Surface Finishing Facility Commissioning: Bridging Facility Design and Construction with Facility Operations and Maintenance

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Good facility design and construction is a formalized process. Surface finishing processes are complex and are usually developed by others. In addition these processes must often comply with multiple standards and surface finishing processes are interdependent and must function as a system. This adds complexity to the design and construction. Commissioning normally begins at the completion of construction and can include: testing of the individual components, processes and systems, acceptance testing, training, and short term operations support. Planning for a commissioning phase in the project provides an opportunity to validate and optimize processes and equipment, chemistries, process control methods, operation and maintenance procedures, and implement changes if necessary. This paper will detail the facility commissioning work completed at Helwan AFB, Egypt. In addition it will identify opportunities to streamline the design and start up process minimizing the time until production begins.

1.0 Introduction

The primary goal of commissioning is to transition new systems from a construction mode to an operations mode. If the completed systems are capable of meeting process requirements the commissioning process will be relatively short; if optimization, augmentation, expansion, or replacement is required the process can become quite complex. This paper will detail the facility commissioning work completed at Helwan AFB, Egypt. In addition it will identify opportunities to improve the design, construction and commissioning process.

2.0 Background

Good facility design and construction is a formalized process with well defined steps beginning with:

- Process Definition and Documentation
- Production Planning
- Site Selection/Validation
- Process Design
- Equipment Sizing
- Facility Layout
- Process Layout
- Civil, Structural, Mechanical & Electrical Design
- Specifications, Design Basis, Bid Solicitation
- Bid Review and Contractor(s) Selection
- Subcontractor Selection
- Change Management
- Construction
- Start Up
- Acceptance
- Commissioning
- Operations and Maintenance

Design and Construction is also an iterative process with well defined phases including:

- Conceptual Design
- Preliminary Design
- Pre-Final Design
- Final Design
- Construction
- Commissioning

As both the design and construction phases progress, and/or the level of complexity and detail increases, opportunities for cost effective change decreases. Effective planning during conceptual design should anticipate facility evolution and facilitate implementation of future required process changes or expansion. Effective commissioning also requires planning and a new trend is to include the commissioning team or contractor in the design. The commissioning contractor's responsibility during design is to focus on operability and maintainability of the constructed facility just as a construction contractor will focus on constructability.

It is easy to lose sight of project objectives during a complex design and construction project where schedule and budget constraints as well as the bias of various parties influence the delivery of the final facility. The following is a list of some of the common factors which drive changes during the design and construction phases:

- Budget
- Schedule
- Process/Production Changes
- Project Team/Personal Changes
- Regulatory Requirements
- Management/Engineering/Operator Review/Bias
- Site Changes/Facility Constraints (Ceiling Height, Available Floor Space, Site Geometry, Etc.)
- Material/Equipment Availability

The design process is iterative, and formal and informal design reviews are necessary to include all stakeholders in the design process. Usually a number of compromises are made to accommodate budget and other constraints. Common compromises impacting the design of the constructed facility include:

- Materials of Construction: Tanks, Piping, Pumps, Heat Exchangers, etc
- Floor Space: Process Layout, Set Up Area, Fixture Storage, Maintenance Aisles, Etc.
- Process Control
- Automation
- Unit Operations
- Equipment Sizing: Tanks, Rectifiers, Filters, Heating/Cooling, Etc.
- Equipment Quality & Maintainability: Rectifiers, Pumps, etc.
- Provisions for Implementation of Future Processes
- Fixturing Required for Operations

3.0 Commissioning

Commissioning follows facility construction and equipment installation and may include start up and acceptance/performance testing. The primary goal of commissioning is to transition new systems from a construction mode to an operations mode. If the completed systems are capable of meeting process requirements the commissioning process will be relatively short; if optimization, augmentation, expansion, or replacement is required the process can become quite complex.

During commissioning the design decisions are validated and if necessary corrected. Surface finishing facilities are very complex and contain numerous interdependent systems. Surface finishing processes are also complex with multiple process steps. The processes are generally based on customer specifications and/or vendor recommendations. Process lines are usually intended to handle a wide variety of substrate materials and possibly conflicting customer requirements. The process commissioning phase provides an opportunity to validate and/or tune processes before entering full production mode at the risk of producing defective products.

Commissioning is itself a very complex activity and a myriad of activities must be completed before any production can be run in the facility. Commissioning must be as organized and as detailed as the design phase to efficiently and effectively demonstrate the facility operation. The commissioning team must test and verify all the major facility systems to ensure these systems provide their designed function. Each process tank is a system of varying complexity and must also be tested. The process tanks are prepared for service, solutions charged and process control procedures verified. Preventative maintenance procedures and schedules must be established and implemented. Process control procedures and schedules must be implemented. Process procedures must be documented and tested for compliance with customer specifications. Finally the commissioning process must successfully transition operations and maintenance responsibilities to the facility staff. Table 1.0 describes the steps that are normally required in commissioning of surface finishing facilities:

Table 1.0 Surface Finishing Facility Commissioning Planning:

Commissioning Phases	**Description**
Preliminary planning	Begins with Project Conception
Team Selection	Best begins with design team selection; select a commissioning team to mage the process. Commissioning team ideally works with owner and design team.

Commissioning Plan Development	Begins with design; plans, checklists, procedures, database planning and design; provide input on construction contract terms/conditions (extended warranty, service agreements, etc). In addition to commissioning plans, there are often other plans and activities that the commissioning team develops as part of the commissioning services, these add value as these plans apply to commissioning and operations. These are listed in Appendix A.
Start Up [Includes Wet Testing]	Start up includes the pre-functional mechanical and electrical testing of equipment and systems.
Corrective Action	Repair/Replacement including coatings inspection and repair. This is the first scheduled period for corrective action based on start up activities.
Preliminary Acceptance Testing	Acceptance testing is performed to validate design performance criteria, and normally, final contractor/vendor payments are tied to successful validation of performance criteria. This acceptance testing step may be iterative until system meets requirements.
System Commissioning and Calibration	This includes utilities such as steam, compressed air, low pressure air, ventilation/makeup air balance, water/wastewater, agitation, etc. It is important to find significant operability/maintainability flaws with mechanical and electrical systems like heating/cooling, agitation and filtration systems during water testing if possible. This will facilitate repair or replacement of components before they are contaminated with hazardous chemicals. Interdependent systems must be commissioned in the proper sequence.
Corrective Action	Second corrective action activity to schedule. Includes remedial repair and replacement resulting from system commissioning.
Tank/Pipe Leaching/ Passivation	Schedule in a sequence to easily transfer amongst like process tanks.
Solution Makeup	Based on client specifications for processes.
Laboratory Commissioning	Verify/validate test methods and equipment.
Process Commissioning	Testing is performed to validate capabilities to produce coatings/treatments which comply with specified customer and/or company standards. Establish control parameters; develop procedures; complete databases for automated systems.
Operator Training	Build equipment/system training into specifications, commissioning team to ensure training requirements are fulfilled.
Final Acceptance Testing	Must be completed before warranties expire.
Optimization	Optimize facility processes for chemical usage, water/wastewater, energy, ventilation, process operations, and maintenance.
Operations and Maintenance Support	Provide support terms of operations training, continued optimization, maintenance, troubleshooting. See Appendix B for a list of other operations support functions.

4.0 Lessons Learned During Commissioning

Integrated Technologies, Inc. was selected as the commissioning contractor after the design was complete and the construction was nearly completed. The following "lessons learned" are based upon 30 months of first hand experience, research and internal brainstorming. Some of these are summarized below.

1.1 Plan for commissioning early in the project. Plan to include commissioning team members in design, beginning early in design can reduce cost of ownership. At Helwan AB, the commissioning team came in near the completion of construction and changes resulting from commissioning took longer and costed more than if commissioning began sooner. Planning early can reduce commissioning time, schedule; also resulting in cost savings.

1.2 Include commissioning schedule and budget in project plans. Schedule and budget coming into commissioning at this later stage were extended by coming in at this later stage. Commissioning schedules and budgets can be reduced by incorporating commissioning activities and design/construction for operability sooner in the project process. Commissioning at Helwan AB in Egypt is only still ongoing because of operational issues by not involving operational expertise early in the project. As an example, process critical rectifiers were purchased and installed without ripple filters. These rectifiers cannot meet the construction specifications as installed, cannot meet Air Force Technical Orders and were therefore found to not be suitable. The commissioning team worked with the OEM to develop a plan for installing ripple filters, and now is working the order through the OEM. These filters must be fabricated and installed prior to commissioning certain critical process such as hard chrome plating.

1.3 Select the proper Commissioning Team. The ideal commissioning team provides a blend of design experience, construction experience and operations and troubleshooting experience in all facility systems and processes.

1.4 Ensure that transition has been properly defined and planned. This allows the owner to understand the commissioning sequence and know when production can begin. At Helwan AB, commissioning has been completed by area and process in a logical sequence. The process support laboratory was commissioned first, followed by the Industrial Waste Treatment Plant (IWTP), the DI Water System, the Air Pollution Control system, surface finishing support processes such as abrasive blast, degreasing, baking, etc.; finally followed by the surface finishing processes. As individual surface finishing processes are completed, these processes go into operation. Operation is defined as "ready-to-go" with short notice. These processes are controlled and weekly makeup is conducted as required. These processes are considered operational after initial compliance loads pass test requirements.

1.5 Consider acceptance timing and impact on warranty. Project schedule, including project phases and tasks must be well defined prior to beginning work to effectively communicate the sequence of work, startup of facility operations, acceptance/ performance testing schedule and handover. Warranty period should commence upon completion of acceptance testing requirements and facility handover. This must be defined during design and included in the contract documents and specifications. Normal vendor quotes includes commencement of warranty at time of shipment or some number of days after shipment, the latest commencing at completion of installation. Politics entered into the project at this stage and the Egyptian Air Force was forced by their headquarters to accept the facility from the constructor before completion lists and punch lists were complete, thereby starting the clock on facility warranty periods. Not all areas in the facility were ready for startup or commissioning and a portion of the warranty period was not used.

1.6 Pre-functional testing and warranty replacement. Pre-functional testing includes a review of equipment design and installation to ensure that equipment installed conforms to specifications and meets process requirements. If equipment is found to not meet requirements, or is improperly or incompletely installed, corrective action is required by the construction contractor team (general contractor, specialties, OEM). Pre-functional testing should follow completion of construction as soon as practically possible in order to rectify any construction or equipment discrepancies. Pre-functional testing can be less complex and time-consuming than other commissioning activities and therefore is a critical path task to minimize schedule impact from corrective actions.

1.7 Document design errors and omissions and negotiate settlements. Included in the pre-functional testing and review is a review of design functionality. Where applicable, a review of OEM equipment for conformance to design intent and specifications is included as a pre-functional check. Additionally, a design review task could be considered important if the commissioning team is brought into the project at a later stage to review both design and construction. This task would include a review of materials of construction, layout and equipment placement, and construction details.

1.8 Geography/Environment should drive design. Helwan AB is located in a desert area south of Cairo, Egypt. The location is very dry, and although the source of water is the Nile River, there were water shortages during the first year of startup. A combination of the desert area, air quality in the greater Cairo area, and the number of cement manufacturers and steel mills in the Helwan area with literally hundreds of stacks surrounding Helwan AB contribute to significantly high particulate matter concentrations. Makeup air filters are in constant need of replacement, with replacement costs in hundreds of thousands of dollars per year. During development of a design basis, these critical environmental factors should have been considered.

1.9 Developing a good production basis is critical to good design. A well defined production basis is critical to good design and it is also important to define the

boundary limits of the process and facility infrastructure during commissioning. It is important to understand facility and process constraints early.

1.10 A well documented and accepted basis-of-design and specifications are important to minimize conflict during performance testing and acceptance. The specification package and design drawings define the scope of work for construction, equipment fabrication and installation. Clearly written specifications including a well documented design basis helps to resolve ambiguity and alleviates errors in equipment and processes which assists the construction team order and install the correct equipment and the commissioning team confirm equipment meets specifications and performs as intended. Equipment or process performance is easy to track and confirm with a well documented basis of design and specification package.

1.11 Never neglect provisions for spare parts. Spare parts are critical during commissioning and later operations. Lack of spare parts impacts schedule for startup and commissioning and can delay operations. Lack of proper OEM recommended spare parts can be magnified in more remote locations, particularly during startup of facilities in overseas locations with local manufacturers or manufactures representation. A typical waiting time (and therefore equipment downtime) of one day to one week can become one month in a location such as Egypt. Owners, engineers, commissioning teams need to have provisions for spare parts included in equipment specifications and ensure that spare parts are delivered with equipment being installed.

1.12 Plan for corrective action in commissioning schedule and budget. Corrective action by contractor, OEM, specialty contractors or the commissioning team needs to be planned in commissioning schedules. Corrective actions need to be scheduled as part of the pre-functional, functional and performance tests as necessary. Some improvements that were not included in design or construction contract documents may need to be purchase and installed or existing installations may require modification from original design. Contingency budgets and schedule for such modifications and improvements must be included in the plan.

1.13 Develop a clear transition plan. The fundamental goal of commissioning is to prepare the facility for operation by the owner, however this transition between the commissioning contractor and the owner can be difficult if the transition is not planned. Handovers from contractor to owner can occur at the completion of various project phases or the transition can be planned as a single event. Partial handover and shared use of the facility requires coordination between the contractor and the contractor to assure efficient and safe operation of the facility. It is also important to recognize that there is a fine line between commissioning and operations and commissioning budgets can be compromised when the contractor becomes entangled in unintended operations support. A schedule with clearly defined dates, handover or completion criteria, and an owner-accepted plan for process operations start is necessary.

1.14 Define roles and responsibilities of the stakeholders. The stakeholders at Helwan

AFB included multiple contractors, funding agencies and the owner. When changes were required, often multiple parties are involved including the Egyptian Air Force, USAF FMS Program Office, US Army Corps of Engineers, the architectural/ engineering company, the private constructor, and Air Force Materiel Command. With this number of parties involved problem resolution and other changes become complex. Often agreements on changes need to be amongst all the parties, and schedules.

5.0 Summary

Effectively planning for commissioning is an integral component of a successful construction or renovation project. An effective commissioning team and plan contributes to a better design and a better as-built facility. The commissioning team must also be able to design and implement necessary changes to the facility.

Plan Early Successful commissioning is the result of good planning early in the project, ideally during the project definition stage. The commissioning team can work with the owner and design team to define project requirements. The commissioning team can verify that a sound basis of design is developed that meets the project requirements. This can avoid change orders, delays, and ineffective operation. Starting the commissioning activities early can also allow the commissioning team to review contractor's completion checklists, contractor startup and testing. It is during this time the commissioning team can develop detailed functional testing procedures and be ready to complete these tests before substantial completion.

Plan for Corrective Action. Just as planning early can reduce commissioning schedule and get a facility operable, productive and profitable sooner, some time and plan for corrective actions will be necessary. No matter how well planned, corrective actions will be necessary, particularly with complex systems. Owners and commissioning teams will find equipment that needs to go through shakedown, parts that require replacements; possible system reworks to accommodate new standards, processes or product lines. Allow for corrective actions in schedules. Ensure that tools, skills and parts are available to complete corrective actions as soon as possible.

Plan the transitions. Ensure that handovers are well defined. Ensure that criteria to accept a facility or a process is well defined and that all criteria for acceptance is complete. Important transitions occur between the construction and the startup/commissioning, and the commissioning and operations. Be sure all documentation of a successful transition exists and is held be the stakeholders. This can include, but is not limited to completed check lists, completed punch lists, performance test results and operations plans.

Appendix A: Commissioning Plans Required for Surface Finishing Facilities

Environmental, Health and Safety
Chemical Storage
Waste Management
Laboratory
Environmental Systems: Water, IWTP, Ventilation/Scrubbers
Utilities: Boilers, Chillers, Air
Information Technology
Spill Prevention and Control
Pollution Prevention
Material Control: Startup, Consumables
Spare Parts
Calibration
Operations and Maintenance
Best Management Practices
Process
Quality Management

Appendix B: Operations Planning and Support

Transition Planning
Process Development
Test Method Development
Work Control Documents
Fixture Design/Build

