SAFETY IN SOLVENT EXTRACTION*

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THE extraction of oil from oil-bearing materials by the use of volatile solvents is a relatively old process. The first patent, relating to a process for the extraction of fat from bones and from wool using Carbon Bi-Sulphide, was issued in France on November 13, 1855, to a Mr. E. Deiss. On December 3, 1856, additional claims covering the extraction of oil from oil-bearing seeds using the same solvent were granted that same inventor. After several years of fighting conservative tendencies, the above process was applied in the practical field to extract oil residue from olives which had already been pressed. Afterward, Deiss built a plant at Marseilles, France, and the process expanded in the Mediterranean Basin, chiefly in France and Italy.

Starting in 1878 with the discovery of new volatile solvents, especially Paraffin Hydro-Carbons, much less dangerous than Carbon Bi-Sulphide, the extraction system rapidly developed and reached new fields in the industry of oil-bearing seeds. The fact that a relatively small number of accidents happened during that period of development is very interesting, especially if we consider the dangerous characteristics of Carbon Bi-Sulphide and if we consider the fact that most of the extraction plants were of very small size and were operated by people who had no special knowledge of chemistry or of the use of solvents.

I remember having seen small plants in Italy operated by farmers who were working with Carbon Bi-Sulphide without any technical knowledge but with the few positive ideas on safety rules given them by the manufacturer of the apparatus—which rules they observed as they did the Law of God. And I think the spread of the use of extraction plants during that period is to a great extent due to that relatively low per cent of accidents.

During the following period with the application of Paraffin Hydro-Carbons as solvent the extraction industry developed in all Europe for the extraction of oil from seeds —due to the relative safety of those solvents used, their low cost, and the fact that those solvents extracted less coloring matter and non-oil constituents than all other known solvents.

When I first came to the United States in 1929 I found the seed oil industry very little interested in solvent extraction. I suppose that was due to two reasons; first, because the prosperity-minded oil crushers paid no attention to the 7 per cent oil left in the cake coming from the presses, and second, because of the many accidents which had happened to dry cleaners who were using gasoline without any knowledge of the safety measures which should be followed in that connection.

Fortunately, the experience gained by forty years of the actual operation of industrial extraction plants has today placed chemical engineers in a position to be of great help in securing a high degree of safety in extraction plants, which fact will be a big factor in the development of such industry in this country.

It was the general opinion that liquid gasoline was far more dangerous than vapors and while due attention was given to any liquid gasoline spilled or dripping in the plant, very little attention was paid to any smell of gasoline vapors noticed in or around the plant.

Another main cause of accidents in the early development of the industry was the wrong impression of the operators that danger of ignition was in the near proximity of the solvent. Very cruel experiences have taught us that, depending upon circumstances, sometimes danger lies even a thousand or more feet away.

Several accidents with severe casualties have happened in Europe because due account was not taken of the role played by static electricity. I remember operators of several plants requiring that the workers wear rubber boots or shoes to avoid the possibility of causing sparks by friction of nailed soles of shoes on the floors—completely overlooking the fact of the discharge of static electricity from those insulated human bodies against the grounded apparatus with which they came in contact.

Human Factors

First of all, a lot of accidents happen because of the peculiar, well-known tendency of human beings to become more and more careless as they grow accustomed to being near danger. With the scientific knowledge of today, it would be possible to design, construct, and operate a solvent extraction plant with an almost perfect degree of safety—could we depend upon a perfect human element.

Today, my opinion is that the men working in extraction plants must be the first object of attention. A rigid discipline must be expected in the plant as well as in the surroundings. Perfect cleanliness at all times, plenty of room, up-to-date equipment and intelligent care of the equipment must give the workers the constant impression of the highly-specialized job they must handle; that impression emphasized at all times by the very minute inspections and exigency of the foreman and the superintendent.

To my mind the worker best adapted to an extraction plant is a quick-thinking, calm, methodical, machine-loving individual. The thought must be impressed upon him that a smell of solvent in the extraction plant should have the same meaning to him as a hole in a ship would have to a sailor. The more delay in taking action in such a circumstance, the worse the danger.

The worker must be thoroughly instructed in the chemical and physical characteristics of the solvent and made entirely familiar with the process before being admitted to the apprentice stage. Each worker must be completely conscious of each step of the operation and know exactly the purpose of the instruments and devices in connection with the process. In that way they may execute orders with 100 per cent precision. There is no place in an extraction plant for an "about"-minded or half-way minded person.

By instruction, I mean real in-

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struction—not merely a series of rules. The superintendent should make frequent examinations to see if the instructions have been thoroughly digested. Danger of explosion must be duly emphasized, but not made an object of exaggerated fear, which gives the impression that the man is powerless. The psychological feeling of the worker should be that he is working in a plant having all the safety factors that science is able to produce and that no known danger will come from that end—the only dangerous part of the plant is himself. He must clearly understand that a mistake or a misbehavior of one of them in the extraction building might cause the death of the innocent and that a well understood surveillance of each other will give to each individual worker more assurance of safety.

Certainly it would be a big step forward if some law were enacted to compel state examination of all workers operating in connection with inflammable solvents. I cannot see why examinations or license are required for operators of pressure boilers and not for workers dealing with gasoline.

In my experience I have always obtained better results by taking intelligent and alert men—men who have never known about gasoline other than as a fuel for automobiles—and instructing them with simple and essential ideas and theories before putting them in the plant. In all special lines of work it is easier to educate a man new in the field than one who thinks he knows all about that particular line or one who has mistaken or distorted knowledge on that certain subject.

To avoid confusion in the minds of the workers, I have found it a big help to paint the different pipe lines of the system with different standard colors. That gives the men a general vision of the movement of the different liquids and vapors, especially when the piping system is very complex. I have found that more helpful than numbered valves or arrangements of that sort. To me there seems to be a curious idiosyncrasy on the part of workers for three-way valves. With the use of such valves there is always the chance that the workers will send a flow of liquid or gas the wrong direction, especially in cases of emergency or excitement. Maybe it is just a hobby of mine, but for that reason I have always avoided three-way valves.

All persons allowed to enter an extraction building must wear shoes with soles made of felt or some material that, when dampened by the natural perspiration of the feet, is a good conductor of electricity. In connection with that provision all gratings, stairways, platforms, piping, and parts of machinery must be thoroughly bonded and grounded.

No place for sitting or hiding and no boxes or cabinets should be permitted in the extraction building. Obviously, the carrying of any sort of matches, lighters, or objects capable of producing sparks must be prohibited—and strictly enforced. It would be well to make workers wear uniforms without pockets.

Purposely, I do not mention smoking, leaving oiled rags or similar substances in the building, or any of the general safety rules which should be elementary knowledge of persons responsible in the operation of any kind of plant.

Buildings

In order to obtain low insurance rates as well as for the sake of safety it is necessary that the extraction building be separated from the building in which oleaginous materials are cleaned and prepared for extraction or where the extracted meal is stored.

It should be located not less than fifty feet from other buildings, far away from main lines of railroads or from residences. The tracks serving the extraction plant must be so arranged that no engine would have occasion to go nearer than two hundred feet. There should be no grass around the building for a radius of almost one hundred feet, the parking of cars should not be permitted within that same radius, and the driveway should be at least fifty feet away.

In designing the extraction building the architect must bear in mind the possibility of an explosion and must try to minimize the catastrophic effect should an explosion occur.

The so-called building should be limited to the steel frame, supporting the extraction and distillation apparatus, with siding and roof of light sheet metal fastened with light clamps. In this way the force of an explosion is minimized should it occur and there would be no projection of material endangering the neighborhood. Such a mass of metal, well bonded and grounded, will act, also, as a protection against lightning—as demonstrated in a plant in Evansville, Indiana, which in 1934 during full operation with all men inside was struck by lightning without any disturbance at all.

The building should be taller than it is wide or long and the upper part should be constituted of louvers which should always be left open—to be closed only in case of heavy rain.

The lower part of the building should be provided with plenty of windows and doors which also should be left open. In this way, inasmuch as the distilling and extraction apparatus and the steam lines—even if they are well insulated—will radiate some heat, there will always be a circulating draft from the bottom to the top of the building, which draft will serve to dilute and carry away vapors coming from any eventual dripping of solvent.

All floors, platforms, and stairways, should be of the grating type to avoid any possibility of mixtures of air and solvent vapors collecting in pocket-like corners.

Plenty of supports should be provided on which to hang hoists to facilitate the handling of pieces of machinery such as condenser heads when removed for cleaning purposes, making such operations as easy as possible and also avoiding the possibility of any shock of machinery parts against the floor, railings, or beams.

No elevators of any kind should be used where the extraction proper is to go on. Conveyors carrying the material to be extracted and those carrying the extracted meal back to the main building should be controlled at both ends of the line in such a way that in the event of fire in either of the buildings the conveyors could be stopped immediately before any ignited material is carried to the other building by the conveying system.

One way to meet that condition would be the adoption of air conveying, which is very well suited for the especially light characteristic of material prepared for extraction. The piping of air-conveying systems may be equipped with quick acting gate valves, cutting all connection between buildings in case of trouble in either building. However, if screw conveyors are adopted, the conveyor which carries the extracted material back from the extraction building should be sloped upward toward the preparation building so that any stream of solvent resulting from a burst pipe or some similar trouble would not flow to the preparation building.

In normal operation the extracted material, soaked with solvent, is treated in order to recover the solvent and to eliminate all traces of it in the extracted meal. The possibility that that operation, through some accident, has not been effected completely and because of this that the vapors are carried into the main building with the extracted meal must be considered. Consequently, safety precautions should be taken to provide for the travel of the extracted material through the main building up to the receiving bins, which should be ventilated and vented with pipes of almost twenty-inch diameter to the outside atmosphere.

I consider an air conveying system which dilutes any solvent vapors accidentally left in the meal with a big volume of air and discharges the mixture through the receiving separator to the atmosphere much safer.

Belt transmissions outside or inside the extraction building should absolutely be avoided. Slow gear transmissions may be permitted if care is taken to keep them well greased or if one of the gears is of bronze. Slow chain transmissions may be used, also, if both sprockets are of bronze.

Conveyor housings should be of non-sparking material. It is true that before the material to be extracted reaches the extraction building it has passed through several magnetic separators and, theoretically, the danger of pieces of iron going through the conveyors has been eliminated. However, there is always the possibility of stones or small fragments of siliceous material being driven around by the fly on the screw conveyor, which could generate sparks if the housings of the conveyors were of steel.

In spite of the fact that from all points of view there are a number of very good electric explosion-proof motors on the market, I cannot suggest any of them for use in extraction buildings. In order to secure more safe operation I prefer to use open motors suitably located in very well-ventilated housings outside the extraction building. Shafts extended through the walls of the building with suitable stuffing boxes may be used to connect motors with machines. In my opinion, danger is in the overheating of motors. Especially in continuous extraction systems where motors must run constantly for weeks if not months, the danger of overheating is always present.

Such danger is increased by the possibility of a quantity of solvent being spilled on a running, overheated motor or nearby and by the possibility that solvent may reach the insulation on electric wires and in this way produce short circuits by dissolving the insulating coating on such wires.

Steam reciprocating pumps handling solvent are recommendable if equipped with extended piston rods with two stuffing boxes and if a closed container is provided between them to collect any leakage from the head. Because of the fact the varying pressure in main boilers makes a uniform speed of such pumps impossible, I would suggest the use of slow-speed rotary pumps in continuous extraction plants, and especially those with single stuffing boxes, naturally driven by motors situated outside the extraction building and running at constant speed; the flow of the solvent to be regulated by a by-pass arrangement. Due to their high operating speed, centrifugal or gear pumps will give trouble after running for some time, because of leakage through the stuffing boxes.

General Precautions

It would be a good thing if all pipings handling solvent, oil or miscella were assembled by welding and if flange connections were limited to the pure necessity. All sections of welded piping should be hydraulically tested under almost eighty pounds of pressure for thirty minutes.

I have found that a good, long-lasting electric conducibility between two sections of piping may be obtained by spraying metallic zinc with a spray gun about one inch around a bolt hole on the outside of both flanges and the one bolt and nut. The same arrangement may be used with all the assembled parts of machinery, pumps, etc., where gaskets are present or where some fear exists that a perfect metallic contact is lacking between two parts of a machine. Sometimes a thin film of oil or grease or a thin coat of rust is enough to interrupt a thorough bonding. Periodic inspections must be made with adequate instruments to detect any slight difference of voltage between two sections of a line, or a machine, or an apparatus.

Many accidents have happened during the cleaning or repairing of tanks and containers used for storing solvents and today everybody knows the precautions to be taken in similar circumstances. Those same precautions must be taken in cleaning extraction apparatus, distillers, stripping towers, etc., and particular attention should be given because of the complexity of the construction and design of those apparatus. Steam should be used in eliminating solvent vapors and special attention given to the removal of condensed water from every part of the apparatus where water may be hidden. The use of compressed air for the above purpose or for cleaning must be avoided.

The high speed of air through the piping during its long travel from the compressor to the building generates a lot of static electricity in the duct. Even if the pipes are very well grounded, a long hose is needed for the cleaning operation and the grounding of such portable hose, even if of flexible metal, is very difficult to obtain. For that reason there is the chance of delivering compressed air charged with electricity which may cause sparks when it comes in contact with grounded objects.

All parts forming the building, stairways, platforms, railings, etc., must be electrically connected in several places by welding copper wire through the main water lines before the introduction of any solvent into the building.

Every metallic moving part that could cause sparks by striking against another metallic part should be made of or lined with bronze, brass or copper. Sometimes there is danger of sparks being caused even by striking the sash against the frame when closing a window. Particular attention to the above precautions must be given and the chance of any occurrence of a condition such as mentioned must be anticipated at all times. For instance, some louvers are operated by chains. If there is a chance that those chains can strike the steel beams of the building, they must be made of brass. At one time I saw a very strange accident. A man was pouring normal Hexane from one five-gallon tin can to another. Some of the liquid spilled on the concrete floor and was ignited by sparks caused by the empty can sharply hitting the floor when dropped.

All hammers, tools, wrenches,

etc., must be made of brass or some equivalent non-sparking material.

All electrical wiring, fixtures, and switches for lights or motors must conform strictly with the Underwriters' specifications and all switch boxes, fuse boxes, etc., should be located outside the building.

Special attention should be given to the sewer system, particularly where the water coming from the water separator is carried away. The sewer serving the extraction building must be trapped in a suitable way several times before reaching the main line of the sewer. In other words, the extraction building must not only have no uncontrolled communication with other buildings above the ground, but under the ground, also.

A necessary precaution is to survey always the water coming from the solvent-water separator because, should the separator not be properly primed, gasoline would go into the sewer.

A good precaution is to avoid U-bendings in pipes handling gasoline from the condenser as there is always a chance of a collection of water at the bottom of the U-bend, caused by condensation, which in severe cold weather might freeze and cause an unexpected and highly dangerous pressure in the distillation system.

If a U-bend is necessary for a liquid seal, as used in reflux lines, it is a good thing to put a drain in the lower part of the "U" and regularly drain the water which eventually will collect there.

If a few drops coming from a leaking valve or flange or junction is dangerous, a large amount of solvent spilled on the floor is far more so. The quick evaporation of solvent in the latter case causes a large amount of vapors which could travel outside the building and be carried by a draft of air in contact with some flame even several hundred feet away. I do not suggest the use of sand or sawdust in a case of that kind. The only safe thing to do is to make those solvent vapors innocuous by mixing them with some uninflammable vapors. The use of Carbon Tetra-Chloride is very good in such instances. For that purpose a large number of pint bottles of Carbon Tetra-Chloride should be conveniently placed around, inside and outside the extraction building, to be thrown on the floor where a gallon or more of solvent has been spilled.

When the factory is shut down for cleaning or other purposes, the whole system must be inspected and before resumption of operations it should again be thoroughly checked. The superintendent should be present at least during the first four hours after resumption of operations. It would be a good idea, also, to have some extra men available at that time to take quick action in case something should go wrong during that dangerous period.

In spite of suggestions of several safety commissions, I do not advise the placing of solvent storage tanks underground. Any accidental leaking of tanks so located could not be easily detected and only after a great amount of solvent were lost and a large area of ground soaked would it be possible to take action. The danger of underground seepage of solvent is obvious because of the length of time such solvent will stay in the ground. I suggest the storage tank be placed above the ground, located over a concrete pit twice the capacity of the tank and capable of catching and holding any solvent which might leak out. The tank should be provided with a four inch safety valve so that in case any leaking solvent collected in the pit caught fire, the pressure generated in the tank would escape through the valve.

The possibility of accidents is considerably lessened with the development of continuous extraction systems. In batch operation the extractors must periodically be opened and closed at the beginning and the end of each extraction. The number of workers and helpers is greater and the handling of the material is more complex. On the contrary, in continuous extraction systems all material is handled in closed containers. There is no need to often open or close valves to admit or withdraw or change the direction of the flow of the solvent in the extractors. Everything is regulated and synchronized according to set conditions.

There is no need for anything more than survelllance in order to be sure that everything is running as it should. In addition to that the possibility of installing automatic controls everywhere reduces the chance of danger which comes from the human element.

NOTE

The authors of the article entitled "A Non-Fatty Oil from Jojoba Seed" published in the November issue, wish to call attention to a previous examination of this oil by R. A. Greene and E. O. Foster (see Botanical Gazette, Vol. 94, No. 4 (1933)) in which they showed that it was a liquid wax.

ERRATA

"A Non-Fatty Oil from Jojoba Seed," by R. S. McKinney and G. S. Jamieson, OIL & SOAP 13, 289 (1936).

It is regretted that the proofreader changed "e" into "a" in the words "eicosenoic," "discosenoic," "eicosenol" and "discosenol" throughout this paper in cases which refer to the unsaturated compounds.

SPRING MEETING

President E. C. Ainslie is beginning the task of arranging the program for the Spring Meeting of the Society. Anyone wishing to present a paper before this meeting should get in touch with Mr. Ainslie at P. O. Box 1724, Atlanta, Ga.

The probable dates of the meeting are May 13 and 14, and the meeting is to be held at Dallas, Texas.

Efforts are being made to obtain speakers of special prominence and the meeting promises to be an interesting one. We urge those who have papers to present to notify Mr. Ainslie as soon as possible since it is desirable to get the final program arranged at the earliest possible date.