The Study on Helium Atmosphere Isolation in HTR Maintenance

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Abstract – The helium as the high temperature gas cooled reactor’s coolant, is low density and easy diffusion. Although the helium has good nuclear performance and radiation stability, the helium has amount of high radioactive material, such as fission gas, graphite dust and aerosol, in operation.

When the high temperature gas cooled reactor is maintained, the problem of helium leakage will occur. The helium with high radioactive material will bring great difficulties on maintenance. How to isolate the leaking helium will be the key issue on high temperature cooled reactor maintenance.

This paper has analyzed the whole process of helium atmosphere isolation scheme which is how to formulated, verified, modified, implemented during maintenance of the helium in Tsinghua Nuclear Energy Institute, and demonstrated the necessity of helium atmosphere isolation during the maintenance of high temperature gas cooled reactor, studied and discussed several feasible kinds of the helium atmosphere isolation scheme, provided some feasible ideas and methods of the helium atmosphere isolation during the maintenance of high temperature gas cooled reactor.

Keyword-helium atmosphere isolation maintenance

I. INTRODUCTION

The high temperature gas cooled reactor nuclear power station demonstration project of HuaNeng ShanDong ShiDao Bay is not only the first high temperature gas cooled reactor demonstration power station within the country, but also a 200,000 kW class high temperature gas cooled reactor nuclear power station with the security features of the fourth generation nuclear energy system. As to the examination and repair on it, currently there is no ripe experience for reference. In this article, several feasible schemes for helium atmosphere segregation are studied and probed into by analyzing the two helium atmosphere segregation schemes during the main helium fan overhaul in Institute of Nuclear And
Some feasible thinking and methods are provided for helium atmosphere segregation during a high temperature gas cooled reactor examination and repair in the future.

I. Necessity of Helium Atmosphere Segregation during High Temperature Gas Cooled Reactor Examination and Repair

The high temperature gas cooled reactor, with graphite as moderator and helium as coolant, is a kind of advanced nuclear reactor which is high in security and generating efficiency and extensive in application. A high temperature gas cooled reactor includes the reactor(s), hot gas pipe(s), vapor generator(s) and main helium fan(s). During the operation of the nuclear power station, the reactor core of the high temperature gas cooled reactor is cooled by helium. Driven by the main helium fan(s), helium passes through the tunnels on the pressure shell walls of the vapor generator(s), hot gas pipe(s) and the reactor successively, enters into and passes through the reactor core where it is heated and warmed up, then the warmed-up helium flows out from the hot gas pipe and into the vapor generator(s), then returns back to the main helium fan(s). During the helium circulation, the heat taken away from the reactor core by the helium is transmitted to and warm up the water of the secondary circuit, the generated steam is used to drive the generator for electricity generation.

As the radioactive graphite powder can be taken from the reactor core by the helium after it passes through the primary circuit, helium atmosphere segregation during the main helium fan examination and repair is able to effectively prevent both helium leakage of the primary circuit and powder diffusion and reduce their impact on staff and environment, therefore the segregation is of great importance. In addition, if effective helium atmosphere segregation is not achieved during the main helium fan examination and repair and the air is introduced into the helium coolant of the primary circuit, the degree of helium purity can be affected; thorough helium replacement for the primary circuit has to be made if there is too much air contained, which is time consuming and require great labor and material inputs, extends the time for nuclear power station examination and repair and increases the cost of examination and repair.

Table 1: Radioactive Elements in the Helium of the Primary Circuit

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Activity Concentration upon being Collected into the Sampling Pot (Bq * L^-1)</th>
<th>Activity Concentration in the Primary Circuit (Bq * L^-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>^{40}K</td>
<td>1.07 × 10^3</td>
<td>3.93 × 10^3</td>
</tr>
<tr>
<td>^{40}Ar</td>
<td>1.08 × 10^1</td>
<td>1.22 × 10^4</td>
</tr>
<tr>
<td>^{85}Kr</td>
<td>1.57 × 10^1</td>
<td>1.60 × 10^4</td>
</tr>
<tr>
<td>^{133}Xe</td>
<td>1.90 × 10^1</td>
<td>1.42 × 10^4</td>
</tr>
<tr>
<td>^{133}Xe</td>
<td>2.59 × 10^1</td>
<td>2.10 × 10^4</td>
</tr>
<tr>
<td>^{90}Sr</td>
<td>3.48 × 10^1</td>
<td>1.91 × 10^4</td>
</tr>
</tbody>
</table>

II. Feasible Atmosphere Segregation Schemes

1. Scheme One

In this scheme, the atmosphere segregation scheme for the replacement of Japanese HTTR helium fan filter is referred to. (Picture 1)

1) Steps

a) Surround and seal the pressure shells of the main helium fan and vapor generator with segregation membrane 1;
b) Separate the main helium fan from the vapor generator, hover them and keep them still, clamp the segregation membrane 1 with two sealing clamps.

c) Divide the segregation membrane 1 between the two sealing clamps into two parts, which should be segregation membrane 1A and 1B connected to the pressure shells of the vapor generator and main helium fan respectively. A sealed space is formed by segregation membrane 1A and the pressure shell of the vapor generator. Shift the main helium fan to the position for examination and repair.

d) Seal the flange opening on the pressure shell of the vapor generator with a blind plate; surround and seal the blind plate and the vapor generator’s pressure shell with segregation membrane 2; remove the segregation membrane 1 and sealing clamps on the evaporator.

e) After the examination and repair, surround and seal the blind plate and the pressure shell of the vapor generator with segregation membrane 3; hoist the blind plate, clamp segregation membrane 3 with two sealing clamps. Divide segregation membrane 3 between the two sealing clamps into the two parts: membrane 3A and 3B connected to the blind plate and to the pressure shell of the evaporator respectively. It should be guaranteed that a sealed space is formed by segregation membrane 3B and the pressure shell of the vapor generator. Put the removed segregation membrane 1 and the sealing clamps into segregation membrane 3A and take them away together with the blind plate.

f) Reassemble the main helium fan, surround and seal the pressure shells of the main helium fan and vapor generator with segregation membrane 1.

g) Remove segregation membrane 3B and the sealing clamp(s) on the evaporator, continue reassembling and reassemble in place.

2) Features:
a) In this scheme, atmosphere segregation can be achieved, and equipment examination and repair are feasible under helium atmosphere;

b) The power equipment such as motor is not required in this atmosphere segregation scheme which is simple and practicable.

3) Difficulties:
a) Segregation membrane division after hoisting of main helium fan. After the hoisting of the main helium fan, the low-density helium can fill the segregation membrane, making sealing clamp separation more difficult.

b) Poor transparency of segregation membrane makes sealing face check and repair difficult.

c) The long segregation bag brings about segregation membrane shrinkage during the rise of the fan’s pressure shell and the risk of segregation membrane being sucked in the evaporator.

d) In step 4, helium upwelling makes the lifting hook unable to fall.

2. Scheme Two

This is a scheme improved on the basis of the relevant content(s) of scheme one.

1) Steps

a) Put a built-up connection mouth on the examination and repair platform, which serves as a support for segregation membrane sticking, set a Parent Segregation Membrane to surround the built-up connection mouth and the pressure shell of the vapor generator.

b) An euphotic board, eight pairs of gloves and two fetch bags are set up on the Parent Segregation Membrane (as shown in Picture 2).
c) Surround and seal the pressure shell of main helium fan and the Parent Segregation Membrane with segregation membrane 1.

d) Separate the main helium fan from the vapor generator, hover them and keep them still, clamp the segregation membrane 1 with two sealing clamps.

e) Divide the segregation membrane 1 between the two sealing clamps into two parts, which should be segregation membrane 1A and 1B connected to the Parent Segregation Membrane and the pressure shell of main helium fan respectively. A sealed space is formed by segregation membrane 1A and the Parent Segregation Membrane. Shift the main helium fan to the position for examination and repair.

f) Cover the flange opening on the pressure shell of the vapor generator with segregation membrane 1A, fill a gas bag with helium in advance, cover the flattened segregation membrane with the gas bag filled with helium, then continue the helium filling to realize tight sticking between the surrounding area of the gas bag and the inner wall of the vapor generator’s pressure shell and the diameter of the gas bag equal to the inner diameter of the flange opening. Separate segregation membrane 1A from the Parent Segregation Membrane.

g) Check the sealing face(s).

h) Seal the flange opening on the pressure shell of the vapor generator with a blind plate; surround and seal the blind plate and the vapor generator’s pressure shell with segregation membrane 2.

i) After the examination and repair, surround and seal the blind plate and the pressure shell of the vapor generator with segregation membrane 3; hoist the blind plate, clamp segregation membrane 3 with two sealing clamps. Divide segregation membrane 3 between the two sealing clamps into the two parts: membrane 3A and 3B connected to the blind plate and to the pressure shell of the vapor generator respectively. It should be guaranteed that a sealed space is formed by segregation membrane 3B and the pressure shell of the vapor generator. Put the removed segregation membrane 1 and the sealing clamps into segregation membrane 3A and take them away together with the blind plate.

j) Reassemble the main helium fan, surround and seal the pressure shell of the main helium fan and Parent Segregation Membrane with segregation membrane.

k) Deflate and bring away the gas bag; continue the reassembling and reassemble in place.

2) Features:
a) The gas bag is applied in this scheme compared with scheme one, simplifying examination and repair and making sealing face examination feasible.

b) The degree of operation difficulty is greatly lowered due to the application of built-up connection mouth in this scheme.

3) Difficulties:
a) The segregation membranes should be customized, they are difficult to process and high in cost.

b) In this scheme, the issue of support should be taken into account while the gas bag is on the top of the evaporator, what should also be taken into consideration is the degree of finish of an evaporator shell’s inner wall.

III. Analysis

1. Successful atmosphere segregation can be achieved through the application of either of these two atmosphere segregation schemes, the
feasibility of a scheme has been verified in the main helium fan overhaul of Institute of Nuclear And New Energy Technology, Tsinghua University, the sealing effect is good.

2. The operating temperature for these two examinations and repair schemes is ambient temperature. As the outer wall temperature of the main helium fan can reach 65 °C during normal examination and repair in normal shutdown, the examination and repair schemes require further improvement.

3. As the leak detectors such as helium mass spectrometer are not available for helium leakage detection, and there is no aerosol real time measuring instrument during the preliminary work, quantitative evaluation on the effect of atmosphere segregation can not be made through these two examination and repair schemes. Improvement is necessary in the future research.

IV. Summary

During the examination and repair of high temperature gas cooled reactor, the examination and repair process is simplified, suitable for operation, safe, convenient and fast through the application of the helium atmosphere segregation scheme, which is able to effectively prevent the out diffusion of helium and radioactive graphite powder of the primary circuit and maintain the degree of purity of the primary circuit’s helium coolant to the greatest extent, reduce the cost of nuclear power station examination and repair and shorten the total time for the examination and repair.

Document for Reference