A CASE STUDY: PERFORMANCE AND ACCEPTANCE TEST OF A POWER AND DESALINATION PLANT

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1. Introduction

Performance tests on a plant are carried out to determine the guaranteed performances which are subject to a penalty. After the construction of the plant is completed, a series of pre-commissioning and commissioning tests are conducted. The performance and acceptance tests are the final tests to prove accurately that the integrated plant will deliver the guaranteed figures, i.e. of power and water reliability throughout its life expectancy at specific heat consumption and rated flows, as specified, tendered, contracted, and supervised during execution and finally tested and certified by professionals.

The commissioning activities, in a dual-purpose plant (as in this case study) are performed in the following stages:

(a) Functional and preliminary tests
(b) Trial run
(c) Initial operation
(d) Reliability run
(e) Performance and acceptance tests

The following considers in detail the performance and acceptance tests of an actual cogeneration plant. It will list the data, which should be recorded during the different tests conducted on the site and the calculation steps taken to verify the guaranteed figures of the plant.

The selected cogeneration plant has the following guaranteed values:

Net power output	115.3 MW
Boiler steam capacity	650.0 t hr^{-1}
Net specific heat consumption	3181 Kcal hr^{-1}
Distillate production	2184 t hr^{-1}

The contractor is expected to carry out several tests at the site to prove that the plant is capable of meeting these values. These tests and calculations are described below.

The performance tests at site are performed after some months of operation. In the Arabian Gulf area this normally takes place during the summer months, i.e. at times with unfavorable climatic conditions. The contractor provides calibrated instruments, measuring equipment and essential special devices and arranges for measurements related to the performance tests. The performance tests are conducted in accordance with the standards and regulation stipulated in the contract document. At the end of the guarantee period, and after all obligations in the contract have been fulfilled, the final acceptance certificate is issued by the owner/engineer to the contractor and the performance bond can be returned to the contractor.

2. Guaranteed Values

2.1. Power Plant Capacity

The contractor guarantees the net maximum continuous rating (MCR) of 115.35 MW for each turbine generator measured at circuit breakers, taking into account the internal power station auxiliaries only and excluding the common auxiliaries, when operating at rated steam conditions, seawater temperature of 35°C, and extraction heat of 170 Gcal h^{-1}.

2.2. Net Specific Heat Consumption of the Power Plant

The contractor is expected to provide guarantees as demonstrated by the following example. The weighted average of the unit net specific heat consumption should not exceed 3.181 Gcal MW^{-1} h^{-1}. Extraction steam is supplied to the desalination unit and condensate is returned to the deaerator with 145 Gcal h^{-1} net, with the following constraint: waste gas temperature at economizer outlet not below 140°C, with a seawater temperature of 32°C, an ambient air temperature of 40°C, relative humidity of air 80 per cent. The net heat value of the natural gas is assumed to be 8026 Kcal Nm^{-3}. The following formula is used to determine the weighted average of the unit net specific heat consumption.

$$Q_{av} = 0.2 \times PL115 + 0.5 \times PL85 + 0.3 \times PL65 = 3.181 GCal / Mwh$$

2.3. Boiler Capacity

The contractor is expected to guarantee the maximum continuous rating of 650.0 t hr^{-1} for each boiler, burning natural gas, operating at rated conditions and at an ambient temperature of 52°C, a feed water inlet temperature of 140°C at economizer inlet and a waste gas temperature of 145°C at economizer outlet.

3. Guarantee Conditions

All tests should be carried out as close as possible to the guarantee conditions, set out in the following example in Table 1.

Item	Unit	Load points		
		MCR	**BMCR**	**PL115, PL85 PL65[2]**
Natural gas LHV	Kcal/Nm^{-3}	-	-	8026
Flue gas temperature at economizer outlet	°C	140	145	140
Ambient temperature	°C	-	-	40
Relative air humidity	%	-	-	80
Power factor Cos ϕ	-	0.85		0.85
Speed	rpm	3000		3000
Live steam temperature	°C	535	535	
Live steam pressure	bar	93	93	
Live steam flow	kg s^{-1}	156.187		[2]
Cooling water inlet temperature	°C	35		32
Distillate production	t h^{-1}	≥2184		≥1896
Top brine temperature	°C	≤112		≤100
Bottom brine temperature	°C	43.2		39
Extracted heat to desalination plant	Gcal h^{-1}	170		145

[1] Nm^3 at 0 °C and 1.023 bar
[2] PL115 = 148.923 kg s^{-1}; PL85 = 117.39 kg s^{-1}; PL65 = 99.692 kg s^{-1}.

Table 1. Typical guarantee conditions.

In case of deviations from the above figures correction formulas or correction curves are used. These correction curves are given in Appendix 7 and are only applicable for this example.

4. Measuring Equipment

For all measurements the contractor provides the necessary instrumentation and test equipment.

All the instruments are calibrated before the test by certified authorities immediately before the commencement of the performance tests. The calibration certificates are submitted to the customer prior to the tests.

4.1. Measurement of Temperature

The temperature is measured by calibrated resistance thermometers or thermocouples. The measuring signal is measured by a calibrated digital ohmmeter/voltmeter via switch-over-box or by an automatic data acquisition system.

4.2. Measurement of Pressure

Pressure is measured by calibrated transmitters or gauges. The transmitter signal is measured by a calibrated digital voltmeter via switch-over-box or by automatic data acquisition system.

4.3. Measurement of Flows

The main condensate flow and steam extraction to the vacuum system of the desalination plant is measured according to DIN 19205 and orifices according to DIN/ISO 5167.

The feed water flow to the boiler is determined using two independent methods. The first method is the direct measurement with the operational installed orifice according DIN/ISO 5167. The second method is the heat and mass balance around the HP heaters and the feedwater tank according DIN 1943.

A sample calculation for the above-mentioned flow (indirect method according to Din 1943) is given in Appendix 4.

4.4. Measurement of the Boiler Fuel Flow

The boiler fuel flow is calculated out of the boiler heat balance using the indirect method for boiler efficiency. The boiler efficiency is determined according to DIN 1942.

4.5. Sampling of Fuels

During the test period samples are taken from the natural gas on three occasions. At each sample time three samples is taken. One sample is used for an immediate analysis by a local laboratory. This laboratory should be agreed by all parties. The second sample is for owner/engineer use. The third sample should remain at a secure place at site for analysis by an independent laboratory.

The first sample is used for the calculation of the preliminary test results. If all parties agree on the results from this sample, this fuel analysis is used also for the final test report.

4.6. Measurement of Electrical Power

The power output of the generators is measured at the generator terminals, with the stationary installed voltage and current transformers. A calibrated three-phase power analyzer is used to measure the electrical power output.

5. Isolation of the Cycle

The accuracy of the tests depends on the isolation of the water and steam system. Extraneous flows should be eliminated from the system to prevent measurement errors and discrepancies.

6. Frequency of Readings and Duration of the Test

Each test will run for a period of two hours. According to DIN 1942 a minimum of 20-30 readings must be taken for each test.

Where an automatic data acquisition system is in use, all the cycles must be 60 seconds.

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Bibliography and Suggestions for further study

Al-Bagdadi A (1998) *Performance and Acceptance Test*, Water and Electricity Authority Report No. 1.