THE ALTERNATIVES TO FINANCIAL LOSSES CONNECTED WITH ACCIDENTS AT THE NEW AMMONIA PLANTS

Here a boiler and machinery insurer recounts its loss experiences of the past 4 years and suggests steps necessary to assure that the picture will be improved.

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The insurance industry generally has followed the philosophy that there is always some way of providing insurance coverage satisfactory to the client and profitable to itself. This philosophy, as practiced by the boiler and machinery insurers, is based on two broad principles: First, on the reliance of their own inspection and risk evaluation methods, and second, on the faith in equipment manufacturers, plant constructors, and the inherent good judgment of most plant operators.

Confidence in this philosophy has been shaken over the past few years by the extremely poor loss experience with ammonia manufacturing plants. It has led, as the politicians say, to an "agonizing reappraisal" of our relationship with this rapidly expanding industry.

The recent record

I would like to tell you something about this experience. With your indulgence I will offer some frank opinions on the present state of things - to which I am ready to admit we have contributed some small part - and then give some suggestions for improvement. The opinions are critical of some practices being followed in the industry. You may not agree with the suggestions. I believe, however, that they are timely at this point in the industry's development.

Hartford provides a substantial portion of the insurance protection for boilers, machinery, and electrical equipment, in all kinds of plants, in the United States and, through a subsidiary company, in Canada. A significant amount of our yearly premiums and an even greater share of losses have been derived from chemical plant risks. Of the chemical plant losses, ammonia plants have the dubious honor of contributing the greatest share.

In a recent issue of a chemical trade magazine that listed producing ammonia plants, 39 out of the 106 enumerated were our clients. It is from this unenviable vantage point that I make these observations.

Although this symposium is not directly concerned with the financial complaints of the insurance business, it is interested in the engineering failures that lead to these complaints. This is a situation where finance and engineering are intimately intertwined, so a few words of explanation may add to a better understanding of what is to follow.

One of the measures of the desirability of an insurance risk is its loss ratio - the relationship of losses to earned premium. Obviously such a ratio can be improved by reducing losses, or by increasing premium, or both. Increases in premium, as you can well imagine, are as difficult to obtain as reductions in losses.

One of the peculiarities of the boiler and machinery insurance business is the necessary emphasis on engineering appraisal of every risk, followed by continuing inspection to reduce accidents. Losses, when they occur, must be investigated, and the causes determined, so that recurrences may be minimized. The cost of maintaining such an engineering and inspection force absorbs a large portion of the premium dollar.

Engineering judgment of the acceptability of any industrial risk is based on loss experience and on the reputation of the designers, manufacturers, installers, and operators of the equipment. This last is especially true in new plants of a type where experience has yet to accumulate. When we are called upon to insure new and unique types of equipment the situation becomes quite different. In such cases we do not have the necessary loss experience to develop adequate rates or proper inspection techniques to keep the loss experience within bounds.

One approach to underwriting unusual risks is the use of deductibles. This means that the policyholder absorbs all loss below a certain deductible amount stated in the policy. This device is an attempt to bring the unusual risk closer to a so-called normal exposure. In 1963 a $50,000 deductible was unusual. But as the new ammonia plants came into being, deductibles rose to $150,000, then to $500,000. Now $1,000,000 deductible insurance is not uncommon.

Discussion of recent experiences

Now, from insurance underwriting matters I would like to share the descriptions of some loss histories.

For purposes of this discussion, I will comment on accidents to four general categories of objects - steam generating facilities; reformers and piping; machinery; and storage facilities.

I have selected 12 of the larger losses to waste heat recovery equipment that have occurred over the past 4 years. Of the ones chosen, the average gross loss attributed to direct damage and business interruption was nearly $200,000 each. The variety of losses include one complete super-heater failure, four cases of tube ruptures in large natural circulation waste heat water tube boilers, and one case of a fire tube waste heat boiler where the loss far exceeded the average because of the damage to the shift converter catalyst caused by escaping water and steam. Weld failures in economizer return bends, relief valve piping failures, and low water conditions brought on by feed pump failures make up the remainder.

Perhaps the most troublesome problem concerns the large natural-circulation waste heat boilers. Accidents to these invariably result in large business interruption losses. Although much is being learned about making repairs, outages have been as high as 27 days following a tube failure.

Causes for these failures are not clearly defined but are due in part to several things. First, failure of designers and builders to recognize in earlier plants that at certain periods of operation the circulation is not positive. This situation has been remedied by devices to induce circulation at start-up, by installing instrumentation to monitor circulation at all times, and by other minor changes in the system.

The second cause still persists, that of water treatment. These complex heat exchangers are extremely sensitive to water conditions, a fact that is sometimes ignored by plant operators. With the present-day knowledge of boiler water conditioning, it is hard to find an excuse for corrosion attack or scale deposits.

Third, many plant owners have been satisfied with a bare minimum of boiler controls, water level indicators, and temperature and draft instrumentation. The waste heat boiler systems in some new plants, as complex and perverse to operate as they seem to be, have fewer controls and fewer and less-knowledgeable operators than many industrial boiler installations of less output and a fraction of the complicated interconnected and interdependent equipment.

Losses to the steam generators in the first of the new plants, and the study of methods used to prevent recurrent failures justify our current recommendations. We feel it is necessary to install duplicate feed pump controls and a drum level indicator, such as T.V. monitor or other visual repeater, in the central control house.

The last cause for heavy business interruption loss in the new steam generators of both types has to do with the difficulty in disassembly and repair. In the fire tube type of waste heat boiler it has been necessary to burn off large transition sections to get at a tube sheet. In the natural circulation water tube types, it has often been necessary to weld the flange faces in order to prevent heavy leakage. Such welding adds to the time spent in returning the boiler to service, and becomes a great inconvenience, and a cause for lost time at the next outage.

Weld failures

There have been almost limitless examples of weld failures in the new plants. Economizer bend welds are only one case in point. In one particular instance 1 in 6 of the total number of weldments were radiographed at the time of construction. However, the quality of welding following each failure was found to be critically inadequate. The same lack of welder integrity and the lack of proper supervision are evident in many places. There seems to be no other way than 100% radiographic examination of such welds in order to keep such failures to a minimum.

Improper choice of metal was at least partly to blame for the superheater failure, which was one loss in a chain of failures following a crash shutdown.

Reformers and transfer piping

There is nothing radically new or different about steam gas reformers, and that may be at least part of the trouble. We have reformers on the books that have been functioning without great difficulty for over 15 years. We have others that have caused severe financial loss that are less than a year old. We picked out 12 cases for study that averaged $300,000 gross loss apiece. In this group were three cracked headers, two cases each of cracked transfer lines, cracked alloy riser forgings, catalyst tube ruptures, and secondary reformer shell overheatings, and one of primary reformer catalyst destruction due to a power failure. There were no pigtail failures in this group, but we have experienced several over the past few years.

The causes for cast alloy headers and tube failures are primarily metallurgical. In times of 30 lb./sq.in. feed gas pressures, tube skin temperatures were about the same as now experienced. However, the higher pressures now employed push the metal closer and closer to critical stress limitations. The failures now are more frequent and are much more disastrous than in the past.

It is a well-known fact there are better alloys than the 25-20 HK type most frequently used, but the data on these more exotic materials is not conclusive, and the cost in most cases is prohibitive. A great deal has to be learned about more suitable and more economically attractive alloys for this service. Non-destructive test methods, heat treatment of alloy forgings, and the proper application of known welding techniques must be pursued.

Losses indicate gross deviations from welding procedures and the wrong choice of welding rods with little thought given to the consequences. It is apparent that closer control of shop welding and tighter supervision of field welding must be obtained by competent welding engineers.

The choice of materials and welding inadequacies are not the whole story. We have encountered situations where unusual stresses have been imposed on reformer assemblies by forced fit-up practices and by poorly adjusted spring hangers. And, as if this punishment were not sufficient, the numerous shutdowns and too rapid start-up periods experienced during the early days of any new plant together with the sometimes inadvertent operation at temperatures and steam-to-carbon ratios in excess of recommended limits must be added.

Transfer line problems have been more numerous than our study indicates. Bulging and cracking of extruded and centrifugally cast piping and several failures of the insulating material used in the newer composite concentric process gas piping have taken place very recently.

Machinery failures

From the standpoint of reliability, machinery objects in the new ammonia plants provide a bleaker picture, if possible, than do reformers and boilers. Compressors and turbines driving centrifugal compressors from 1963 through April, 1967, accounted for 49.4% of the dollar loss attributed to ammonia plant failures. Some conception of the kinds of losses experienced can be gained when it is recognized that seven turbine accidents resulted in total losses of $2,326,000 for direct damage and business interruption. This averages $335,000 per failure.

In the same period 12 various compressor accidents caused total loss of over $3,000,000, an average of $251,000 per accident.

It is difficult to pick out a typical example to elaborate upon, but if I were able to discuss each turbine and compressor loss, it would be noted that nearly every failure leads to numerous concomitant failures in the chain reactions that follow.

Operator misjudgment often enters the picture, as in the case where an operator started a synthesis gas compressor by means of the low pressure turbine without admitting steam to the high pressure turbine. The rotor of the high pressure machine was wrecked due to windage friction. Such an occurrence substantiates our conclusion that in far too many cases inexperienced, inadequately-trained operators are in charge of equipment worth millions of dollars.

One case involved several instances of quickly repeated bearing failures of a newly installed turbo compressor. The chain reaction from emergency shutdowns required 13 days for the necesary corrections and return to production. The cause for this particular failure was finally determined to be misalignment, which had existed since the day the machine was incorrectly installed and was entirely a result of poor workmanship.

Another case initiated by a broken 1/4 in. connection to a lube oil line forced a crash shutdown and again, a series of system upsets caused, among other things, the loss of a superheater. It took 8 days to clear up the damage and make the necessary temporary repairs to get the plant back on the line.

In another new plant, strainers were not provided in the suction line to compressors. A 2 in. square which had been cut out of the metal piping during construction, and was not removed from the line, entered the compressor and seriously damaged the inlet guide vanes. Fortunately, spare parts were on hand, and the machine was returned to service in 8 days.

Ammonia storage

Concerning ammonia storage facilities we are happy to report there have been no large losses to ammonia storage vessels, although we are well aware of the potential and exercise rather severe underwriting restrictions in recognition. The one case of pipeline failure that could have been catastrophic was reduced to the level of an inconvenience by a remotely controlled shutoff valve adjacent to the tank. It almost goes without saying that we favor the installation of such valves in all cases.

It can be appreciated that as insurers, with access to what might be considered confidential information in many cases, we could not be too specific in describing the accidents just mentioned. The immediate causes, however, are of interest since they have been or could be eliminated, but we feel it is essential that we offer some opinions about the underlying reasons for the present unhealthy experience now being studied by the insurance industry.

Much has been said and written about the size of the new plants - too many eggs in one basket. To quell any misunderstanding, it is not the mere concept of single line operation or large physical size of equipment that causes consternation among insurers. We have long accepted as risks large boilers, turbine-generators, and transformer installations that also function as units. Large single line machines in the lumber, steel, and air separation plant industries, just to name a few, are common place and operate with a considerable degree of reliability.

Methods of plant purchase

Some of the reasons for the evident lack of dependability in ammonia plant equipment must be blamed on the method of purchase. We presume that the plant owner is motivated by the feeling that the boom may be transitory and that engineering advances may make a new plant obsolete in a few short years. Hence, he resorts to whatever measures he thinks are required to get the plant on stream as cheaply and as soon as possible.

Competitive bidding and the use of bonus penalty provisions become incentives to the contractor to cut corners, to deviate from previous high standards, and to forsake conventional practice to appease the dictates of economy at the expense of reliability. For example, the use of a single lubrication console to serve two large steam driven centrifugal compressors is such an innovation. This type of installation represents a saving over providing a separate lubrication system for each machine. But it also makes certain that two machines, not one, will suffer the consequences should the oil pump system fail, stop, or should the oil become contaminated or a lubrication line breaks.

Safety devices

The philosophy of operating large ammonia plants from a central control house, remote from the area of the large high speed compressors, leave these machines highly vulnerable to major damage if they are not shut down at the first indication of impending trouble. Here again, there is conflict between common sense on the one hand and the dictates of "getting by" on the other.

The speed at which these machines operate and the very close clearances between moving and stationary parts permit little time for human intervention to prevent major damage. There are many devices available that will shut down a machine upon excessive axial movement of the rotor. There are those devices that will act upon the occurrence of excessive vibration to shut down the unit at the first sign of incipient trouble resulting from excessive bearing wear, rotor unbalance, misalignment or any other reason.

Hartford Steam Boiler feels so strongly about the necessity for such safety devices that they are a mandatory insurance requirement for all centrifugal compressor installation that operate unattended or semi-unattended. It should not be taken as a blanket indictment against all suppliers that these safety devices are omitted from machines that they provide. It is recognized that quite often some of these devices and in some cases all of them, are encouraged and recommended by the manufacturers. Unfortunately, their use does not extend to all machines, as we think it should.

Spare parts program

To an insurer it seems incredible that the management of a multi-million dollar single-line plant, which has the high profit, high loss-potential of the modern day ammonia facility, should so determinedly resist the acquisition of vital, spare parts for critical equipment. The management of a plant costing several million will often deplore the spending of a small fraction of plant cost to obtain vital replacement components for the machines, reformers, and boiler objects that have a lead time of four months to a year in the event a major repair is required.

The possibility of a 6-month production loss in plants having daily insurance exposures ranging to $50,000 a day is a risk that cannot be tolerated by any insurance company. The large, often one-of-a-kind, always high-exposure machines already mentioned, have produced dollar losses of such magnitude that provisions for individually-owned, readily available spare parts for vital rotating and stationary components has become an absolute prerequisite for boiler and machinery insurance coverage. Replacement tube nests for key heat exchangers, alloy tubing for reformers, and sections of alloy transfer piping, are in the same category.

Operation beyond nominal rates

At the current price of ammonia there is a great incentive to push a plant beyond the parameters recommended by the manufacturer. The search for limiting areas of plant equipment "bottlenecks" (if you will) begins before the plant is constructed and continues until it is demolished.

This we have to accept as progress. Up to a point, we must admit, such action pays off. However, as insurers, we would be most happy to see every plant operate at 90% of its design rate. Further we are convinced that in the long run a year's production at that rate might exceed the production turned out by a plant operating alternately at 150% and zero.

Since we are not naive enough to believe that any plant will stay within bounds, we suggest as a reluctant alternative that each increment of plant output be added only after careful and studious evaluation of the ultimate results. Such an evaluation may prove to be one of the alternatives to risking a large financial loss.

Plant operators

We watched the start-up of a new ammonia plant a few months ago. Looking over the shoulder of a young operator we noted the water level in the disengaging drum of a waste heat unit vacillating between 0 and 90% as he fiddled with the manual feed pump control. Such examples are not isolated. Too frequently, like the unbroken horse and the novice rider, the plant and the operators start off together.

There must be more emphasis on operator training prior to plant start-up. The instigation of emergency drills and written procedures for operators to follow and periodic evaluation of operational procedures is necessary if operator-caused losses are to be kept to a minimum.

There is no reasonable substitute for a conscientious and informed operator. He must be given enough instrumentation so that he can be kept aware of process function not only in routine but during periods of startup or emergency. Controls should be situated where they can be readily reached.

Where do we go from here?

The financial backers of most chemical plant projects must have some assurance that their investment will survive the inevitable catastrophic loss. Few operating companies, however well-off financially, can withstand the loss of profits, fixed and continuing expenses, a long outage entails. In short, we know that some kind of insurance coverage is a necessity.

However, insurance companies cannot survive the current loss experience with ammonia plants. The sacrifice of the insurance industry on the altar of economics is not the answer. Many underwriters have already seen fit to withdraw from the market. The financial loss to our company, only one of several, to be sure, has been so devastating over the past three years as to cause our management to consider withdrawal from insuring all ammonia plants.

After great deliberation, however, it was decided to continue in the search for realistic underwriting methods that would allow us to remain as one of the underwriters of the ammonia business. This, to be accompanied by endeavors in all ways practicable to encourage the return to higher standards of engineering, construction, and operation.

We are convinced that such efforts will be beneficial if conducted in conjunction with a tempering of economic goals on the part of the ammonia industry, together with increased cooperation among designers, manufacturers, builders, operators and insurers. Without this re-evaluation of objectives by all concerned parties the rather unpleasant alternative is continuing financial loss, that sooner or later will become unbearable.

Discussion

G. SORELL, M.W. Kellogg Co.: I would like to comment on your reference to "better" alloys. It is my opinion that the term "better" is too broad and tends to be confusing unless it is referenced to a particular criterion. An alloy may be better from a strength point of view, but may have lower ductility and toughness. This in fact is the ever-present dilemma with all the candidate materials for reformer tubes and headers. From a metallurgical point of view, all of these high temperature alloys represent an effort to achieve a practical balance in trading off some high temperature strength for improved ductile properties.

Specifically, you mentioned that there are better alloys than HK-40. This is most decidedly true for external manifold and piping systems where it is far more difficult to predict and control stress patterns as compared to straight, free-riding catalyst tubes. Therefore all of the high carbon cast alloys are judged to be less desirable than inherently more ductile wrought materials such as Type 310 stainless steel or Incoloy. This is reflected in our own designs, none of which employ cast outlet headers or transfer lines.

On the other hand, HK-40 is definitely superior to the commercial wrought alloys for the reformer catalyst tubes themselves where strength at high temperatures is of paramount importance. In fact, the design of modern high pressure, high temperature reformer furnaces rules out any of the available wrought alloys, and HK-40 has established itself as a widely accepted industry standard.

New alloys are being developed which strive to combine high strength with good ductility, both in the new and aged condition. So far, the outlook is not too bright. These newer wrought alloys utilize either higher carbon and/or some alloying ingredient such as aluminum to achieve the required strength levels. This in turn lowers their ductility and weldability, especially after exposure to high temperatures, and one again comes face to face with the strength vs. ductility compromise.

BADGER: Insurers are dependent almost wholly upon manufacturers, and on loss experience, for the knowledge they possess in evaluating insurance risks. According to one major supplier of reformer tubes, there may be better alloys in the future than HK-40. Data on the new alloys is not yet complete and costs are too high. In this light, it is true that HK-40 is the best now presently available.

Q. You recommend that vibration probes be installed on centrifugal compressors that are operated unattended or semi-attended. In what category do you place centrifugal compressors in ammonia plants for the installation of vibration probes and controls for shutting them down upon high vibration?

BADGER: We require vibration cut-outs on pipe line compressors that are completely unattended. We recommend them in installations that are semi-unattended; installations where an operator is not standing by. We are inclined to class compressors in ammonia plants in this latter category. However, this is not at the moment mandatory for insurance coverage, it is just a strongly worded recommendation.

Q. Do you charge an extra premium to a client who does not carry a proper spare parts inventory?

BADGER: It's simpler than that. We refuse to insure.