Commissioning and Start-up of QAFCO 5 and 6

The Process Plants of Qatar Fertilizer Company (QAFCO) are located at 2 sites in Mesaieed Industrial City. The new site for QAFCO 5 and 6 is located at about 3 km west of the old site of QAFCO 1 to 4 Plants.

Q5 and Q6 Projects were the biggest expansion activity ever undertaken by QAFCO, increasing the ammonia and urea capacities by 1.6 and 2.8 million Metric Tons (MT) per year, respectively. The Engineering, Procurement, Construction and Commissioning (EPCC) contract for this project was signed with a consortium comprising of Saipem of Italy and Hyundai of South Korea in 2 stages. The Q5 contract was signed on the 2nd of December 2007. Q6 Contract was signed as an amendment to Q5 Contract on 9th of October 2009.

This paper describes QAFCO's experience in the commissioning and start-up of the process facilities, the problems encountered and key lessons learnt during the commissioning.

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Introduction

QAFCO has 2 production sites 3 km apart. The sites are separated by other industrial infrastructure and access roads. QAFCO 5/6 project, on a Greenfield area of about 1 million m^2, consists of the following process facilities:

1. Two Ammonia plants (TopsoeTechnology) with design capacity of 2200 metric ton per day (MTPD).
2. Two Urea plants (Snamprogetti Technology) with design capacity of 3800 MTPD.
3. Two Urea Granulation units (Uhde Fertilizer Technology) with design capacity of 3850 mtpd
4. One UFC-85 plant (Perstorp Technology) with design capacity 85 mtpd
5. Two Urea Bulk Storage Halls with capacities of 100,000 and 175,000 MT, both with reclaimers and Pipe Conveyor System.
6. Two independent Urea Export systems, with a capacity of 1000 MTPH to the export jetties. both using Pipe Conveyors
7. Power Plants consisting of 5 Co-generation units with auxiliary firing for additional steam production, Steam Turbine Generator and 2 Auxiliary Boilers
8. 132 KV sub-station connected to Kahramaa (local power company), to 5 new co-generation units and to the existing Qafco distribution network.
9. Desalination unit of 225 m^3/h capacity.
10. Waste Water Treatment facilities consisting of Thermal Concentrators and Evaporation Ponds.
11. Seawater multi-cell Cooling Tower, Closed Cooling Water Units and

Electro-chlorination System for Hypochlorite Production
12. Interconnecting Piperack (ICPR) carrying the Sea Water, Ammonia lines, desalinated water and Nitrogen.
13. New substation to distribute power to the old Qafco site
14. Two ammonia storage tanks with steel pressure inner tank and reinforced full height independent concrete outer protection wall of 50,000 MT each and with 1000 MTPH loading system for export.
15. New Jetty extension for Large Vessels.
16. A CO_2 inter-connection line to export excess CO_2 from old site to Q5/6 site.

For synergy and integration purposes 2 of the Co-generation units and the items 13, 14,15, and 16 listed above are located in the old Qafco site.

The Q5 and Q6 projects were the biggest expansion activity ever undertaken by QAFCO. Together Q5 and Q6 projects consumed more than 120 million man-hours to complete the construction and commissioning. At the peak of construction activities there were 15000 people from more than 60 different nationalities working on site.

Company Commissioning Philosophy

QAFCO has developed a complete commissioning manual that sets the objectives of the commissioning activities in its major Projects. The basis of the commissioning manual is the vast experience QAFCO made from recent commissioning of major facilities:

- QAFCO-3 Expansion Projects - commissioned in 1997
- QAFCO-4 Expansion Project - commissioned in 2004
- Melamine and Urea 1 Revamp Projects - commissioned in 2008/2009.

QAFCO 3 and QAFCO 4 Expansion Projects were 2 complete production trains, each consisting of an Ammonia plant, a Urea plant, power generation facilities, Ammonia storage tanks, and complete utility facilities.
Qafco commissioning manual describes the requirements and responsibilities for planning, control, organization, execution, administration and documentation of the commissioning activities. The commissioning manual has been updated for Q5 and 6 Projects with the lessons learned from recent projects and was included in the contract. It was part of the company documents that contractors shall strictly comply with. Some of the key resources involved in the earlier projects were also transferred to the new Q5 and 6 Project to ensure maximum use of the relevant in-house experience.

The company commissioning planning had 3 critical elements.

1. **Utilization of Company Resources for all commissioning activities.**

The EPCC contract strategy put the responsibilities for commissioning execution on the contractor(s), with a requirement to use the company human resources for all the commissioning activities. This strategy served QAFCO well in the recent major EPC projects like QAFCO 3 and 4. The company personnel get the necessary training and get engaged in the actual work of commissioning, while the responsibility lies with the contractor. The strategy also helps contractors to limit its commissioning manpower to few key resources supported by equipment vendors and process licensors. This commissioning strategy requires the contractor and company commissioning organizations to be close and work together as one team. The two commissioning teams were each headed by a commissioning manager who reported to their respective project management. The company commissioning resources, operators and technicians, were functionally reporting to the contractor commissioning manager and administratively to company commissioning manager. Figure 1 describes the Commissioning Organization adopted for the Project.

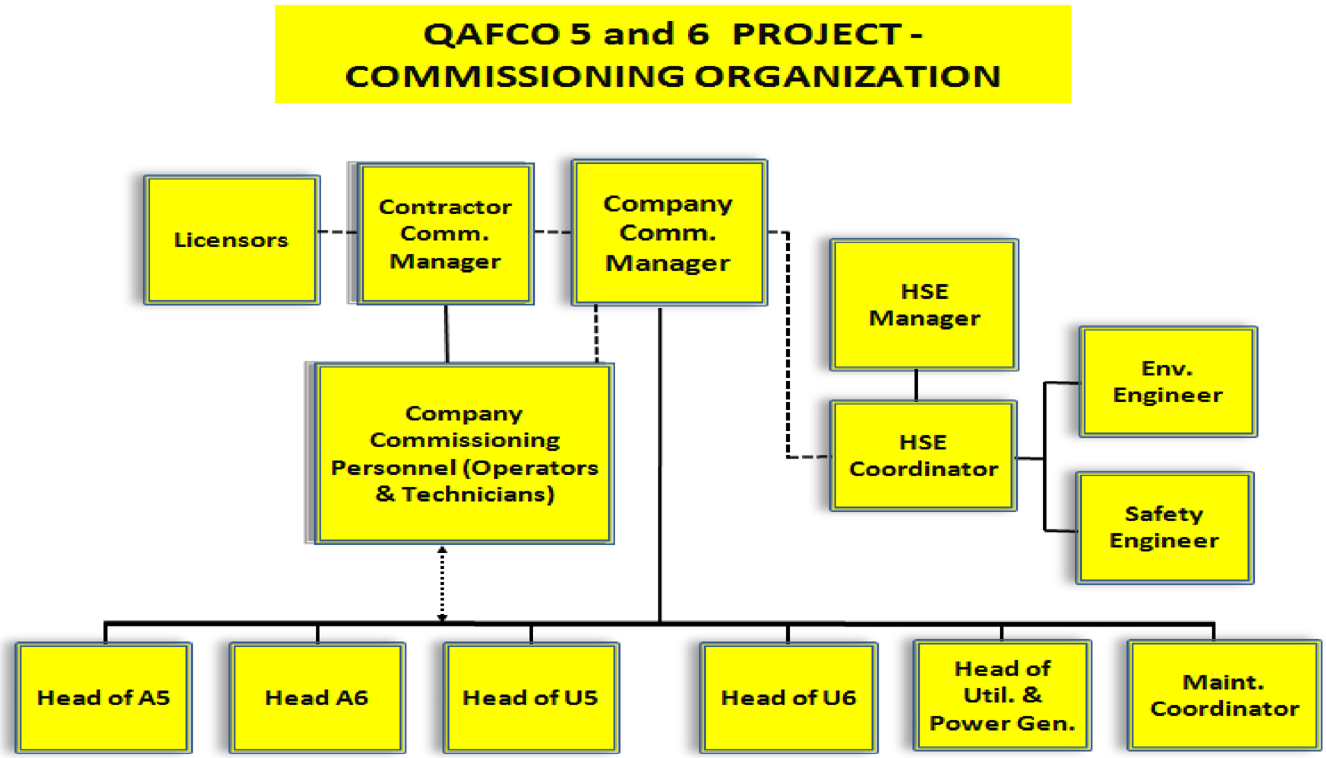

Figure 1 - Simplified Commissioning Organization

2. Engaging Company Commissioning Resources during Construction Phase

The **second critical** consideration was the selection and deployment of the plant operators and technicians well before commissioning activities. The objective was to give these company resources the full grasp of the project by having them experience the construction and commissioning phases. This prolonged exposure has given the operating staff insight into the equipment design and valuable training opportunity.

As a rule of thumb, QAFCO has been deploying the operation staff to the major project about 12 months before the start of the commissioning. The logic is to give the operation staff enough time to complete all the training requirements and participate in important construction activities.

3. Selection of Commissioning Teams

The 3rd **critical element** is the selection of the commissioning teams. The formation of the commissioning team started with the selection of the commissioning manager and other key operation personnel that had relevant experiences. Part of the team was tasked to participate in the detailed engineering activities at the contractor's headquarters. The rest of the team was tasked to build the new organizations, and source 50 % of the operators and technicians from the existing QAFCO plants. Based on company experience with similar projects, a decision was earlier made to transfer 50% of the operators and technicians from existing QAFCO plants, and complement with the other 50% new recruits to get an ideal mix of experience and youth.

The entire batch of shift supervisors and operators was transferred to Q5 about 10 months before the start of the first commissioning activities in the utility plants.

After a brief introduction to the project followed by project safety training, the commissioning teams were divided into groups led by a supervisor. The teams were each assigned to a number of operation units (called systems), and were given the following 2 sets of responsibilities, with the objective to have them ready to take control of Operations:

1. Get On-the Job-Training

- To fully study the systems allocated to them.
- To assist in its mechanical completion (punch list walk downs, punch list clearing etc.)
- To prepare commissioning procedures for their systems.
- To conduct internal presentations and training material of the allotted system.
- To develop its operating instructions.
- To develop its field and control room log sheets.
- To participate in its functional checks, develop and correct its DCS graphics.
- To carry out all the commissioning activities related to that system.

2. Assist Construction Activities

The commissioning teams were deployed to the project during construction phase, as discussed above. The teams were engaged in a number of construction and pre-commissioning activities required for the mechanical completion milestone.

The commissioning teams were tasked to lead the punch list walk downs, punch list clearing, air blowing, hydro test follow up, reinstatements, cleaning of the tanks and vessels, water flushing, inerting and preservation of equipment, lube oil flushing and motor solo runs.

A multi discipline walk-downs were carried out for the punch listing of each commissioning package. The shift supervisor was appointed as the team leader responsible for the management of punch items. Once the punch items were recorded in the master punch list, it was his responsibility to follow the corrective actions and subsequent closure. Most of the time multiple verifications were required to complete and clear punch items.

Air blowing and water flushing activities were part of mechanical completion. After each activity a certificate was prepared and loaded into the project management system. Mechanical completion was declared only when all the certificates have been loaded into the system. The commissioning team was fully involved in these activities.

Lube oil flushing of the compressor common lube oil system, air blowing of the process piping and steam blowing, were some of the longest time-consuming activities. For some machines the oil flushing continued for more than three months. Continuous monitoring was required for this important activity.

Steam blowing was included as a commissioning activity where special attention was required. This activity required close coordination with other plants as well as good planning. The circuit to be blown was identified and marked. A temporary silencer was installed at the blow-off points wherever required. All the wooden scaffoldings or any other flammable material were removed from the vicinity of the selected circuit. Wherever possible, the insulation was completed. Area was barricaded at the steam release point.

Most of the steam blowing was done during the mid-day break or during the night when the number of workers at site was minimum. Few failures of the internals of silencers were experienced as shown in figure 2.

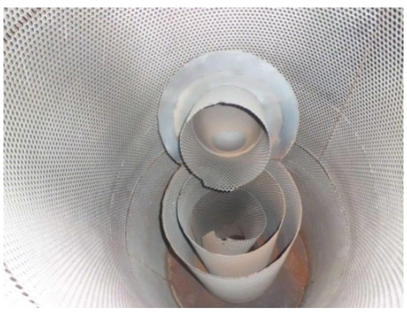

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Figure 2 - damaged steam silencer

Operator Training Programs

Training was an integral part of the preparation for commissioning activities. It was a requirement that all the training for the company operation and maintenance staff had to be completed before the start of the commissioning activities. Programs were a mix of specialized vendor and licensor training, process training and in-house training derived from the writing of the operating instructions for all plant systems. A series of discussion workshops were conducted when each operating instruction was completed.

Commissioning Sequence

All of the start-up utilities, except the initial desalinated water used for flushing activities and sea water cooling had to be produced at the new site. The commissioning needed careful logical sequence to meet the demands for other utility systems. The following sequential commissioning order was decided and the construction organization was directed to deliver the process areas based upon commissioning priority.

- DCS systems for utilities and cogeneration units
- Desalinated water storage and pumping
- Sea water launching pumps
- Instrument air system with temporary cooling tower
- Nitrogen system and fire water system for Cogen-2 area
- Water Demineralization systems
- Waste water system
- Natural gas system
- Auxiliary boilers with temporary cooling tower
- Steam system
- Desalination Plant
- Sea water cooling system
- Closed cooling water system

This sequential commissioning order shown in Figure 3 was followed.

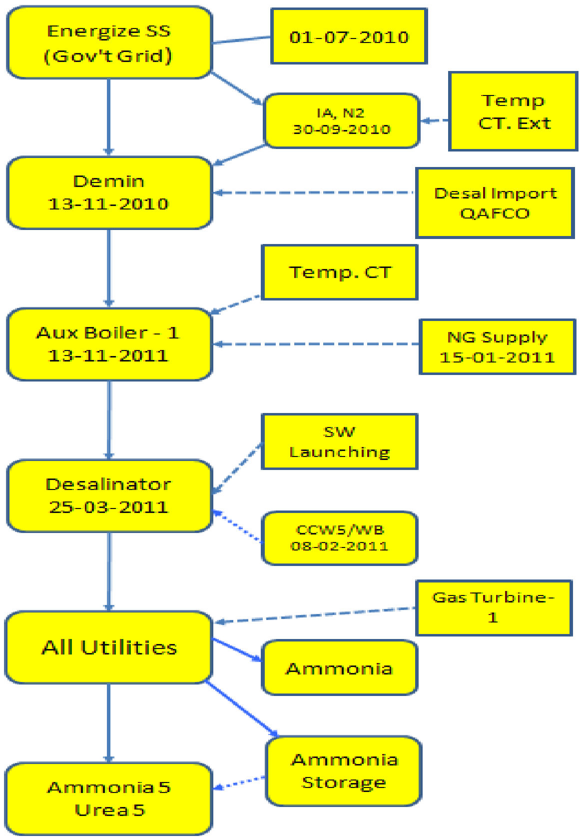

Figure 3 - Actual Commissioning Sequence

Commissioning Packages (CP)

The project commissioning organization has broken down plant systems into smaller packages called *"Commissioning Packages (CP)"*. A CP is defined as smallest practical scope of work unit for commissioning constituting a functional unit, which will be tested by commissioning to prove its suitability for operation.

The commissioning (dynamic verification) activities would normally follow the mechanical completion of systems, and the construction organization would then declare a system (package) complete and ask for Certificate from the commissioning organization.

The following Commissioning Packages (CP) have been established for the Project.

Systems	Q5 PROJECT	Q6 PROJECT	TOTAL
	No. of CPs	No. of CPs	No. of CPs
Total	956	444	1400
Operational systems	900	428	1328
Utilities	166	55	221
Ammonia-5	86	0	86
Ammonia-6	82	0	82
Power generation and distribution	225	75	300
Urea 5 (incl UFC)	87	2	89
Urea-6	0	116	116
Ammonia storage	19	0	19
Material handling	16	14	30
HVAC	25	15	40
Instrumentation	103	115	218
Electrical field	83	35	118
Buildings	8	1	9
Non operational systems	56	16	72
Instrumentation	5	0	5
Civil	51	16	67

Table 1 - Breakdown of Project CP's

The project had 1400 CP's of which 1328 were operational systems and 72 non-operational systems. The largest numbers of CP's were the power generation and distribution plants.

Commissioning Profiles

As part of project planning the CP's were assigned specific "commissioning start and finish" dates at the project planning stage. These dates were logically linked to the planned "Mechanical Completion and Hand-Over to Commissioning dates". The following commissioning profiles show the planned commissioning and the actual profiles achieved.

The deviations in the planned and achieved profiles are indicative of the extent of delays that part of the project has experienced during construction.

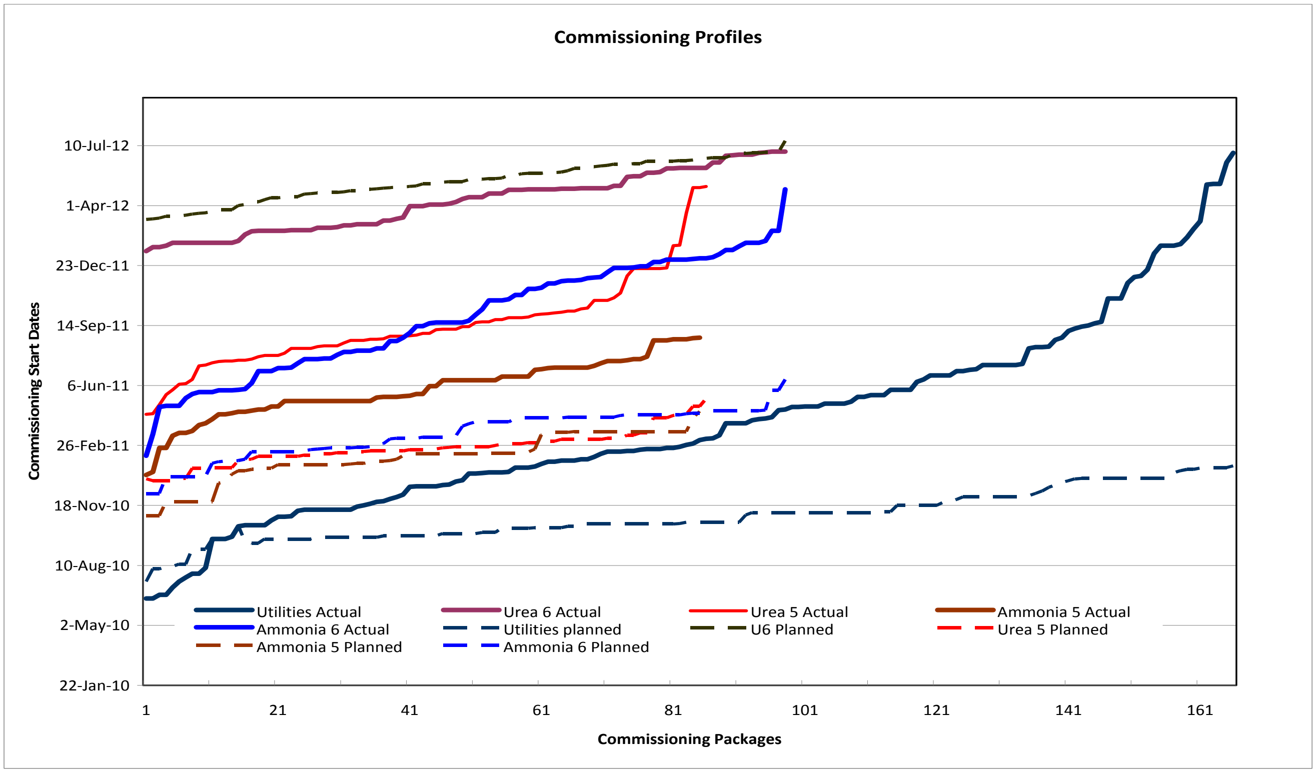

Figure 4 - Overall Commissioning Profiles

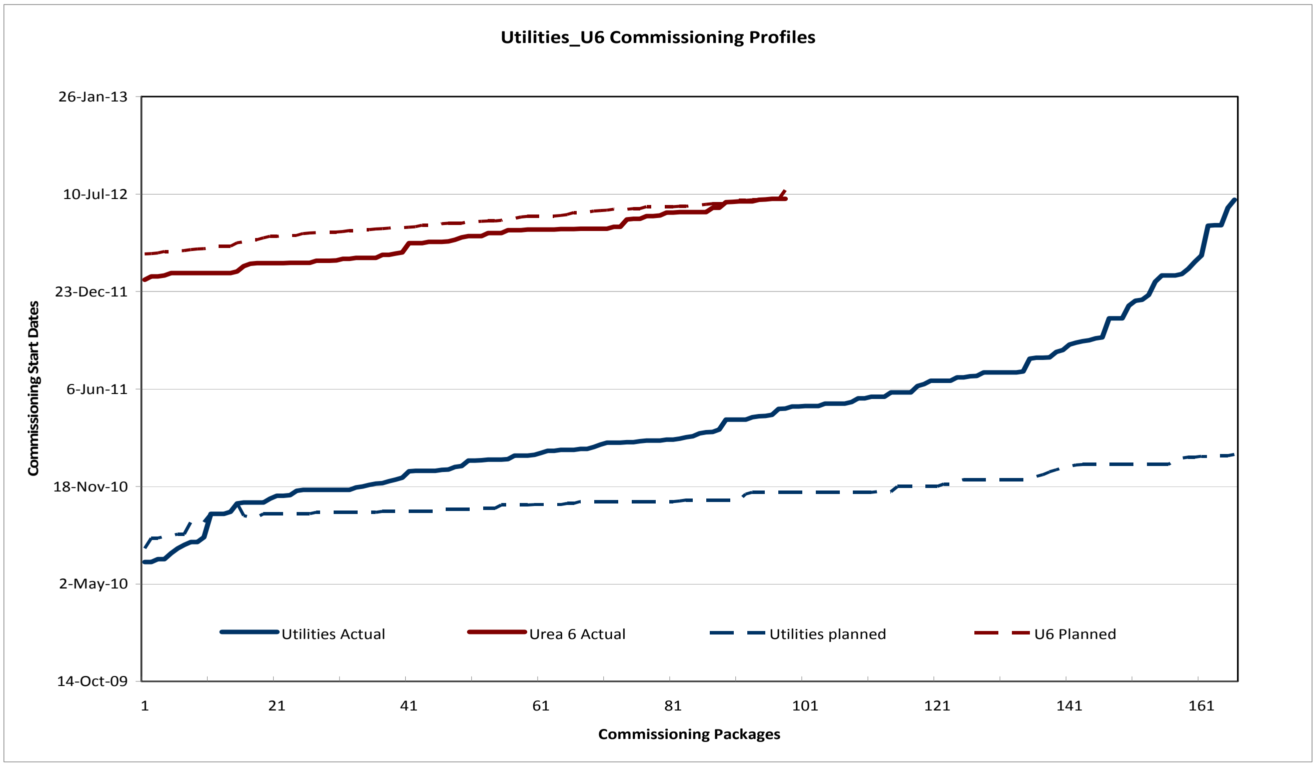

Figure 5 – Utility Systems and U6 Commissioning Profiles

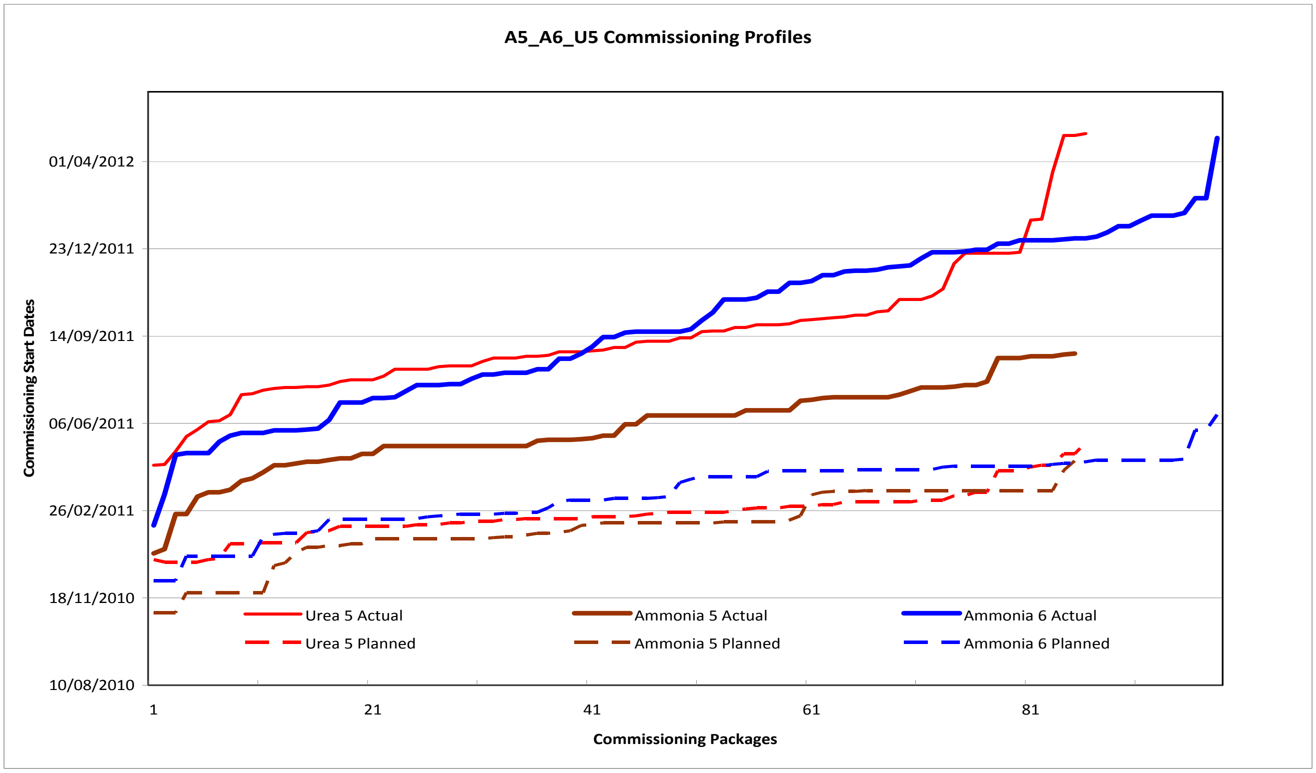

Figure 6 – A5, A6 and U5 Commissioning Profiles

Commissioning activities of all process facilities have progressed in parallel and uninterrupted as can be seen in the profiles. The organization was well focused and well trained to perform. Urea-6 plant commissioning was completed ahead of schedule as many of the lessons learned in Urea-5 commissioning have been considered. In all other areas (A5, A6, U5 and Utilities) there have been some delays in commissioning. Main reasons for the delays in commissioning were:

- A general delay in the Hand-Over from Construction due to factors like local summer weather conditions of high temperatures and high humidity which restricted working hours.
- Number of Engineering and Design changes executed locally.
- Rearrangement of the commissioning sequence and availability of Temporary Commissioning equipment.
- The failure of the Waste Heat Boiler of A5 early in the commissioning phase (Sept 2011) and the subsequent long repair time required had affected the overall commissioning progress of the A6 and U5 plants.

HSE Training Requirement

The training on HSE construction and commissioning requirements was mandatory for all the commissioning staff. A training passport was issued to each individual. In the passport all the training programs attended were marked and stamped in the passport. It was mandatory to carry the training passport on site. The HSE department carried out random checks on the passports. Any deficiencies found were referred back to the training center where all the training programs were scheduled six days in a week. Records were kept in a master list, and one could find the status at any time. 100% compliance with all HSE training programs was required.

Project Safety Performance

The project safety performance was excellent. Table 2 has the summary data for both Q5 and Q6 Projects.

HSE Performance Statistics	**Cumulative**		**Targets**	
	Q5	**Q6**	**Q5**	**Q6**
Man-hours Worked (Const+Commiss)	104,152,200	16,032,390		
Total Accidents	**2656**	**195**		
Fatalities @	0	0		
Lost Time Accidents	22	3		
First Aid Cases	2356	170		
Medical Treatment Cases	34	7	-	
Restricted Work Cases	91	7		
Fire Incidents	39	4		
Property Damages	87	3		
Environmental Releases	15	1		
Traffic Accidents	12	0	-	
Days Lost	1076	215		
Lost Time Accident Frequency Rate (LTFR) = Number of LTA x 1,000,000) / Total Worked Man-hours	0.211	0.189	0.4	0.4
Total Accident Frequency Rate (TAFR) = Number of Accidents x 1,000,000) / Total Worked Man-hours	25.5	12.1	35	35

Table 2 - HSE performance statistics for Q5 and Q6 Projects

The notable statistics extracted from the table are:

1. Q5 and Q6 projects, together consumed more than 120 million man-hours to complete the construction and commissioning. At the peak of construction activities there were 15000 people from more than 60 different nationalities working on site.
2. No work-related fatalities in the whole project. There were, however 4 cases of

sudden deaths experienced with worker population during the project. Investigations concluded that these sudden death cases were not work-related incidents.

3. A total of 25 Lost Time Accidents (LTA) with 1291 days lost have been recorded during construction and Commissioning.
4. Only 6 and 2 LTA's have been recorded respectively for Q5 and Q6 during the Commissioning period.
5. Target Performance of Lost Time Accident Frequency rates (LFTR) and Accident Severity Rates (ASR) have been achieved.
6. 20 Million (20,005,170) and 5.2 Million Man hours (5,220,130) without LTA has been accumulated respectively for Q5 and Q6 Project.

Challenges Faced

There were many challenges the project has faced. In this chapter we will cover some of the main ones that had direct consequences on the commissioning and start-up activities.

Size of Project was a challenge

Execution of a project of this size – 2 Ammonia Plants, 2 Urea plants, UFC 85 Plant, 200 MW Power Generation and distribution systems, integrated steam and utility network, Storage and Export facilities - on a Greenfield site is a big challenge as described in the introduction chapter.

Interconnecting Pipe Rack (ICPR)

The 2 QAFCO sites are more than 3 km apart. They are connected by the ICPR on which the vital communications links, flow of products from Q5/6 site and utility inter-change between the sites are supported and managed. The new site fully depends on the availability of the ICPR, which runs over third party land with underground pipe corridors, high tension cables and industrial service roads.

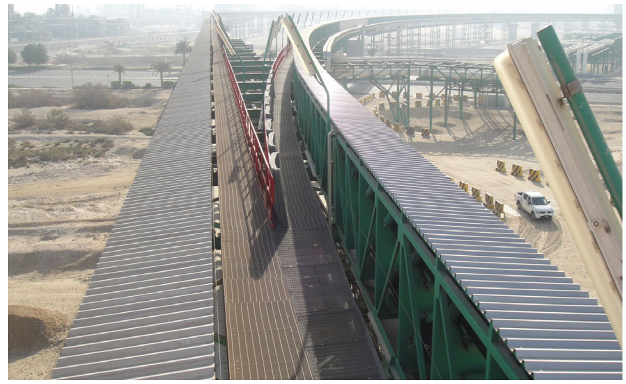

Figure 7 – Interconnecting Pipe Rack (ICPR) between the QAFCO Sites

A New Greenfield Site

Q5/6 site was a Greenfield area, which means that all needed commissioning utilities had to be internally generated at site. To meet the desalinated water requirement was especially challenging. The initial requirement of desalinated water was met by importing from QAFCO site via the interconnecting piping between the two sites. An initial requirement of 50000 m^3 was imported at a rate of maximum $60m^3/hr$ for flushing activities and starting of the first demineralization plant. It was evident from the beginning that for the sustained operation of the first auxiliary boiler, it was necessary to produce desalinated water internally at site.

Temporary cooling tower sourced from the local market had been erected for the initial cooling water supply for the initial start-up of instrument air compressor and auxiliary boiler, as the permanent cooling water system was not available due to construction delays. The temporary tower was about 5 tons and 6mx2.4mx2.89m in size.

The commissioning sequence had to be reviewed to reflect these commissioning needs.

Challenging Installations

The location of the new facilities at QAFCO has generated a number of unique engineering solutions that posed a challenge during the commissioning phase of the project. Two of these Challenging installations are the Urea Product Pipe Conveyor Systems and the Sea Water Cooling Towers.

Pipe Conveyor Systems

Urea product from Urea 5 and 6 is stored in two bulk halls E and F with capacities of 100000 and 175000 MT respectively. Bulk urea export from QAFCO is being done via two Jetties. A network of enclosed trough conveyors allows urea 5 and 6 plants to send their product to either of the bulk halls E and F. Pipe conveyor system was selected as the obvious solution to move granular urea in a single go from the bulk halls E and F to the Jetties. This selection eliminated the need for multiple transfer points and conditioned galleries. Urea product is reclaimed from the bulk halls and transferred to the pipe conveyor which envelops the product, thus protecting it from dust and humidity. Two pipe conveyors are used to send urea products from Q5/6 to either Jetty 1 or 2. The conveyors snake through 2.8 km of twists and turns. They cross third party land, roads and pipelines on an Interconnecting Pipe Rack (ICPR) without the need for a gallery, transfer points or any other protection from the elements.

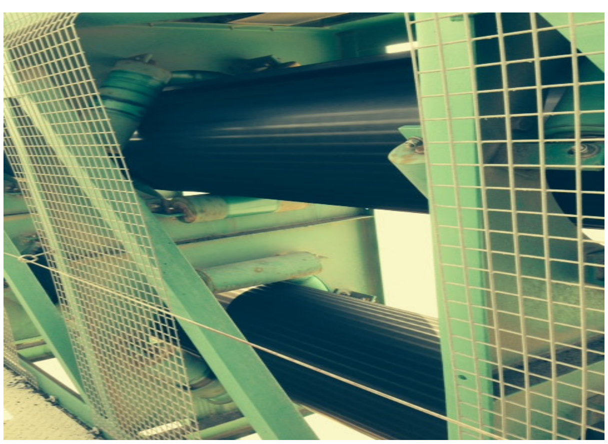

Figure 8 – Pipe Conveyors for Bulk Urea

Sea Water Cooling Towers

Situated at around 3 km away from the sea, the cooling needs of the new facilities at Q5/6 could not be supplied by a “once through” sea water supply system similar to the ones installed at the existing production trains. The lack of land for the sea water pumping station, environmental constraints and the impossible task of routing multiple large diameter supply and return sea water lines from the sea front to the new site under existing underground pipe corridors, high tension cables and other underground installations meant that another cooling solution had to be found.

The selected solution was a multi-cell cooling unit evaporating sea water to achieve the cooling needs of the new facilities. A set of 2 sea water launching pumps supply make-up of 10.000 m3/hr through two 36 inch supply lines to the cooling towers. The make-up lines and 2 blow-down lines from the cooling towers are routed on the ICPR under the urea pipe conveyors.

The sea water system at Q5/6 consists of two independent circulation loops, each one supplying one train and the common utilities.

The two sea water loops circulate around 120 000 m^3/hr of sea water and evaporate around 2000 m^3/hr depending on the weather conditions. The system is balanced by 8000 m^3/hr of blow-down and 10 000 m^3/hr of fresh sea water make-up.

Figure 9- Sea Water Cooling Towers

Weather Conditions during Summer Months

Local climatic conditions are a major challenge during the hot summer season in Qatar. A number of measures were implemented on site in order to minimize the impact on commissioning and construction activities during the time when the Heat index (temperature/humidity combination) exceeded the allowable limits. These included measures for limiting outdoor activities to those that have direct impact on schedule, enforcing frequent rest periods, providing shaded and cooled areas near to the areas of activity and making sure people are kept hydrated throughout the day with ample supply of cool potable water.

Failure of Waste Heat Boilers (WHB) of Ammonia Plants

On the evening of September 8th 2011 A5 plant was running with normal process conditions at approximately 100% load. At around 20:30hrs, during his routine plant survey, one of the field operators observed a small fire at the E0309 (HP-steam super heater) channel flange. He immediately informed the shift supervisor and the DCS operator via the radio and the fire was put-off shortly after by operational staff using dry chemical powder extinguisher.

The leak could not be attended online and after stopping the plant it was discovered that the Waste Heat Boiler was leaking. Internal inspection revealed failure of inlet tube tube-sheet joints, damaged refractory and broken ferrules.. The unit was repaired and plant was restarted and operated at reduced capacity. Two subsequent failures and repairs were experienced with A5 WHB.

After the 1st failure of A5 WHB, A6 unit was inspected and some tubes have been plugged as a result.

These frequent failures had negatively impacted the start-up of the other Ammonia and the Urea plants. A5 WHB was replaced in February of 2014. A6 WHB was also replaced in April 2014.

Corrosion in a Medium Pressure Decomposer (MPD) of Urea Plant

Right from the initial start-up, excessive corrosion rates were experienced in the Medium Pressure decomposer (MPD) of both Urea plants. The corrosion products from the MPD were changing the urea product color. The corrosion rate accelerated when the plant load was increased and the temperatures of the condensate at the inlet of medium pressure decomposer increased.

After the onset of the corrosion process (loss of passivation layers) affecting the material chosen for the MPD unit, process adjustments and temporary measures could not stop the corrosion.

Both MPD's have been replaced, in Nov 2013 and Feb 2014 respectively for U6 and U5. Tubes of the new units are made from urea grade stainless steel material 25:22:2 Cr/Ni/Mo.

Lessons Learned

1. Deploying Company Commissioning Resources early during Construction phase offers the best training opportunities and reduces construction mistakes.
2. Shift from construction to commissioning site - the whole Construction site

was brought under commissioning responsibility at about 70% overall progress. From that point the operation staff was engaged and the Commissioning Work Permit Rules applied. This shift had positive safety implications as the incident rate significantly dropped.

3. Aligning construction and commissioning priorities. It is important that Construction is flexible enough to respond to the Commissioning requirements through
4. Contracts to include commissioning reviews sessions during engineering to identify how the facilities will be commissioned and the modifications needed to allow quicker and more systematic commissioning of the facility.
5. Temporary Equipment – Proper planning of temporary commissioning equipment like boilers, cooling towers was critical during early commissioning phase, to avoid operating process units outside operating limits.
6. Commissioning Spares - insufficient commissioning spares can lead to delays.
7. Preservations – Lack of proper preservation of some equipment resulted in leaking of many ball valves, control valves and blockage of caged valves.
8. Lack of drain points in the steam system resulted in longer heating time for some machineries.
9. Collect Trip and Interlock logics and diagrams in one area/document. – There was confusion as logic blocks are described in separate vendor documents,, and may not be reflected in the main plant shut down logics.
10. OTS - Operator Training Simulator – OTS was not delivered at the right time for operator training during the commissioning phase. An OTS to be effective training tool should be delivered and set up early, preferably during construction phase.

References

1. Project Contract Commissioning Manual Appendix E 35 - Q5-PT-M000.01003
2. Project HSE Manual for Commissioning.
3. Sudden Death Cases on the Project Site– Contractor Report L-SH-PT-05592 dated March 2010.
4. A5, A6, U5, U6 and Utilities Commissioning Reports.
5. Commissioning Records
6. Project Management Documents.

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