Cellular Glass Designing and Processing Technology for Cryogenic Insulation

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ABSTRACT

Cellular glass is applied as cryogenic insulation material in central process module of YAMAL LNG Plant. Cellular glass’ inherent characteristics such as hard, fragile and so on, bring much difficulty to prefabrication and processing and quality risk could be easily left because of processing defects. Based on the actual cryogenic insulation design and processing for YAMAL LNG Plant, this paper analyzed and researched processing technology of cellular glass for pipe and special-shaped pieces such as tee, elbow where insulation quality problem easily takes place, whilst to realize innovation in processing technology and ensure the insulation quality. These processing technology mentioned in this paper are based on the polar climate environment. Fact proved that the processing technology of cellular glass fully meet the requirements of the cryogenic insulation so that normal operation of liquefied natural gas processing plant can be effectively guaranteed.

INTRODUCTION

The main composition of LNG (Liquefied Natural Gas) is methane which is colorless, tasteless, non-toxic and non-corrosive. To improve the efficiency of transportation, natural gas under normal pressure can be transformed into liquefied natural gas, with its volume changing into 1/625 by reducing temperature to -162°C in LNG plant. In order to maintain temperature requirement of liquefied natural gas (LNG), it is very important to design and construct insulation[1][2].

YAMAL LNG Plant project is located in the Arctic Circle, which belongs to the typical polar climate. Cellular glass is applied as cryogenic insulation material regarding of excellent insulation effect. Because its shape of the factory is cuboid (see Fig.1), cellular glass should be processed into different shapes to adapt to shape of pipe or fittings (see Fig.2). But cellular glass’ inherent characteristics such as hard and fragile could cause much difficulty to prefabrication and processing[3]. Especially for cryogenic insulation of special-shaped pieces such as tee and elbow, it is very difficult and cumbersome to prefabricate and process cellular glass and potential quality risk is easily left because of processing defects. Once insulation fail, seriously freezing will occur (see Fig.3). In the eyes of requirement of

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cryogenic insulation, this paper analyzed prefabrication and processing technology of cellular glass in order to realize the innovation design and ensure perfect insulation quality.

**PROCESSING TECHNOLOGY OF CELLULAR GLASS FOR PIPE INSULATION**

**Processing Shape of Cellular Glass**

Cellular glass must be provided in half sections for pipe whose DN is 12 inch and less. Half sections shall consist of hollow cylindrical sections split lengthwise in a plane that includes the cylindrical axis. Cellular glass for pipe whose DN is from 14 inch to 24 inch must be fabricated in half sections or in quarter sections according to cellular glass size. If half sections or quarter sections are big so that it is difficult to fabricate, segments also can be acceptable. When 26 inch and above, segmented pipe insulation shall be fabricated. Segmented pipe insulation shall be fabricated in equal widths so that no additional field cuts are required. Please see Table 1 for more information.

![Figure 1. Cellular glass billet.](image1.png)

![Figure 2. Cellular glass after being processed.](image2.png)

![Figure 3. Freezing of cellular glass.](image3.png)

**Table 1. Process Shape and Joint Quantity.**

| No. | Size         | Process Shape     |
|-----|--------------|-------------------|
| 1   | NPS≤12”      | Half Section      |
| 2   | 14”≤NPS≤24”  | Half Sections / Segment |
| 3   | NPS>24”      | Segment           |

| No. | Size         | Joint Quantity   |
|-----|--------------|------------------|
| 1   | NPS≤6”       | No more than 1   |
| 2   | 6”<NPS≤18”   | No more than 3   |
| 3   | NPS>18”      | No more than 4   |
| 4   | Segment      | No more than 2   |

**Requirement of Cellular Glass Joint**

For the insulation of pipe whose DN is 6 inch and below, there shall not be more than one fabrication joint per half section. If the pipe section’s inner radius is bigger than cellular glass’s thickness 150mm or the pipe section’s outer diameter is bigger than cellular glass’s width 450mm, the fabrication joints shall increase. Pipe insulation that is designed for pipe sizes greater than 6 inch and less than 18 inch shall not have more than three fabrication joints per half section. Pipe insulation
that is designed for pipe sizes 18 inch and above shall not have more than four fabrication joints. Please see Table 1 for detail.

Insulation curved sidewall segments shall have no more than two fabrication joints per sidewall segment. There shall be no visible voids in the adhered joint nor shall any adhered joint exceed 1/16 inch (1.6 mm) in width.

Cellular glass pipe insulation shall be fabricated from the minimum number of insulation blocks. Sectional pipe insulation shall contain no more than four through joints per full section of insulation, excluding the half section mating plane. Bond joints which meet other bond joints must meet at 90° angles, must be a minimum of 1 in. (25.4mm) in length and shall not cross. Fabricated sections of insulation shall be a minimum of 1/2 inch (12.7mm) thick (see Fig.4).

**PROCESSING TECHNOLOGY OF CELLULAR GLASS FOR TEE INSULATION**

Whether equal tee or reducing tee, their intersecting lines are "saddle shape". Rigid insulation materials (Cellular glass) cannot be prefabricated just the same as saddle shape because of irregular shape, however only to be approximately cut, ensuring impervious seam and cold insulation effect (see Fig. 5)[4].

**Equal Tee**

For equal tee, cellular glass is processed by the way of vertical cutting machine or two-dimensional semi-auto cutting machine for accurate cutting 45° oblique and then be butted seamlessly. Cellular glass for equal tee insulation is also processed along intersecting line.
Reducing Tee

For the process of cellular glass for reducing tee, intersecting line can be drew taking advantage of CAD, and then put drawings into two-dimensional semi-auto cutting machine for cutting.

PROCESSING TECHNOLOGY OF CELLULAR GLASS FOR ELBOW INSULATION

It is very difficult to prefabricate and process cellular glass for elbow because of both being rigid and elbow’s irregular surface. To ensure no gap between cellular glass and elbow for excellent insulation performance, different shop design of cellular glass shall be accomplished according to different size of elbow.

Once Shaping Elbow

Once shaping elbow should be adopted when elbow insulation outside diameter is 6” or less and insulation thickness is small. Processing principle is shown in Figs. 6&7. Firstly, corresponding cellular glass cuboid shall be prefabricated with length, width, height being respectively R1, R1, D and then to diagonally fix cellular glass cuboid by clamp device and push the lever around to prefabricate cellular glass. It is important to note that the above cellular glass prefabrication for elbow could not be carried out because fixed axis will be located inside cellular glass cuboid when the thickness of insulation is larger than 6" which is equal or greater than the R. When cellular glass shall be installed with multi-layers structure, only the first layer can be cut by once shaping elbow in order to meet the requirements of staggered joints between sequential layers.

Three-way Elbow

When insulation outer diameter is 6” or less and insulation thickness is a little bigger, cellular glass shall be processed as square or three-way for elbow insulation. For square elbow, no external force in the vertical direction of the joint can lead to loose joint. Therefore, artificially external force shall be imposed and removed after adhesive already cure when two butt joints are fixed. If above requirements can't be met, three-way elbow shall be chose.
For three-way elbow, larger space will be occupied because of its inherent structural characteristics. If space is not enough for installing, three-way elbow should not be chose.

No gap between outer face of elbow and inner surface of cellular glass could be left for above two elbow forms. Loose wool or other flexible material should be filled inside gap in order to satisfy the demands of heat preservation. In addition, an additional insulation thickness should be added when insulation requirement is strict because the inner side of elbow is not a right angle which can lead to local thinned insulation thickness (see Fig. 8).

**Mitre Type Elbow**

Cellular glass shall be processed as mitre type for elbow insulation when elbow insulation outer diameter is greater than 6". Cellular glass shall be firstly cut as shell with circumferential direction angle 180 degree. And then shell is cut into a certain number of curvature pieces according to the design size, finally to assemble these pieces into an integrated mitre elbow.

The number and size of prefabricated pieces shall be accomplished by the way of CAD lofting (see Fig.9.). The width of both ends for each piece of cellular glass is different. The narrower end should be more than width of stainless steel band selected during constructing insulation on site. Another end width should be less than 100 mm, otherwise inner side of mitre elbow won't be able to close to outer surface of elbow. When cellular glass is divided into two layers or more, staggered joint can be achieved through extending width of cellular glass pieces located in two outmost side to avoid throughout joint.

**CONCLUSION**

It was very important for cryogenic insulation to ensure normal operation of liquefied natural gas processing plant. Especially for processing technology of cellular glass for special-shaped pieces such as tee and elbow, processing work should be carried out by innovative and careful design. Otherwise, it was easy to
leave hidden dangers. The above processing technology mentioned in this paper were developed on the base of the polar climate environment. Fact proved that the processing technology of cellular glass fully meet the requirements of the cryogenic insulation so that normal operation of liquefied natural gas processing plant can be effectively guaranteed.

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