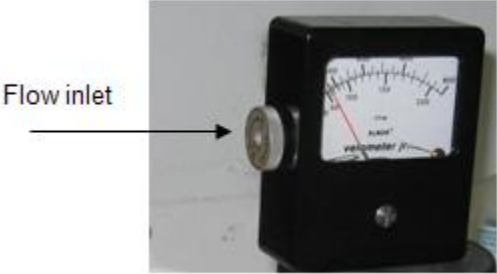
Fig. 7 Fan



FAN OPERATION

It is important that the fan be run only during amalgam burns and for a short time afterwards to clear the ducts. It should be turned off at all other times to minimize re-emission of captured mercury. Place a stencil on a surface near the fan reminding operators to turn off the fan. See Part D for a stencil.

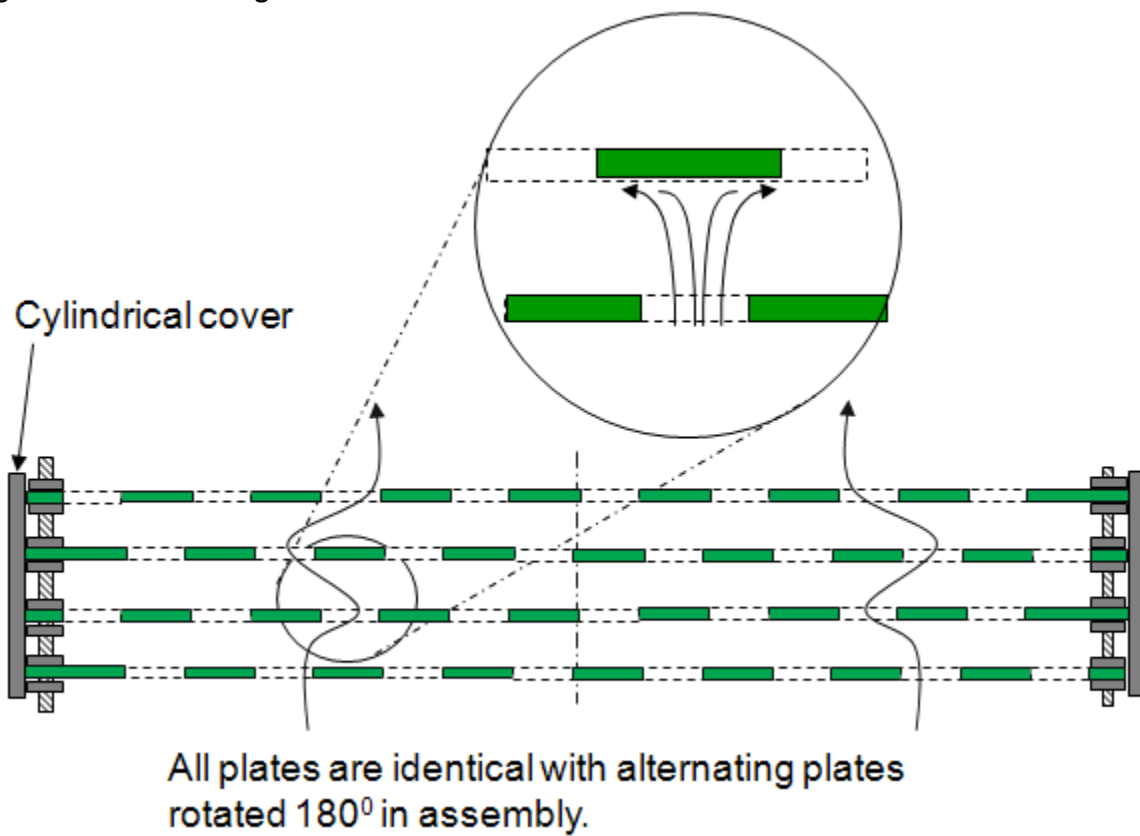
Fig. 8 Air Speed Monitor



Baffle Plate Configuration

- The baffle plate assembly forces the air flow through slots. The four individual plates are aligned so that the mercury aerosol particles passing through a slot will impact and adhere on strips of the downstream baffle.
- More baffle layers can be added to increase overall collection efficiency.
- The plates are combined into the assembly using threaded dowels with nuts holding the plates 20 mm apart
- Figure 9 illustrates the baffle plate configuration.

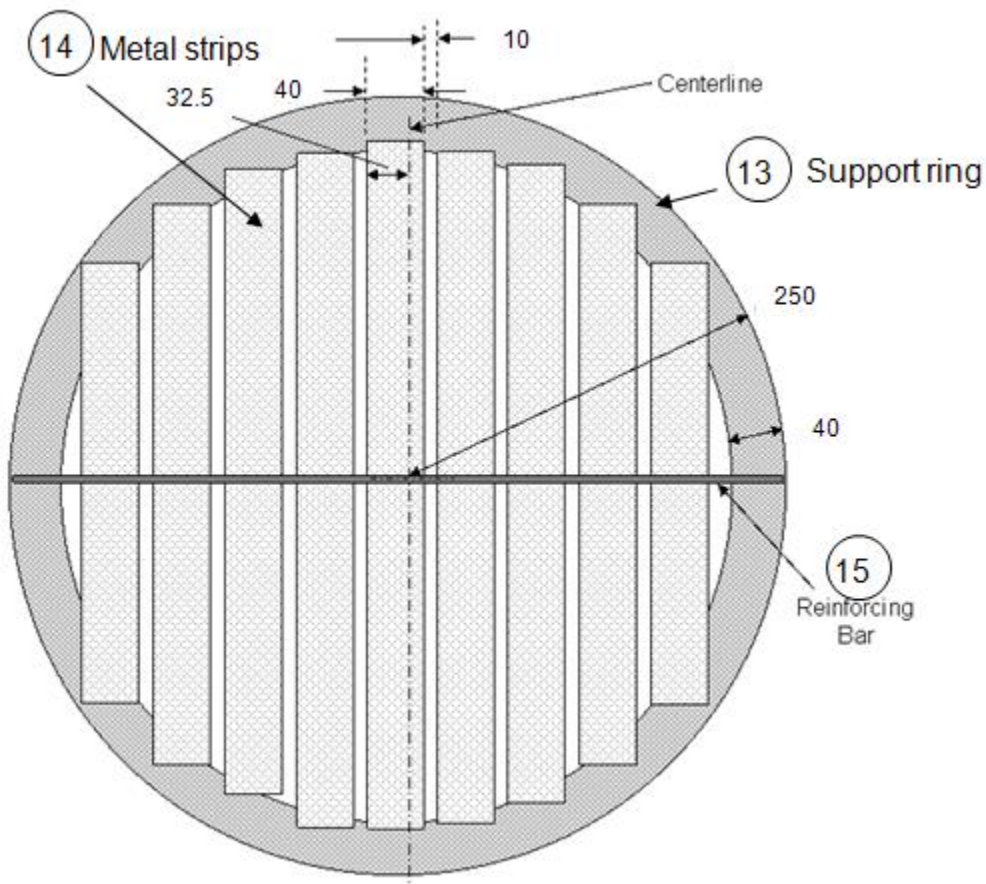
Fig. 9 Baffle Plate Configuration



Individual Baffle Plate Construction

- For each individual baffle plate 40 mm wide metal strips (Item 14) are welded onto a flat ring (Item 13).
- First attach the longest (middle) strip so that the edge of the strip is offset 32.5 mm from the centerline of the ring. Adjacent strips are added with 10 mm spacing between strips.
- A 3 mm reinforcing bar (Item 15) is welded across the strips to add stability.
- Each of the four plates is constructed identically with the slot openings on each individual plate offset from the plate centerline. The alternating plates are assembled with a 180° rotation so that, because of the offset, the solid strips are over open slots on the plate below.
- Figure 10 illustrates the individual baffle plate construction.

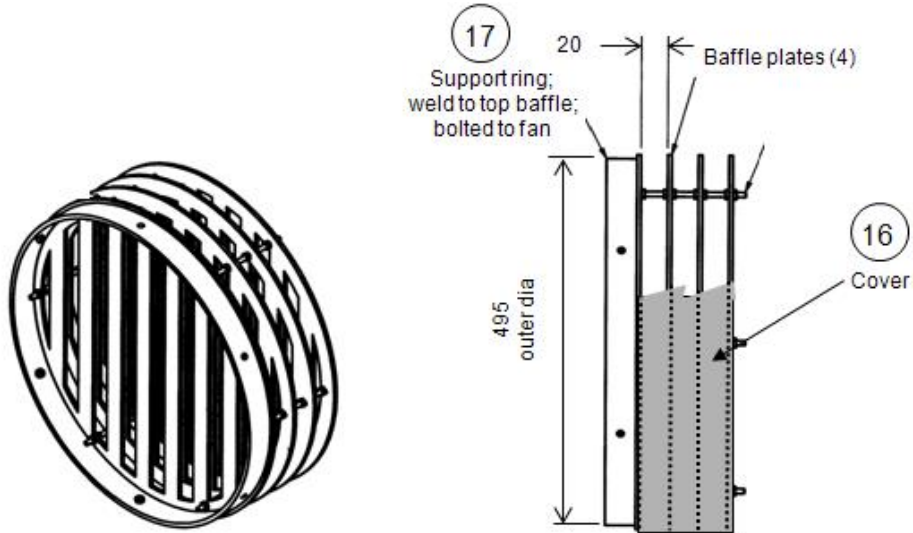
Fig. 10 Individual Baffle Plate Construction



Baffle Plate Assembly

- A cover of 2 mm thickness (Item 16) is attached around the assembly. This will result in the flow going through all plates in the assembly, instead of going around and bypassing some of the plates.
- A ring (Item 17) is welded to the top of the baffle assembly for bolting it to the fan housing.
- Figure 11 shows the baffle plate assembly

Fig. 11 Baffle Plate Assembly



Final System Assembly: Figure 12 shows photographs of the final system assembly.

Fig. 12 Photographs of final system assembly



DRAIN AND FLASK MERCURY DAILY

The mercury should be drained daily from the spigot (not shown here, but shown in fig. 1) into a strong plastic or steel container with a top for sealing and preventing mercury escape.

Part B: Alternate system configuration

This part describes recommended changes in system dimensions for different hood and mercury collection system configurations. Note: a vertical position for the system is recommended, where possible, to enhance mercury collection and reduce re-emission of mercury. The primary design changes for the collection system are alternate sizes for the fan and the baffle assembly and connecting parts (Fig. 13 and 14).

Fig. 13 Cut away drawing of system with changes in fan and baffle plate dimensions

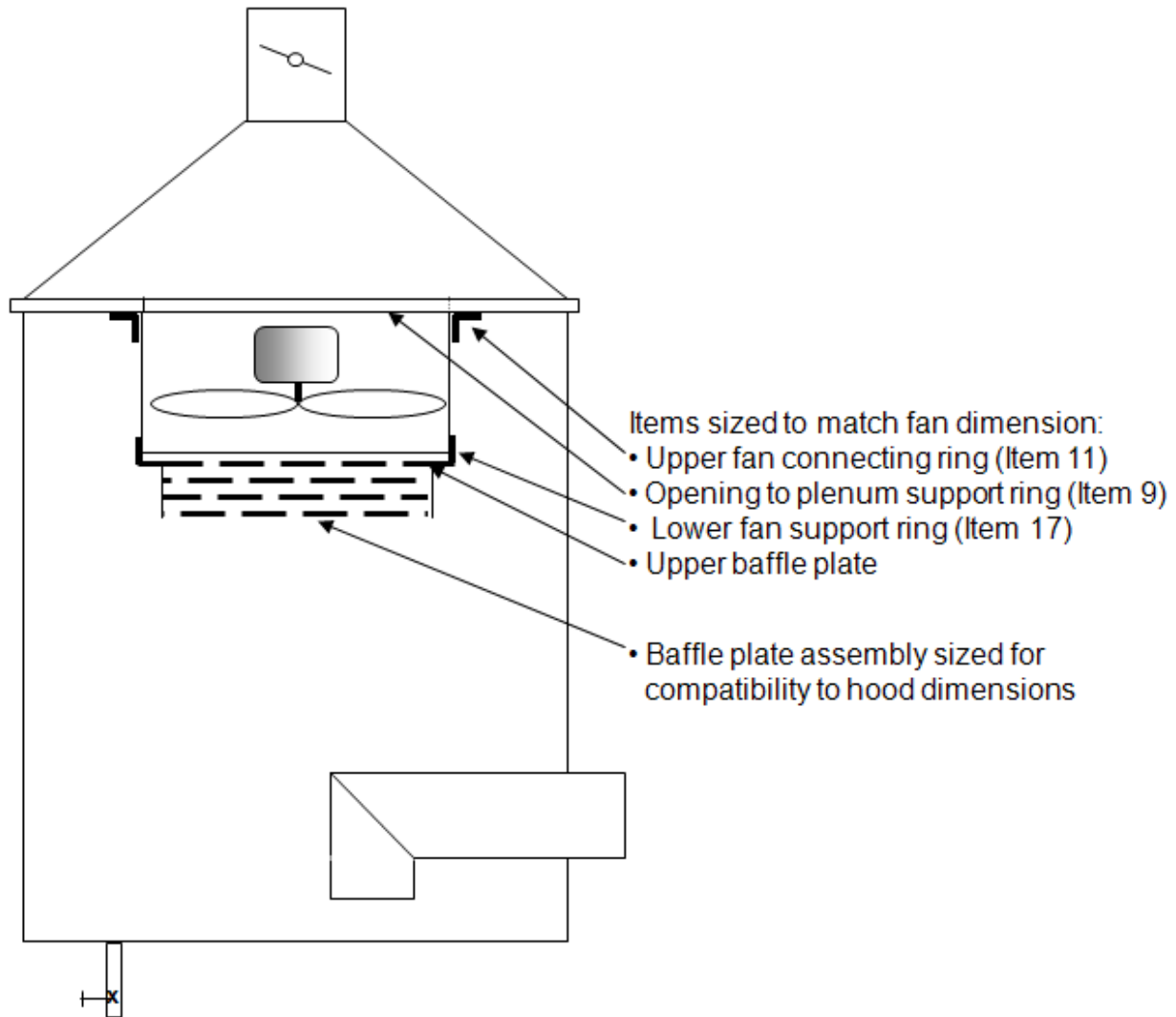
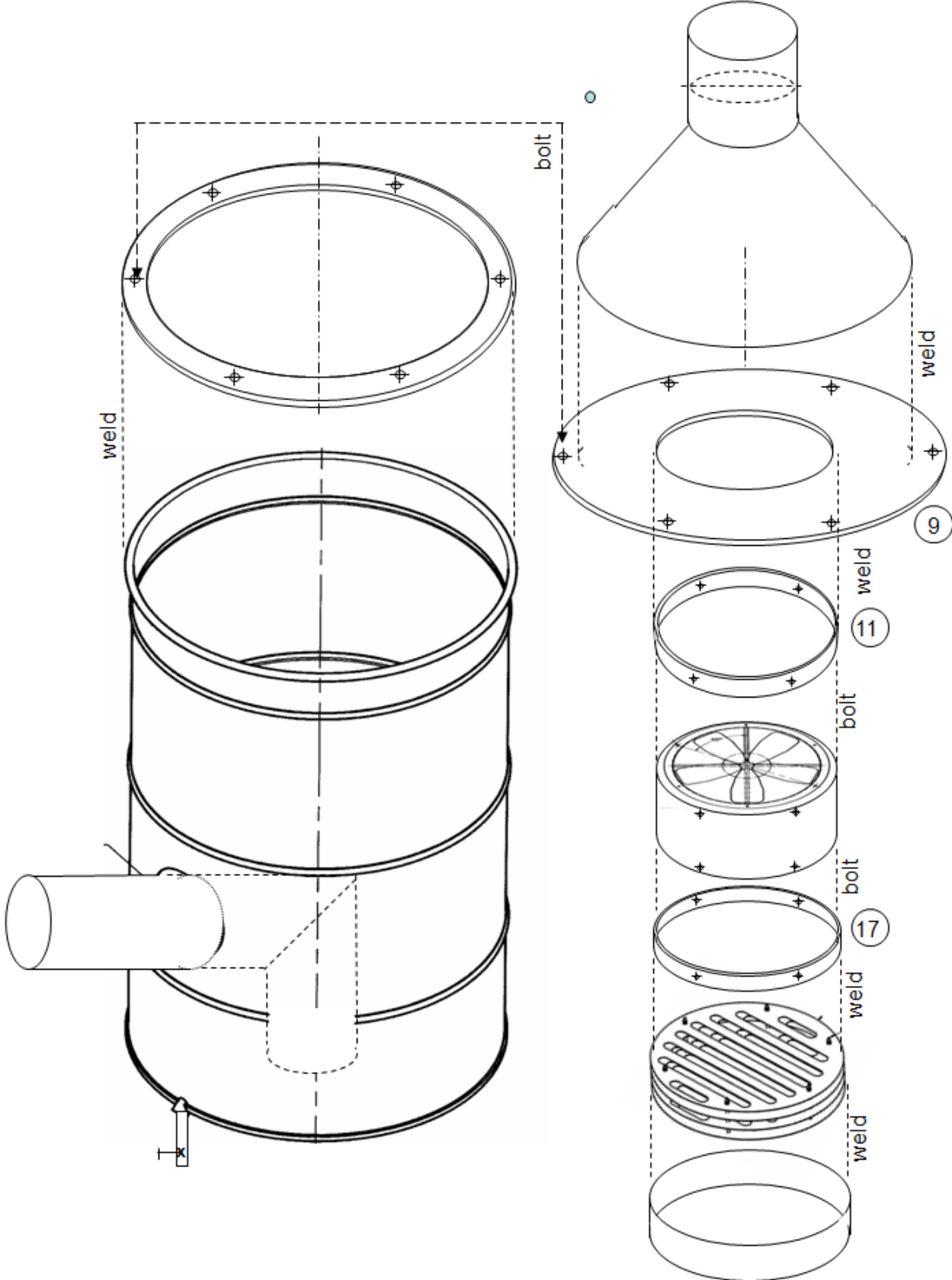


Fig. 14 Expanded view of system with changes in fan and baffle plate dimensions



Calculating dimensions for alternate system configuration

The following is the recommended procedure for obtaining system dimensions compatible with design objectives for mercury particle capture. Fig. 13 shows system dimension legend, fig. 14 baffle design.

1. Calculate hood opening (face) area

$$A_f (\text{m}^2) = w_f \times h_f$$

2. Calculate volume flow rate to give 0.4 m/sec hood face velocity:

$$F_f (\text{m}^3/\text{sec}) = 0.4 A_f$$

3. Calculate radius of individual baffle plate (inside supporting ring)

$$R_{in} (\text{mm}) = 210 \text{ square root } (F_f / 0.1)$$

where

210 mm = the baffle plate radius (inside the supporting ring) of the base design

0.1 m³/sec = the volume flow rate through the system for the base design.

The outer radius of the supporting ring:

$$R_{out} = R_{in} (\text{mm}) + 40 \text{ mm}$$

The metal strips for an alternate design are to remain at 40 mm wide, 10 mm spacing between strips, and 32.5 mm offset from plate centerline for the first strip.

4. Calculate the desired system volume preceding the baffle plate assembly to give a mercury transit time of 6 seconds:

$$V (\text{Volume before baffles}) = 6 \text{ sec} \times (F_f, \text{m}^3/\text{sec})$$

where

$$V = (\text{hood volume}) + (\text{sum of exhaust pipe segment volumes}) + (\text{drum volume})$$

Hood volume :

$$V_h = (\text{volume lower}) + (\text{volume upper})$$

$$= (p \times q \times h_l) + (1/6) q) h_u (2axb + axq + bxp + 2px) h_u$$

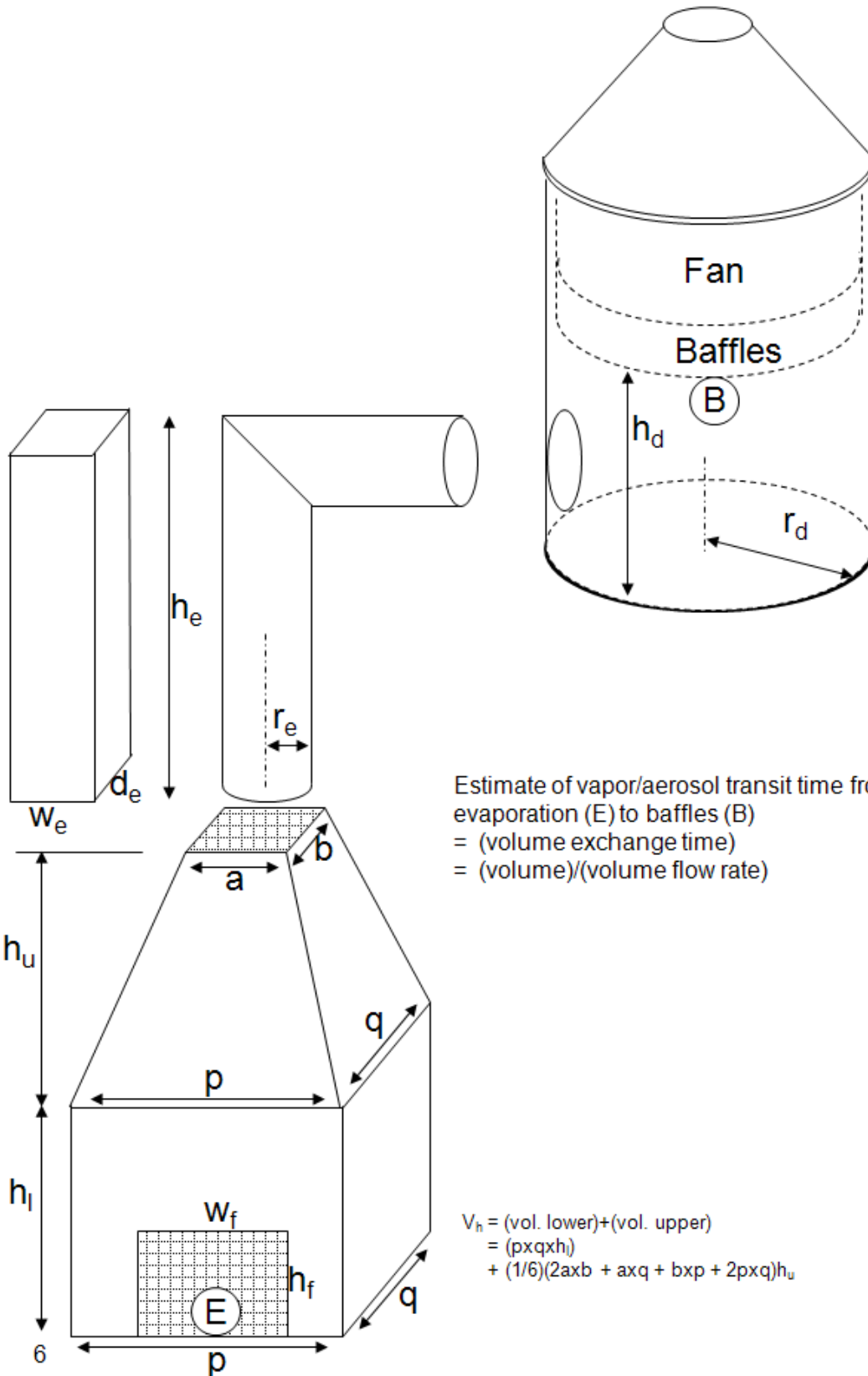
Volume for each exhaust pipe segment:

$$V_e = h_e \times r_e^2 \times 3.14 (\text{round}), \text{ or}$$

$$= h_e \times w_e \times d_e (\text{rectangular})$$

$$\text{Drum volume: } V_d = h_d \times r_d^2 \times 3.14$$

Fig. 13 System dimension legend



Example calculation of dimensions for alternate system configuration

Calculate hood opening (face) area

$$\text{Assume: } A_f (\text{m}^2) = w_f \times h_f = 0.25 \times 0.25 = 0.0625 \text{ m}^2$$

2. Calculate volume flow rate to give 0.4 m/sec hood face velocity:

$$F_f (\text{m}^3/\text{sec}) = 0.4 A_f = 0.4 \times 0.0625 = 0.025 \text{ m}^3/\text{sec}$$

3. Calculate radius of individual baffle plate (inside supporting ring)

$$R_{in} (\text{mm}) = 210 \sqrt{F_f / 0.1} = 210 \times \sqrt{0.025 / 0.1} = 210 / 2 = 105 \text{ mm}$$

where

210 mm = the baffle plate radius (inside the supporting ring) of the base design

0.1 m³/sec = the volume flow rate through the system for the base design

The outer radius of the supporting ring for the example alternate design:

$$R_{out} = R_{in} (\text{mm}) + 40 \text{ mm} = 105 + 40 = 145 \text{ mm}$$

The design of this baffle plate is illustrated in Fig. 14.

4. Calculate the desired system volume preceding the baffle plate assembly to give a mercury transit time (volume exchange time) of at least 6 seconds:

$$V (\text{Volume before baffles}) = 6 \text{ sec} \times (F_f) = 6 \times 0.025 = 0.15 \text{ m}^3$$

where

$$V = (\text{hood volume}) + (\text{sum of exhaust pipe segment volumes}) + (\text{drum volume})$$

Assume hood volume :

$$V_h = (\text{volume lower}) + (\text{volume upper})$$

$$= (p \times q \times h_l) + (1/6)(2axb + axq + bxp + 2pxq)h_u$$

$$= (0.4 \times 0.4 \times 0.4) + (1/6) (2 \times 0.2 \times 0.2 + 0.2 \times 0.4 + 0.2 \times 0.4 + 2 \times 0.4 \times 0.4)0.4$$

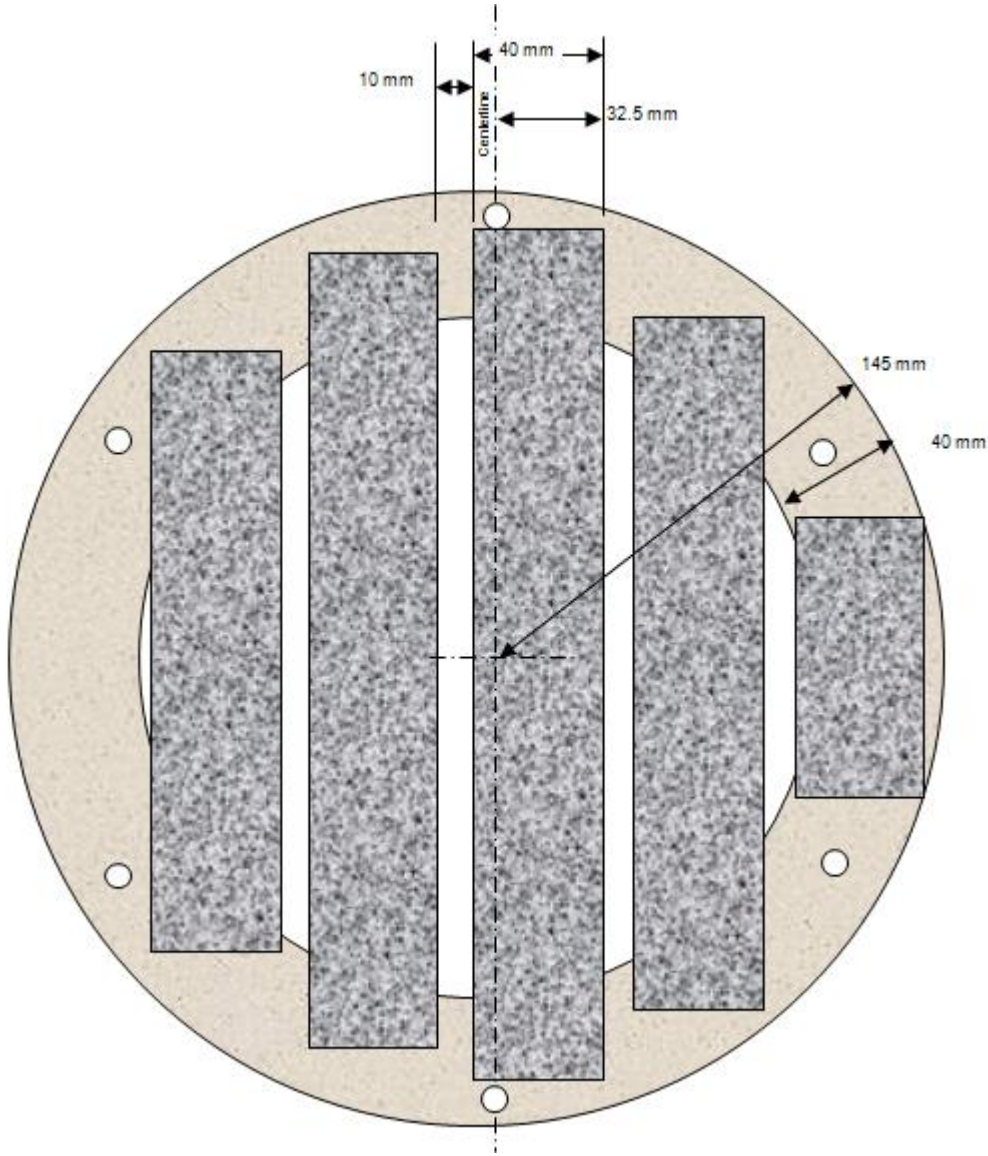
$$= 0.1 \text{ m}^3$$

Drum volume:

$$V_d = h_d \times r_d^2 \times 3.14 = 0.5 \times (0.3)^2 \times 3.14 = 0.14 \text{ m}^3$$

The combined hood and drum volume exceed the desired volume to give a transit (volume exchange) time of at least 6 seconds. Therefore the volume of the exhaust pipe segments is not critical to the design.

Fig. 14 Baffle plate design for alternate system configuration example



Part C: Alternate system Installation configurations

The installation of each system needs to be adapted to the configuration of the gold shop for which it has been made. A typical hood-and-exhaust system without a mercury collector is shown in Figure 4-1. Installation can be either horizontal or vertical, and the inlet can be from the side or bottom of the drum if the inlet is appropriately designed (see Figure 3-2). Some of the collector installation options are illustrated in Figures 15 and 16. Figs. 3a and 3b illustrate changes in system construction depending on side vs. bottom inlet. We recommend vertical installation whenever possible to reduce evaporation and re-emission of mercury.

Fig. 15 Vertical Mercury Collector System Installation with Side Entry

PREFERRED CONFIGURATION TO MAXIMIZE MERCURY CAPTURE

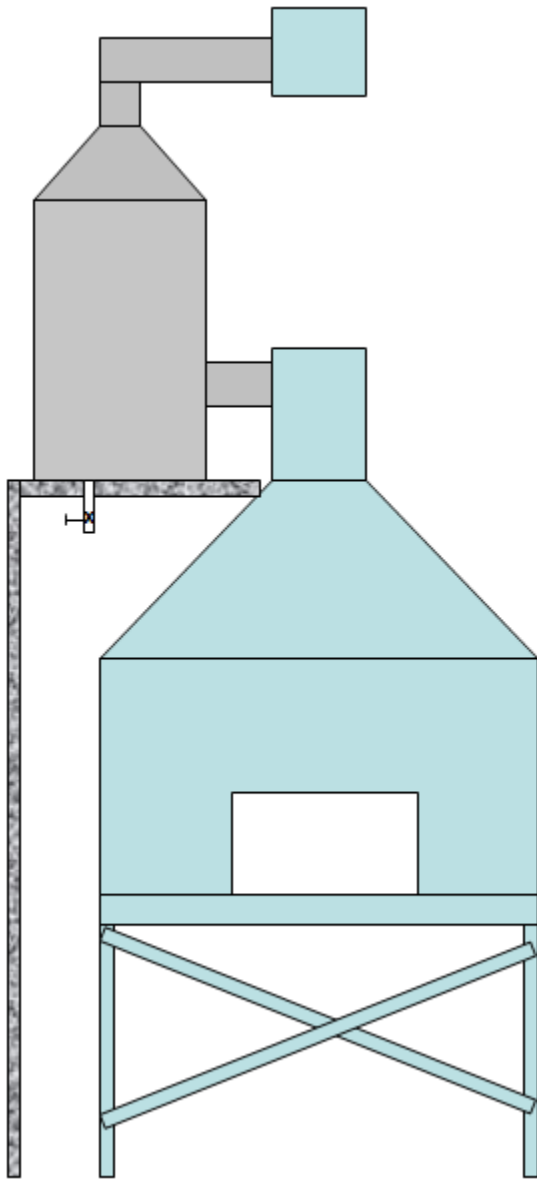
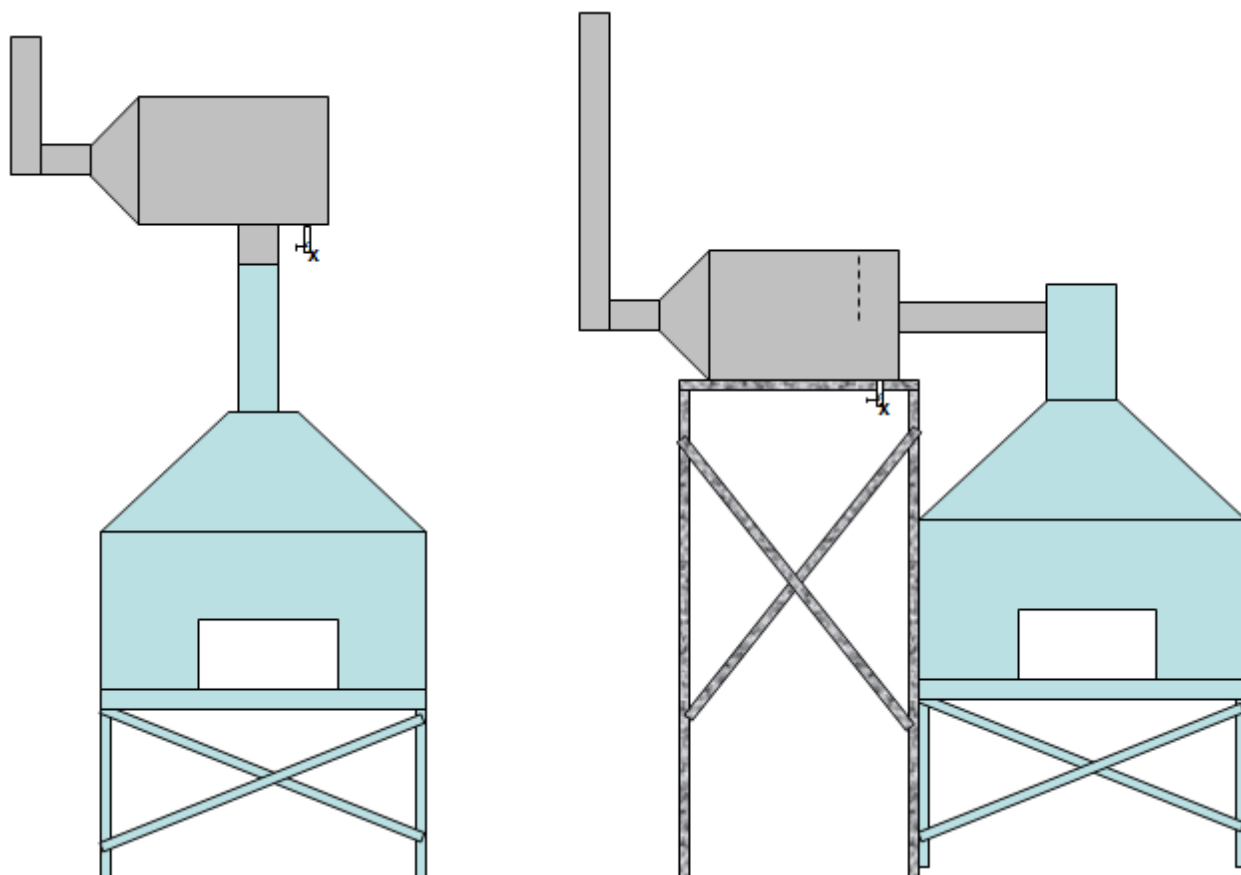


Fig. 16 Horizontal Mercury Collector System Installation with Side and Bottom Entry

LESS DESIRABLE CONFIGURATION FOR MAXIMIZED MERCURY CAPTURE



Part D. Recommendations to Ensure Best Performance

Research has shown that the Mercury Capture System (MCS) does capture and collect mercury, with expected efficiency of 80%. An MCS not constructed and installed in a recommended manner may perform with a significantly lower mercury capture efficiency. Please follow the guidance throughout the manual, and in particular, to provide best performance and to prevent re-emission of captured mercury. See text box below:



IMPORTANT RECOMMENDATIONS TO ENSURE BEST PERFORMANCE

Installation:

- A vertical orientation in design is best, with less surface area inside the drum which will reduce evaporation and re-emission of mercury.
- Ensure a close contact or connection interface between the mercury capture system and the exhaust chimney from the hood, to minimize air flow leakage at the attachment point, and to enhance upward air flow.
- Position the MCS as far away as possible from the hot fume hood and blowtorches, as added cooling allows mercury to collect better in the MCS.
- Ensure that the bottom spigot can be easily reached for daily flasking of the captured mercury.

Operation:

- Exhaust fans must be run ONLY during amalgam burns and for a short time afterwards to clear the ducts.
- Ensure daily flasking from the bottom spigot of captured mercury after amalgam burns. Sturdy plastic or steel flasks with stoppers or sealed tops are recommended for environmentally sound mercury management. Recycle existing containers where possible.
- Place a stencil above the spigot to remind operators to drain and flask daily. See fig. 1 for placement of the spigot and stencil and Part D for an example of a stencil.

Stencils

Drain and Flask Stencil

It is recommended that a reminder be stenciled above the MCS spigot to encourage daily flasking and draining. Cut out the template below. For placement, see fig. 1.



Fan Operation Stencil (Turn off fan)

This message reminds operators to turn off the fan when done burning amalgam. Place



ADDENDUM

Basis for calculation of dimensions for alternate system configuration to ensure proper air flow:

The overall system including the hood, exhaust pipes and mercury collector should be designed to provide proper balance of critical flow parameters. Proper scaling is essential.

Velocity of air into the hood face should be at least 0.4 m/sec during operation.

This provides operator safety by preventing exposure to toxic fumes in the hood.

The largest fan that can be accommodated in the drum is 500 mm diameter, which will provide a nominal flow of 0.1 m³/sec. With this flow, a hood face area of 0.25 m² will provide the desired face velocity of 0.4 m/sec. A larger area for the hood face opening should not be used since this will result in lower face velocity.

The system has been designed to obtain maximum capture efficiency of particles with 4 microns, or greater, diameter. This criterion requires balancing of two design parameters:

- 1. The velocity of the aerosol through the gaps in the baffle plates should be maintained above the design level to optimize collection of the particles.** For the flow rate of 0.1 m³/sec, the baffle design with 500 mm outside diameter (420 mm diameter inside the support ring), and 40 mm metal strips with 10 mm gaps, will give the theoretical optimal collection efficiency. To maintain this optimal efficiency, the area inside the supporting ring should be proportional to the volume flow rate. For example, if the flow rate is reduced by a factor of 4, the inner diameter of the supporting ring should be reduced by a factor of 4; the diameter is reduced by a factor of $\sqrt{4} = 2$. For a fixed face velocity 0.4 m/sec, the flow rate is proportional to the hood face area. If the hood face area is fixed in advance, this becomes the driver for the baffle plate area inside the supporting ring.
If it is desired to use a smaller fan that provides lower flow rate, the area for the hood face opening should be reduced to maintain the 0.4 m/sec face velocity.
- 2. The transit time of mercury particles from the point of evaporation to the baffle plates should be at least 6 seconds.** This transit time, assumed to be equal to the volume exchange time) will allow the particles to coagulate to larger sizes of 4 microns, or greater, diameter that are more easily captured by the baffle plate assembly. The transit time can be increased by increasing the volume of the hood and exhaust pipes, or by decreasing the flow rate. However, decreasing the flow rate requires: (1) using a smaller hood face area to maintain the face velocity of at least 0.4 m/sec, and (2) reducing the diameter of the baffle plates to maintain the velocity through the gaps.