FIRE AND EXPLOSION RISKS IN THE MODERN AMMONIA PLANT

The basic vulnerability of big, single-train plants points to the possibility that multiple units may have long-term economic advantages.

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The problem of safety in operating ammonia plants is not restricted to any one operator, designer, insurance underwriter, or country. Thus the following comments on the safety experiences of these plants is presented not only for our particular interest, but for the ammonia industry in general.

The Oil Insurance Association is one of three or four predominant underwriting groups in the United States which provide fire and explosion insurance coverages in the general petrochemical field. Naturally, this includes ammonia, ammonium nitrate, and urea manufacturing facilities among many others.

Our group consists of about 60 major stock fire insurance companies who originally pooled their underwriting capacities in order to provide sound, orderly coverage for the petroleum industry. As a normal outgrowth of these activities, the petrochemical field soon became an important segment of our business.

How hazardous is ammonia?

When you think about it, ammonia is not a very hazardous product from a fire viewpoint. It is almost ironic that we all have had so many problems with its manufacture. Even more ironic might be the fact that this group has been meeting for years to discuss mutual problems and loss experiences. Perhaps, however, there is a basic lesson for all of industry to be learned from these facts.

The difficulties and hazards in producing a relatively non-hazardous end product should not be obscured by the fact that the product itself is relatively non-hazardous. I have frequently heard knowledgeable people ask what there is to worry about in an ammonia plant! The gist of their comments is that it won't burn very easily and has a very low explosion potential! Many people were saying similar things about McCormick Place in Chicago before it was destroyed by fire last winter.

Let's quickly review some of those things that can't burn or explode in an ammonia plant. Can natural gas do this; can hydrogen; can synthesis gas; can equipment containing gases ranging from 2,000 to 5,000 lb./sq. in. in pressure fail? Can air separation plants containing pure oxygen be contaminated? Certainly, they all can and have from time to time. The incidents have resulted in many millions of dollars in lost or damaged equipment plus many millions more in lost sales. If there were really no hazards, we are sure there would be no insurance indemnity purchased; on the contrary, most every operator does and will continue to purchase indemnity for the foreseeable future.

Underwriters in the boiler and machinery field have their problems and concerns over ammonia manufacture, too. So there will be no misunderstanding, however, you should realize they are concerned only with loss or damage to equipment, machinery, boilers, etc. resulting from mechanical or electrical breakdown. Our group is concerned only with damage resulting from fire or explosion.

We both, of course, are directly involved with the loss of plant earnings resulting from any of the basic perils each of us insure against. There have been a devastating number of equipment failures, which in almost every case could have or have led to further damage from fire and explosion. So you see, there is a very close parallel between our two groups, but the distinction between the two areas of insurance coverage should be well understood.

Effect of large, single-train plants

Prior to the advent of the large, single-train plant concept of the past several years using the basic steam-methane reforming process, a high percentage of ammonia production relied on the air liquefaction route. Our association along with other underwriting pools, was involved with a considerable number of serious losses involving contamination of one sort or another in these air units. In reviewing past transcripts of these meetings, it was noted that several of these have already been reviewed in depth. Due to increased diligence, technical improvements, and ever enlarged operating experience, however, the problems with these plants has been sharply reduced in recent years.

During this same period, we also had several serious losses resulting directly from metals failures and particularly from hydrogen embrittlement. These difficulties, too were recognized and metallurgical improvements made to sharply reduce these failures, as well. But to give you some indication of the monetary values involved in the past, here are four examples with approximate dollar values:

1. Air separation unit explosion - East Coast.
   Property damage value in excess of $1,200,000; loss of earnings unknown, but plant was out of service about 4 months.
2. Air separation unit explosion - Gulf Coast.
   Property damage value in excess of $2,000,000; loss of earnings not insured, but unit was out of service for over 4 months.
3. Ammonia plant containing air separation unit - Middle West.
   Explosion due to in-line vessel failure. Property damage in excess of $800,000; loss of earnings in excess of $1,000,000 with downtime over 3 months.
4. Hydrogen piping failure in ammonia plant - Midwest.
   Property damage loss in excess of $50,000; loss of earnings in excess of $200,000. Plant idled for several weeks.

Of the most concern at the moment, however, are the large new, single train plants. Our group is involved with at least six of these at the present time, along with several more in various stages of construction and design. These plants range in size from 500 to 1,500 tons/day with earning potentials (basically sales less cost of raw materials) ranging from $25,000 to $75,000 a day. The need for the protection of the earnings of such plants via insurance contracts is certainly easy to demonstrate. Shutdowns of even the shortest time periods can expose thousands of dollars of earnings. To contemplate losses due to serious fire damage at machines or vessels requiring months to repair or replace is simply staggering.

Now, there might very well be legitimate questions as to whether we aren't being overly pessimistic about the possibilities of failure and damage to large pieces of equipment or machinery. After all, they are very rugged; designed and manufactured by highly qualified suppliers; installed by highly reputable construction firms; and finally, operating experience has not demonstrated a plague of fire or explosion losses of major size.

At first glance—and even a second—much of this is true, especially in the area of ruggedness and design by highly skilled engineering companies. Unfortunately, however, there has been and continues to be a plague of breakdowns which are becoming unbearable to boiler and machinery underwriters. Now, when a compressor fails for any reason, or a line ruptures, or a furnace tube splits, or any one of a dozen or more mechanical problems cause plant upsets, the release of highly flammable gases, under high pressure, is always a constant threat. Both explosion and fire "torch" effects, in our opinion, could severely damage or destroy vital equipment resulting in both large physical damage and extended periods of shutdown while that equipment is being repaired or replaced. And not only is one portion or unit of the plant shutdown, but the entire plant is out of production.

Three case histories

Fortunately, for us at least, a great number of the pure mechanical breakdowns have not led to disastrous fires or explosions. There have been enough, however, to demonstrate the probabilities of much more serious loss occurrences. Three of these might be of interest to you from our viewpoint:

Case 1: Valve and relav failure. This event took place in early 1966 in a large new plant in process of coming on stream. It occurred at the reformer furnace when an undetermined electrical disturbance within the main plant complex caused a 110-v. monitoring circuit on the control system to fail. This initiated an automatic plant shutdown procedure which worked exactly according to plan except for one failure.

It seems as though one of the fuel gas cutoff valves to half the main reformer furnaces did not close due to mechanical linkage "hang up" in a relay. This allowed burners to continue in operation under one half the furnace, even though feed gas and steam flows were cut back due to the shutdown procedures underway. Before manual closing could be affected, two tubes were split and much of the catalyst in the remaining tubes in that section damaged.

In total, the upset resulted in excess of a 3-week shutdown, with dollar losses estimated in excess of $1,000,000 for plant earnings. Property damage estimates were in the $75,000 to $100,000 range.

One of the main points to be reviewed here is that a really minor mechanical occurrence on a simple valve and relay device resulted in a damage estimate well in excess of $1,000,000. Another fine point revealed is that here was a massive 1,000 plus ton/day plant, completely dependent on that same small valve and relay. There was no parallel train to at least provide a portion of the final product.

Coincidentally, an interesting sidelight also developed when it was learned that necessary tube replacements called for replacement of ring gaskets at the cap flanges on the reformer tubes which were very difficult to obtain. With this as an example, we wonder how many other such relatively minor parts are also difficult to find when they are needed in a hurry?

Case 2: Weld failure. This problem occurred at the secondary reformer in another 1,000 plus ton/day plant. It was due pure and simply to a weld failure on the internal sleeve attached to the burner assembly. This allowed the entire burner to fall to the catalyst bed below. Due to uncontrolled burning via the mixing of incoming air and primary reformer gases, severe overheating of refractories occurred with a resultant burn through of the vessel shell. This in turn involved control valves and other appurtenant equipment at the top of the vessel.

Cool down, internal repairs, and warm up after completion of repairs, entailed a 12-day loss of production. Estimates of damage are still not clear, but property loss appears to be in the $30,000 to $50,000 range with earnings losses probably exeeding $400,000.

In the course of the repair work both internally and externally, several interesting points should be noted: (1) the internal assembly holding the burner was extensively redesigned with greatly strengthened welding throughout; (2) in the course of welding repairs it was found that after the patch job on the outer shell was completed, it was necessary to re-do the job the next day because of faulty work the day before, resulting in the extension of plant idleness.

Again, here was a major plant dependent on the integrity of a relatively minor welding job which didn't pass the test.

Case 3: Broken valve stem. This incident occurred in a 1,000 ton/day plant with which we are involved, but due to insurance contracts in force at the time, information is somewhat restricted. Nevertheless, the highlights of the incident should serve as a good demonstration of what can happen in these plants.

This upset occurred at the start-up heater in connection with, and adjacent to the ammonia coverter. For some reason unknown to us, the plant had been shut down for a relatively short period and it was necessary to bring the converter catalyst bed back to proper operating temperature. To do this is rather a straightforward procedure familiar to all ammonia plant operators. Synthesis gas is circulated through the startup heater, ammonia converter, coolers, syn gas compressor, and back to the startup heater.

The heater itself was a vertical unit with vertical alloy tubes and welded return bends. Firing was by natural gas with automatic shutoff for low gas pressure. There was a 6-in. gate valve of presumably the proper pressure rating and alloy.

The heater had been charged with synthesis gas and the burner ignited about 10 min. prior to the loss. Additionally, the valve between the heater and the converter had also been opened prior to light off. In the 10 min. or so between light off and the loss, it was noted that the heat relationship between the two vessels was not what it should be. The valve was checked and it appeared to be open. Moments later a heater tube split releasing the 1,200 lb. "syn" gas which immediately ignited.

Fire duration involved only 5 min. or so, but in this time serious damage was done to heater internals, shell, and adjacent control equipment. Both suction and dicharge valves to the heater were in relatively close proximity to it and very difficult to approach. Eventually, however, the suction valve was closed manually and the fire extinguished.

Subsequent investigation revealed that the valve stem in the discharge line valve was broken and that in fact, the valve had never really been opened. The split tube then resulted from the obvious fact of no flow through the heater. It was reported that only four tubes had to be replaced and that other tubes remained in relatively good condition requiring only stress relief.

Apparently, the control monitoring system provided was not arranged to indicate "no flow" conditions through the heater since only 10% of the discharge volume from the syn gas compressor actually goes to the heater, the balance being bypassed during the start-up. Damage to the startup heater was generally reported as above. But there are reports of secondary upsets at the primary reformer due to an upset on the control system for the steam drum there, which then filled with water, and in turn spilled over into the reformer tubes causing catalyst damage.

Actual property damage losses are not known to us, but they are estimated in the $100,000 range with plant downtime in the neighborhood of 3 weeks. Based on the capacity of the plant and general sales prices prevailing at the time, earnings loss to the plant probably exeeded $500,000.

We have frequently recommended remote, power operations on both discharge and suction valves in and around similar heaters and the converters, but in this case they were both manual. It would seem that if the suction valve could have been closed rapidly, even though the fire was of relatively short duration, damage to the heater could have been reduced. Even more important, plant downtime might very well have been reduced.

With regard to the broken valve stem, we suppose this could happen to anyone, but the fact that this was a new large ammonia plant again emphasizes the difficulties which can occur. Further, it again repeats the vulnerability of total plant production to a relatively minor occurrence.

With the three foregoing examples, a rough addition of dollar losses indicates straight property damage approximately $250,000 with concurrent earnings losses near $2 million. This from just three relatively minor occurrences! Imagine what potential still exists involving vessels or machinery that could be out of service for months.

Basic hazard still exists

As we have indicated on various occasions in the past, the basic concept of these plants is a tribute to the ingenuity and vision of the designers. We are sure that they and all others involved with the construction and operation of these plants are more concerned with the troubles they have had than even we underwriters, who have had to pick up some of the pieces. We further believe that just as many of the earlier problems in the older ammonia plants have been solved or reduced, so will many of those we are having today in this new generation of plants.

We fail to see, however, that the basic vulnerability to total shutdown and the corresponding loss of earnings will ever be completely elimated. As underwriters we could probably rearrange insurance contracts in such a manner as to elimate much of the potential loss if necessary. Such would not, however, lessen the potential for the operator. He will still be confronted with equipment delivery delays, labor problems, inevitable operational upsets and so forth.

What can the operator do? Certainly there are not any easy answers, but it would seem that a reappraisal of the total plant investment would be one place to start. If additional monies to increase plant reliabilities are needed, then such investments should be made. This should include increased inventories of vital spare parts and equipment; redesigns of control and monitoring systems; re-evaluation of the metallurgical requirements; increased operator training; increased emergency dumps, bypasses, and shutdown controls; and last but not least, a reappraisal of builtin fire and explosion protection.

In the case of future plants, we strongly urge as strong a re-evaluation as possible of the "single-train" concept. If 1,500 tons of production are needed, why not build two 750-ton units, or three 500-ton units. Further, the race toward absolute minimum costs for these plants must be slowed down. A 10 - 20% increase in basic investment could very well lead to long term economic advantages far ahead of the position present plant owners now find themselves in.

In closing, it should again be mentioned that problems of safety in operating ammonia plants are not restricted to any one operator, designer, insurance underwriter, or country. If our comments cause even the smallest reappraisal and review of the present problems, we will have accomplished our objective.