AIR AMMONIA PANEL

A panel looks at the design, fabrication, and testing of vessels for high pressure service

G.P. Eschenbrenner
M.W. Kellogg Co.
New York, N.Y.

Helmut Thielsch
Grinnel Corp.
Providence, R.I.

W.D. Clark
Imperial Chemical Industries, Ltd.
England

Discussion

Q. Do you do anything in non-destructive testing after hydrostatic testing, such as radiography, or ultrasonics inspection on the big units?

ESCHENBRENNER: You cannot answer this just by size. If we used quenched and tempered steel for a vessel we would use much more extensive inspection procedures than the normal code requirements. Size or thickness alone are not governing, it depends also upon what type of steel is being used. For plain carbon steel, stress relieved, the conventional method of x-rays and surface testing would be adequate. If we go to an alloy steel or a quenched and tempered steel, we would have to do considerably more.

Q. In H. Thielsch's discussion he showed cracks on a reformer header. He showed a crack that started at the surface of the header and extended through the wall thickness. In another example cracking occurred below an elbow. What was the cause of the stresses? In dissimilar metal joints reference was made to adverse service experience at high temperatures. Do you consider HK alloys and others in the family, such as HF, dissimilar, and what do you consider high temperatures? How did you repair the castings where the cracks extended half-way through? How essential did you consider the need to make this repair immediately?

THIELSCH: With respect to dissimilar metals, I consider them dissimilar if there are major differences in their coefficients of expansion. Examples are joints between chromium-molybdenum, alloy steels and stainless steels. I would not consider weld joints between HK-30 or Incoloy dissimilar. Nevertheless, I would prefer welding HK-30 or HK-40 with type 310 high-carbon stainless steel electrodes instead of using Inconel 82 and 182 filler metals.

The cracking in the ammonia reformer was primarily caused by stresses resulting in rotation of the ring header. The crack in the elbow was visible at the surface adjacent to the weld. It did not penetrate through to the inside surface, as some of the cracks in the ring header did. All of the cracks were repaired in the field under careful supervision. On these high alloy steels particular care has to be taken when repair welding is done. Many welders desiring to deposit "perfect" weld metal, grind out at least half of each weld pass which they have deposited. This tends to result in severe residual stresses in the weld deposits, shrinkage and distortion. As little grinding as possible should be done. Thus specific electrodes should be used which result in weld deposits from which the slag is easily removed. The slag should then be removed with thorough wire brushing. Slag and porosity, within the acceptance limitations of the applicable codes, are not harmful and may be far less damaging than severe levels of residual stresses.

Q. Would you comment on the hazards involved in a crack that penetrates one third or half-way through the metal and then terminates, such as the picture of the crack shown in the casting?

THIELSCH: Castings frequently contain some internal metal separations which may be narrow and tight. They may extend across a third of the wall thickness or more. They are most critical when they extend to the surface. If a plant is operated continuously at 1,600 °F and is not shutdown, a crack that extends through 80% of the wall may not propagate. It is assumed, of course, that severe tensile stresses across the crack, and that fatigue are absent. If the same plant is shut down 20 times or more during a year, a crack that may only be a third across the wall of a piping component can lead to a failure. In the plant discussed, cracks were revealed in every one of the fittings checked. Replacement of the fittings with new ones was not possible because of time. Thus any crack that had an extent of more than one-half at the surface was repaired. Cracks that were shorter than one-half inch, even though they might have extended to the center of the fitting, were not removed. This decision was based on judgment and experience with similar components in related plants. A perfect metal does not exist commercially. Any metallurgist can take one of the metals used in these plants and examine them under a microscope at magnifications of 100, 500 or 1000 diameters. The defects appear, of course, extremely large and might readily be considered extremely hazardous to the uninitiated. In fact, if we expose metals to such an examination, we might not even use them. Yet they are satisfactory for the intended service.

Q. I'd like to pose a situation and then ask for advice. Suppose the urea reactor has blown a gasket and it has been drained and the gasket has been replaced and we wish to hydrotest the vessel to test out the gasket at 1½ times its operating pressure. It is a February midnight shift with the outside temperature at 10 °F. The vessel has a steam jacket system which is not used in normal operation. Is there anything particular to do or to be alerted for in such a situation?

ANON: A way of handling this might be to ask for a minimum tempering temperature. With welding manuals specifying a full first weld heat treatment the effect you're looking for might be achieved by the minimum temperature spec. for final stress relief.

Q. Assuming we did use water, what temperature range do you suggest we hold?

ESCHENBRENNER: There have been curves presented for ASTM materials which for different thicknesses state reasonably safe transition temperatures. These were taken from statistical data and if you should get a poor melt or some poor materials, you can still be in trouble. The better way would be to perform impact tests on the actual material used.

Q. In his presentation H. Thielsch stressed that we should be particularly mindful of the inspection of piping systems particularly in new plants. You indicated we would test more thoroughly than is normally done. Do you have an opinion of what the cost of such additional inspections might be?

THIELSCH: On the example which I showed, the header with the cracked fittings had been erected. Thus severe cracking was discovered as result of final inspection. There is merit, after a plant is erected prior to insulation, that a final thorough inspection is made. This should include a careful examination of those components and materials which have had a history of problems or failures in similar plants. Very considerable and practical experience with materials, fabrication, welding, heat treatment and other operations should be utilized in this final inspection. As stated earlier, many defect conditions may be quite harmless. In fact, their removal and repair may lead to other more serious defect conditions not as readily detected by non-destructive inspection. Other conditions to be checked should include uniformity of heat treatment and methods of heat treatment by the fabricator. Repaired welds, in particular, are sometimes not properly heat treated. At times hardness testing may provide useful information, particularly where heat treatments are questioned. The temperature control instruments on furnaces or stress relieving equipment may occasionally read 100 or 200 degrees lower, or higher, than the actual temperatures. Severe variations in hardness values can provide critical notch conditions and lead to failure. These are also referred to as "metallurgical notches". It is not practical to apply a lump sum price to a proper quality assurance program. Inspection and tests should be performed in logical sequence and should include checking for those conditions which are most likely to lead to failures.

Q. Could much of this be covered by tight specifications on your bids?

THIELSCH: If a specification is too tight, it may not allow for judgment and changes in procedures when they might be necessary. Excessive tightness may also lead to excessive repairs or rejections. Some freedom in specifications is desirable. Yet they should still be tight enough to provide for a satisfactory job.

ESCHENBRENNER: The process industry has to tighten up on material specifications. H. Thielsch said this in his presentation and sometimes this is easier said than done. If we talk about plate and tubing material, which are controlled by established specifications which offer a large latitude, most likely being governed by the lower quality suppliers. If you ask for tighter specifications you may get a flat refusal or you may get a statement that tests will be run for information only and acceptance is still governed by the ASTM specification. While you may know what constitutes a better plate, it is not always easy to get it, particularly in the United States, in Europe it is a bit easier.

Q. I've been concerned with the quenched and tempered steels. It appears to me that we are pushing these too fast. I feel the contractors have felt they were good to start using from a competitive situation, and have moved in with them at a more accelerated pace than is desirable. In getting the yield point fairly close to the ultimate tensile strength involves problems that we may not have fully realized.

ANON: A way of handling this might be to ask for a minimum tempering temperature. With welding manuals specifying a full first weld heat treatment the effect you're looking for might be achieved by the minimum temperature spec. for final stress relieve.

Q. I feel we are actively applying these steels too quickly and in too many different thicknesses that might cause stress concentrations. We are getting cases of incipient cracking and I have an inherent suspicion that we may have a bull by the tail.

ANON: One of the reasons we're using the quench tempered steels is that not only are they cheaper but we can do certain things we could never do at all. For instance, a 1,000 ton convertor in a low strength steel designed for the ASME code is not permissible, at least in England. Hence the advantages of high strength steel are considerable. I'm not so very worried about the yield/ultimate ratio. If I were I wouldn't go on an airplane, especially when it lands. The yield/ultimate relationship for the undercarriages is about 99%. Admittedly, standards of fabrication inspection that are put on such components is a great deal higher since the inspection of pressure vessels is child's play as to what goes into aircraft undercarriages; there is enough experience to prove their reliability.

Q. My point is that we are moving in too quickly and your comments are apropos. Surely we must have a little more caution and better inspection in using these steels; perhaps not so complete as with aircraft, but more so than we have had in the past.

ESCHENBRENNER: Better testing becomes essential, not only for ammonia plants, but also for hydrocracking plants where extensive troubles were experienced. But quenched and tempered steels are used for purposes other than strengthening. For low temperature forgings without quench and temper it would not be possible to meet acceptable impact values. If we stay with carbon steel, quench and tempering improves the forging without increasing the strength by improving the grain structure. For alloy steels a quench and tempering operation if done correctly and properly controlled makes a better steel, not only from strength considerations but the structures is improved with more uniform physical characteristics. As we go to thicker steel plates, if these are not properly heat treated, we will get uneven temperatures and changing physical values across the thickness.

Q. What reliance is justified in ultrasonic inspection as a substitute for radiography, and can you mention the type of surface conditions you would insist on, as well as the manner in which the permanent record would be kept?

ANON: It depends on the type of equipment. On base metals, plate, and pipe materials ultrasonic inspection is an excellent tool. Welds on vessels where the outside and inside surfaces are machined, can be quite frequently satisfactorily inspected even though there are tight crack conditions which can be missed by ultrasonic inspections. Where the crack is extremely tight it does not deflect the sound wave. In welds in piping systems which have a rough internal countour, I'm not very convinced with ultrasonic inspections. I prefer radiography on these, even though I realize cracks may not all be noted by this method.

CLARK: I'm a bit suspicious of radiography on thick vessels and tight cracks. I think radiography would be less likely to find a tight crack than ultrasonics. We have used ultrasonics instead of radiography on certain large vessels and there are some types of cracks by fillet welds you can't get by radiography. Ultrasonics is best in this case. You don't keep records in detail unless the ultrasonics survey shows there are no cracks. You can have a routine scan by ultrasonics and as long as it says nothing you can record it. As soon as you find something suspicious you start working by hand and you can't record that in any way. This is the feature of ultrasonics, you rely so much on the personal quality and integrity of the man working the ultrasonic set.

ANON: We had one particular case where we had one four-inch forging that had supposedly been ultrasonically inspected three times. Subsequently we found a very serious defect where a piece literally fell out.

JENKINS, Sinclair: When I was with a previous company we had some problems with the reformer, and I would like to relate my skepticism of ultrasonic testing. We had one of the finest testing companies in the country go through the testing. We were making a very difficult weld. We had the catalyst tube, with a reducer on its bottom and a pigtail on the bottom of that. The testing company passed all of the welds (butt welds) which were made and subsequently we went back and found defective welds. We went back and X-rayed all of the welds and found about 20% were defective according to radiography. This might have been the poor technique involved in the ultrasonic testing. However, the company we employed had one of the best reputations in the country. I don't know what else you can do.

CLARK: If you've got a coarse grained HK-30 or HK-40, ultrasonics won't work.

Q. Is there a thickness limitation on quenched and tempered steels and concerning safety factors, I believe the European values are lower than in the United States, what are the differences?

ESCHENBRENNER: Presently in the United States the ASME factor for design from ultimate material strength is 4 although 3 is generally accepted. For the new ASME Code it is Yield/1.5 and Ultimate/3. The German Code has Yield/1.5 and no limit on Ultimate although there is a requirement that Yield/Ultimate should not exceed 0.8. If that is exceeded, then additional safety factors are added. Generally European codes will permit lower safety factors.