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MODIFICATION OF THE EXHAUST SYSTEM IN THE WELDING LAB OF DURLAND HALL AT KANSAS STATE UNIVERSITY

by

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CHAPTER I

INTRODUCTION

Arc welding is a process for joining metals by heating with an electric arc or arcs with or without the application of pressure and with or without the use of filler metal. The process includes shielded welding which uses gas or a solid flux to blanket the weld. Arc welding is used to fabricate nearly all types of carbon or alloy steels, the common nonferrous metals, and is indispensable in the repair and reclamation of metallic machine parts.

Arc welding with coated rods introduces a health hazard from the release of nitrogen-tetroxide fumes. The respiratory system of a welder is not infrequently exposed to both gases and particulate matter. The inhalation of any foreign substances other than those present in normal clean air may be eventually harmful to the lungs or other organs of the human body. The ultimate toxicity of these substances depends primilarily upon their concentration and the physiological response of the body. The contamination of nitrogen tetroxide fumes in the atmospheric air might lead to diseases called Siderosis, Anthraiosis, Stannosis and Aluminosis.

The great variety of shapes and sizes of weldments impose a severe burden on the designer of exhaust equipment. General ventilation is seldom adequate and if made so, is wasteful of heat because of the excessive volume of exhaust air.

The facilities available for arc welding at the welding laboratory of the industrial engineering department, Durland Hall, Kansas State University is a typical example of the inadequacy of general ventilation.

The welding lab is generally used by students to learn the techniques of gas and arc welding. Though ventilation is quite adequate for gas welding alone, the dense fumes produced by arc welding have been a serious problem. Furthermore fumes from the arc welding booth have been known to escape from the booths and contaminate the entire welding lab (Figure 1).

It is evident from Figure 2 and Figure 3 that between the two types of welding arc and gas types, arc welding is the more serious and an effective means of exhausting is a necessity.

The objective of this report is to design and implement an effective and economical ventilation system for the arc welding facilities at the welding laboratory of the industrial engineering department, Kansas State University.

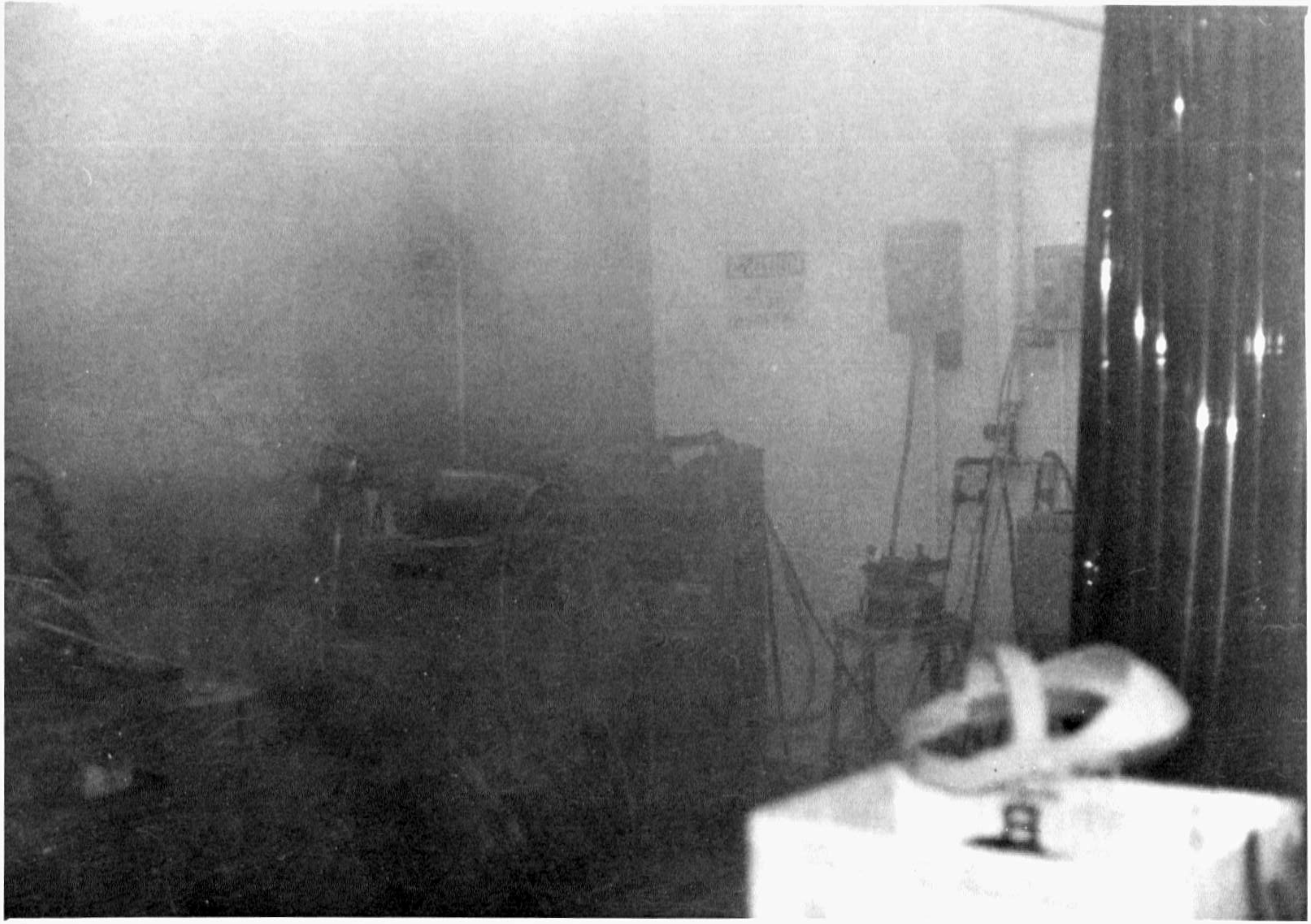

Fig. 1. A View of the Welding Lab While Arc-Welding is in Progress.

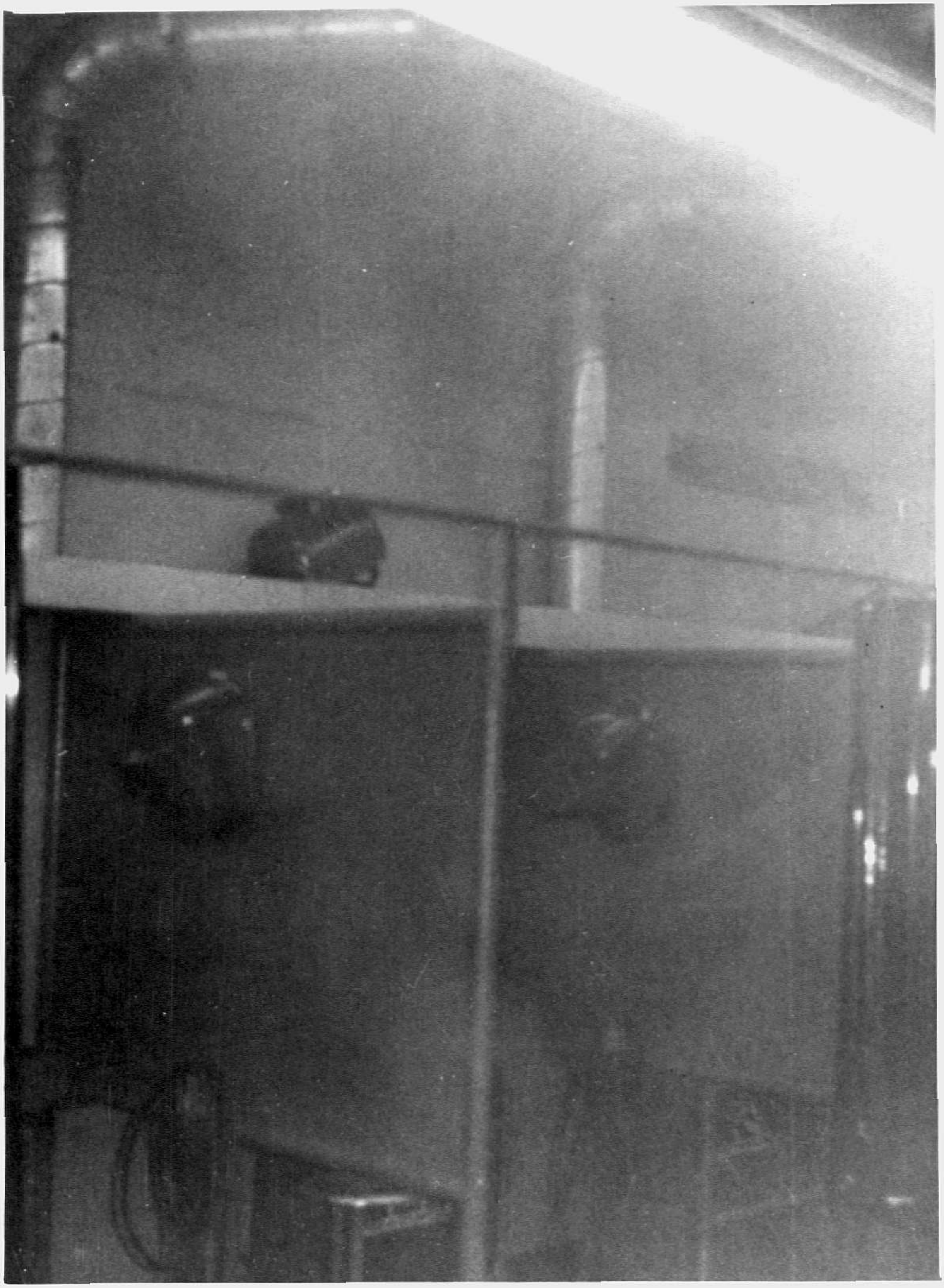

Fig. 2. A Partial View of the Arc-Welding Facility. Notice the Air Contamination.

Fig. 3. A View of the Gas Welding Facility.

CHAPTER II

DESCRIPTION

This chapter is devoted to a detailed description of the welding laboratory situated in Durland Hall, Kansas State University.

The facility has a total floor area of 1322.5 square feet. The arc welding booths are situated along the south wall and take up 145 square feet of floor area. Gas welding is done in a central area and the entire floor plan is given in Figure 4.

Each of the arc welding booths has a width of 50 inches, the partition wall being 52 inches deep. A screen is provided which when drawn during the welding process, protects people who are elsewhere in the welding lab from the ultra violet radiation of the arc. The south wall is protected against damage by a metal shield along the back edge of the welding table.

Eight work areas, are provided in the gas welding area. Regular exhaust outlets on the ceiling are provided above the gas welding facility.

An exhaust hood is provided along the entire length of the south wall. It projects out to a length of 12 inches from the wall and has a height of 4 inches. The top level of this hood is at a height of 3 feet above the welding table level.

Six exhaust ducts are connected to the exhaust hood at the top. Each of these exhaust ducts are 6 inches in diameter. These are connected to the main exhaust system at the top. They are equipped with blast gates (Figure 5).

The layout of the ducts, hood and the eight booths is given in Figure 6. It is evident from this figure that the position of the ducts

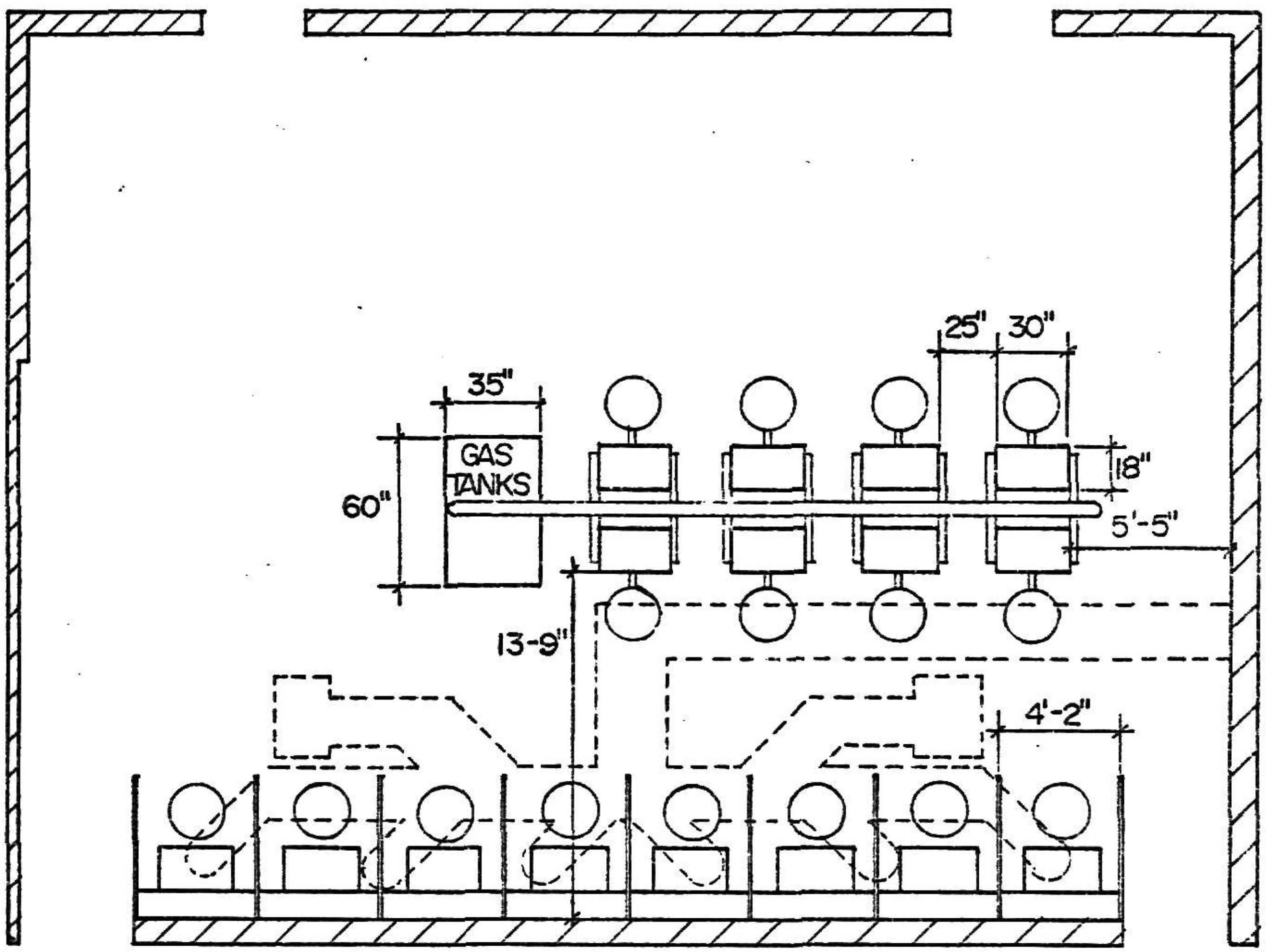

FIG.4 FLOOR PLAN OF THE WELDING LAB.

Fig. 5. A View of the Arc-Welding Ventilation System with the Hood, Ventilation Ducts and Their Blast Gates.

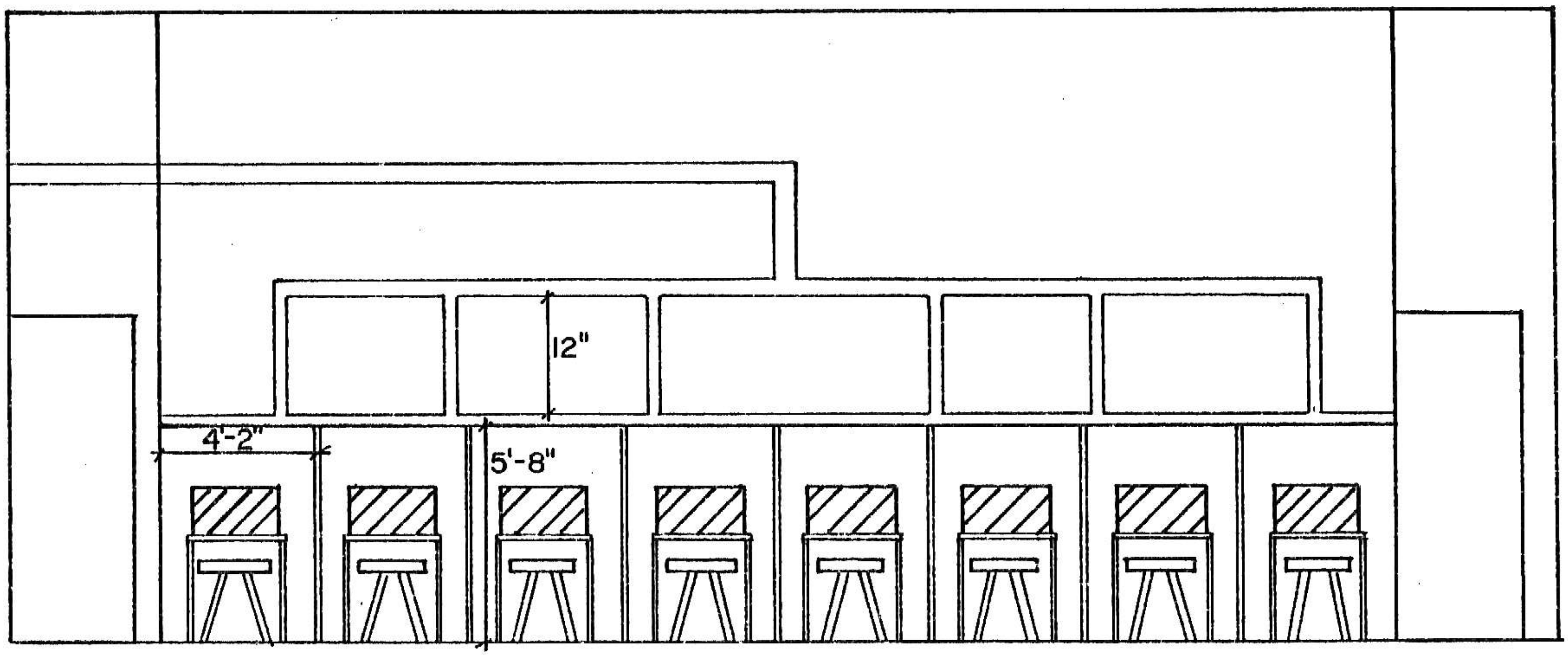

FIG. 6 FRONT VIEW OF THE SOUTH WALL.

over the booths leaves some of these booths with no duct directly over them. This is shown more clearly in Figure 7 and Figure 8.

It is easy to picture air and fumes moving through the work area in a straight path from the contaminant source to exhaust fan, almost as if travelling inside an invisible duct. However, this does not usually occur. The incoming air diffuses throughout the booth. Some of it passes through the zone of the release of the contaminants and dilute the contaminants to a lower concentration. The dilution continues as the material moves further from the process until the contaminated air is removed by the exhaust hood and ducts in the welding lab however, a considerable time period elapses before all contaminated air is exhausted. The large distance from the welding zone to the hood contribute to an inefficient exhaustion, resulting in contaminated air escaping into other areas of the welding lab.

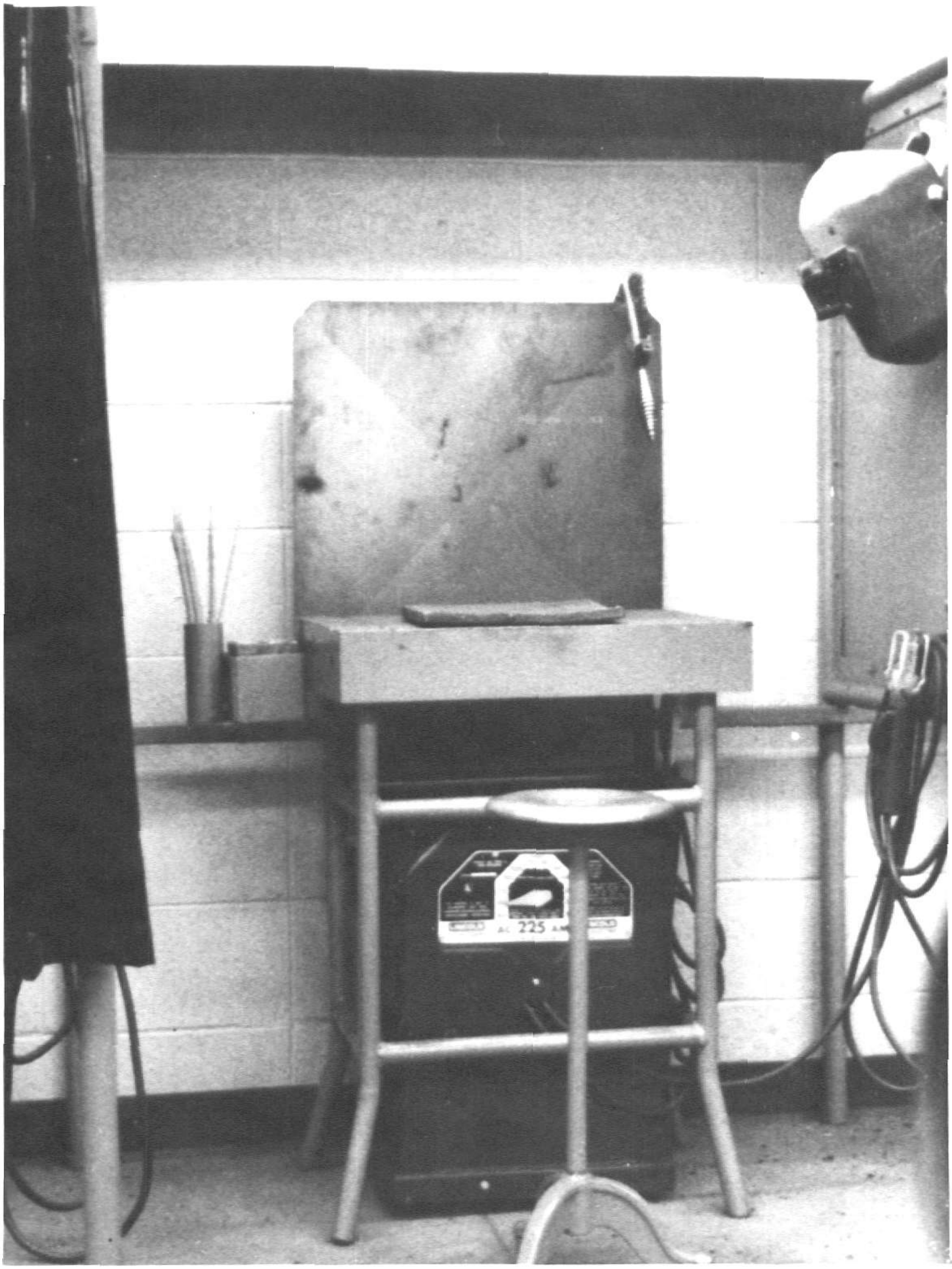

Fig. 7. Front View of the Booth Which has no Duct Coming Directly Over it.

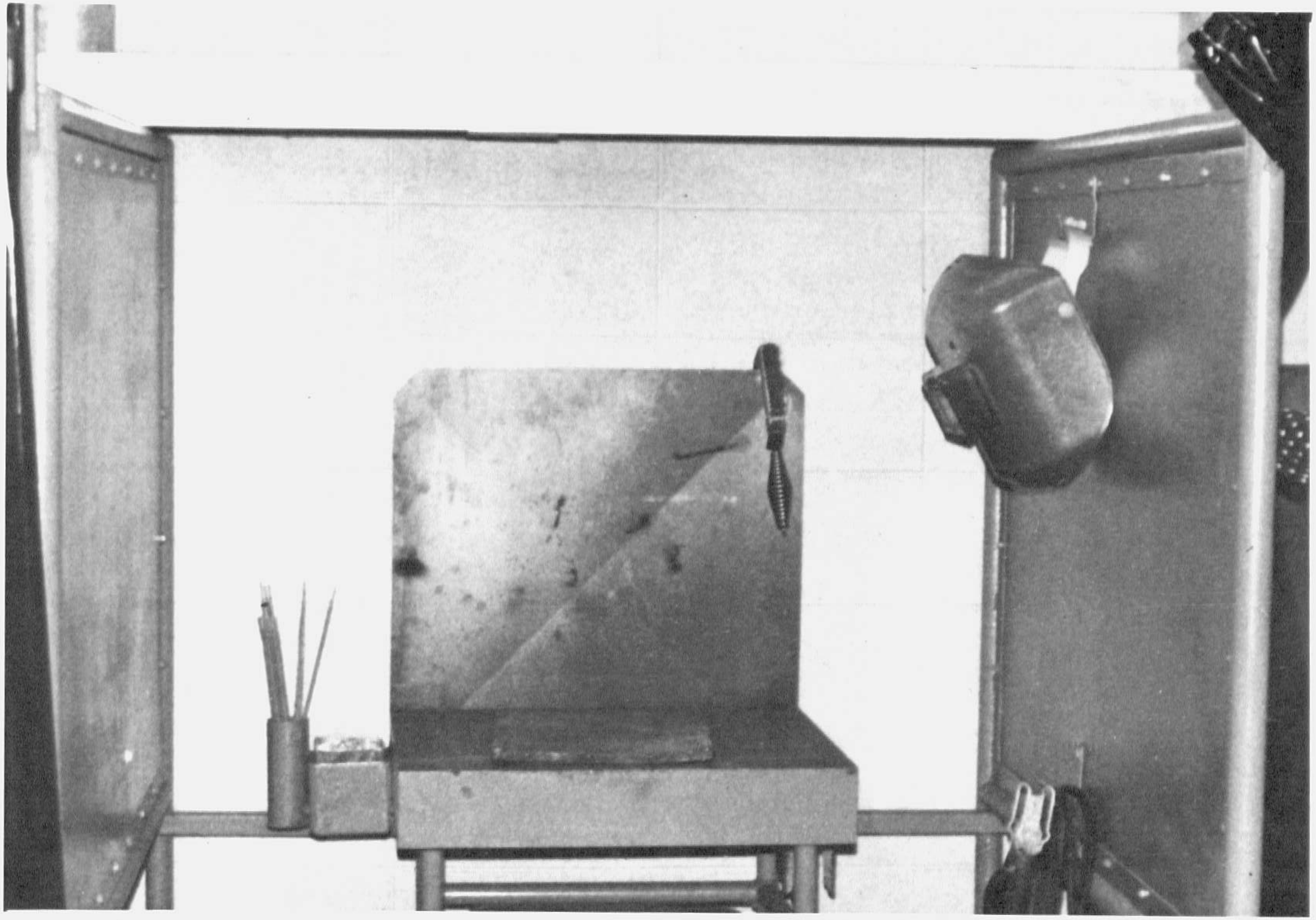

Fig. 8. Front View of the Booth Showing the Two Ducts Through Which Contaminated Air is to be Exhausted.

CHAPTER III

ANALYSIS

Due to the fact that the ducts provided on the top of the hood are located at a distance of 3 feet from the point of fume generation, we can, classify the present exhaust system as a type of general ventilation.

There are two major types of ventilation: dilution or general ventilation and local exhaust.

Dilution Ventilation or General Ventilation

Dilution occurs when contaminants released into the workroom mix with air flowing through the room. Either natural or mechanically induced air movement can be used to dilute contaminants. Dilution ventilation should generally be used to meet these criteria.

- Small quantities of contaminants released into the workroom at fairly uniform rates.

- Sufficient distance from the work to the contaminant source to allow dilution to safe levels.

- Contaminants of low toxicity or fire hazard.

The major disadvantages of general ventilation are that large volumes of dilution air may be needed and that employee exposures are difficult to control near the contaminant source where dilution has not yet occurred.

Local Exhaust Ventilation

Local exhaust systems capture or contain contaminants at their source before their escape into the workroom environment. A typical system consists of one or more hoods, ducts, an air cleaner if needed and a fan as shown in Figure 9. The big advantage of local exhaust systems is that they remove contaminants rather than just dilute them. Even with local exhaust some airborne contaminants may still be in the workroom air due to uncontrolled sources or less than 100% collection efficiency at the hoods.

A second major advantage of local exhaust is that those systems require less airflow than dilution ventilation systems in the same applications. The total airflow is important for plants that are heated or cooled since heating and air conditioning costs are important operating expense.

It is well known fact that dust (fumes) particles in tne small micron sizes, even if impelled at extremely high original velocities travel a very short distance in air, a matter of few inches at the most. Thus the fine fume particles of health significance follow the air currents. Exhausting is therefore most effective only if the exhausting hood or duct be brought very close to the point of fume generation. It is recommended in all the literature surveyed for this report, that the distance be in the range not exceeding 12 inches.

In table 1, the OSHA standards for local exhaust requirements for general welding and cutting are summarized.

The OSHA standards list the volumetric airflow needed to develop air velocity at varying distances from the hood opening. However, the airflow rates in the OSHA standards are lower than current recommendations in the ACGIH (American Conference of Governmental Industrial Hygienists) Industrial Ventilation Manual. The two are compared in Table 2.

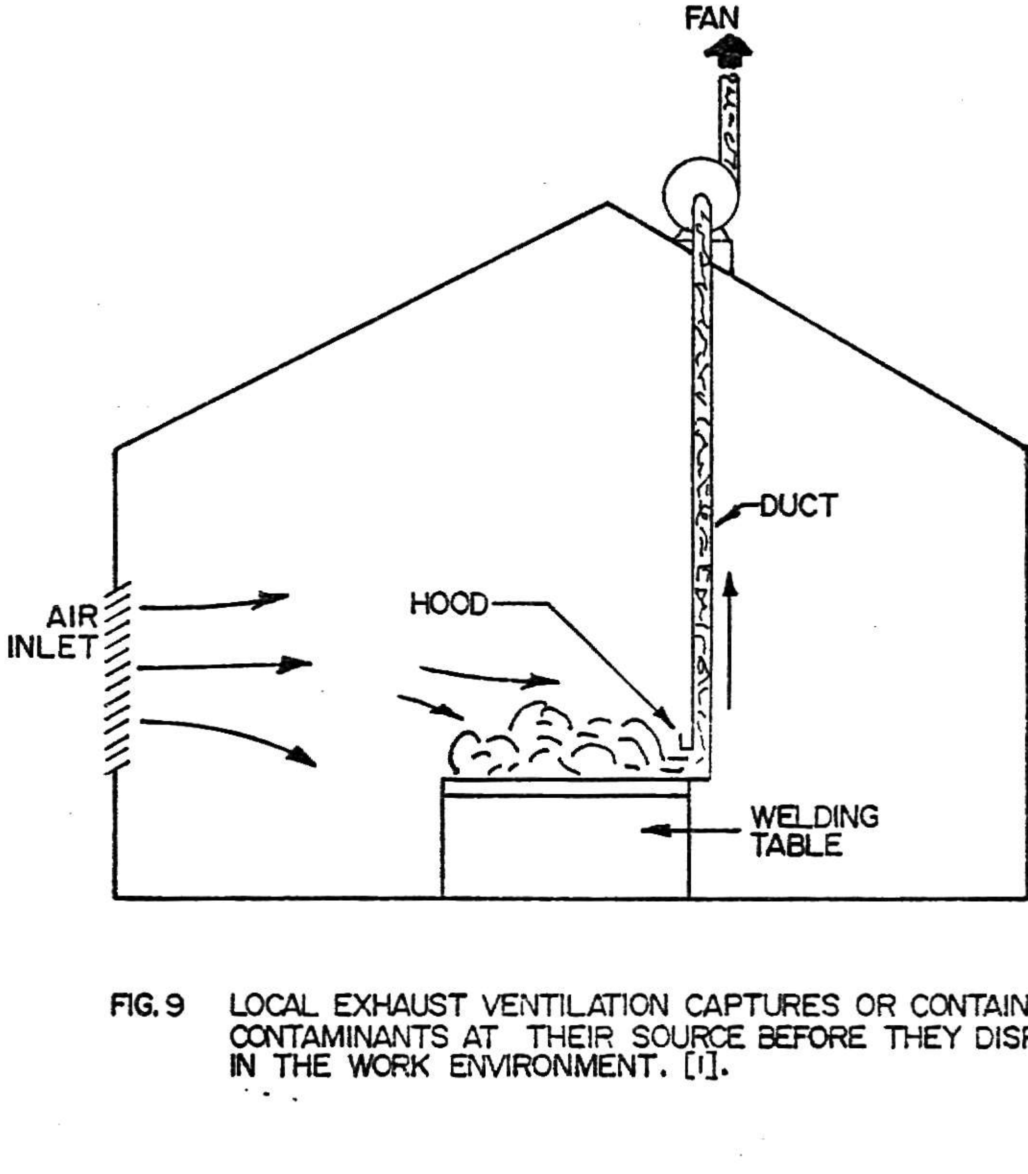

FIG. 9 LOCAL EXHAUST VENTILATION CAPTURES OR CONTAINS CONTAMINANTS AT THEIR SOURCE BEFORE THEY DISPERSE IN THE WORK ENVIRONMENT. [1].

TABLE 1. FEDERAL OSHA LOCAL EXHAUST REQUIREMENTS FOR GENERAL WELDING AND CUTTING

Freely Movable Hood	Fixed Enclosure
Requires 100 ft/min velocity toward hood through welding zone when the hood is at its most remote point from the point of welding.	Requires 100 ft/min velocity away from the welder.
The airflow (ft^3/min) needed to accomplish this velocity using a 3-inch-wide flanged suction opening is:	A fixed enclosure, by definition, has a top and at least two sides which surround the welding or cutting operations.

Welding Zone (distance from arc or torch), inches	Minimum Airflow, ft^3/min	Duct Diameter, inches
4-6	150	3
6-8	275	3.5
8-10	425	4.5
10-12	600	5.5

TABLE 2. COMPARISON OF FEDERAL OSHA STANDARDS FOR MOVABLE WELDING HOODS WITH THE CURRENT ACGIH MANUAL RECOMMENDATIONS.

Centerline distance of welding zone from the face of the hood.	Airflow into Hood, ft^3/min	
	Federal OSHA Standards	ACGIH Guidelines (1976)
4-6	150	250
6-8 or 9	275	560
8-10	425	NA
9-12	NA	1,000
10-12	600	NA

The ASHRAE guide to ventilation rates for typical industrial equipment specifies that the usual transport velocity for welding should be between 2,000 f.p.m. to 4,000 f.p.m. and the airflow should be 600 c.f.m. at a distance of 10 to 12 inches from the arc.

Students of IE 550-609 of Spring 1977 undertook to measure these values. The mean air velocity was found to be 4450 f.p.m. and the mean airflow was of the order of 850 c.f.m. However the measurements were made at the inlets of the ducts, which are located 3 feet from the arc and do not meet the criteria laid down for distance in the ASHRAE guide.

As mentioned earlier, Figure 6 points out the inadequacy of exhausting due to the existing arrangement of the booths and exhaust ducts. Fumes generated at two of the booths need to find their way vertically for a distance of 3 feet and then to the suction provided through the ducts which are not centrally located over these booths.

The problem then is that if we consider the existing duct and booth arrangement as permanent, one must come up with an effective exhausting system which overcomes this problem of distance between the point of fume generation and the point of fume collection. In other words, the objective now can be defined as the design and implementation of a local exhaust system.

Local exhaust systems that do not enclose or confine the contaminant are recommended as a last resort because exhaust volumes are large and control can be so easily upset by cross drafts in the area. However, since the nature of welding that is carried on in the welding lab is of a learning nature, since the welding lab is usually not subject to excessive cross drafts, and since the booth can be screened off from such air currents, proper local exhaust system can be a most effective solution.

CHAPTER IV

HOOD SELECTION AND DESIGN

In order to bridge the distance between the point of fume generation and the exhaust hood and ducts, an intermediate hood was designed.

The hood is the most important part of a ventilation system. No local exhaust system will work properly unless enough of the contaminants are retained or captured by the hoods so that the concentration of contaminants in the workroom air is below acceptable limits. The keys to good hood selection are a knowledge of airflow principles, an understanding of the plant process, and familiarity with employee work patterns around each process.

Without going into great detail it is necessary to point out that the air velocity distribution around the hood opening, the interaction between airborne contaminants and the following airstreams entering the hood determine whether the hood, and hence to whole system, will work properly.

There are three major types of hoods, each working on a different principle.

ENCLOSURES: Hoods that surround the contaminant sources as much as possible. Contaminants are kept inside the enclosure by air flowing in through openings in the enclosure.

RECEIVING HOODS: Some processes "throw" a stream of contaminants in a specific direction. For example, a furnace emits a hot stream of air and gases that rises above the unit. These hoods are positioned to catch the contaminants thrown at it. A major limitation to the use of receiving hoods is that gases, vapors and the very small particles that can be instilled and retained in the human respiratory system do not travel very fast in air unless carried by moving air.

CAPTURING HOODS: These are hoods that reach out to capture contaminants in the workroom air. Airflow into the hood is calculated to generate sufficient capture velocity in the air space in front of the hood. This hood is widely used since it can be placed alongside the contaminant source rather than surrounding it as with an enclosure.

For our purpose, the capturing hood type best suits our needs. It protects worker's breathing zone, offers flexibility in the shape and size selection of the weldments, and minimizes the existing airflow requirements.

Capturing hoods create directional air currents of sufficiently high velocity to capture contaminants in the workroom air near the hood. Their big advantages are that these hoods usually interfere less with the work operations than other hoods and also they can be positioned close to the contaminant source so that the worker is not between the source and the ventilating hood.

The capturing hood selected for our purpose is popularily known as a side draft capturing hood. The face area (or opening) of the hood is selected on the basis of source size and the minimization of velocity losses.

The face area of the hood opening should meet the following three criteria.

1) In order to minimize the velocity losses in the system, sudden contraction or expansion of cross sectional areas are to be avoided. Therefore, the face area of the hood should be approximately the same as the exhaust duct area.

2) To be classified as a side draft capturing hood, the width to length ratio of the hood opening should be greater than or equal to 0.2 ($W/L \geq 0.2$).

3) The dimensions should be of such size that the opening can effectively cover the fumes from the common weldment sizes.

Keeping the above three criteria in view, it was decided that the hood opening be of 3 inches in width and 12 inches in height.

In order to construct an integeral exhausting system, the original exhaust hood is now to be sealed off from its only open side, the bottom. The side draft capturing hood is to be securely connected through an integeral system with the original duct, hood and the capturing hood.

Turning our attention now to the point of location of this opening near the zone of contaminent release, the following important criteria to be mentioned. The first criteria is whether the hood develops adequate capture velocity to capture the contaminants; the second is whether the capture velocity is distributed over the zone in which the workroom contaminants are generated or released so that enough contaminants are collected to reduce worker exposure to acceptable levels.

Perhaps the easiest way to visualize the operation of a capturing hood is to picture the hood as creating an imaginary enclosure adjacent to the hood as shown in Figure 10. The imaginary enclosure is not formed by walls or baffles but by air currents with the needed capture velocity moving into the hood. Any contaminants released inside the 'enclosure' is captured.

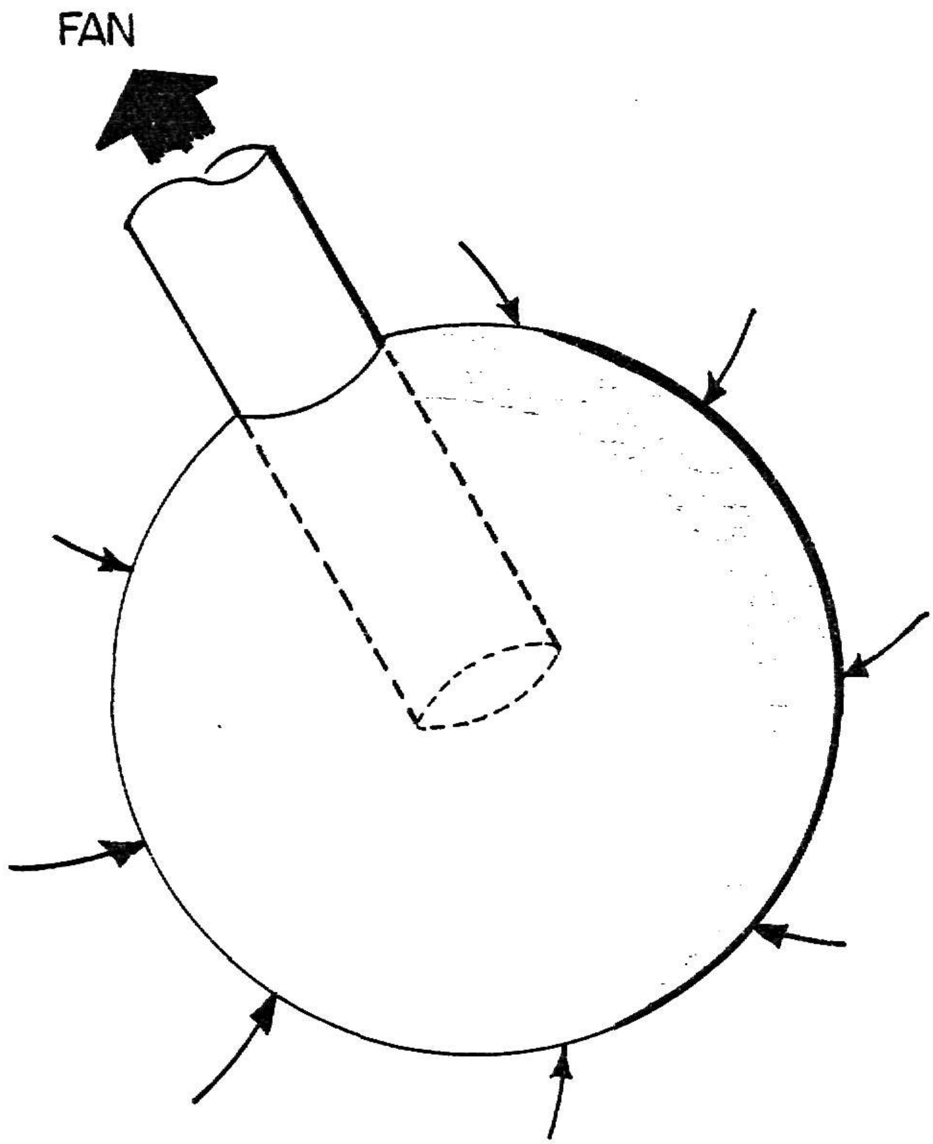

FIG. 10 THE CAPTURE ZONE AROUND AN OPEN DUCT IS A SPHERE BOUNDED BY VELOCITY CONTOURS WITH THE NEEDED CAPTURE VELOCITY. CONTAMINANTS RELEASED INSIDE THE SPHERE WILL BE CAPTURED WHILE THOSE RELEASED OUTSIDE MAY ESCAPE. [1].

Recommendation for velocities for different operations are published in the ACGIH manual as shown in Table 3. These recommendations have served the test of time and in general are adequate for most substances.

Proper distribution of the capture velocity is the second factor in designing capturing hoods. The function of the hood is to create the 'imaginary enclosure' as shown in Figure 10 that was described earlier.

Equations describing how the velocity decreases with increasing distance from the hood have been available for 35 years. The problem is that many of these relationships refer only to the centerline velocity, that is the air velocity along a line extending out from the center of the hood or duct. The equations describe the velocity at a point outside of the hood but do not define the velocity distribution across the hood face. For example, the centerline velocity outside a free hanging plain hood is

$$V_X = \frac{Q}{10X^2 + A}$$

where V_X = air velocity at X, ft/min.

Q = air flow into hood, ft^3/min.

A = area of hood face, ft^2

X = distance from the hood along hood axis, ft.

A plot of velocity as a function of distance for a typical plain hood illustrates the limited reach of capturing hoods as shown in Figure 11. But regardless of centerline velocity, the velocity contours of a plain opening hood and a flanged opening (Figure 12) hood shows that between these two, a plain opening hood is more inefficient for two reasons

TABLE 3. RANGE OF CAPTURE VELOCITIES

Condition of Dispersion of Contaminant	Examples	Capture Velocity, ft/min
Released with practically no velocity into quiet air.	Evaporation from tanks; degreasing.	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.

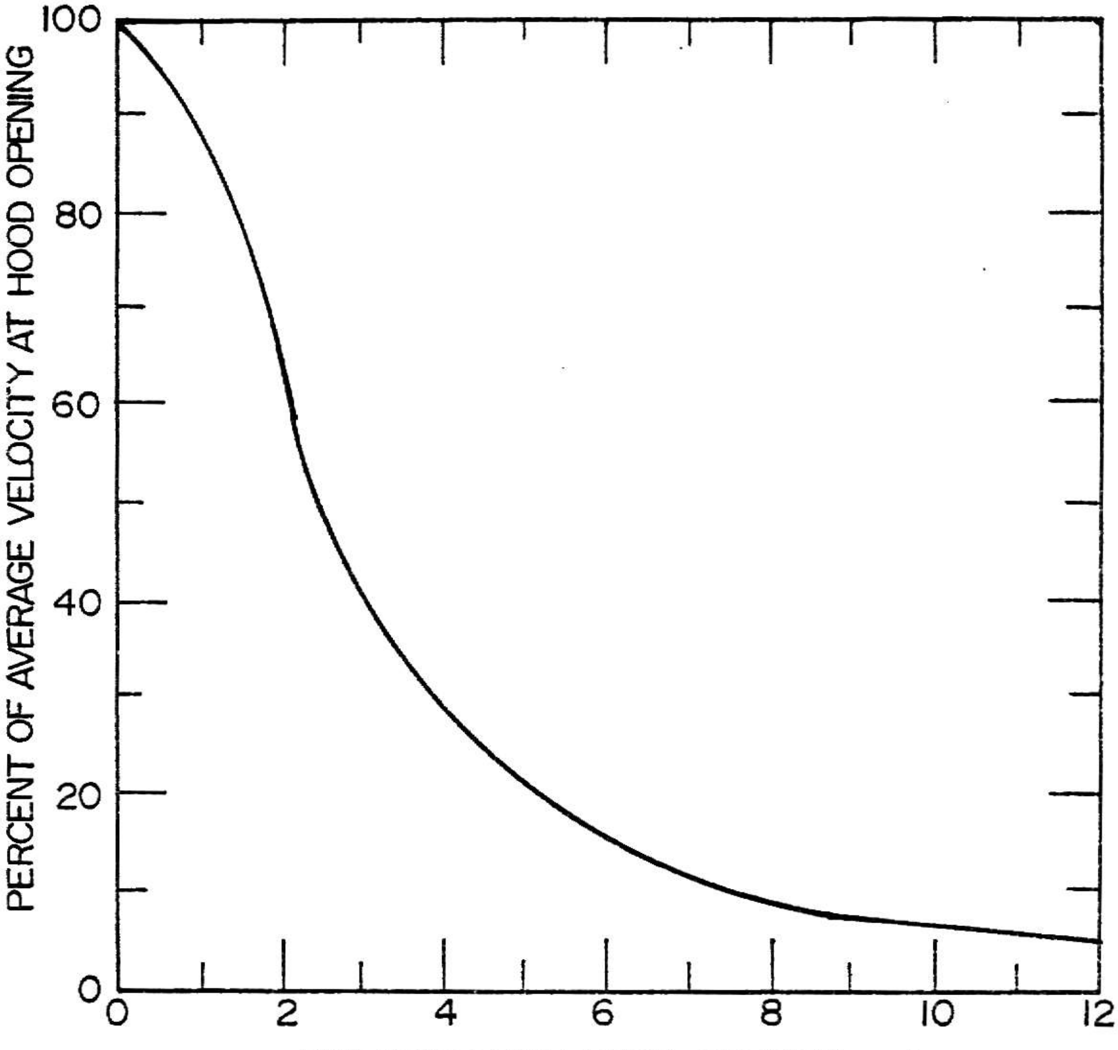

FIG. 11 INWARD AIR VELOCITY AS A FUNCTION OF DISTANCE FROM HOOD OPENING FOR A PLAIN (UNFLANGED) HOOD. [1].

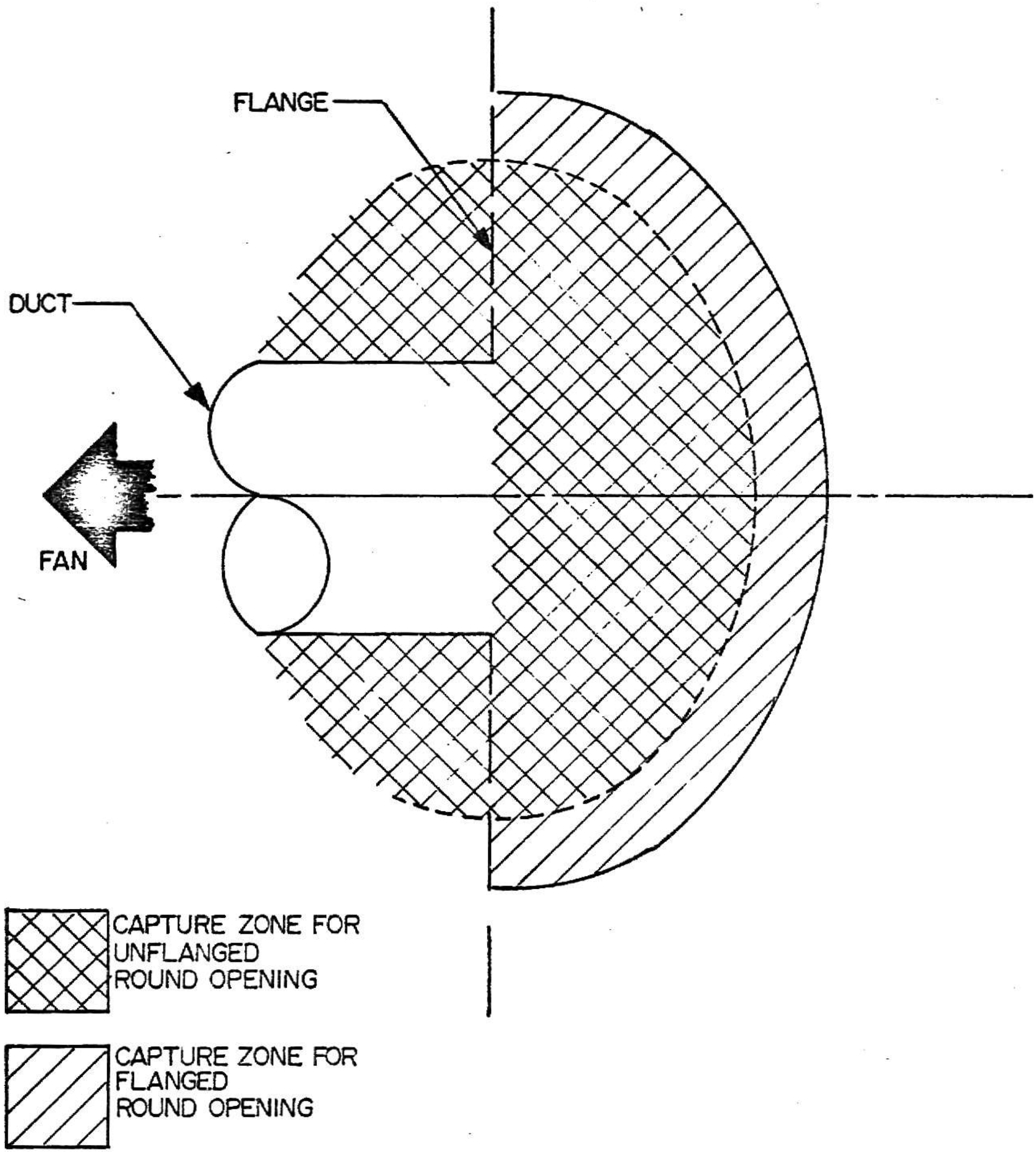

FIG. 12 A FLANGE INCREASES THE SIZE OF THE CAPTURE ZONE IN FRONT OF A DUCT OPENING. [1].

- it draws air from behind the hood outside the contaminant zone, and

- the sharply bending air streams flowing into the hood from behind interfere with smooth velocity contours in front of the hood where contaminants are generated. In other words, the velocity distribution is poor.

Addition of a flange to the plain hood changes the equation for centerline velocity to

$$V_X = \frac{Q}{0.75(10X^2 + A)}$$

This increases the capture zone.

In addition to a flanged hood, capture velocity is also aided if the hood provides a directional rounded contour as shown in Figure 13.

All these points have been taken into the design calculations and the following diagram illustrates the intermediate side draft capturing hood (Figure 14).

The adjustable feature of the moving platform on which the weldments are placed now enables the zone of contaminant release to be within the capture zone of the hood.

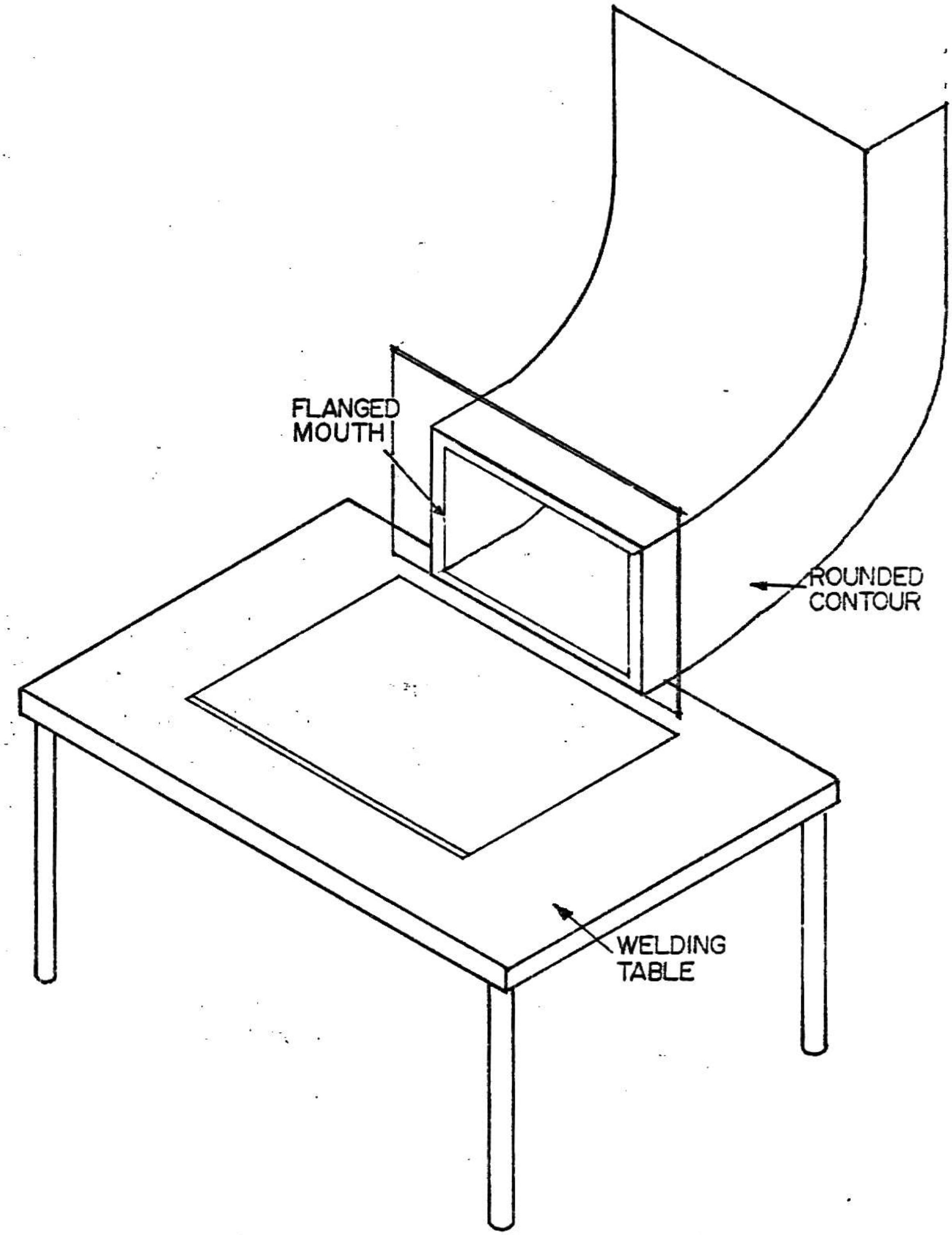

FIG. 13 A SIDE DRAFT CAPTURING HOOD WITH FLANGED OPENING AND ROUNDED CONTOUR.

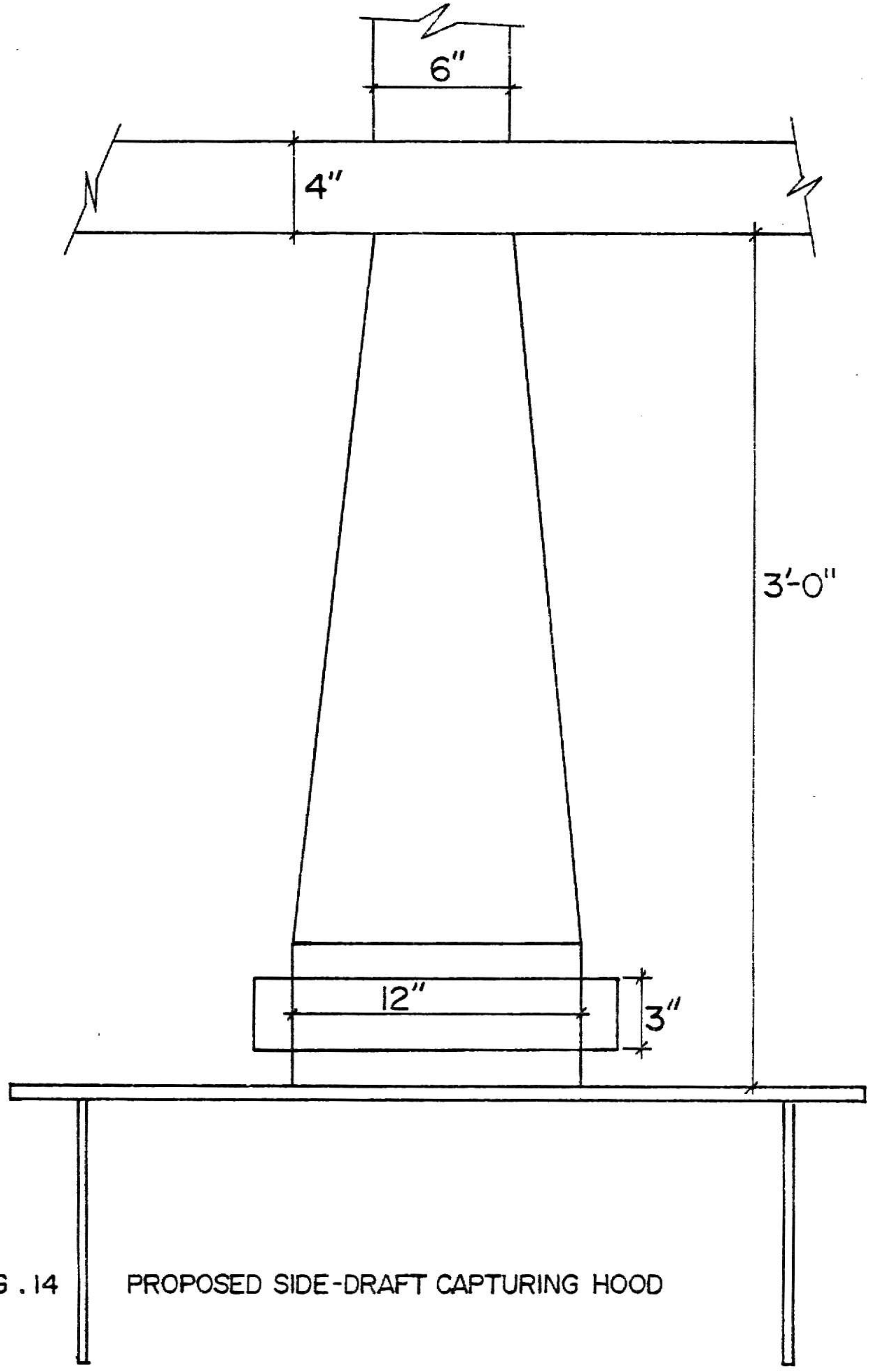

FIG. 14 PROPOSED SIDE-DRAFT CAPTURING HOOD

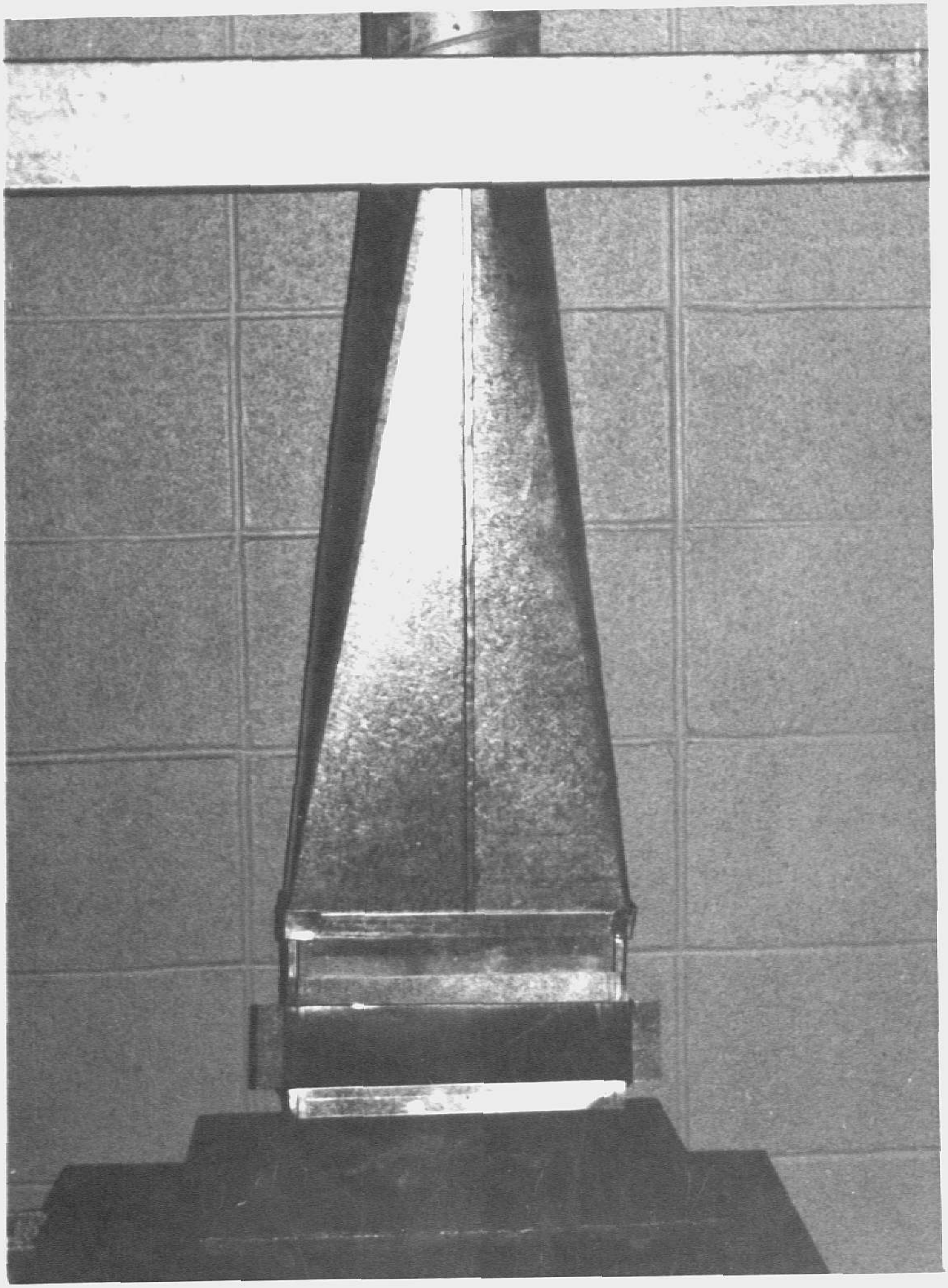

Fig. 15. Fabricated Side-Draft Capturing Hood.

CHAPTER V

CONCLUSIONS

An experimental side draft hood was fabricated with the before mentioned design specifications (Figure 15). A corresponding opening in the back plate of the welding table will be made and the hood bolted to the plate from behind.

This arrangement was tested for the capture velocity values and these were found to have a mean air flow of 500 c.f.m. Tests were also conducted with a smoke tube and photographic evidence shows that this setup works quite efficiently. A clear contrast can be seen when comparing the original setup as shown in Figure 16 with the proposed setup shown in Figures 17 and 18.

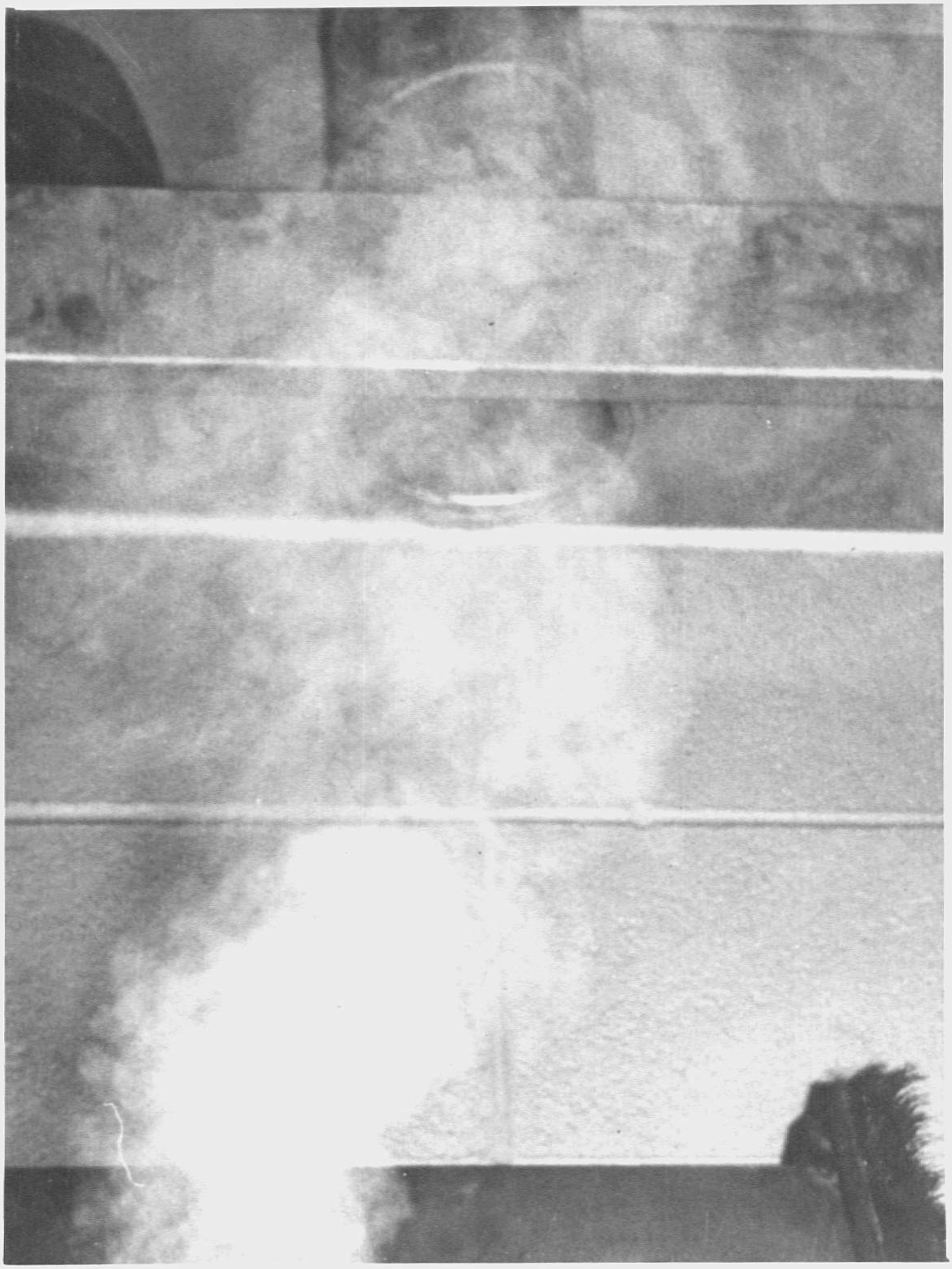

Fig. 16. Original Ventilation System Being Tested for Efficiency with a Smoke Tube.

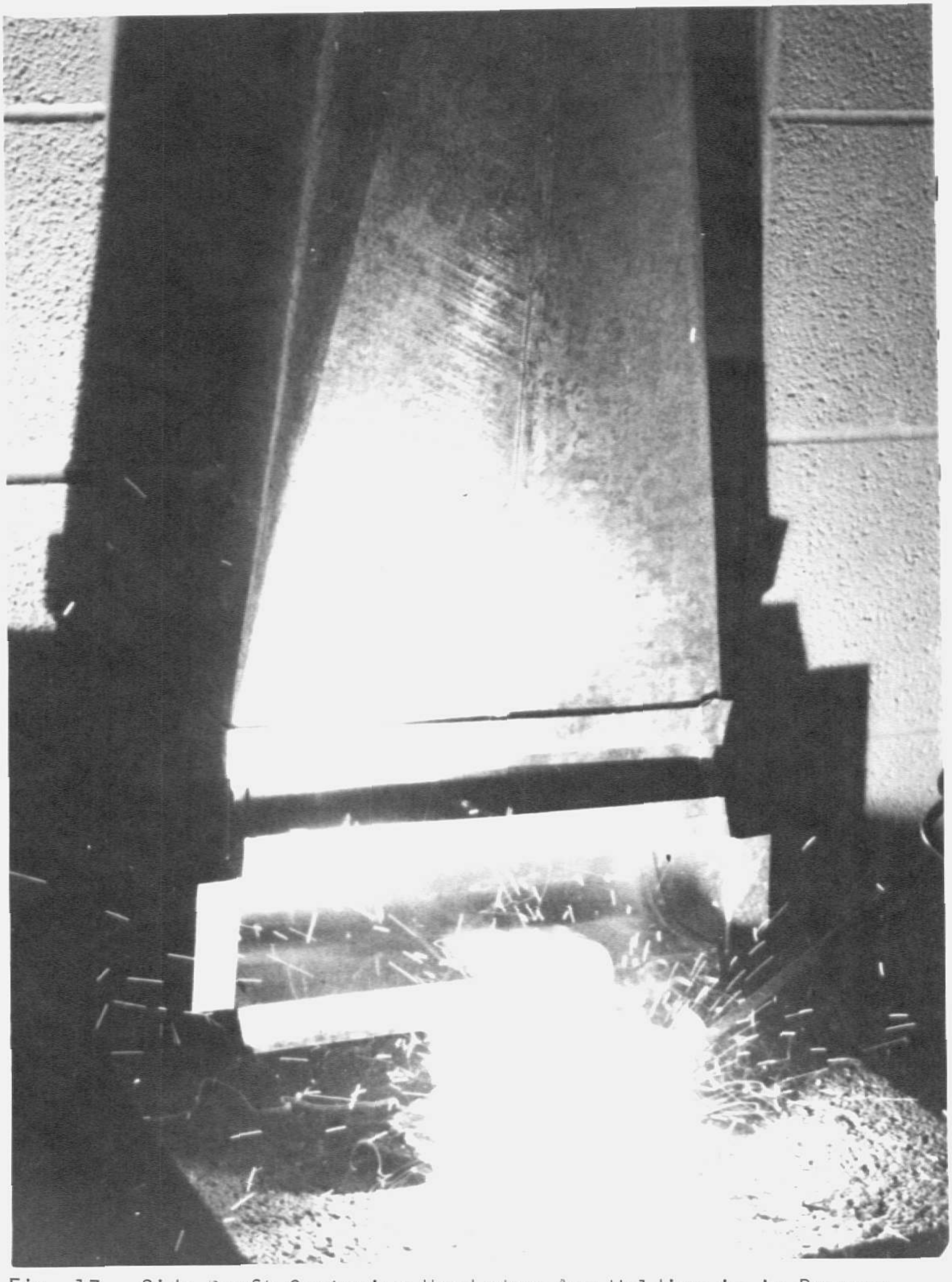

Fig. 17. Side-Draft Capturing Hood when Arc-Welding is in Process.

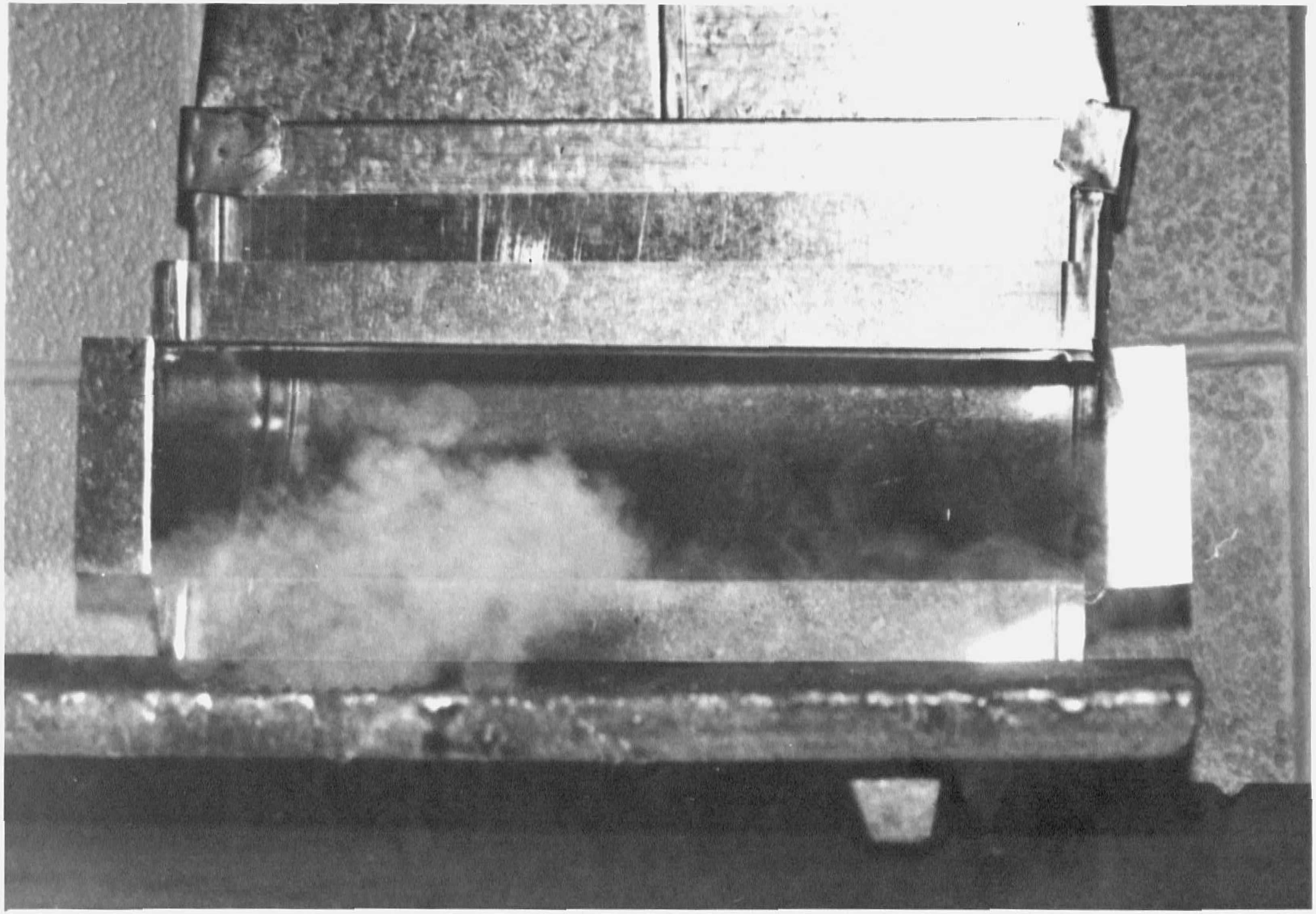

Fig. 18. Testing the Side-Draft Capturing Hood with a Smoke Tube.

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1. Henry J. McDermott, Handbook of Ventilation for Contaminant Control, Ann Arbor, Michigan, Ann Arbor Science Publishers Incorporation, 1976.

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ABSTRACT

The health hazard problem of arc welding fumes polluting the atmosphere in a welding lab was studied at Kansas State University. On analyzing the existing system, it was found that the six exhaust hoods located over the eight welding booths were installed at three feet from the point of arc, causing the pollution problem. It is recommended in all the literature surveyed for this report, that the distance be in the range not exceeding 12 inches. Among the various alternative solutions, the most economical redesign and modification of the duct system was undertaken for study. A newly designed side draft capture hood, extending close to the work place was installed. This lowered the exhaust velocity required from about 850 c.f.m. to 500 c.f.m.