Safety in Solvent Extraction Plants – Europe

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ABSTRACT

The solvent extraction process is recognized as having a high hazard potential, arising from the use of large quantities of volatile and possibly explosive liquids. However, when statistical records are studied, it is found that most accidents in this industry, as in all industry, are caused not by technological failure but by human error.

However, technical precautions *must* be taken, especially those relating to the prevention of any sources of ignition which might initiate a dust or solvent explosion. To ensure complete study, the whole process must be examined so that consideration is given not only to the hazards of solvent vapor ignition but also to the equal risks of dust explosion in either seed preparation or post-extraction processing. In this connection, it must be remembered that a major dust explosion can be equally as devastating, if not more so, as a solvent explosion.

It is assumed in this paper that managers of solvent extraction plants will be aware of the relevant laws and codes of practice developed in most industrialized countries to counter these fire and explosion hazards; therefore, apart from some discussion of the problems of static electricity, rules and regulations are not duscussed in detail.

Most important, because of the far-reaching implications, is a consideration of plans for the safety education of people at all levels—a program considered by the author to be a necessary foundation for safety training.

It is concluded that "safety" must no longer be mistakenly regarded as an extra work load for hard-pressed management, but that it *must* be accepted as a normal part of everyday life by people at all levels.

INTRODUCTION

In the presentation of a paper to a group of very experienced people in the solvent extraction industry, it would not be constructive just to tell them something that they already know: that this process presents a serious fire and explosion hazard. The fact that they *do* know it is clear to the author, who undertakes safety surveys in many different kinds of factories in many countries. Whenever he sets out to survey *any* high-hazard factory, such as a solvent plant, a hydrogen plant, or a plant using ethylene oxide, he finds that the department carrying out the most hazardous process is usually the safest part of the factory, and it seems certain that the reason for this is that everybody is so well aware of the possible hazards involved that the greatest care is taken not to have an accident.

ACCIDENTS

In saying that "we must take care not to have an accident," are we sure how we define what an accident really is? In nearly all industries and countries, we see documents which are called "accident statistics," but when we examine them we usually discover that they are no more than classified lists of injuries: injuries which are really only the *results* of accidents and not the accidents themselves. If, on the other hand, we consult the most authoritative dictionary of the English language, we find that an accident is defined as "an event without apparent cause." If we now go back and study our so called "accident statistics," we find that in nearly every case the injury happened not because the cause *could* not be foreseen but becuase it *was* not foreseen; further, we usually find that it *could* have been foreseen if somebody had been wise enough to look for it!

We are, therefore, forced to the uncomfortable conclusion that the beautifully printed accident "statistics" which we have accepted for years are not really accident statistics at all, but merely an embarrassingly public list of the number of times we have failed to prevent an accident, generally by failing to realize that hazards exist.

HAZARDS

Let us therefore return to the question of safety in solvent extraction and how we should look for the hazards therein. This paper considers the solvent extraction plant as a complete entity, beginning with seed intake and ending at the extracted meal silos. In the interest of brevity, only a very brief mention of the major hazards is made, the broad principles of their prevention being outlined later. We have noted that nearly all hazards *can* be foreseen, if somebody will take the trouble to do so, and when we start to think of all the hazards there might possibly be in the extraction process, it seems to be a very formidable task. This task may, however, be considerably shortened if we bear in mind the words of that unknown genius who said that there are only two causes of accidents: MEN and WOMEN.

A study of international statistics of industrial injuries shows that, in very general round figures, only 10% of them are caused by technological failure; the 90% remainder (the hidden mass of the iceberg) are caused by some human being acting in a very careless way. It is particularly important to remember that this human being is not necessarily the victim of the accident nor is he necessarily a normally stupid or careless person. Naturally, this does not mean that we can dare to ignore the 10% technological factor, but the very fact that it is as low as this is an indication of the engineering care which does go into plant design and installation.

It must be emphasized that, while serious fires and explosions are happily fairly rare in this industry, it is almost certain that if everybody examines their own internal accident statistics they will find that injuries due to slips, falls, using tools, and so on are probably just as numerous in the extraction plant as they are in any other industry. This paper does not deal with these but will demonstrate later that there is an overall method of accident prevention which will be as effective with them as it is with the more spectacular explosions.

HAZARDS OF PROCESS

Seed Handling

It is impossible in practice to handle large quantities of oilseeds or similar material without creating or releasing large quantities of dust; therefore, in nearly all conveying, elevating, and storage operations, there is a very real risk of dust explosion. The author has noted in the past that, while there has always been an acute awareness by management of the serious consequences of a solvent explosion, the risk of dust explosion has not always been given the respect it deserves, and yet a major dust explosion can be as big a disaster as a solvent explosion.

The principles of dust explosion prevention are rather similar to those relating to solvent explosion: containinment of dust, freedom from naked flame or high temperature sources of ignition, and so on. There are also proven techniques of dust explosion containment, explosion venting, and explosion suppression if ignition does occur. These are well documented in the technical literature.

All these preventive and remedial measures are mostly of a technical nature, and yet, in nearly all the dust explosion incidents which the writer has investigated, each plant was designed in a perfectly safe way but had been allowed to become unsafe because of a number of human errors: inadequate inspection and maintenance, poor housekeeping, and very often a wrongful acceptance of the idea that a dusty environment is normal in this industry.

Solvent Extraction

Although, as has been pointed out, the accident statistics of the solvent extraction plant are likely to reveal far more personal injuries than major explosions, the results of the latter may be so disastrous that considerable care must be taken at all stages of design, operation, and maintenance.

The theory is simple: we are using very large quantities of an extremely flammable liquid; we know that this liquid will readily evaporate to form a heavy vapor; we know that if a mixture of this vapor and air occurs within the approximate limits of 1 and 7% it will explode violently if ignited. Therefore, all we have to do (in theory) is to ensure that hexane vapor and air are never allowed to mix. This is preventable by ensuring that no hexane is allowed to leak out of the system; that no air is allowed to leak in; and, as an added precaution, just in case they do mix, there must be no sources of ignition nearby.

In practice, this may not be quite so simple. We all know that pump-glands, pipe joints, and many other weak points of the system may leak and allow hexane to escape. Furthermore, there is no completely successful system of feeding meal into the extractor without incorporating a small quantity of air as well. All of us in our different countries have certain national standards or codes of practice which demand flameproof or explosion proof electrical apparatus. Similar standards or regulations exist which govern the storage and handling of hexane and similar solvents. This paper does not dwell upon these aspects because they are so fundamental to the extraction operation that one imagines that they are well known to all readers. Instead, the writer comments upon some other points which are not so well documented and about which there is always some measure of disagreement between different operators.

First of all, the fire and explosion hazard would disappear if we used a fluorinated hydrocarbon solvent, as would also the high cost of flameproof electrical equipment. While this would please all safety engineers, they would certainly be assured by nearly all their colleagues on the process side of the business that, apart from additional cost, this would result in an unacceptable product; so it is not proposed to discuss this matter further, although perhaps it may provoke some discussion among the experts later in the Conference.

Next, mention is made of a few points about the risks of static electricity. While it is possible to demand certain legal safeguards in the electrical power system, there can be no possible man-made law which prohibits the generation of electrostatic charges. On the contrary, there are some fundamental laws of physics which ensure that static will be generated in the appropriate circumstances and, therefore, we have to deal with the problem. The author's own Safety Advisory Service within Unilever has for long recommended that the defense against static begins by being associated with precautions against lightning, and we now advise that all metal reinforcing rods in the concrete base slab are bonded to each other by spot-welds during construction and that this mass—and all structural steel work—is firmly and permanently connected to a good system earth which complies with local or national regulations.

The reason for bonding the reinforcement in this way is that the enormous voltage of a heavy lightning strike on a steel-framed building is likely to cause cracking or even disruption of the concrete base slab. Not only may concrete missiles be generated in this way, but the electromagnetic effects of very heavy currents seeking the easiest way to earth may, by inducing secondary voltages in nearby steelwork, cause severe and incendiary sparking in the hazard area.

Having thus provided a good system earth, we can now connect to it all steel frameworks, gantries, plant, and pipework. This recommendation naturally includes the hexane storage tanks and requires that all pipe, pump, and similar flanges are bridged by earth continuity straps.

A strict procedure for receiving incoming hexane from road or rail tankers should be instituted and maintained. Road tankers should, after parking at the reception point and switching off, be left for 10 minutes for the exhaust system to cool off before operations begin. The vehicle should be connected by flexible cable and clips to the system earth. In the case of rail tank cars, the same system of earthing is advised because it is unwise to rely upon running rails as an effective low resistance earth, especially in dry weather. Before connecting up delivery hoses, checks should be made that both road and rail tankers are completely immobilized by their brakes or in some other way, and that barriers and rail stops are used to prevent impact by other moving vehicles. Hoses should not be connected until after the earthing connection is made, and this connection should be maintained until all hexane transfer has ceased and until hoses have been removed, drained, and stowed away.

Pumping arrangements should be designed and controlled so that at no point in the system does the liquid velocity at any time exceed one meter per second, and that any hexane entering any tank does so by a submerged inlet.

A special point about the possibility of static ignition when using CO_2 as an inerting medium is made because this is based upon an actual case history. The author does not personally believe that any useful purpose is served by providing an automatic CO_2 system for use as a fire extinguisher inside the body of the extractor becuase, as long as the atmosphere within that space is either below (or more usually far above) the explosive limits, ignition will not take place. If, on the other hand, ignition does occur within the explosive limits, the flame front will travel considerably faster than CO_2 can enter, so that, in either case, the CO_2 serves little purpose. There may be a good reason for using it under manual control as an inerting gas during start-up or shut-down, but we return to that later.

The case history to which I refer concerns a horizontal extraction plant situated in a steel-framed enclosed building. An automatic CO_2 system was fitted, and disaster occurred in the following way. Because of an instrument fault there was a false automatic fire signal; the CO_2 discharged into the body of the extractor and displaced a large cloud of hexane vapor through the vents into the building; after which ignition occurred, resulting in a very serious explosion. Investigations suggested very strongly that the actual cause of ignition was a spark produced by a high static charge carried on CO_2 "snow" particles. This generation of electrostatic charges when high pressure CO_2 is released has, during the last few years, resulted in much useful scientific discussion on the subject, and information and advice on its prevention can be obtained from appropriate expert sources. When this plant was rebuilt, the CO_2 was modified so as to be under manual control only, and great care was taken to ensure that venting of vapor, if it did occur, was ducted safely to atmosphere at a high level.

A further period of hazard occurs during start-up and shut-down because in either case there is a risk of forming an explosive gas/air mixture inside the extractor. It is reported to be common practice in the U.S. to purge with hot hexane vapor at a high flow rate. The author has no personal experience of this method, but he has not heard of any explosion occurring during this hot-purge period. While it will be admitted that a moment, however short, must come when a dangerous mixture of vapor and air exists, it seems that an inert gas purge would probably fail to remove pockets of residual liquid and therefore create a sense of false security. Similarly, steam-purging (which has been recommended) is likely, by evaporating pockets of residual solvent, to create a bigger hazard than it removes. The whole question of purging at start-up and at shut-down, together with purging at unplanned shut-down, is still a long way from being completely resolved, and one hopes this will be the subject of discussion later.

Hazard Areas

This paper says little about hazard areas in relation to legislation and codes of practice because all these have been well publicized in most countries and are generally based on the IEC 79 recommendations. For example, in the United Kingdom we recognize three classified areas:

1. *Zone 0 area:* in which an explosive gas/air mixture is continuously present or present for long periods
2. *Zone 1 area:* in which an explosive gas/air mixture is likely to occur in normal operation
3. *Zone 2 area:* in which an explosive gas/air mixture is not likely to occur, and, if it occurs, it will only exist for a short time.

It will be appreciated that, in a short paper, space does not permit an exhaustive discussion of the various electrical and other codes of practice which serve to ensure as far as possible the operational integrity of a hazard area. These are published and may be studied at any time.

Accepting that all codes and regulations have been complied with, the essential and perhaps more difficult feature is ensuring that the integrity of the hazard area is maintained, and not destroyed by human carelessness. It is so easy to say, "None of our employees would be stupid enough to smoke in the hazard area," but it *has* occurred. One would imagine that the mechanic disconnecting a solvent pipe flange for maintenance purposes would never omit to ensure before doing so that the pipe has been drained of all liquid solvent and purged, yet this too has been known to happen.

We shall return to problems like these, but there is an important point to make about hazard areas in general: that is, to devise and maintain a strict disciplinary system of control, so that not only are unauthorized people prevented from entering but so that it can be known at all times exactly who is in the area. In the case of the explosion caused by static from CO_2, to which earlier reference was made, one of the men who died was not known to have been in the hazard area until his body was discovered later. He had a good reason to go there and he was authorized to do so, but nobody knew he was there.

Post-Extraction Processing

Let us now pass to post-extraction processing—on one hand the distillation of miscella and on the other hand recovery of hexane—while the extracted meal is dried, toasted, conditioned, and finally stored in silos. Only a brief mention is made of these because they present the same major hazards of fire, vapor explosion, and dust explosion as the solvent extraction process, with the added importance that the presence of residual solvent vapor in extracted meal will materially enhance both the chances of a dust explosion and also its violence if ignition does occur. Furthermore, if a dust explosion occurred in a very large and almost empty silo, it could have a severity reaching disaster proportions.

ACCIDENT PREVENTION

We have seen that fires, explosions, and other accidents may be caused by technological failure or by human failure. We have seen that human failures outnumber technical failures by a factor of 9 to 1. We have recognized that technological safety measures are in many cases laid down by national and international regulations, and we are compelled to admit that no form of regulation can, by itself, possibly control human behavior.

As has been said that the majority of accidents are caused by human carelessness, and, having studied many examples, the author is forced to certain conclusions:

1. An act of human carelessness is not necessarily that of the victim: it can be the designer, constructor, maintenance man, manager, and so on.
2. Careless acts are often the result of an individual's unspoken faith that "it cannot happen to me."
3. Careless acts also originate from a number of beginnings: (a) persons have received no instruction about their jobs; (b) persons have received inadequate instructions about their jobs; (c) they have not understood these instructions; (d) they have forgotten these instructions; or (e) they have, because of ignorance or laziness, decided to modify their instructions.

Even these most common causes of unsafe acts do not exhaust all the possibilities, but they do emphasize the need for adequate instruction. The Unilever Safety Service describes this kind of instruction in two different ways: safety education and safety training.

Safety education is defined as a process of developing people's knowledge of hazards so that they learn to think and behave safely at all times and in all places, on the road and in the home as well as at work.

Similarly, safety training is defined as the process of developing a person's skill in the use of safe working methods and in the application of safe practices, both relating to particular jobs.

It will be seen, then, that safety education is the foundation slab upon which a program of safety training can subsequently be built, and, although the educational program is far more difficult and takes much time and effort, it must be undertaken as a *continuing* activity if subsequent safety training is going to be successful.

Everyone will realize that space does not permit a full description of methods, but the leading points should be:

1. Top management must *visibly* support all safety efforts if they are to be successful.
2. Management at all levels must be involved, and seen to be involved, in the implementation of safety educational and training programs.
3. Safety managers, safety engineers, and similar professional advisers must guide, assist, plan, and coordinate the efforts of management, but management's responsibility for safety cannot and must not be transferred to them.
4. Education must be neither formal nor academic but should consist of a continuing cooperation between managers and men in activities such as hazard surveys or other practical means of inculcating safety education as may be planned by a competent safety manager and implemented by management.

In this brief outline, we have looked at the solvent extraction process and we have seen that, in common with nearly all other industries, some 10% of the accidents which happen are due to technological failure, the remaining 90%

being due to unsafe human acts.

Nevertheless, because of the possibly disastrous consequences of failure, we have emphasized the need for continual technical monitoring of design and process, especially in relation to existing national or regional laws and codes of practice.

Assuming that all technical requirements have been, and continue to be, carried out, we have considered the institution of a continuous program of safety education as a basis for safety-integrated training.

The end product of all these activities is the inculcation in everybody's mind of the ideas that safety is *not* something that has only to be considered in dangerous plants, that safety is *not* something you talk about on the first Tuesday of each month, but that safety *is* something which becomes a *normal part of human everyday life,* in the home, on the road, and at work.

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