THE LAY-OUT OF INDUSTRIAL BUILDINGS.

PAPER

THE ESSENTIAL PRINCIPLES OF THE LAY-OUT OF INDUSTRIAL BUILDINGS AND EQUIPMENT.


Foreword: Complete descriptions of the lay-out and equipment of industrial plants frequently appear in papers before technical societies and in the technical press. But there is absent from these accounts any complete analysis of the many interrelated factors which enter into the evolution of an efficient design. Among these are questions such as the selection of the site, the lay-out, the relation between departments, the class of building, its architecture, also the paramount consideration of the economy of fuel, power, and internal transport, and the effect upon the design of the advent of new materials and scientific control of processes. Many of these factors are in conflict, and great judgment must be exercised in attempting to reconcile them. The present paper briefly discusses the various elements, and outlines the principles of their effective combination. Being an extensive subject, the survey must be confined to major questions only.

I.—CHOICE OF SITE.

In a former address* the writer outlined, inter alia, the chief factors entering into the selection of sites for large industries in Europe and America:

"Apart from the paramount question of national defence, the chief determining factor is the purpose for which each manufacture is to be undertaken—whether it is to be for local consumption, or, if not, what proportion is to be for export. Then the final location is one of endeavouring to obviate unnecessary transport by placing manufactures near the source of raw materials—for example, the steel works should be near the mines or seaports. The problem is further complicated by the various raw materials required for an industry lying in various places remote from each other; here it is common to transport the less bulky to the source of the more voluminous—the ore to the coal, for instance, although a proportion of the lighter material may be back-loaded to the source of the heavier, and factories may be established at both places. . . . Factories for the export of heavy goods are located near the seaports, main canals, or else on the international trunk lines of communication. All these innovations require the migration of the industrial community and the building of new cities, complete with all their services."

In the course of history, industries have often sprung up in localities not the most suitable for them, because some gifted

family happened to reside there, and started from small begin-
nings. Also, through the efflux of time, local circumstances
favourable to an industry may slowly alter, and thus require
the migration of the industry. Such is the history of two great
Victorian firms, one in Castlemaine and the other formerly in
Wangaratta, but both now centred in Melbourne.

Obviously the smaller industries cannot require the migration
of labour; they must locate themselves near to sources of supply
of suitably trained operatives, who are usually found in large
cities, where there have been long established industries of the
same kind.

Industries where the ratio of labour to other charges is high
should be near abundant supplies of labour: e.g., textile, clothing,
and shoe factories.

On the other hand, such factories as brickworks, cement works,
liime kilns, etc., must be adjacent to the quarries. Again, where
the products are of small value for a given weight, like cement
and especially bricks, it is particularly important to choose a
site near the market for their products, or at least near to a
convenient port, as in the case of cement.

Such industries as are accompanied with obnoxious fumes
should be away from the city, and preferably on the leeward side
in relation to the prevailing wind.

Climate is less important now than formerly, except in indus-
tries where the operatives are directly exposed to the weather;
for, the conditioning of air within buildings can now be cheaply
carried out.

Proximity to roads, railways, wharves; availability of power,
gas, water; also facility for disposal of trade wastes and sewage
—all these are important factors. Their relative importance
depends upon the industry concerned; for example, values of
fuel and power, expressed as a fraction of value of production,
very greatly between one industry and another. Competitive
alternative modes of transport are desirable. In large industries
it is important to have railway side tracks running into the
works, and if possible with separate loading and unloading bays.
Plentiful supply of water is essential to certain industries, such
as paper mills, tanneries, and chemical works.

Although proximity to a metropolis is advantageous for the
ready supply of labour, disposal of products and availability of
supplies, yet a factory right within a city has to carry heavy
fixed charges on its land. Although this may be set off by an
annual increment in land value, that is not a consideration
pertinent to the industry itself. It is generally necessary to
build such factories with many storeys in order to secure an
adequate return on the land investment. But such a lay-out
may not improve the efficiency of operation. The class of
industry determines the class of building, and necessarily the choice of site is determined by the lay-out appropriate to that industry, where it is important to provide convenient routing of the product.

The relative merits of horizontal and vertical planning are important in connection with the selection of a site.

The choice of site may greatly affect the class of building construction, and hence its cost; for a building remote from other structures does not require the same fire protection.

Topography.—The natural form of the ground may greatly affect the choice of site. In many industries it is advantageous to have a slow grade, about six inches per hundred feet, in the direction that the product is advancing. For instance, such a grade reduces the services of a shunting engine in the handling of railway trucks. But advantage is taken of sloping ground chiefly in the chemical industries, such as ore refining, tanneries, etc., where it is often convenient to terrace the side of a hill so as to enable the fluids to flow by gravity from vat to vat in succession. This avoids a multiplicity of pumps, which may have to propel corrosive liquids. The recent advent of special corrosion resistant pumps, however, has rendered this of less importance. Disused quarries may be adapted to special purposes, such as reservoirs for cooling water, dumps for waste products, or else the slope of the sides may be terraced and utilised as aforementioned.

As an illustration of the use of sloping ground, Fig. 1 shows a cross section of an open-hearth steel works where full advantage has been taken of the natural features. The coal is dropped out of the trucks into the concrete storage bin, whence it is lifted by the grab, transported and dropped into the bunkers above the gas producers. The coal may also be stored on the adjacent land to the left. The scrap yard is on the same level as the charging stage of the open-hearth furnace; hence it is unnecessary to lift the charging boxes, which are simply picked up by the charging machine and directly charged into the furnace. In addition to this, the depth of excavation for the regenerators beneath the furnace is greatly reduced. This diagram was prepared to illustrate a number of points that will be considered later in the paper.

Geology.—The choice of site is greatly affected by the character of the foundations. The nature of the works may be such that it is desired to construct large subterranean conduits or basements; and neither soft silt nor igneous rock is easily amenable to such treatment: for the former requires expensive shoring and perhaps coffer-dams and airlocks, while the latter also is very expensive to excavate. It is often better in either case to
elevate the entire plant or the portion of it concerned; otherwise a site with better ground may have to be sought.

In soft foundations, in spite of high first costs, it is better to elevate the firebrick settings of all furnaces, ovens and boilers, and set them on rigid steel floors, so constructed that settlement of supports cannot produce differential movement in the settings, with consequent cracking and by-passing of gases. These supports should be elevated so that moisture from the sodden ground cannot creep up into the settings and destroy them or hamper their efficiency.

Silt.—With heavy loadings, the added cost of foundations in silt may determine the choice of another site on superior ground. For example, with the moderate average loading of 520 lb. per square foot, a structure covering an area of 170 feet by 50 feet required 146 timber piles, each of 70 feet driven length. The piling alone cost £3102, equal to 7/3 per square foot. Allowing for additional costs for concreting the pile-heads, it may be assumed that, if it had been possible to erect the structure on firm ground, it would have saved ten shillings per square foot. In other words, other things being equal, the justifiable additional expenditure on *terra firma* in order to avoid such foundations would be £60 per foot of city frontage of 120 feet depth. The loadings on buildings of many storeys are far greater than that given above; and the saving by erection on good ground is greater in proportion.

If it is decided finally to erect the works on silt, then the relative merits of raft and pile foundations must be canvassed. Raft foundations, unless the loading is practically constant, require to be very rigidly constructed. The load per square foot should be as uniform as possible, so as to reduce the flexural tendency of the raft, which should be designed to sustain the maximum bending moment to be imposed on it. If possible, the floor and walls should be built integral, and the walls may with advantage be reinforced diagonally, as in the design for earthquake areas. Even this rigid structure may slowly heel over owing to differential settlement; for, although the loading may be uniform, the ground itself may not be uniform in supporting power. If possible, a bore survey should be made over the site, followed by loaded test piles. If bedrock or a stiff layer of clay is found sufficiently near the surface, the works may be carried on piles, otherwise a raft must be constructed. Where there is a thin layer of clay, say 30 feet beneath the surface, but of insufficient thickness to support a common pile, the Macarthur concrete pile may give satisfactory results.* This pile is like

an inverted mushroom formed *in situ*, which spreads the load over a large area of the clay. Even piled structures suffer from differential movements if the pile toes are not in firm ground. During the rebricking of elevated retort settings continual movement was noted, both downward and upward, although they were supported by piles.

In corrosive and shifting soil it is often advisable to put all pipes and cables overhead, unless circumstances favour the construction of well-drained conduits.

*Room for Extensions.*—In selecting a site, it is necessary to consider the value of the land, the amount of clearing and initial preparation, the necessary space for buildings, stores, and yards, and finally what room is available for extensions.

*Co-operation Between Neighbouring Factories.*—Before leaving the subject of the selection of a site for a works, the writer wishes to emphasise the importance of the collaboration of different industries for their common good by utilising each other's surplus of power or heat. This was outlined by the writer in a former address.*

"Wherever two or more factories in the same neighbourhood find that the interconnection of their electric generators, or of their steam mains, would improve the total load-factor, they proceed to make a careful estimate of the economies that would ensue. If these are sufficiently promising, simple contracts are drawn up between the parties, who agree to give and take power or steam as required. A more steady load is thus secured on the boilers and generators of the more efficient plants, and it is possible to cease running the least efficient for part or whole of the time. Sometimes it is producer gas, water gas, or coke-oven gas that is so distributed; or it may be found that a factory with a large boiler equipment furnishing steam for its heating process can, by interposing a back-pressure turbine, supply power to a neighbouring machine shop. . . . It is generally found that while one factory requires much steam, another requires much power; and the most economical way to satisfy both these wants is for the one to take the steam exhausted from the back-pressure engines or turbines which supply power to the other. The economies of this procedure were fully demonstrated in a former address;† where it was shown that the supply of heat to industry requires the consumption of many times the amount of fuel consumed purely for power generation."

Where there is a probability of reasonable continuity of prosperous business in any group of industries located side by side, the possibilities of such co-operation should be thoroughly explored.

*"Industrial Reciprocity in the Supply of Power and Heat,"* Presidential Address, Proceedings, V.I.E., March, 1931.

As a corollary to this, when selecting a site for a works, the manufacturer should bear in mind that he may be able to enter into such arrangements with his projected neighbours for their mutual benefit. This is not academic; it is already being done in Australia.

II.—PLANNING THE LAY-OUT.

First, flow sheets should be prepared showing diagrammatically the sequence of operations and the inter-relation of departments. From this, more comprehensive plans should be drawn, showing the sizes of the various machines and the raw products in course of manufacture. It is most convenient at this stage to prepare cut-outs in card of the various buildings, machines, and items of plant, and move them around on the proposed plan of the site to assist in arriving at the best arrangement.

It is usual to separate the inflammable processes of an industry from the rest, the wood-working from the metal, for instance, by housing them in separate buildings. At least they should be separated by adequate fire screens. In such industries as oil refineries and explosive works, the various departments are separated by large distances. Paint works should be similarly subdivided.

The works administrative offices and testing laboratories should be centrally placed, but in a quiet spot.

The size of the repair shop and the amount of its equipment depend upon the class of industry and the accessibility of adequately equipped outside firms. The repair shop and works store should be close together, and as central as possible.

The advantages of buildings with many storeys here come in for consideration. Many industries require a three dimensional lay-out, such as flour mills, sugar refineries, breweries, distilleries, and chemical works. The shortening of internal transport, the use of gravitational flow, and the conservation of heat losses, all dictate this form of plan. In preparing a lay-out for such industries, it is useful to construct a rough scale-model, particularly when dealing with entirely new processes. It prevents oversights and mistakes that may have to be rectified subsequently upon the job itself. This applies especially to sloping conveyors and large skew ducts.

Provision must be made for sufficient stand-by plant, especially in the power and heat generating departments. Also, adequate storage capacity must be provided for fuel, raw materials and general stores, the amount in each case depending upon the class of industry, its location, the frequency of delivery, also the desirable reserves to be carried as dictated by market fluctuations and industrial troubles.
The plant must not be cramped; adequate thoroughfares must be provided. Room for extension in each department must here be taken into consideration. The lay-out should be of such form that the leaving of room for extensions does not seriously interfere with the present working efficiency. It is easy for textile mills to extend by repetition on a floor above. In this case, ample allowance must be made in foundations and columns, also room for additional lifts, stairs, fire escapes, etc. The weaving department, however, prefers to extend horizontally, for it requires daylight via a saw-tooth roof. But in three-dimensional factories extension is not so easy; it must be made horizontally, repeating the same vertical disposition of plant.

The form of building and the number of storeys depend upon the class of industry, also upon the foundation strength and value of the land. Generally the heavier industries are housed in one-storeyed buildings, although it is common to house portions on an upper floor. Fig. 2 shows a foundry where the pattern shop and light core work are situated on mezzanine floors. Similarly the lighter machine tools of a machine shop may be housed on the upper floors, while the heavy tools are installed in the side bays of the ground floor, the central bay being reserved almost entirely for erection. Each bay may be served by its own travelling crane. Exceptional circumstances may warrant the construction of a building of many storeys to house a heavy industry; such a case is the locomotive works of the Baldwin Locomotive Company, which has five floors.

High roofs are necessary where much hot air and gases have to be dissipated. For this and other reasons the form of roof over the open-hearth furnace shown in Fig. 1 is preferred to a double-gable construction. The fumes are readily dissipated through the open dormer. Also, ashes and dust deposited on the roof are more easily washed away by the rain; and choked spouting cannot cause the discharge of rain water into the building. The overhanging roof of the open dormer prevents driving rain from entering the building.

For single-storey buildings the saw-tooth roof gives the most natural lighting. Although unsightly when viewed from the side, it is particularly applicable to factories situated between adjoining buildings which would preclude the use of windows in the side walls. There is no difficulty in building the centre bay higher than the outer bays, as indicated in Fig. 3, so as to accommodate a travelling crane.

Chimneys.—The number and position of the chimneys may involve many conflicting considerations. The flues between the furnaces and stacks should be as short as possible, in order to conserve the draught. But other factors may prevent this;
and then, if possible, a fan should be installed. For example, in Fig. 1, after passing through the waste heat boiler, the waste gas from the furnace is propelled by the fan beneath and across the scrap yard to the main flue, which discharges the gas, with that of the other furnaces, to a common chimney. A stack placed nearer to the furnace would interfere either with the gantry in the scrap yard or with that above the charging platform. Were there no waste heat boiler, the stack would have to be placed very near to the furnace to conserve the draught, for the temperature, 1240° F., of the flue gas would preclude the use of a fan. Otherwise the flues would require to have very large cross-section, and the stack would have to be very high in order to maintain adequate draught. If the stacks, one per furnace, were placed alongside the furnace regenerators, they would get in the way of the overhead gantry charging machine: a charging machine, running on the charging platform, would then be required—a practice that is not universally desirable. Sometimes the stack is placed between the scrap yard and the charging platform; in this case two rows of columns become necessary, one for the gantry of the scrap yard, and the other row for that of the charging machine; this is expensive, and it embarrasses the transfer of scrap.

Chimneys serve for the dual purpose of creating a draught and of removing the waste gases to the higher atmosphere. If the gases are obnoxious, as in some chemical works where waste fumes are discharged up the chimney, the height must be sufficient to secure adequate diffusion. But the majority of chimneys need to be only high enough to produce the draught. The draught fan has reduced this height, so that, for example, the top of the stacks of a modern central power station are only a few feet above the peak of the roof. Moreover, the fan renders the draught independent of the weather—a very important advantage in the running of furnace settings.

III.—Construction of the Building.

The materials selected depend upon the proximity to other structures and on the materials available. Structures erected in city streets must follow conventional lines. But those built in large grounds have greater latitude, and the steel work is often left exposed. Of course, the most fireproof buildings are those of reinforced concrete, and concrete cased steel structures having concrete floors and brick or concrete walls.

The so-called “slow burning mill” construction in timber is more fire resistant than is exposed steelwork. Fig. 4 shows this type of construction, which should be more often used in factories of timber—instead of the conventional floor of many timber beams, notched in or supported by steel hangers, and
stiffened by light wooden “bridging.” In mill construction all beams and girders are of large dimensions, and should be dressed all over and have the edges chamfered to prevent them from easily taking fire. The beams rest on top of the timber girders, and they sustain a heavy plank floor. The upper columns rest on metal pintles (not shown in Fig. 4), which stand on the tops of the lower columns, and are protected from the fire by the beams within which they are concealed. The cost is not greatly in excess of that for common timber construction; but the behaviour during a fire is far superior.

The great majority of industrial buildings, when erected away from adjacent buildings, are steel-framed structures, diagonally braced if necessary. The walls between the columns may be filled with 4½-inch brick screens, thin screens of concrete, or they may be entirely of corrugated iron. Corrugated sheets and shingles of asbestos cement for roofing are growing in importance on account of their superior durability and heat insulation as compared with that of corrugated iron. Roofing of the former material subjected to the fumes of acid sulphate of ammonia has shown no deterioration during the thirty years of its service; it is still in service.

For buildings to carry heavy vibrating machinery, such as large printing presses, reinforced concrete is the most appropriate material. Such machinery should be laid on flexible rubber pads, and should be bolted down with rubber clearances all around the bolts and nuts.

When designing the roof principals, it should be remembered that they are liable to be required subsequently to support
telepthers, shafting, small motors, and occasionally heavy loads when slinging portions of the plant.

The deep girders supporting the floor beams should be run across the building rather than along it, for this facilitates the passage of light into the building, and improves the ventilation. Also, the girders furnish good supports for shafting suspended on short hangers.

Many items of chemical plant are erected in the open, and the structures, platforms, and weather protection may be integral with the plant.*

**Welding Construction.**—The judicious use of electric welding in structural design, if handled by competent persons, can save from 20 to 30% of the cost of the structure. But, in order to ensure safety, and at the same time to effect all the economies of which welding is capable, the designer must have an intimate practical experience of the design, fabrication, and erection of welded structures, which few possess. And it is advisable that he should have a thorough knowledge of the higher theory of the strength of materials. Many precautions must be observed, and the structure must be very closely inspected during all stages of construction.

Very rigid structures can be made by welding; for all joints can be rendered quite stiff. This involves important problems in secondary stresses that cannot be safely ignored. Nevertheless, there can be a considerable reduction in dead-load, particularly in long-span conveyor structures.

The safety of welded structures under impactive loading was fully tested in Melbourne by the construction of a 30 inch-ton impact testing machine. This was used to test full size welds under impactive tension and tearing. The results were entirely reassuring. Consequently there need be no hesitation in the use of welding for the construction of cranes and similar structures subject to suddenly applied loads. Also the fatigue behaviour of the weld is now well understood, and can be provided for. But the distortion of members by the weld will always be a problem, especially in plate work; and it is necessary to have considerable experience of the behaviour due to shrinkage, of the design of jigs to prevent distortion, and of the use of pre-distortion, in order to carry out major welding operations with complete satisfaction. Great savings can be made by welding, but there is great risk of failure, or of unforeseen expense, if handled by inexperienced persons.

*"How a Manufacturing Plant was Evolved from a Chemical Formula." Paper by R. J. Bennie and H. E. Grove, Proceedings, V I.E , November, 1930.
IV.—Ventilating and Air Conditioning.

The amount of ventilating required depends upon the processes concerned, the quantity of heat, dust or noxious fumes evolved, and the number of operatives present in a given space. Noxious fumes and, as far as possible, dust should be removed by exhaust fans, with cowls directly over the plants producing them. In foundries and forges ventilation is accomplished by natural convection; to achieve this a high roof is necessary, with ample outlets at the peak, such as by a louvred dormer. Also, where the building is standing apart, it is possible to have large openings in the side walls. Suction vents in the roof, although very effective when the wind is blowing, do not assist ventilation in still weather.

Though not so important as in Canada or Middle Europe, it is economical in the winter to warm certain of our factories here. The temperature required depends upon the amount of exercise involved in the operations, the number of operatives present in a given space, and the heat, if any, given out by radiation from the plant. Each operative normally gives out about 500 B.Th.U’s. per hour, and artificial illumination contributes its share; each 200 watt lamp yields 682 B.Th.U’s. per hour. It is too often forgotten that practically all of the power absorbed by machinery is converted to heat; every horse power generates 2593 B.Th.U’s. of heat hourly. This is an important consideration when designing the ventilation of cramped spaces housing heavy machinery, such as the press room of a large newspaper office.

In addition to furnishing adequate temperature, some degree of motion should be given to the air; for this stimulates the nervous system, it is more healthy, and induces greater output by the operatives.

One of the cheapest methods of heating, especially in factories having exhaust steam available, is by hanging suspension heaters eight or ten feet from the floor. These are simply compact grids of steam piping, gilled perhaps, behind which a small ventilating fan operates. In front of the pipes, louvres are placed to deflect the warm air downward. Where live steam is to be used, a small steam turbine operates the fan and discharges the steam into the grid of piping, where it is condensed by the air from the fan. The same device, where electric fan operated, can be used for cooling if cold brine is circulated through the pipes. For this purpose more piping is usually required in the grid.

In the spinning and weaving departments of textile mills the correct humidity is as important as the temperature of the air. Indeed, it is always more healthy to condition the air rather than merely to warm it. Here it is generally necessary to install
a complete air-conditioning plant, where the air is scrubbed of its dust by water sprays or oily filters, and then warmed and humidified. In special cases, as in the coating of photographic emulsions, it may be necessary even to precipitate electrostatically the very finest dust particles which may have escaped the air-washing plant. This procedure is common in central power stations, also in smelters, where arsenical or other poisonous or valuable solid material in the flue gases is prevented from polluting the surrounding country. Electrostatic precipitators are also capable of removing many of the obnoxious odours from such industries as tanneries and other chemical works. Such smells are usually contained in small fluid vesicles of size 0.5 to 0.1 micron, which float about in the air.

Cooling and Refrigeration.—In warm climates it may be necessary to cool the air in the building, either for general comfort or to maintain the optimum temperature for the process. In confectionery factories, for example, it is necessary quickly to cool the individual sweets in order to maintain desirable characteristics, also to expedite the manufacture. Here, too, the use of appropriate insulation is a primary consideration. The air may be cooled merely by scrubbing with chilled water in the air-conditioning plant, provided the temperature required is above 34° F.; otherwise brine or ammonia coils are necessary.

Regarding the generation of cold, the conventional steam or motor driven compression refrigerator is usual. But important savings can often be made by cooling with exhaust steam, the heat of which is sufficient to actuate an ammonia absorption refrigerator. In this plant ammonia is evaporated from a concentrated solution at 150 lbs. pressure; it is then cooled and liquified, passed through an expansion valve, where some of it boils, and its temperature drops. The ammonia vapour is then reabsorbed in cooled weak liquor from the boiler, and the concentrated liquor is finally pumped back to the boiler to complete the cycle of operations. This is a very economical mode of producing cold in works where waste heat or exhaust steam is available.

V.—Illumination.

It is generally conceded that the most effective illumination for weaving sheds is daylight, and it is usual to lay out these factories with a single storey, or at least with the weaving room on the top floor. The roof is universally of saw-tooth construction. The advent of “daylight” lamps and other sources of filtered light may modify this in the future.

In other industries natural light is less important, and it must be remembered that even daylight must be paid for: there are
large glass surfaces to maintain and clean, additional fuel is required for space heating due to the leakage of heat from the building through the glass, and perhaps great additional cost of a single-storey factory spread over an extensive area of land may have to be incurred.

In buildings with low ceilings, the natural illumination in the centre is less than that near the windows; here it is necessary to install prismatic glass in the upper panes to throw the light inward, and to supplement the illumination of the inner bays with artificial light. On walls exposed to the summer sun it is advisable to use special glass, opaque to radiant heat.

The illumination via the walls may be easily secured by using glass bricks, which may fill the whole space between the columns from floor to ceiling. But it is not advisable to carry these right down to the floor, for light beneath the eye tends only to create glare.

In general, the object to be attained is bright illumination of the work with softer lighting of the background and the rest of the room. Shadows should be soft, and specular reflection from polished surfaces should be suppressed by the use of frosted globes and diffusing shades. To avoid fatigue, it should be unnecessary for the pupils to be continually readjusting themselves for different brilliancies. All naked filaments should be so shaded that they are invisible even from the corner of the eye.

The colour of interior walls, principals, and machinery is receiving more attention now than formerly; for it is recognised that appropriate colour in the surroundings greatly influences fatigue and output. Pure white walls, although they reflect most light, are depressing, and soon show discolouration. A slight tint to warm this up will be beneficial; and a dado up to the eye level slightly darker than the walls tends to lessen glare. The painting of columns, roof principals, and cranes with bright colours at no extra cost makes the factory more cheerful; similarly, all machine tools and other machinery may profitably be painted with bright colours of light hue. If machinery is clean from the start, it is more likely to be kept clean, and experience has shown that the painting of machinery in bright colours leads to a general improvement in maintenance. Of course, surfaces exposed to coal dust, tar, spillage and the like cannot be treated in this manner.

VI.—Fire Prevention and Protection.

Prevention.—The best way to prevent fires is to avoid having large quantities of inflammable materials exposed at one time. They should as far as possible be kept in airtight metal bins; and all scrap should be removed as soon as made. Wood shav-
ings and saw dust should be drawn out by an exhaust air system, to be deposited in a cyclone separator. Ample gangways should be provided for the removal of heavier scrap, which meanwhile should be thrown into bins.

These matters greatly affect the design of the works. For example, inflammable materials should be housed in buildings divided by frequent fireproof partitions, just as explosives are housed in small quantities in separate dumps; also, such coal as is liable to spontaneous combustion is best stored less than twelve feet deep, and should be handled by a grab, which is capable of quickly digging out the inflamed portions.

Protection.—The use of slow-burning timber construction has already been referred to as being more difficult to inflame and slower to burn. It will be noticed, also, that sprinklers can protect much more effectively this type of construction than the common timber floor. This will be clear from an examination of Fig. 4.

When distilling inflammable liquids, the heating medium should, if possible, be steam, or hot water at boiler pressure. If the cost is not considered excessive, a fluid like diphenyl, or diphenyl oxide, may be used. Diphenyl oxide has a melting point of 81°F., and a boiling point 496°F., and throughout its working range it is an extremely mobile liquid. In consequence of its high boiling point, it can be safely used as a heating agent without inducing a pressure in the pipes greater than the atmosphere. Saturated steam at this temperature would exert 595 lbs. gauge pressure. Of course, the furnace containing the heating drum for the diphenyl oxide must be sufficiently remote from the place where it is used, and special insulation must be applied to the pipes to conserve the heat at such high temperatures. Apropos, the writer has found that if tar-treatment tanks are heated by hot gases carried in insulated metal cased ducts from a furnace separated from the plant, reasonable security from fire is attained at small cost.

The works should be piped with adequate fire mains, and be equipped with foam mains, pumps, and portable extinguishers, according to the class of industry. Sprinklers should be on other mains than hydrants, and should be separately controlled, and the control valves of sprinklers and hydrants should be in readily accessible places. In works not situated near adequate city mains, sufficient reserves of water should be stored in high tanks either on towers or on top of the building. But, in the latter case, the supports should be thoroughly protected: this is too often neglected. If the works are situated beside a river, a large cooling pond, or other reservoir, adequate pumps should be installed, and these should be driven by some source of power not likely to be interfered with should
a fire occur. The pumping plant should be supplemented by a large storage tank placed on an independent tower. There is a strategy in the lay-out of fire-fighting equipment, and when planning a works it is well to consult the fire underwriters and the fire brigade.

VII.—ARCHITECTURE.

The amount of consideration and expense to be devoted to architectural treatment depends upon the class of industry and the locality in which the factory is to be placed. Apart from fulfilling civic ideals, architectural treatment involves appraisal of the sales promotional value and the psychological effect upon the employees.

The architectural treatment of common mill buildings is not difficult, and need not entail great expenditure. Factories built within the city must conform to conventional standards. The main principle is to secure some unity of design by preserving simple proportions between the parts, and by binding them together with continuous vertical or horizontal bands. In factories having the plant arranged in three dimensions, such as central power stations, sugar refineries, breweries, flour mills, etc., an effective treatment is to use flat roofs or parapets to conceal their moderate sloping roofs, and the facade may be stepped back where the coal bunkers bestride the boiler house. Thus the form of the building is synthesised from a series of rectangular blocks. Another treatment of the problem is rather to accentuate the roof, and use steep gables, which may be stepped. Often the architectural appearance may be greatly enhanced by choosing an alternative position for an overhead tank or bin, so as to preserve the balance of masses.

Where the factory is subdivided into a number of buildings, an attempt should be made to secure harmony of grouping and of style. Nothing is more depressing than an ill-disposed litter of sheds, clad with sheet iron, accompanying a central office built like a suburban hotel. There is no reason why a plant should be positively ugly. Untidy appearance symbolises inharmonious internal arrangement, and suggests possible inefficient operation due to lack of foresight: It is a bad advertisement.

Nevertheless, it is often difficult effectively to clothe the plant of a chemical works without shattering the Lamp of Truth, for the building must then conceal the functions which it normally should symbolise. But that is no reason why the plant should be left stark:

"When what to oblivion better were resigned
Is hung on high to poison half mankind."

Even a structure covered with corrugated iron may have pleasing proportions.
The engineer should endeavour in every way to co-operate with the architect in attaining a common object—an efficient plant housed in a handsome building.

VIII.—The Supply of Power and Heat.

Combined Supply.—The supply of power and heat is a problem with many aspects. In most small works, and in factories of any size that require very little heat, the use of power from the public supply is unquestionably most economical. Even in large works, consuming both power and heat, it is economical to obtain portion of the power from outside sources when the power load is very variable. The problem merits special investigation in each instance; for great savings may often be secured. The writer reviewed this question in a former address.*

Wherever it is possible to utilise in the processes of the factory most of the steam exhausting from back-pressure engines or turbines, or steam bled from mixed-pressure turbines, it is economical so to do, and generate all the required power within the works. Occasionally it is economical even to generate surplus power for export. Again, wherever it is possible cheaply to raise steam from the waste heat of furnaces, it is economical to generate power from the waste heat for use on the works, and even to export the surplus. For example, one of the larger London gas works generates from waste heat 94% of the steam used on the works. Of course, this procedure is most effective when there is reasonable synchronism of the demand for power and for process steam in the first case, and synchronism of the supply of waste heat and the demand for power or steam in the second case. But, in the first case, any deficit of process steam can be supplied by bleeding live steam into the process steam main; and in the second case, a steam accumulator is suggested, or the waste heat boiler may be occasionally fired by an auxiliary furnace.

When the instantaneous demand for steam for process work fluctuates, or differs greatly from that for power, it may be economical to discharge the steam from the engines or turbines at relatively high back pressure to a Ruth steam accumulator, where it may be stored in water until required. Admittedly the thermodynamic efficiency of the power generation is low, but where all the heat discharged from the engines is subsequently used in the processes of the factory the thermodynamic efficiency of the heat engines is of no consequence whatever. Ruth steam accumulators are also used for storing live steam where the supply and demand do not synchronise; for example, in con-

The Lay-out of Industrial Buildings.

When designing a factory for a heat consuming process, all the possibilities of utilising waste heat and exhaust steam should be thoroughly explored. Many alternative propositions usually require consideration. Heat balance sheets and flow diagrams should be prepared, showing all the possible alternatives, from which the most suitable project may be chosen.

Example from the Gas Industry.—In this connection the gas industry affords a particularly interesting illustration, for here both classes of economy are applicable, namely, recovery of waste heat in the boilers of the retort house and water-gas plant, and the use of the exhaust steam in the chemical processes of the works. The manufacture of gas has already been outlined by the writer in a former address.* The features relevant to the present discussion are as follow:—Coal is carbonised in retorts which are externally heated by producer gas made from coke or breeze. The coal gives up its gases, and the residual coke is usually steamed for some time before it is discharged. The steaming produces a small quantity of water gas, and helps to cool the coke by utilising some of its sensible heat. The hot, burnt producer gases, passing out of the combustion flues, flow through a recuperator, where they transfer portion of their heat to the incoming secondary air. They then pass through the waste heat boiler, and finally exhaust to the stack. In the water-gas plant coke is air blown to incandescence, and the producer gas so generated is consumed with additional air in heating the carburettor and the waste heat boiler. After appropriate operations of the valves, the incandescent coke bed is steamed, and the water gas so generated is carburetted with oil and passes into the works gas stream. Live steam from the boilers is required to operate the exhaust fan on the waste heat boiler of the retort house, the air blower and auxiliaries in the water-gas plant, the exhausters that propel the gas on its journey through the works, for electric power generation, and lastly, maybe, for operating an intense cooling plant to dehydrate the gas. Steam supplied at 10 to 15 lbs. gauge pressure is suitable for all other purposes, namely, to steam the grates of the retort house producers, to steam the retorts, to steam the water-gas generators, to operate the ammonia recovery plant, to refine the benzol, and lastly, if required, to operate an ammonia absorption refrigeration plant for the dehydration of the gas. This process steam may be supplied wholly or in part by the exhaust from the engines, turbines and steam pumps. Of the many possible alternatives, the

appended table shows a thoroughly workable arrangement whereby all the steam required on the works is generated from waste heat. How far it is feasible to gather and utilise all the exhaust steam from the auxiliaries depends upon the compact arrangement of the plan and the foresight of the designer. The utilisation of the sensible heat of the gas from the retorts or the water-gas generator is complicated by the deposition of tar. Its use is not indicated in the table. Nevertheless, in Germany it is occasionally recovered, about 15 B.Th.U. per cubic foot of gas.

The relevant portions of a gas making plant utilising waste heat and process steam are shown in Figure 5. In this diagram the waste heat boiler, high up in the retort house, furnishes live steam for the engines driving the exhauster and the electric generator, and the exhaust steam is shown as supplying the needs of the retort house producers, the retorts, ammonia stills and the intense cooling plant (absorption-ammonia refrigerator) of the gas dehydrating plant.
THE LAY-OUT OF INDUSTRIAL BUILDINGS.

ECONOMY OF HEAT IN INDUSTRY—UTILISATION OF WASTE HEAT AND BACK-PRESSURE STEAM.

Illustrative Example Chosen from the Manufacture of Town Gas.

Bases of Table—Coal is carbonised in continuous vertical retorts, and one-half of the available coke is converted to water-gas. Steam is generated in waste-heat boilers, and is used for driving the engines and turbines. The back-pressure steam from the engines and turbines is utilised in the various processes of manufacture.

Steam Generated and Utilised Expressed per Ton of Coal Carbonised per Hour.

<table>
<thead>
<tr>
<th>Live Steam</th>
<th>Process Steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generated</td>
<td>Consumed</td>
</tr>
<tr>
<td>Retort House—15,700 c.ft. of 503 B.Th.Us. per c.ft.—</td>
<td></td>
</tr>
<tr>
<td>Waste-Heat Boilers</td>
<td>1410</td>
</tr>
<tr>
<td>Exhaust Fan of Waste-Heat Boilers</td>
<td>71</td>
</tr>
<tr>
<td>Steaming the Retorts</td>
<td></td>
</tr>
<tr>
<td>Steaming the Producer Fires</td>
<td></td>
</tr>
<tr>
<td>Ammonia Recovery: 24 lb. per 1000 c.ft.</td>
<td></td>
</tr>
<tr>
<td>Carburetted Water Gas—16,600 c.ft. of 503 B.Th.Us. per c.ft.—</td>
<td></td>
</tr>
<tr>
<td>Waste Heat Boilers</td>
<td>991</td>
</tr>
<tr>
<td>Steaming the Gas Generators</td>
<td></td>
</tr>
<tr>
<td>Air Blowers—19.2 lb. per 1000 c.ft.</td>
<td>318</td>
</tr>
<tr>
<td>Auxiliaries—7.37 lb. per 1000 c.ft.</td>
<td>122</td>
</tr>
<tr>
<td>Power Raising and Processing—On 32,300 c.ft. of Mixed Gas—</td>
<td></td>
</tr>
<tr>
<td>Exhausters—0.2 k.w. per 1000 c.ft. (back-pressure turbo-compressor consuming 50 lb. per k.w.h.)</td>
<td>323</td>
</tr>
<tr>
<td>Electric Power Generation—One k.w. per 1000 c.ft. (a very liberal allowance; seldom exceeds 0.6 k.w.). Condensing turbine at 21 lb. k.w.h.</td>
<td></td>
</tr>
<tr>
<td>Dehydration of Gas by Intense Cooling—Refrigerating Machine and Pumps—(0.4 k.w. per 1000 c.ft. and back-pressure engines at 50 lbs. per k.w.h.)</td>
<td>646</td>
</tr>
</tbody>
</table>

The Table shows how all the power and steam required on the works may be generated from waste heat. The extent to which the above economies may be made depends upon the lay-out of the works and the constancy of the loads. But Birks ("Trans. Inst. Mech. Eng.," v. 127, p. 30) shows how in a similar works 94% of the steam is generated from waste-heat boilers.

The data of the above were chosen from English and American authorities, and were fully discussed by the author in a thesis recently presented to the University of Melbourne, entitled "A Survey of the Economy of Steam in the Manufacture of Gas."
The Boiler House.—The position of the boiler house should be chosen with care. It is generally preferred in a central position, so as to conserve heat losses from the steam piping, and it should be as near as possible to the prime movers. The need for short pipe runs may be overstressed, however, for it is common in oil refineries to have steam pipe runs of as much as half a mile in length.

If solid fuel is being used, the boiler house may well be on the street frontage, so as to avoid traffic of coal wagons within the works or the expense and congestion of conveying plant. This is important, on small works particularly. When liquid fuel is consumed, however, the boilers can be placed anywhere most convenient; and the oil can be piped to them, while the fuel tanks can be placed elsewhere. Liquid fuel gives opportunities for greater elasticity of plan; variation of load is also more easily met by the semi-automatic control of the burners.

The use of hand or automatic stoking is a question dependent on the size of the works and the duties of the boiler attendant. Automatic stokers give greater efficiency, and they are now obtainable in very small sizes. The installation of special grates to consume waste products, such as bagasse, sawdust, and scrap, requires attention where applicable. Similarly, in localities having cheap inferior fuels, the use of these should not be overlooked. Some of them are best converted to producer gas, and then consumed in the boilers.

In factories within the city, where space is extremely valuable, a compact boiler room is very important. Provided a high-steam storage capacity is not required, a modern high capacity boiler may prove sufficiently compact. In one of these boilers the heat transfer rate is increased many times by compression of the air before its combustion by a turbo-compressor to about 20 lbs. gauge. It is then admitted to the combustion chamber, where fuel oil is sprayed in or compressed town gas is admitted and consumed. After passing around the evaporator tubes and across those of the superheater, the waste gases enter a gas turbine coupled to the turbo-compressor, and expand down to atmospheric pressure again, thus returning some of the energy spent in compression. In large units there is even a surplus of energy from the gas turbine. The waste gases finally pass through a feed heater. Under the high pressure in the combustion chamber, and with the high velocities of 450 to 900 feet per second, the hot gases very rapidly transfer their heat to the heating surfaces, which are streamlined both to reduce friction and to accelerate the rate of heat transfer. The velocity of the water in the tubes is about ten times the rate of evaporation. This is secured by a centrifugal pump, which circulates
the water between the tubes of the evaporator and a steam separating chamber. In this manner evaporation at over 100 lbs. per hour per square foot of evaporator heating surface is achieved, and over 20 lbs. per square foot of total heating surface. Special governing devices are incorporated for maintaining water level, and the quantity and proportion of fuel and air. The efficiency of this plant, anywhere above one-fourth full load, is over 90%. It can be put into full operation from cold in five minutes; and its performance will rise from one-half load to the full load demand, or reduce from full load to half full load demand in less than ten seconds. This type of boiler is so compact that a complete plant for generating 55,000 lbs. of steam per hour requires a space of less than 18 feet square by 25 feet high.

This is 6.8 lbs. of evaporation per cubic foot of necessary boiler room space, leaving room for withdrawal of tubes for inspection and repair. It is claimed that the high velocity of the water in the tubes of these boilers prevents deposition of scale.

A more modest departure from standard practice is found in another class of boiler specially suitable for confined spaces, and generally consuming liquid or gaseous fuel. This is a fire-tube boiler, with small tubes 50 diameters long, through which the hot gases are drawn at high velocity, about 300 feet per second, by a draught fan exerting a suction of as much as four inches water gauge. These boilers evaporate about 18 lbs. of water per hour per square foot of tube heating surface with a nett efficiency of 80 to 85% without economisers. They are very compact. About 6 lbs. of water are evaporated per hour per cubic foot of necessary boiler room space if gas or oil fired. They are particularly suitable for use with gas and for waste heat boilers.

Waste Heat Boilers.—The thermal efficiency of all fuel consuming furnaces necessarily is low because the difference of temperature between entrance and exit is very limited; the outgoing gases must be hotter than the product. Much saving can be made by the use of recuperators or regenerators, yet great heat resources are still available for steam raising. The temperature of the waste gas leaving the regenerators of an open-hearth furnace or large glass tank is about 1240° F., while that of the flue gas leaving a retort house recuperator is at least 950° F. Approximately 30% of the heat of the coal passes out of the regenerators or recuperators, and at least 25% of the heat of the fuel can be converted into steam. This is a considerable quantity; for a 75 ton open-hearth furnace consumes 2½ tons of coal per hour in its producer, and the waste heat boiler could therefore generate about 17,000 lbs. of steam per hour. Some authorities would even claim that 33% of the
heat of the coal could be recovered. Similarly, a modern continuous vertical retort house, making 2½ million cubic feet of gas per day, will generate in its waste heat boiler about 6000 lbs. of steam hourly; and, operating continuously through the year, it will save the consumption of 2160 tons of coal beneath a fuel-fired boiler. Consequently, the waste heat boiler will be completely amortised in less than three years.

The use of waste heat boilers did not meet with success until the principles of their operation were fully grasped. In a fuel-fired boiler the proportion of the heat absorbed is about 65% by radiation and 35% by convection and conduction; but in the waste heat boiler, owing to the low radiation coefficient of the cooler gases, only 62% is absorbed by radiation, and the remaining 38% must be recovered by convection and conduction, and even then at a much lower temperature difference between gas and water. When it was understood that gases transmitted their heat at a greatly enhanced rate when travelling at high velocities through small tubes, the waste heat boiler could at last be designed to operate as a compact and efficient plant. The fan at the outlet of the boiler induces a velocity high enough to secure this rapid transfer of heat, and at the same time greatly reduce the deposition of dust. The fan, in addition, renders the draught on the furnace or retort setting independent of the weather, to which experience has shown that it is particularly susceptible. There should always be a by-pass flue, so that the boiler may be cleaned and inspected without interfering with the operation of the furnace.

The aforementioned estimated savings incurred by the use of waste heat boilers are based upon an efficiency of 75%; but an efficiency as high as 90% has been obtained with this class of boiler. The writer has closely observed a set of these in operation during the last ten years. Their performance was satisfactory in every way.

Care should be taken lest the temperature of the waste gases should be cooled below the dewpoint of the sulphuric acid vapour present. This temperature depends upon the amount of sulphur present in the coal. It is usually about 400°F. Brown coal briquettes possess less than half the proportion of sulphur, so there is little probability of the acid depositing in the tubes of the boiler or economiser above 300°F. say. In waste heat boilers operating on exhaust gases from internal combustion engines, as before, the minimum permissible temperature is dependent on the sulphur content of the fuel. Probably the dewpoint is far lower than 300°F.

The Engine Room.—As far as possible, all power generators, engines, pumps, compressors, and hydraulic pumps should be grouped together in the engine room, under the skilled super-
vision of the engine-room staff, and away from dust and dirt. Of course, minor circulating pumps must be placed on their respective circuits, and cannot be brought into the engine room; but where possible they should be grouped in subsidiary pump rooms for their better protection. Where exhaust steam is utilised in the processes of the factory, turbines are preferred to steam engines as prime-movers, because there is less contamination of the steam by oil.

Internal Combustion Engines.—The use of gas engines and other internal combustion engines in factories has not in the past received the attention it merits. It is interesting to note, however, that the gas industry abroad is now successfully installing in factories gas engines fitted with waste heat boilers for supplying steam or hot water. A similar use of Diesels in larger works is a field meriting further exploitation; for although their thermal efficiency may be 35 to 40 %, 25% of the fuel's heat is carried away in the jacket water, and upwards of twice this amount in the exhaust gases. Most of this is recoverable where some of the jacket water may be used as feed water for the boiler. This is not to be confused with the Still engine, where the waste heat boiler was used to supply steam to a steam engine built integral with the oil engine. Our purpose is to indicate the use of the heat for process purposes. About 2½ lbs. of steam can be raised per brake horse-power hour. The writer has already referred to the recovery and utilisation of waste heat from Diesels in connection with the municipal power plant at Mecklenburg-Schwerin.* The boiler need not oppose an undue back-pressure on the engine. Many waste heat boilers are operating in retort houses on natural draught; but a fan is useful because it renders the design of the boiler more compact, and greatly increases the attainable efficiency. In some cases it is beneficial to exhaust the engine into a well-insulated brick-lined vessel, so as to reduce the pulsations in the flow of the gases through the boiler tubes.

Gas Producers.—Wherever great quantities of heat are continuously required, such as in open-hearth steel works, glass works, potteries, etc., producer gas is the best form of fuel on account of its cheapness and the ease of its conveyance and control. When a higher calorific value than 150 B.Th.U.’s. is required, a water-gas plant may be installed. This operates automatically, and provides gas of quality 300 B.Th.U.’s., or up to 550 B.Th.U.’s. if carburetted with oil. The writer briefly described this type of generator in a previous address.†

As far as possible, the producers should be located in groups, in order to effect better supervision and to simplify the fuel-handling plant. Also, they should be located so as to minimise internal fuel traffic. But, since the pipes conveying the gas must be large, and because about 12% of the heat of the fuel is contained in the sensible heat of the gas, it is extremely important to place the producers as near as possible to the furnaces where the gas is to be used. Where the gas is scrubbed with water, however, to remove the dust which might contaminate the product, as for refined glassware, etc., it is not so important to place the producers near the furnaces.

Most fuels operate satisfactorily on simple stationary grates. For example, most gasworks retorts are heated by producer gas made in rectangular chambers built in the setting, and having simple stationary grates. By this means, also, the loss of sensible heat is minimised, for there are no external flues. Similarly, brown coal briquettes operate perfectly on simple grates. Of course, the correct use of steam beneath the grate will reduce clinker troubles; but with black coal or coke, where it is desired to avoid hand clinking, with its fluctuation in producer performance, the mechanical grate is necessary.

For open-hearth furnaces, glass tanks, etc., most of the dust must be removed from the gas. This is done by passing it into a chamber, where its velocity is reduced and its direction is reversed suddenly. There are many designs based on this principle. The dust trap and all the gas mains must be brick lined and well insulated if it is desired to conserve the sensible heat. They should be fitted with doors at frequent intervals for removing the dust. This is accomplished preferably by vacuum cleaning equipment, for it is considered undesirable to send men into ducts which may contain pockets of noxious gases; also, the pipes may be cleaned while still too hot for a man to enter. Some of these cleaning doors should be designed as explosion doors. An idea of the size of these gas mains may be formed from the practice of allowing about eleven square feet of cross section per ton of fuel consumed per hour. When it is desirable to clean the gas, its sensible heat is sacrificed in the washing plant unless the gas is first passed through a waste heat boiler. After passing through the washers, where the gas is scrubbed with water, and preferably through an electrostatic precipitator, the gas is clean enough for use in gas engines and for heating furnaces for making the highest quality of glass or enamels.

**Furnaces, Ovens, and Muffles.—** Although producer gas is favoured for continuously operated furnaces, the use of oil or tar is very economical for firing intermittent ovens such as those
for annealing steel castings. Liquid fuel is economical for furnaces where circumstances do not favour the construction of producers. In all cases the use of regenerators or recuperators greatly reduces the fuel bill, but care must be taken to preserve an even pressure in the furnace to prevent leakage of the gases or the ingress of cold air. One of the advantages of the use of a waste heat boiler, as shown in Fig 1, is that the draught can be controlled by the fan and its damper, so that the furnace pressure can be maintained neutral. Devices are used in the retort house which are capable of maintaining the desired pressure in the retorts with an accuracy of one-fiftieth inch of water gauge. These can be applied equally well to furnace pressure control.

With producer gas the use of a recuperator or regenerator is essential to economy. In the annealing furnace the temperature difference between the hot gases and the castings must be as small as possible, for it is important not to overheat the surfaces or thin portions of the castings. Consequently, to secure rapid heat transfer to the metal, it is necessary to have a rapid swirling motion of the gases in the furnace. This connotes a large volume of gas entering the furnace at a temperature only slightly greater than the annealing temperature; and this gas must leave the furnace with only slight reduction in temperature, so that it must carry away most of the heat that had entered. The regenerator will recover much of this, and will act as a heat store between heats. Moreover, in order to prevent burning the castings, the atmosphere in the furnace should be slightly reducing. The writer suggests, therefore, that, instead of diluting the atmosphere with air to keep the flame temperature sufficiently low, some of the flue gases from the regenerator outlet might be induced into the burner air stream.

For heat treatment furnaces, which require extremely critical temperature control, thermostatically operated town gas burners are pre-eminent. And with gas the oxidising or reducing atmosphere in the furnace is capable of more accurate maintenance. Accordingly, gas is extensively used for such purposes, and where it is desired to secure a special patina or surface finish on metallic articles or enamels.

For ovens in small factories, for baking lacquers and for similar purposes, thermostatted-controlled gas is a very convenient heating agent. In larger works, however, it is economical to heat the ovens by steam coils, or, better still, by circulating the hot water from the boiler and returning it thereto.

IX.—ECONOMY OF WATER.

In planning a works for a chemical process, great savings in the annual water bill can be effected by paying due attention to
the conservation of water. The cold water entering the works may be used for cooling purposes in gas or vapour condensers and in the jackets of internal combustion engines. Some of it may then be used for feed water, thus recovering some of the waste heat, or it may be used in those washing processes where the warmth of the water does not matter or may be of some advantage. Only when it is polluted may it be discharged from the works, but in large works it is often economical to recover many of the polluting constituents, such as lanoline in wool scouring, or ammonia, oils, and sometimes cyanides from gas-works wastes.

The economical use of water in factories is likely to become more important in Australia than in other countries owing to the dearth of water. The use of cooling towers and the careful planning for the repeated use of the same water should be more frequently studied; and if it becomes polluted merely by fine solids in suspension, it may be refiltered cheaply in a compact sand filter, and may be used again, only a small fraction being lost in periodically flushing out the filter.

X.—Conveying, Elevating, and Transporting Materials.

Here again the principle should be applied, as far as consistent with other factors, of laying out the equipment so that the transporting machinery will perform multiple functions. In retort houses it is common for the coal and coke to be handled by the same chain of buckets. Often coal and ashes may be so handled, but corrosive ashes are best handled by separate means. In steel works it is common for the one travelling crane to handle scrap both for the furnace and the mixer.

Little can be said under the heading of mechanical handling without entering into undue detail, but it may be pointed out that continuous conveyors are generally more economical in first cost and total power consumed than are grab transporters. The latter should be reserved for handling large materials, such as uncrushed coal and ores; but here the best arrangement generally is the use of grabs for loading on to rubber belt conveyors. It must be remembered that the grab exercises a series of very heavy loads of short duration, so that, for a small total power output, the power system requires to be very large.

Sequence Controls.—Where material is transported on a succession of conveyors, provision should be made of an automatic sequence control, whereby it is rendered impossible to start any conveyor until all the conveyors following it or machines directly fed by the conveyors are in operation, and so that if any machine or conveyor in the sequence stopped through any cause, all the conveyors and feeding devices prece-
ing it would be automatically brought to rest. This is necessary to prevent congestion. For example, a push-plate conveyor delivering coal to the bunkers may stop through a fault in the motor, a broken chain or blown fuse. If the elevator and coal crusher preceding it are not immediately stopped, congestion will occur at the point where the elevator delivers to the push-plate conveyor, and will probably cause damage to the conveyors.

When designing the transporting equipment, piping, conduits, etc., it is necessary to ensure that repairs and alterations to portions do not cause interference with the remainder. All pipes and cables should be routed, so that each can be taken down without interference with the rest, and all connections of pipes and cables to machines should be located so that minor repairs or complete replacement of the machines would involve the least dislocation of pipes and cables. Once again it is necessary to advise the construction of scale models at least of those portions of the plant where complicated connections of piping and conduits are inevitable.

All pipes, conduits, valves, and switches should be easily identified by appropriate labels, so as to avoid confusion and mistakes in operation liable to occur especially by new employees unfamiliar with the lay-out. The use of different colours of paints on pipes for each kind of service is helpful in this connection.

XI.—POWER TRANSMISSION WITHIN THE FACTORY.

Only the broad lines of this extensive subject can be touched on here. The use of electric power in small motors, one per machine, or one per small group of machines, is growing in favour; for, notwithstanding the high first cost, the energy is used economically, and great elasticity is possible in the choice of lay-out of the machines. Nevertheless, it is too often forgotten that common belting, with shafting running on ball or roller bearings, is far cheaper in first cost, and it is even more mechanically efficient; also, sudden overload or mechanical obstruction merely causes belt slip. In some recent single-storey machine shops the shafting has been sunk in large conduits, and the belting is brought through openings in the floor near the driving pulleys of the machines. This avoids the tangle of overhead belting, and the shafting can readily be supervised by attendants in the conduits. The use of multiple Vee belting, and especially the use of motors mounted on pivoted supports so as to maintain the correct tension, also the advent of reliable compact friction clutches and speed-changing mechanisms, have given greater scope for the use of belt-drive.
The motors, switch gear, etc., as far as possible should be grouped into a few standard types and sizes, so that a small stock of spares may be sufficient.

In dust-laden atmospheres totally enclosed motors and switch gear should be used. The same precaution should be taken in places where the air is liable to contamination of corrosive or inflammable gases, or explosive powders such as flour or coal dust.

Measures for Safety.—Due attention to safety may at times considerably influence the plan of lay-out; for the machinery should be so disposed as to minimise liability to accident. In addition all machinery should be equipped with safety guards and appropriately-placed power cut-outs. Freedom from accident depends upon many factors, including, inter alia, fatigue and clear vision. The latter has already been dealt with, but to reduce fatigue as far as possible, adequate headroom should be maintained on gangways, and reasonable grades on stairways. The lay-out must not be cramped, so that operatives have to be continually on guard. The ventilation must be good, particularly around warm, steamy places. The knowledge that a factory is a safe place to work in gives confidence to the operatives and beneficially influences their work.

XII.—Scientific Control and Internal Communication.

Every day the importance of exact scientific control of processes is more keenly felt, and the modern factory must be fully equipped with the instruments appropriate to the particular industry. In chemical works, especially, the processes are controlled by securing the correct environment of temperature, pressure and concentration of the constituents at any given time, and these must be maintained within close limits. In such cases recording as well as indicating instruments are recommended, for they furnish a check upon operations.

Many automatic devices are now obtainable for regulating any of these factors according to a given time schedule. These greatly simplify the work of the staff, but require to be checked by frequent reference to recording charts.

The advent of superior methods of communication and supervisory control has further facilitated the maintenance of the desired operations, whether they be the flow of fluids, electric current, maintenance of temperature, pressure, concentration, acidity, alkalinity, or other factor. For example, by means based upon the automatic telephone selector, besides securing telephonic and teleprinting communication, it is possible to secure local reading of distant instruments, to operate distant machines, start and stop pumps, open and close valves in inaccessible
places, etc., and at the same time it is possible to receive signal verification that such operation has been successfully carried out, so that the device acts as a check upon its own performance as well as upon that of the rest of the plant. It is also possible to introduce interlocking mechanisms whereby any series of operations cannot be carried out in a prohibited sequence.

There are many simpler but less ambitious distant control and distant indicating devices.

These instruments may exercise considerable influence upon the lay-out of the plant, for it is possible by these means to place valves and machines in relatively inaccessible places, or at distant parts of the site, and to operate them from afar and know that they are operating correctly.

XIII.—Use of Special Materials.

It is not proposed to enter into the changes in detail of the design of plant due to the advent of new materials. Our purpose is merely to indicate their influence on the lay-out.

For example, a vat may be placed in a relatively inaccessible position if it has a reasonable life. The addition of a small quantity of copper to lead, at negligible cost, greatly increases its resistance to the corrosion of acid sulphate of ammonia. Similarly steel containers can be protected from corrosion or erosion by coating with rubber. The rubber is cemented on to the sandblasted surface, and it is vulcanised in situ. Hard rubber is more chemically resistant than soft rubber. These coatings can easily be patched on the job. The use of special alloys for vessels liable to corrosion comes under this category.

Again, rubber may exercise considerable influence on the loading of the structure, for it may often displace heavy lead-lined vessels. Similarly, the use of special pyrex glasses, for evaporating pans for highly corrosive fluids, has displaced more expensive semi-precious metals, and consequently the size of the evaporator has been increased.

The introduction of heat-resisting irons and steels has exercised considerable influence on design. For example, it is possible to make fans capable of handling hot gases, thus facilitating the control of the draught on furnaces. And the recent advent of non-warping, heat-resisting cast iron has proved of special value in the construction of furnaces and retort settings.

The bottom door castings of vertical coke ovens must fit so as to remain air-tight over their entire length of eight or ten feet. This is only possible with special pearlitic cast iron.

The use in industry of the plastics, whether of cellulose, nitrocellulose, or bakelite, has greatly simplified the lay-out of chemical industries. Pumps of bakelite and centrifugal pumps of metal, lined with rubber, are now available for handling
corrosive fluids; and rubber linings in pipes and ducts can protect them from corrosion and from the attrition of grit. Consequently, it is no longer necessary, in designing the lay-out of chemical plant, to provide for gravitational flow of corrosive fluids between vats arranged in cascade: the non-corrosive pumps and piping have simplified the problem and have given greater elasticity to the design.

XIV.—Conclusion.

The design of industrial buildings and plant has been shown in this paper to be a problem with very many facettes, where great ingenuity has to be exercised in order to reconcile the various conflicting factors and to secure the maximum economy. The paper indicates the close inter-relation of the many factors involved, and special emphasis is placed upon the multiple use of resources, whether they be of conveyors, of water, or by the use of by-product heat or power. The desirability was stressed of exploring the possibilities of exporting surplus power or steam to neighbouring factories.

The work of design should be entrusted to an engineer, not necessarily expert in the industry concerned, but rather to one whose experience extends over a wide field of enterprise, who should act in close consultation with the experts of the particular industry. In this manner the designer can introduce ideas and improvements which he has observed elsewhere in industries of a totally different nature, or improvements suggested to him by problems he had solved in connection with them. He will thus contribute greatly to the advancement of all industries, which will each benefit by the exchange of ideas through him.
Fig. 5. THE UTILISATION OF WASTE HEAT AND BACK PRESSURE STEAM. Applicable in most heat consuming industries. The steam generated in the waste heat boiler, operates the engine of the gas turbine and the waste heat from the engine is used for the absorption refrigerator. Also for the recovery of the ammonia and for operating the gas dehydrating plant.
Author/s:
Bennie, Roy James

Title:
The essential principles of the lay-out of industrial buildings and equipment (Paper)

Date:
1939

Persistent Link:
http://hdl.handle.net/11343/24812

File Description:
The essential principles of the lay-out of industrial buildings and equipment (Paper)