INTERNATIONAL LABOUR OFFICE

SAFEGUARDING PETROLEUM REFINERIES AND THEIR WORKERS

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SAFEGUARDING PETROLEUM REFINERIES AND THEIR WORKERS

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This is the second[1] *in a series of articles on safety work in the petroleum industry. The author wishes to express his acknowledgment of the assistance rendered him by* Dr. J. M. Adams, Dr. W. J. McConnell, Mr. F. L. Newcomb, Mr. D. V. Stroop, *and* The American Petroleum Institute *in the preparation of the article.*

Almost every industry has certain hazards peculiar to itself. The inherent hazards of the petroleum refining industry are due to the volatile nature of crude petroleums and many of their products. Vapours from these products are flammable and fires or explosions will result if they are permitted to escape and become ignited. In addition, a few may be toxic, and inhaling them may cause serious illness or even death. The reality and importance of these hazards have been proven by the occurrence of serious accidents; but it has also been proven that the possibility of accidents, intoxications, fires and explosions can be greatly reduced by taking suitable precautions.

During the three-year period 1939-41 inclusive, representative oil companies have reported to the American Petroleum Institute 525 refinery fires. A few of these have been costly but the total reported loss of $1,577,484 gives an average loss of only $3,000.00 per fire.

Because of the vital part played by petroleum products in the present global conflict, it is necessary that every effort be made to safeguard petroleum refining operations and workers. The production of toluene and glycerine for explosives, super motor fuels and lubricants for war planes, raw materials for synthetic rubber, and all the normal petroleum products for fuelling and lubricating the vehicles and weapons of war and the industrial plants behind the guns, make the safe operation of petroleum refineries of supreme importance at this time. The 100,000 men who man America's petroleum refineries, as well as the hundreds of thousands of other workers who supply them with raw materials and distribute the finished products, must work safely in order to maintain a constant and uninterrupted flow of essential petroleum products.

Fortunately, most of the larger refining companies and the more progressive of the smaller units have been combatting accidents, fires and explosions for fifteen or twenty years and records show that despite the fundamental dangers peculiar to the handling of flammable materials at extremes of temperature and pressure, the petroleum refinery is a safer place in which to work than the average industry, and refinery employees are nearly twice as safe on the job as off. For example, here are some real accident prevention achievements:

Wood River Refinery, Standard Oil Company (Indiana) worked 6,879,296 man-hours without a disabling injury.

Baton Rouge Refinery, Standard Oil Company (Louisiana) worked 4,216,600 man-hours without a disabling injury; the mechanical division of this refinery worked 5,593,800 man-hours without any one being disabled.

Safety instruction is a continuous, vital part of the every-day work at almost all refineries. However, war has brought a need not only for more intensive accident and fire prevention because of heightened activity at refineries but also for protection against possible enemy attempts to stop their operation by sabotage and

[1] The first article in this series ("Petroleum. A Portrait in Safety", by H. N. Blakeslee), was published in *Industrial Safety Survey*, Vol. XVII, No. 4, pp. 121–129.

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bombing. These added dangers have been met with increased protective measures, including the training of more workers, the manning of additional fire brigades, and the establishment of additional first-aid stations. In an emergency, practically every man in a refinery will have a specific job to do. Years of training in the protection of their plants against normal dangers has engendered among refinery workers a spirit of loyalty and understanding that has been of the utmost assistance in meeting war problems. Some of the protective measures are probably not yet in operation, but the fundamental problem of obtaining employee awareness and cooperation was easily solved.

Safeguarding petroleum refining operations and workers is becoming more and more complicated because the production of petroleum products is rapidly becoming a chemical manufacturing industry. Constantly improved automotive equipment requires improved fuels and lubricants to keep abreast with its development; consequently, the refinery of to-day is much more complicated than when the various petroleum products were produced by comparatively simple fractional distillation of crude oil. While considerable quantities of motor fuel and lubricants are still produced by primary distillation of crude petroleum, the quality and quantity produced is insufficient to meet present day demands and a number of new refining processes have been developed. These new processes have not only introduced new accident and fire hazards but many of them make use of toxic materials which may affect the health and well-being of refinery workers unless precautionary measures are rigidly observed. That these problems are being effectively met is indicated by the fact that the safety record of petroleum refineries still ranks above the average of all industries engaged in the war effort.

Some Essential Principles in Petroleum Refining Operations

In order to understand petroleum refining and its hazards, one must first appreciate the nature of the material from which the refiner makes his finished products. Crude oil is composed essentially of carbon and hydrogen. But carbon and hydrogen have the remarkable ability to combine chemically to form a great number of different "hydrocarbon" compounds, each of which has its own characteristics and a particular temperature at which it will boil. The boiling points of the hydrocarbons in crude oil range from about -260°F or -160°C (a hydrocarbon gas) to temperatures so high that the compounds break down or "crack" before they get a chance to boil. Many of the boiling point temperatures are so close together that it is impossible to separate the hydrocarbons as pure substances, by distillation alone. Consequently, the refiner separates from the crude oil groups of hydrocarbons which boil within a limited temperature range. These groups are called "fractions"—such as the gasoline fraction and kerosene fraction.

Furthermore, there are different types of crude oil, depending on the number and composition of the hydrocarbons present. To analyse each crude for all of the hundreds of hydrocarbons present is an impossible task. Yet the refiner must know what is in his raw material. This he learns by separating the crude into fractions and determining what hydrocarbon "families" are represented in each. The grouping of hydrocarbons with similar characteristics into families (the Paraffin Family, the Aromatic Family, the Naphthene Family, etc.) and the relatively easy chemical determinations of these families gives a chemical picture of the raw material. It also permits the refiner to classify the various crude oils that enter the refinery. Among the compounds in crude oil, some make a gasoline engine start easily, while others have just the opposite effect; some make the engine a giant of power while others turn it into a noisy weakling; some make good lubricants while others do not; a few simply smell bad. These gaseous, liquid, solid, good, bad and indifferent compounds make up the refinery's complex raw material.

It is the refiner's task to bring order out of this confusion—to retain the good, eliminate the bad and convert the indifferent compounds into useful products. The processes used to convert all parts of the crude into useful products are: distillation, treating, cracking, synthesis, compounding and blending.

By "distillation", the refiner lines up the members of the chemical families in the order of their various boiling points and marches them off as gasoline, kerosene, etc. As the selected groups or fractions leave the still, other compounds which, in the selected fraction, are useless for the purpose intended tag along. "Treating" removes these undesirables. Even the bad smell is removed and, as proof that the oil man never wastes anything that can possibly be used, this bad smell is sometimes saved to give an odour to domestic gas so that leaking gas can be detected by the nose instead of being revealed by an explosion. Most of the "bad" compounds, such as those removed by treating, and whole groups of "indifferents"—fractions too heavy for gasoline or kerosene, too light for lubricating oil and not required for fuel oil—are converted by heat and pressure, that is, "cracking", into a mixture of compounds which like the original crude has a wide range of boiling points. Among the many compounds created by "cracking", a large percentage are especially suited as fuel for cars (cracked gasoline).

Other compounds created by cracking are the starting point for the "synthesis" of rubber substitutes, alcohol, additive agents for fighting grade aviation fuel, lubricants, etc. By "compounding" various non-petroleum substances with certain treated fractions, the refinery creates products for special purposes. For example, soaps compounded with lubricating oil make grease. By the "blending" of various finished fractions their different qualities are combined to meet exactly the special requirements of a certain product. In general it may be said that every drop of crude is converted into useful products, in spite of the variation in the chemical composition of crude from different oil fields.

This ability of the modern refiner to make use of every part of the crude oil, as well as different types of crudes, is a great achievement. In the old days the character of the crude oil directly determined the kind of products that could be made. To-day this handicap has been overcome. Products of the highest quality can be made from many different crudes because refinery men know how to alter the chemical set-up of the oil and convert all compounds into useful products.

The changes the refiner makes in the size and shape of the hydrocarbon molecules which make up petroleum may be classified into five groups: (1) Subdividing (Cracking); (2) Rearranging; (3) Combining; (4) Adding; and (5) Deducting.

Subdividing (Cracking).—If hydrocarbon molecules are heated enough and held long enough at the elevated temperature they crack themselves into pieces. To make light oils from the heavy oil, the big molecule is cracked into several smaller molecules. Since the new, light oil molecules are smaller, their A.P.I. gravities are higher and their boiling points and melting points are lower than those of the bigger molecules used as feed stock. When these larger molecules are cracked, solid carbon (coke) is left behind in the cracking equipment when the refiner permits the liquid and gaseous hydrocarbon products to come out. Except for the coke, the total products of the thermal cracking reaction are something like a crude oil because they include light, medium and heavy oils and some gases. Thus, in a sense, thermal cracking may be used by the refiner to make crude oil out of a material such as gas oil. Originally no catalysts (substances which initiate and assist chemical reactions without themselves being changed) were added to stimulate or direct the cracking reaction, but recently new methods using catalysts have been found greatly to increase the production of gasolines with especially desirable characteristics. Catalytic cracking is therefore being used more widely.

Rearranging (Reforming and Isomerisation).—The mixture of natural and cracked gasolines made in the refinery sometimes does not meet the requirements of modern automobiles. It may "knock" in the engine enough to annoy the user. So the refiner may have to improve the gasoline to make it knock less. One of the methods he uses for this purpose is a treatment of the heavy fractions of natural naphthas and is called "reforming". Reforming may be done in the same equipment as that in which cracking is done, but at somewhat different temperatures and pressures. In reforming there is not so much change in the size of the molecules but the atoms are re-arranged by the effects of heat to make other hydrocarbons more suitable for automobile fuel and little, if any, coke is formed. Sometimes the refiner needs to make additional amounts of the branched-chain hydrocarbon isobutane for use as one of the raw materials in the alkylation process described below. In many cases the refiner has available the straight chain hydrocarbon, butane, either as a constituent of the gases from the field or as one of the gases produced in cracking. Butane has the same number of carbon and hydrogen atoms as isobutane. The difference between them is in the arrangement of the carbon atoms in the molecule. When two hydrocarbons have the same number of carbon and hydrogen atoms but the arrange-

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ment of those atoms differs, then the chemist says that one compound is an "isomer" of the other. The process of making an "iso" compound out of its corresponding normal compound is, therefore, called "isomerisation". The isomerisation of butane is one of those reactions which needs the stimulating and directing effect of a suitable catalyst to make it work fast enough to be practicable.

Combining (Polymerisation and Alkylation).—The word "polymer" is used by the petroleum chemist to refer to a product formed by the union of two or more identical, unsaturated hydrocarbons to make one larger molecule. A good example of "polymerisation" used in the oil industry is the process in which a molecule of isobutylene is made to unite with another molecule of the same material. As successive molecules of isobutylene are added to the larger molecule of the polymer, the weight of the molecule increases, the A.P.I. gravity decreases and the boiling point and melting point increase. By controlling the reaction, therefore, the refiner can make the product either a light liquid for use in gasoline manufacture or a solid for use as a plastic. In many reactions in petroleum chemistry a hydrogen atom of the saturated paraffin hydrocarbons may be knocked off from the molecule and some compound quickly put in place of the hydrogen before the carbon bond has a chance again to grab the hydrogen atom. The word "alkylation" is used to define the process which results in attaching an alkyl radical to another molecule. In petroleum chemistry the alkylation reaction refers to the attaching of an isobutyl radical (formed from isobutane) to an unsaturated hydrocarbon such as isobutylene to form a larger, more complex molecule of the paraffin series. The help of a catalyst or high temperature and pressure are necessary to effect the alkylation reaction. The approved current method is to use sulphuric acid as the catalyst. The product formed (called "alkylate") is excellent for blending with other materials to make aviation gasoline.

Adding (Hydrogenation).—The refiner sometimes wants to make a saturated hydrocarbon out of an unsaturated one and often wants to make light products out of heavy ones. The first of these objects can be accomplished by adding one or more hydrogen atoms to the unsaturated molecules. Such a process is called "non-destructive hydrogenation" because the molecule is not broken up before the hydrogen atoms are added. The second object may be attained by a combination of cracking and adding hydrogen atoms to the resulting smaller molecules. Since the molecules of the feed stock are first broken up by cracking, this combination is called "destructive hydrogenation". By use of a suitable catalyst and control of the reaction, the materials produced may be gasoline, kerosene, and gases only. All of these products are smaller in molecule size and are more generally saturated than the feed stock.

Deducting (Dehydrogenation).—"Dehydrogenation" means the removal of hydrogen. A saturated hydrocarbon molecule often behaves as if it were very reluctant to permit a hydrogen atom to be withdrawn, so the directive influence of a catalyst is necessary in the dehydrogenation reaction. A good example of a "non-destructive dehydrogenation" is the production of butylene from butane. The reaction can also be combined with cracking so that the two or more unsaturated molecules of the product are each smaller than the feed molecule and hydrogen is evolved. This kind is called "destructive dehydrogenation".

The hazards encountered in the production of petroleum products at refineries will be discussed in order of their relative seriousness or importance under two general headings: I. Fire and Accident Hazards, and II. Occupational Health Hazards.

I. Fire and Accident Hazards

The rare occurrence of extensive petroleum fires and their effective control to-day stands out in marked contrast to the experience of oil men twenty or more years ago. A comparison of the enormous quantities of petroleum products handled and the relatively few serious fires occurring to-day with the comparatively small quantities and relatively great destruction during the early years of the industry, points conclusively to the vast improvements made by refiners in recognising the hazards and employing efficient means of prevention and protection, although from time to time costly fires still occur.

It will be possible in this discussion only to point out some of the principal fire hazards, the essentials of fire prevention in oil refineries, and the principles of adequate protection. Since each refinery, owing to its location, topography of the

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ground, construction, layout, charging stock handled, products made and organisation of personnel, presents a separate and distinct problem, it is not practicable to make specific, detailed recommendations.[1]

Fire Hazards in Refineries

As in any other plant or factory, there are three requisites for the genesis of a fire in an oil refinery, namely: (1) a flammable substance; (2) the presence of air or oxygen; and (3) a source of ignition.

Explosive Range of Petroleum Vapours.

Generally speaking, the various liquid petroleum products and their vapours are flammable and become explosive when mixed in certain proportions with air. Ordinarily, the explosive range for gasoline and crude oil vapours is from 1.0 per cent. to 6.0 per cent. by volume, with air. The range is wider for hydrogen sulphide gas—approximately from 4.3 per cent. to 46 per cent.

Storage Tanks.

As vapour hazards may exist wherever petroleum products are handled, one should assume that all petroleum storage tanks may contain explosive mixtures of vapour and air and take precautions accordingly. If a tank is sealed to the atmosphere and is provided with suitable gas vents, an explosion is unlikely. However, whether a tank is practically empty or almost full, if it is opened so that air can enter, an explosive mixture of vapour and air is likely to be created; and the explosion hazard may become serious if this mixture is forced out of the tank by the introduction of liquid, by the application of heat or by an increase in temperature of the surrounding air. A tank that has been opened for the purpose of cleaning is not considered safe from explosion until it has been properly ventilated or gas-freed. Moreover, it is important to remember that even after these precautions have been taken, an explosive atmosphere may be created within a short time by the stirring up of sediment at the bottom of the tank while cleaning; by the admission of contaminated air from adjacent tanks or through leaking valves; or by an increase in the temperature of the surrounding air, by sunlight striking directly on the tank, or by the heat from a welding flame used when making repairs to the shell of the tank. Therefore, tests must be made with a reliable combustible gas indicator just prior to the beginning of the work and at intervals during the progress of the job, unless the job is of short duration.

[1] For more specific information see "Fire Protection in Refineries", published by the American Petroleum Institute, New York.

Primary Sources of Ignition.

According to the Travelers Insurance Company, a majority of oil tank fires (especially wood-roofed tank fires) occur in summer. In one summer, for example, there were 86 oil-tank fires known to be due to lightning; and as the records for a number of years indicate that many of the oil fires are caused directly by or through the influence of lightning, it is important to consider this particular source of hazard with special care.

Lightning.—The great heat of a lightning flash can ignite petroleum vapours. Experience has shown that a direct hit is unlikely to damage an all-steel, gas-tight tank, or ignite its contents. Secondary discharges may be caused by a lightning stroke within a radius of several hundred feet from where the direct hit occurs. Such sparks cannot ignite wood, but can set fire to explosive vapours.

We cannot control either the generation or the accumulation of atmospheric electricity, and only to a limited extent can we control the discharge when it is directed towards the earth. We know that when the difference in potential is great enough, there is a discharge between one cloud and another, or between a cloud and the earth. Furthermore, when clouds are near the earth, a cloud-to-cloud discharge may be attended by an inductive disturbance on the earth which is heavy enough to cause sparking between terrestrial objects. The limited control we have of earth-to-cloud or cloud-to-earth discharges consists (1) in providing sharp, upwardly-directed conducting points sufficient in number and capacity to dissipate terrestrial charges silently, and thereby prevent them from attaining a potential high enough to make a disruptive discharge possible; and (2) in providing a well-grounded metallic conductor of generous cross section, safely to take care of any disruptive discharge that does occur.

We know that electrical energy can be transmitted through a conductor harmlessly (that is, without the formation of sparks or arcs, or the development of a dangerously high temperature anywhere), provided that the amount to

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be conducted does not exceed the carrying capacity of the conductor—and there is no break or gap in the conductor. A gas-tight, all-steel oil tank composed of a steel shell, a steel roof, fitted with hatches or other openings that are closed tightly on the approach of a storm, and provided with a vent that is properly protected by flame-arresting screens, fulfils these conditions quite well. Such a tank has ample conducting capacity to carry away the electrical energy in case of a direct hit; the tightly closed hatch precludes any chance of sparking or arcing; and the gas-tight construction and guarded vent prevent the accumulation of rich and explosive mixtures of oil-vapour and air in any way that could result in harm. Thorough bonding together of all metallic parts of the structure, adequate grounding of the electrical system, and the elimination of explosive vapours, are desirable forms of protection against secondary lightning discharges. Many tanks complying with the conditions here enumerated are known to have been hit by lightning without any unfortunate consequences, and no doubt there have been a great many more hits that have not been observed and which did not cause fire. This is the proof of the pudding.

Static Electricity.—Static electricity is produced during the flow of air, vapour, water or oil and around moving belts, flywheels or wherever matter is in motion. It has been demonstrated that under certain conditions a spray of falling oil can produce extraordinary electrical discharges—sparks several feet long. A good general rule for combatting static electricity is to keep everything electrically bonded and grounded. In filling operations such as of cans, barrels, trucks, or tank cars, the ends of the supply line are electrically connected to each other and to ground. In filling large tanks, overshot lines are avoided and fill pipes are submerged where possible. Gaugers touch their bare hands to hand-rail at top of stairs, to discharge any static that might have accumulated on their body *before* opening gauge hatches. The back or blank side of the gauging tape is kept in contact with the edge of the gauge hatch while lowering and raising the tape.

Steam injected into a tank can generate large static charges and should be introduced through a swing pipe or by a thoroughly grounded expanding nozzle. Even the condensate from the steam injection dropping from a cold roof will generate static electricity but the air displaced by the injected steam generally prevents any trouble. Water flowing through a rubber hose will generate static electricity. When tank bottoms are being washed down by means of a water hose stream through shell or roof manholes, the nozzle or play-pipe is bonded metallically to the tank shell. Spray painting and sand blasting can also develop static electricity and care must be exercised when these operations are used around the refinery. Spraying insulated objects is particularly apt to cause an accumulation of static charges. The grounding of the nozzle and machine will reduce this hazard. Air and steam leaks from high pressure lines produce static charges which can accumulate on insulated objects that are in or near the path of the jet.

Stray Currents.—Stray currents, particularly around electric railways or welding machines, are apt to flow through the ground if wet, or through pipe lines or wire fences.

Spontaneous Ignition.—Almost all crude petroleums contain some sulphur, and when the sulphur content is high there is likely to be a deposit of a sulphur compound on the inner exposed surface of storage tanks. Among other things, this deposit contains iron sulphide, which absorbs oxygen readily. Under favourable conditions, this absorption may be so rapid that the deposit becomes incandescent and ignites the oil vapours if any are present. Fortunately, only a very limited number of crude petroleums contains enough sulphur to cause trouble of this kind; but the danger should be borne in mind. When tanks containing high sulphur crudes are being pumped out, a small amount of steam released in the tank will wet the sulphur deposit on the shell and prevent its spontaneous combustion.

Spontaneous ignition caused by decomposition is an ever-present hazard, and can be eliminated only by good housekeeping and proper ventilation. Some of the substances which are most subject to spontaneous ignition are: vegetable oils, sulphides, lamp-black, iron filings, scale from tanks, charcoal, coal and coke.

Welding.

Welding is always a fire hazard and is done only after a thorough inspection of conditions and then only under constant supervision. A written "Hot Work" permit, issued after a combustible gas test in all enclosures, is essential.

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Miscellaneous Sources of Ignition.

The many hazards around heating plants are obvious and need not be mentioned, except to say that live steam lines will ignite wood if placed in direct contact and especially in a confined air space, because of the fact that when wood is heated and allowed to cool off the flash or ignition point is reduced. All are familiar with the hazards of matches, sparks, cigarettes, etc. so they need not be considered here. The sun's rays have also been known to start fires where they are allowed to shine for some time through water bottles, sample bottles and other glass articles.

Care should be taken in the use of automobiles and trucks in locations where explosive vapours are likely to exist. There is also the hazard of illuminating systems. No open lights and none but vapour-proof globes with protection against mechanical injury should be used. Breaking of electric light globes or relamping can cause dangerous sparks. All electric wiring and all electric machinery and equipment should be kept in perfect condition at all times. A flashlight or electric lantern of an approved type is safer than an extension cord and lamp.

Essentials of Fire Prevention

Here are some essentials of fire prevention which are considered at most oil refineries:

(1) *Systematic Planning.*—A modern petroleum refinery is systematically planned, with a zoning of the plant to provide for different operations and proper avenues of communication. Spacing of equipment is carefully studied to reduce possibility of fire spread; roadways or fire breaks are maintained between batteries of stills, groups of other equipment and at frequent intervals in tank fields, to permit movement of fire-fighting equipment and provide advantageous and safe positions to combat such fires as may occur. Refinery construction in general is of fire-resisting material. Vital agencies such as power houses, water and foam pumps are located where least exposed to hazard. Oil piping and control valves are so arranged as to permit ready transfer of petroleum stocks in case of emergency. Equipment wherein oil is heated or which operates under pressure is equipped with suitable safety valves for relieving excess pressures and the discharges of these valves are led to safe places to reduce the possibility of their ignition. Electrical equipment is carefully selected and installed. Lighting fixtures in rooms where petroleum products are handled and in other locations, where combustible or explosive vapours may be present, are of the approved type. Sewers are of ample size, not only to care for surface drainage, but to carry away quickly spills of oil in case of equipment failure and to handle large volumes of water necessary in case of fire. Such sewers have been equipped with adequate separators at their outlets to prevent the discharge of oil which might endanger other property.

The exclusion of fire hazards receives careful consideration in the design and specifications of each proposed structure and all equipment. Design engineers should have a very clear conception of the conditions of operation and the functions of each unit and its relation to surrounding equipment. The engineering department is kept informed by participation in conferences and exchange of data with the development, operating and inspection groups on all manufacturing equipment performance, especially on high pressure cracking and continuous distillation units. By this co-operative arrangement the designing engineers receive the benefit of all available knowledge on the conditions of operation of new installations.

(2) *Proper Care in Operation* where flammable materials are handled involves mainly the human element. The selection of men to take charge of operations and the instruction of the personnel in safe methods of operation are probably of greater importance in preventing fires and accidents than any other single factor. Carelessness invariably leads to unsafe conditions with greater chance of fires and accidents. Definite instructions are issued and no infraction of the rules is tolerated, such as the use of short-cuts, make-shifts, etc. All violations of the instructions receive suitable discipline and continued failure to comply results in discharge.

(3) *Inspection.*—The intelligent and regular inspection of refinery plant equipment by properly trained personnel is essential and an inspection group is organised. All equipment operating under high temperature and pressure, such as cracking and pipe stills, is subjected to a very rigid inspection at regular periods. The inspection consists of external and internal examination, together with drilling and measurement of all the sections where corrosion and other agencies are apt to affect the strength of

the unit. Tube elements of furnaces on cracking and pipe stills are measured for inside diameter after each run by a special measuring tool. If any elements are found below the standards that have previously been fixed as safe, they are removed. With drums or pressure vessels a hydraulic test is applied in addition to the examination and drillings. This inspection group usually has the authority to order the repairs necessary to place the unit in a safe operating condition.

(4) *Good Housekeeping* cannot be minimised as a necessary item in accident and fire prevention. Good housekeeping embraces the maintenance of the entire plant in a neat, clean and orderly condition and clearly indicates the extent of the management's success in impressing its force with habits of carefulness. Avoidance of waste by looking after the little things helps much towards successful operation as well as maximum safety and minimum fire risk. There is no place where good housekeeping is more necessary than in an oil refinery.

(5) *Reduction of Fire Hazards.*—It is possible to reduce the hazards in oil refineries by avoiding all unnecessary flammables. Wood ignites at a lower temperature than oil or oil vapours, therefore all combustible structures such as wooden roofs, ladders, runways, fences and old shacks are eliminated where possible. Oil spills due to breakages, accident, carelessness and leaks, allowing a stream of oil or vapours to travel considerable distances and come into contact with open flames or other sources of ignition, have caused many serious fires. Extreme care is exercised to prevent such spills. Most large oil fires either begin with an explosion or spread from unimportant fires by vapour explosions. The explosibility of vapours in closed spaces is determined and measures are taken to keep the vapours outside the explosive limits. Various methods are used to accomplish this end. In some cases it is best to keep the vapour too rich to explode and, in others, too lean; and sometimes it can best be done by introducing an inert gas that will make the mixture too deficient in oxygen to burn. When their explosibility cannot be controlled practically, they are guarded as if they were dynamite. Tanks containing explosive vapours are avoided as far as possible, and attended only by reliable men who understand the nature of the vapour. Concrete or masonry supports are used on all elevated tanks, unless the tanks are in isolated locations and not subject to exposure. To avoid breakage and leakage, steel and malleable valves are used instead of cast iron in places where a strain is apt to be thrown upon them. Brass valves melt down quickly if exposed to intense heat and should not be used where there is any possibility of their being exposed to fire. Gate valves are provided at strategic points in all oil lines so as to cut off the flow, in case of breakage.

(6) *"Hot Work" Permits.*—Many fires and explosions in oil refineries have been caused by lack of adequate precaution in performing hot work. Hot work in refineries includes oxy-acetylene cutting and welding, electric welding, heating and driving rivets, operations entailing the use of lead melting pots, tar kettles, etc., and all other uses of torches or flame on mechanical operations. Before any open fire or flame is allowed, a written hot work permit, signed by the fire chief and a department superintendent after investigation or test, is obtained by the operator. Many cases have been found where such operations would have been dangerous had they not been investigated and prohibited. There is also a similar fire permit arrangement covering the use of fires or open flames on board tankers, tugs, and barges at the docks. Special permission from the operating forces to do hot work usually consists of a permit in writing issued daily. The operating supervisor, having jurisdiction over the equipment on which hot work is to be done, may issue a permit to the mechanical supervisor after he has ascertained to the best of his ability that everything is safe, that all oil and gas lines to the equipment have been blanked, and that the equipment is oil or gas free. A combustible gas indicator is used to determine the concentration of combustible gas in the air and, if this concentration is greater than 0.2 per cent., a permit is not issued until the concentration is reduced below that limit. Hot work permits are usually issued in duplicate form, one copy remaining with the operating supervisor executing it and the other given to the mechanical supervisor. This permit may also be used in conjunction with a second permit consisting of a heavy card five inches wide and twelve inches long made up in the form of a green tag with two sections, perforated between. The sections have spaces for designation of equipment and work to be done, type of fire equipment at hand and signature of both

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the operating and mechanical supervisor. Both sections of the permit are given to the mechanical supervisor who attaches the second section to the welding or hot work equipment. In actual practice the permit tag is issued daily and is made out from the notations on the first permit.

Fire-Fighting Facilities

There are four classes of fire-fighting facilities: (*a*) High Pressure Water Systems; (*b*) Steam Smothering Lines; (*c*) Foam and Other Smothering Systems; and (*d*) Portable Extinguishing Equipment. Effective results may be obtained from the use of plant fire-fighting organisations.

(*a*) *High Pressure Water Systems.*—Distribution of high pressure water for fire purposes is usually kept separate from low pressure systems used for utility purposes. Utility supplies are not taken from the high pressure system except in special cases and then only in small quantities. The source of supply should be equal to at least 24 hours' maximum pumping capacity.

The use of booster pumps between low and high pressure systems where they parallel one another, should be encouraged. Pumps in fire service should be well distributed. Distributing lines are looped to minimise interruption due to breaks; hydrants are placed at frequent intervals, and hose threads conform to the nearest city fire department's equipment. An ample supply of hose is essential. Use of stationary play nozzles for special risks, on docks or the tops of high structures, is strongly recommended. Large sized lines and an adequate number of pumps of ample capacity mark a successful system. A fairly recent development, which is proving quite successful, is the use of fog nozzles with high pressure water.

(*b*) *Steam Smothering Lines.*—The effectiveness of steam smothering depends upon an adequate supply of steam of fair quality. Controlled connections to oil pump rooms, gas exhauster houses, receiving or tail houses of still batteries, are good practice. Frequent steam hose connections around refinery equipment handling hot oil are essential since steam is more effective as a fire prevention agent than it is for fighting fire.

(*c*) *Foam Systems* follow the design and approved practice now well recognised in the petroleum industry and outlined by the National Board of Fire Underwriters. Within recent years foam generators employing a supply of dry powder and high pressure water have been developed; and it appears that for certain well grouped risks where the distance to the farthest located risk is not great, they may at times be used to advantage, with a saving in initial cost and some slight decrease in maintenance. There is also now on the market an air foam which requires no chemicals other than a stabiliser. This foam is formed by agitating the solution in the presence of air which forms a frothy mixture. The well established formulas and rules regarding quantities of foam solutions and rates of application required, are intended to combat adverse conditions and are safest to follow in designing systems.

Foam acts as a smothering blanket which floats over the surface of the burning oil. The foam is produced by a mixture of two solutions, one of which contains aluminium sulphate, while the other contains sodium bicarbonate, together with certain other substances such as glue, glucose and licorice which form a suitable foam. The aluminium sulphate and the dilute acid combine with the sodium bicarbonate to form an incombustible gas (mainly carbon dioxide), while the glue, glucose or licorice causes the mixture to froth, instead of giving off the gas freely into the air. Thus a smothering blanket is formed, which under proper conditions effectively shuts off the supply of air or oxygen and causes the fire to die out. Other substances may be used to create the foam but in order to get good results, three essential conditions must be satisfied: first, the chemical reaction that takes place must generate an incombustible gas; second, the froth-creating constituents must yield bubbles of a high degree of permanence so that the froth will not easily break down but will persist for a considerable time. In particular, the froth or foam must be persistent enough to withstand a fall of several feet, as it enters the tank and settles down upon the burning oil. Third, a plentiful quantity of the foam must be supplied.

It is neglect of the third condition which is almost invariably responsible for failure when it occurs. There must be a sufficient quantity of both solutions immediately available and the piping and pumping facilities must be adequate to ensure the placing of at least a five-inch blanket of foam over the entire surface of the oil within five or six minutes. Allowing six gallons of foam for each gallon of mixed solution and knowing the area of the oil surface that is to be blanketed, it is a simple matter to calculate the total amount of solution that will be needed; but to this calculated amount a liberal additional quantity should be added as a safety factor and as an allowance for the partial dissipation of the foam from heat and other causes. The foam should always be present in sufficient quantity to ensure that the oil will remain well covered for a considerable time after active combustion has ceased, to guard against a spontaneous rekindling of the fire before the tank and the surface of the oil have become sufficiently cooled. Finally, it should be remembered that diluted sulphuric acid does not combine with sodium bicarbonate rapidly and freely at temperatures in the vicinity of the freezing point; and for winter protection in our northern latitudes it is important to store the solutions in a moderately warm place.

The new Carbon Dioxide Smothering Systems which have been developed recently for large storage tanks have been found to be extremely effective under certain conditions.

(d) *Portable Extinguishing Equipment.*—All of the approved hand fire extinguishing equipment on the market has its place in the protection of oil refineries and is an essential adjunct to the larger central high pressure water, steam smothering and foam systems. These items of equipment are thoroughly covered by the *Regulations of the National Board of Fire Underwriters for the Installation, Maintenance and Use of First-Aid Fire Appliances.* In addition, hose houses are supplied with extra spanner wrenches, hose clamps (for repairing breaks in hose), picks, shovels, buckets, lengths of ½ inch rope, extra hose gaskets, axes, crowbars, metal shields for protecting men from heat, fire-proofed blankets, wooden troughs for protecting hose passing over hot pipe lines, extra hydrant wrenches and tapered wooden plugs of various sizes for plugging broken pipe lines.

Photo: Standard Oil Company of New Jersey

Fig. 1.—Acid-type goggles must be worn when working on equipment containing acid, caustic or other corrosive materials. Note sheet lead shield around flanges and valves.

One large eastern refinery has equipped its 50-car gasoline loading rack with a mono-rail on which are operated two 40-gallon foam extinguishers. These can be quickly shifted to any point on the rack by one man. The provision of effective fire-fighting equipment that can be handled by a few men is an important consideration in present-day refinery operation.

Organising for Combating Fire

The utmost promptness in applying whatever fire-fighting facilities the refinery may possess constitutes a highly important element in successfully fighting oil or any other fires. Hence, an effective organisation is quite as important as adequate equipment and without it the equipment may be practically useless. However, there are as many feasible methods of organisation as there are plants and the subject of such organisation must be given individual study for the refinery concerned. In each, there should be a fire-fighting force under a competent head with efficient assistants. This force should be formed of the regular employees and should be subject to drill. In small plants where the workers live close by, the fire-fighting force may be subject to call night and day and be so divided that a part is always on duty in the plant. In larger plants or those remote from workers'

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homes, it may be necessary to have a separate organisation for each shift. In some large refineries it is advisable to zone a plant, with an organisation complete for each shift in each zone.

Here is a brief outline of an actual organisation in an eastern refinery:

A fire chief and one or more assistants have been appointed. Trained plant operators have been grouped into fire companies in all sections of the plant and respond when there is a First Alarm Fire, with the nearest hose carriage to the scene of the fire, when the fire is in their zone. Fire companies have been assigned to fire trucks, which they drive to the fire on all First Alarm Fires, regardless of the location.

For Second Alarm Fires, additional Yard Fire Companies with hose carriages respond together with the City Equipment if available. If occasion requires, a selected group of mechanics is called in for moving lines or pumps and for transferring stored products. Certain individuals from the fire organisation have definite assignments during serious fires, such as care of oil separators, fire and foam pumps. In extreme emergencies at night, on holidays, and Sundays, a siren is blown, which summons additional selected mechanics and operators.

Combating Tank Fires

After a tank fire starts, there are two methods of fighting it: with steam and with foam. Steam as normally applied is not effective unless the roof remains on the tank, which is seldom the case. Tank fires usually start with an explosion which blows off the roof. In such cases, steam is ineffective but is of value in preventing the ignition of exposed tanks nearby. The most efficient method of extinguishing a serious tank fire is to cover the burning area with foam. Other methods of handling these fires have been developed such as water spray, carbon dioxide, carbon tetrachloride; however, no records are available of actual fires extinguished to prove their merit. They appear to work under certain conditions but a "test" tank fire is a very unsatisfactory way of proving what will happen in a real fire in a driving storm.

Boil-Overs.

Boil-overs are always a menace in crude oil tank fires and as a result of experiments made by the Standard Oil Company of California, it has been found that additional barriers of corrugated iron sheets greatly reduce the area covered by burning oil. Therefore, a trailer equipped with corrugated sheets and stakes for their erection is desirable. This same trailer should carry portable shields to protect hose men from the intense heat of the tank fire.

Combating Still Fires

Next to tank fires, the most frequent are those in stills. Usually these are small fires caused by small oil or vapour leaks. They are generally extinguished with hand extinguishers, steam jets, water hose, or by "pumping out" the still, with negligible loss. Occasionally, however, something lets go and a still cracks open, a high pressure drum explodes or an oil line breaks and a fire is started. That such fires are so few in number is largely due to expert engineering and continuous inspection. The least leak, defect or wearing out of any part is almost certain to cause a fire. Only continuous inspection and expert operation will prevent still fires. However, a great deal has been accomplished by providing facilities to prevent the spread of such fires and means for controlling them quickly under the most severe conditions.

Controlling Spread of Still Fires.

Many refineries provide a fire wall 12 to 18 inches (30 to 45 cm) high around every battery of stills where practicable. Other refineries do

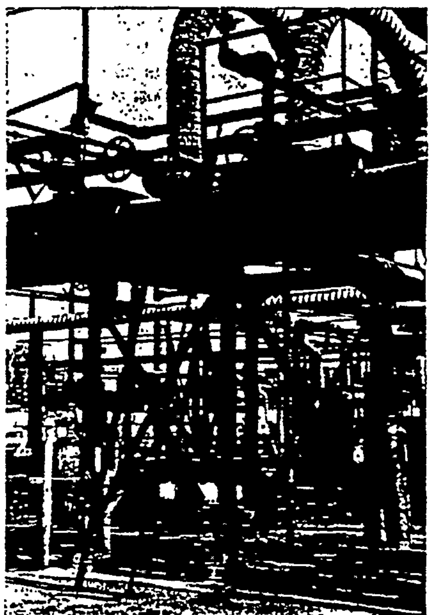

Photo: Standard Oil Company of New Jersey

Fig. 5.—Steel ladder and platform for overhead valves.

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not install such fire walls but it is usually possible to utilise the rear wall supporting the condenser boxes as part of this surrounding fire wall. It is desirable to break up the fire areas as far as practicable by means of fire walls among the units of any battery of stills so that a flood of hot oil pouring from a break will endanger as few adjoining stills as possible.

Particular attention should be paid to the method of supporting all oil and vapour lines. Most frequently these pipe lines are carried overhead on unprotected structural steel work. Any severe fire will bring them down in short order, often before effective fire-fighting can be started. These oil lines may drain other stills and the additional fuel added to the blaze may cause it to become uncontrollable. All supports for such lines in the most critical areas are usually protected with a fire-resistant material.

Handling Still Fires.

A great many still fires are the result of carelessness and are caused by pumping over when charging or permitting water to get into a charging stock causing immediate opening of safety releases or equipment failure. One of the simplest and most effective ways of handling a serious still fire is to pump out the burning still and those menaced as quickly as possible. The importance of having large pumps and large pumping-out lines is apparent. It is also essential that the pumping-out valves be equipped with remote controls so that they can be operated safely and surely, usually from back of the condensers. As with tank fires, one of the most effective means of extinguishing a serious still fire is foam applied through hose streams. Experience has shown that water improperly used in extinguishing burning oil acts as a vehicle for spreading the fire. However, it is of advantage in keeping nearby structural steel work cool. For this reason the cautious use of water in keeping the area cooled until the foam system can be brought into action is advisable. The water should then be discontinued and the foam hose streams used, as the simultaneous application of water and foam will result in the water breaking down the foam.

The protection of refineries which cover large areas, by insulated steam lines or fire foam equipment, is expensive but worthwhile. Danger spots are boiler house, acid plant, stills and electrical equipment. The lightning hazard can be lessened by preventing the accumulation of communicative mediums such as hovering gases or vapours. Such accumulations can be reduced by painting the tanks a light colour, which retards evaporation. However, in the final analysis, fire prevention and fire protection are problems of administration and organisation. This important work has, on the whole, been properly organised, thoroughly studied, conscientiously executed and, last but not least, inspired by attention from the management, and has achieved notable success.

Accident Causes and Measures for Combating Them

Readers should not conclude from the foregoing discussion that *fires* are the only source of fatalities and property damage in refineries. They are, however, the principal potential source and have, therefore, been given major consideration. A general idea of the part played by other sources may be obtained from the following classification of causes of 295 fatal injuries reported over a period of eleven years for refining departments to the American Petroleum Institute:

Causes	Per cent.
Fires and explosions	55
Falls and falling objects	19
Burns by acid, caustic, hot water and steam	6
Electrocution	6
Striking objects, or being struck or caught in moving equipment	5
Asphyxiation	4
Traffic accidents	2
Heat prostration	1
Equipment failure	1
Drowning	1

Since there is nothing in the foregoing list of accident causes peculiar to petroleum refineries and the methods for preventing such accidents are similar in every respect to those universally used in other industrial operations, a mere outline of some of the chief measures being employed to combat them will be given.

Measures in General Use in Present-Day Petroleum Refineries for Safeguarding Employees.

These measures include mechanical safeguards of neat and accessible design on flywheels, shafting, couplings, gears, and belts. Suitable platforms for oiling overhead machinery. Where possible, machinery is shut down during oiling periods. Safe belt-shifters on all belt-driven equipment requiring the shifting of belts for "idleness" or change of speed.

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Safe and secure piling of bulk material such as cartons, drums, boxes and miscellaneous packages so that a bump or jar will not cause them to topple over. Clear alleyways and walkways free from debris with flooring that is in good condition and free from oil, grease, wetness or chuck-holes. Use of non-skid floor covering in wet and slippery locations, open grating on outdoor operating platforms and stair treads to eliminate snow and ice hazards. Clean, well-lighted, well-ventilated buildings with enclosed elevators and stairways in suitable design and number to allow safe exit in case of fire or emergency. Portable ladders of suitable design, free from flaws and defects, equipped with safety shoes. Goggles for use in grinding, chipping and handling chemicals, coloured for welding and furnace observations (see fig. 1).

Tools in first class condition. Wrenches with clean, sharp jaws. Hammers, chisels, sledges, and punches free from burred or 'mushroomed' heads and with flawless wood handles. Rigid inspection of tools before checking out and after checking in. Non-sparking tools for hazardous locations. Safe portable tools and lamp cords.

Safety railings in front of doorways leading directly to driveways from which a view of an approaching vehicle is obstructed. Railings around open pits. Stairways with railings to cross over conveyor belts and conveyors (see fig. 2). Safety extension cords and lamps for entering tanks, vessels and boilers.

Protective clothing, such as rubber boots, aprons, gloves and respirators and helmets for use in working with chemicals, electricity, sand blasting, dusty atmospheres, coke removal and tank cleaning operations (see fig. 3). Asbestos suits, hoods, gloves and shoes for use in case of fire. Block-off blanks to be installed in nozzle flanges for isolating vessels when it is necessary to enter them for inspection, repairs, or cleaning. Warning signs at hazardous locations (see fig. 4).

Wherever cars are loaded or unloaded, standard car movers are generally used instead of the finger and toe-smashing pinch bars formerly employed. There are also provided safety type tools and gadgets for opening and closing doors on box cars, as well as safety tools for opening and closing pockets on coal cars.

Areas in which chemicals are used and handled are equipped with eye-wash fountains and shower heads located in close proximity to the hazards. Suitable rubber clothing and apparel are available and located as conditions dictate.

Close attention is given to the operating condition of safety valves and automatic controls on boilers, air systems, pressure vessels of cracking plants, de-waxing plants, refrigerating equipment, gas-recovery systems, fuel systems, positive displacement pumping systems, and any system depending on safety valves or controls for safety. Continuous flushing with water, if necessary, and blocking off with suitable firewalls and traps of all trenches leading to and from buildings and process areas to prevent injury due to fire or explosion.

Gas masks are located at strategic points, canister types for use in locations not entirely deficient in oxygen, for ammonia, gasoline vapour, hydrogen sulphide, tetraethyl lead, and chlorine. Fresh-air positive pressure type masks for use in entering buildings, vessels or tanks in which a deficiency of oxygen exists (see fig. 5).

Improvements in processes, engineering revision and equipment modernisation, continue to be made daily, with the objective of manufacturing safely, both to personnel and public, the products which are so vital under present conditions. Modern petroleum refining equipment is scientifically designed and built of corrosion-resisting metals in stills and furnaces, so controlled with precision instruments that the control room personnel of a distillation unit, for example, is able to ascertain readily just what is occurring at any point of the process. Temperatures, pressures, crude charge and products by type and quantity in every part of the equipment are seen at a glance.

Employees are encouraged to correct all unsafe conditions and to report those beyond their control. Good housekeeping is essential to every safety programme and the co-operation of every employee must be obtained if accidents are to be eliminated. Safety suggestion systems of one sort or another are very helpful in this regard and every suggestion made in good faith should be acknowledged.

Bulletin boards in every department, changed regularly with timely and interesting posters, have been found valuable in maintaining employees' interest in safety and represent, to the workers, in some degree the interest of management in accident prevention. Well chosen payroll inserts, used occasionally, create interest, particularly if seasonal and not overdone. General safety meetings of employees, held at regular intervals and never allowed to drag or become boring, with one or two interesting speakers, safety movies, a comedy or other light entertainment, are used with great success at many refineries for combating accidents.

Doing a Job Safely means giving Proper Attention to the Details!

II. Occupational Health Hazards

According to Dr. William J. McConnell, of the Metropolitan Life Insurance Company, the health hazards of petroleum refineries vary widely in extent and severity, depending upon the composition of the oil being handled, the location of the plant and the personnel employed, the concentration of the toxic substance and the duration of exposure. They include not only those potential health hazards incidental to the processes used from the time the crude petroleum arrives at the refinery until it leaves, but those related to the introduction of improved refinery operations and maintenance of equipment. The worker in a small refinery is perhaps exposed to a greater number of hazards than the worker in a large refinery, because in the former instance the duties are more general and less specialised than in the latter. Different refineries have equipment of various designs and use various processes which are not standardised. It must be remembered also that the volatility and toxicity of the products increase with rises in temperature. A hazard which exists in one type of refining plant may not exist in another plant. For example, hydrogen sulphide is a most serious and deadly hazard. Fortunately, this gas is present in only a few crudes and is very probably due to contamination of the oil by sulphur deposits in the earth. Furthermore, the toxicity of the products of the petroleum refining industry varies with their sources of origin and is often due to the impurities which they contain. Consequently, in speaking of any health hazard in the refining industry one must qualify his statement by saying that the hazard in question may exist if a certain substance is encountered or if a certain impurity is present.

Photo: Mine Safety Appliances Company, Pittsburgh.

Fig. 3.—A properly protected tank gauger—full-view face piece, canister mask, hard hat, safety shoes. Note guard rail on edge of tank, back of gauging hatches.

Skin Affections

Prosser White classifies skin affections caused by oil and its products, according to the substance encountered, as follows:

(1) Benzine—mineral oil, gasoline or naphtha, causing superficial dermatitis, dry scaly skin, eczema, pimples and pustules.
(2) Burning oils or oils for lighting, causing papular and pustulous eczema, folliculitis with or without acne and abscess.
(3) Residues, causing erythema, senile keratosis, warts, ulcers and skin cancer.

Many other observers have found and reported similar skin lesions among workers in refineries. All agree that cleanliness is an important factor in preventing the high incidence of these affections. Schwartz believes that the pigmented papillomata could in a large measure be prevented by the compulsory wearing of gloves and cleansing hands with soap and water before eating lunch and immediately after stopping work for the day. Oil acne and wax warts, he suggests, can also be prevented by having the men take shower baths, using plenty of soap, immediately after stopping work for the day, and changing to clean clothes. The gas or vapour of crude petroleum may be irritating to the skin and respiratory tract.

Toxic Gases and Vapours

Hydrogen Sulphide.

Hydrogen sulphide, when present, is not only the principal cause of corrosion of expensive equipment, but is also a serious health hazard.

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This gas is heavier than air and is soluble in water and oil. It is characterised by an offensive odour resembling that of rotten eggs, although in high concentrations of the gas the sense of smell is quickly deadened so that it cannot always be relied on as a warning sign. Even in very small concentrations, the gas causes a respiratory paralysis that is followed by heart failure and death.

Sub-acute poisoning may be produced by long exposures to concentrations as low as 0.005 per cent. by volume. The gas is irritating to the eyes and mucous membranes. Conjunctivitis, pharyngitis, and bronchitis may result from exposure to low concentrations. A chronic form of hydrogen sulphide poisoning, characterised by digestive disturbances, headaches, lassitude, cold sweats, and local irritation to the eyes and the respiratory tract, is generally believed to result from prolonged exposures to low concentrations of hydrogen sulphide.

Complete protection against the inhalation of hydrogen sulphide is essential. The degree of protection afforded by the use of canister-type gas masks, hose masks, and self-contained oxygen-breathing apparatus against this gas, as well as against petroleum vapours, is reviewed in detail in Bulletin No. 231, United States Bureau of Mines (1925). Additional protective measures consist of designing equipment properly to eliminate places of exposure, instructing workmen to avoid exposure by using respiratory protective equipment when working in contaminated places, and by training them in methods of emergency treatment. Adequate protection against petroleum vapours which have anaesthetic effects when inhaled, is also afforded by wearing breathing equipment.

Volatile Hydrocarbons.

Inhalation of volatile hydrocarbon products of petroleum produces affections of a general nature, depending upon the origin, degree of purity of the product and the percentage of hydrocarbons boiling at high or low temperatures. Exposure to these vapours in small workrooms, tanks, boilers and locations where there is an insufficient supply of oxygen may cause loss of consciousness and even death unless the victims are rapidly removed into the open air. Inhalation of small quantities of the vapours gives rise to headache, dizziness and intoxication resembling that of a drunken man. Inhalation of moderate quantities of the volatile hydrocarbons for long periods of time, even when sufficient oxygen is present, causes buzzing in the ears, feeling of heaviness in the head, marked intoxication and sometimes amnesia and unconsciousness. In some cases, according to Koelsch, there is a state of excitement progressing to a maniacal condition with delirium, hallucinations, muscular tremor, clonic spasms, sometimes neuritis, paraesthesia, difficult deglutition and speech, shooting pains in the neck and chest, fall in body temperature, especially in the peripheral parts, with cyanosis and sensation of cold and diminution in the respiratory rate and pulse.

Photo: Standard Oil Company of New Jersey

Fig. 4.—A properly guarded location where dangerous gases may be present.

By means of experiments carried out on prisoners in a penitentiary at Bucharest, Felix found that in most of the cases five to fifteen grams of volatile gas per litre of air inhaled for seven to twelve minutes caused dizziness, nausea, vomiting and sleepiness, as well as congestion of the conjunctiva and a sensation of burning in the chest. Anaesthesia and sleep were produced by inhaling 20 to 40 g per litre of air for eight to twelve minutes, with individual variations from a marked susceptibility to a considerable resistance.

The inhalation of 45 mg of light benzine (naphtha) vapour per litre of air causes death of such animals as dogs and cats at the end of two hours, but 60 mg per litre of air, or exceptionally even 80 mg per litre, could, in some cases, be borne for 20 minutes without any inconvenience. HAGGARD found in his experimental work on the effect of gasoline vapours on dogs that the first disturbances occur with a concentration of 85 volumes per 10,000 volumes of air. When the concentration reached 156, the animal was not able to keep upright; with 102 volumes per 10,000 volumes of air muscular spasms are caused, and with 162, epileptiform convulsions occur. Another animal lost consciousness with a concentration of 238 volumes per 10,000 volumes of air, and death occurred after two minutes with 243 volumes.

The effect on the blood of exposure to the distillates, naphtha and gasoline, remains a controversial subject. Some investigators have found that solvents marketed under the name of "gasoline" or "benzine" actually contain enough coal tar benzol to give rise to symptoms typical of benzol poisoning. Benzine, which is a mixture of hydrocarbons obtained exclusively from the second portion of the fractional distillation of crude petroleum, is too frequently confused with "benzene", a product resulting from the destructive distillation of coal. Benzine belongs to the aliphatic series of hydrocarbons, which have comparatively little effect on the blood, whereas benzene is a member of the aromatic series which are toxic and very definitely affect the blood and the blood-forming organs.

Chlorinated Hydrocarbons.

Chlorinated hydrocarbons are more or less extensively used in refineries for improving lubricants, in the preparation of various specialty products and in fire-extinguishing equipment. Dr. W. F. von OETTINGEN, Principal Toxicologist, National Health Institute, states that chlorinated hydrocarbons cause industrial poisoning by the inhalation of their vapours, occasionally by absorption through the skin, and rarely by ingestion. Safe maximum permissible concentrations for extended exposures of chlorinated hydrocarbons vary from 500 parts per million parts of air (methyl chloride) to 10 parts per million parts of air (tetrachlorethane). Although their action on the nervous system is less specific than that of most anaesthetic hydrocarbons, their injurious effects involve a larger number of tissues. Certain of the higher members have a depressing action on the heart and degenerative changes in the heart, liver, and kidneys have been frequently observed. Death may result from degenerative changes after recovery from the anaesthetic action is complete. Light, heat and oxygen tend to decompose the chlorinated hydrocarbons to varying degrees and such compounds may form phosgene and hydrogen chloride under certain conditions. Both of these gases are highly irritating. Since phosgene is about 100 times as toxic as any of these compounds, even slight decomposition may increase their toxic effect several times.

There is a huge amount of information available on the toxic properties and physiological effect of some of the more widely used chlorinated hydrocarbons. Much of the data is not, however, of a critical nature. Nevertheless, the literature does present some generalised descriptions and correlations of their toxicological properties which are very helpful.

When the hydrocarbons are chlorinated, four constituents may ordinarily be present: the paraffin hydrocarbon, chlorine, hydrogen chloride resulting from the reaction, and the chlorinated hydrocarbon or a mixture of these. The toxicity of such a system is determined by the most toxic element which is chlorine. When chlorine in the system has been substantially reduced through reaction, the toxicity will be determined by other factors such as the amount of hydrogen chloride and the nature and quantity of the chlorinated hydrocarbons present. Consequently, consideration must be given to the toxicity of all possible chlorination products which might be obtained from a particular hydrocarbon.

Information on the toxicity and mechanism of the action of the various chlorinated hydrocarbons is considerably muddled. For example, some investigators say that trichloroethylene is considerably less harmful than carbon tetrachloride; but in the opinion of many it is not as much less harmful as is usually stated. Some investigators say that certain groups of chlorinated hydrocarbons cause fatty degeneration in the liver and that other groups have an action primarily on the nerve tissue or function. None of these theories are too well worked out at the present, although both types of action are evident. All that we can conclude at the present is that *all chlorinated hydrocarbons are potential hazards and should be treated accordingly.*

The chlorinated hydrocarbons usually referred to are the volatile substances or those that give off enough vapours to contaminate the air. There are, however, some chlorinated hydrocarbons that have very low or no appreciable vapour pressure. "Halowax" or chlorinated naphthalene is an example of such a substance. Halowax, however, has given serious trouble when heated. When the chlorinated substance also contains fluorine in the molecule, such as dichlor-difluormethane, they appear to become stabilised and are rendered less harmful. This might not hold true for all compounds containing chlorine and fluorine.

The saturated paraffin hydrocarbons are only moderately toxic. Methane and ethane under normal conditions act as simple diluents and have no serious physiological effects. The higher members of the series show a narcotic effect that increases with increase in molecular weight. However, the actual practical hazard tends to decrease with the high molecular products owing to the decrease in vapour pressure.

Whenever chlorine has completely reacted in the molecule, there will be a stoichiometrical equivalent quantity of hydrogen chloride so that there will always be acid gases present of strong warning properties. It is doubtful that sufficient hydrogen chloride will be present to cause much discomfort, but repeated exposure of considerable duration daily to small but irritating amounts might possibly cause severe irritation of the nose and might even produce perforation of the nasal septum similar to that produced by chromic acid mist. The strong penetrating odour of hydrogen chloride is easily detected and should serve as an ample warning of leaks.

If respiratory protection against acid gases (chlorine and hydrogen chloride) and organic vapours (chlorinated hydrocarbons) is provided, workers will be reasonably safeguarded. Combination acid and organic vapour canisters, approved by the United States Bureau of Mines, are available for a total concentration of two per cent. With the gaseous or highly volatile hydrocarbons and chlorinated products in confined spaces, there is danger of oxygen deficiency and an approved hose mask should be used.

Aside from the respiratory hazard from the chlorinated hydrocarbons another factor to be considered is dermatitis. Protective creams, safety clothing, personal cleanliness and careful workmanship should aid in controlling this risk.

Sulphur Dioxide.

Sulphur dioxide is encountered in certain oil refining operations, but does not as a rule cause acute poisoning, because the gas is so irritating to the eyes and mucous membranes in small concentrations that it serves as a warning signal to leave before any poisonous effects are experienced.

Other Gases and Vapours.

Other gases and vapours which may be encountered in petroleum refining operations are chlorine, ammonia and chemicals used in fighting fires. Acids and alkalies are used in large quantities and may cause injuries from chemical burns. In addition to chlorinated hydrocarbons, certain complex amines and ketones are employed in lubricants to produce a better quality and every precaution should be taken to avoid exposure to these highly toxic compounds.

Tetra-Ethyl Lead

A serious refinery health hazard that must be guarded against is tetra-ethyl lead which is added to gasoline for the purpose of increasing its efficiency. Most of the gasoline produced and sold in the United States is treated with this compound which is necessary for the smooth operation of the later models of automobiles, nearly all of which have stepped up their compression ratios. Experience has shown that the careless and improper handling of ethyl fluid leads to very serious consequences but that no trouble whatsoever results when a few simple instructions are followed. Tetra-ethyl lead, which is the principal constituent of ethyl fluid, is an oily liquid which shows a decided tendency to creep through the seams or joints of containers and pipe lines, thereby supplying abundant opportunities for leakage. Moreover, it is a heavy material of almost twice the weight of water, so that containers of suitable size for the operation of mixing gasoline are handled with difficulty and with ever present danger of physical injury to the worker, as well as with the likelihood of bursting if dropped or subjected to unusual violence. Tetra-ethyl lead has an appreciable vapour pressure at ordinary temperatures and if exposed to heat, the vaporisation of the fluid develops considerable pressure within containers; under extreme conditions (conflagration) this may result in bursting the container with ignition of its contents, and in case of containers having been exposed to the hot sun's rays a sudden escape of vapour will occur when the container is opened. Dr. R. A. KEHOE, Medical Director of the Ethyl Corporation, states that the oily (fat soluble) and somewhat volatile character of the material gives it a peculiarly hazardous quality among lead compounds in that absorption takes place in the human body both by way of the unbroken skin through contact and by way of the lungs through inhalation. Since all refiners rigidly observe the instructions issued by the manufacturer of this product, both in blending it with gasoline and in cleaning storage tanks, serious difficulties are no longer encountered in the handling and blending of tetra-ethyl lead.

Photo: Standard Oil Company of New Jersey

Fig. 5.—When necessary to enter enclosed areas where gas may be present a fresh-air hose mask must be worn. Blower must be located so that *fresh air* is obtained.

Cleaning Storage Tanks for Ethyl Gasoline.

Tetra-ethyl lead, alone or dissolved in gasoline, slowly decomposes to yield crystalline tri-ethyl lead compounds. Under normal storage conditions this decomposition is almost inappreciable but over a period of years variable amounts of such deposits can be found in the scale on the sides and at the bottom of storage tanks. If the sides or bottom of such a tank are cleaned in a dry state, finely divided dust containing tri-ethyl lead salts may be suspended in the air and may be inhaled by unprotected workmen who may enter the tank. The inhalation of these compounds, according to Dr. KEHOE, causes irritation of the respiratory mucous membranes and the skin, accompanied by violent sneezing, weeping, and burning of the skin. If this sharp warning be ignored, further exposure may result in rapid absorption and "acute intoxication". Recently, Dr. STEARNS of the Boston Psychopathic Hospital reported a case of encephalitis due to tetra-ethyl lead or tri-ethyl lead in a man who was engaged in cleaning gasoline storage tanks, although it is reported he wore an asbestos suit and a gasmask connected with a pipe line to a fresh air supply Repeated exposure to small amounts may lead to chronic lead poisoning. It is a simple matter to prevent lead poisoning of this type either by cleaning the tanks in a wet state or by the use of air line masks during cleaning. Actually a combination of these two safety measures is employed in routine cleaning at refineries in general. This work should be done exclusively by experienced men who have been instructed in handling ethyl fluid and who have been certified in writing by the company doctor within the previous six months as authorised to clean ethyl gasoline tanks.

So much has been written regarding the dangers of ethyl fluid and the safe method of handling the product that a further review of the subject is unnecessary here. The hazard has been minimised where proper mixing equipment and adequate storage are provided. As a further precaution, all those engaged in handling the product are periodically examined for signs and symptoms of lead poisoning.

Sandblasting Operations

A hazard which has been introduced by improved refinery operations is the possibility of contracting silicosis by men doing sandblasting work, unless special precautions are rigidly observed. Sandblasting is largely employed as an economy and efficiency measure and is used to clean storage tanks, drums, towers and other refinery process equipment to remove rust and prevent corrosion. This operation generates considerable dust of a high silica content, which when inhaled over a period of time, causes a fibrosis of the lungs known as silicosis and predisposes the individual to tuberculosis and other respiratory diseases. There is now a voluminous literature on the subject of silicosis. Effective protection against inhalation of the dust is afforded the operators by providing efficient positive pressure helmets. All men doing this work should be physically sound. Abundant ventilation should be provided at all times and the helmets worn by the operators should be supplied with adequate filtered air. There is a definite danger of men working in the vicinity of sandblasting operations and near exhausts from areas being sandblasted; therefore work in such areas should be reduced to a minimum and conducted, insofar as practical, on the windward side.

Welding

Welding is an operation of ever-increasing importance in the petroleum industry, especially in construction, maintenance and repair of plants and equipment. Reports show that many accidents have resulted from inadequate precautions in gas and electric welding and flame cutting operations. The growing use of coated or shielded welding electrodes has introduced further health complications. Certain groups of workers are exposed to heat, variations in temperature, dampness, and to the ultra-violet and infra-red rays and the gases and fumes incident to welding and cutting operations. It is evident from the extensive use of the oxy-acetylene flame and the electric arc with only an occasional report of injury, that the health hazards are in general not widespread. However, theory, scientific investigations and practice indicate that harmful air contaminants may be either produced or encountered under some conditions of use and that cases of injuries have been reported. The amounts of the harmful air contaminants depend on the procedures used, size of the flame or arc and metal or rods used. The hazards to health vary with the quantity of deleterious substances produced and the exposure duration of workmen to them. While there may be health hazards when welding is done in the open, they are definitely produced by cutting and welding operations in closely confined spaces. These hazards may be minimised by the use of proper personal protective equipment and adequate ventilation. Since full and complete information on welding and cutting operations is so readily available, further discussion is unnecessary.

Metallising Operations

Like welding, metallising operations (the spraying of molten metal on objects) are of importance to the petroleum industry and are used rather extensively at certain refineries. The hazards due to exposure to metallic fumes and dusts depend upon the toxic properties of the metals involved, the concentration of fumes and dusts in the working atmosphere and the duration of the exposure. The most harmful fumes and dusts are usually those produced by metallising with chromium, lead, cadmium, copper and their various compounds. Adequate respiratory protection that covers the body will prevent skin absorption of toxic metallic fumes and dusts. Persons engaged in metallising operations may incur accidental injuries due to (*a*) fire or explosion; (*b*) excess metallic fumes and dust; (*c*) oxygen deficiency; and (*d*) other hazards coincident with the operation.

Medical Supervision.—Employees engaged in metallising operations should have a physical examination periodically at least once a year to ensure that the precautionary measures which have been provided are giving the necessary protection.

Personal Protection.—When spraying metals in closed vessels or confined areas, or when spraying lead, chromium, zinc, copper and cadmium and their various compounds in open areas, an approved hose mask supplied with air from an uncontaminated source should be worn. Where compressed air is used, an efficient filter should be installed in the air line to the mask to remove impurities and offensive odours. When spraying copper bronzes, steels and similar hard metals in open areas, an approved cartridge type respirator should be used. In open areas, the operator should take full advantage of wind currents, taking a position so that the wind is at his back and blows the fumes and dusts away from him. Adequate body protection such as

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gloves with long gauntlets and cover-alls that fit tightly at the wrists, neck and ankles should be worn.

In general, only the operator should be allowed in the vessel or confined space when metallising is being done. Other persons in a vessel or confined area where metallising operations are being performed should be provided with protective equipment similar to that of the operator. When metallising is frequently performed in shops or buildings, booths equipped with hoods and exhausters should be provided.

When metallising in a closed vessel or confined area, a man should be stationed outside the manhole or opening to render assistance if necessary. Goggles with lenses in accordance with the United States Bureau of Standards density formulas should be worn by operators and others whose eyes may be exposed to the flame.

After metallising with the more harmful metals, operators should wash their hands and face and clean their finger nails before eating. At the end of the shift they should bathe, change to fresh clothing and again clean their finger nails. The teeth should be brushed twice daily.

Comparative Health of Petroleum Refinery Workers

Despite the health hazards discussed in the foregoing paragraphs and perhaps other possibilities of occupational disease in the petroleum industry, statistical data on the frequency and distribution of diseases and affections peculiar to petroleum refineries are very limited. The more acute poisonings are perhaps reported as accidents rather than occupational diseases, and chronic diseases or secondary complications may be of insufficient severity to attract special attention. The affections most frequently associated with the industry are the various diseases of the eyes, skin diseases, and gastro-intestinal disorders.

According to Dr. McConnell, the chief reason for the low incidence of occupational affections among petroleum workers may be credited to the enforcement of the industry's progressive measures for the prevention of exposure to toxic gases and vapours, and any exposure that does occur is usually the result of accidents and irregularities in the operations. Mechanical safeguards to lessen the hazards have been installed. The general practice is to confine gases and vapours in a closed system at all times. Vents specially designed to remove toxic gases and vapours to places where they can be safely discharged are in general use. Careful plant inspections are made and the workmen are instructed to avoid breathing the gases and vapours and to keep out of places where gases may collect. Tanks that must be entered are steam cleaned and ventilated and men are provided with protective equipment. Most of the employees are instructed in rescue methods and first aid. Protective and rescue devices are well maintained and are available at all times.

Generally speaking, petroleum refinery managements, through their medical and safety departments, have been alert to their health hazards and have spent considerable money and effort in finding practical solutions to their problems.

Protective and Precautionary Measures

In order to combat properly the hazard of toxic and flammable gases and vapours, it is necessary that certain available protective measures be remembered. There is probably no substitute for adequate ventilation. Natural ventilation is often inadequate and general or local exhaust ventilation must be used. The substitution of less hazardous materials, the isolation of operations involving the use of toxic materials to separate rooms, exhaust hoods and adequate ventilation are frequent means of combatting these hazards.

Nowhere in industry can one say that man's life depends more on the dependability of a gas detecting instrument than in the petroleum industry. Many organisations use one of the very oldest instruments for the detection of noxious gases, the human nose. While the sense of smell was used first and in many places is still in use, it cannot be classified as the ideal means of detecting toxic or explosive gases. When continually used to detect odorous gases or vapours, the sense of smell becomes dulled. This does not occur overnight but is a gradual lessening in efficiency of this faculty. Several very deadly gases are odourless. Therefore, the sense of smell cannot safely be used to detect the presence of dangerous gases.

Satisfactory protective measures cannot be applied until the hazard has been evaluated. For these reasons some other means of gas detection must be used to determine when toxic gases are present in dangerous concentrations and, in the case of petroleum vapours, when

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such gases and vapours approach explosive concentrations. Petroleum refiners are coming to depend more and more on instruments for the protection of their equipment and the lives of their employees.

Combustible Gas Indicators

In the last few years, combustible gas indicators have been developed especially for the use of refiners. These have been adopted and are widely used to-day by most progressive refineries with unusual success and have resulted in definite savings in life and property as well as in the elimination of excessive steaming of tanks and equipment during gas-freeing operations. Since steam is costly, the use of combustible gas indicators results in reduced operating expenses. The principle of operation in most of these indicators is to pass the air under test over a wire which is heated to a temperature that will ignite the gas present. At the same time, the change in resistance of the wire produced by the increase in temperature from this ignition is measured. The Wheatstone Bridge principle is employed to measure this change in resistance. The increase in resistance is proportional to the amount of heat generated by the sample. Since the petroleum gases encountered all generate approximately the same amount of heat per unit volume at the lower explosive limit, the scale of the instrument can be calibrated to give direct readings in per cent. of the lower explosive limit. Most of the indicators are designed for use in concentrations below the lower flammable limits of the gases or vapours to be tested, although they can be used to show whether the concentration of a flammable vapour is within the lower or upper limits or under the upper limit. For greatest accuracy, these instruments must be calibrated against the gases which are to be tested. General purpose instruments are available that will show with a fair degree of accuracy the percentage of any flammable vapour or gas that may be present in the air being tested if the amount is below the flammable limit. Instruments of this type are also available that will show toxic concentrations of gases, such as carbon monoxide and hydrogen sulphide and oxygen deficiency, as well as the concentration of combustible gases that may be present. Pocket-sized indicators are also on the market and these are found to be of great convenience to the safety engineer in making field tests. The combustible gas indicators of the type described above will not indicate the amount of flammable gas present if there is an oxygen deficiency or if there is a concentration of the gas in the atmosphere above the upper flammable limit. In the latter case, a dilution valve must be used to secure readings. A combustible gas indicator fitted with a special adaptor may be used for indicating the presence of benzol in air samples.

Where there is a constant hazard of the concentration of combustible gases reaching the lower explosive limit, an instrument which continuously indicates the concentration of these gases should be provided. Several such instruments are available on the market.

Carbon Monoxide Detectors

A number of instruments have been developed which do what man's nose could never do—detect the presence of carbon monoxide and in some cases sound a warning when the concentration reaches the lower toxic limit. It has been found that 0.02 per cent. of carbon monoxide is toxic when breathed continuously over long periods of time. Only recently a portable instrument has been developed that will detect these concentrations in various parts of the refinery, in garages and in the cabs and bodies of motor trucks. A more recent development is an alarm which will sound when the lower danger limit of 0.02 per cent. is exceeded. This alarm is being applied in certain phenol purifying rooms where carbon monoxide is employed.

Instruments for determining Dust Concentrations

The *Zeiss Konimeter* and the *Bausch & Lomb Konoscope* are examples of commonly used grab sample collectors. With both these types, a microscope is included in the instrument so that samples, usually about thirty in number, can be read in any convenient darkened room. It should be emphasised that these instruments give comparative results only and that more conclusive and accurate determinations of dust contaminants should be made by means of an impinger or an electrostatic precipitator. Lead fumes or welding fumes and mercury should be collected with the electrostatic precipitator, for other collecting methods are not efficient when particles of this size range are encountered.

Estimation of Halogenated Hydrocarbon Vapours in Air

Vapours of halogenated hydrocarbons can be determined by the various physical methods

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used for the general estimation of organic solvents in air. These methods include absorption on activated charcoal or on silica gel, condensation and measurement of the vapour tension of the re-evaporated halogenated hydrocarbon, use of the interferometer, absorption of ultra-violet light, and other non-specific methods. Since these methods are non-specific, they cannot be used in the presence of other solvent vapours unless only a total vapour concentration is required.

Oxygen Deficiency Indicator

Whenever the flame of a miner's flame safety lamp will burn, there is more than 16 per cent. oxygen in the atmosphere surrounding the lamp. This is sufficient to support life. For this reason the flame safety lamp has had a very wide use as an oxygen deficiency indicator. Owing to limitations in the protection afforded against propagation of flame by the screens or gauzes, the use of this device in a suspected atmosphere, where there is any possibility of the existence of hydrogen, acetylene or other flammable or explosive gas, must be prohibited. However, in the past few years, the *Wolf Oxygen Deficiency Indicator* has been developed. It consists of a modified miner's flame safety lamp in which a sample of the suspected air is drawn by means of an aspirator bulb and passed directly into the combustion chamber of the lamp. If the flame dims, the oxygen is lower than normal. If it goes out, the oxygen content of the sample is below 16 per cent. The instrument is protected by a very efficient flashback arrester, and since it is always operated in the clean air, sampling a combustible or otherwise dangerous mixture is a safe operation.

Hydrogen Sulphide Indicator

A very handy portable indicator for hydrogen sulphide, one of the most deadly gases met around refineries, has been developed recently by the United States Bureau of Mines. It consists of an aspirator bulb which draws a sample of air to be tested through a glass tube containing silver cyanide which changes colour in the presence of hydrogen sulphide. A unit volume sample is drawn by giving the bulb ten full squeezes and the amount of hydrogen sulphide is indicated by the length of the stain in a replaceable detector tube. This length is measured against a scale on the instrument so that the percentage of hydrogen sulphide can be read directly. When one considers that the greatest concentration to which a human being can be exposed safely for a fifteen minute period is 0.03 per cent., it will be readily appreciated that this instrument is extremely helpful for field use where workers are likely to be exposed to this hazard. Much lower concentrations are definitely indicated on the tubes and scale of this detector. While hydrogen sulphide has an unmistakable odour in small quantities, the longer the exposure is continued and the more frequently a person is exposed to it, the less effect it will have on the olfactory nerves.

Personal Protective Equipment against Gases, Vapours and Dusts

Of the various personal protective devices which may be used, the hose mask, the self-contained oxygen-breathing unit, the supplied-air respirator or gas mask, canister gas masks, and the various types of chemical-cartridge and filter respirators are the most commonly used at petroleum refineries.

Hose Masks.

Hose masks afford a supply of fresh air to the wearer either by having pure air pumped to a tight-fitting face-piece from a small hand operated blower, or by permitting the breathing of fresh air through a hose whose open end is placed outside of the zone of contamination. They are especially useful not only in contaminated atmospheres but also where a deficiency of oxygen may be found. Their use is somewhat limited because they require an additional man for operation of the blower type except where motor-driven blowers may be used safely and the length of hose which can be used in the fresh-air breathing type is limited. If the hose exceeds 25 feet in length a blower should be provided; otherwise. the free end of the hose should be equipped with a funnel screened to prevent the entrance of foreign substances. Life lines are necessary to permit the removal of the wearer from contaminated atmosphere if he should be accidentally overcome. The construction of later models is such that the hose line may be utilised as a life line when men are working through a side manhole of a tank.

Self-Contained Breathing Apparatus.

Self-contained oxygen-breathing units afford the wearer an adequate supply of respirable air by supplying oxygen from a small tank carried on his back. They are made in several sizes and weights depending upon the length of protection desired. Their chief use is found in atmosphere deficient in oxygen, such as manholes and enclosed tanks.

Supplied-Air Respirators.

These are intended for use in operations where protection from dust, vapours, or gases is required but from which the wearer can escape without the use of the respirator. They consist of either a half or full face covering to which fresh air is constantly supplied from a compressed air line, in an amount always in excess of that required for breathing. The excess air flows out through the exhalation valve, or about the face-piece. On operations such as welding, paint spraying and others, they are especially preferred.

Canister Type Gas Masks.

Masks of this type are used where the concentration of the contaminating gas or vapour is below the maximum for which they are intended, either 1, 2, or 3 per cent., depending upon the type of gas and the canister. An adequate supply of oxygen is an imperative necessity and under no circumstances should canister type masks be used unless the atmosphere is definitely known to contain a minimum of 16 per cent. oxygen. The neglect of this requirement has resulted in many fatal accidents. In operation, the contaminated air enters the canister, passes through the sorbent which removes the contaminate either by absorption (as in the case of gases such as sulphur dioxide); adsorption (such as the removal of organic vapours); by the combination of both absorption and adsorption; or by catalysis (such as the removal of carbon monoxide). The purified air then passes to the tight-fitting face-piece of the wearer. Canister type masks, using a special neutralising agent, usually afford sufficient protection for tank gaugers, pipe-line inspectors, and others who work in unconfined places; but hose masks should always be used by workers in tanks and in other restricted places where the air may contain insufficient oxygen to sustain life or the poisonous-vapour concentration may be great.

Chemical-Cartridge Respirators.

These are devices affording protection against toxic gases and vapours of comparatively low concentrations. They are used for prolonged wear in atmospheres offering the chronic rather than the acute type of exposure. They are intended for use only in toxic atmospheres from which the wearer can escape without respirator.

Filter Type Respirators.

Filter type respirators are devices affording protection against toxic dusts and are similar to the chemical cartridge types in construction and use with the exception that the cartridge is replaced by a suitable filter and holder.

The United States Bureau of Mines has set up schedules and specifications for all of the above types of protective devices except chemical cartridge respirators. This enables refiners and safety men to select those devices which are manufactured to the high degree of perfection required for meeting these specifications.

Organisation for Accident Prevention

Success in any programme or operation will be assured only if the work is well organised, systematised and continuously maintained. There must be centralised control and leadership. With these principles in force, co-operation is bound to result; and co-operative efforts in any line of endeavour can mean but one thing—Success. Organised safety work has a powerful influence on the loyalty of employees and on the morale of the whole organisation. Employees come to regard safety activities as a measure of company interest in their welfare and any let-up in such activities is sure to be followed by a falling-off of the men's efforts in other directions and by lowered morale all along the line.

A safety organisation is primarily a planning and service agency authorised to see that its plans, accepted as company policy, are carried through to successful conclusion. It is the essence of successful planning that motives are formulated as little as possible on the basis of tradition, hunch or guess and as largely as possible on the basis of objective research, inspection, investigation and experience. Any organised programme must be designed, planned and executed to inculcate into the minds of all employees a constant feeling of safety consciousness. All foremen and workmen must be trained to think and must, before attempting to perform any task, be trained to ask themselves whether they have outlined the safe procedure, whether the necessary safeguards are being provided and whether all necessary precautions are being followed. When this achievement becomes a reality, it may be truly said that the organised safety programme has become effective. Such a safety programme depends to a great degree upon co-ordination with other departments. Mr. J. L. Risinger, Safety Director, Socony Vacuum Oil Company, tells us it is fundamentally imperative that:

(1) Company executives recognise the importance and vital necessity of a definite and effective organisation of a safety department; that its objectives are well defined and that its channels of procedure are kept open.
(2) That the safety supervisor be big enough that his ideas merit the consideration of senior executives in their planning; that he be tactful enough to effect the correction of hazards and adherence to standards of safe practices without friction; that he be thorough enough to be correct in detail and not lose his sense of proportion to the extent of over-emphasising non-essentials. The value of the programme is greatly depreciated when the leaders of the programme itself spend most of their time overboard.
(3) That the safety organisation function effectively with service departments, planning agencies and operating departments, so that safety links its way into and through every activity of the company from the chief executive, not only to the newest and lowest paid workman, but beyond the gates to the prospective workman and to the homes and recreation centres of employees' families.

Varying conditions at different units affect each local safety organisation but insofar as possible safety work should be organised uniformly. The practice of one large petroleum company having refineries in various parts of the United States is described below.

For Plants having between 500 and 5,000 Employees.

The most effective organisation is to have a General Plant Safety Committee consisting of the heads of the larger departments. The size of this General Plant Committee varies from about ten to fifteen members. It is headed by the assistant superintendent of the plant. Under this Committee's direction are a number of standing Sub-Committees, arranged to inspect definite departments, although in some cases they are assigned a very wide range of duties. As an illustration, the work assigned six Sub-Committees at one of the large refineries is as follows:

Laboratory or Chemical Department.
Mechanical—which takes in the various shops of the plant.
Shipping—which covers the safety of loading racks, barrel house, cooper shop, etc.
Pressure Stills.
Construction and Maintenance—which covers the safety of the various crafts engaged in general construction and maintenance work.
Manufacturing—which takes in various plant operations on stills, agitators, wax plant, etc.

The personnel of the Sub-Committees is very important. At the larger points each Sub-Committee consists of six or seven members. At smaller points, from three to five members. These men, as a rule, are foremen or sub-foremen appointed by the local chairman. It will be seen that at a large refinery the total number of committee members whose duty it is to carry out the safety programme is from 50 to 75 men.

Work of Sub-Committees.—Each Sub-Committee makes a monthly inspection of the areas and departments assigned and holds a meeting in which it discusses and reports all the unsafe conditions or practices which they have unearthed. Its suggestions and recommendations form the subject matter of the General Plant Safety Committee which likewise meets each month. The Sub-Committees' recommendations or suggestions are arranged in numerical order and are continued on future minutes of meetings until properly disposed of. The General Plant Committee's minutes are in turn sent to the Sub-Committee members so that they may know the disposition of each item. Many items that are brought up by the Sub-Committee are of such a nature that they can be immediately taken care of without any help from the General Plant Committee.

The chairman or secretary of the General Plant Committee keeps the Sub-Committees functioning and attends as many of their meetings as possible. One of the most important provisions of the plan is that this chairman or secretary should see that action is taken on the Sub-Committees' recommendations and send out

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word as promptly as possible as to the disposition of each recommendation. There is no greater stimulus than for the Sub-Committeemen to know that their work is viewed as important and their recommendations acted on promptly by the management.

The minutes of the Sub-Committees naturally reflect the work which is required to advance safety but in order that some record of individual work accomplished may be secured, each Sub-Committeeman distributes among the various foremen a blank form on which each foreman's monthly accomplishments can be reported. It reads:

During the past month I have personally corrected or had corrected unsafe physical conditions and have cautioned employees against unsafe practices as follows.

After this sentence a space is left for the various items to be listed. The blank form then continues:

If you cannot personally correct an unsafe condition or practice advise the Committee either by letter or in person. When cautioning a fellow-employee against an unsafe practice or condition, be sure to speak with courtesy and consideration.

In Smaller Plants.

The most effective method of safety organisation in plants of between 100 and 500 employees is practically the same as in the larger plants. The General Plant Committee is naturally smaller but as in the case of the larger plants the local superintendent and his staff officers are the members. The assistant superintendent and the employment supervisor are chairman and secretary respectively. The standing Sub-Committees are three in number. Instead of lining up their work by departments it is more specialised. For example, three Sub-Committees function in the following manner. One, a Sub-Committee on plant inspection; another a Sub-Committee on safety equipment; and third, a Sub-Committee on fire organisation and equipment. As is the practice at the larger plants, each Sub-Committee meets separately and not with the General Plant Committee. The same method of numbering recommendations is followed and found very satisfactory.

One important matter of organisation at the small plants is the appointment of several workmen to each of the Sub-Committees. These workmen serve for three to six months, which makes it possible in the course of a year or two to have in the forces a substantial number of workmen who have become familiar with many of the plant's safety problems and had intimate contact with that part of the supervisory force on whom falls the responsibility for safety. This practice brings the safety work home to the workmen better than any other method and reduction in accidents has been largely due to the conscientious work of the plant Sub-Committees.

Special Sub-Committees.—At various times there are special Sub-Committees at work on such matters as safety campaigns, standardisation or investigation of safety equipment, first-aid teams, etc. The secretary of the General Plant Safety Committee is the one on whom falls the responsibility of keeping the safety work going. He is the key man of the safety organisation and the effectiveness or success of the safety work depends upon his efforts. He arranges the Sub-Committee meetings, instructs new employees in safety, investigates causes of accidents and arranges for the investigation and determination of action on those suggestions or recommendations which require executive approval. It is necessary for him to arrange special campaigns, gang meetings, etc. to keep up the interest. No matter how effective the safety organisation may be, old subjects must be revived and given a new interesting turn, and personal interest must be quickened wherever it may be found to lag.

Safety Guards.

A large refinery in New Jersey, in addition to the members of the local safety committee, has appointed "Safety Guards", one for every 100 men working in the department. The duties of these guards are to check any unsafe condition or practice and report them to their foreman. Numerous instances of unsafe conditions and practices have been reported by the safety guards to the safety department. A safety guard was appointed as inspector of ropes, cables, cranes and all hoisting tackle used in the plant. It is his duty to maintain in first class condition all ropes used on fire equipment, safety boxes containing life rings at the piers and those on top of condenser box platforms. Gas masks are also maintained in first class condition. All face-pieces of masks are turned in to the safety department every three months for sterilisation and cleaning in hot water, which keeps the rubber pliable and prevents hardening and cracking. It is a rule that face-pieces should be turned in for sterilisation and washing immediately after being used. This prevents the promiscuous use of the masks by different persons and each employee wearing one knows that it is clean and sterile. Another safety guard was appointed as tool inspector. He covers the entire yard once every three months, checking the tools used by each individual employee. The work of this inspector or safety guard reduced accidents due to unsafe tools 90 per cent. and the results from increased production and satisfied employees is beyond computation.[1]

Maintaining Employee's Active Interest in Safety

After all is said and done, accidents, fires and explosions will continue to occur in refineries unless every employee's active interest in accident prevention is maintained. Maintaining interest in safety is a perplexing problem of management and from past experience it would seem logical to assume that, where accidents are on the increase, attention should be given to re-enthusing the foremen and workmen with the safety idea through such means as safety talks, circulation of safety literature, meetings, competitions, the use of effective posters, special accident score boards and other proven means of presenting the subject which will catch the attention and make the right impression. However, in order to maintain consistent interest in the prevention of industrial injuries in any operation, the employees must be convinced that the management is actively and aggressively interested in safety work.

[1] For further information on Safety Organisation see *Organisation for Accident Prevention*, published by the American Petroleum Institute.

CONCLUSIONS

Petroleum refining operations involve the handling of crude oils having variable compositions, under wide variations in temperatures and pressures, in more or less elaborate equipment consisting of a maze of pipe lines, tanks, vessels of all sorts, steam, gas, and electrical apparatus. Vapours and gases from petroleum and its products are flammable and may cause fires, explosions and, in a few cases, serious illness or death through inhalation. Nevertheless, these dangers have been greatly reduced and in many instances wholly eliminated by complying faithfully with known precautionary measures and by the employment of suitable means such as have been described and others that have proved effective.

More constructive safety work is now being done in most modern refineries, starting in the early engineering phases of a job and carried through into the construction, even to the extent of complete operating rules, and a training period for the operating personnel prior to the starting-up of the operation. Many new pieces of equipment have had a development of this type and have operated with surprisingly good experience with respect to the absence of fires and accidents. All this has resulted in a profitable reduction in operating costs and disability compensation claims, as well as in raising the morale of the personnel and increasing the efficiency of the workers.

In closing, it may be added that the monetary loss is no longer a true gauge of the fire and accident cost in refineries; it is the interruption they cause in the continuous supply of vital petroleum products to our armed forces which is of prime importance to-day.

SOME RECENT I. L. O. STUDIES

Joint Production Committees in Great Britain

Describes the system of joint production committees in individual factories, mines, shipyards and other establishments that has been developed in Great Britain in order to secure full labour-management co-operation in war production.

CONTENTS

Montreal, 1943. 74 pp. Price: 50 cents; 2s.

Life Saving Measures for Merchant Seamen in Time of War

The safety of merchant seamen was one of the principal subjects of discussion at the Twelfth Session of the Joint Maritime Commission of the International Labour Office, which was held in London from 26 to 30 June 1942.

The Commission had before it, as a basis for its discussion on safety at sea, a survey prepared by the International Labour Office which gave a comparative summary of the rules on life-saving appliances applicable to foreign-going cargo vessels of the merchant navies of Great Britain, the United States of America, the Netherlands and Norway.[1] (This survey dealt with the rules of these countries as they stood at about April 1942.) The British Ministry of War Transport, which at the time the Commission met had almost completed a revision and consolidation of its wartime safety appliance rules, made available to the Commission full information concerning the new and amended rules it was about to issue. In the light of all this information, the Commission adopted unanimously three resolutions on safety at sea, the texts of which are reproduced in the present report.

In one of these resolutions the Commission requested the Office to "communicate to Governments as soon as possible . . . a summary statement of the life-saving measures best calculated to protect merchant seamen in time of war". This booklet has been compiled in compliance with the Commission's request.

The statement presents—it is believed for the first time in such a form—a concise exposition of the latest rules for the protection of the lives of merchant seamen in time of war, which will no doubt also serve as a basis for any revision of such rules, nationally and internationally, which may take place when peace is restored.

[1] Published in the *International Labour Review*, Vol. XLV, No. 6, June 1942: "The War and Merchant Seamen: II—Life-Saving Appliances", and available as an offprint, price 5 cents or 3d.

Montreal, 1942 59 pp. Price: 35 cents; 1s. 6d.

STUDIES IN WAR ECONOMICS

Six essays on war finance, wages, housing, food prices, etc.

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Montreal, 1941. 199 pp. Price: $1; 4s.

LABOUR CONDITIONS IN WAR CONTRACTS

An analysis of the labour clauses and similar regulations applying to war work in Canada, the U.S., and Great Britain, and a brief discussion of some of the problems involved.

"As an introduction to the study of labour legislation in wartime, the book is admirable ..."—*Industrial Canada.*

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