The China Academy of Space Technology (CAST) designed and built a new world-class Assembly, Integration and Test Center (AITC) at Tianjin, China. The 1400kN electric vibration system, KM8 thermal vacuum chamber and an acoustic chamber are built to support the future environmental testing needs of China space station program. The Reverberation Acoustic Test Facility (RATF) is about 4000 m$^3$ in volume and can achieved an empty chamber acoustic overall sound pressure level (OASPL) higher than 156dB. It is the second largest acoustic facility in the world.

Keywords: ACOUSTIC FACILITY, SPACECRAFT, 156dB

1. Introduction

The China Academy of Space Technology (CAST) is tasked to develop new Assembly, Integration and Test Center (AITC) to support the developing of space station program (the model is shown as Figure 1), lunar exploration program and etc. In the AITC, there is world’s largest electric shaker (1400kN), and the Chinese largest thermal vacuum chamber (KM8) and reverberation acoustic chamber. The Beijing Institute of spacecraft Environment Engineering (BISEE) gets the contract to design and construct these systems.

The Reverberation Acoustic Test Facility (RATF) is about 4000 m$^3$ in volume and can achieved an empty chamber acoustic overall sound pressure level (OASPL) higher than 156dB. The RATF will provide an efficient support for environment testing needs of China and world’s space program in the future.

Figure 1: The model of the Chinese space station.
2. Specifications

Specimen’s size: The RATF’s test chamber shall physically allow a 8m diameter and 20m tall test specimen, and its weight is up to 30 ton.

Launcher requirements: the typical acoustic test spectrums of the existing launchers in the world.

Spatial homogeneity: better than ±3dB in the test volume

3. Design and Construction

3.1 Configuration

RATF usually composes of building, sound generation system, gas generation system, and control system. Figure 4 shows the principle of acoustic test. Specimen is placed in the middle of the chamber and then the sound generation system generates high level sound pressure field. The specimen is excited and its performance in acoustic environment is verified.
3.2 Buildings

In reference with above-mentioned specification, the useful dimensions of the chamber: 14.5m (Length) × 11.5m (Width) × 24m (Height).

These dimensions offer a sufficient number of modes in the low frequency domain (7 modes in the first 1/3 octave) and a useful test volume 4000 $m^3$. Figure 5 displays the photo of chamber building during construction.

A first concrete wall and envelop is 0.7m in thickness. Horns rooms located at the west and north sides, and the anechoic tunnel is on the top of the chamber.

A second concrete wall located at least 2m away of the first one. This will give a large empty volume for acoustic absorption in order to limit external acoustic noise.

In order to obtain the specified acoustic performances, some serious constraints exist on the way the concrete walls will be realized. The following tolerances have to be respected:

1) Dimensions: ± 10mm;
2) Verticality: <10mm over the 24m height;
3) Planarity: <2mm over 1m.

Figure 4: Principle of acoustic test.

Figure 5: Construction photo taken at April 2014.
A sliding door resulting in a useful 10m × 22m entrance (the mass of the door is roughly 200 tons). The door moving on two rails, and the guiding system used for the slide door will be based on a rolling cylinder system.

Figure 6: The sliding door of the chamber.

3.3 Sound generation system

The functional specification related to acoustic performance (156dB) has lead to the noise configuration: 4 LF-60 modulators, 6 EPT-200 modulators and 10 modulators made in China. The modulators connected to 20 exponential horns: 20Hz (2 sets), 40Hz (2 sets), 80Hz (2 sets), 100Hz (2 sets), 160Hz (5 sets) and 200Hz (7 sets). These horns were installed in the west and north wall of the chamber, shown as Figure 7.

Figure 7: RATF’s horn walls layout.

3.4 Gas Generation system

The sound system configuration described here-above, induces the following specification on the gas flow (gaseous nitrogen):

1) Maximum flow rate: 800Nm³/min;
2) Gas pressure (absolute): 2.5 ± 0.5 Bar.

In addition, the system should allow 10 acoustic runs per day at maximum flow rate, and duration of each test is 3 minutes. Figure 8 shows the overall principle of the gas generation system.
Figure 8: Principle of gas generation system.

Liquid nitrogen stored in two 30 m$^3$ tanks at 16bar.

Two evaporators installed in a pool (11m × 7.5m × 4m) filled with water. Two 30m$^3$ gas tanks were used to store the nitrogen gas, and reduce the fluctuation of pressure. A picture of the gas generation system under testing is shown as Figure 9.

Independent and controlled inlet is designed for each modulator by using electric valves and pressure transmitters.

Figure 9: Testing photo of the nitrogen generation system.

4. Acceptance test

4.1 Max OASPL

The maximum acoustic overall sound pressure level (OASPL) in empty chamber is higher than 156dB.

Figure 10: the spectrum of maximum OASPL
4.2 Spectrum test
The test spectrums of the typical existing launchers in world are shown as Figure 11.

![Figure 11: the spectrum test result](image)

4.3 Modal density test
The modal number test result is shown as Figure 12, and modal density of 1/3 Oct frequency band is shown in Table 1. The modal density of the chamber is shown as below.

![Figure 12: Test result of modal number](image)

<table>
<thead>
<tr>
<th>1/3 Oct (Hz)</th>
<th>Number of modal</th>
<th>Modal density</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>7</td>
<td>0.85</td>
</tr>
<tr>
<td>31.5</td>
<td>15</td>
<td>2.05</td>
</tr>
<tr>
<td>40</td>
<td>21</td>
<td>2.28</td>
</tr>
</tbody>
</table>

4.4 Reverberation time ($T_{60}$)
Table 2 shows the reverberation time test result of 4000m$^3$ RAC.
Table 2 Reverberation time of 1/3 oct

<table>
<thead>
<tr>
<th>1/3 oct</th>
<th>31.5Hz</th>
<th>63Hz</th>
<th>125Hz</th>
<th>250Hz</th>
<th>500Hz</th>
<th>1000Hz</th>
<th>2000Hz</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_{60}(s)</td>
<td>25.1</td>
<td>24.3</td>
<td>23.7</td>
<td>31.4</td>
<td>25.6</td>
<td>20.9</td>
<td>13.3</td>
<td>27.9</td>
</tr>
</tbody>
</table>

4.5 Spatial homogeneity

The spatial homogeneity test results are shown in Table 3.

Table 3 Spatial homogeneity of 1/3 oct

<table>
<thead>
<tr>
<th>1/3 Oct(Hz)</th>
<th>31.5</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
<th>OASPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial homogeneity (dB)</td>
<td>2.4</td>
<td>0.54</td>
<td>0.4</td>
<td>0.44</td>
<td>0.5</td>
<td>0.94</td>
<td>0.96</td>
<td>1.28</td>
<td>2.21</td>
<td>0.5</td>
</tr>
</tbody>
</table>

5. Application

The RATF was put into use at October 2015 after acceptance tests. It was used to perform an Acoustic Fill effect test and analysis of Spacecraft, shown as Figure 14. The result obtained enabled BISEE to define an implementation methodology and incorporate it into the ISO 19924《Space systems-Acoustic testing》.
6. Conclusion

BISSE designed and constructed a new big RATF. It offers 4000 m$^3$ useful test volume and a sufficient number of modes from the first 1/3 octave (25Hz). The entrance is 10m × 22m, and the OASPL is higher than 156dB. The RATF will provide an efficient support for environment testing needs of China and world’s space program in the future.

REFERENCES