Jack Buller
National Board of Boiler and Pressure Vessel Inspectors

MECHANICAL INTEGRITY INSPECTION FOR PRESSURE RETAINING EQUIPMENT

SCOPE

- Applicable construction code governing pressure retaining equipment.
- Jurisdictional regulations, i.e. State, OSHA.
- National Board's role, i.e., certifications, monitoring qualifications and vessel registration
- Describe two accidents relating to improper or lack of inspection activities. Eastern Canadian refinery and at a Midwest petroleum refinery .

- Applicable National Codes Governing the Fabrication of Pressure Retaining Items
  - ASME Section 1 – Power Boilers
  - ASME Section VIII – Div. 1 Pressure Vessel
  - ASME Section VIII – Div. 2 Alternate Rules
  - ASME Section IV – Low Pressure Boilers
  - ASME B31.1 – Power Piping
  - ASME B31.3 – Chemical and Refinery
  - ASME Section V – Nondestructive Examination

- Various States and Provinces of Canada regulate by Legislation the installation and inspection of pressure retaining equipment. Federal OSHA, particularly in the Petro Chemical Industry there are stringent guidelines relating to the inspection and maintenance of pressure retaining equipment. This regulation is written in Federal Register 1910. Process Safety Management (PSM) Section J. OSHA makes periodic audits in the Petro Chemical Industry based on PSM requirements and extensive accident investigations.

- The National Board of Boiler and Pressure Vessel Inspectors was founded in 1919. The National Board is organized for the purpose of promoting greater safety to life and property. This provides a concerted action in maintaining uniformity in the construction, installation, inspection, and repair of boilers and other pressure vessels and their appurtenances. This also assures acceptance and interchangeability among jurisdictional authorities empowered to assure adherence to code construction and repair of boilers and pressure vessels. The National Board is made up of Chief Inspectors from the various states and cities of the U.S. and Provinces of Canada. Administrative offices are located in Columbus, Ohio. The National Board functions in several ways. First is registration because it's an inspection program documented by the filing of the manufacturer's data report. Since 1921 more than 29 million pressure vessels have been registered. Registration is what may be said is a pressure vessel's birth certificate. Registration identifies and verifies that equipment is constructed to the applicable Code, permitting the industry to track a particular boiler or pressure vessel to determine its fabrication criteria. Along these lines the National Board has a registration program in which to file repairs and alterations to inservice pressure vessels. This allows the inquirer to know precisely what has been done to the vessel, a key to safe operation.

The next important function the training and certification of commissioned inspectors. Commissioned inspectors must meet rigid experience and educational requirements prior to passing a two-day examination. This exam is given in each National Board State and Canadian Provinces. The National Board prepares and grades the exam and if the candidate passes and meets the required qualifications is issued a National Board Commission. Additionally, most Jurisdictions review the individual's qualifications and will issue certificates of competency allowing he or she to inspect vessels in the applicable Jurisdiction. About 4500 commissioned inspectors are employees around the world. National Board Commissions are renewed yearly, with proof of competence.

The National Board also owns the world's only independent testing laboratory for the testing and certification of boiler pressure relief devices. This lab is considered by ASME to be "State of the Art" and is the comparison lab for all other pressure relief device testing facilities.

The National Board is a key resource for manufactures and inspection companies around the world for training and pressure vessel information.

The National Board Inspection Code (NBIC) is a living document, establishing rules of safety governing the repair, alteration and inspection of pressure retaining items. The National Board Inspection Code Committee is charged with the responsibility for maintaining and revising the NBIC. The committee is composed of individuals representing Jurisdictions, Owner-Users, government agencies, manufactures, and repair firms. The various task groups answer questions and provide interpretations to the industry. The National Board Inspection Code Committee is a balanced committee meeting regularly to discuss or make rule changes. The NBIC is an ANSI document requiring all changes to be balloted for 60 days and any negative comments must be resolved prior to rule change.

Next on the agenda we will address two refinery accidents caused by inadequate inspection, repair procedures and lack of response to technical recommendations.

The first accident to be discussed occurred in a large Midwest refinery in the middle 1980's. The first picture shown on the screen depicts the intensity of the fire and explosion, picture #2 is the upper 41 ft portion of the 61ft vertical vessel, which landed one half mile from the blast site. The vessel fell on an electrical tower. Seventeen people were killed and 21 injured in this terrible accident.

The ruptured vessel was part of the process stream and identified as an amine absorber in which hydrogen sulfide is stripped by using the additive mono ethanol amine (MEA) to absorb the hydrogen sulfide gas in the production of propane and butane.

The vessel was a six course vertical vessel built to the ASME Section V111 Div 1 Code and placed in service in 1970 with an operating pressure of 200 psi at 100 degrees F. The steel was a common SA 516 -70. (A drawing is shown on the screen.)

History shows in 1979, during the inspection turnaround, examination revealed extensive hydrogen blistering and cracking in course #2. This section was replaced at that time with the same material (516-70) and thickness as in the original construction. The welding was done manual (SMAW) without the use of pre-heat or post weld heat treatment. In 1976 during another inspection, hydrogen induced cracking was noted in course #1 and a Monel liner was installed covering the bottom of the vessel including course #1. In 1984 the vessel, which in service developed a 6” hydrogen crack that propagated to 31” this resulted in a vessel rupture, explosion and fire.

The vessel fractured in the heat affected zone between the welded repair of sections 1 and 2. The 31” crack had propagated to a depth of 90 to 95% of the vessel wall thickness. The fracture occurred at the axial stress level of less that 10% of the strength of the steel.

Post rupture microscopic examination of the various cross sections through the weld joint area showed the cracking originated in a hard micro structure in the heat affected zone and progressed in a manner characteristic of hydrogen related damage in hard steels. The HAZ exhibited hardness up to 450 Brinell (45 HRC) equivalent to a tensile strength of over 200,000 psi in the region of the weld cracking.

Welding procedures, repair methods, and inspection procedures must include careful consideration of potential failure modes in corrosive environments. If pressure vessels or allied components are operating in an aggressive environment, special steps should be taken to assure that individuals with pertinent expertise are involved in the planning and review states of design, inspections and repairs. When distress signals are present take the time to evaluate the cause and determine what special precautions are necessary.

SUMMARY

The problems of in-service cracking of weld zones can be minimized by attention to the important factors summarized below:

. Preheat or post weld heat treat weld joints that may develop a hard HAZ when corrosive conditions are met.

. Inspect weld HAZs for cracks by suitable NDE method if hard HAZs are suspected.

. Field repair welds are likely to have hard HAZs unless proper preheat or PWHT is applied.

. Small welds on thick members and arc strikes are examples of conditions resulting in rapid heating and cooling and are likely areas for trouble.

. Shop welds made according to the ASME Code may also crack in service under severely corrosive conditions.

. Preheating field weld joints will help drive off the dissolved hydrogen that has been picked up by the steel in service.

. Be particularly cautious when inspecting critical components in unfamiliar corrosive service, especially when prior history reveals problems and when field repairs have been made.

The second accident I would like to discuss briefly involved a tube rupture in a fired heater at a refinery in Eastern Canada. Two workmen were killed and another injured.

The heater was located in the refinery process flow and specifically the Naphtha Hydrobon Charge Unit and installed in 1974. The unit operated from 1974-1976 and from 1987 to the present. The heater was idle during 1977-1986. This unit had a history of tube failures dating back to 1993. Six (6) tube failures including the last rupture, in which the fatalities occurred. After each of the prior failures, caused by excessive skin temperatures and corrosive elements, the resultant recommendations were to upgrade the tube material from 5 chrome ½ moly to 9 chrome 1 moly, these recommendations were ignored and not implemented. Further problems occurred during the period of operation 1993-1998. The ceramic casing insulation was removed and replaced with a fiber batting (K-Wool type). Due to the corrosive elements within the furnace, these elements passed through the insulation and the furnace casing deteriorated and became porous due to sulphurous gases to percolate though to the exterior shell where they condensed and produced acid which caused many perforations. It was recommended to replace the insulation with ceramic castings and renew the casing. This recommendation was in the process of implementation when the explosion occurred.

At the time of the tube failure and explosion, three workmen were at the site. The operator, his assistant and a welder who was doing air arc gouging on the upper casing. This was being done to expedite the removal of the casing for the pending shut down.

Picture #1 depicts a workman air arc gouging in the refinery. You will notice the intensity of the sparks.

The assumption for the cause of the explosion resulting from the tube rupture was as follows:

. It is assumed that the tube rupture extinguished the fire in the furnace. The energy released was estimated at around 115 tons a minute of super rich hot naphtha/hydrogen gas escaped through the corroded openings in the heater casing, which reached the welder air arc gouging on the casing, creating a source of ignition.

Picture #2 shows the heater in a previous explosion when ceramic insulation was in place. You will note the bulged casing.

Picture #3 shows the recent explosion, the casing did not restrain and shows no indication of gas flow restriction.

Picture #4 shows the intensity of the fire.

Picture #5 is the ruptured tube.