should also be demonstrated. This includes the use of first-aid equipment.

There is an old saying "familiarity breeds contempt." We must be constantly alert to see that this does not apply to us as solvent-plant operators. Where operation proceeds smoothly over a period of time, there is the danger that carelessness may creep in and disregard for hazards may develop. It is up to supervisory personnel to see that this does not occur.

Safety inspections and checks of safety equipment should take place at specified intervals. This is done preferably by the safety director or some other person who is not a member of the operating department. Such a person is more likely to recognize potential sources of trouble than are those who live with the operation day by day.

Unscheduled shut-downs of a solvent plant are expensive, and frequently temporary repairs will be made to prevent a shut-down. Such temporary measures should not compromise safety and should not involve undue hazards. Decisions in these matters require an accurate appraisal of conditions and the exercise of sound judgment. The expense of a shut-down is preferable to continued operation under hazardous conditions.

A review of the safety records of solvent plants will reveal that most of the serious accidents can be traced to carelessness, disregard for hazards, and failure to observe established safety measures. Realization of the ease with which some of these accidents could have been prevented is indeed distressing when one considers the cost in suffering, human lives, and destruction of property. Each member of the operating team should resolve to be ever alert so that he does not endanger himself, his fellow workers, or the property of his employer.

Special Equipment and Operating Features Which Contribute To Safety in Extraction-Plant Operations

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IT IS, OF COURSE, difficult to over-emphasize the importance of safety in our extraction plants because a safe operation has tremendous bearing not only on our personal safety but on our jobs as well. There are very few minor fires in extraction plants; any fire at all is likely to be a major one, resulting in serious loss of property, personal injury, and extended loss of production.

It is our intention to discuss certain special equipment and operating features which can be built into the extraction phase of an oilseed processing operation to improve the safety rating. These remarks will be limited to the hazards peculiar to hexane solvent-extraction plants and more particularly to the fire and explosion hazards inherent in such an operation. Such special features will be discussed from an engineering point of view as they affect the safety which we all want to have in our operations rather than from the point of view of the plant-safety supervisor or the insurance man. In some cases, of course, these three viewpoints, engineering, safety, and insurance, are identical; other cases arise however where good engineering judgment indicates a limit to the safety equipment which should be installed in a plant. This does not mean a de-emphasis of safety but rather a need for more emphasis on the personnel and operating phases of safety. It is probably impossible to build a solvent-extraction plant which cannot be blown up by poor operation or careless personnel.

Before discussing specific safety items, it would be well to review the physical properties of hexane, the most commonly used solvent, which make it a hazardous liquid. Hexane is a relatively low-boiling solvent, which means that it has a relatively high vapor pressure at any given temperature and that, at any place where there is hexane liquid, we are likely to encounter a rather high concentration of vapors. Fires and explosions, of course, do not take place in the liquid as such but only in the vapor phase and specifically only when the vapors are mixed with a proper amount of air or oxygen. When expressed as percentage by volume, the explosive limits of hexane in air are 1.2% for the lower explosive limit and 6.9% for the upper explosive limit. Another way of looking at this would be to determine by calculation at what temperatures of the liquid we will have a vapor over the liquid in the proper proportion with air to form an explosive mixture. By calculation, we find that the lower explosive temperature, if we can coin a phrase, is —5 degrees F., which corresponds closely to the closed cup flash point. The upper explosive temperature is found to be approximately +35 degrees F. Hexane liquid and vapors, which are at equilibrium with air in a confined space above this upper explosive temperature cannot be ignited and are therefore relatively safe; it should be noted however that equilibrium conditions are attained rather slowly because of the wide specific gravity difference between air and hexane vapors.

Normal extraction operations in which hexane is present are carried out in the range of 120° to 155° F. so that as long as there is liquid hexane present in these operations and the system is confined, the vapors over the hexane will be above the upper explosive limit and do not represent a hazard. The major hazards in extraction operations therefore arise from two causes: one, when the liquid is not confined to a closed space; and two, during start-up and shut-down periods when the equipment is cold and/or equilibrium conditions are not present.

The seven basic rules for the safe handling of flammable liquids in general are to (1) isolate the hazard, confine the liquid, ventilate to prevent explosive mixtures, instal explosion vents where needed, eliminate ignition sources, educate employees on hazards and safeguards, and provide adequate fire protection.

With this outline in mind a number of safety features which can be built into an extraction plant to improve the safety rating of the operation will be discussed. It is not intended to cover all of the safety precautions, equipment or otherwise, which are necessary for a safe operation but rather to describe only certain special features which may be of unusual interest.

Inert-Gas Purging of Extractor. The greatest period of hazard in the extraction building probably occurs when the extraction equipment is shut down either for regular cleaning and maintenance or because of a mechanical failure. As the extractor cools, the hexane vapors inside the extractor condense and create a partial vacuum within the unit. If no special precautions were taken, air would be drawn into the extractor during the cooling period and, at some locations within the extractor, the vapor concentration would be within the explosive range. The same situation would, of course, occur if instead of letting the extractor cool with the vapors still inside it, the vapors were to be swept from the extractor by a stream of air. To prevent an explosive mixture from forming at this time, some of the vapors can be swept out of the extractor by a stream of inert gas. One method of providing such an inert gas is by means of an inert gas generator. The general practice in using this type of machine is to ventilate the extractor with three volumes of inert gas over a period of 2 to 4 hrs. The mixture of inert gas and hexane vapors leaving the extractor is taken through the normal vent-cooling system to recover the majority of the hexane, and the inert gas is then vented to the atmosphere. In the case of a mechanical failure when the extractor still contains flakes, the flow of inert gas is continued for a much longer period, probably 10 to 20 hrs. during the period that the flakes are draining. In either case, after the inert gas purging has been completed, the extractor is opened and the inert gas vapors swept out by means of a positive flow of air.

This flow of air can be provided by means of portable blowers, but a better method is to have a permanently-installed fan adjacent to the extractor which can be connected to the extractor during the shut-down to provide a higher volume flow of air. A fan sized to give a complete air change every two to four minutes will not only make it possible to enter the extractor sooner after the inert gas purging is completed but will also maintain more pleasant working conditions within the extractor during the shut-down.

During the start-up operations the inert-gas purging procedure should be again repeated so that the oxygen content within the extractor will be reduced to a level such that an explosive mixture will not be formed when hexane is introduced into the extractor.

Building Design and Ventilation. The extraction building should be separated by at least 50 ft. from the milling building and preferably 100 ft. from other structures. It should be constructed entirely above grade with no connecting tunnels or pits. Below grade areas form natural collecting pits for solvent vapors. Tunnels are especially hazardous; even tunnels which connect only with the milling building should receive special attention to insure that adequate ventilation is provided.

Particular care should be taken that solvent vapors cannot reach the area adjacent to the boiler house. If adequate separation is not feasible, retaining walls should be constructed between the boiler house and the extraction building.

In the best of solvent plants there will still be accidental leaks and spills, during which time the basic rule of "confining the liquid" will be violated. In order to prevent formation of an explosive mixture within the building at such times, it is necessary to maintain adequate ventilation so that sufficient air will be available to maintain the concentration of the vapors below the lower explosive limit. Since hexane vapors are almost three times as heavy as air, a closed building should be ventilated by fans which take suction near the bottom floor level and any other solid floor levels and discharge out of doors. These fans should have a capacity of 5–10 CFM for each square foot of solid floor area in the solvent extraction area, hexane pump rooms, etc. In the case of plants having a limited area of land around the extraction building, it is necessary to give consideration to the places where these fans exhaust so as not to expose the extraction plant or surrounding areas to an unusual hazard. In such cases it may be desirable to have an exhaust duct for the fan along the outside of the building to raise the exhaust 10 or 15 ft. so that additional diffusion of the solvent vapors will be obtained as they again settle to the ground. The other approach to proper building ventilation is, of course, to have no building at all or a building with no enclosing walls. An example of such a building is shown later. An additional advantage of such construction is that it provides good explosion venting, minimizing damage in the event of an explosion.

Combustible Gas Alarms. Combustible gas alarms which are set to give an audible warning signal when the concentration of solvent vapors at the sampling point reaches 20% or 40% of the lower explosive limit are a valuable aid in maintaining plant safety. The generally recommended sampling points are the following: the flake conveyor bringing flakes from the milling operation to the extractor; a point in the extracted meal stream on the way back to the meal-grinding operation; points on the lower floor of the extraction building at which solvent vapors are likely to accumulate following a solvent spill; a finished oil-sampling location to give an alarm in case the oil has a low flash-point; the control room or switchboard room; and the main sewer drain from the plant.

Such alarms in addition to being valuable safety measures also help to control and improve plant operations by making the operators aware of minor solvent losses which, while not particularly dangerous, are nevertheless costly.

Fire Protection. Some form of automatic fire protection is universally recommended. This is generally either the use of automatic sprinklers which are individually thermostatically controlled or the use of the automatic deluge system. In the case of automatic sprinklers the intention is not necessarily to extinguish a flammable liquid fire but rather to cool the structure and equipment to minimize damage. The thinking here is that it may not be desirable or practical to extinguish a large fire because of the possibility of explosive mixtures forming immediately after the fire goes out. The automatic sprinklers in an extraction building are generally set up on an extra hazardous spacing, and particular care is taken to be sure that the intermediate building spaces under solid floors and large pieces of equipment are well sprinkled.

The deluge system uses open-head sprinklers controlled by one automatic valve in the main sprinkler supply line so that, in case of fire, the entire building is sprinkled immediately.

Either system requires an adequate and immediately available supply of water. This generally means a water high tank and an automatic gasoline and electrically-driven fire pump to maintain the water pressure in the system during and after the high tank has emptied.

Electrical Installation. All of the electrical switch gear, motor, etc., within the extraction area should be of the explosion-proof type designed as Underwriter's Class 1, Group D Rating. Such equipment is not necessarily vapor-tight so that solvent vapors cannot get into the equipment, but rather the equipment enclosures are designed so that they will contain an explosion of solvent vapor without rupturing and without permitting the flame to get out of the enclosure. Switchboard rooms and control rooms which contain electrical equipment not of the explosion-proof type must be adequately ventilated or pressurized to prevent solvent vapors from getting into the enclosure. It is also desirable to elevate such rooms above the ground level and, if possible, to separate them by some distance from the extraction building in order to minimize the possibility of solvent vapors getting in. A modern elevated control room adjacent to the extraction equipment is shown in Figure 1. This room while adjacent to the extraction equipment to permit easy operations is constructed at the second floor level and is pressurized by a fan which takes its suction from above the roof level. The placing of all of the starters, push-bottons, and other electrical controls in such a room not only appreciably reduces the initial electrical investment within the plant but also permits easier electrical trouble-shooting later on.

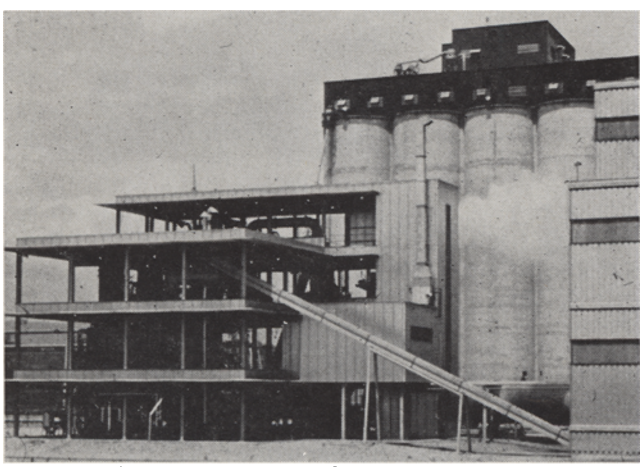

FIG. 1. Extraction building, showing enclosed elevated control room in right-hand front corner of building.

All conveying and processing equipment which handles the flow of solids through the extraction building should be electrically interlocked so that a plug-up in one place of equipment does not plug up all of the preceding equipment. This is not only a good operational feature but also a good safety feature since it means that only one piece of equipment rather than several must be opened up for unplugging.

Mechanical Seals on Pumps. To minimize solvent leakage and loss, all pumps handling hexane or miscella should be equipped with mechanical seals rather than packed stuffing boxes. The developments made in such seals over the past 10 years have given us seals which are practically 100% leak-proof and which have a very good service life. Such seals also deserve consideration for use on extracted flake conveyors and other conveyors handling hexane-solid mixtures.

Overflow Tank or Dump Tank. It is good practice to provide a buried hexane overflow tank or dump tank adjacent to the plant; an overflow line from the hexane work tank or the extractor conveys the excess hexane or miscella which accumulates in these locations, during an emergency shutdown, safely out to the overflow tank. If this were not done, the excess solvent could find its way to the conservation vents on these devices and then spill out on the ground adjacent to the building. This tank should be checked daily, and pumped, if necessary, so that it is empty at all times.

Explosion-Proof Inter-Communication System. A number of plants have installed inter-communication systems to provide easier and better coordination between the operators throughout the plant. Explosion-proof transmitters and receivers are available for such systems; these are a valuable aid in maintaining safe operations.

Use of Meal Drier Following Meal Desolventizers. The use of a steam tube meal drier, following the meal desolventizing equipment, provides additional protection to insure that solvent vapors will not flow with the meal to the meal-grinding building. A recent installation is shown in Figure 2. Here the drier also serves as the meal conveyor to bring the meal from the extraction building back to the meal building. It is heavily aspirated at the feed end so that any solvent vapor which should get out of the desolventizer during periods of poor operation is removed from the meal before it gets to the meal screens.

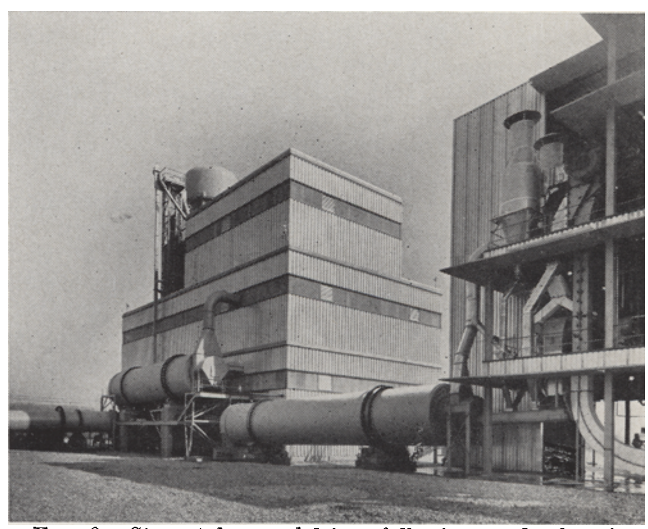

FIG. 2. Steam-tube meal-drier, following a desolventizer-toaster.

Improved Flake Seal to Extractor. The point at which the prepared bean flakes enter the extractor bears close watching. Under certain operating conditions a slight pressure can be developed within the extractor which will have a tendency to force hexane vapors back through the flake-conveying system to the milling building. The use of the inclined wet-

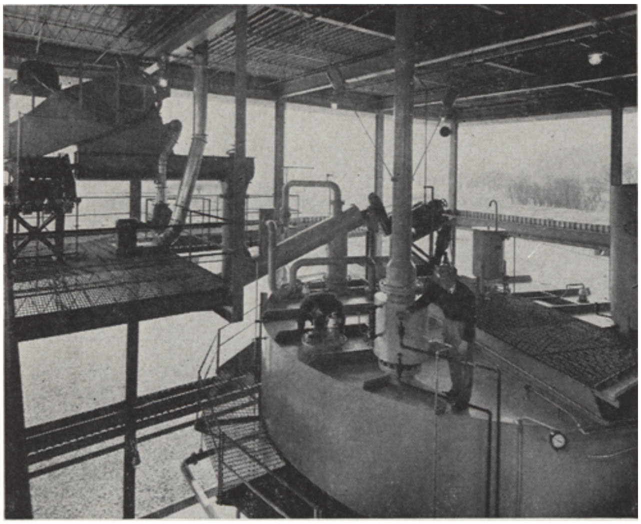

FIG. 3. Inclined wet-loading conveyor preceded by plug seal conveyor—an improved method of sealing the flake inlet to the extractor.

loading conveyor has made possible a major improvement in sealing the extractor at this point. Such an installation is shown in Figure 3. Additional safety features include a dry plug seal conveyor for the flakes ahead of the inclined seal conveyor and adequate aspiration on the head end of the flake elevator coming from the milling building. It is at this point that the previous mentioned sample for the combustible gas analyzer is taken. The safety of the older style, gate-loading device used on many basket extractors can be improved by providing ventilation to the outside for the upper loading device. A vertical stack through the roof will provide a good draft and normally will help to prevent any large amount of hexane vapor from seeping back to the milling building.

Maintenance Procedures. During maintenance shutdowns, safety rules must be enforced with special care. The large number of people in the plant, their relative unfamiliarity with the operation, and the fact that equipment containing solvent vapors may be open increase the chances for an accident and make careful education in, and strict enforcement of safety mandatory.

Purging and ventilating procedures for the extractor were mentioned previously. Building ventilation must be maintained at normal efficiency. It is also advisable to run aspiration fans, the vent fan, and any other similar equipment during the shutdown to provide additional ventilation.

Welding or flame-cutting operations should never be permitted within the extraction building or the surrounding area. Strict enforcement of this rule from top management on down not only eliminates a very potent hazard but also adds important emphasis to the whole safety program.

Processing Equipment Improvement. Mention should also be made of a significant number of process-equipment improvements which have been made during the past 10 years and which have contributed greatly toward safer operations. Among them are the following:

- improved evaporators of the vertical rising-film type which have greatly reduced the quantity of miscella in process in the distillation system;
- the use of bubble cap or disc and donut oil-stripping columns which are not likely to plug and therefore mean less danger of producing a low flash point oil;
- the desolventizer-toaster which has greatly improved the meal-desolventizing operation;
- mechanical and process improvements to extractors which have increased the operating reliability; and
- simplification of the over-all plant design by improved layout and the use of fewer pieces of equipment to do a given job.

These remarks have been limited to hazards within the extraction building. Of course, safety is not confined to this building alone, but considerations involving the hazards of flammable liquids extend also to the milling building, boiler house, the solvent unloading station, the oil-loading station, and other facilities which may be adjacent to the extraction building. In addition, of course, each of these facilities has its own specific safety problems.

Personnel training for safe and efficient operation is another very important factor. As mentioned previously, there is no plant built which cannot be made unsafe by poor operating procedures. Personnel training, as well as engineering for safety, is a continuous job which deserves attention and supervision from each individual concerned with the operation of an extraction plant. The motto "Safety First" is not good enough in an extraction plant; rather it should be "Safety Must Be First."

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Safety Permeates All Manufacturing Operations

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JUST AS IN THE CASE of the Ten Commandments, plant design and operating procedures that are safe, from both a personnel and property standpoint, are ideals to which practically all can subscribe. Likewise most engineers or others concerned with plant design and operations find that it is much easier to subscribe to an ideal than to follow safe practices in the every-day conduct of the business. This is true for a number of reasons, not the least of which is the fact that safety permeates all manufacturing operations, whether it be the design of a soap kettle, the running of a solvent extractor, the handling of a truck, the layout of a milling room, the generation of hydrogen, the lighting in grain elevators, the removal of fumes from the laboratory, the power plant maintenance schedule, the wiring of office equipment, or the piping of the refrigeration unit. Although the unknown or the unexpected are lurking about all plants to a greater or lesser extent, one cannot gainsay the thesis that accidents don't