Comparison and research of acoustic emission testing standards for atmospheric storage tank

Shuxin Zhang¹ *, Weibin Wang², Yufeng Yang², Qiang Zhang², Gang Wu¹, Jinheng Luo¹, Xunchang Dong³

¹Tubular Goods Research Institute, China National Petroleum Corporation & State Key Laboratory for Performance and Structure Safety of Petroleum Tubular Goods and Equipment Materials, Xi’an, Shaanxi 710000, China
²Pipeline R & D Center, PipeChina North Pipeline Company, Langfang, Hebei 065000, China
³PetroChina Tarim Oilfield Company, Korla, Xinjiang 841000, China

*Corresponding author’s e-mail: zhangshuxin003@cnpc.com.cn

Abstract. The acoustic emission testing standards ASTM E1930, BS EN 15856, JB/T 10764 and Q/SY GD 0211 for atmospheric storage tank are compared and analysed. Combined with production practice, the revision direction and reference suggestions of acoustic emission testing standards for atmospheric tank were proposed.

1. Introduction

Atmospheric tank is an important storage facility for crude oil and refined oil, which is widely used in petroleum and refining industries. Its volume is generally 2000 m³ ~ 100000 m³, once the leakage occurs, it will cause huge property losses and environmental pollution. At present, the maintenance of storage tank is periodic inspection, which needs to stop production. It is not only time-consuming and laborious, but also has certain safety risks. Therefore, it is of great significance to carry out on-line inspection to evaluate the health status of storage tanks. The on-line inspection technology of storage tank mainly includes internal inspection robot, ultrasonic guided wave, acoustic emission inspection [1 ~ 4]. Because the bottom of the tank is usually covered with a layer of oil sludge, the internal inspection robot cannot walk freely, so the technology is still in the research stage, and there is no engineering application case. Ultrasonic guided wave can be used to inspect the inner annular plate from the outer plate, but usually the outer annular plate of storage tank is covered with the outer anti-corrosion coating, so the coating must be removed to carry out the inspection, thus the application is limited. Acoustic emission technology is almost the only practical on-line inspection technology for tank floor.

Acoustic emission testing has developing for a long time. Since 1997, Vallen Company carried out the acoustic emission testing project of storage tank, the testing technology has been widely used and developed, forming a series of testing standards. However, there are some differences between domestic and foreign standards, and even some clauses are not unified, resulting in the inspection results cannot be compared.

In this paper, the acoustic emission testing standards at home and abroad are compared and analysed. Combined with the production practice, the revision suggestions of the acoustic emission
testing standards for storage tanks are proposed, which is of great significance to further improve the evaluation method of tank floor and guide the on-line inspection and maintenance of storage tanks.

2. The survey of standards at home and abroad for acoustic emission

2.1 foreign acoustic emission test standard
In 1997, ASTM organizations abroad issued the standard of acoustic emission testing for liquid metal tanks of atmospheric / low pressure bearing, ASTM E1930-97 [5], "standard test method for examination of liquid filled atmosphere and low pressure metal storage tanks using actual emission", which was revised in 2002, 2007, 2012 and 2017 respectively. European standard was built based on "acoustic emission detection project for storage tank" project (Contract No. "smt4-ct97-2177") which was carried out in 1997 by Rhine, CESI spa, Vallen, Shell and Dow. In 2010, the acoustic emission testing standard for corrosion defects of metal tanks bearing liquid was issued in BS EN 15856:2010 [6], non-destructive testing - actual emission - General principles of AE testing for the detection of corrosion within metallic bonding fixed with limited.

ASTM E1930 specified personnel qualification, equipment, safety measures, equipment calibration, test steps. EN 15856 specified personnel qualification, equipment, test steps, data analysis and other aspects.

2.2 domestic acoustic emission test standard
Since 1990s, the Institute of special inspection of China, Northeast Petroleum University and CNPC pipeline science and technology center have successively carried out acoustic emission testing research, and formed JB/T 10764-2007 [7], nondestructive testing and evaluation methods for acoustic emission of atmospheric pressure metal tanks, Q/SY GD 0211-2011 [8], on-line acoustic emission detection and evaluation of bottom plate of vertical cylindrical steel welded tanks.

The contents of JB/T 10764 referred to ASTM E1930-02, and added evaluation methods of tank floor. The acoustic emission parameters, event number and hits number were used to classify the health condition of the tank floor, and the maintenance suggestions of tank are given according to the classification. Q/SY GD 0211-2011 not only refers to ASTM e1930-02, but also absorbs the idea of evaluation and classification in JB/T 10764-2007. In informative Appendix F, the evaluation process of inspection results of acoustic emission signal for the tank floor is specified. The leakage probability level of tank bottom is determined by the sparse degree of event number positioning, and the activity of acoustic source is defined by the number of events per unit per hour and the average energy of the event, the corrosion degree of tank floor is obtained by leakage possibility level and acoustic source activity.

3. Comparison and analysis of standards

3.1. Scope of application
Table 1 lists the scope of each AE standard. It can be seen that all four standards are applicable for the new / in service inspection of liquid metal atmospheric tank. Only JB/T 10764 covers the tanks with medium as gas. In fact, atmospheric tanks are usually not used to store gas. ASTM E1930, BS EN 15856, JB/T 10764 all cover the inspection for tank wall, roof and bottom plate, Q/SY GD 0211 cover tank floor inspection only.

| Standard         | Scope                                                                                     |
|------------------|-------------------------------------------------------------------------------------------|
| ASTM E1930-2017  | Suitable for new and in-service storage tanks with liquid medium                         |
|                  | For flat-bottomed storage tanks, wall and roof can be inspected. Only when the sensor is arranged on the floor, the corrosion can be inspected |
|                  | When the operating pressure is greater than the detection pressure, the                   |


inspection is invalid
Suitable for carbon steel, stainless steel, aluminium alloy and other metal storage tanks

BS EN 15856:2010 Suitable for storage tank carrying liquid medium
Suitable for corrosion detection of petroleum and petrochemical metal storage tanks, qualitative evaluation and maximum re-service time recommendations can be given
For flat-bottomed storage tanks, it can detect the bottom plate and wall below the liquid level, and for floating-roof storage tanks, it can detect the roof of the tank.
Only active defects can be detected. During the detection process, if the corrosion process stops, then no acoustic emission signal can be detected

JB/T 10764-2007 Suitable for storage tank carrying gas or liquid medium; atmospheric pressure or less than 0.1MPa; low pressure new and in-service metal vertical storage tank; tank wall and tank floor
Q/SY GD 0211-2011 Suitable for the inspection and evaluation of the acoustic emission technology of the corrosion degree of the bottom floor of the vertical metal storage tank, which carry liquids, atmospheric pressure.

3.2 Acoustic emission system requirements
The standard specified the requirement of acoustic emission inspection system, including sensor, signal line, couplant, preamplifier, power supply signal cable, signal processor. Chinese JB/T 10764-2007 and Q/SY GD 0211-2011 are formulated with reference to ASTM E1930-02, and only have additional agreements on signal acquisition, other acoustic emission system parameter settings are consistent with the ASTM E 1930-02 standard. Since the Q/SY GD 0211-2011 standard is only for the inspection of the tank bottom floor, the sensor resonance frequency setting range is 30~60kHz. BS EN 15856:2010 involves less requirements for acoustic emission systems, and only specified the sensors and signal acquisition. It requires that the wave propagation mode in the liquid should be used for the inspection of the tank floor, and the resonance frequency of the sensor should be 20 kHz~80 kHz. In terms of signal acquisition, JB/T10764-2007 and Q/SY GD 0211-2011 clearly require acquisition amplitude parameters, and BS EN 15856:2010 does not give clear requirements.

Table 2. Acoustic emission equipment.

| standard          | sensor resonance frequency setting for wall inspection | Typical signal line length is 2m | The noise level should not be greater than 5 microvolts rms; | The gain change should not exceed ±1dB; | The hit duration should be accurate to ±10μs | The defined time of hit should be 400μs |
|-------------------|-------------------------------------------------------|---------------------------------|-------------------------------------------------------------|-----------------------------------------|---------------------------------------------|----------------------------------------|
| ASTM E1930-2017   | 100~200kHz;                                           |                                 |                                                             |                                         |                                             |                                        |
|                   | 30~60kHz;                                             |                                 |                                                             |                                         |                                             |                                        |
|                   | The sensitivity should not be greater than 3dB.       |                                 |                                                             |                                         |                                             |                                        |
|                   | Using waves to propagate in liquids, the resonant frequency is 20kHz~80kHz, and | Not required | Not required | Signal acquisition should output at least the following parameters: | Acoustic emission |
| BS EN 15856:2010  |                                                        |                                 |                                                             |                                         |                                             |                                        |
using waves to propagate in metals, the resonant frequency is 100kHz–300kHz.

hit count, parameters characterizing background noise, peak frequency, duration, rise time, energy, arrival time

JB/T 10764-2007

Basically consistent with the requirements of ASTM E1930-2017, it specifies the signal acquisition output parameters, including count, amplitude, duration, rise time, energy, and arrival time.

Q/SY GD 0211-2011

Consistent with JB/T 10764-2007 requirements

3.3 Test procedure

In the practice process of acoustic emission test for storage tank, the placement of sensors, instrument calibration, selection of pressurization methods, and detection time are all key parameters.

The layout of sensors involves the height, spacing, and number of sensors. In ASTM E1930, the sensor installation spacing needs to be determined based on the attenuation characteristics. The maximum sensor spacing for regional positioning is equal to 1.5 times the attenuation radius, and the maximum sensor spacing for calculation positioning is equal to the attenuation radius. The three standards of BS EN 15856:2010, JB/T 10764-2007 and Q/SY GD 0211-2011 all suggest that the sensor spacing should not be greater than 13m. The height of the sensor is not clearly specified by ASTM E1930, and the other three standards are different. For crude oil storage tanks containing sludge, only BS EN 15856:2010 and JB/T 10764-2007 recommend that the sensor is higher than sludge. BS EN 15856:2010 clearly indicates that if a sludge storage tank is contained, there will be a large error in defect positioning.

For the surface treatment of the installation position, only the Q/SY GD 0211-2011 standard requires that it reaches St3 according to the rust removal level, and the other three standards require good coupling.

Testing instrument calibration method, ASTM E1930-2017, JB/T 10764-2007, Q/SY GD 0211-2011 three standards recommend the use of lead break test, the lead break position is required to be at least 10cm away from the sensor, and the peak amplitude requirement of the sensor is different. BS EN 15856:2010 requires the use of Hsu-Nielsen source to be 50mm from the centre of the sensor for sensitivity testing. The average error of the 4 sensitivity tests should be within ±3dB, which is also the most stringent test.

Pressuring method and inspection time. Generally, the four standards all require testing in a pressurized environment. Only BS EN 15856:2010 requires that the tank liquid level is only 1m greater than the sensor installation position. Other standards have harsh requirements for pressurized environments. ASTM E1930-2017 and JB/T 10764-2007 require the medium level to be between 75% and 100%, and Q/SY GD 0211-2011 requires the level to be above 85%. Testing time ASTM E1930-2017 does not require standing time. It is sufficient to test at 100% medium level for 30 minutes. JB/T 10764-2007 requires a standing time of at least 2 hours and a testing time of at least 1 hour, but it does not specify a 1h test environment, Q/SY GD 0211-2011 requires standing for at least 12h, testing twice, at least 10h each time.
Figure 1. Pressuring procedure for acoustic emission test.

Table 3. Acoustic emission test procedure.

| standard | Sensor height | Sensor spacing | Surface treatment | sensitivity test | Pressuring method | Test time |
|----------|---------------|----------------|-------------------|------------------|-------------------|----------|
| ASTM E1930-2017 | Not required | For regional positioning, the inspection radius needs to be determined according to the attenuation characteristics. Clean surface and free of impurities to ensure good coupling. The tank inspection with calculated positioning is adopted, and the maximum allowable sensor spacing is determined according to the attenuation characteristics. For the regional positioning method, the maximum sensor distance is 1.5 times the | Lead breaking test, the lead is at least 10cm away from the sensor, and the average peak amplitude change does not exceed ±4dB; When event positioning is required, adjacent sensors should detect signals exceeding the threshold, and the positioning accuracy should be | No clear requirements for newly built storage tanks; For in-service storage tanks, the detection level should be between 75% and 100% of the highest operating level. | According to the pressurization program |
The first row of sensors should be set at a distance of 1m from the bottom plate, and the second layer of guard sensors should be set at 4-6m, directly above the first row of sensors, at least 1m away from the liquid level. When the oil sludge affects the wave propagation, the two rows of sensors must be raised. But this should be negotiated with the tank operator, because this

| attenuation radius, and for the calculation positioning method, the maximum sensor distance is equal to the attenuation radius. | within 5% of the sensor spacing. |
| --- | --- |

Evenly distributed around the tank, avoiding manholes, welds, and the spacing should not exceed 15m. Practice has proved that 13m is more maneuverable.
The number of sensors in each row is not less than 6. The distance between the sensor and the weld seam should be more than 200mm.

BS EN 15856:2010

The first row of sensors should be set at a distance of 1m from the bottom plate, and the second layer of guard sensors should be set at 4-6m, directly above the first row of sensors, at least 1m away from the liquid level. When the oil sludge affects the wave propagation, the two rows of sensors must be raised. But this should be negotiated with the tank operator, because this

The Hsu-Nielsen source is set at 50mm away from the center of the sensor for sensitivity testing. The average error of the 4 sensitivity tests should be within ±3dB.

The liquid level should be at least 1m above the sensor. For flat-bottomed storage tanks, the storage tank should stand still during testing, with no liquid in or out, and the heater turned off. It is usually sufficient to stand for 24 hours.

The most ideal detection environment is: no wind, no rain, no direct sunlight. It can be tested at night. Test for at least 1h. If waveform signals are collected, these signals cover at least 30min. Collecting several times can be used to improve the evaluation results.

It can be tested at night. Test for at least 1h. If waveform signals are collected, these signals cover at least 30min. Collecting several times can be used to improve the evaluation results.
will cause a larger positioning error.

The sensors are arranged on the tank wall with the same height as possible, and should be 0.1m-0.5m away from the bottom plate, and higher than the sludge depth. The sensors are arranged on the tank wall with the same height as possible, and should be 0.1m-0.5m away from the bottom plate, and higher than the sludge depth.

When using regional positioning, the inspection radius needs to be determined according to the attenuation characteristics. When the number of events is used for positioning, the maximum allowable sensor distance is determined according to the attenuation characteristics.

Clean surface and free of impurities to ensure good coupling. Consistent with ASTM E1930

The detection level should be at 85% to 105% of the maximum operating level. Under special circumstances, the liquid level is more than 1m above the sensor installation position. Before testing, it should be allowed to stand for more than 2h.

The floating roof storage tank: set on Floating roof storage tank: not more than 1.5 times the attenuation radius, and for the calculation positioning method, the maximum sensor distance is equal to the attenuation radius. The sensor spacing should not be greater than 13m.

Q/SY GD 0211-2011 The floating roof storage tank: set on Floating roof storage tank: not more than St3 Lead The height of the liquid level according to the liquid level test, (0.3mm should be more Close the inlet and outlet valves to eliminate the
8

3.4 Result evaluation

ASTM E1930-2017 uses 5 indicators to evaluate the condition of storage tanks. When the indicators reached some extent, other non-destructive testing methods are required to make further inspection. These 5 indicators are the acoustic emission signal, signal duration, number of hits, large amplitude hit, and signal strength. During load holding state, the acoustic emission signal indicates the continuous yield or damage during the creep process, or the continuous change of the defect under the stress level. The signal duration characterizes the overall activity. If the acoustic emission signal consistently exceeds this value, it indicates that the tank is in poor operating condition. The number of hits is mainly used to evaluate the storage tanks in service. When the number of hits is too large, it indicates that the storage tank has more defects. A large amplitude hit indicates that the crack is growing. When it is found that the amplitude is also increasing as the load increases, it indicates that the crack is growing. The signal strength indicates that the defect area responds as the load increases.

BS EN 15856:2010 requires that the difference in the arrival time of different signals is used to locate acoustic emission events, when the events are adjacent, they can be regarded as the same time and represent the same acoustic emission source. The number of acoustic emission events per unit time (1 hour) in the acoustic emission activity evaluation area is used to rank the storage tank floor’s health condition. The rating ranges from "silent acoustic emission source" to "severe acoustic emission source", corresponding to the maximum service period and immediate opening of the tank for maintenance.

JB/T 10764-2007 provides the acoustic emission evaluation method of the storage tank floor in the standard context. Calculation positioning and regional positioning are used to analyse the classification of acoustic emission sources, and further to classify the health condition of the tank bottom plate.

Calculation positioning analysis is to obtain the number of events through triangulation analysis of hits. The bottom of the tank is divided into grids. The grids can be square or round, and the side length or diameter should not be greater than 10% of the tank diameter. The number of events per hour E in a grid is used to evaluate the corrosion classification of the bottom plate.

The regional positioning analysis is based on the number of hits per hour H collected by each channel to classify the corrosion level.
Furthermore, the maintenance priority order of tank is further analysed according to the analysis result of calculation positioning or regional positioning analysis.

Q/SY GD 0211-2011 provides the acoustic emission evaluation method of the storage tank floor in the informative appendix. The two parameters of leakage probability level and acoustic emission activity are used to describe the results, and then they are placed in a matrix to evaluate the final tank bottom floor rating.

Event location is obtained by calculation from the difference of hit arrival time, the degree of event concentration is used to describe the leakage probability level, and the number of events per unit time per area and the average energy per unit time per event is used to describe the acoustic emission activity.

4. Discussion
According to the above comparative analysis, there are big differences between domestic and foreign about acoustic emission inspection and evaluation standards, mainly in the aspects of acoustic emission scope, inspection procedures, and evaluation methods.

4.1 Scope
ASTM E1930, BS EN 15856, JB/T 10764, Q/SY GD 0211 standard test ranges are all covering liquid storage tanks, but not specify which kind of liquid medium. In the actual application process, the liquid medium includes crude oil, gasoline, diesel, and water. The density of different media is different, and the propagation speed of the acoustic signal is different, which will inevitably affect the result. In addition, the bottom of crude oil storage tanks is usually covered with a layer of sludge. Different thicknesses of sludge will dissipate different acoustic emission signals. The result needs to be corrected according to the thickness of the sludge. Martín Sanchez[9] et al. carried out acoustic emission detection on a gasoline tank with a diameter of 15.68m and a height of 10.52m in 3000m3, using 8 sensors (35kHz) to be evenly arranged and tested for 1h, and the Vallen AMSY-5 AE system was used for inspection and post-processing. The research found, the cathodic protection system will produce some noise, which will affect the test results. Acoustic emission detected one active leakage defect, and the other one was not detected because the area was covered with sludge and no leakage occurred. Zhang [10] et al. conducted an acoustic emission test on a 20,000 m³ crude oil storage tank, and found that acoustic emission is an effective online detection technology that can qualitatively evaluate the corrosion status of the crude oil storage tank bottom plate. Compared with the actual situation, the test evaluation results is conservative, it believes that the acoustic emission rating results of sludge crude oil storage tanks must be revised.

ASTM E1930, BS EN 15856, JB/T 10764, Q/SY GD 0211 standard test ranges are divided according to the location of the storage tank, ASTM E1930, BS EN 15856, JB/T 10764 all cover the tank wall, top and bottom, Only Q/SY GD 0211 is only for the inspection of the bottom of the storage tank. In engineering practice, acoustic emission technology is mainly used for bottom plate corrosion detection, and it is applied in storage tanks of 2000m³~100000m³. However, for large storage tanks, as the diameter of the bottom plate increases, the attenuation of the acoustic emission signal continues to increase, which will make it difficult for the signal at the centre of the tank to propagate to the tank wall. According to ASTM E1930, the sensor installation distance needs to be determined according to the attenuation characteristics. The maximum sensor distance for regional positioning is equal to 1.5 times the attenuation radius, and the maximum sensor distance for calculation positioning is equal to the attenuation radius. The author measured the attenuation characteristics on gasoline tanks, and found that the attenuation radius was about 5m, which means that the distance between the regional positioning sensors should be 7.5m, and the distance between the calculated positioning sensors should be 5m. In the standard, it is recommended that the maximum sensor spacing should be less than 13m. The radius of the 100,000m³ storage tank is about 80m, and the radius of the 20,000m³ storage tank is about 40m, which are far greater than the maximum sensor spacing of 13m and the attenuation radius measured by the author of 5m, so the central corrosion signal of the storage tank will not reach
the tank wall. However, from the results of the American PAC acoustic emission detection and analysis software, the acoustic emission can detect the corrosion signal of the centre of a 100,000m³ storage tank, which is inconsistent with the standard and actual situation. For large storage tanks, the acoustic emission detection range can only cover a certain range of the bottom of the storage tank. It is recommended that the acoustic emission detection of large storage tanks can shorten the sensor spacing and increase the number of sensors.

4.2 Inspection procedure
The difference about inspection procedure is the sensitivity test and the pressurization procedure. The sensitivity test is to calibrate the equipment to ensure the repeatability of the test results. The standards all recommend the use of lead break test for calibration, but there is no clear regulation on the size of lead cores, and the requirements for lead-breaking positions are different, so the results of testing according to different standards will be incomparable. It is recommended to clarify the parameters such as the position of the lead, the size of the lead core, and the angle of the lead, as shown in Figure 2, or use a standard signal generator to make the detection results consistent and comparable.

![Figure 2. Lead break test.](image)

4.3 Result evaluation
ASTM E1930-2017 adopts five indicators: acoustic emission signal, signal duration, number of impacts, amplitude impact, and signal intensity to evaluate the tank condition; BS EN 15856:2010 adopts acoustic emission activity/ the number of acoustic emission events per unit per hour to rank storage tanks floor condition; JB/T 10764-2007 uses calculation positioning and regional positioning to analyse the classification of acoustic emission sources, and uses the number of events per unit time per unit area and the number of hits per unit time to evaluate the corrosion status of the tank bottom; Q/SY GD 0211-2011 uses two parameters to describe the results of leakage probability level (the intensity of the number of acoustic emission events) and the acoustic emission activity (the number of events per unit time, the average energy of the event) to obtain the final tank rating.

E. Hodaei[11] et al. conducted acoustic emission detection on a crude oil storage tank with a diameter of 9m and a height of 7.6m with a diameter of 600m³, 5 sensors were evenly arranged and tested for 1h, and a triangulation method was used to locate and analyse the acoustic emission signal to obtain the tank floor. Distribution of the events was obtained. The study found that the degree of corrosion and thinning of the tank floor is positively correlated with the distribution of the number of events. Sekine K. et al. [12] carried out acoustic emission testing, magnetic flux leakage testing, and ultrasonic testing on nearly 20 storage tanks, and compared the testing results. The results showed that the source positioning results were different from the actual situation, while the concentration of events can effectively reflect the severity of the corrosion of the in-service tank bottom. Therefore, it
can be inferred that acoustic emission can qualitatively reflect the corrosion status of the bottom of the tank, but corrosion defect cannot be accurately located.

For the four standards of acoustic emission domestic and abroad, the selected acoustic emission evaluation indicators are not the same, and none of them provide a clear classification method for the classification of storage tanks. For inexperienced inspectors, the results cannot be rated. Given this situation, combined with previous studies, it is recommended to use two parameters, the intensity of acoustic emission events and the number of events per unit time to evaluate the floor condition.

5. Conclusion
The study found that the four domestic and foreign acoustic emission testing standards, ASTM E1930, BS EN 15856, JB/T 10764, and Q/SY GD 0211, have differences in scope, procedures, and evaluation methods. The main conclusions and recommendations are as follows:

(1) ASTM E1930, BS EN 15856, JB/T 10764, Q/SY GD 0211 acoustic emission testing standards all cover liquid storage tanks. While in the actual application process, the liquid medium includes crude oil, gasoline, diesel, water. The density of different media is different, and the propagation speed of the acoustic signal is different, which will inevitably affect the result. It is recommended to give evaluation methods according to the type of media.

(2) For large storage tanks, as the diameter of the bottom plate increases, the attenuation of the acoustic emission signal continues to increase, which will make it difficult for the signal at the centre of the tank to propagate to the tank wall. It is suggested that the acoustic emission detection of large storage tanks can shorten the distance between sensors and increase the number of sensors.

(3) ASTM E1930, BS EN 15856, JB/T 10764, Q/SY GD 0211 all recommend the use of lead-breaking test for sensitivity calibration, but there is no clear regulation on the size of lead-breaking lead cores, and the requirements for lead-breaking positions are different, so it will cause incomparable test results according to different standards. It is recommended to clarify the parameters such as the position of the lead, the size of the lead core, and the angle of the lead, or to use a standard signal generator to make the test results consistent and comparable.

(4) ASTM E1930, BS EN 15856, JB/T 10764, Q/SY GD 0211 acoustic emission standards do not provide a clear classification method for the classification of storage tanks, and for inexperienced inspectors, the results cannot be rated. It is recommended to use two parameters, the intensity of the number of acoustic emission events and the number of events per unit time, to evaluate the results, and to clarify the grading standards.

Acknowledgments
The authors are grateful to the fund support of National Key R&D Program of China (2017YFC0805804).

References
[1] Jiang Linlin, Li Lingjie, Su Bihuang, Wang Zhitao, Zhang Yanjun.(2021) Application of acoustic emission technology in the corrosion detection of storage tank bottom plate. Corrosion and Protection, 42(02): 56-59+77.
[2] Jiang Linlin, Han Wenli, Xu Zhongping, Wang Zhitao, Su Bihuang. (2016) Research status of acoustic emission on-line detection technology for storage tank floor. Corrosion and Protection, 37(05): 375-380.
[3] Bi Haisheng, Li Zili, Cheng Yuanpeng, Chen Jianfei, Wang Jun. (2015) Discussion on the correlation between corrosion rate of atmospheric storage tank bottom plate and acoustic emission activity. Corrosion and Protection, 36(06): 573-576+ 589.
[4] Li Zili, Bi Haisheng, Cheng Yuanpeng, Chen Jianfei, Rong Haixia, Wang Jun. (2014) Application and prospect of acoustic emission technology in metal corrosion research. Corrosion and Protection, 35(06): 598-601.
[5] ASTM E1930 – 97. Standard Test Method for Examination of Liquid Filled Atmospheric and Low Pressure Metal Storage Tanks Using Acoustic Emission.

[6] BS EN 15856:2010. Non-destructive testing-Acoustic emission-General principles of AE testing for the detection of corrosion within metallic surrounding filled with liquid.

[7] JB/T 10764-2007. Non-destructive testing. Atmospheric pressure metal storage tank acoustic emission testing and evaluation method.

[8] Q/SY GD 0211-2011. On-line acoustic emission detection and evaluation of the bottom plate of a vertical cylindrical steel welded storage tank.

[9] Sánchez M., Cardenas N., & Dominguez V. A. (2012) Acoustic emission testing of aboveground petroleum storage tanks: Risk assessment and lessons learned [J]. Process Safety Progress, 2012, 31(2), 159–164.

[10] Zhang Shuxin, Sun Bingbing, Luo Xiaowu, Zhou Huiping, Weng Xiang, Zhu Yongbin, Luo Jinheng. (2020) On-line detection and verification of acoustic emission of crude oil storage tank floor. Petroleum Tubular Goods & Instruments, 6(02): 75-78.

[11] Hodaei E., Javadi M., Broumandnia A., Sadeghi S H. (2012) Evaluation of acoustic emission inspection of oil tank floor via tank bottom plates thickness measurement. Journal of Mechanical Research and Application, 4(3) , 37-44.

[12] Yuyama S, Yamada M, Sekine K. (2007) Verification of acoustic emission testing of floor conditions in aboveground tanks by comparison of acoustic emission data and floor scan testing. Materials Evaluation, 65(9):929-934.