Abstract: Along with the rapid development of nuclear power program, nuclear safety authority in China stipulates more strict safety control measures. Among them, as safety related non-destructive examination activities, NDE providers have to get NDE licenses according to HAF601 requirements for domestic suppliers or HAF604 requirements for foreign suppliers before they can provide services such as in-factory NDE or in-service inspections for nuclear power components. On the other hand, inspection qualifications have to be taken before the site pre-service inspection or in-service inspection implements in nuclear power plants. CITC, the CGNPC Inspection Technology Company, Ltd., is the specific non-destructive examination provider for nuclear power industry. The experiences in NDE licensing and inspection qualification upgrade its capabilities on carrying out various inspection activities. The article describes the experiences and feedbacks from such licensing and qualification processes, and also the practices on pre-service and in-service inspections for various nuclear power components for 1000MW PWR units.

Keywords: NDE Licensing, Inspection Qualification, In-service Inspection, Nuclear Power Plant

1. Introduction

The increasing demand of electric power calls for rapid development of nuclear power in China. While nuclear safety has its top priority among various elements regarding construction and operation activities of nuclear power, Chinese nuclear safety authority (NNSA) stipulates strict safety control measures by facing the new development era of nuclear power since early 2007. Among them, HAF series safety supervision stipulations related to nuclear safety components were published and put in force at the beginning of 2008.

As safety related non-destructive examination activities, NDE providers have to get NDE licenses according to HAF601 requirements for domestic suppliers or HAF604 requirements for foreign suppliers before they can provide services such as in-factory NDE or in-service inspections for nuclear power components. On the other hand, inspection qualifications have to be taken before the site pre-service inspection (PSI) or in-service inspection (ISI) implements in nuclear power plants.
CITEC is the specific non-destructive examination provider for nuclear power industry. The experiences in NDE licensing and inspection qualification upgraded its capabilities on carrying out various inspection activities, which leads to successful implementations on pre-service and in-service inspections for various nuclear power plants with 1000MW PWR units.

2. Safety Regulations regarding Pressure retaining Components

Regarding safety management and supervision of pressure retaining components, there are two different laws for nuclear power and non-nuclear power industries in China. For the non-nuclear power industry, the Rules on Supervision and Control of Special Safety Equipment (Order No. 373), which was issued by the government on 11th of March, 2003, and amended by the Order No. 549 on 14th of January, 2009, put into force on the 1st of May 2009, is applicable to the design, manufacture, installation, operation, inspection and testing of boiler and pressure vessels, pressure piping, lift and handling mechanical equipment, etc.

For the nuclear power industry, the Rules on Supervision and Control of Civil Nuclear Safety Equipment (Order No. 500), which was issued by the government on 4th of July, 2007, and put into force on the 1st of January 2008, is applicable to the design, manufacture, installation and non-destructive examination of civil nuclear safety equipment. The civil nuclear safety equipment mentioned in these rules means the equipment performing the function of ensuring nuclear safety in the course of using civil nuclear facilities, including the mechanical and electrical equipment for nuclear safety.

To implement such rule of Order 500, there are four (4) nuclear safety regulations issued by NNSA, including the Regulation on Supervision and Control for design, manufacture, installation and non-destructive examination of Civil Nuclear Safety Equipment (HAF601), Regulation on Control for certification for the non-destructive examination personnel of Civil Nuclear Safety Equipment (HAF602), Regulation on Control for certification for the welder and welding operator of Civil Nuclear Safety Equipment (HAF603), and Regulation on Supervision and Control of Imported Civil Nuclear Safety Equipment (HAF604).

Besides to the rules and regulations issued by the government and authority, the design, manufacture and in-service inspection of pressure retaining components for nuclear power plants shall also observe the following codes:

- ASME code, which is applicable to AP1000 units;
- RSE-M and RCC series standards, which are applicable to M310, CPR1000, and EPR units;
- Russian codes, which are applicable to WWER units;
- Chinese National Standards, GB, JB, EJ series, etc. These standards are partly applied in the nuclear power area. And the overall application of these standards is being pushed forward.

3. Licensing Requirements for NDE Organizations of Nuclear Safety related Components
The licensing requirements for domestic NDE supplier of nuclear safety related components are stipulated in the Order 500 and HAF601.

It is stipulated in the Order 500 that the organization for design, manufacture, installation or non-destructive examination of civil nuclear safety equipment shall apply for license in accordance with the provisions of the Order. The organization applying for license for non-destructive examination of civil nuclear safety equipment shall meet the following conditions:

1. having the qualification of a legal person;
2. having work experiences for five years or more in a field which is related or similar to the one to be engaged in;
3. having technical people who are qualified after being examined and commensurate with the work to be engaged in and among whom the ones for non-destructive examination of the civil nuclear safety equipment shall acquire the necessary qualification certificates;
4. having the premises, facilities and equipment appropriate for the work to be engaged in; and
5. having sound management system and quality assurance system and quality assurance program that conforms to the provisions for supervision and control of nuclear safety.

It is stipulated in HAF601 that the organization applying for NDE licensing for civil nuclear safety equipment shall apply to the nuclear safety authority in China for NDE licensing of different NDE methods. The NDE methods include: Radiographic Testing (RT), Ultrasonic Testing (UT), Eddy Current Testing (ET), Liquid Penetrate Testing (PT), Visual Testing (VT), Magnetic Particle Testing (MT), and Leak Testing (LT).

The licensing requirements for foreign NDE supplier of civil nuclear safety equipment are stipulated in the Order 500 and HAF604.

The foreign organization that carry out the design, manufacture, installation or non-destructive examination for the civil nuclear facilities located within the territory of the People’s Republic of China shall meet the following conditions:

1. abiding by the laws, rules, nuclear safety regulations of the People’s Republic of China;
2. having acquired the appropriate qualifications prescribed by the nuclear safety authority of their own countries;
3. using mature or verified technologies in design, manufacture, installation or non-destructive examination of civil nuclear safety equipment; and
4. adopting the national or industrial standards of the People’s Republic of China for civil nuclear safety equipment, or the standards approved by the nuclear safety authority.

The foreign organization that carry out the design, manufacture, installation or non-destructive examination of civil nuclear safety equipment for the civil nuclear facilities located within the territory of the People’s Republic of China shall be registered by the nuclear safety authority before carrying out relevant activities. The organization, who applies for registration of
non-destructive examination activities of civil nuclear safety equipment, shall submit their application according to the non-destructive examination methods.

4. Practice on CITEC NDE Licensing Activities

As a sub-company of CGNPC, CITEC is a joint venture company invested by China Nuclear Power Technology Research Institute Co., Ltd. (CNPRI) and TECNATOM, S.A. in accordance with Regulations for implementation of The Law of the People’s Republic of China on Sino-Foreign Equity Joint Ventures and its implementing rules and other related laws, regulations and rules.

CITEC was founded in China on October 23rd, 2007, with the purpose of providing pre-service inspection and in-service inspection services for nuclear power plants.

With the assistance of TECNATOM who has more than 40 years experiences on NDE for nuclear power plants, CITEC submitted application documents to NNSA to apply for the Non-destructive Testing License for Civil Nuclear Safety Facilities according to the requirements of HAF601 in July, 2008. The process of the licensing was carried out as bellows:

Documentation review → questions & answers → dialogue → blind tests on mock-ups → on-site checks → nuclear safety expert review → NNSA review and approval.

In September, 2008, NNSA accepted the application and began the evaluation processes as planned. The documentation review, questions & answers, and dialogue were held from September, 2008 to February, 2009. And from February to May, 2009, the blind tests on mock-ups and on-site checks were carried out. The expert review was held in May, 2009, and the NDE license was finally issued by NNSA on May 26th, 2009. This license includes all the seven (7) NDE methods (RT, UT, ET, PT, MT, LT, and VT).

The blind tests on mock-ups include the following inspections:

(1) Manual UT inspection for RPV nozzles to safe ends dissimilar metal welds.
(2) Manual UT inspection for vessel body welds with thick wall.
(3) Automatic ET inspection for Steam Generator tubes (including data analysis).
(4) Manual UT inspection for pressure vessel internal cladding.
(5) Automatic RT inspection for RPV nozzles to safe ends dissimilar metal welds (underwater).
(6) CCTV/UT inspection for RPV body welds and safe end welds (underwater).
(7) Automatic ET and UT inspection for RPV closure head studs.

The NDE License for Civil Nuclear Safety Facilities makes CITEC become one of the few companies who could perform all the pre-service inspection and in-service inspection services for nuclear power plants (NPPs) in China.
5. Inspection Qualification Requirements for In-service Inspection of Nuclear Power Plant

The inspection qualification mentioned in this paper has the same meaning in Europe, and it also has similar meaning to the word of Performance Demonstration in US.

The inspection qualification requirements for PSI and ISI for nuclear power plant have not been stipulated in the rule or regulation in China until now. However, such requirements have been specified by the inspection codes or standards such as ASME XI or RSE-M 1997. And the NPP owners have promised that the inspection qualification of the in-service inspection technologies should be made according to the in-service inspection codes or standards.

NNSA asks that all NPP owners must employ the technologies which have been qualified for the PSI and ISI according to the codes or standards selected. NNSA will review the inspection qualification plan, supervise the inspection qualification process, and assess the inspection qualification results.

For CPR1000 and EPR units, the inspection qualification should be carried out according to the requirements of RSE-M 1997. The ENIQ methodology is employed for reference. ENIQ methodologies include technical justification, open trial, and/or blind trial. The personnel, procedure and equipment could be qualified separately. The acceptance criteria of the qualification are chosen according to different items.

For AP1000 units, the code requirements of ASME XI should be met. The PDI system in USA should be employed for reference. The PDI methodologies could be also technical justification, open trial, and blind trial. The personnel, procedure and equipment are qualified as a whole system. And the qualification items and the acceptance criteria of the qualification are definitely defined in the appendix VIII of ASME XI.

6. Practice on Inspection Qualification Activities for LingAo Phase II Nuclear Power Units

According to the requirements of NNSA, the NDE provider shall be qualified for the implementation of PSI or ISI for nuclear power plant. The inspection qualification shall be done under the requirements of RSE-M (ENIQ system) for CPR1000 and EPR units and ASME XI (PDI system) for AP1000 units.

The power plant owner of LingAo Phase II CPR1000 units (unit 3 and 4), together with the PSI provider CITEC, applied for inspection qualification to NNSA in early 2008. And the following requirements were given by NNSA in response:

(1) The inspection qualification for PSI and ISI shall be implemented according to the requirements of RSE-M 1997 as promised by the power plant owner.

(2) Specific inspection qualification team should be organized to take charge of the inspection qualification, and the inspection qualification shall be done under ENIQ methodologies.

(3) NNSA would supervise the whole inspection qualification process.
The inspection qualification plan includes fifty (50) items, which were given in the following table:

<table>
<thead>
<tr>
<th></th>
<th>UT</th>
<th>ET</th>
<th>RT</th>
<th>PT</th>
<th>VT</th>
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<td>4</td>
<td>0</td>
<td>8</td>
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<td>2</td>
<td>1</td>
<td>1</td>
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<tr>
<td><strong>Sum</strong></td>
<td>18</td>
<td>2</td>
<td>17</td>
<td>4</td>
<td>7</td>
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</table>

The inspection qualification process was carried out as follows:

- Procedure review → technical justification → dialogue → equipment validity test → open trial → blind trial → nuclear safety expert review → NNSA review and approval.

From the establishment of the inspection qualification team in early 2009 to the final approval of the qualification results in August 2010, the whole process lasted for about 20 months.

The specific qualification which is very important in the inspection qualification includes six (6) items:

1. Automatic UT inspection for RPV nozzles to safe ends dissimilar metal welds.
2. Automatic UT inspection for RPV safe end to reactor coolant pipe welds.
3. Automatic UT inspection for RPV nozzles to shell welds.
4. Automatic UT inspection for bonding of RPV internal cladding in core region.
5. RT inspection (circumferential exposure) for RPV nozzles to safe ends dissimilar metal welds.
6. ET inspection for steam generator tubes.

The inspection qualification blocks used for specific qualification were designed and manufactured with the same material and welding procedure as the real equipment in nuclear power plant. And the artificial defects were designed and manufactured as the mechanical fatigue crack by qualified manufacturer.

The RPV inspection equipment named TIME is used for UT and TV inspection. And the equipment TEDDY+TESAR is used for ET inspection for steam generator tubes. These equipments were introduced from TECNATOM through technology transfer, and CITEC has ungraded the equipments for the application in China.

Separated equipment named TENIS-G is used for RT inspection for RPV nozzles to safe ends.
dissimilar metal welds, which were jointly developed by CITEC and TECNATOM.

All above mentioned equipments have been multiply produced by CITEC to satisfy the market needs in China.

Through CITEC’s best efforts, the fifty (50) inspection qualification items mentioned above were successfully passed, and CITEC got the qualification and certificates from NNSA to provide the PSI and ISI services for LingAo unit 3 and 4. Such inspection qualification results could also be used for other CPR1000 units, which are with the same design as LingAo unit 3 and 4.

Successful PSI of LingAo unit 3 and 4 were carried out from the middle of the year 2009 to the end of 2010, and ISI of unit 3 were also carried out in the autumn of the year 2011, which demonstrated the excellent quality of CITEC’s inspection technologies and the inspection team. And more PSI of Unit 1 and 2 of Hongyanhe Nuclear Power Plant, Unit 1 and 2 of Ningde Nuclear Power Plant is now in progress by CITEC. Besides, the new inspection qualification for the PSI and ISI of Taishan EPR units is now in progress. And the site PSI activities will be initiated by the end of year 2012 for such EPR units by CITEC.

7. Conclusions

Nuclear safety has top priority in the construction and operation of nuclear power plants. Chinese nuclear safety authority (NNSA) stipulates strict safety control measures to non-destructive examination activities for nuclear power industry. NDE providers have to get NDE licenses according to HAF601 requirements for domestic suppliers or HAF604 requirements for foreign suppliers before they can provide services such as in-factory NDE or in-service inspections for nuclear power plants. And inspection qualifications have to be taken before the site PSI or ISI implements in nuclear power plants.

Through five years’ rapid development, CITEC has successfully built its technical capabilities to provide PSI and ISI services for NPPs. The NDE License for Civil Nuclear Safety Facilities makes CITEC become one of the few companies in China who could provide all the PSI and ISI services for NPPs in China. And the inspection qualification for CPR1000 units passed makes CITEC provide PSI and ISI services for the similar units with excellent quality.

By the end of year 2011, CITEC has successfully implemented the PSI services for LingAo unit 3 and unit 4, the first ISI for LingAo unit 3. And more PSI for Hongyanhe unit 1 and 2, and Ningde unit 1 and 2 is now in progress.

References

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