韓國非破壞檢査 第3卷 第1號, pp. 12～18, 1983

ACOUSTIC EMISSION TESTING OF SPHERICAL PRESSURE VESSEL DURING HYDROTESTS

水壓試驗中의 球型壓力容器에 對한 AE檢査

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⟨Received; 3 May 1983⟩

ABSTRACT

This paper describes the procedures and results of an acoustic emission testing performed during hydrotest of spherical pressure vessel for propane storage. A computer based multi-channel real time monitoring and source location analysis AET-4900 system was used for AE testing.

The vessel was extremely quiet throughout the entire test run and especially 6 to 14.5kg/cm^2, it is normal operating pressure range. After exceeding 14.5kg/cm^2, one of the 20 sections showed the most event in any one section 11 total but there were scattered at different locations.

In order to confirm the events seen in horizontal weld line of that section, proof testing was performed with ultrasonics and radiography.

I. INTRODUCTION

Acoustic Emission is a method of nondestructive testing in which high frequency stress waves coming from areas of active defect growth are detected and analyzed. In recent years acoustic emission became a viable testing method for determining the integrity of many structures such as pressure vessels, piping, and aircraft frames and also in the study of fiber re-enforced plastics and other advanced materials.

When a material of some kinds is placed under load potential elastic strain energy increases across various portions of the microstructure of material. Normally, strain energy is distributed evently throughout the entire area of the material with no defect. However, if a defect is present, a discontinuity of this strain energy occurs causing local stress concentrations around the area adjacent to the defect. Once this stress concentrations becomes too great a crack will grow, relaxing the localized stresses. When this happens, the strain energy must be conserved. Such portion of the material may be transferred locally along the crack, some may be released as heat, but a portion is also released as a stress wave, travelling throughout the material. It is the detection of this wave that forms the basis for acoustic emission testing.

The phenomenon that a stress wave strikes and causes the sensor for a detectable voltage output above a reference threshold is called an 'event'. By studying the number and intensity of events received during a test as a function of either time or load, a great deal of information as to how the test material or structure behaves under load can be obtained. Normally during an acoustic emission testing, one is concerned with the occurance of a single or even a number of events. Most material when placed under load will produce acoustic emission, expecially if it is the first time it has been an applied load. It is the trend line of events that determines whether or not the material is becoming unstable. If the material is stable the acoustic emission rate should go to zero as loading is halted. It events continue after load hold has been achieved the material's stability would be in doubt. What is performed is to survey the propane storage sphere to pinpoint areas of active defect growth. In order to do this a technique known as event source location was used. By grouping a number of sensors in on array on a structure and timing the event arrival at each one, the location of defect can be calculated. Once the location is determined, other NDT methods such as ultrasonics or radiography can be used to identify and size the defect more effectively.

II. ACOUSTIC EMISSION TEST

1. Test Apparatus

Model: AET 4900
Manufacturer: Acoustic Emission Technology Corporation
The AET 4900 System divides two sections:

1) The data acqusition system, consisting of;
   a. the analog front end (sensors, preamplifiers, signal processor)
   b. the digital front end or front end processor (AE channel modules, A/D converter, bin processor modules)

2) The host system, consisting of;
   a. the host prosessor (main computer)
   b. the system terminal and display
   c. the disk subsystem
   d. all other system peripherals.

Block diagram of AET-4900 system is illustrated in Fig. 1.

2. Test Procedure

1) Preliminary study and planning

This is concerned with the definition of test details on the basis of documents, agreements with the purchaser and investigation on site. Test details include AE monitoring phase, number of sensors and their positions, location of the measurement station, calibration, measurement and analysis time schedule.

2) Sensor, preamplifier and cable positioning

Sensor are mounted on the outer vessel surface. The acoustic coupling between sensor and vessel wall is obtained by means of slight local grinding, few drops of grease as acoustic couplant and pressure from a magnetic device. Amplifier is set very close to each sensor and connected by means of special low noise cable to sensor.

3) System set up

A total of 12 channels were used in an interlocking triangle arrangement to cover the propane sphere (Fig. 2). This arrangement has the advantage of utilizing the fewest number of channels while still assuring that an event will occur within a given maximum distance of any three array sensors. The sensor's peak resonant frequency was 175 KHz. They were attached to the vessel with magnets using grease as acoustic couplant.

Signals from the sensors were fed to preamplifiers which provided a fixed gain of 40 dB (100X). From here cable passed the signal to an AET model 4900 Acoustic Emission System. Overal system gain was set at 75dB referenced to 1.0 volt fixed threshold.

4) Calibration of AE system

After accurate check of AE system, calibration was performed using a high frequency pulser and Pentil pencil break in order to confirm the correct source locations in every monitored section. This established a velocity of sound value for the computer as well as verifies good system operation.

5) Pressurization

Figure 3 outlines the pressure schedule used for hydrotesting the spherical pressure vessel strating at $6kg/cm^2$ and completion at $23.5kg/cm^2$. During the pressurization, holds of 5 minutes duration were maintained in order to check AE response. The completion of the test run took approximately 5800 seconds.

6) On-line monitoring and analysis of AE during hydrotest

When the calibration has been completed, the hydrotest can be started together with AE monitoring. During the various pressure steps AE data were collected under the operating condition. A permanent record of all the data useful for location and classification of AE sensors was recorded on floppy discs for future analyses.

7) Off-line AE data analysis
Further analyses are carried out on recorded data immediately after the pressure test to identify and classify each significant source.

3. Test statistics

- Vessel : Propane Storage Sphere Tank
  Diameter : 10m
  Material : A60H
  Operating Pressure : $14.5 kg/cm^2$
  Test Pressure : 6 to $23.5 kg/cm^2$
- AE System ; AET Model 4900
  Number of Channels: 12
- Array Configuration; Equilateral with dome & base Sensors
- Inter Sensor Distance; 5.5m
- Velocity of Sound; 2.1×10^5 cm/sec – 5.3×10^5 cm/sec
- Sensor Frequency; 175KHz, AET AC 175L
- Filter Bandpass; 125 – 250 KHz
- Gain: 75 dB Ref. 1.0 volt fixed threshold

III. RESULTS AND CONCLUSIONS

Overall response showed that the vessel was in satisfactory condition. The vessel was extremely quiet throughout the entire test run and especially from $6 kg/cm^2$ to $14.5 kg/cm^2$ its normal operating range. After exceeding $14.5 kg/cm^2$, events were reported but never exceeded 5 events/min., and at most times the response was zero. The vessel showed no signs of event concentration during any portion of the test run. Section 12 (Sensors 7, 8 & 12, Fig. 4) reported the most events in any one section, 11 total, but even there they were scattered at different locations. Relative amplitude of the events was extremely low as was the total number of threshold counts. During all load hold points no events were recorded.

In conclusion, events received during the test run were of low amplitude and well scattered, showing no signs of concentration. The events seen in Section 12 do not represent any significance, however since equipment was available on site, the horizontal weld line in this area (Fig. 5) was checked with ultrasonic testing. Several flaws in welding seam between Sensor 7 and 8. Maximum flaw detected was evaluated as 3mm FBH (flat bottom hole). In order to confirm these area were radiographed. Views of the areas showed porosities and slag inclusions deemed in all probability acceptable to Code and Standards.

ACKNOWLEDGEMENTS

This work has been sponsored by the Honam Oil Refinery Co., Ltd. The authors are grateful to Honam Oil Refinery for support and grateful to Mr. David A. Berry, Senior Engineer of the AET Corp. for helpful discussion and data analysis during test.

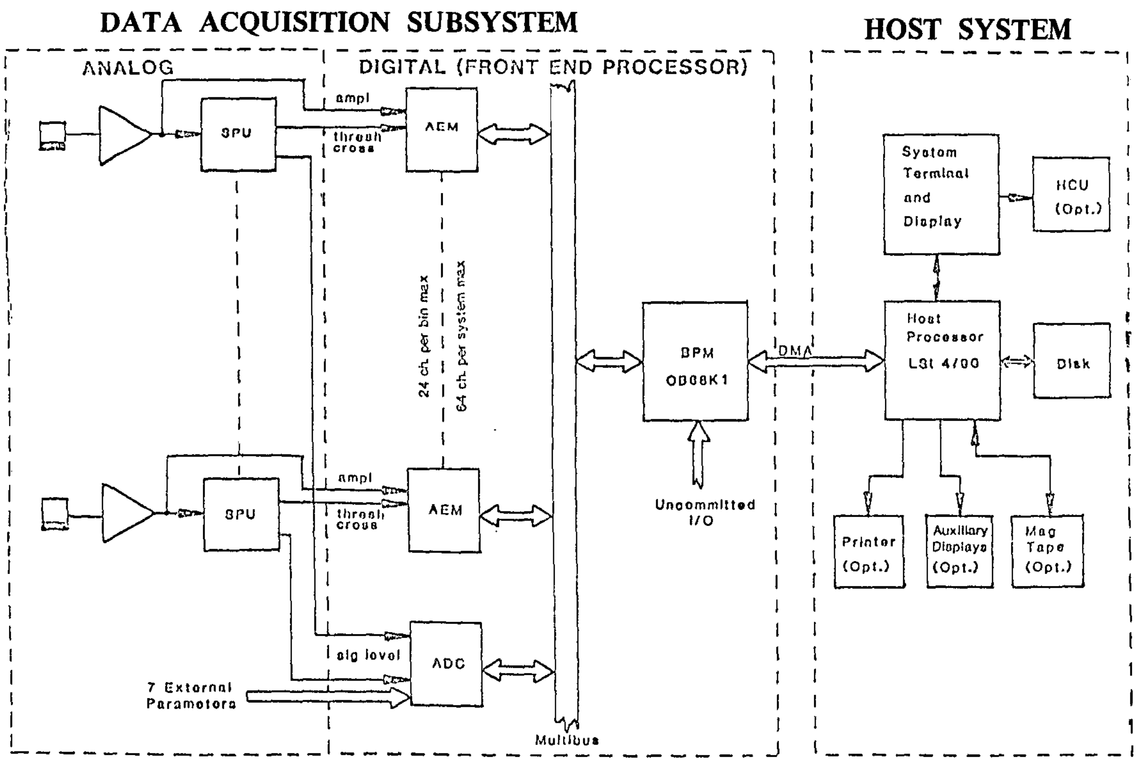

Figure 1. BLOCK DIAGRAM: AET 4900 SYSTEM

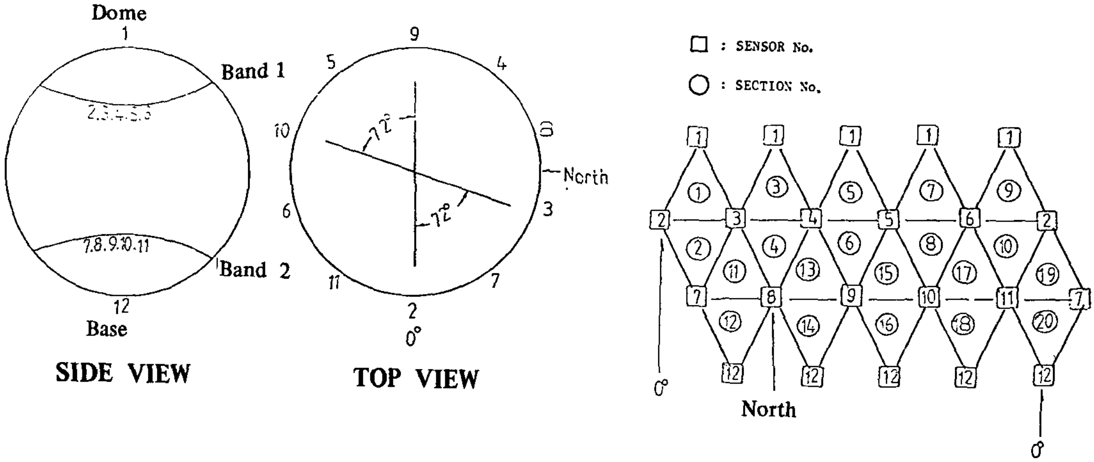

Figure 2. SENSOR ARRAY FOR HYDROTEST

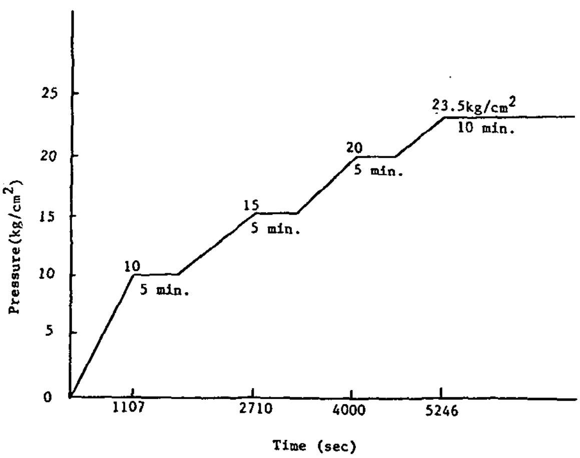

Figure 3. Hydrotest Pressurization

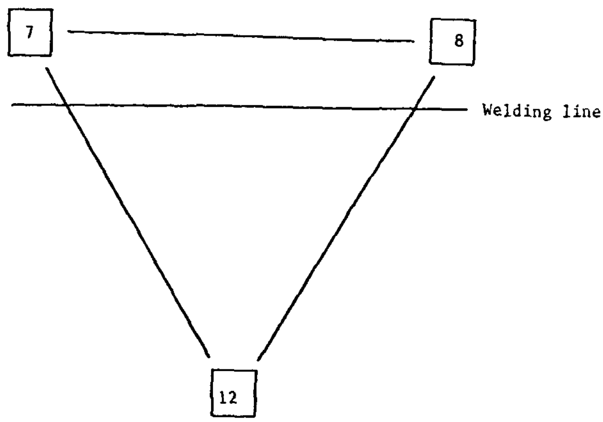

Figure 4. Distribution of Events by Location in Section 12 (Sensor 7, 8 & 12)

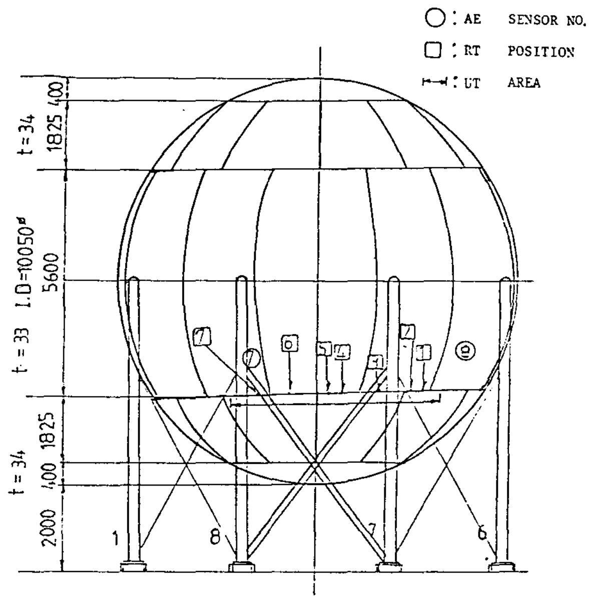

Figure 5. Outline of Area Inspected by Ultrasonic & Radiographic Testing

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