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CHINA NUCLEAR SCIENCE AND TECHNOLOGY REPORT

核电厂在役检查计划与协调

SCHEDULING AND COORDINATION FOR IN-SERVICE INSPECTION OF NUCLEAR POWER PLANT

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摘　要

基于核动力运行研究所(RINPO)在广东大亚湾核电站役前检查和在役检查的实践经验，并结合我国在役检查的特点，简要阐述了在役检查的前期准备和计划，包括对检查组织机构、检验设备/工具、检验技术、备品备件及消耗材料、检验人员和检验文件的要求；同时，重点介绍了在核电站大修期间，如何在有限的时间、人力和特定环境下科学地、周密地计划和安排在役检查各种活动以及加强现场协调和管理的必要性，从而保证在役检查任务的顺利完成。

Scheduling and Coordination for In-service Inspection of Nuclear Power Plant

LI Songbai
(Research Institute of Nuclear Power Operation, Wuhan)

ABSTRACT

Based on the practice and experiences of pre-service and in-service inspections for Daya Bay Nuclear Power Plant (NPP) by Research Institute of Nuclear Power Operation (RINPO) following RSEM code, requirements of utility and actual situation in China, the in-service inspection preparation for organization, techniques and equipment/tooling, materials, personnel and documentation is briefly described. And the scheduling and coordinating consideration for planed in-service inspection activities during NPP outage is emphatically introduced.

INTRODUCTION

During the operating life of a nuclear power plant, components might be exposed to influences such as stress, temperature, irradiation, hydrogen absorption, corrosive attack and fretting which, single or combined, might result in changes of material properties even growth of flaws. The purpose of in-service inspection (ISI) is to find out these changes to ensure the components through life of a nuclear power plant to operate in satisfactory conditions in regard to safety. Therefore, it is necessary to arrange and plan the ISI for plant components periodically so as to judge whether the components or systems are acceptable for continued safe operation of the plant or whether remedial measures should be taken[1].

Usually, the in-service inspection activities are implemented during refuelling outage. But at this time, numerous and various activities are planned such as refuelling, maintenance, modification and in-service inspection that cant not be done while the plant is in operation. The time devoted to the outage is the most significant contributor to plant unavailability. Any factor affecting outage schedule due to unsufficient preparation, scheduling or coordination will cause enormous costs or damage, and is unacceptable by the owner. So well and sufficient preparation and scheduling for in-service inspection, and effective coordination among various participants, are the keys to successful ISI. Much attention shall be paid thereto, especially for the ISI activities in critical path of the outage. For another reason, most of in-service inspection activities are performed in a radioactive environment. To minimize radiation exposure to personnel to a value as low as is reasonably achievable (ALARA), all activities shall be prepared and scheduled carefully and elaborately. RINPO, one of main contractors engaged in in-service inspection for Daya Bay NPP, has successfully fulfilled pre-service inspection and two times ISI for twin units (except for RV inspection which was performed by IC company). As a main coordinator and the head of Technical Coordination and Plan Group of RINPO, the author went through all the said activities and gained many experiences thereof. Based on these experiences and practice, the paper is intended to summarize and introduce the ISI preparation, scheduling and their performance, and the anthor hopes that they could promote the mutual communication among the people of the same line.

1 IN-SERVICE INSPECTION PLANNING AND PREPARATION

1.1 Organization Establishment

Usually, the utility of NPP will delegate the ISI to one or several competent organizations with contracts in which the service scopes, work conditions, equipment/tooling required, spare parts and consumables, technical specifications and requirements should be specified. After signing the contracts, the contractors shall establish an efficient and adaptable organization to control and coordinate the contracted in-service inspection in which the responsibility distribution and interface control shall be clearly described in the ISI quality assurance programme. Fig. 1. shows a RINPO organization chart for ISI of Daya Bay NPP. Project manager is fully in charge of the said in-service inspection. Site manager, appointed by project manager, is to be responsible for site implementation of ISI activities, and technical coordination and plan group is to establish plan and schedule for preparation and implementation of ISI works, coordinate all the external and internal interfaces, and arrange the activities thereof.

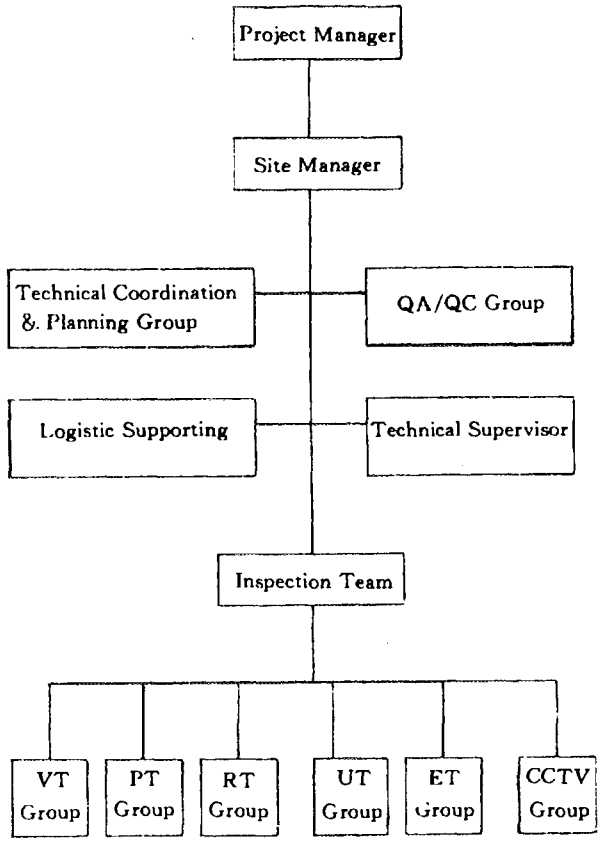

Fig. 1 RINPO In-service Inspection Organization Chart

1.2 Inspection Techniques and Equipment

Examination methods and techniques used shall follow the requirements of National Nuclear Safety Guide HAF0302 and the technical specifications described in the contracts. It is important that the ISI shall make use of the same methods, techniques and types of equipment/tooling as those which were used in pre-service inspection (PSI), and if practical, the same personnel should be arranged. The following examination methods were used in Daya Bay NPP either in PSI or ISI by the same batch of personnel:

a) Automatic ultrasonic inspection (UT) for reactor pressure vessels (including RT checking for vessel in/out nozzle welds) (by IC company);

b) Eddy current examination (ET) for RIC thimble tubes, reactor pressure vessel studs/nuts and steam generator tubing;

c) Manual ultrasonic test (UT) for parts/welds of components, and measurement of thickness

d) Radiographic test (RT) for welds and to verify the existance of thermal sleeves;

e) Liquid penetrant test (PT) for part/weld surfaces;

f) Acoustic emission detection (AT) for leakage during hydrotest;

g) Visual examination (VT), which includes close circuit television (CCTV) examinations;

h) Magnetic partical examination (MT) for the components.

The key equipment/tooling used are listed as follows:

a) MIS machine for reactor pressure vessel;

b) Remote-controlled multi-frequency eddy current test systems (MIZ-18) for RIC thimble tubes, steam generator tubing;

c) RPV stud/nut inspection system for reactor pressure vessel studs/nuts;

d) Closed circuit television (CCTV) inspection system for steam generator channel head cladding;

e) Closed circuit television (CCTV) inspection system for pressurizer internal cladding;

f) Underwater television inspection system for reactor vessel internals;

g) Acoustic emission detection system for the main primary sysem;

h) Sets of positioning tools for radiographic test of primary piping welds on steam generator nozzle and other welds, as well as valves;

i) Televisual inspection and foreign object extraction tools for steam generator secondary side tubesheet;

j) Televisual inspection tools for tanks and heat exchangers;

k) Sets of manual ultrasonic test equipment (USD10 and CTS36).

At least 5 months before examination, all the equipment/tooling shall be available and be in satisfactory status. The consequent off-site equipment set-up, function test and validation shall be performed by qualified personnel, and monitored by QA personnel in accordance with the approved procedures.

After shipping and handling, the equipment/tooling shall be resetup, validated and calibrated on site with documents to show that the equipment/tooling is in acceptable conditions.

1.3 Spare Parts and Consumables

Sufficient spare parts and appropriate consumables shall be prepared, and a

purchasing plan should be established accordingly.

The spare parts are those which might be replaced in case of the used inspection equipment/tooling are out of order on site. All the spare parts shall be validated if applicable.

The main consumables cover ultrasonic test probes and coupling medium, radiographic test radioactive source, films, developing products, flexible cassettes, IQI, filters and intensifying screen, eddy current test probes, cartridge, disk, extention cables, CCTV test videotapes, liquid penetrant products. The numbers and characteristics of the consumables should meet the requirements of the relevant technical specifications. All consumables shall be certified with the documents such as probe characteristic certificates, the certificates for the concentration of sulphur and chlorine in cleaning and dye penetrant product, and of the materials to be used in or on NPP components.

1.4 Examination Personnel

1.4.1 Examination Personnel Training

The training for the ISI participants shall include the aspects named as:

a) NDE qualification and certification training;

b) Nuclear safety training;

c) Job training.

NDE qualification and certification training shall be organized and performed by National Authorities such as Chinese NDT Society or the equivalent organizations following the related stipulation.

Nuclear safety training consists of the training on radiation protection (RP), industry safety (IS), NPP emergency evacuation, NPP maintenance quality assurance, NPP specifications and stipulations, outage experience feedback, which is to upgrade the participants nuclear safety and quality conciousness.

Job training is to promote the skill of participants so that the examiners, working in radiation environment, could finish works following ALARA principle, which incorporates nuclear basic knowledge training, examination documents training such as the RSEM code, the general ISI programme, examination procedures, and examination specific programs, quality assurance training, practical training on mock-up or reference blocks which includes equipment/tooling adjustment, disassembly and reassembly, erection, dismantle in simulation conditions such as working in tenting (SAS) environments.

1.4.2 Examination Personnel Qualification and Authorization

As per the utility specification, all individual participating in the activities related to quality and safety should be qualified and authorized. Different rosters require different level qualifications and authorizations: Fig. 2 demonstrates the main process of training and authorization required for ISI of RINPO staff. For instance, inspection team leader shall be qualified and authorized as NDT Ⅲ, RP Ⅲ & NS Ⅲ, and group (working) supervisor shall be authorized as RP Ⅱ. Particularly, team supervisor for television inspection of cleanliness of steam generator secondary side tubesheet shall be RP Ⅲ, NS Ⅲ and A3 (mechnical authorization). All authorizations for RP, NS, Mechnical or Electrical are the responsibilities of the contractors.

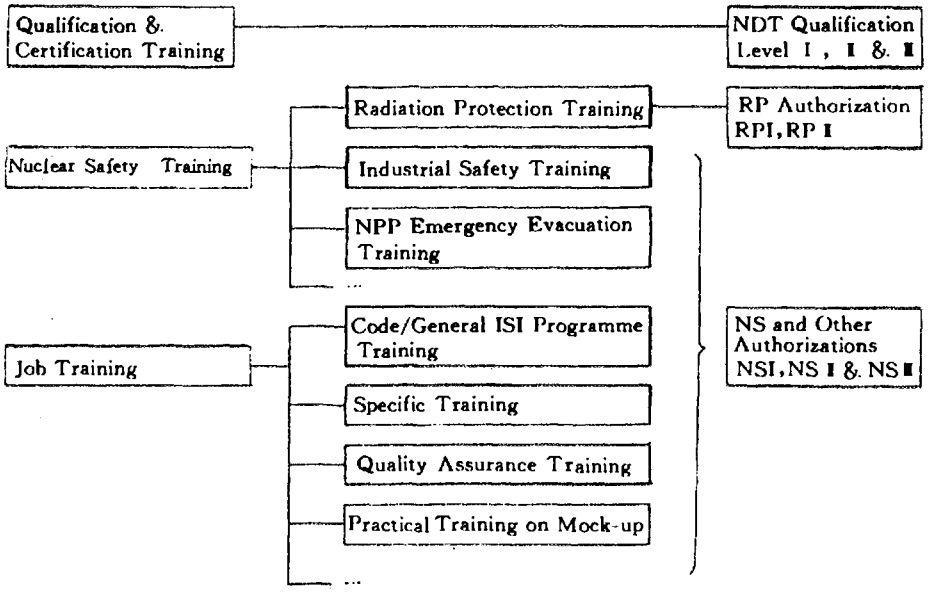

Fig. 2 In-service Inspection Requuired Qualification and Authorization

1.5 Documentation Preparation

1.5.1 Documents Provided by Owner

The purchaser shall provide the technical specifications and requirements required for ISI, and be responsible to draw up an ISI general programme approved by National Nuclear Safety Authority (NNSA) for the operating plant[2]. According to the general programme, and plant operating and maintenance experience feedback, an ISI yearly plan would be issued, which details the list of the component parts/welds subject to examination, as well as the examination methods, procedures, equipment/special tooling to be used. The yearly plan should be available for the performer at least six months before the outage to facilitate the contractors' preparing.

1.5.2 Documents Prepared by Contractors

The documentation prepared by contractors could be divided into two levels:

a) Programmatic policies and procedures;

b) Work-oriented documents.

The former includes the quality assurance program description of in-service inspection, and relevant management procedures. Whereas the latter mainly covers as follows,

a) Project control documents;

b) Equipment/tooling and material specifications;

c) Equipment/tooling validation;

d) Equipment/tooling connection specifications;

e) Delivery schedule/manufacture schedule for ISI equipment/tooling, spare parts and consumables;

f) Training plans;

g) Pre-operating testing for ISI equipment/tooling;

h) Examination procedures, specific programs and quality plans;

i) List of result synthesis reports and overall report for each unit….

All the documents shall be listed and identified in Index of Engineering Document (IED) which shall mark the date of submittal thereof.

2 IN-SERVICE INSPECTION SCHEDULING AND PERFORMANCE

2.1 In-Service Inspection Activities Scheduling

Fig. 3 is an example of critical path for 101 outage schedule of GNPS, the main activities in nuclear island (NI) for 101 outage are: a) refuelling;

b) Works on valves and radiographic test and CCTV examination on steam generators performed at low loop level of primary circuit;

c) Reactor vessel inspection;

d) Requalification of modification;

e) Maintenance works;

f) Other ISI works (1st complete ISI).

The ISI activities shall be scheduled in the outage time window from milestone disconnection to fuel loading (seeing also Fig. 3). The following factors should be considered while the ISI schedule is prepared.

a) Outage schedule;

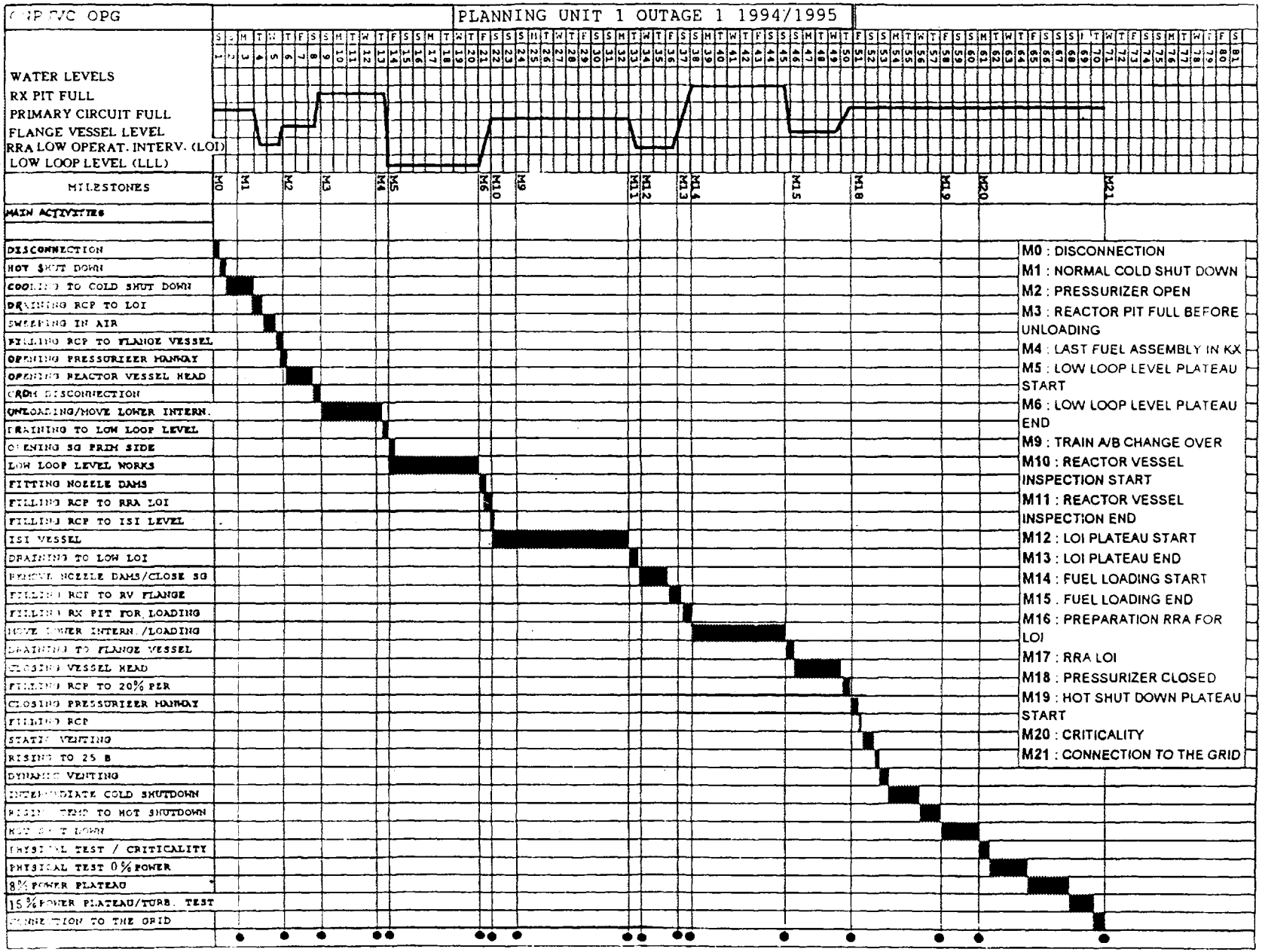

Fig. 3 Schematic of GNPS 101 Outage Critical Path Schedule

b) ISI activities sequence;

c) Limitation for access Reactor Building (RX) during outage;

d) Blocking schedule and status;

e) Prerequisites status;

f) Outage maintenances activities;

g) Radiation protection and ALARA action;

h) Manpower.

2.1.1 Outage Schedule

Outage schedule would directly affect the schedule of ISI. All the ISI activities including additional or retest and data analysis shall be finished before fuel loading, and some activities must be done on specific time window. For example, during-hydrotest visual inspection shall be performed during hot shutdown, the RIC thimble tube eddy current test shall be done before unloading but after pressurizer manhole opened; whereas, the CCTV inspection for steam generator channel head cladding and radiographic test for steam generator nozzle welds shall be conducted at low loop level.

2.1.2 ISI Activities Sequence

Some ISI activities are interacted or interdependent. That means one must be conducted before or after another. These mainly include: after-lancing television inspection for SG 2nd side tubesheet shall be completed before eddy current test for SG tubing started, because the after-lancing inspection results will show the sludge status and foreign objects remained in the tube sheet which may require additional eddy current test from primary side therearound. For steam generator and pressurizer manway, ultrasonic test shall be done after the CCTV and RT examination for cladding/welds finished to ensure that the CCTV equipment/RT tooling erection did not damage the manway surface. And for the components to be examined by liquid penetrant and ultrasonic simultaneously, liquid penetrant test shall be done before ultrasonic test because ultrasonic couplant might affect the assessment of liquid penetrant test. Whereas the visual inspection during atmospherical peressure shall be finished after insulation removal but before site decontaminating and dusting, otherwise the leakage or seepage evidence (discoloration or residue of boric acid accumulation from borated reactor coolant leakage) might be removed. Liquid penetrant test for steam generator nozzle welds and radiographic test for some RCP piping welds shall be done before the SAS (tenting) is installed as the SAS might block examination accessibility.

2.1.3 Limitation for Access RX Building During Outage

As there are specific radiation and industrial risk in reactor building, reactor building access shall be controlled. GNPS stipulates that, when airlocks are closed, only 20 people (including 4 for utility RP and operation staff) are limited to access to reactor building. Specific " Access Permit" shall be applied for by the persons involved in works and approved by plant relevant supervisors. So, from disconnection to end of cold shutdown (milestone M0-M1, seeing also Fig. 3), no more than 16 workers are permitted to work inside reactor building. During hot shutdown, hydrotest is performed and visual inspections thereunder have to be done. And at end of cold shutdown, the preparation of RIC thimble tube eddy current test would be started. Therefore, plan and manpower arrangement shall be optimized.

When one air-lock is opened, limitation to 100 people for access to RX Building. This meane, during fuel unloading or loading, that only 100 people (including unloading or loading personnel) are permitted to work inside nuclear island. The equipment hatch is also closed during shutdown and fuel unloading/loading. The examination equipment/tooling shall be transported to site at appropriate time so that they could be used while the equipment hatch is closed.

2.1.4 Blocking Schedule and Status

The big difference between ISI and PSI is that any work in RX during outage shall be requested and permitted. All activities during the outage of GNPS shall be requested by the performers or owner in advance so that the outage plan group could arrange all wrok within outage schedule, and make rolled plan for outage. After the work request is approved by the purchaser hierarchy, a permit request for the activities shall be applied, which includes work order, requalification certificate and work complete sheet, job risk analysis and permit request. The emphases shall be placed on the activities of analysis for job risk and those requiring blocking. They are shown as below.

a) Radiographic test for steam generator nozzle welds and CCTV examination for steam generator channel head cladding shall be done at low loop level (primary circuit blocked).

b)CCTV examination for pressurizer internal cladding shall be done at the level of water lower than that of area to be examined and manway available;

c) All other radiographic test for parts or welds shall be done at the condition that no water inside thereof and insulation removed, so the RT for auxiliary RCP system, feedwater flow control (ARE) system, auxiliary feedwater (ASG) system,

main steam (VVP) system, turbine bypass (GCT) system and residual heat removal (RRA) system shall be performed while the examined systems are in blocking status.

d) The television inspection for SG secondary side cleanliness shall be performed while the SG 2nd side is empty (blocked).

e) Ultrasonic test on primary pump flywheels shall be implemented while primary pump in blocking;

f) Visual inspection (internal) for tanks and heat exchangers shall be done while the components is blocked;

g) Eddy current test on steam generator tubing shall be done at the conditions of no water in tubing, tube internal surfaces dryed, manways available and nozzle dams in place.

2.1.5 Prerequisites Status

The utility is responsible for the examination prerequisites which are listed below. But the performer shall specify, in advance, these conditions in relevant documents such as specific programs, coordinate timely among related departments of utility and other contractors for the required prerequisites, and check them before examination performance:

a) Insulation and support rings removal;

b) Surface ground;

c) Scaffolding installation;

d) Cable access holes opened;

e) Tenting (SAS) built;

f) Equipment hatch opened;

g) Lighting satisfactory;

h) Temperature appropriate;

i) Drying enough;

j) Power supply provided;

k) Compressed air distribution system available;

l) Nozzle dams of SG in place or no dams in place;

m) Manholes, handholes, eyeholes or inspection access holes (such as radiographic test access plugs) removed or opened and so on.

2.1.6 Outage Maintenance Activities

Some in-service inspection shall be done after the relevant outage maintenance activities are finished or before the maintenance activities are started. Some exam-

ples are listed below:

a) Ultrasonic test for primary flywheel shall be done after maintenance of the pump finished;

b) Sludge lancing for steam generator secondary side tube sheet shall be finished before the radiographic test for SG nozzle welds;

c) Before-lancing or after-lancing television inspection should be done before lancing started or finished and dried;

d) Some visual inspection for tanks or heat exchangers (internal) shall be done after the manways are repaired;

e) Radiographic test for primary valves shall be done after valves repairing are finished but before the valve covers are closed.

f) Eddy current test or ultrasonic test for RV studs/nuts or for SG and PR studs shall be done after these studs/nuts are removed, transported to examination area (such as AC building) and cleaned and so on.

2.1.7 Radiation Protection and ALARA Action

Because most of in-service inspection activities have to be performed at a harmful environment of radiological condition, the radiation protection (RP) control shall be implemented through different kind of measures by the utility and contractor to ensure the safety of national, purchaser and contractors, and to meet the radiation protection requirements. The key point is to minimize radiation exposure to personnel to a value as low as is reasonably achievable (ALARA).

The target of ALARA management for in-service inspection during outage is to optimize radiation protection, to minimize the original items of the plant unit, to avoid unnecessary exposure, to strictly control the contamination of personnel, equipment and work-site, to balance the relationship among the protection from internal and external contamination, worksite preparation and collective dose and finally to control the in-service inspection collective dose within the ALARA level. The main measures taken for the ALARA control are as follows:

a) A RP training with clear objective will be organized for all participants, especially for the main management personnel and work supervisors;

b) The regular communication among the different work groups, the utility RP control section and other contractors for timely feedback experience will be strengthened;

c) Special personnel who are responsible for RP and industrial safety are appointed to monitor the compliance of radiation protection regulation and to provide

the support on site staffs with assistance or proposal;

The detailed steps on-site taken for ALARA during ISI are:

1) Set up shelters with lead plates in the " Hot Points" such as the valves, special piping or components which are near the worksite. For instance, the valves and piping near SG 2nd side handholes are covered by lead plates;

2) To fill in the piping or vessels to be examined. For example, the steam generator secondary side shall be filled in by water while the ultrasonic test for them is performing. The RV internals shall be under water while television inspection is carrying out, and the tube bundle shall be under water while the steam generator 2nd side internal structures and welds are in examination.

3) To set up special tenting (SAS) for some components such as steam generator channel head, pressurizer manway, RIC thimble tubes to avoid internal contamination;

4) To put on additional radiation protection clothes (lead clothes, air clothes, plastic clothes), wear the aircap to avoid internal contaminatin in some area;

5) To use remote controlled inspection equipment/tooling to minimize work time on harmful radiation exposure site, such as MIS machine, MIZ-18 systems, CCTV systems and other tooling;

6) To strengthen off-site training to promote the skill of work personnel to reduce working time;

7) To optimize work plan and personnel arrangement;

8) To increase manpower to reduce the individual dose. For example, for RCP212 215 valve RT checking, steam generator secondary side television inspection, more manpower is arranged.

2.1.8 Manpower

To manage ISI costs within budget, it is very important to make a good plan, to maximize individual performance and to optimize staffing during ISI performance.

Fig. 4 is the ISI schedules for steam generators during outage 101 of GNPS which were established as said above.

2.2 In-service Inspection Coordination and Performance

In order to assure the smooth implementation of ISI activities during outage, eyes should be kept on the interface control and coordination among various activities as mentioned in 2.1, and among the utility, contractors and subcontractors. So all organizations and departments involved in outage shall work in close cooperation

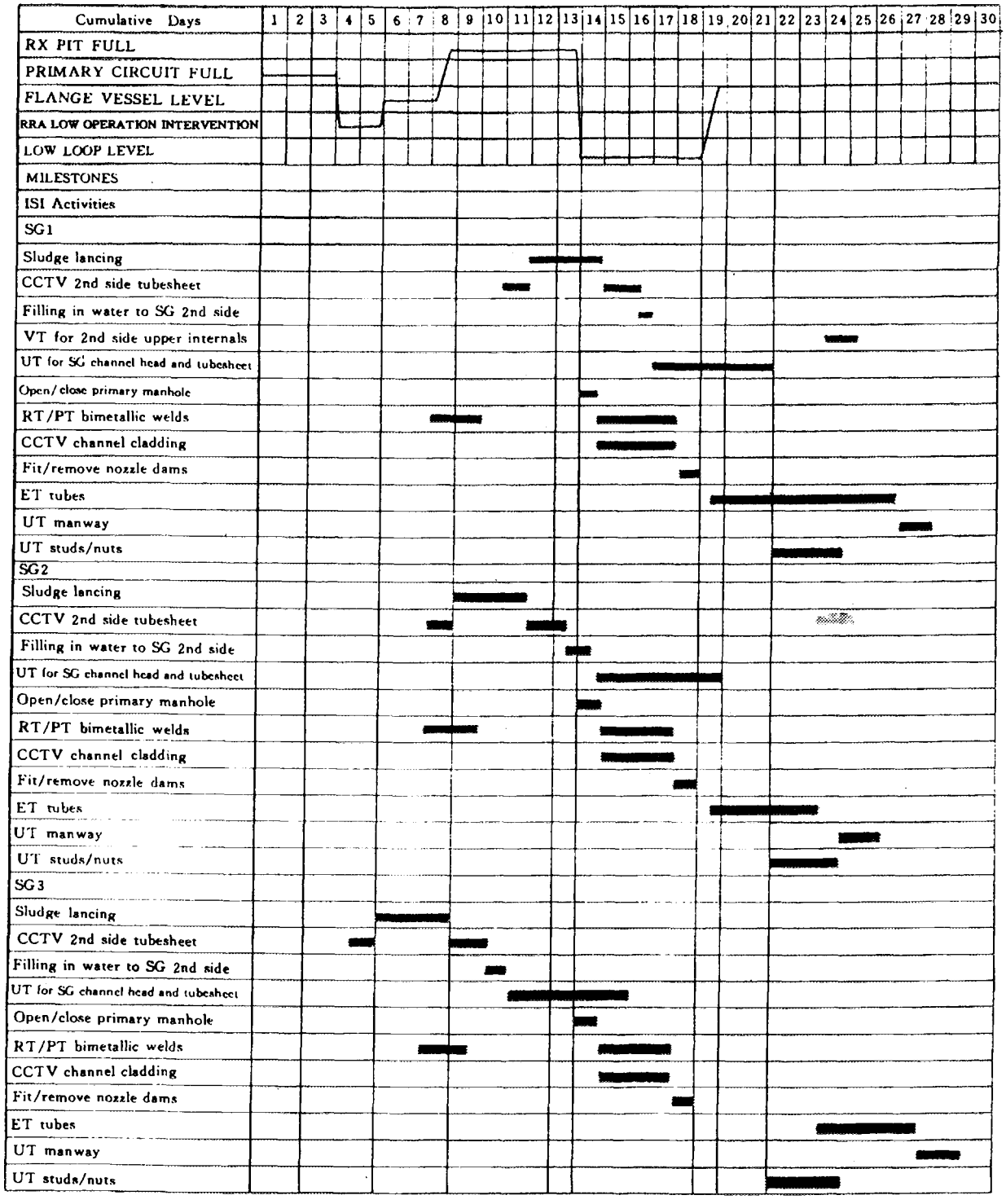

Fig. 4 Schematic of Steam Generator ISI Activities Schedule during 101 Outage

with each other. To this end, the contractors shall keep the purchaser fully informed of all pertinent information with respect to the performance of the services.

In practice, an ISI daily report is submitted to the utility responsible department to present the works done in the last day, to be done today and next day,

pending problems encountered, and requests and recommendations. And the official reports for the examination shall be handled over the utility for them to timely grasp the examination results.

For contractors, to know actual outage schedule and other work progress related to ISI, close communication with the utility outage organization shall be enhanced. The kick-off meetings shall be organized, if necessary, between the purchaser, ISI contractors and other contractors engaged for the purpose of the power station outage to liaise the work interfaces and to arrange outage schedule concerned with ISI. During outage, contractors should attend the coordination meetings as may be needed for the service inspection such as Daily Coordination Meeting and Outage Planning Meeting organized by the utility. The coordination meeting is to report on accomplishment, main problems experienced and lessons learned of last 24 hours, to define the next work schedule, critical path and subcritical path and to coordinate all interface problems and technical problems. The latter meeting is to mainly discuss and arrange the schedule for next three days and exchange information, and to present the newest permit request by implement sections for validation by plant planning group through coordination. In the light of the latest information from the said meetings and other coordination activities, contractors could update the ISI schedule day by day, and the permitted works could be implemented accordingly.

3 CONCLUSION

The in-service inspection activities shall be performed by qualified and authorized personnel utilizing the validated equipment/tooling according to approved procedures in scheduled time. So well preparation and arrangement for equipment/tooling, participants, documents and schedule as well as effective coordination are the keys to successful implementation of in-service inspection.

REFERENCES

1 International Atomic Energy Agency. In-service inspection for nuclear power plants. IAEA Safety Series No. 50-SG-O2. Vienna, 1980

2 CHEN Jidong. Daya Bay Nuclear Power Station systems and operation (In Chinese). Beijing: Atomic Energy Press, 1994

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