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 # 11

Industrial Hygiene Considerations In Plant Location and Design

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Sick employees and aroused neighbors are a poor complement to a successfully designed and located industrial plant

The chemical engineer is aware of his responsibilities in the design of a manufacturing plant and its equipment, along with the selection of plant location, for errors in judgment may be costly. He must make no departure from engineering principles that are soundly conceived and executed. Consequently, he consults with his associates in chemical research and in pilot plant operation to benefit from their experience. Plant capacity is discussed with the sales department and problems in personnel and operation are reviewed with production people. Other interested groups also gather about his conference table so that his final blueprint is a result of careful planning, down to the handling and flow of materials in the most economical manner.

The industrial hygienist has now become a member of this planning team. He provides the chemical engineer with an understanding of the working environment that may result within the plant when the chemical process is begun. From a study of the process he also provides an evaluation of how good a neighbor the plant will be in the community where it is to be located.

More precisely, the industrial hygienist sees that operation of the new plant will not result in employee ill health, through exposure of workmen to chemical mists and vapors or to harmful gases or dusts. He tries to make certain that the new plant will not cause unfortunate community relations because of air or stream pollution. The industrial hygienist discusses the toxicology of the various chemicals, the raw materials, intermediates, products, and by-products, and interprets the extent and nature of any health hazard in their handling and use. It is then frequently possible to plan for the control of both plant and community environment where it may be needed, and make this control a definite part of the chemical engineer's blueprint. The important consideration is that this control be applied in advance of plant construction and operation.

Chemical Plant Location

Included in the many factors that determine the ultimate location of a chemical plant are those pertaining to maintenance of employee and community good health. One factor is that of climate. Sudden changes in temperature, of course, will freeze pipes and burst valves unless planned for in advance. Sudden temperature changes also may lead to a higher incidence of respiratory illness among plant operators. Exposure of man is just as important as exposure of equipment. In colder climates, the chemical engineer can plan this process so that workmen do not frequently need to leave and reenter a warm workroom in order to carry out their duties. Such duties may be to operate valves or pumps or take measurements at tanks or collect samples, to bring in raw materials, or remove products. Workmen often will not trouble to put on a cap and a heavy coat each time they must leave a warm building.

A warmer climate offers less of this type of exposure, but thinking in terms of workmen should extend to protection against high wind, driving rain and snow, excessive heat, and freezing cold. The high temperatures, perhaps as high as 120° F., and excessive radiant energy that occur at furnace-tending or kiln-firing can be lessened by the use of reflecting baffles at operating points. Air-conditioned control rooms and ventilated steam line tunnels improve working conditions and lead to smooth production.

The location of a plant in a warm climate also may offer certain disadvantages. The increased volatility of solvents, for instance, may constitute a potential health hazard of some magnitude. While toxic concentrations might be safely circumvented by local exhaust ventilation, the daily handling of solvents in a warm climate poses a problem of an elusive chance exposure to vapor level concentrations that might not exist except for the fact that the average temperature is higher. Occasional spills, leaks, flushing of kettles, open filter presses, open drains, sumps, and so on may be sources of solvent vapor. These vapor sources may cause atmospheric concentrations of that low order of magnitude which consistently plague industrial hygienists for satisfactory answers as to their physiological significance.

Complementing the conditions cited above is the personal element involved in such exposure. Warmer climates mean less clothing and therefore more body surface exposure to industrial materials. This means enhanced opportunity for skin contact with irritant solids, liquids, and gases. Coupled with this are the factors of excessive workroom temperatures and the greater discomfort in wearing protective respiratory equipment and clothing.

Once the working conditions with respect to climate have been resolved, there are other factors which might play a part in the successful operation of a plant. These include prevailing wind movement, terrain and adjacency to woods, mountains, farmland, streams, residential areas, and other industry. In considering plant location, we move then from the problems within the plant to those outside the plant.

The matter of prevailing wind move-

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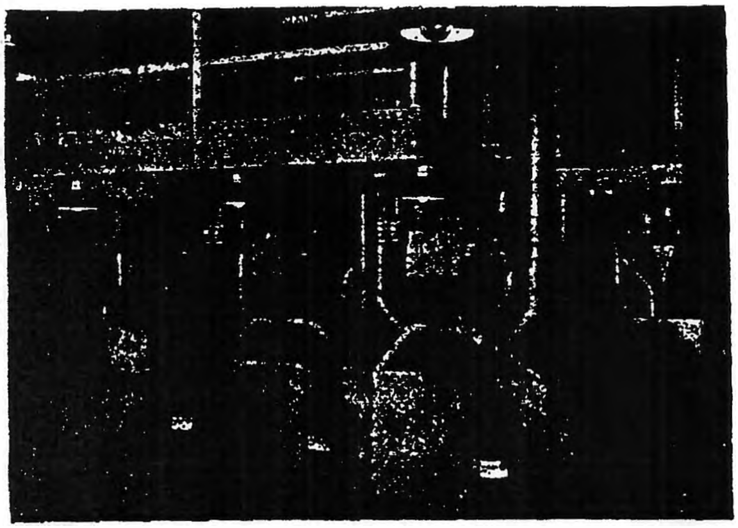

Exhaust ventilation and process hood enclosures installed as a part of the process appearing on the original engineering blueprint

ment is of prime consideration in air pollution. Prevailing wind, with respect to the plant, should not be in the direction of nearby residential areas or other industry if possible. Neither should the plant be located in the direction of uncontrolled or excessive "airfluent" from other industries, if, by inquiry or through chemical tests, it is revealed that the wind carries airborne material of an undesirable nature.

A proposed plant location should be carefully surveyed and evaluated for existing air pollution, preferably with the aid of studies involving physical and chemical tests. The industrial hygienist knows that any future investigation and control will eventually fall upon his shoulders.

At Donora, Pa., it was observed that a mountainous area can be conducive toward formation of a weather condition known as inversion. When this condition prevails, any discharged gases and fine dusts may stay near the plant site without normal dilution or dispersion. Moreover, any plant located in a valley is limited as to stack height and may discharge gases on a level with residential areas located on the hillside. Discharged air contaminants have been known to follow the course of valleys downwind for several miles, damaging plant life.

The matter of terrain may be important if sloping terrain drains toward residential areas. While this consideration delves into the sphere of stream pollution experts, the industrial hygienist is well aware of these problems and watches lest his activity contribute to stream pollution.

For example, at one location, two settling basins were established to hold liquid wastes. One contained acid wastes and the other a sulfur compound. If these wastes were combined, H_2S gas would be formed in heavy concentration at about the center of the plant site. These two settling basins were therefore discharged by separate flumes and at different times to the same stream a short distance away. However, when this stream became stagnant, the two effluent substances united and a blanket of H_2S rose up and drifted through a residential area. This usually occurred at night, and the annoying odor of gas awakened the inhabitants.

Control of such situations can be planned in advance. The potentially injurious effects of airborne chemical substances to those handicapped by respiratory illnesses make such planning mandatory. What may be only a nuisance to healthy people may be serious to patients in a hospital.

It is, of course, assumed that adequate water supplies are available. If, however, the supply is from a stream or river, the advice of stream pollution experts may affect water treatment costs. If the waste discharge of the plant is into the same stream, then limnological surveys should be conducted, both before and after plant location, as a basis for avoiding litigation.

"Airfluent" from a plant situated near woodland might be damaging to trees. It is also conceivable that over a long period of time there might be sufficient deposition of solid flammable material to constitute a fire hazard. Plant location with respect to farmland and residential areas is important because of potential odor nuisance or chemical damage to buildings, crops and foliage, or livestock eating contaminated foliage.

When location of a plant site is being chosen, neighboring plant processes should be considered, for possible mixing of two or more airborne materials might produce undesirable odors or visible fume. A review of some simple chemical reactions should serve to indicate what possible combinations would produce such fume.

Hydrochloric acid and ammonia constitute an example. At a certain plant it is reported that these two gases would come together, forming an ammonium chloride fog that would form a dense blanket and carry down wind about the plant site and over into adjoining property. On another day, it would form at another spot, depending upon wind direction. It was not until a number of chemical reactions had been checked and process vent stacks examined that the two offending stacks were located. Hydrochloric acid was escaping one, and ammonia the other. Although 100 feet apart, occasionally the two gases would escape at the same time when wind direction was just right to carry the discharged gas from one stack directly across that from the other stack. A similar situation may occur when waste acid is discharged to a stream containing traces of ammonia.

Chemical Process Design

While industrial hygienists find many points of interest in the problems of chemical plant location, they can, perhaps, make their greatest contribution by applying themselves to preventive measures that will maintain industrial workers' health. In this activity they seek to prevent the exposure of people to the raw materials, intermediates, final products, or by-products of the chemical industry that may be toxic. Preventive measures can apply effectively in chemical and related industries, because it is here that a great variety of chemical substances are handled by workmen.

A number of the newer substances coming from the research laboratories of the chemical industry, particularly the organic chemicals, are found to exhibit some degree of toxicity to human beings. The industrial hygienist seeks to examine these chemicals through toxicological investigation to learn more precisely the potentiality of each chemical for causing illness. This field of industrial toxicology differs from the pharmacology of clinical toxicology and chemotherapy and from criminal toxicology, in that animal exposure studies are undertaken to simulate closely the opportunity for worker exposure in industry. The information derived from industrial toxicological studies gives the industrial hygienist data on several types of exposure so that he may organize, evaluate, and interpret this information for industrial management, chemical engineering groups, and plant operating personnel in terms of a safe working environment.

For the chemical engineer, this interpretation must be in practical and understandable terms. It must answer questions such as: "May contact with the skin be permitted, and, if not, what protection must be taken to avoid it? Is the inhalation of dust or vapors of this substance harmful, and what effect will it have on workmen? Can certain amounts of these chemicals be permitted in the form of dusts, mists, or vapors in the atmosphere of chemical plants and can they be tolerated by workmen?" The answers to these and similar questions must tell the chemical engineer exactly how to use and handle toxic substances safely.

When the industrial hygienist and the chemical engineer sit down together and review plans for a new chemical process, there is a real opportunity for the precal engineer may [illegible] to design and install equipment needed in various chemical reactions handling several materials and resulting in a final product. This process equipment must be housed in a suitably designed plant. What, then, is the interest of the industrial hygienist in the design of production equipment?"

Hygienist Explains Hazards

The industrial hygienist must discuss the nature of the raw materials and how raw material *A* must be handled with care to avoid the inhaling of dusts, and how chemical *B* must likewise be handled cautiously, perhaps in a closed system so that vapors or gases given off will not form a contaminant in the workroom atmosphere. These factors must be carefully pointed out and the reasons given as to the nature and extent of hazard, so that a practical and economical solution can be attained. Between them, the planners may decide to install a ventilated hood enclosure at the manhole of a reaction kettle. The engineer can see that his design would otherwise be inoperable because it might be directly responsible for the illness of workmen, unless the exhaust ventilation is installed before the process is begun

In the handling of compound *B*, it may be decided to pump the material to a storage tank, then to a weigh scale, and then to the reaction vessel rather than to require men to pour the material into pails, carry it up ladders and dump it by hand, where they may be exposed to irritant vapors or to skin contact from a splash or spill.

Next, it may be necessary to run the reaction product through a filter press. From the nature of the reaction, the industrial hygienist can inform the design engineer that men who open the press to remove the filter cake will be exposed to solids or gases that may be harmful. Between them, they notice that no ventilation enclosure has been provided for this filter press and so this provision may now be added to the blueprints.

Let us follow the process a step farther. We may find open centrifuges, open whizzers, or open settling tubs. Information can be provided as to what the working environment will be like near this type of equipment, so that control measures, if needed, again can be applied to the blueprint before process installation.

Reading Blueprints

The industrial hygienist sees a line on a blueprint pointing upward and ending in an arrow. This line is labelled "vent." Looking further, he comes across a line pointing downward ending in an arrow which is labeled "to the sewer." The question immediately arises as to what reaction products are discharged into the atmosphere or what waste products are discharged to the sewer.

There is, at this point, a chance to project the chemical process design into [illegible] it is determined that the gases, mists, or vapors discharged into the air from the reaction will result in an air pollution problem, then the design of some means of control, such as condensing or scrubbing, will need to be added to the blueprint. The treatment of waste products by neutralization or reaction to form an inert substance may be necessary in some cases and a sketch of this treatment, too, may be added to the blueprint as a phase of preliminary prevention

It must be borne in mind that the industrial hygienist is only one member of a planning team and does not begin to know all the answers. Other members of the team include those from research groups, product development, safety, production, and sales groups.

Machines Must Fit the Man

Considerable thought is being given today to the design of industrial machines. This trend involves a study of human anatomy and the related subjects of fatigue and health, so that machines may be designed to fit the man who is to operate them. The same is true in the chemical and related industries. Process equipment can be designed to fit the operating staff who, after all, have quite a responsibility in the success of any production. Sufficient space between the equipment units has been mentioned Available headroom and the introduction of stairways rather than vertical ladders has been a contribution of safety groups The location of sampling points is important, for it is difficult to take a sample of a liquid if the valve is located two feet above the man's head In the case of certain liquids, it would be unfortunate if any were spilled on the skin or splashed into the eye.

Then too, it should never be necessary to lie down on the floor underneath a reaction vessel in order to obtain a sample. Attention to such a detail as the technique of taking a sample when hazardous chemicals are involved becomes an item of considerable importance to the man who is engaged in sampling. Here again, preventive engineering through forethought may prevent a bad burn, a skin rash, or the loss of an eye. Provision for vacuum sampling, through a closed system, frequently can be a matter of original design. Neither is it necessary to open a large kettle manhole and dip out a sample using a flask on the end of a long stick. This method of sampling would not be wise if toxic vapors escaped the kettle manhole during sampling.

The design and location of piping may result in discomfort unless the demands on the operator in the plant are kept in mind. Pipe location may result in tripping injury or head injury or may provide an obstruction which must be crawled under or climbed over several times a day in the course of an operator's duties. The location of valves at convenient levels is also important. These are but a few of the items that extend thinking beyond the factor of industry's employees [illegible] picture

An example of one difficulty may serve as an illustration A rosin melter was needed in a plant and one was obtained and located according to blueprint on the first floor of a building It seemed to be convenient to locate a chute from the second floor down into the melter, so that the rosin drums might be opened and the rosin dumped into a crusher and run down into the melter.

It turned out, however, that dumping and crushing rosin was a dusty operation and a considerable nuisance to the "operator." Of course, when the melter was heated, the vapors came up through the chute and crusher and into the building, contributing to an already disagreeable situation. There was absolutely nothing wrong with the design of the melter, the chute, and the crusher. The foundation was solid and the superstructures were well supported, but the operating nuisance might have been prevented

Convenient Housekeeping

Another item of design that is helpful to plant operating personnel is providing for convenient housekeeping The sloping of floors for flushing, the provision of drains in the right places, a piped vacuum cleaning system, and the location of equipment with proper clearances add much to the ease of housekeeping.

I have only touched on the ways the industrial hygienist may help the chemical engineer. The examples given are only indicative of the innumerable problems that may arise. Basically, the contributions that industrial hygienists may make to the chemical and related industries in the matter of plant location and design are twofold: providing correction for existing unsatisfactory environmental situations, and preventing such occurrance in the future

While the industrial hygienist must be familiar with the problems of plant location and design, his greatest responsibility is to incorporate his special knowledge of health hazards with the considerations of efficient and economic production. There was a time when American industry showed too little concern for the physical well-being of working men. However, for at least the last 20 years, management has become increasingly aware of its obligation to protect health and provide good working conditions for its employees Millions of dollars have been and are currently being spent in this human investment Management also realizes that this consideration for its employees' health and for good working conditions, along with being an unobtrusive member of a local community as far as air and stream pollution are concerned, has paid off in the additional benefits of better employee relations and general good will.

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