THE FOUNDRY - ITS REAL POTENTIAL HEALTH HAZARDS

George E. Tubich
Tubich and Associates
Grand Rapids, Michigan

ABSTRACT

Silica, carbon monoxide, and metal fume are high priority health hazards in foundries. Noise and vibration, heat stress, illumination, and ionizing and non-ionizing radiation are physical agents with high priorities. A priority list is presented for foundry areas from a ventilation standpoint; the cleaning and finishing area tops the list. Looking at priorities among types of metals cast, the high temperature (ferrous) alloys have the highest priority. Ferrous foundries also account for the greatest majority of foundry workers. The reduction of the silica hazard will be achieved by the use of ventilation approaches; substitute sands for silica do not appear to be a long term solution.

Silica dust exposure is the major potential foundry hazard. Carbon monoxide is a major potential hazard in cupola operations. Foundrymen must be aware of its sources, symptoms, and treatment in case of emergency.

Metallic fume problems are greatest in processes in which the metal is molten, e.g., melting, pouring, welding, arc air, and less in abrasive grinding operations. The degree of potential health hazard associated with fume is dependent on the type of metal being cast.

The question of the formation of cancer agents during thermal decomposition of mold and core binders and additives is a subject for ongoing research.

Noise and vibration are not discussed here because they are handled in-depth in succeeding presentations.

Heat stress effects can be reduced by training workers to maintain their water and salt balances.

Good illumination affects productivity as well as safety and health.

The use of ionizing radiation is rigidly regulated in the foundry.

INTRODUCTION

The foundry, as well as many other industries, has a wide variety of potential health hazards. These have been classified as chemical and physical risks; at times they may occur simultaneously. It is virtually impossible to develop a list or priority classification that is accurate and precise at all times because of the many variable factors involved. However, when proper consideration and evaluation is given to the variable factors, number of people involved, concentration factors, and degree of toxicity, an order of priority can be developed which may serve as a useful guide.

For the foundry, the following chemical hazards appear to be of real significance.

1. Silica.
2. Carbon monoxide and certain other products of thermal decomposition.
3. Certain metallic fume and particulate - lead, manganese, chrome, nickel, etc.

There are some who believe that the physical risks are of secondary importance as compared to the chemical risks because of the type or nature of impairments. In the foundry the following physical conditions are of importance:

1. Noise and vibration.
2. Heat stress.
3. Illumination.
4. Ionizing and non-ionizing radiation.

Let no one be misled in any way by the above statement about the importance of various foundry risks for under certain conditions either the chemical risk or the physical risk may be of real significance. It would be well for all of us to reflect on John Donne's quotation - "Any man's death or injury diminishes me".

FACTORS INVOLVED IN DEVELOPING AN OCCUPATIONAL DISEASE

In one way or another a combination of some or all of the following factors may have the potential to produce an occupational disease:

1. Toxicity of material.
2. Concentration in breathing zone.
3. Particle size.
4. Length of exposure.
5. Individual susceptibility.

Particle size is perhaps the factor least understood by foundrymen. In order that silica dust can be inhaled into the deeper parts of the lungs to produce a health effect, it must be in the respirable range. There are several classifications of a specific respirable range; many consider particles that are 10 microns and less to be respirable. Particles larger than 10 microns are referred to as non-respirable and are removed from the body by the upper respiratory and lung clearance mechanisms.

The following facts concerning particle sizes are presented to provide some understanding of dealing with very small particles:

1. The respirable dust (<10 micrometers) which is a health hazard is much smaller than the diameter of a human hair (40 micrometers).

2. The limit of visibility extends down to about 40 micrometers, which helps to hide the presence of the respirable dust.
3. In still air, a 1 micrometer silica particle will settle less than 0.5m in an hour. This emphasizes the ability of respirable dust to persist in the foundry general environment.

POTENTIAL HEALTH HAZARDS BY OPERATION

In the foundry there are certain basic operations where excessive exposures to airborne contaminants are most frequently encountered, particularly when ventilation controls are ineffective or non-existent. The principal operations where ventilation control or approved personal protective equipment is almost a must in every case because of inherent problems are listed below, in a broad order of priority:

1. Cleaning and finishing.
2. Sand systems.
3. Shakeout and core knockout.
4. Material handling systems.
5. Melting and pouring*.
6. Molding and coremaking.

This order that has been developed cannot be accurate and precise at all times because of the many variable factors involved. However, when proper consideration and evaluation are given to these variable factors, e.g., the number of people involved and the toxicity of the contaminant, an order of priority can be a very practical guide. This order applies only to chemical factors and not physical factors.

In terms of the type of foundry, priorities would be:

1. Steel.
2. Iron.
3. Brass and bronze.
4. Aluminum.
5. Magnesium.

It may be noted that risk potential is considered to be greater in the higher temperature alloys.

Bureau of Labor Statistics (BLS) data for May, 1979 gives the estimated number of foundry <u>production</u> workers as follows:

1.	Ferrous	201,800
2.	Non-ferrous	84,300
		286,100

BLS has issued a projection that the rise in production workers from 1976 to 1985 will be about 15 percent or 43,000. Of this amount 30-40 percent will be in growth and the remainder for replacement.

*Priority listing may vary according to type of metal cast.

Information on the distribution of foundry production workers by operation is fragmentary, and is estimated below:

1.	Cleaning and finishing	70,400
2.	Sand systems	4,600
3.	Shakeout and core knockout	10,900
4.	Material handling systems	24,700
5.	Melting and pouring	29,800
6.	Molding and coremaking	116,800

CHEMICAL RISKS

Silica

Virtually all of the above production workers have a certain degree of exposure to silica dust and, dependent on operation, may have varying exposures to other contaminants. Accordingly, it seems evident that silica dust is the major problem and controlling the silica exposures will in many instances control other exposures.

From time immemorial silicosis has been a continuing problem in the foundry industry. It is unfortunate that there is no recent study data on the incidence of silicosis in the foundry. The last published data was in 1950. This study revealed that approximately 10 percent of the workers had some degree of silicosis. Today, it can only be assumed that improvements in the foundry over the past 30 years have brought about some reduction in the incidence of silicosis.

On a number of occasions it has been suggested that a non-silica aggregate, e.g., aluminum silicate, chromite, olivine or zircon, be substituted for silica. However, based on usage and production capabilities this is not reasonable. Today, the foundry industry uses some 10 million tons of silica sand each year. The total production of all non-silica aggregates is barely 500,000 tons per year. In addition, the cost of non-silica aggregates is approximately 4-6 times that of silica sand. The NIOSH study of health hazard control technology in foundries records many approaches to controlling silica dust. These should be thoroughly reviewed and applied or modified to fit the particular problem. Also, dilution ventilation with proper distribution of make-up air and approved personal protective equipment should be considered.

Carbon Monoxide

Carbon monoxide (CO) is one of the oldest poisons known to man, and men have been subjected to it ever since the first fire was kindled. Until there is a better understanding of CO, it will continue to be a problem.

Today, it has been determined that the potential for exposure to CO of employees at the workplace is greater than that for any other chemical or physical agent. Not only is CO an important industrial poison, but it is also the greatest single non-industrial hazard, for it is readily found in the home, automobile, and other places. CO is a colorless, odorless, tasteless, noncumulative, and non-irritating gas. All of these properties increase its danger, for an individual will not realize when he is being exposed.

Sources of Carbon Monoxide--

Carbon monoxide will be given off wherever there is incomplete combustion of a carbonaceous material. Therefore, gas, oil, kerosene, wood, coal, coke, core and mold additives, resin binders, and many other organic materials will emit CO, the amounts depending on combustion efficiency. There is an old expression that says, "Where there is smoke, there is fire". Remember it in this way, "Where there is smoke, there is carbon monoxide".

The cupola is the major source of CO generation in the foundry. About 8 times more CO is emitted from a cupola than particulate matter. While much of the CO is either burned or emitted into the atmosphere, there is ample leakage at the charging and bottom doors and iron and slag spouts to produce significant CO exposures. Typical CO concentrations from the cupola and other foundry operations are shown in Table 1. This data was compiled from a number of different studies and represents conditions of poor to good control measures.

Table 1. Range of carbon monoxide concentrations in certain foundry operations.

Location	No. of readings	Range of CO, ppm*
Charging deck	100	10-600
Iron and slag spout	60	15-200
Floor level - cupola	53	10-300
Pouring green sand molds	75	25-600
Pouring resin bonded molds	50	25-400
Shell core molding	25	10- 75

Absorption of CO--

There are certain factors which enter into the absorption of CO:

1. Concentration of CO.
2. Length of exposure.
3. Rate and depth of respiration.
4. Amount of exertion.
5. Altitude, temperature, humidity and air movement.
6. State of health, e.g., age, size, smoking habits, emphysema, anemia, coronary heart disease.

Carbon monoxide is classified as a chemical asphyxiant because it produces its harmful effects by cutting off the oxygen or fresh air supply from tissues of the body. Ordinarily, the oxygen that is inhaled is carried from the lungs by the red blood cells to all parts of the body. This combination with the red blood cells is very important, for just breathing oxygen is not enough to maintain life. The oxygen must combine with the red blood cell and circulate through the blood stream and be carried to all parts of the body. Unfortunately, CO can combine with the hemoglobin of the red blood cells to form a relatively stable compound, carboxyhemoglobin (COHb), which deprives the body of its oxygen. This action of CO results in more persons succumbing to acute CO poisoning than any other single toxic agent except alcohol.

The phrase "percentage of blood saturation" is commonly used in discussions concerning CO poisoning and can be defined as the percentage of hemoglobin of the blood combined with CO instead of oxygen. The symptoms of poisoning more or less parallel the blood saturation level and are shown in Table 2.

Table 2. Symptoms of carbon monoxide poisoning related to the percentage of blood saturation of CO.

Percentage of blood saturation	Symptoms
0-10	None.
10-20	Tightness across forehead, possible headaches.
20-30	Headache, throbbing in temples.
30-40	Severe headache, weakness, dizziness, dimness of vision, nausea, vomiting and collapse.
40-50	Same as previous item with more possibility of collapse and syncope, increased pulse and respiration.
50-60	Syncope, increased respiration and pulse, coma with intermittent convulsions.
60-70	Coma, with intermittent convulsions, depressed heart action and respiration, possible death.
70-80	Weak pulse and slowed respiration, respiratory failure and death.

The symptoms decrease in number with the rate of blood saturation. When high concentrations of CO are inhaled, the employee may not experience any of the symptoms shown in Table 2 but may suddenly collapse. Death in these cases is due to paralysis of the respiratory center. Heavy work or exercise and high temperature and humidity with little or no air movement tend to increase respiration and heart rate and consequently result in more rapid absorption of CO.

Sometimes CO does not work as quickly as this, but its effects are just as deadly. Often the first symptoms of lower concentrations, e.g., tightness across forehead, headache, throbbing in temples, dizziness, nausea, vomiting, are confused or misinterpreted as the symptoms of other illnesses. However, CO absorption is continuing and unless recognized, its serious effects progress to the same end results.

Treatment--
Prevention is always the best way to deal with accidents, but sometimes they happen despite our best efforts to foresee all possibilities. When they do occur, knowing what to do and acting quickly can save a life. This

is especially true in cases of acute CO poisoning where time is of the utmost importance. These are the steps to take:

1. Remove the victim to fresh air immediately - avoid extremely cold locations. If breathing has stopped or is irregular, begin artificial respiration at once.

2. Call a doctor immediately. Also send for an ambulance service or rescue squad, fire or police department, for special equipment to help revive the victim. However, do not wait for this help to arrive; start first aid without delay.

3. Continue artificial respiration when the emergency equipment arrives, providing both kinds of treatment at the same time until natural breathing returns, unless otherwise directed by a physician. Continue artificial respiration for two hours or more if natural breathing is not restored.

4. Continue application of oxygen, as provided through the emergency equipment, for 15 to 30 minutes after natural breathing returns. This will assist in quickly ridding the blood of CO.

5. Keep the victim warm with blankets or other covering. After the victim begins to breathe again, keep him still, warm and quiet, to stave off any danger of shock.

6. Aid circulation by rubbing the arms and legs. The sooner proper circulation is restored, the sooner the patient will recover.

7. Avoid use of stimulants such as coffee or tea, since these may strain the heart.

8. See that the patient has rest and plenty of time to recover slowly to avoid any strain on the heart.

Prognosis--
In most cases of CO poisoning, recovery takes from a few hours to several days. All the damage done in these cases takes place during the time the gas is combined with the blood causing anoxia in the tissues. If this anoxia is both prolonged and severe, there is a possibility that a degenerative process may occur in the brain giving rise to after-effects. These after-effects depend on the area of the brain affected and the extent of the degeneration. If the anoxia has not been too severe or prolonged, there may only be irritation of the brain cells without degeneration. In this case, the symptoms will disappear leaving no after-effects. However, if a degeneration is once set up in the brain, it may remain stationary or

become progressively worse, ending in death. Sometimes, in cases where the degeneration becomes progressively worse, after the blood has been entirely freed of the CO, there may be a period of time during which the victim has apparently recovered from the acute effects of the gas, only to have a relapse with severe after-effects.

Once the brain cells have degenerated, they are never regenerated and the effects produced become permanent. The after-effects manifest themselves in the form of loss of memory, paralysis, amnesia or other mental disorders and are most liable to occur in those of advanced years or in those having coronary heart disease. The number of victims suffering after-effects is extremely low in comparison to the number of victims severely asphyxiated.

Regardless of how high the percentage of saturation of the blood has been, practically all the CO is eliminated in 8-10 hours, but a small amount of CO may remain in the blood for a much longer time. Once the blood has been freed of CO, the red blood cells are found to not be destroyed or altered in any way and they immediately resume their normal function.

Metallic Fume and Particulate

The degree of potential health hazards associated with fume and particulate is dependent upon the type of metal being cast. Some of the more significant metals are lead, manganese, chromium and nickel. Metallic fume can be encountered at melting, pouring and the various types of welding and brazing operations. Some of these operations may also emit carbon monoxide, nitrogen dioxide and other contaminants. The particulates liberated during grinding operations are usually not as significant as the fume because particulates from most grinding operations are usually of a large particle size.

Coal Tar Pitch Volatiles

There appears to be increasing evidence of carcinomas of the respiratory system in foundrymen. While there are no straightforward conclusions as to a single etiological agent or agents, there are strong suspicions that agents responsible may be formed during the thermal decomposition of a wide variety of organic additives and binders used in the foundry processes. Possible explanations are:

1. The presence of unidentified carcinogens in the air.
2. Synergism between various contaminants.
3. Different exposure in the 1940's.
4. Smoking habits of the worker.

There is little question that before an unequivocal answer is possible much additional work will be required of the many parameters involved. One study on this matter is now being conducted by NIOSH.

PHYSICAL RISKS

Noise and Vibration

A number of excellent papers on this topic are to be presented in these sessions. Accordingly, no comments on this subject will be presented.

Heat Stress

A big step toward maintaining the efficiency and well being of foundry workers exposed to heat can be achieved by an uncomplicated education program of teaching these workers to drink enough water and consume enough salt to replace that lost through sweating. This will combat the problem of worker fatigue caused by heat exposure. Although rapid strides have been made in the mechanization of foundry operations, worker fatigue still ranks as one of the critical factors in productivity. Studies have shown the following:

1. Failure of the body to get enough water during the working day is one important reason for heat fatigue.

2. A worker's thirst is not a reliable indicator of the amount of water he needs to avoid fatigue.

3. Most workers consume only two-thirds of their hourly requirement.

4. To get enough water, workers must force themselves to drink water even when they aren't thirsty.

The human body is a self-regulating mechanism which automatically demands the water it needs to make up for losses due to exertion and heat exposure. For many workers, however, there is a time lag in thirst, which allows the fatigue cycle to begin. The worker ends up being less efficient than he need have been for a good part of the day, and leaves the job more tired than necessary.

Illumination

Light and lighting are so universally applicable, controllable, and essential, however, they have been so generally neglected from every viewpoint of seeing. Good illumination is a vital factor in health and safety and productivity. The best worker with the best eyes, equipped with the best tools, becomes unsafe and inefficient when handicapped by poor illumination. The benefits of good illumination cannot be over-emphasized particularly when consideration is given to the fact that the cost is minimal when compared to many other in-plant control systems.

Ionizing Radiation

Those foundries using this type of radiation are usually regulated by state agencies and must adhere to rigid control programs accordingly and only due to adverse situations is this a significant problem.

PREVENTIVE MAINTENANCE AND HOUSEKEEPING

To be successful in any control program there is a great need to develop and carry out a well-planned preventive maintenance program for all control equipment and a sound housekeeping program. Those foundries that have been most successful in achieving a good environmental control program have found these two factors to be most essential.

AIR BALANCE

Another factor that requires serious consideration is the air balance. If there is a great difference between the amount of air exhausted as compared to the amount of air supplied, the effectiveness of the control systems will be reduced. A frequent mistake with the air supply systems is poor location and distribution.

Most often the supply air should be introduced at no higher than 2.5-3m (8-10 ft) above the floor level and so located that it will not be quickly removed by a nearby exhaust system. Proper air balance is a most important factor in achieving good control.

RECIRCULATION

The energy costs involved with exhausting heated room air to the outside is receiving a great deal of attention. NIOSH has conducted several seminars and investigations into this matter and their publications are available. In addition, the AFS recirculation committee will, within the next several months, have available further study data conducted at foundries.

COMMENTARY

The foundryman, through his technology, has created a wealth of new methods and materials. This has taken up so much of his total time, effort and ingenuity as to leave him little opportunity to learn what might be the ultimate effects upon himself. The foundryman, as well as many others, derives an undue comfort from the crude statistics that the people in no previous society have been known to die young in such small numbers and to live old in such large numbers. The easy conclusion is that we are healthier now than ever before and that modern life holds no serious threat to health. However, if we examine these statistics carefully, we find that we have extended the unproductive extremes of infancy and senility.

In law, the suspect is innocent until his guilt is proved beyond reasonable doubt. In the protection of the health of foundrymen such absolute proof often comes too late. To wait for this proof is to invite disaster or at least to suffer unnecessarily in the period of waiting. Today, a considerable amount of significant work is available on foundry control technology. Evidence that better working conditions and better equipment are essential to the production of quality products and attractive to the highest type of workman is now conclusive. The present problem, therefore, is not to convince management of the need but to show management that the time is now.

QUESTIONS, ANSWERS AND COMMENTARY

Question (P. Maganus, Milwaukee Valve Company, Inc.):

You indicated that illumination is a most economical inplant safety measure on the basis of the defective vision that the employees seem to have in the foundry industry. Is this true only in the foundry industry?

(Editor's note: In his verbal presentation Mr. Tubich indicated that illumination is a good area where health, safety, and productivity can be improved. He said to consider two points:

1. Illumination is probably the cheapest of all inplant control measures.
2. Of the 40 and older population, 50-90% have defective vision of some sort).

Answer (G. Tubich):

The diminishing of vision with age is true for the entire population. When we're talking about investments, I am contrasting the amount of money necessary to improve illumination with the much higher amounts necessary to, for example, ventilate a cleaning and finishing operation.

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NIOSH Project Officer: Dennis O'Brien
Project Manager: Robert C. Scholz

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