Installation of API 610 Centrifugal Pumps to achieve a Flawless Start up for a Large Project

Presentation by:

Rob Vaughan &
Bill Robertson

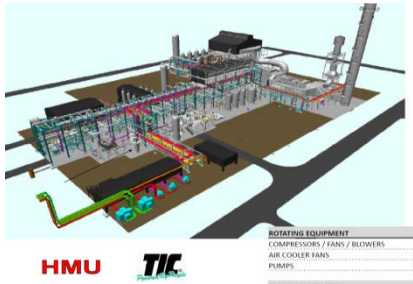
Scotford Upgrader Expansion 1 (SUEX-1)

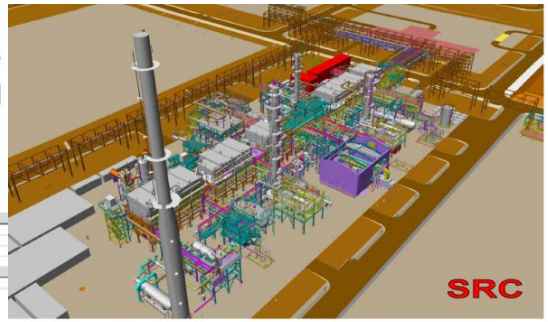
- Shell's Oil Sands Scotford Upgrader Expansion 1 Project installed 251 API 610 centrifugal pumps. The plant was successfully started up in the spring of 2011. Shell has developed a worldwide quality program aimed at delivering a Flawless Start-up. This presentation focuses on the installation of these API 610 centrifugal pumps. Topics from each phase of the project will be discussed from initial design, specification, inspection, installation, preservation, and commissioning & start-up.

Scotford Upgrader Expansion 1 (SUEX-1)

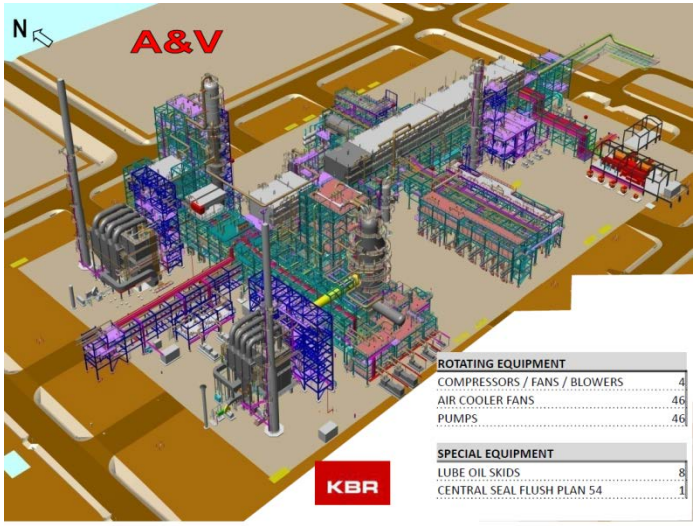
Introduction to Project &

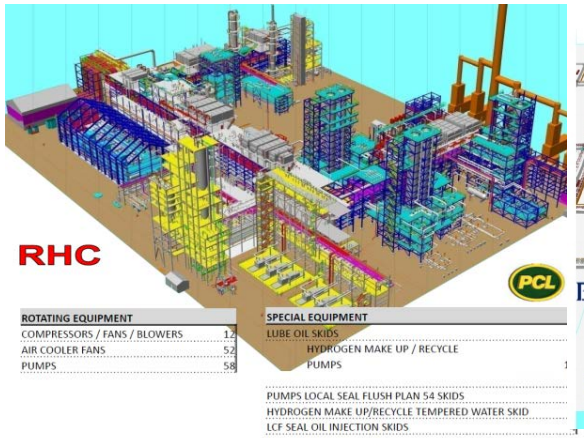
Pump Scope

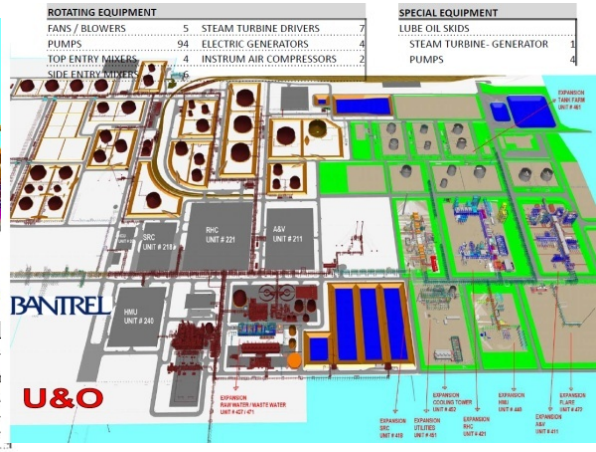




- 21 orders for 251 pumps from 1 vendor
- Ranging from 10-3000KW all API610 design
- 8 manufacturing sites worldwide
- $100M total for purchase order
- 4 Area Works Construction Contractors
- 5 process units for a 100 BBPD Heavy Oil Upgrading Facility
- Engineering and procurement done from 5 locations worldwide with 17 EPC Design Engineers working on rotating equipment with oversight from 3 Shell rotating equipment personnel
- Prime construction contractor was a joint Shell and Bechtel owners team.







Presentation Outline: What Will Be Covered

Rotating Equipment Path to Start-up

- Design

1. Review Lessons Learned from previous Shell projects and incorporate into Purchasing Documentation & Technical Specifications
2. Specification selection leading to clarification rounds with vendors to ensure alignment on expectations
3. Key Learning's from Design Phase

- Procurement

4. Identify ITP and Quality Surveillance Strategy
   - 3rd Party Inspection vs. Client Inspection
5. Key Learning's from Procurement Phase

- Construction

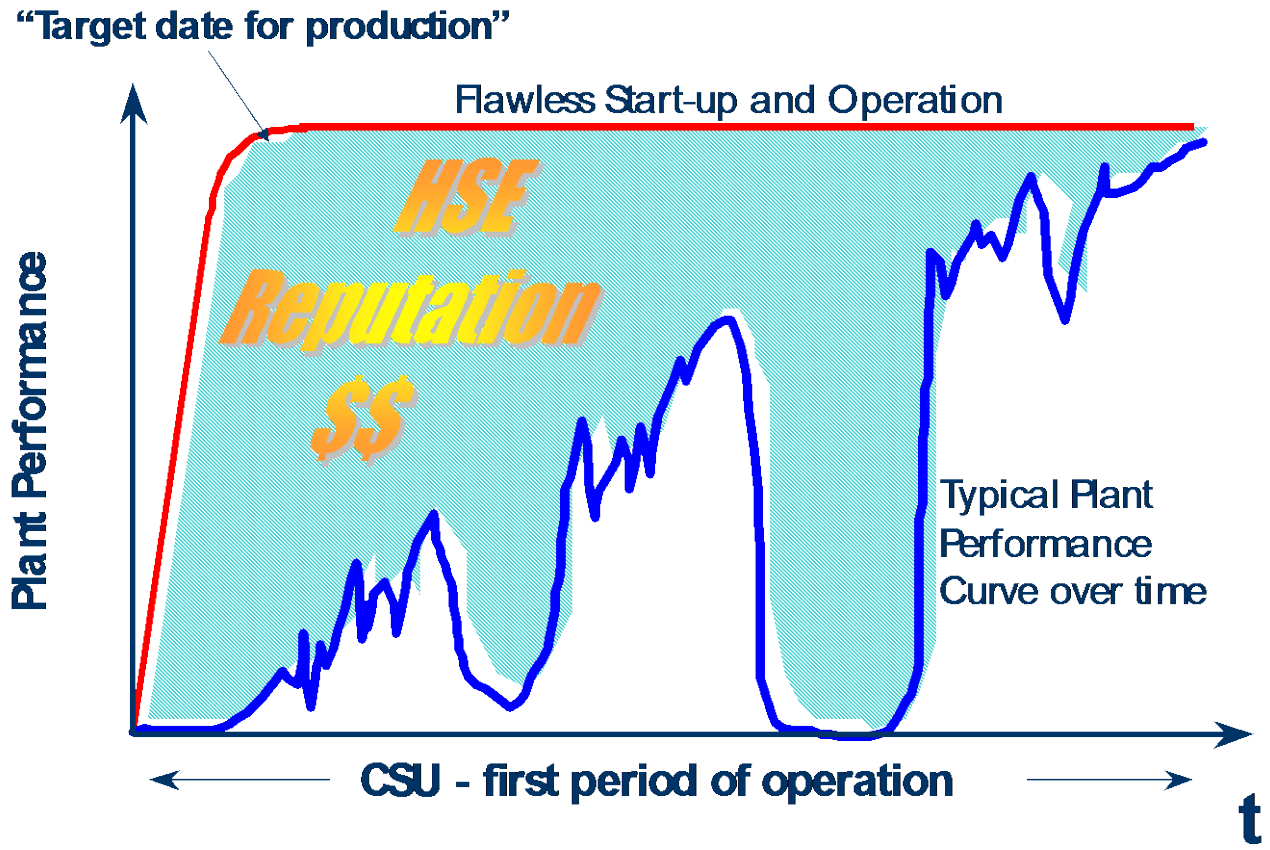
6. Rotating Equipment Construction Organization
7. Engineering Receipt Inspection Program & Non Conformance Record Generation
8. API 686 Installation & Shell's Minimum Requirements for Rotating Equipment
9. Inspection and Test Plan
10. Construction Installation Issues
11. Key Learning's from Construction Phase

- Start-up

12. Mechanical Completion
13. Pre-Start-up Issues
14. Start-up Issues and Outcome

Shell's Quality Program Flawless Project Delivery

- Shell has a formal World Wide Quality Program aimed at delivering a Flawless Start-up



Design: LL and Specification Selection

Shell's Quality Program Flawless Project Delivery

•Lessons learned (LL) and Practices Worth Repeating (PWR) were reviewed and carried forward from previous projects. It is important to capture both positive and negative experiences from a variety of sources (previous project mgmt, maintenance, operations, industry colleagues, etc)

•Our LL list went through many review cycles producing quality input being placed in the contractual language of the purchase order. (Sources of contractual language include ITP's, audit plan, technical specifications, technical notes, drawings, etc)

•Specification selection leading to clarification rounds with vendor is a process that can not be rushed and needs to take multiple rounds. All relevant LL and PWR were reviewed with vendor

Machinery Learnings From AOSD – Upgrader and Scotmods
Compiled by Rob Vaughan
Updated: Aug 20, 2009

	Learning/Comment	Source	Proposed Action for AOSPE	DISPOSITION	Status
1	Centrifugal Pumps DEP 31.29.02.30-SCAN				
1.1 1.1.1 1.1.2 1.1.3 1.1.4 1.1.5 1.1.6 1.1.7 1.1.8 1.1.9	P-22201A/B, P22301 Multiple failures 1. Erosion 2. Inner case bending 3. Warm-up issues 4. Thrust bearing failure 5. Fire on insulation 6. Inadequate insulation 7. Warm-up from bottom a all hot pumps 8. Circulation warm-up line c/w pump will save 10 m3/hr of HGO 9. Cut all new on warmup line – use long radius in particulate service	RCA team RHC-SCTU03-00103/040065/04/0134	Incorporate RCA recommendations into Centrifugal Pump DEP 31.29.02.30-SCAN where possible. Consider using 410 S/S and 3x50% pumps during FED 3 design. 1. Erosion – Consider using a diffuser pump with a stiff shaft in this service. Eliminate impeller wear rings. DEP 31.29.02.30-SCAN, Section 3 has these requirements. 2. Inner case bending – Don't use 316 S/S on a multistage pump above 300 deg C. DEP 31.29.02.30-SCAN Appendix 1 table 1-1 3. Warm-up issues – Consider automated warm-up system for this service. FED 3 design. 4. Thrust bearing failure – FED 3 design 5. Fire on insulation – FED 3 design 6. Inadequate insulation – FED 3 design 7. Warm-up from bottom casing drains – DEP 31.38.01.11para 4.2.2.5 8. See 3 above. 9. FED 3 design		DEP complete FED 3 design not complete. Added 3x50% pumps on PFD 1. Complete 2. Complete 3. 4. 5. 6. 7. Complete
1.2	P-22201A/B, P22301 Seal failures – seal axial growth inadequate	Jarrett	Ensure hot pump axial growth during warm-up is conveyed to seal vendor. Add this requirement to the mechanical seal DEP.		
1.3	RHC charge pump spillback lines too small – need more flow P21106 and many other examples of inadequate min flow at startup and normal running	High Priority list	Review during FED 3 on a per pump basis. This is not necessary on all pumps.		
1.4	RHC P22201B spillback line rupture	High Priority list	Added a paragraph stating that all spillback lines in black oil service needs to be min schedule. DEP 31.38.01.11 para 4.2.2.1.7		Complete
1.5	P-2240IC seal fire	High Priority list	Fire on mechanical seal due to a design issue with the seal flush system – when the stand pump was being flushed there was less of a seal flush flow add to seal DEP requirement for flow alarm on seal flush		
1.6	Top-Top pumps increase maintenance time, increase platforms, increase safety hazards, and increase warm-up issues	High Priority list	DEP 31.29.20 para 5.4.2.1 states that top top is required for pumps above 200C thermal growth issues. Leave DEP as is.		Complete

Design: LL and Specification Selection

Lessons Learned Example:

LCF Charge Pump

- Experienced Erosion issues led to diminished performance and poor life of thrust bearing
- Leaks occurred at the head gasket due to differential expansion in the casing during the warm up of the pump, especially in the winter time
- This was reviewed with the vendor and led to design a centrifugal, between bearing, 9 stage, radially split, double casing BB5 pump including a:
  - Oversized balance drum with solid tungsten carbide bushing
  - Carbon steel barrel with Stainless Steel Overlay
  - Addition of 4 temperature indicators, top / bottom, inboard and out board of the casing to help operator to warm up pump evenly
  - External balance line with Ultra sonic flow meters
  - Tungsten Carbide direct laser deposit on impellers and sleeves
- String Test of Prototype LCF Charge Pump revealed issues with rotor dynamics with balance drum and vibration issues with skid and motors

Design: LL and Specification Selection

Key Learning's from Design Phase

- To do a proper and complete Lessons Learned Review takes a lot of time! **{PLAN AHEAD}**
- Incorporating these learning's into the contractual language of the Purchasing Documents is Critical to being able to get what you need.

- Specification clarification / review meetings with vendor can not be rushed and need to be documented to ensure alignment on expectations.
- Our Project experienced too many late changes to purchasing documents resulting in escalating costs and projected schedule delays due to confusion of specifications requiring more clarifications.
- There were too many drawing inconsistencies with fabricated equipment. Issues found after fabrication had begun, due to coinciding events of concurrent fabrication and engineering.
- Developed an effective process with vendors and EPC to keep track of all new relevant issues to track them to closures. Rolling Action Item List (RAIL) worked well.

Identify ITP Requirements & Quality Surveillance Strategy

- Having detailed clear Inspection and Test Plans is very important as this provides a leading indicator of the quality of the equipment you will be receiving

- Debate between 3rd party contract inspectors being used for inspections vs. client personnel (maintenance, operations, project resources) for inspections

- SUEX-1 used a combination of 3rd Party contract inspectors and dedicated client personnel inspection. We had dedicated client personnel providing full time inspection at vendor shops during fabrication of critical equipment orders

- Schedule many multidisciplinary visits to package equipment vendors to ensure that all disciplines get adequate representation during inspection

Key Learning's from Procurement

- 3rd Party Inspection was an expensive program that produced ultimately poor results with regards to pre-inspected equipment being sent to site with obvious poor quality.

- Need to have better alignment on expectations and alignment with 3rd party contract inspector to ensure goals are clear. *Remind them they are to report all findings and they work for the Client not the Fabricator.*

- Do not let Procurement / Expediting drive the quality out of vendor shop. If necessary keep equipment at vendor's shop as long as possible to provide time to correct known deficiencies. Transferring scope or known rework to site is not a good idea as it will push out your schedule and drive up your costs.
- Use more client personnel for critical equipment inspection, { Example BB5 Charge Pumps} especially for prior to shipment inspection. Best results are to have the receipt inspection done at the vendor shop prior to shipping of equipment.

- For Packaged Equipment use multi-disciplinary client inspection teams. Our results indicated that rotating equipment vendors are being asked to package and their competence or experience is not high within the other disciplines, etc (tubing, piping, heat trace, wiring, CSA, CRN & ABSA issues…etc)

Construction Program Outline

- Construction Organization Alignment
- Engineering Receiving Inspection Program {Top Findings, upon receipt of equipment}
- Installation Procedures {API 686 Installation & Shell's Minimum Requirements for Rotating Equipment Installation}
- Field Construction Inspection Test Plans

- Construction Issues
  - —Cleanliness & Preservation {Pre and Post Installation}
  - —Levelling & Soft Foot
  - —Grouting
  - —Field Machining
  - —Piping Installation

- Alignment
- Construction Key Learning's

Construction Organization

- Daily meetings with Operations, Vendor Field Representative, Shell Millwrights & Project Engineering staff for inspection assignments and overall alignment
- Formal weekly meetings with Area Works Construction Contractor. These meetings have Rolling Action Item Lists and allow the AWC to have clear communication lines to the project for immediate issue resolution
- AWC has direct access and works continually with Shell Inspection on a daily basis
- Rotating Equipment Installation Workshops once a month, site meetings to review installation procedure at various stages of project. Key aspects of upcoming jobs

Benefits of this Construction Organization

Resulted in Success

- Clear open lines of communication between field and engineering

across all companies e.g. (Construction Contractor, Projects & Operations)

- Timely issue resolution
- Management aware of team progress and sometimes included into meetings

Engineering Inspection Receipt Program & NCR Generation

- EIR Program consisted of all Equipment to receive inspection upon arrival to site by Shell Operations and Maintenance Staff.
- For the Rotating Equipment the team consisted of 8 millwrights, 2 contract inspectors, and 3 engineers dedicated to program
- All equipment received inspection according to premade checklists & all deficiencies were photographed and recoded for NCR records ***(used API 686 Ch 3 as guide for checklist development)***

- For 251 pumps a total of 1062 ERRORS FOUND CAUSING 313 NCR'S TO BE WRITTEN!

- Typical Deficiencies Discovered during EIR Inspections

Engineering Receipt Inspection Check lists

25183-110-GQR-M02-00003, Rev. 1
Inspection Test Record (ITR) – Engineering Inspection Request (EIR)

INSPECTION TEST RECORD (ITR)
ENGINEERING INSPECTION REQUEST (EIR)

PROJECT NAME		PROJECT NUMBER	
EIR NUMBER		P.O. NUMBER	
REQUEST DATE		MATERIAL RECEIPT DATE	
INSPECTION DATE		MRR NUMBER	

DESCRIPTION OF MATERIAL TO BE INSPECTED

ENGINEERING DISPOSITION
(CHECK AS APPLICABLE)

ACCEPT AS IS	☐	NO (IF "NO" COMPLETE THE FOLLOWING UOS&D CONDITION AND DISPOSITION)
	☐	YES
UOS&D CONDITION		
UOS&D DISPOSITION		
SPECIAL STORAGE REQUIRED	☐	NO
	☐	YES (IF "YES" COMPLETE REQUIREMENTS SECTION)

REQUIREMENTS

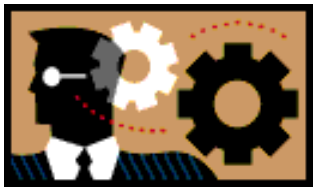
SIGNATURES

RESPONSIBLE FIELD ENGINEER	PRINT		DATE	
	SIGN			
WAREHOUSE SUPERVISOR	PRINT		DATE	
	SIGN			

ENGINEERING INSPECTION REQUEST CHECKLIST
ROTATING EQUIPMENT

	Item	Yes	NA
1	Preplanning: Review weights, configuration and method of shipment before arrival at job site. Determine type of equipment to unload the shipment.		
2	Preplanning: Offsite (shop) inspections completed and documented.		
3	Visual Inspection for physical damage or contamination.		
4	Verify Shipping protection intact.		
5	One (1) print copy of Installation Manual received with shipment and forwarded to designated person.		
6	Verify Loose components/packages matches packing list.		
7	Verify Special tools matches packing list.		
8	Special handling instructions carried out per Manufacturer rigging drawings.		
9	Equipment and components visually inspected to comply with Purchase Order.		
10	Equipment and components properly are tagged and matches Process and Auxiliary P&ID's.		
11	Equipment and components dimensionally inspected to comply with General Arrangement Drawing		
12	Verify Equipment and components Nameplate information matches associated Data Sheets.		
13	Verify Vessels and pressure relief valves on skid are stamped with CRN Number.		
14	Verify proof of CRN registration for pressure fittings in Manufacturers Record Book (MRB).		
15	Verify Pipe flanges stamped as ASME B16.5		
16	Verify Flange faces undamaged and properly coated.		
17	All bare steel surfaces, shafts, couplings, valve stems coated with rust preventive compound.		
18	Plugs and caps are in place, desiccants unsaturated, and equipment lubricated as required. Note: Grease is not permitted on Equipment with Oil Mist lubrication.		
19	Verify required pressure still holds for inert gas blanketed equipment.		
20	Verify Tapped openings in stuffing boxes and gland plates are sealed / plugged. Verify Mechanical Seals shipping locking tabs are engaged.		
21	Grout surfaces coated and clean. Equipment paint condition verified.		
22	Electric Motors: Insulation resistance – to -ground test conducted and recorded; Nameplate with CSA Marking.		
23	Electric Motors & Accessories: Junction Box terminals clean, dry and no physical damage. Cover reinstalled and sealed.		
24	Control Panels/ Gauge boards / Instruments adequately secured, preserved and protected from damage.		
25	Verify Instruments are CSA certified.		
26	Verify proof of CRN registration for pressure instruments and thermo wells in Manufacturers Record Book (MRB).		
27	Damage report issued to shipper/vendor.		
28	Verify Placement & storage of equipment is acceptable.		

Typical EIR Program Deficiency Findings From Several Shell Projects

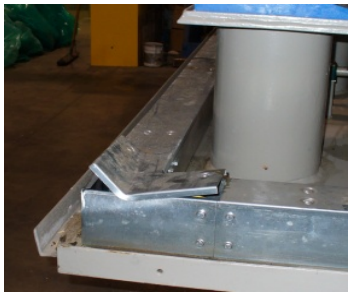


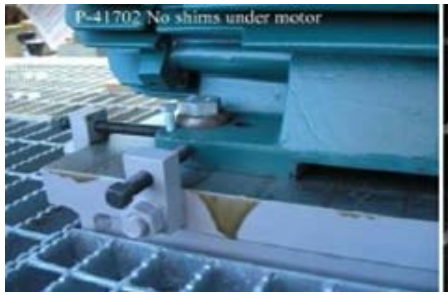
- **Why is an EIR Program Necessary:**
- To find missed items from factory inspection, it is critical to catch prior to installation
  {Last chance to verify, to get it right}
- For Documentation Reasons, you need accurate records (photographs of every issue works best)
- Capture the LL for the next project and pass along the findings to improve the quality of the equipment coming from our future vendors

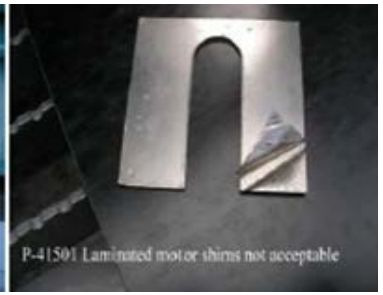
- **When to perform an EIR inspection:**
- ASAP... at PM warehouse
- Important to take equipment out of packing and inspect it; then start preservation program.
- Do not want the Construction Contractor to have to deal with late known problems that should have been found at either the pre-shipment inspection or during an EIR.
- EIR findings that require action are very expensive and distracting to a construction contractor's schedule.

Construction Issues

Typical EIR Program Deficiency Findings From Several Shell Projects





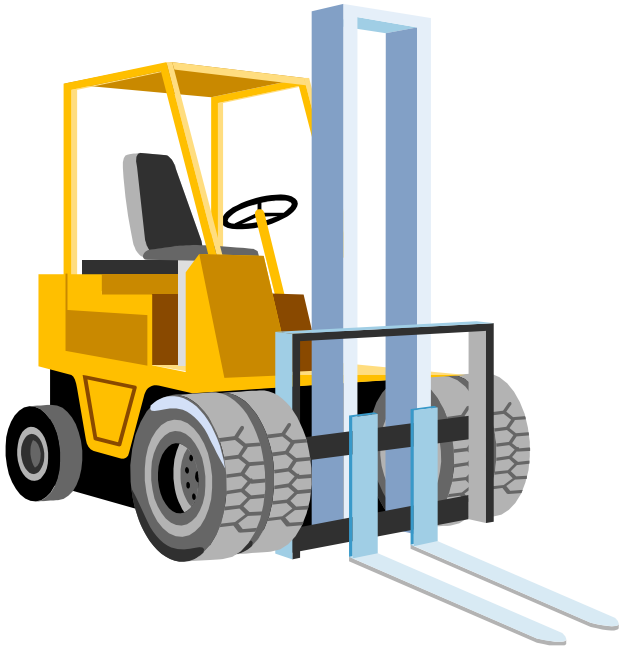


Typical issues:

- 1. Damage due to shipping
- 2. Verify ship loose items (misplaced, lost in transit, never shipped, etc...)
- 3. Shims not laser cut and/or are the wrong size
- 4. Motor does not have 8 jacking bolts
- 5. Suction/discharge/drain flanges are not covered with a metal closure
- 6. Water present in the case and drain lines
- 7. Oil mist lubricated bearings preserved with grease
- 8. Mounting pads do not meet the level requirements of API 610 and Purchase Order
- 9. Baseplate lacks levelling screws
- 10. Motor is bolt bound

Installation Procedures

- Installation Procedure {API 686 & Shell's Minimum Requirements for Rotating Equipment Installation}
- Need to be reviewed and signed off by Constructor, and Shell
- Important to obtain input from Operations & Project staff as well as, for AWC buy in



SCOTFORD UPGRADER EXPANSION 1 PROJECT

PROJECT CONSTRUCTION PROCEDURE
MINIMUM REQUIREMENTS FOR ROTATING EQUIPMENT INSTALLATION
25183-110-GPP-GCEM-00005, Rev. 0, 2008-09-10
Prepared by: Bill Robertson
Approved by: Cameron Gerdes

SCOTFORD UPGRADER EXPANSION 1 PROJECT

PROCEDURE NO: 25183-110-GPP-GCEM-00005, Rev. 0, 2008-09-10

PROJECT CONSTRUCTION PROCEDURE
MINIMUM REQUIREMENTS FOR ROTATING EQUIPMENT INSTALLATION

Discipline Team Lead Rotating	Mechanical Rotating Resident Engineer	Manager, Field Engineering	Shell Manager, Quality
Bill Robertson	Donny Issa	Cameron Gerdes	Mark Lecuyer

NO	DATE	REVISION	BY	CHKD	APPR
0	2008-09-10	ISSUED FOR USE	B. Robertson	D. Issa	C. Gerdes

	SHELL CANADA LIMITED SCOTFORD UPGRADER EXPANSION 1 PROJECT PROJECT CONTRUCTION PROCEDURE MINIMUM REQUIREMENTS FOR ROTATING EQUIPMENT INSTALLATION	25183-110-GPP-GCEM-00005	REV 0

Security Level 2
Electronic documents, once printed, are uncontrolled and may become outdated.
Refer to electronic documents in InfoWorks for current revisions.

Inspection and Test Plan

Key Points ITP's

- Important to provide list of key surveillance, review, witness and hold points to construction contractor for ITP development
- Need clear expectations on ITP steps as the ITP is contractual language

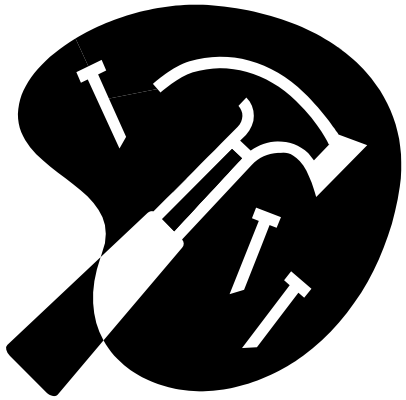
- For SUEX-1 the Major Hold and Witness Points for the Field Inspection and Test Plan for Centrifugal Horizontal Pumps were:

Hold

- Hold:
  - Submit Contractor Installation Work Packages (first of every kind)
  - Pre-grouting Meeting for alignment of path forward
  - Oil System Installation, verification and flushed
  - Final Alignment

Witness

- Witness:
  - Pre-installation Baseplate level check
  - Pre-installation Preliminary alignment
  - Pre-installation soft foot check
  - Soft foot check
  - Piping equipment / suction system cleanliness
  - Pipe stress and flange alignment



Inspection and Test Plan

Field Inspection and Test Plan of Centrifugal Horizontal Pumps

INSPECTION TEST PLAN	25183-110-GQR-MP1-00002, Rev. 0
DATE SUBMITTED	2008-04-23
WORK LOCATION AREA	COMMON
ITP DESCRIPTION	*Field Installation of Centrifugal Horizontal Pumps*

TASK #	TASK DESCRIPTION	TECHNICAL REQUIREMENTS (See Note 1 Below)	OFFSITE WORK	ONSITE WORK	VERIFYING DOCUMENTs: ITR's (See Note 2 Below)	CONTRACTOR	BECHTEL/SHELL	THIRD PARTY INSPECTOR
						I - INSPECTION S - SURVEILLANCE W - WITNESS H - HOLD R - REVIEW P - PROVIDE		
1	2	3	4	5	6	7	8	9
A	Verification Prior to Installation							
A.1	Material receiving		N	Y	25183-110-GQR-MB2-00001 Inspection Test Record (ITR) - Unsatisfactory Over, Short, and Damage Material Form (UOSADM)	W	S	
A.2	Verify name plate data is correct	Equipment Data Sheet	N	Y	25183-110-GQR-MP2-00002 Inspection Test Record (ITR) - Centrifugal Horizontal Pumps Installation Checklist (M16)	I	S	
A.3	Verify equipment preservation	Preservation Procedure (Vendor) 25183-110-GPP-GCE-00027 Construction Procedure (CP) - Preventative Maintenance* 25183-110-GPP-GCEM-00003 Construction Procedure (CP) - Rotating Equipment Storage and Preservation*	N	Y	Preventative Maintenance Card	I	S	
A.4	Submit installation procedure	Installation Manual (Vendor) API 686 Recommended Practices for Machinery Installation & Installation Design ESTD 11-3.01 Rotating Equipment - Installation, Checkout & Testing 25183-110-GPP-GCEM-00002 Construction Procedure (CP) - Minimum Requirements for Rotating Equipment Installation* 400.1416.000.055.001 Common Concrete - Standards General Notes	N	Y	Installation Procedure / Work Package (Contractor)	I	R/H	
A.5	Verify equipment subcomponents ASSA inspection requirements (where applicable) are completed	25183-110-GPP-GCE-00009 Construction Procedure (CP) - Certifying Pressure Equipment and Piping Systems in Alberta* 25183-110-GPP-GCEM-00001 Construction Procedure (CP) - Coordinating Inspections of Pressure Equipment with ASSA*	N	Y	ASSA Certificate of Inspector "A" Number	I	R	
A.6	Verify foundation release		N	Y	25183-160-GQR-DB2-00002 Inspection and Test Record (ITR) - Concrete Pour Card [C02]	H	S	
A.7	Verify anchor bolts projections	API 686 Chapter 4 Para 2.10.8 400.1416.000.055.001 Common Concrete - Standards General Notes	N	Y	25183-160-GQR-DB2-00002 Inspection and Test Record (ITR) - Concrete Pour Card [C02]	I	S	
A.8	Verify anchor bolt location	General Arrangement Drawing (Vendor) API 686 Chapter 5 Para 3.5.4 Foundation Drawing	N	Y	25183-160-GQR-DB2-00002 Inspection and Test Record (ITR) - Concrete Pour Card [C02]	I	S	

Construction Issues

Preservation & Cleanliness

{Pre and Post Installation}

SCOTFORD UPGRADER EXPANSION 1 PROJECT
PROJECT CONSTRUCTION PROCEDURE
STORAGE AND PREVENTATIVE MAINTENANCE
25183-110-GPP-GCEM-00002, Rev. 0, 2008-06-19
Prepared by: Tina Yeung
Approved by: Cameron Gerdes

SCOTFORD UPGRADER EXPANSION 1 PROJECT

PROCEDURE NO: 25183-110-GPP-GCEM-00002, Rev. 0, 2008-06-19

PROJECT CONSTRUCTION PROCEDURE
STORAGE AND PREVENTATIVE MAINTENANCE

Manager, Contracts Ned Burrows	Manager, Construction Tom Eggleston	Director, Construction Carl Lake	Manager, Resident Engineering Alan Jahns
Manager, Field Engineering Cameron Gerdes	Manager, Quality Assurance Richard Valdez	Shell Manager, Quality Mark Looijer	Shell Manager, Construction Fred Hodges
Manager, Procurement Hugh Deighton			

NO	DATE	REVISION	BY	CHKD	APPR
0	2008-06-19	ISSUED FOR USE	T. Yeung	D. Karpiak	C. Gerdes

	SHELL CANADA LIMITED SCOTFORD UPGRADER EXPANSION 1 PROJECT PROJECT CONTRUCTION PROCEDURE STORAGE AND PREVENTATIVE MAINTENANCE	25183-110-GPP-GCEM-00002	REV 0

Security Level 2
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Construction Issues

Preservation {Pre Installation}

- Important to have constant surveillance as conditions on a construction site change daily with work activities, weather, etc.
- Heated indoor storage and constant auditing are best preservation program ***(API 686 Ch 3 par 1.5.1-1.5.19)***
- Assign ownership of program early {our experience went through 2 preventative maintenance companies during project}
- Define on an equipment tag basis what equipment needs what type of PM; have PM Cards and an overall database; follow up with regular inspection.

Shell VSI 68
Mineral Oil

CHESTERTON

HEAVY DUTY RUST GUARD

Chevron

CHEVRON SRI GREASE
NLGI 2

DARINA* XL
PREMIUM MULPDSURPOSE GREASES
FOR TOUGH, LASTING PROTECTION

Construction Issues

Preservation

{Post Installation}

Issues

- Hoarding damaged / removed exposing equipment to weather
- Water in Lube Oil skids
- Short / modified dip sticks
- Gear boxes with no oil
- Uncovered flanges
- Tubing and insulation damage
- Incomplete PM cards
- Key to audit regularly and express importance to construction contractor

Shell VSI 68
Mineral Oil

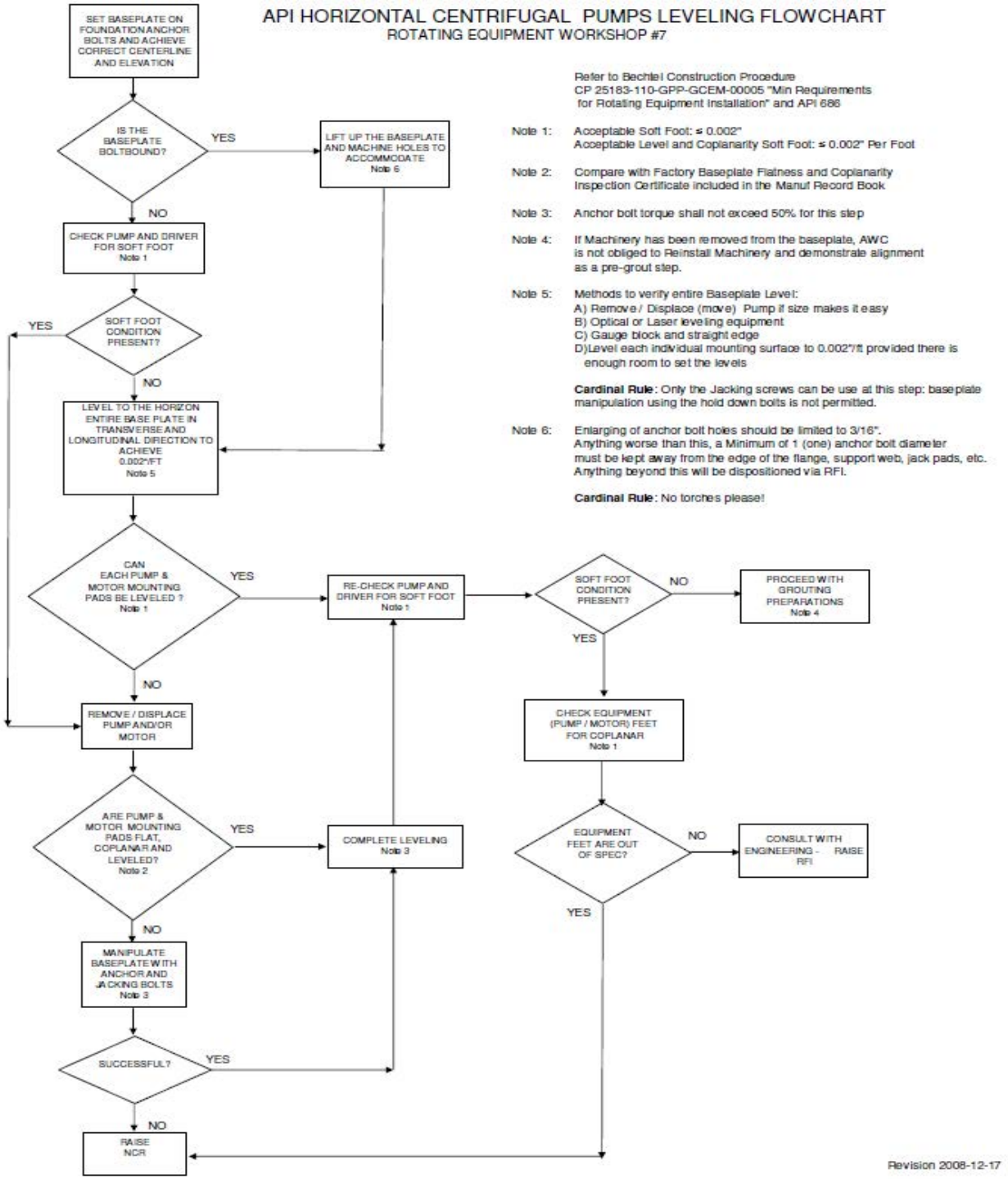
CHESTERTON
HEAVY DUTY RUST GUARD

Chevron
CHEVRON SRI GREASE
NLGI 2

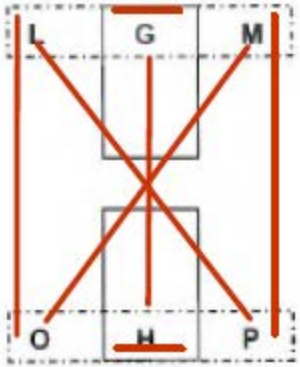
DARINA* XL
PREMIUM MULPDSURPOSE GREASES
FOR TOUGH, LASTING PROTECTION

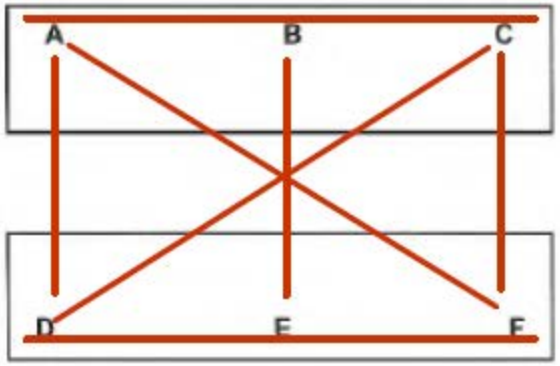
Leveling & Soft Foot

- Room for levels on pump pedestal so pump does not have to be removed to mount level
- Ensure motor is not bolt bound; this is critical for alignment
- API 686 tolerance of 0.002” per foot is a very tight ***(API 686 Ch 5 3.9.4.4 leveling & Ch 7, paragraph 5.4.4.1 soft foot)***
- Level can only be achieved after a constant temperature of the steel, concrete and air is normalized {anticipate 24-36 hrs of constant temperature}
- Test & calibrate levels regularly. Use multiple levels to ensure accuracy {these things get dropped, damaged and uncalibrated very easily}



Leveling & Soft Foot





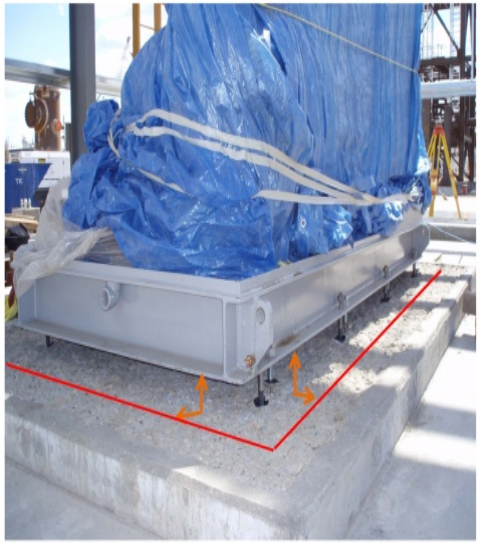
Follow Procedure

Test if pump or pedestal is not level

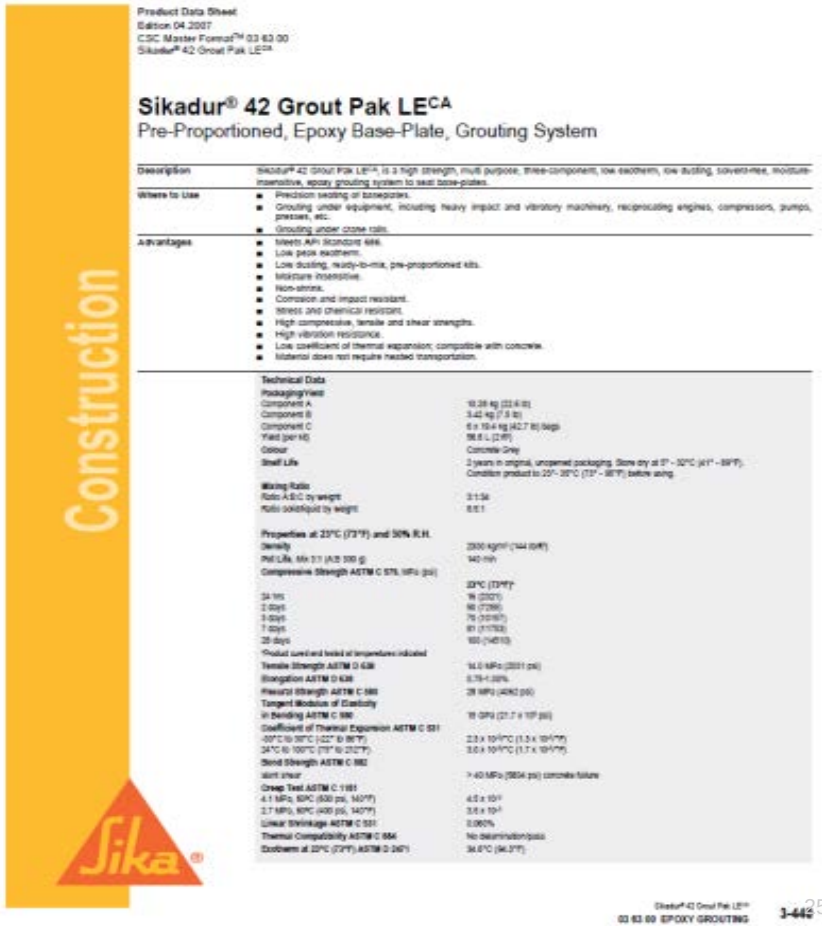
(API 686 Ch 5 Appendix D Figures D1-D10)

Need Pre Grout NCR Agreement Sign off by vendor

“YOU GROUT IT YOU OWN IT”



- Desire to achieve Concrete Surface Profile 9
- Chipping (not bush hammering) to remove top laitance layer and expose cracked aggregate ***(API 686 Ch 5 par 3.6.2)***
- Preparation of bottom of base plate (buff/clean)
- Ensure area is clean (no oil, water, dust, rags)



Construction

Product Data Sheet
Edition 04.2007
CSC Master Format™ 03 63 00
Sikadur® 42 Grout Pak LE^CA

Sikadur® 42 Grout Pak LE^CA
Pre-Proportioned, Epoxy Base-Plate, Grouting System

Description	Sikadur® 42 Grout Pak LE^CA is a high strength, multi purpose, three-component, low exotherm, low dusting, solvent-free, moisture-insensitive, epoxy grouting system to seat base-plates.
Where to Use	▪ Precision seating of baseplates. ▪ Grouting under equipment, including heavy impact and vibratory machinery, reciprocating engines, compressors, pumps, presses, etc. ▪ Grouting under crane rails.
Advantages	▪ Meets API Standard 686. ▪ Low peak exotherm. ▪ Low dusting, ready-to-mix, pre-proportioned kits. ▪ Moisture insensitive. ▪ Non-shrink. ▪ Corrosion and impact resistant. ▪ Stress and chemical resistant. ▪ High compressive, tensile and shear strengths. ▪ High vibration resistance. ▪ Low coefficient of thermal expansion; compatible with concrete. ▪ Material does not require heated transportation.

Technical Data

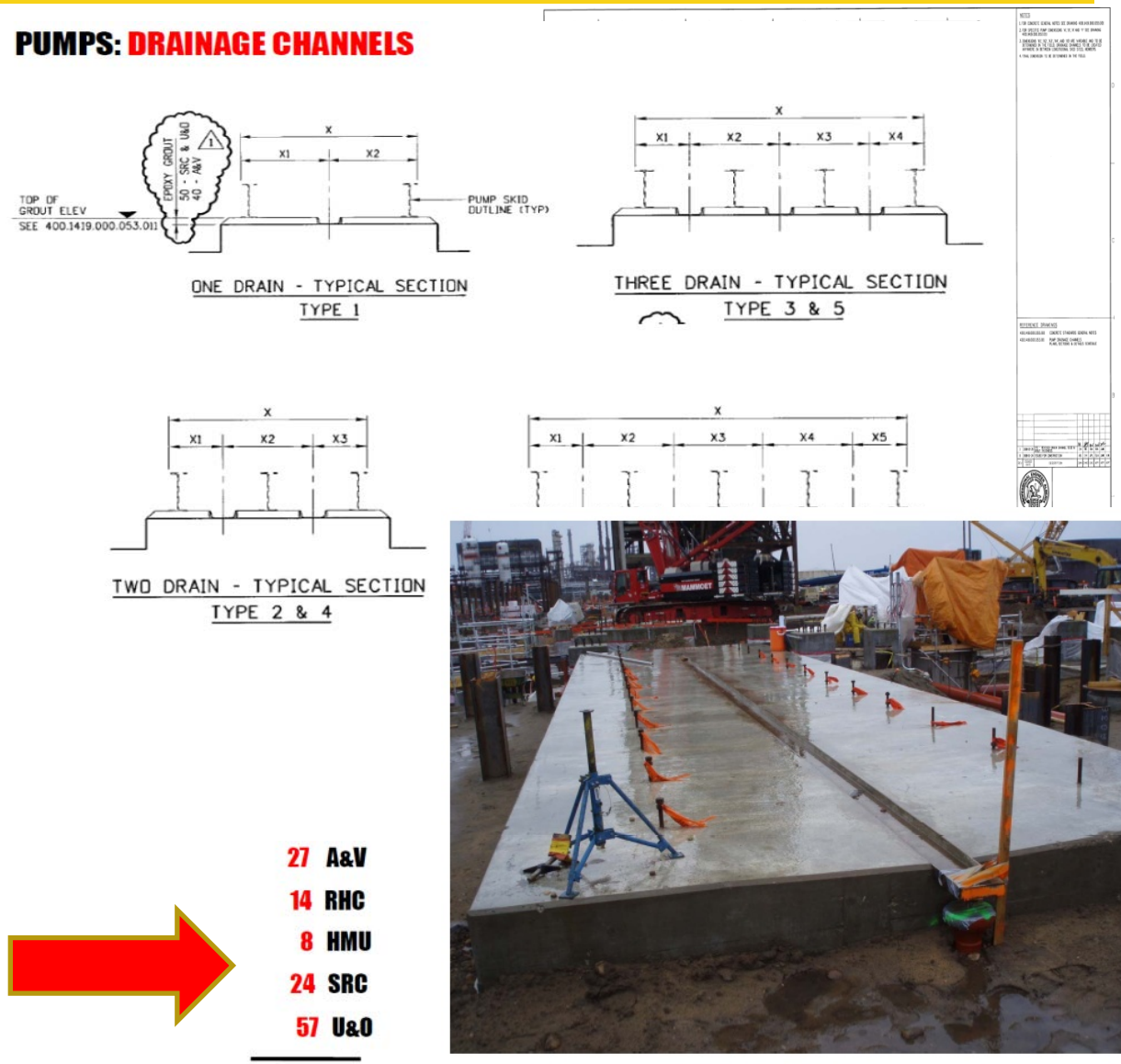
Packaging/Yield	
Component A	10.28 kg (22.6 lb)
Component B	3.42 kg (7.5 lb)
Component C	6 x 10.4 kg (42.7 lb) bags
Yield (per kit)	56.6 L (2 cf)
Colour	Concrete Grey
Shelf Life	2 years in original, unopened packaging. Store dry at 5° - 32°C (41° - 89°F). Condition product to 20° - 30°C (73° - 86°F) before using.
Mixing Ratio	
Ratio A:B:C by weight	3:1:34
Ratio solid/liquid by weight	8.5:1
Properties at 23°C (73°F) and 50% R.H.	
Density	2300 kg/m³ (144 lb/ft³)
Pot Life, Mix 3:1 (A:B) 500 g	140 min
Compressive Strength ASTM C 579, MPa (psi)	
	23°C (73°F)
24 hrs	76 (11021)
2 days	88 (12760)
3 days	79 (11457)
7 days	81 (11753)
28 days	100 (14510)
*Product cured and tested at temperatures indicated	
Tensile Strength ASTM D 638	14.0 MPa (2031 psi)
Elongation ASTM D 638	0.79-1.00%
Flexural Strength ASTM C 580	28 MPa (4062 psi)
Tangent Modulus of Elasticity in Bending ASTM C 580	19 GPa (27.7 x 10⁶ psi)
Coefficient of Thermal Expansion ASTM C 531	
-50°C to 26°C (-22° to 80°F)	2.8 x 10⁻⁵/°C (1.3 x 10⁻⁵/°F)
24°C to 100°C (75° to 212°F)	3.0 x 10⁻⁵/°C (1.7 x 10⁻⁵/°F)
Bond Strength ASTM C 882	
steel shear	> 40 MPa (5804 psi) concrete failure
Creep Test ASTM C 1181	
4.1 MPa, 60°C (600 psi, 140°F)	4.5 x 10⁻⁵
2.7 MPa, 60°C (400 psi, 140°F)	3.6 x 10⁻⁵
Linear Shrinkage ASTM C 531	0.060%
Thermal Compatibility ASTM C 884	No delamination/pass
Exotherm at 23°C (73°F) ASTM D 2471	34.6°C (94.3°F)

Sika®

Sikadur® 42 Grout Pak LE^CA
03 63 00 EPOXY GROUTING 3-442

Grouting

- New U-Channel Design Advantages of less grouting (only of Main I-Beams), cheaper construction time, safer design for product leaks or spills path to main drain
- Requires Rigid Base plates (offshore base plates design)
- Experienced a design error as civil wanted the U-channel to reside in the grout layer and mechanical wanted it in the concrete foundation
- Caused some extra time and drawing revision to resolve



Construction Issues Grouting

- Need continuous temperature of 25 C, Hoarding required for temperature control even in summer time
- Heat is the key to getting good grout flow
- Important that temp of bags, concrete, foundation & base plate are all constant at temperature prior to starting; may need circulation fans to keep temperature; leave on for 24 hrs post grout ***(API 686 Ch 5 par 3.12.9)***
- Perform sample test cubes for quality assurance
- Perform a pre and post level check for verification

25183-110-GQR-C02-00001, Rev. 0
Inspection Test Record (ITR) – Grout Request/Release [C01]

GROUT REQUEST/RELEASE C01

CONTRACTOR		SYSTEM NO.			
EQUIPMENT NO.		DRAWING NO.		REV.	
TEST DEVICE MFG., S/N		TEST DEVICE TAG NO.			

REFERENCE DOCUMENT NO.	REV.	REMARKS

ITEM TO BE GROUTED	LOCATION	ELEVATION	COMMENTS

REQUESTOR ____ DATE ____

LOCATION SKETCH (OPTIONAL)

PLAN VIEW

GROUT RELEASE (CHECK IF APPLICABLE) INITIAL AND DATE

☐ CIVIL	☐ ELECTRICAL	☐ INSTRUMENTATION	☐
☐ PIPING	☐ MECHANICAL	☐ START UP	☐

RELEASED FOR GROUT ____ DATE ____

INSPECTION ITEM	ACCEPT	REJECT	N/A	REMARKS
GROUT MATERIAL STORAGE AS PER MANUFACTURERS INSTRUCTIONS	☐	☐	☐	
SURFACES PROPERLY PREPARED	☐	☐	☐	
ITEM TO BE GROUTED IS PROPERLY POSITIONED AND SUPPORTED	☐	☐	☐	
SHIMS TO BE ☐ LEFT IN PLACE ☐ REMOVED	☐	☐	☐	
GROUT FORMS ADEQUATE	☐	☐	☐	
PRE-SOAK COMPLETE	☐	☐	☐	
MANUFACTURED GROUT IS AN APPROVED PRODUCT GROUT TYPE	☐	☐	☐	
GROUT PROPERLY MIXED	☐	☐	☐	
TEMPERATURES WITHIN SPECIFIED RANGE AIR GROUTED ITEM MIXED GROUT M&TE ID NO. DRY GOUT EXPIRATION DATE	☐	☐	☐	
GROUP PLACEMENT METHOD DATE	☐	☐	☐	
CURING METHOD	☐	☐	☐	
IF CURING IN COLD WEATHER - MANUFACTURES RECOMMENDATIONS FOLLOWED FOR PRE- AND POST- INSTALLATION - PROPER HEATING AND HOARDING PROVIDED	☐	☐	☐	
CURING COMPLETE, FORMS REMOVED, FINISHING AND/OR PATCHING COMPLETE DATE	☐	☐	☐	
CLEAN UP COMPLETE	☐	☐	☐	

GROUT CUBE TEST RESULTS (COMPRESSIVE STRENGTH)

3 DAYS	5 DAYS	7 DAYS	28 DAYS

COMMENTS

SIGNATURES

PERFORMED BY	COMPANY	NAME	DATE
INSPECTOR		PRINT SIGN	
EPCM/SHELL REPRESENTATIVE		PRINT SIGN	
OTHER		PRINT	

Construction Issues

Field Machining

Scotford Upgrader Expansion 1 — **NON-CONFORMANCE REPORT (NCR)** — PROJECT # 25183

SECTION 1 – To be completed by Stakeholder

NCR #:	251838-G61-[illegible]
UNIT NAME	AREA/WBS/WP #:
CONTRACTOR'S NAME:	CONTRACT #: STARTUP SYS. #:
REPORTED BY [print name]:	DATE:
AFFECTED DISCIPLINE:	CODE ITEM YES ☐ NO ☒

DRAWING/SPECIFICATION/ITEM #	REVISION #	EQUIPMENT # / DESCRIPTION

CONTRACT # / P.O. #	CONTRACTOR/SUPPLIER

NON-CONFORMANCE TYPE: SUPPLIER ☒ CONTRACTOR ☐ DAMAGE ☐ CONSTRUCTION ☐ PROCURE ☐

NON-CONFORMING CONDITION DESCRIPTION — CHECK IF DIGITAL PHOTO ATTACHED ☐

RECOMMENDED DISPOSITION: REJECT ☐ REWORK ☐ REPAIR ☐ [R.E. concurrence required] USE AS IS ☐ [R.E. concurrence required]

DISCIPLINE FIELD ENGR / INSPECTOR'S REVIEW: Print & Sign DATE:

AFE'S CONCURRENCE [print & sign]: DATE:

FINAL DISPOSITION: REJECT ☐ REWORK ☐ REPAIR ☐ [Shell's concurrence required] USE AS IS ☒ [Shell's concurrence required]

R.E. CONCURRENCE [print & sign] N.A. ☐	DATE	SHELL CONCURRENCE [print & sign] N.A. ☐	DATE

DESIGN / FIELD CHANGE REQUIRED YES ☐ NO ☐ — TDN #: N.A. ☐

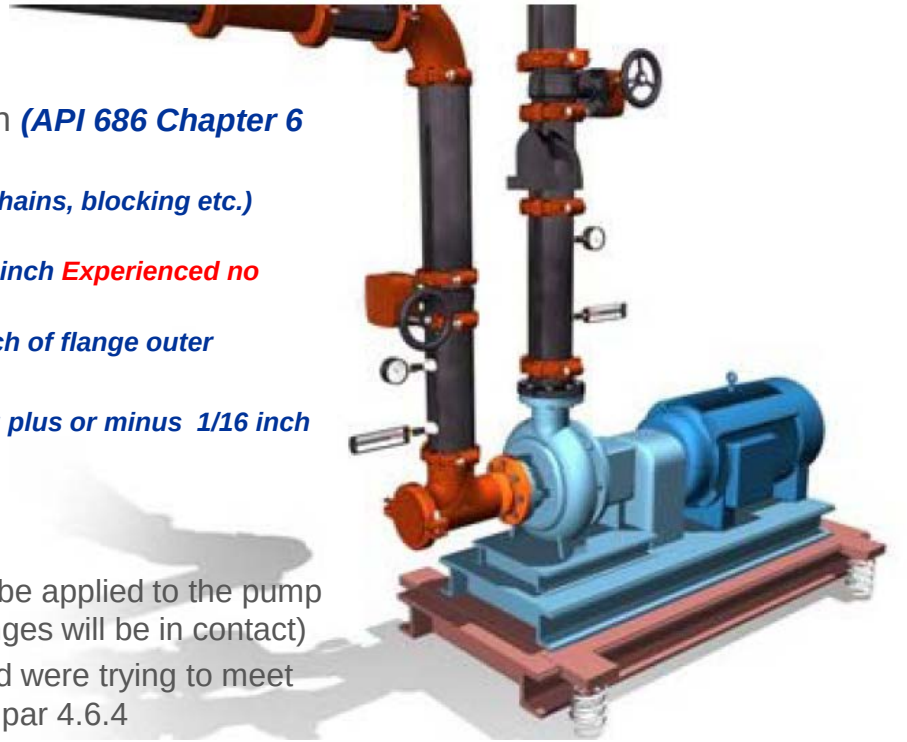
DWG/SPEC #: REV. — CODE INSPECTOR CONCURRENCE [print & sign] N.A. ☐ DATE

DCN/FCN/FCR #: N.A. ☐

- Field Machined 30 out of 251 base plates approximately 12%
- Estimated ~ $20,000 per base plate and a week to ten days schedule delay to resolve
- Need to be sure if it is the Pump feet or the Pedestal that is to be machined
- Critical for NCR's agreement from vendor prior to grouting

"YOU GROUT IT YOU OWN IT"

Piping Installation



- API 686 Piping Alignment Requirements are defined in ***(API 686 Chapter 6 paragraph 4.6.1-4.6.4)***
  - ***4.6.1 No Sprung flanges to connect piping (i.e. use of straps, chains, blocking etc.) Experienced no issues with requirement***
  - ***4.6.2 Pipe Flange and Pump Flange need to line up within 1/16 inch Experienced no issues with requirement***
  - ***4.6.3 Flange Faces shall be parallel to within 0.001 inch per inch of flange outer diameter Experienced no issues with requirement***
  - ***4.6.4 Flange face separation shall be within the gasket spacing plus or minus 1/16 inch Experienced many issues with this requirement***

The Issue with 4.6.4:

- The piping designer intentionally allowed a vertical load to be applied to the pump nozzles in the cold condition. (i.e. the piping and pump flanges will be in contact)
- The Piping Fitters were unaware of this intentional load and were trying to meet the dimensions of the isometric drawing and API 686 Ch 6 par 4.6.4
- This caused excessive and costly piping alignment / installation time
- The resolution was to verify the load on the nozzle in the cold condition as per the piping design. This entailed providing the pump nozzle loads to the field and performing verification (i.e. prybar or load weigh scale)

- Adjustment of the spring hangers or spring supports as a method of achieving piping alignment is not acceptable. ***(API 686 Chapter 6 paragraph 4.7.3)***. Must be in the cold locked position ***Experienced no issues with requirement***

Piping Installation

Alignment

- Very few alignment issues as all parties agreed that alignment needs to be per API 686
- ***(API 686 CH 7 par 5.4.2.4)*** All shims shall be full bearing, with max of 5 shims ***(API 686 CH 7 par 5.4.2.1)***
- We experienced good success with alignment. Success can be attributed to earlier leveling, soft foot checks and rough alignment chart

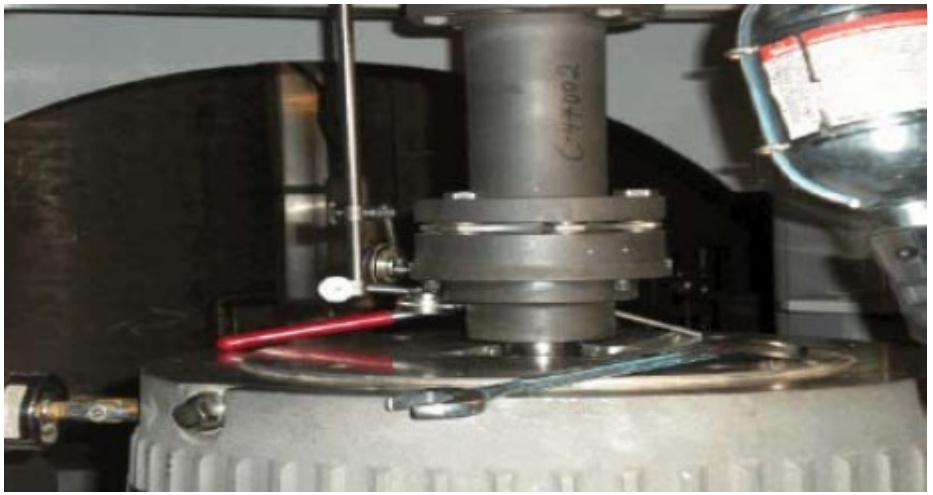
25183-110-GQR-MP2-00002, Rev. 0
Inspection Test Record (ITR) – Centrifugal Horizontal Pumps Installation Checklist [M16]

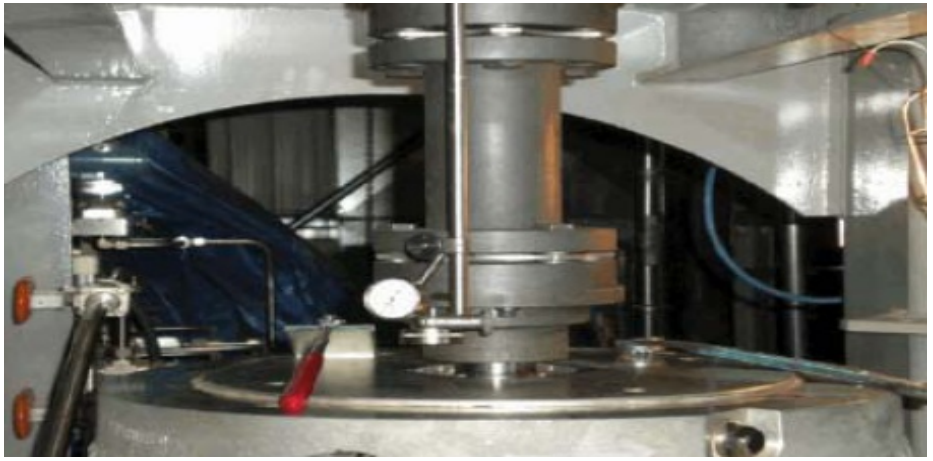
	CENTRIFUGAL HORIZONTAL PUMPS INSTALLATION CHECKLIST	M16

CONTRACTOR			SYSTEM NO.			
EQUIPMENT NO.			DRAWING NO.		REV.	
TEST DEVICE MFG., S/N			TEST DEVICE TAG NO.			

NO.		DESCRIPTION	YES	N/A
		VERIFICATION PRIOR TO INSTALLATION		
1	A.2	NAME PLATE DATA IS CORRECT		
2	A.4	SUBMIT INSTALLATION PROCEDURE		
		WITNESS POINT (SHELL/EPCM) SIGNATURE		
3	A.9	VERIFY JACKING BOLTS LEVELING PADS DISKS ARE INSTALLED		
4	A.11	VERIFY DRAIN U-CHANNELS UNDER BASEPLATE ARE IN PLACE AND FORMED PER DESIGN		
		PRE-INSTALLATION		
5	B.2.2	BOTTOM OF EQUIPMENT SOLEPLATE IS CLEAN, DRY, AND FREE OF CONTAMINENTS		
6	B.2.4	EPOXY PRIMED SURFACES ROUGHENED PRIOR TO EQUIPMENT PLACED ON FOUNDATION		
7	B.2.8	BASEPLATE LEVEL		
		WITNESS POINT (SHELL/EPCM) SIGNATURE		
8	B.2.9	PRELIMINARY ALIGNMENT		
		WITNESS POINT (SHELL/EPCM) SIGNATURE		
9	B.2.10	PRELIMINARY SOFT FOOT CHECK		
		WITNESS POINT (SHELL/EPCM) SIGNATURE		
		INSTALLATION		
10	C.2	GROUT POUR/INSPECTION		
11	C.3	SEAL COAT AND GROUT		
12	C.4	TIGHTEN ANCHOR BOLTS		
13	C.5	GROUNDING STRAP		
14	C.6	SOFT FOOT CHECK		
		WITNESS POINT (SHELL/EPCM) SIGNATURE		
15	C.7	PIPING/EQUIPMENT/SUCTION SYSTEM CLEANLINESS		
		WITNESS POINT (SHELL/EPCM) SIGNATURE		
16	C.8	PIPE STRESS AND FLANGE ALIGNMENT		
		WITNESS POINT (SHELL/EPCM) SIGNATURE		
17	C.9	PIPING CLAMPS/SPRING HANGERS INSTALLED AND SET		
18	C.10	VERIFY SUCTION STRAINER IN PLACE		
19	C.11	AUXILIARY PIPING CORRECT LOCATION		
20	C.12	VERIFY VENTS AND DRAINS		
21	C.13	VERIFY SEAL/SEALING SYSTEM INSTALLED		
22	C.14	OIL MIST FITTINGS		
23	C.15	SHAFT TURNS FREELY		
24	C.16	COUPLING: SPACER GAP/AXIAL LENGTH		
25	C.17	OIL SYSTEMS INSTALLED/CHECKED/FLUSHED		
		HOLD POINT (SHELL/EPCM) SIGNATURE		
26	C.18	COOLING SYSTEM CHECKED		
27	C.19	FINAL ALIGNMENT IS COMPLETE		
		HOLD POINT (SHELL/EPCM) SIGNATURE		
28	C.20	EQUIPMENT HOLDDOWN BOLTS/SHIMS/DOWELS		
29	C.21	SHAFT END FLOAT – WITHIN LIMITS		
30	C.22	GEAR CHECKED (IF APPLICABLE)		
31	C.23	DRIVER CHECKED		
32	C.24	COUPLING ASSEMBLED AND BOLTS TORQUED PER VENDOR REQUIREMENTS. GUARDS INSTALLED.		

25183-110-GQR-MP2-00002, Rev. 0 Page 1 of 2





Key Learning's from Construction

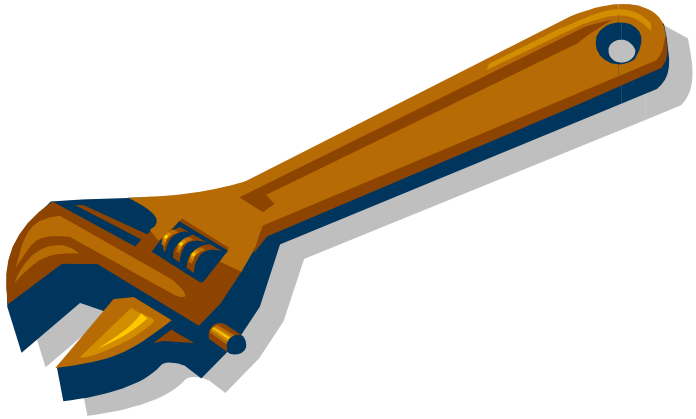
- Job site demands and tasks are ever changing and daily meetings with owner inspection team is vital
- Need a strong relationship between Construction Contractor, Operations and Project Team to ensure clear communication and for rise and resolution of issues
- Our monthly workshops were excellent forums to get alignment and increase trust in building working relationships
- Vendor Representation on site full time to approve NCR's for immediate implementation is vital to construction phase success
- API 686 tolerance of 0.002" per foot is a tight tolerance to achieve
- Ensure all pressure vessels related to rotating equipment (filters, seal pots, etc.) have proper ABSA registration and Canadian registration numbers
- Ensure all tubing related to rotating equipment receives proper documented pressure testing as per requirements stated in Pressure Equipment Safety Regulation Section 4 criteria defined in B31.3 (pressure tubing is to be tested as pressure piping)

Mechanical Completion

- Requires Multidisciplinary Organized Walk downs!
- There will be findings
- Key learning - budget time to resolve issues &

determine what needs to be resolved before or after Start-up.

PUNCHLISTING SEASON



Pre-Startup Issues & Checklist

Pre-Start-up Issues

- Experienced leaks on pump seals due to poor preservation (residual hydro test fluid)
- Flushing of auxiliary lube oil and barrier fluid systems took a lot of time. Cleanliness issues found
- Motor Bump testing done to IEEE Standard for (TEFC) Totally Enclosed Fan Cooled Squirrel Cage Induction Motors found high vibration issues, resulting in additional stiffening support being required
- The need to loop check and fully function check all instrumentation prior to start up is critical and takes a great deal of effort and time

Rotating Equipment System Walkdown Checklist

1. NCR's complete
2. MOC's complete
3. ITR's complete
4. P&ID matches the field installation
5. Review construction work packages
6. Vendor manual available
7. Instrument tubing supported adequately
8. Ensure all TI's read ambient temperature
9. Instrumentation installed and loop checked
10. Ensure tubing pressure testing is complete
11. Bently Nevada system configured and loop checked
12. Oil Mist system installed
13. Oil mist tubing has correct slope to bearings
14. Oil in bearings
15. Constant level oilers set correctly
16. Breathers installed on bearing housings
17. Seal locking tabs rotated out
18. Ensure plugs in seal glands are correct
19. Ensure tubing connected to mechanical seals
20. Ensure the correct oil is in bearing housings
21. Ensure lube oil system level instrumentation has been calibrated
22. Lube oil flush complete
23. Ensure oil touches the TI in lube oil return lines
24. Insulation and heat tracing installed on lube oil system
25. Aluminium cable trays – check for sharp edges
26. Coupling guards in place
27. Insulation and heat tracing complete
28. Correct gaskets installed

Start-up Issues and Outcome

Issues

- Unanticipated high vibration of pumps running off of BEP
- Minor cavitation issues
- Very few leaks, casing, tubing, instrumentation, etc
- Mechanical Seals preservation damage (residual hydro test fluid)
- Minor vibration of motor bases
- Strainers with a weak delta pressure design

Outcome

- Plant was commissioned and Start-up in Spring of 2011
- No major incidents, and start-up progression achieved a Flawless Start-up

OVERALL SUCCESS!!

Questions