

# *Research on maintenance and application of data management system for salt cavern*

*Li Pei, Qian Jian-guo*

Liaoning Technical University  
Liaoning, Fuxin, China

*Zhu yi*

Chinese Academy of Surveying and Mapping,  
Beijing, China  
zhuyi@casm.ac.cn

**Abstract**—With the growing demand for energy of China, oil and gas storage safety will directly influence the development of Chinese economy, The use of salt cavern storage of oil and gas because of its unique advantages has become an important way for oil and gas storage, which has shown a good application effect in many countries. China is abundant in underground rock salt resources and is provided with geological conditions of basic construction of salt cavern storage. In order to exploit salt cavern for oil and gas, in the construction and management process of salt cavern, people must performed shape measurements on the salt cavern, and then analyzed the measuring data processing. In this paper, by the German SOCON company salt cavern surveying data as the research object, in-depth analysis of the record format salt cavern surveying data, using C# language programming to achieve the salt loading data, establishing salt cavern data application system, and realizing three-dimensional model of salt cavern exhibition, and also put forward a method to calculate the volume of the cave. To improve the security of the salt cavern gas storage, pave the way for the further study of salt cavern gas storage optimal shape.

**Keywords**—*salt cavern; oil and gas; C# language; three-dimensional model; secondary development;*

## I Introduction

China Petroleum and Economic Technology Research Institute released data show that in 2014 China's crude oil consumption of about 5.08 tons, 2.98 tons of crude oil imports, external dependence of 58.66%, close to 59%. This indicates that our country has a high degree of dependence on foreign oil

supply, that is to say, the degree of China's crude oil market is affected by the international market. Land department data show that in 2014 China's natural gas consumption of 180 billion cubic meters, an increase of 7.4%, of which 58 billion cubic meters of natural gas imports, external dependence of 32.2%. The above shows that China has entered the ranks of the energy consuming countries, the energy reserve strategy is urgent. How safe and effective storage of energy is a problem that must be considered in contemporary china. Security, stability, and funds to consider the use of salt cavern storage oil and gas with the existing oil and gas storage tanks, offshore storage of other storage compared with high safety and reliability, as oil and gas storage is the best choice. Salt mine resources in our country are rich, wide distribution, rock salt mining capacity is huge, with in the short term built large-scale underground salt cavern gas storage conditions and capabilities, and has great prospects for development. Therefore, the construction of salt cavern gas storage with broad prospects for development, in-depth study of salt cavern to promote the development of energy economy in our country and to ensure China's energy security has important significance <sup>[1-2]</sup>.

At present, salt mining in China each year the natural formation of dissolved cavity volume of about 5 million cubic meters. However, most of the caverns are in vacant state. How to use and safe management of salt cave effectively, the international use as a repository for our reference. Salt cave is an important factor to ensure the stability of salt cavern. Reasonable salt cavern cavity shape can be effectively reduced the deformation of wall rock in the cavity, and maintain the repository effective storage capacity, but also conducive to salt

stress release, can effectively improve the stability of salt cavern storage library. So the salt cavern data for building 3D model of salt cavern can not only display of salt cavern gas storage capacity and storage capacity, which are salt cavern of security and stability has the vital significance [3].

## II salt cave utilization status overview

### 2.1 Salt cave

Salt cavern refers to the special solution made or mining technology formed by the cave in the rock salt, huge volume and good sealing. Under high temperature and high pressure rock salt has certain plasticity, with very low permeability and good creep, make its become a ideal sealing storage medium material, also for the storage of those insoluble substances in the salt and water provides a great and safe underground storage space. International usually use salt cavern underground gas storage construction, used to support natural gas long distance transportation pipelines, seasonal peak shaving and emergency peaking; also for storing crude oil and liquid hydrocarbons are strategic reserve; salt cavern can also used for compressed air energy storage and storage of hydrogen storage, to solve the problem of renewable energy power generation balance; salt cavern is also applied to the disposal of industrial waste and hazardous substances; in recent years, in the use of salt cavern of carbon dioxide sequestration also launched a extensive research work [4-6].

## III salt cave data

### 3.1 Method for measuring the data of salt cave

Due to the late start in the construction of salt cavern storage library, the technology is not mature, especially the problem of measurement has not been solved, only with the help of foreign experience and measured data. The German search space (SOCON) company has a more mature salt cavern measurement and monitoring technology.

German search space (SOCON) companies using BSE type sonar range finder for salt cavern measurement, before the measurement, to fill in the measurement log, including temperature, sound velocity, pressure, tube boots position, etc.. The rotary BSE sonar range finder is divided into horizontal and inclined measurement during the construction survey. As

shown in Figure 1, ultrasonic probe tilting device can change the ultrasonic probe acoustic emission direction, which can of salt cavern cavity top and bottom or salt cavern cavity body hidden part, the special position of measurement. From bottom to top every five meters to do a level measurement, in the same horizontal plane scanning every 3 degree measurement point, recorded a total of 120 points, and gradually become smaller with the section, level measurement application measured every 2.5 meters measured. On the basis of the horizontal measurement, the selective vertical measurement is carried out. In the process of vertical measurement, every 15 degrees is measured. In general, there are 24 faces. Both horizontal and vertical measurements are recorded in polar coordinates [7-8].

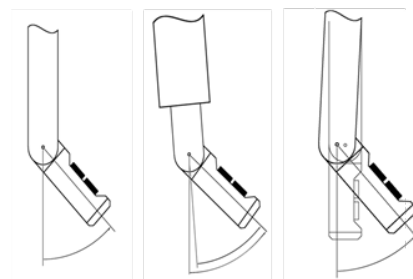


Fig. 1 Sonar transceiver department rotation schemes

Salt cave sonar plays an important role in controlling the shape of salt cavern and maintaining the stability and safety of salt cavern gas storage. In order to ensure salt cavern in accordance with the design of the best shape and the volume of the cavity of the construction, the use of sonar measurement and monitoring technology is an important means to ensure the safety of salt caverns necessary measures. At present, the equipment of the sonar survey equipment of the German search company is also used to construct our country's first deep underground salt cavern gas storage—Jintan salt cave.

### 3.2 Salt cave data file format

At present, it is widely used to measure salt cavern shape of the salt cavern by using sonar measuring instrument. Salt cave data is finally generated. Dat file. Specific data acquisition and processing procedures as shown in Figure 2 below.

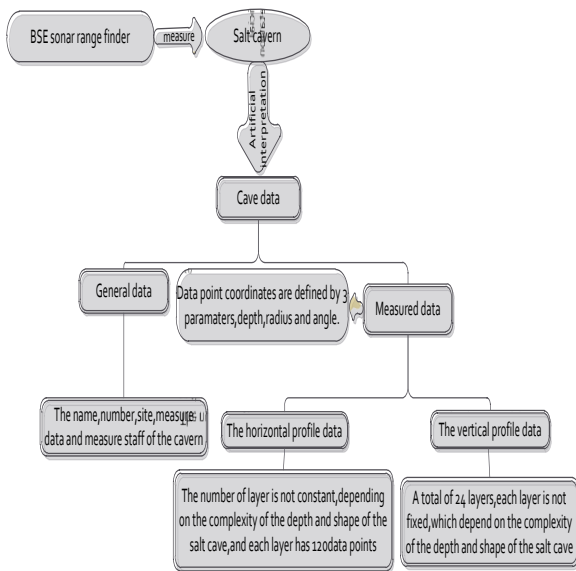


Fig. 2 Salt cave data format

#### IV system function

##### 4.1 System architecture

Through the research of salt cave data file format, using the C# language and the Direct3D interface, a simple and practical salt cavern data management and maintenance system is developed. As shown in figure 3.

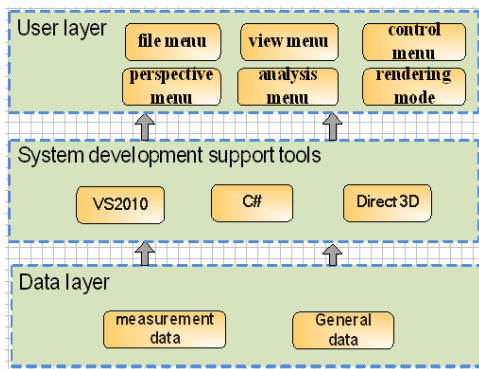


Fig. 3 System architecture diagram

##### 4.2 Main functions of the system

In this system, there are six main functions of file, view, control, perspective, analysis and rendering mode.

##### 4.2.1 File menu

On the file menu, read and display the function of salt cavern data, click the file - open, select ready data file in the open file dialog box, such as Figure 4 3D view of data points.

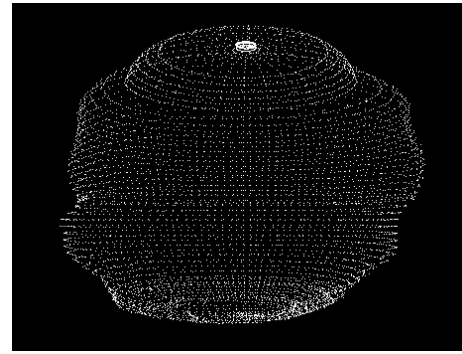


Fig. 4 3D view of data points

##### 4.2.2 View menu

In the View menu, it provides a full range of data about the salt cave model, before and after the display, so as to view data from various angles. Figure 5 for the view

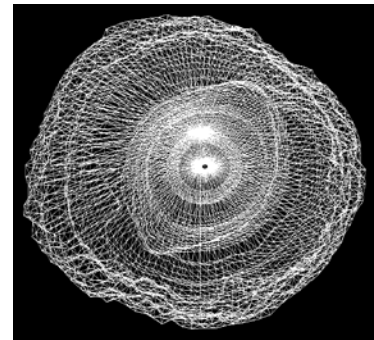


Fig.5 Top view

##### 4.2.3 Control menu

Control menu provides a dynamic control of the salt cave data, you can use the mouse to drag the rotation of the salt cave shape, you can also use the direction keys to zoom and translation.

##### 4.2.4 Perspective menu

The menu is a point, line two display mode.

##### 1) point mode display

In point mode function, the horizontal and vertical data of salt cavern can be viewed as well as integrated navigation.

##### 2) line mode display

Line mode provides the same point of the display function, the same horizontal line, vertical line and all integrated display. Figure 6 is a vertical line mode.

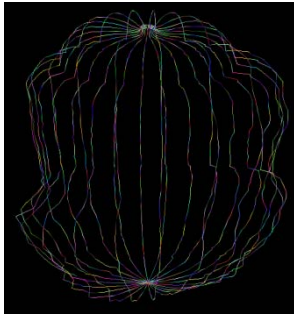


Fig.6 Vertical Line Mod

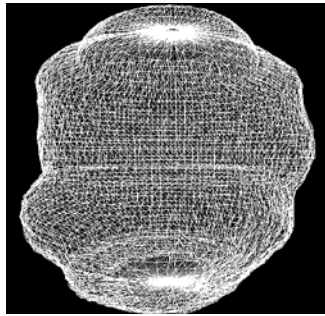


Fig.7 Horizon and vertical Line Mode

#### 4.2.5 Analysis menu

A key factor to measure the stability of salt cavern is the projection of salt cavern in the horizontal direction. In order to ensure the safety of salt cavern, avoid salt cave is too close to collapse, resulting in serious accidents, need to make each salt cave and the distance between the surrounding features far from the safe distance. The drawing of the salt cave plan includes the shortest horizontal distance between salt caverns.

The menu is used to display the maximum projection line. The maximum horizontal projection line image is obtained by loading the salt cave data. Then the maximum projected area is filled.

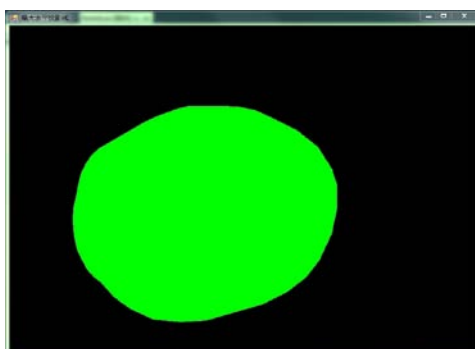


Fig.8 Maximum horizontal projection line

#### 4.2.6 Rendering mode

The rendering mode is mainly generated by the surface model of salt cavern, which is prepared for the further calculation of the volume of salt cavern.



Fig. 9 Salt cavern model

Deep salt cave is generally located in the surface of 2000 meters below, at this time, the temperature around the salt cave is about 80 degrees Celsius, the shape of the salt cave is easily influenced by temperature and other physical factors, salt cave volume is difficult to determine, so the calculation of salt cave volume has been the focus of research. On the basis of profound study of salt cavern surveying data and found each horizontal section area can be calculated, and according to the depth profile each section between the height can be calculated, and presents the application of the mathematics platform volume calculation formula:

$$V_i = 1/3 * h_i * (S_i + S'_i + \sqrt{(S_i * S'_i)}) \quad (1)$$

$$V = \sum_{i=1}^n V_i \quad (2)$$

Among them:

$V_i$ : the I platform for the volume;

$S_i$ : the area on the surface of the I platform;

$S'_i$ : under the surface area of the I platform;

$h_i$ : the height difference between the upper surface and the lower surface of the I platform;

$n$ : according to the specific depth of salt cavern, salt cavern can be divided into the total number of body.

The horizontal section area is solved by mathematical analysis method. Firstly, the horizontal profile is decomposed into a number of triangles in the center of the scan points and the arbitrary adjacent measuring points are obtained. Choose a

measurement point as the starting point, and the measurement points are arranged in a clockwise direction. The measurement points are recorded in polar coordinates. Firstly, the coordinates are converted into (X, Y), then the triangle area is calculated:

$$S_i = 1/2 * \begin{vmatrix} X_i & Y_i \\ X_{i+1} & Y_{i+1} \end{vmatrix} \quad (3)$$

$$S = \sum_{i=1}^n S_i \quad (4)$$

Among them:

$S_i$ : the  $i$  triangle area;

$S$ : the horizontal section area;

$n$ : sum of the number of triangles formed by the measurement points

## V Conclusions and outlook

In this paper, salt cave survey data as the research object, in-depth analysis of salt cavern measurement data record format, using C# language design salt cave 3D view system on the VS2010 platform, complete salt cave point cloud data 3D model and salt cave solid model, and use the three-dimensional program should use interface DirectX and Direct3D to speed up three-dimensional graphics display. The design of this system has the function of amplifying, reducing the 3D shape, observing the salt cave, the point and line, the maximum horizontal projection line and the solid model, and basically realized the 3D visualization of salt cavern.

But the salt cavern volume estimation formula is a relatively large amount of computation, and accuracy is determined to rely on to the individual selected platform number remains to be further optimization.

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