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PART III, APPENDIX A11

END OF ASSEMBLY, COMMISSIONING AND TESTING



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1. INTRODUCTION

This appendix concerning testing and commissioning is divided into the following sections:

- Planning and Coordination
- Factory Acceptance Tests (FAT)
- End of Assembly
- Cold Test
- Warm Test
- Trial Operation Period

In each section the minimum requirements for the activities are described.

2. PLANNING AND COORDINATION

2.1 Planning

FAT

A detailed plan for the FAT's shall be worked out during the detailed design phase of the project by the Contractor. Especially the FAT for the Control and Monitoring System (CMS) shall be highlighted as a central activity of major importance, which requires its own detailed plan. The detailed plan and procedures for the CMS FAT shall be available at least six months prior to start of the cold tests.

Commissioning

An overall plan for commissioning shall be available 3 months prior to end of Assembly.

The overall plan for commissioning shall include all phases and aspects of the commissioning and shall include, but not be limited to:

- Detailed activity plan, to be updated weekly
- Commissioning instructions including
 - Description of the commissioning organisation
 - Staffing schedule
 - Reporting manner and standards
 - Coordination methods, e.g. meetings, exchange of data, forms, etc.
 - Description of inspections prior to test start
 - Description of tests
 - Description of trimming and stabilisation of process and operation
 - Description of Performance test, including Guarantee test
 - Description of labelling and safety measures and precautions, including regular information on activities
 - Description of commissioning documentation and forms, including documentation of present status
 - HSE documents

A detailed plan for the cold tests shall be available at least two months prior to start of the cold tests.

A detailed plan for the warm tests shall be available at least two months prior to start of the warm tests.

The plans shall be incorporated in the commissioning instructions and shall be available in hard-copy as well as in electronic form. The plans shall be coordinated with the Employer.

2.2 Coordination and Organisation

The Contractor is responsible for coordination and shall provide the outline for the overall commissioning of the Facility.

The commissioning status plans and activities shall be coordinated and adjusted under the control and surveillance of the Employer.

The Employer has the right to participate in any of the tests described below, including but not limited to FAT, SAT, pre-commissioning test, commissioning test and Performance and Guarantee test.

Coordination shall take place in the form of regular meetings such as daily morning meetings and detailed commissioning meetings.

2.3 Reporting

The Contractor shall inform the Employer on progress of the commissioning. This information includes the commissioning status plan according to Appendix B3 *Requirements for Planning and Reporting*.

Documentation of the results of the commissioning activities and the present status shall be reported.

Emphasis shall be placed on any deviations from the plan as well as issues requiring special attention and effort as well as tasks requiring the Employers attention or participation.

Forecasts for the upcoming period shall be included in the report.

The reports shall be available in hardcopy as well as in electronic form.

Reports shall be submitted regularly as deemed necessary by the Employer.

3. FACTORY ACCEPTANCE TESTS (FAT)

For mechanical, electrical and CMS equipment the Contractor shall carry out FAT, as described below, in the presence of Subcontractors.

The Contractor shall execute various inspections and tests at the workshop/factory of Subcontractors. The inspections and tests shall verify that the equipment is supplied in accordance with the specifications and intentions. Any faults, errors or omissions identified at the FAT shall be corrected before installation at site.

FAT shall be carried out for all single functionalities, for groups of functionalities and for all process equipment.

3.1 FAT – Mechanical Systems

FAT shall as a minimum be carried out for the following mechanical systems (not exhaustive and not prioritized):

- Steam headers
- Boiler parts
- Boiler drum
- Incinerator parts
- Ash and IBA conveyor systems
- Heat exchangers
- Pumps
- Fans
- Turbine parts
- Gearbox between the main steam turbine and generator
- Dust removal equipment
- SNCR equipment
- Flue gas treatment components (tanks, vessels, scrubbers, waste-water treatment)
- Cranes
- Safety valves

These tests include inspection of foundries, machining of components, balancing of rotating equipment etc.

It shall be emphasized that the above list does not relieve the Contractor of carrying out FAT for other mechanical systems as required.

3.2 FAT – Control and Monitoring System (CMS)

In principle each system shall be tested at one joint FAT, where each system is fully tested in all operation areas.

The following shall be included, but not limited to, in the FAT for the CMS.

The FAT shall cover final functional tests of all application software prepared for site operation with simulated inputs and outputs connected. During the loop testing the CMS failures shall be recorded on test incident sheets. The CMS data links shall be 100% tested. A 100% string test with system panels and operator interfaces connected by data link/hardwired cables shall be performed. The equipment shall be subject to functional tests following shipment and re-assembling of CMS at site.

The tests shall prove the operation of the CMS and every part of it and its performance under all conditions and sequences which may arise in service. The test shall include as a minimum:

- Exercising of all hardwired inputs/outputs and associated logic;
- Exercising of all internal signals and associated logic, including those distributed via data link throughout the CMS;
- Exercising and presentation of all user interface and facilities including graphics;
- Checking all equipment failure modes, i.e. self diagnostic, power supply dip, I/Os, memory battery back-up etc.;

- Memory and control processor functions not used in the programme shall be fully tested and exercised;
- Interaction between logic channels to be checked;
- Demonstrate the degeneration and recovery of the CMS following different possible hardware and software failures. This shall include detection of communication errors, and the operation of any self-diagnostic facilities;
- Demonstrated the capability of the CMS to remain in operation during corrective maintenance work;
- Demonstrate operating of CMS facilities including load, dump, initialisation and recovery;
- Demonstrate connection of peripheral devices such as disc drives, VDU's and printers;
- Demonstrate the correct operation of all communication protocols used in the CMS;
- Tests on all modules of the CMS. These tests shall demonstrate that all requirements in each area have been met;
- Electromagnetic compatibility testing.

The test procedure shall define any database to be used for factory acceptance testing. The content of the databases shall be subject to review by the Employer.

All system documentation has to be complete and residing at the CMS. All listings have to be free of pencilled (patched) corrections. The CMS has to be free of patches. All hardware diagnostic programs shall run during FAT.

All respective process CMS suppliers shall carry out a "pre FAT" involving both the programmers and the respective process specialists/engineers before the actual FAT is carried out (involving participation of the Employer). The "pre FAT" is carried out with the purpose of eliminating malfunctions concerning general functionality and operator and engineer interfaces. The respective CMS supplier must be able to prove that a "pre FAT" has been executed by means of filled-in checklists.

The FAT will thus demonstrate the overall functionality without being interrupted by faults that has to be corrected. This will allow the Employer to focus on the overall process implementation and overall functionality of the CMS system when he participates.

3.3 FAT – Electrical Systems

FAT's shall as a minimum be carried out for the following electrical systems (not exhaustive and not prioritized):

- Redundancies and spare capacities
- High voltage switchboards
- Transformers
- Low voltage switchboards
- Generators, including synchronization, excitation, etc.
- Emergency power supply system
- Safe power supply systems
- Big motors and frequency converters
- Local control panels and local operation panels

Routine tests shall as a minimum consist of:

- power frequency voltage tests
- measurement of dielectric losses, partial discharges, resistance of main conductors, switching times of circuit breakers and switches

- mechanical testing and interlocking
- visual inspection

Type tests shall be according to the Contractor's and IEC standards and be carried out or have been carried out on the switchgear or a representative part of it.

It shall be emphasized that the above does not relieve the Contractor of carrying out FAT's or tests for other electrical systems as required.

4. END OF ASSEMBLY

4.1 End of Assembly – mechanical and electrical completion

- The Contractor shall with a mechanical and electrical completion notification demonstrate to the Employer that erection of the Materials and Equipment is finalized.
- The mechanical and electrical completion notification can be supplemented with mechanical and electrical completion notification for sub systems.
- The Contractor's detailed plans for cold and warm test shall be presented and accepted by the Employer before commencing the commissioning phase.
- A punch list from the mechanical and electrical completion notification shall be presented and accepted by the Employer before commencing the commissioning phase.

4.2 Punch list

A punch list containing defects and omissions to be rectified shall be prepared by the Contractor and be available before end of Assembly. The punch list shall be continuously updated until Preliminary Takeover.

Particularly, an updated and approved version of the punch list shall be available before commencement of cold tests and warm tests and before conclusion of the warm tests, i.e. approved punch lists are a prerequisite for agreement on various protocols as outlined below.

The punch list shall contain corrections required to complete the installations according to the specifications.

The indicated punches shall be categorised with the following defect category, agreed between Employer and Contractor:

- A, Remedy before the start of cold commission
- B, Remedy before the start of hot commissioning
- C, Remedy before Preliminary Take Over of Contract Object

In general, all punch list items shall be corrected prior to Preliminary Take Over.

The following checks shall be executed and documented for the punch list as a minimum:

- Installation meets P&ID's
- Installation meets specifications with regard to mechanical and electrical properties and functioning
- Control of location
- Insulation and conservation

- Control of all weldings and joints of piping systems and components
- All others tests and documents required in accordance with the PED
- Mechanical and electrical safety checks according to relevant standards

The pressure tests, which require presence and acceptance of notified bodies, shall appear from the control plan and the Employer shall be invited to inspect such tests.

For cleaning of systems the following provisions shall have been taken into account:

- The entire live-steam system including the turbine bypass pipe system shall be cleaned by blowing out; consequently, measures must be taken during erection and cold start-up to verify that blowing-out can be carried out safely and with low effort; the fluid systems shall be flushed
- In order to keep the period of blowing-out of the steam system as short as possible, it must be verified that the steam and condensate system piping with fittings, etc. are free from any mechanical obstruction
- All fluid systems are to be kept clean prior to and during erection, otherwise long flushing times, and consequently loss of fluid must be expected
- All equipment and piping of the entire steam and condensate system are to be provided with a sufficient number of nozzles for draining and flushing
- For blowing-out, the Contractor shall provide sufficiently dimensioned auxiliary equipment and silencers that are also to be mounted by him and then dismantled on completion of the blowing-out
- The Contractor shall make sure that all safety devices such as valves, which are shut off during pressure tests are put back into operation after the test. The Contractor shall register such measures as part of the control plan
- Ducts shall be cleaned as well

The end of Assembly shall be recorded in a protocol. The protocol shall include a list of all components (drive systems and instrumentation equipment), subdivided into function groups. When the check has been completed, these components are to be initialised by the Contractor. The check of the instrumentation equipment/drive system is not completed until the graphic display has been checked.

The Contractor shall administrate the protocols for testing the function groups. In these protocols the Contractor is to confirm that the function sequences, signals and graphic displays are in full working order. Each function group is tested during mechanical completion at least to the extent that it can be operated alone (possibly with simulations). Operation together with other groups or with process control equipment is performed as far as appropriate and possible. Otherwise this forms part of the cold or warm start-up.

The end of assembly protocol shall be signed by the Employer and the Contractor when:

- All of the above listed checks have been performed
- An updated and agreed version of the punch list is available.

5. COLD TEST

During the cold test the proper functioning of all parts of the supplied installation will be tested without media.

Cold tests shall be performed when the Contractor has finished the final Assembly on the site and after the end of assembly Protocol has been signed by both parties. The Contractor shall give minimum 5 Working days notice to initiate the cold tests.

The cold tests shall include, as further specified below, but not limited to:

- Site Acceptance Test (SAT) of CMS
- Test of signals
- Test of systems and safety functions
- Pressurizing of compressed air systems and blowing out
- Energizing of electrical systems
- Lockable service switches checked
- Control of interface between motors and MCC
- Direction of rotation tested
- Electrical motors idle test (4 hours run without coupling)
- Completion of loop testing
- Calibration of instruments
- Testing of control valves, transmitters, switches etc.
- Testing of operational control of equipment
- All systems cleaned flushed
- Interlocks/shut down systems
- Pressure test of relevant components and systems
- Termination of all occupational health and safety issues meaning that all escape routes, fire sectioning etc. must be completed as well as any safety issues in relation to storage and handling of consumables and residues.
- Rotation tests are carried out. When the rotation test has been completed, the Contractor decides whether the drive system shall be electrically isolated or not.

Further, all safety systems necessary for operation of the Contract Object must have been tested and found fully functional and operational as part of the cold tests.

When all Materials and Equipment of the Contract Object successfully pass the cold tests and an updated and agreed version of the punch list is available the cold tests protocol shall be prepared and signed by both parties.

5.1 SAT, Control and Monitoring System (CMS)

A Site Acceptance Test (SAT) of the CMS shall be carried out, with the tests covering as a minimum, but not limited to, the following items:

- Process description as basis for the SAT;
- Process screen graphics and other operator interfaces;
- Alarms;
- Operator and engineering facilities;
- Reports;
- Automation level;

- Redundancies;
- Main CMS performance and spare capacities;
- Sub-CMS systems performance and spare capacities;
- Education and training.

The SAT will start up during cold test and continue in the warm test.

The SAT shall be carried out for all single functionalities, for group of functionalities and for all process systems.

These tests shall comprise all of the functional tests carried out in the FAT together with verifying actual interfaces and communication links, plus any additional tests/inspection checks necessary to ensure the overall integrity of the CMS.

During the loop testing any CMS failure shall be recorded on test incident sheets, together with the "time to repair". The resultant information is expected to be comparable to the availability figures provided.

5.2 Test of Signals

After installation of the CMS at site the Contractor shall perform test of all signals.

Test of signals covers function test of the different components, including control of signals.

The Contractor shall draw up a detailed plan for test and control of components and control systems. Before implementation of the plan it shall be presented to the Employer.

The plan shall ensure that: Components are brought from a stage where they are calibrated, that the entire CMS has been checked and controlled and that sub-systems, of which the components are a part, have been controlled, are faultless and ready for operation.

5.3 Test of Systems

The tests of systems include:

1. Test of systems covers e.g. performance tests of all water and air systems and complete function test of all sub-systems (dry running).
2. Repeated start/stops of independent electric motors; this shall include, testing of emergency stops, local control panels and other control and safety devices
3. EMC measurements by an independent party and monitored by the Employer as mentioned in DS/EN 61000-6-2 and DS/EN 61000-6-4.
4. Sequences of operation of all automatics and all components shall be controlled, and all safety systems and interlocks shall be tested and controlled.
5. The systems for measuring emissions must be operational at completion of cold test
6. All instrumentation and process control systems that are not bound to the process, such as the communication systems, video monitoring and filing of operational data, must be functional at completion of cold start-up.
7. Any other tests required to check the proper functioning of the supplied installation, including, but not limited to:
 - adjusting of limit switches
 - setting of speed monitors/regulators
 - setting of set point for switches

- checking of all parameters for the electrical, measurement and control system
- as may be directed by the Employer or any other tests required by a statutory inspectorate or body

The resulting protocols of the safety test must be included in the Line Documentation in accordance with Appendix A14.7 *Documentation*.

6. WARM TEST

Warm test (test with fuel/waste) may only start after the cold test has been completed and the cold tests protocol has been signed by both parties. Any issues related to health and safety must be resolved and completed prior to commencement of warm tests, e.g. safety issues in relation to storage and handling of consumables and residues must have been taken care of. Furthermore, all safety systems necessary for operation of the furnace and boiler and other necessary systems must have been tested and found fully functional and operational before any warm testing can commence. During the warm tests the proper function of all parts of the Contract Object under full and partial load conditions shall be tested.

The warm test of the Line shall include:

- Drying out of refractory.
- Steam blowing.
- Commissioning of turbine/generator.
- Trimming of Line.
- Functional tests.
- Environmental tests.
- Electrical black out tests.
- Electrical island mode tests.
- The power system shall be tested and be in compliance with local Legal regulation for thermal power station units.

The warm test is performed in at least the following steps:

1. Flushing.
2. Preparation, i.e. filling up the boiler, commissioning the flue gas treatment, combustion air systems, waste charging, incineration, ash removal and other subsystems.
3. Drying of the refractory, by operating at the temperatures given in the refractory curing curve.
4. Boiling at low combustion capacity; boiling shall be carried out several times in accordance with program. The equipment shall be flushed several times after each boiling process.
5. Commissioning of the feed water tanks and feed water pumps.
6. Blowing out of the live steam system up to the turbine inlet. Blowing-out is repeated until the level is accepted by the Contractor of the turbine. When blowing-out has been completed, the headers, feed water and condensate tanks are cleaned. Steam Blowing shall be performed during daytime.
7. Trimming of the boiler until the steam quality is in accordance with requirements.
8. Commissioning of the turbine bypass systems and turbine/generator set.
9. Trimming of the Line components and system to achieve stable operation, to meet the functionalities and the guarantees given.

The Employer shall be entitled to inspect the refractory lining, the scrubbers (if any) including demisters, etc. after drying-out and the Contractor shall include such inspection in their commissioning time schedule.

Feeding of waste shall only commence during the course of which it can be demonstrated that all other systems, such as grate, air systems, ash and IBA conveyor systems, conveyance of consumables, measuring systems, CMS etc. are working correctly. Further the parts of the flue gas cleaning, which are necessary for cleaning the flue gasses in accordance with the environmental guarantees according Authorities, shall be commissioned and in operation before any feeding of waste. Special attention in this regard shall be appointed to the avoidance of build-up of memory effect of dioxins and furans.

As part of the warm test, the operating states relevant for the safety aspect (safety systems, interlocks) are to be run deliberately, and all components are to be checked to ensure that they are functioning properly.

During warm tests, the Employer's personnel who have received theoretical training are to be involved as far as possible in the operation/ supervision of the components. Responsibility remains with the Contractor until Preliminary Take Over.

The Contractor shall not be entitled to reduce the number of personnel during this stage.

During the warm test it must be possible to run all process control systems in automatic operation without fault. The operation must be optimized to meet functional, environmental and guarantee requirements before the Trial operation period can commence. It is acceptable to carry out additional optimization of the process control during the Trial operation period.

The warm tests shall be considered to be complete when:

1. The start-up and shut down of the individual Line's components and the total Line have been successfully completed on three consecutive occasions.
2. All components of the Contract Object have been continuously and successfully in operation without problems or defects, that would result in a hindrance, limitation or hazard to normal operation.
3. All control loops, alarms, trip settings, interlocks and safety devices have been set and successfully tested, and all temporary commissioning measures and setting in the CMS have been removed.
4. QAL 2 have been carried out and reported successfully.
5. The proper and complete functioning of the main and auxiliary systems has been shown that normal operation of all Line parts is not hindered, fundamentally limited or being brought into danger.
6. It is possible to run all process control systems in automatic operation without fault.
7. Environmental guarantees are fulfilled. The Contractor shall make sure that the environmental guarantees are fulfilled in such time margin before the start of the Trial operation period, that the Employers evaluation of the data can be finalised before start Trial operation period.
8. Noise emissions are in accordance with Contract.
9. Continuous production of energy corresponding to nominal thermal load with waste as a fuel.
10. Education of operation and maintenance personal has been finalised.
11. Black out test and CMS safety modes ensured through necessary tests, both on auxiliary fuel (natural gas) and waste. The results of the tests shall be evaluated by all parties involved an accepted by the Employer before continuing to an island mode test.

12. The total Line must run 48 hours without critical alarms and less than <100 alarms/day on average.
13. The Contractor shall strive to have 0 alarms on the alarm list and a long-term average of less than <100 alarms/day at the end of the warm start-up period.
14. Island mode is successfully tested. The test shall be carried out with operation in island mode according to the requirements of the Authorities, however operation for minimum 60 minutes must be demonstrated, unless other required by the Employer.

When all equipment of the Contract Object has successfully passed the warm test and an updated and agreed version of the punch list is available the warm test Protocol shall be prepared and signed by both parties.

7. TRIAL OPERATION PERIOD

The commissioning period is followed by the Trial Operation Period. Conditions for entering the Trial Operation Period are described in the Contract.

Before commencement of the Trial Operation Period, the Contract Object shall – through a number of tests – be deemed ready for secure, faultless and continuous operation in accordance with guarantee requirements, the environmental requirements and the functional requirements in accordance with the Contract.

A limited amount of alarms from the Contract Object are permitted during the Trial operation period: less than <100 alarms/day and less than < 10 critical alarms/day as a long-term average. The Contractor shall document the fulfilment as part of the 300 hours Performance test where both criteria shall be fulfilled on daily basis and over the total length of Performance test, respectively. The list of alarms shall be a part of the Contractor's punch list, which the Contractor throughout the Trial Operation Period shall strive to reduce.

7.1 300 hours Performance test

A 300 hours Performance test shall begin within 30 Days after the start of the Trial operation period. The tests shall demonstrate that the guarantee, functional and environmental requirements are fulfilled. The 300 hours performance test is further described in the following.

A minimum of 300 hours of continuous operation of Contract Object is required for this test, which shall not be interrupted by any form of stop or adjustment, leading to operational results which do not fulfil any of the guarantees, functional and/or environmental requirements. During the test the Contract Object shall be operated by the Employer, but the Contractor shall be available in the control room.

The Contractor shall register and document all guarantee and environmental values as well as consumption of consumables stipulated in the Contract including measurements not appearing directly from the CMS. These are read at level meters or similar on tanks or containers as agreed with the Employer. The results shall be presented clearly in a report. This report shall be available not later than 21 days after end of the test. The basis for calculation of the results of the 300 hours Performance test shall be based on the procedure for a guarantee test is stated in Appendix A20 *Procedure for Guarantee Test*.

The instrumentation and measuring equipment of the Line can be used to verify that all requirements are applied with during the 300 hours test, except for environmental guarantees

where third party measurements are required. If uncertainties about fulfilment of guarantees occur in the period from the end of the 300 hours performance test until the end of Guarantee period, than procedure according to the Contract is applied.

The Contract Object may not be trimmed during the entire Performance test period. A minimum of 300 hours of continuous operation is required for the Performance test, which shall not be interrupted by any form of stops or adjustments. If the Line is stopped or if any of the operational results do not fulfil the guarantee, functional or environmental requirements a new test of 300 hours must be carried out in whole extend.

7.2 Requirements of 300 hours Performance test

The Contractor shall at latest one month prior to the start of the 300h Performance test prepare a test program for the parameters which he intends to document during the Performance test. The program shall include a description of how he intends to measure and document the individual parameters. The Contractor's test program shall be approved by the Employer before the 300 hours Performance test can commence.

7.3 Test procedure

7.3.1 BEFORE START OF 300 HOURS PERFORMANCE TEST

The Contractor is responsible for extraction of all necessary data from the CMS for own use during the test.

The Contractor shall ensure that all instruments reporting to the CMS are calibrated prior to the beginning of the 300 hours Performance test.

Calibration of weight cell of the waste cranes shall be carried out before start of the 300 hours Performance test. The weight cells must be calibrated with two test weights of known weight corresponding to approximately a full grab load and half a grab load.

The Contractor shall, to the extent possible, ensure that different kinds of waste with various heating values are available and mixed during the performance test enabling operation in as many load points as possible in the capacity diagram in Appendix A13 *Process and Design Data*.

7.3.2 DURING THE 300 HOURS PERFORMANCE TEST

All consumption of energy, water and chemicals during the test period shall be measured.

All guarantee values regarding emissions, consumptions and productions must be documented.

Guarantee values for emissions must be documented by environmental reports possibly complemented by third party measurements.

To document consumptions of gas oil, chemicals etc. manual measurements or values extracted from the CMS can be used.

Trend curves showing relevant energy and flue gas parameters such as electricity production, emissions, flows, temperatures, pressures etc. extracted from the CMS shall be printed every third hour during the Performance test. Each trend curve must show one-minute mean values with a 4 hour time axis.

Relevant energy and mass balances shall be extracted from the CMS as a part of the 300 hours Performance test documentation.

Every day a daily report shall be elaborated and submitted by the Contractor. The daily report shall as minimum include all data on hourly average, trend curves, operators log including registration of any changes made and alarm list. The exact form of the daily report shall be agreed between the Contractor and the Employer during the planning of the 300h Performance test. The daily report shall be discussed at the morning meetings during the test period and be basis for decision if the operation fulfils the requirements for continuing the test period.

7.3.3 AFTER 300 HOURS PERFORMANCE TEST

The Performance test shall result in a report describing the operation and the performance of the Contract Object. The report shall be based on calculations and corrections in accordance with the procedures stated in Appendix A20 *Procedure for Guarantee Test* and correction curves issued by the Contractor.

The reports shall include the following chapters:

- Preconditions and progress during the 300 hours Performance test
- Documentation of fulfilment of guarantee values (consumption of energy, water, chemicals and other consumables, emissions, production of electricity and district heating etc.)
- Relevant heat and mass balances
- Relevant correction curves cf. the Contract
- Relevant trend curves
- Comments and conclusion to the 300 hours Performance test.