OCCUPATIONAL INJURY CONTROL

TYPES OF VENTILATION AND THEIR USES

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Ventilation, in one form or another, is the most widely used type of control. Many types of ventilation are not recognized as forms of control, nor are they even recognized as ventilation. In the next 20 minutes we will be discussing the various types of ventilation and we will break them down into three major categories: namely, natural ventilation, dilution ventilation, and local exhaust ventilation. Each type of ventilation has its advantages and its disadvantages. These advantages and disadvantages will be discussed.

The simplest type of natural ventilation utilizes outdoor air movement - the wind velocity that occurs naturally. No roof or walls are present to act as barriers to this wind velocity. The simplest example would be an oil refinery. The mere fact that the wind is blowing in the general area around the plant is sufficient to remove the toxic vapors from the processing area; or at least dilute them to a level below the TLV. The advantage of this, of course, is that no expense is incurred in connection with it. If you tried to do anything else in an oil refinery, considering the layout, the piping, and the vast areas that are covered, it would be extremely expensive. Disadvantage? What happens when the wind isn't blowing? True, there is always a little wind motion, but is there sufficient wind motion in a calm to remove these vapors and gases rapidly enough so that the concentration is held down?

The second big disadvantage is obvious. What happens in cold weather? What happens in the rain, if the man must go out to maintain vast pieces of industrial equipment such as reformers, catalytic crackers, and so on? The man, obviously, must climb around them and repair them in the rain. True, they don't have to do it too often; but on a routine basis they do have to go around and check the operation. So the advantage in using an atmospheric pressure gradient to create ventilation for the control of gaseous and vaporous contaminants is offset by the disadvantages of variable atmospheric air movement, the atmospheric temperature, and with anything else that comes with the atmosphere - rain, sleet, hail and so forth. There is no protection for the worker. However, this type of ventilation is rather widely used. Probably the best examples of it would be refineries, some large chemical companies, and some coke-making operations.

Natural ventilation can also be used to remove the contaminants from within buildings. Here, the problem is rather different. The air movement is dependent not only upon the atmospheric conditions (the velocity of the wind and the direction in which the wind is moving), but it is also affected by the "Thermal head" or the "Chimney effect" of the hot air inside the building. This effect will cause the warmer air in which the men are working to rise to the ceiling, and therefore, most of the natural ventilation will be floor-to-ceiling air circulation. The amount of dilution obtained, will depend upon the locations providing outside air. Frequently, the buildings will have windows located high upon the outside walls. Sometimes they have monitor roofs, so-called "saw-tooth" roofs. These saw tooth roofs have windows in them. The windows in the walls combined with the windows in the saw-tooth roof will cause an in-flow of air. The amount of in-flow depends upon a multitude of factors. How many windows do you have to open? What is the velocity of the wind? What is the direction of the wind? How many doors do you have open? All of these factors and many others, will determine the total volume of air which will enter the plant. As a rough rule of thumb, design engineers usually assume that in an ordinary shop building (no tighter than usual, no more cracks, no more ill-fitting windows than you would find in the usual shop), there will be approximately three air changes per hour; that is, three times the shop volume of air will be circulated through the shop during each hour. In a tight new building, this volume might fall to as low as one air change per hour. On the other hand, in an old building with a high wind velocity, it could go to six, seven or eight changes per hour.

Within the building itself, the location of the windows where the air is entering the building, and the locations where the air is leaving the building will determine whether or not there are corners or pockets in which the air may fail to circulate. For example, you may have a welding operation in a corner of a building. This corner could well be a rather stagnant pocket of air; and to have one air change per hour in that particular corner, three or four air changes per hour out in the general shops might be required. If you have a welding operation there, and the natural ventilation is not adequate, you will have troubles and will have to go to something besides natural ventilation.

This problem leads to rather weird ways of assuring that the air will be evenly distributed. You have probably seen some buildings that have a series of louvers just about at floor level and possibly three or four feet high. These louvers allow the air to enter close to the ground. This may be a great idea - sometimes. Suppose, for example, that the air is entering and is also blowing across the surface of the tank before it reaches a worker. The natural ventilation may be blowing fumes from that tank right into his face. Tomorrow, with the wind coming from another direction, it might well be blowing fumes to his left, or to his right, or straight up above him. So, natural ventilation can be used to control certain exposures, but the hazards it controls must be relatively non-toxic; for example, such a hazard as mild steel welding fumes. As a matter of fact, natural ventilation is one of the specified permissible conditions for mild steel fumes. The simple rule of thumb derived from the ANSI Standard says that if you are working with E6011 or E6012 mild steel welding rod on mild steel plate, and you have a shop volume of 10,000 cubic feet per welder with natural ventilation, the conditions will be adequate and acceptable for controlling the fumes. On the other hand, if you are using any other type of welding rod; if it has a different alloy, even if it's mild steel that has a rod coating which is alkaline or which contains fluoride, you must use something besides natural ventilation, because you are producing more toxic fumes. Iron oxide itself coats the lung; true; but it doesn't produce any disabling pathology or disease. It merely coats the surface of the lung. It doesn't interfere with vital capacity. As a matter of fact, men will sometimes tell you they are healthier because of it. On the other hand, fumes can become excessive in some of those corners where you don't get natural ventilation. If the concentration of fumes goes above the TLV so that the concentration is more than 5 milligrams of iron oxide per cubic meter of air, the worker may get nose, throat, and possibly even lung irritation. Whether this is due to the iron oxide or some of the gaseous products that occur in the arc, is a moot question, since the TLV of 5 milligrams per cubic meter will control other contaminants. If you do not exceed the TLV for iron oxide, the other contaminants will be well within acceptable limits.

The disadvantages of natural ventilation being used inside buildings are pretty obvious. It is not only a matter of wind velocity or wind direction and the amount of open wall space. In the winter time the men have a tendency to close the windows and doors, so that the amount of air circulating in the building is greatly reduced. They do this as a matter of comfort without much thought about the build-up of gaseous concentrations or welding fume concentrations, or ozone production. So they will close these open areas. They will close the windows. They will close or block the louvers. They will close the overhead windows, if they can. In the process, they limit the amount of air that is removed; the number of air changes per hour within the shop. In the winter time it is extremely difficult to get the number of air changes that you are looking for unless you happen to have an old shop that doesn't fit tight, and you have a strong wind. In cases like this, even the closing of the windows will not preclude your getting at least three air changes. But what happens on a cold, calm day? If the men insist on closing the windows and as many other openings as they can to cut down on the cold drafts, it will cause the build-up of concentrations above the TLV. This is another disadvantage of natural ventilation within a building or within a structure.

The second broad category of ventilation is what I prefer to call mechanical general ventilation, rather than "dilution" ventilation. I like to avoid the term "dilution" ventilation; because, when you say this, you assume that you are getting the dilution you want. As I pointed out before, any currents in a building may very well interfere with this so-called dilution. What do we mean by dilution ventilation? Instead of relying on thermal head or wind velocity, to remove contaminated air from the building, we use fans to blow the air out.

This is probably the most widely used and misused type of ventilation. It seems logical and it seems easy to apply it to an operation which is generating a fume or a solvent vapor. The reasoning goes like this - Close to the operation we have an outside wall, so let's just cut an opening in the wall and slap a propeller type fan with automatic louvers in the opening. This will draw the air away from that man's breathing zone, and therefore, it will remove the contaminants and we will be controlling that operation. It sounds good. It looks good. It's simple. But, there are many things wrong with it. The fan may be so far away from the tank that any cross-draft across the surface of the tank will overcome whatever the fan is supposed to be doing and blow the material back in the man's face. The fan may even cause the cross-drafts. But, the biggest problem we have is common to all kinds of mechanical ventilation. This problem is make-up air. Now, you must keep in mind that a propeller type fan (one of these four-bladed units that are mounted in the wall and driven by a belted down motor) can produce only a slight negative pressure inside the building. They are primarily air movers. Any time you put a fan in a wall or in any operation, you must keep in mind that the air must come from somewhere. This fact is frequently forgotten.

A typical example of this occurred when I was on a dry cleaning survey in Washington, D.C. I entered a little dry cleaning shop. You know what they look like. They have about a 30-foot front and they go back maybe 80 feet. This means they are actually like a tunnel 30 feet wide, 16 feet high and 80 feet long. As I got about one-third of the way into the shop, I detected the odor of Perchloroethylene. I walked past the dry-cleaning unit toward the back wall. In the back wall, the owner had installed a fan, five feet in diameter with automatic louvers. These light-weight aluminum louvers open when the fan is running and close when it is off. He had this five foot fan running. A fan that big should produce a tremendous amount of air-change in a building that small. How come I was picking up the odor of Perchloroethylene? I went back and looked at the fan. I looked through the rotating blades at the outside louvers. I noticed the louvers were just barely quivering instead of standing wide open. This meant that the fan was moving no air at all. I knew what the problem was, but I couldn't decide how to explain it to the owner. So, I went to the owner of the shop.

"You're getting a build-up of Perchloroethylene vapor in your shop and you are going to have to increase the ventilation or enclose the process."

"But that can't be, I've got that great big fan! I just put it in about six months ago. The fan's going all the time and it's working like a charm."

"Well, do you think it's pushing air out?"

"It must be pushing out a lot of air," he said.

"If it's pushing out vast quantities of air, where is the air coming from?"

"What do you mean,'where is the air coming from'? It doesn't have to come from anywhere."

"Oh yes it does!"

"It's coming from the shop."

"OK, how does it get into the shop?"

"Well, it's already in the shop."

"Look, have you ever tried to suck a thick milk shake up in a straw? You suck and you suck, and you never get a drop of milk shake in your mouth. Right?"

"Sure..."

"Your mouth was producing a suction, but the milk shake was so thick that it wasn't moving up the straw into your mouth. In other words, you were establishing a negative pressure in the straw but you were getting no flow at all. That's exactly what your fan's doing. Your fan is establishing a slight negative pressure within the building, but it can't do any more than that. It can't move a cubic foot of air unless that air can come from somewhere in response to the slight negative pressure that the fan is building up."

"Oh, yes. We've got a place where the air is coming from. Sure. It comes into the building from above the doors at the front of the shop. You know, it gets hot in here and we like to have fresh air come in through the transom in the front. That's where it's coming from."

"OK, let's go take a look at it."

So we went up to the front. I'm sure you've seen double doors that have a transom about a foot and a half high, and maybe six or seven feet wide. Now, the size of that opening should allow a fair amount of air to come through with that big fan in back. Not nearly what that fan could handle, but at least it would be supplying some air. We went up to look at it. Well, this transom is also where they put their air conditioners. So, that's where the air comes from! Good idea, except this happened to be the month of May. In November it had been cold outside, and they had placed a piece of Celotex across that particular transom so that the cold air could not enter. Yes, there was the fan back there running, but the fan can do nothing unless the air is coming from somewhere.

Another disadvantage when using dilution ventilation to control fumes is that vast quantities of air are required. For example, if you are working with something that has a threshold limit value of 1 ppm and you generate only one cubic foot of vapor per minute, you will have to dilute that cubic foot of vapor with one million cubic feet of air. That air will have to be air conditioned, or heated, depending upon the outside temperature. It will have to be tempered to meet the indoor criteria for temperature and humidity, whatever they happen to be in that location. So you can see immediately that it is impossible, or nearly impossible, or certainly unfeasible to use dilution ventilation to control vapors with very, very low TLV's. Unless you are talking about something that has a TLV of four or five hundred ppm (which cuts you down to possibly 2,000 cubic feet of air per cubic foot of vapor generated) dilution ventilation is not feasible. Beyond that, the economic cost becomes highly unreasonable. We usually don't consider using dilution ventilation for anything other than something like mild steel welding, or solvent vapor with a TLV of around four or five hundred ppm because the amount of air required for dilution becomes fantastic. You are going to have dilution air circulating all over the shop. It's going to cost you money.

The last type of ventilation which is used for control of atmospheric contaminants is so-called local exhaust ventilation. This type of ventilation has a higher initial cost and is more difficult to design; but the overall cost, considering tempering of make up air, installation cost, and yearly operating costs, is vastly superior to the other types. It is more amenable to the true job of protecting the man, of controlling the concentration of any particular contaminant, and of controlling in it a relatively small volume of air. With local ventilation, this is more readily accomplished - and more accurately, too. The basic idea behind local exhaust ventilation is to control at the source. The objective is to move in as close to the particular operation as possible and to capture the air contaminant when it is contained in a relatively small volume of air. A good example of this is welding fume again. The welding fume is generated in an arc which may well be one quarter of an inch in diameter with an arc length of three eighths of an inch. The iron is vaporized in the arc; and, in the air surrounding that arc, the iron is oxidized to iron oxide. As you can see, the fume is generated in a small volume of air. A large amount of fume is generated in that small volume. Because it is hot (well over three thousand degrees) the air has a tendency to expand and rise and carry with it the iron oxide fume. This is the reason you see the characteristic brownish plume rising from a welding operation. Now consider this. If you can capture those two or three cubic feet, containing all of the welding fume, you have to exhaust only two or three cubic feet of air to totally control the fume. Compare this with the 2,000 cubic feet per minute per welder which is required for dilution ventilation. You are never going to get the exhaust volume down to two or three cubic feet. You can't get that close to the arc. Even if you did, the air velocity would have a tendency to destabilize the arc. But, if you can do it in 10 cubic feet, and move it to the outside or to a filtering unit, you have accomplished a lot. When all the welding fume is concentrated in a few cubic feet, your make up air is only a few cubic feet. You don't have to supply nearly as much make up air.

Local exhaust can also be used on tanks. In the case of a solvent cleaning tank, you can put a slot about an inch wide across the back edge of the tank. Connect that slot to an exhaust duct. Establish a velocity of 2,000 feet per minute in that slot. The total volume of air which you will need will be related to the surface area of the solvent in the tank. Usually, it will be 100-150 cubic feet per minute per square foot of tank surface. Now, you'll have a high concentration of solvent in the duct because you are collecting all of the vapor close to the source, collecting it when it has diffused into a relatively small amount of air. The concentration in the duct will be high, but the concentration around the man - that's our main interest - the man - the concentration around the man will be minimal. That's what we're trying to do. Get minimal exposure of the man.

Now, lest you think that make up air is a problem only with the small shops, let me assure you that this is one of the most common problems in all industry. You will seldom see an industrial plant which does not have a negative pressure inside the buildings. This is primarily because there is a provision made for some of the equipment; provision for bringing in make up air to replace what the fan is pulling out. This air will be heated or cooled, depending on what is required at the particular time of the year, and it will be brought in at known amounts equal to what you propose to take out of the building. The drawback to this is that when they start building a plant, they install enough make up air units to equal the amount of air being exhausted by the local exhaust or dilution ventilation. But, unfortunately, there was never an industrial building built which did not have changes long before the first worker entered the plant. Once they start working, they are constantly adding new machinery. Machinery that requires ventilation. But they do not think about make up air. As a result, a negative pressure is produced. You can tell this yourself the next time you visit a shop. Go to one of the doors. The door should open outward. As you try to open the door, notice how hard it is to open. If the door swings open very easily, there is very little negative pressure in the building. But if considerable force is required to pull that door open, be a little suspicious of negative pressure within the building. Look down at the bottom of the door. Can you see where leaves and so forth have been blown back as air was drawn through the crack under the door? Are leaves, cigaret butts and bits of paper being blown away from the door on the inside? This indicates that there is a strong air flow through the crack at the bottom of the door. This is another good indication that you have negative pressure. If you have any negative pressure in the building, all of your ventilation fans will be reduced in their ability to remove air, because any fan works against a negative pressure in order to move a known volume of air. If you increase that negative pressure, you reduce the amount of air that's drawn from the building or drawn by any exhaust fan from any particular operation.

I once was invited to see "our new automated pouring line." I knew the man very well. He was a pretty good design engineer, so I thought that I would like to see this "automated pouring line."

It was a beautiful layout. The sand molds were filled and placed on a roller conveyor which moved them to the pouring line equipped with an effective side hood. The poured castings then passed into a cooling tunnel with ventilation provided by fans at both ends of the tunnel. It moved from the tunnel directly into a shake-out tunnel where the castings were shaken on a vibrating grid and the waste sand fell through to be conveyed back into the process. The two boxes of the mold went straight on down the roller conveyor and back around the automated line. The hot parts themselves were hooked off the roller conveyor by a worker. It was a beautiful design. When they started their first pouring, my friend ran around and flipped a half dozen switches. The fans started up, and everything worked beautifully - for about two minutes.

Then every door in the foundry popped open. The doors I am talking about are retained with a bullet catch that looks something like a large ball bearing with a spring behind it. These are usually built into the overhead doors that allow trucks to come in. But the negative pressure inside that building was high enough to pop those doors open. They all stood open about four or five inches.

This operation produced some other rather queer effects in the foundry. There was another cooling tunnel which relied on thermal head; that is, the actual heat of the gases rising from some very large castings on another line. After the automated pouring was started, the air was coming <u>down</u> that stack, blowing across the large castings, and blowing smoke and fume out into the open casting area. This was bad enough. The core oven, which was around the corner from the automated pouring line, was baking cores. It, too, relied on thermal head. When they started that automatic pouring line, the fumes were coming <u>down</u> the oven stack and out into the core room. Unfortunately, one of the breakdown products of the drying oils used in core-making is acrolein, which is extremely irritating to the eyes. It didn't take long for them to decide that they were going to have to shut down that automated pouring line. This is another example of failure to provide make up air. When that automated pouring line was operating, there was a negative pressure increase sufficient to overcome, not just thermal head, but even the thrust of some propeller type fans in the ceiling. The clean air could be seen coming down against the push of the fan blades. Any time you have a negative pressure inside a building, you are reducing the volume of air which any type of fan is drawing from that particular building. All fans operate by establishing static pressure across the inlet and the outlet. That static pressure is limited. If you increase the difference in static pressure across that fan, you will immediately cut down the output of the fan. There is no way of getting around that.

To summarize, the most expensive type of ventilation to install, but certainly not the most expensive to operate, is local exhaust ventilation. It requires a smaller fan, a smaller volume of air, and a smaller use of horsepower on a yearly basis because you are handling two, three, four, five hundred cubic feet of air per minute. The second most feasible, from our point of view (and a very poor second), would be dilution ventilation. Here, your contaminant must have a relatively low toxicity (a high TLV), or you have trouble. Dilution ventilation requires vast amounts of make up air. True dilution is difficult to obtain.

Natural ventilation is highly variable and is the very poorest type of ventilation in any type of building.

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