but not on the other. Now the employees at all plants are under strict instructions to lock all switches when a machine is being repaired.

Sell It

Many employees have the mistaken idea that a safety program is for the benefit of the company only. Your third factor therefore, in selling safety to your employees, is to show them that they too will gain by cooperating with your program. Deep down in most human hearts is a desire for security, a desire to live and a desire for freedom from the consequences of disaster. Jobs mean security, food, clothing, family, and recreation. Self-preservation, "Nature's First Law," involves not only protection against death but protection from accidents that might result in injury or impairment to health. Sell the employee on his own pocket-book. Show him how he can profit in dollars and cents by cooperating with the safety program. Everyone loses when an employee has a serious injury. Aside from his own pain and suffering, his family has the anxiety and the loss of income. The company loses in several ways, but usually the invisible loss is much greater than the visible loss.

It is only natural that the employee likes to feel that he is essential or at least important to the organization. He likes to feel that he is trained for his particular line of work and that he could not be replaced easily. I feel however that the employee should be made to understand that your safety program is important and you demand his full cooperation.

Do It

I have visited plants, held meetings, pointed out hazards, in fact, have done all the things I might normally be expected to do, then before I could get home, a serious accident would occur. Your safety program, if planned—and it must be planned—is only a mass of talks, booklets, rules, and posters until it is put into practice by men, materials, and action. First, management must be sold. You may be the best safety director and/or may have the best supervisory force in the world, but unless you have the whole-hearted cooperation of management your safety program will not be successful. H. Woodhead, president, Consolidated Vultee Aircraft Corporation, said several years ago "a good safety record, in my opinion, is the proof as well as the result of good management." When you have succeeded in selling management, then it should be comparatively easy to sell operations. Your supervisors with the assistance of the safety director are charged with the responsibility of selling the program to the employees.

I saw one of our supervisors one day cutting metal with the acetylene torch without wearing his goggles although the machine had a nice new sign on it which read "Do No Use This Machine Without Goggles." A pair of goggles hung on the machine. When I called his attention to the fact, he said that it would take only a few minutes for the job and that he had no goggles with him. With that I reached for and handed to him the goggles from the machine. That it takes only a fraction of a second to lose an eye from hot metal is not the sad part of the story. To any employee who saw him or heard of that unsafe act he has foreover lost any influence he may have had in the promotion of accident prevention.

In summarizing, I would like to point out that accident control is as much a part of your operations as protein control or extraction. Until your organization from top management down realizes this, your safety program cannot be successful. Tell your employees about your program. Show them the correct way to do the work assigned to them and further illustrate with posters and warning signs. Show the employee that the program is not for the benefit of the company entirely but for his profit too. Your supervisors should set a good example before their men. Endeavor to imbue each and every employee with a desire to protect himself and those associated with him from accidents which may result in injury or death. And remember too, that accidents do not happen, *They Are Caused.*

Safety Aspects of Handling Heavy Fuel Oils

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WHERE ADEQUATE SAFETY provisions are incorporated in the design of heavy fuel oil installations and where appropriate operating procedures are followed by personnel who recognize the potential danger of fire, there is little hazard involved in the use of heavy oil as a fuel. Fires in heavy fuel-oil-fired plants have been quite infrequent, but where they have occurred, they have generally been traced to one or more of the following causes: faulty design in equipment, excessively high oil temperatures, introduction of water into the system, contamination with low-flash hydrocarbon, and improper mechanical repair procedures. This paper discusses some aspects of each of these potential fire-cause factors and some recommendations on fire extinguishment with heavy oils.

Faulty Design of Equipment

Excellent guides for the design of heavy-oil-handling facilities are contained in the N.F.P.A. Flammable Liquids Code No. 30 and N.F.P.A. Standard on Oil-Burning Equipment No. 31. These publications and those of reputable oil-burning equipment manufacturers, if carefully adhered to, should provide reasonable design safety protection. For this reason this subject need not be dwelt upon except to mention some design failures which have caused fires in the past or have contributed to the severity or difficulty of the extinguishment of fires.

A design feature which should not be tolerated in heavy-fuel-oil installations, or in any other hydrocarbon-handling facility, is overshot filling lines to tankage. This applies equally to recirculation lines and pressure-relief return lines. The process of free fall of liquid from top of a vessel to the liquid surface is a prolific generator of static electricity. If the vapor space contains a hydrocarbon-air mixture in the flammable range, an internal tank explosion can easily result. There are many well-substantiated cases of fires caused by this phenomenon in the record. Two of these cases are known to have occurred in heavy-oil storage. One occurred in a power plant installation where the fuel oil was being circulated through an external heater and returned to the storage tank through a top connection. Another took place in an asphalt storage facility. Asphalt was being charged to a 15 × 30-ft. vertical dome roof tank through a fired heater into an overhead line which allowed the asphalt to cascade to the surface through a free drop of approximately 15 ft. This procedure resulted in an internal tank explosion and fire, which ultimately involved several other similar tanks. There were at least three fatalities as a result.

An additional design failure caused this fire to be far more serious than it would otherwise have been. All the tanks in this installation were so constructed that their roof-to-shell joints were stronger than their shell-to-bottom joints. Each tank explosion therefore resulted in failure of the shell-to-bottom joint. Each tank left its foundation like a skyrocket, spilling its entire flaming contents. This type of occurrence leads to the recommendation that tanks in heated heavy hydrocarbon service should be constructed with the roof-to-shell joint deliberately made weaker than any other seam in the tank. This is standard practice on new tankage, but older existing tankage may not always be so constructed. Riveted tanks particularly may not have been designed in this manner. Replacement of roof-to-shell rivets with aluminum rivets or replacement of rivets with a light single-pass weld are two methods of guarding against tank rupture and oil spillage.

Excessively High Oil Temperatures

At atmospheric temperatures heavy fuel oils are essentially hazard-free both from the fire-prevention and personal-health standpoint. Injury from skin contact with the liquid or inhalation of vapors is so remote a possibility as to need no treatment in this paper.

It is necessary however in the handling of heavy fuel oils to heat them above atmospheric temperatures. Generally heating is required to allow the fuel to be efficiently pumped through the system. Heating for pumpability is usually accomplished in the bulk storage tank or in a smaller day tank if one is provided. Further heating is also required in order to raise the fuel to its proper atomization temperature to insure efficient combustion. Atomization heating is normally accomplished in an external heater between the pumps and the burners.

Number 6 or "Bunker" fuel oil has a viscosity range of between 45 and 300 Saybolt seconds furol at 122°F. The maximum range of viscosity which will assure free and efficient pumping of bunker fuel is between 400 and 500 Saybolt seconds furol. The viscosity of heavy fuels decreases very markedly with the increase of temperature. For example, oil which has a viscosity of 300 SSF at 122°F. has a viscosity of 3200 SSF at 77°F. Similarly oil with a viscosity of 100 SSF at 122°F. has a viscosity of 700 SSF at 77°F. It will be seen therefore that heavy fuel oil usually cannot be effectively pumped at average atmospheric temperatures even as high as 77°F., and it is necessary to reduce the viscosity to a maximum of about 400 SSF.

Oil with a viscosity of 300 SSF at 122°F. would have to be heated to a theoretical temperature of 118°F. whereas oil with a viscosity of 100 SSF at 122°F. would only have to be heated to a minimum temperature of 88°F.

The minimum flash temperature of bunker fuel oils is 150°F., and typical oils will have flash points well above this minimum and quite commonly on the order of 180°F. Heating in bulk storage or day tanks for viscosity reduction to meet pumpability requirements should never result in oil temperatures which approach the flash point of the oil.

Probably a maximum limit of 125°F. would provide adequate pumpability and give reasonable assurance of fire safety by providing a 25°F. margin below the minimum flash temperature. Exceeding this nominal limit is undoubtedly not uncommon in many installations. In many cases fuel oil tanks are deliberately held at temperatures as high as 150°F. or higher.

Sometimes, although a temperature as low as 120°F. is desired and thought to be maintained, much higher temperatures are actually achieved through lack of effective temperature control.

In the spring of this year a disastrous fire occurred on the West Coast in which a tank in a heated heavy-oil service boiled over because of the introduction of water or low flash hydrocarbon. Although details of this occurrence were not readily available, the preliminary report prompted us to review the methods used to control the temperature of our own heavy-fuel-oil installations.

We found that, in all but one such installation, the oil temperature was controlled by thermostatic regulations of steam to the heater coils. The single exception involved an older plant with low pressure boilers where 15 lbs. of steam were used to heat the oil. We were assured that steam pressure could not exceed 15 lbs. and tank oil temperatures could not exceed 140°F. Unfortunately modifications were subsequently made to the boilers, which resulted in greater production of hotter steam. This, in turn, very soon caused the tank to overheat and boil its contents over the top. Fortunately this tank had a weakened roof seam, and there was no large spillage of oil. Also fortunately the spilled oil did not find a source of ignition. Since that time we have made very sure that all bunker tanks are equipped with thermostatic shut-off controls and further that these controls are checked periodically for proper operation.

Heating to provide proper atomization viscosity generally requires temperature levels above the flash point of the fuel and on the order of 180°F. to 240°F. Whether electrical or steam heaters are used, this heating is done in a closed system (and so is safe). Fuel oil which leaks or sprays out of such systems at temperatures above the flash point is readily ignitible upon reaching any source of ignition. An additional consideration, even when ignition does not occur, is the hazard to personnel from contact with fuel oil at elevated temperatures.

Thermostats should be so located as to sense temperature in the hottest portion of the liquid, generally rather close to the steam coils. They must be placed low enough in the tank so that it is impossible for the liquid level to fall below the thermostat. In addition, it is necessary to keep enough oil in heated tanks completely to cover the heater coils. Low liquid levels and uncovered heated coils allow thin films of oil to be heated to temperatures well above the flash point and possibly even near the autoignition temperature. Maintenance of hot oil piping in good, leak-proof condition is a basic requirement for fire prevention and protection of personnel.

Introduction of Water or Light Hydrocarbon Into the System

It is not uncommon, where steam coils are used to heat heavy oils, to find some water in the tank because of leakage from the coils. Atmospheric condensation may also result in the appearance of water in oil tanks. If the temperature of the oil should then exceed 212°F., the water would flash to steam, probably causing a tank roof rupture and boil-over of the tank contents.

Contamination of heavy oils with low flash hydrocarbon, such as solvents or motor fuels, lowers the flash point of the mixture out of all proportion to the percentage of the contaminant. Upon heating, the vapor space in tanks containing contaminated oil may very easily be placed in the combustible range, where it needs only a source of ignition to cause a fire. Contamination with low-flash materials is usually inadvertent, but at least one case on record was deliberate. In this instance a tank truck load of heated heavy fuel oil was being delivered to a plant which apparently had a dirty furnace. In the belief that alcohol added to the fuel would clean the furnace, the customer proceeded to pour some into the dome of the truck tank. While the alcohol was being poured in, the truck exploded. The source of ignition undoubtedly was static electricity generated by the free fall of the alcohol onto the liquid surface. The combustible mixture was produced as the alcohol was vaporized by contact with the heated fuel oil.

Improper Mechanical Repair Procedures

A high proportion of fires involving petroleum occur during shut-down, start-up, and mechanical repair work. Particular attention should be given to these operations to insure against accident. Even the seemingly nonhazardous job of cleaning heavy-fuel-oil tanks can result in fire. This job is usually done with hot water jets or steam. Particularly where hot water is used, it is absolutely necessary to pump out all possible fuel oil and allow the heating coils and residual oil to cool before introducing water. Failure to do this was the cause of at least one very costly fire. Here again, the water flashed to steam as it contacted the hot coils, the tank roof came off, oil spewed out, found a source of ignition, and flashed.

Hot work, such as welding and burning, should not be done even on outer surface of heavy fuel tanks without first cleaning the interior surface to bare metal. This has been tried many times in the past and has also resulted in explosions.

Combustible gas indicators should never be used to determine whether the vapor space in heated tankage is within the combustible range. These instruments are reliable only at atmospheric temperatures. The safest procedure is not to perform even cold mechanical repairs on heated tanks without allowing them to cool. Where such jobs must be performed while the tank is hot, calculations based on oil temperature and flash point are likely to be more reliable than combustible-gas-indicator readings.

Fire Protection

The first precaution to be taken in fire protection of heavy-fuel-oil installations is proper design. Tank spacing and distances from adjacent buildings should conform to N.F.P.A. standards. Dikes should always be provided around above-ground heated tankage to contain the contents in case of spill or tank rupture. Piping should preferably be of welded or flanged steel construction, particularly within the diked area. Storage tanks should be equipped with a steam-smothering or foam-inlet connection.

Fire fighting on tanks containing heated heavy oils presents a difficult problem. If such fires are not very rapidly extinguished, the oil temperature steadily increases at the burning surface and this temperature wave progresses steadily down through the body of the oil. As the oil temperature exceeds the boiling point of water, application of foam or water can become hazardous. Foam will rapidly break down and, if applied at normal rates, may cause a slop-over to carry burning liquids outside the tank. Also solid water streams or continuous water fog streams directed into the tank could cause a slop-over. Any boil-over or slop-over is very hazardous as the burning liquids can carry into the air and flow over fire banks to endanger personnel and equipment in the vicinity.

Water should be applied to cool the outer surface of the tank on fire and any adjacent tanks or structures exposed to the radiant heat. Careful application of foam or frequent short-interval application of water fog to the burning surface may be attempted to smother the flames or cool the surface below the ignition temperature.

Wherever there is a possibility of boil-over, personnel attending the fire should be limited to those actually required by fire-fighting activities, and strict precautions should be taken to prevent fire fighters from being trapped.

Summary

1. Make sure fuel oil handling facilities conform to N.F.P.A. standards.
2. Avoid overshot filling lines.
3. Provide weakened seams on above-ground tank roofs.
4. Limit storage tank or day tank temperatures to 125°F. Provide positive control to prevent overheating.
5. Make sure thermostats are located in the hottest part of the oil. Operate storage so as not to uncover either the thermostat or the heating coils.
6. Do not contaminate fuel oil with water or light hydrocarbon.
7. Cool tanks and heaters before introducing water for cleaning.
8. Do not perform hot work repairs above the liquid level on tanks in service.
9. Do not rely on combustible-gas-indicator readings when the temperature of the vapor space being sampled is above atmospheric.
10. Be wary of boil-overs when lighting fuel oil tank fires.