

COMPRESSOR OPERATION

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PARADEEP REFINERY PROJECT
A Sunrise Project for a Sunshine Future



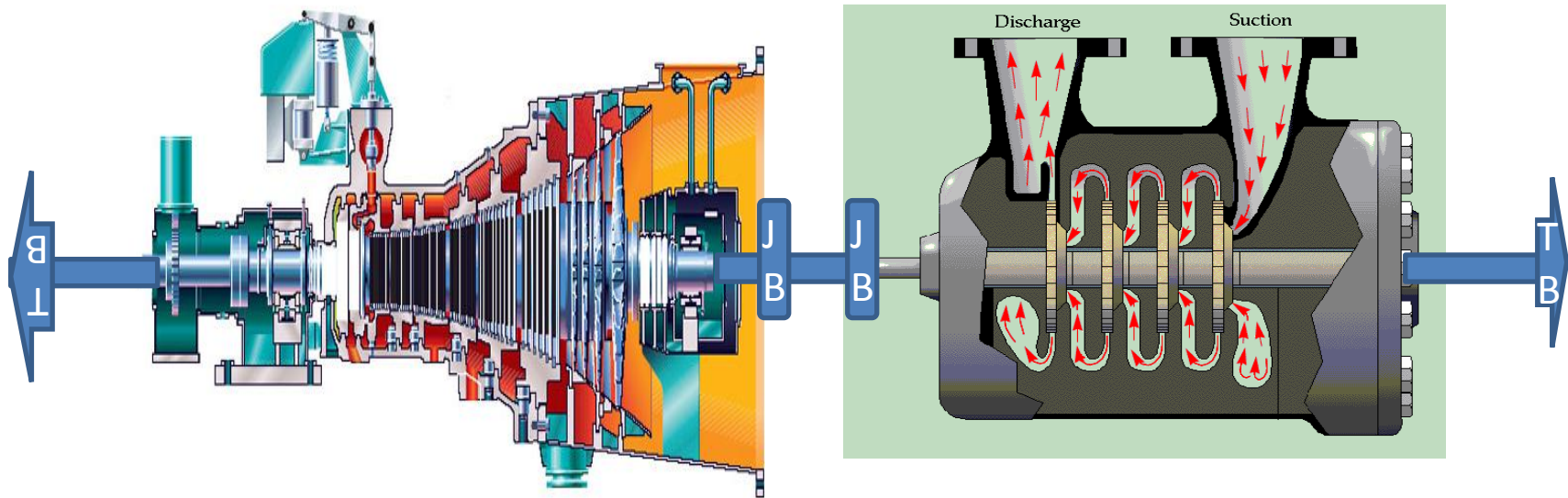
- **Introduction**
- **Compressor Takeover From Maintenance**
- **Start-Up**
- **Normal Running And Monitoring**
- **Trip/Emergency Shutdown**
- **Hot/Cold Start Up**
- **Shutdown And Handover To Maintenance**



INTRODUCTION

- **Compressors are complex machines.**
- **Complexity lies in the forces(thermal, mechanical stresses etc) that are acting on the machine components.**
- **Operating personnel should understand the systems and procedures thoroughly.**
- **SOPs on various operational procedures should be available handy.**
- **Operating personnel should be very attentive and follow all the safety norms while in the vicinity or working with compressor.**

COMPRESSOR COMPONENTS





COMPRESSOR COMPONENTS

- Compressor
- Turbine Drive
- Governor
- Anti-surge System
- Bearings (Temp, Vibration, axial displacement)
- LO System (cooler, Filter, accumulators, mist eliminator)
- Barring System
- Gland System
- Condensate System
- Rundown Tank

COMPRESSOR – TAKEOVER FROM MAINTENANCE

1. Ensure that all the jobs are completed as per the Job list.
2. Get the clearance from maintenance departments (mechanical / electrical / inst).
3. Ensure that blinding & deblinding is done for Normal Running condition.
4. Physically look around the compressor to check if there are any incomplete jobs.
5. Ensure removal of debris, tools and tackle, scaffolding in the compressor area.
6. Ensure area is cleaned properly and there is no oil spillage
7. Ensure proper lighting.



COMPRESSOR STARTUP

Depending on the Compressor vendor and type there will be minor variations in the compressor operating procedures. The procedure presented in the following slides gives general idea which will be common for all the centrifugal steam driven compressors.



STEPS DURING STARTUP

1. Preparation.
2. Establish cooling water.
3. Establish separation seal buffer.
4. Startup oil system.
5. Establish seal system.
6. Take turning gear inline.
7. Start live steam piping warm-up HP side and LP side.
8. Steam turbine chest valve Initial warm-up.
9. Lineup the gland steam condenser.
10. Line-up vacuum condenser in line.
11. Preparation of compressor.
12. Starting steam turbine.
13. Compressor loading and stabilizing.



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STEPS DURING STARTUP

PREPARATION

- Ensure all the utilities are commissioned namely Cooling Water, Plant air, Nitrogen, HHP/HP/MP/LP Steam
- Get the clearance from maintenance departments(mechanical/electrical /instrumentation (if maintenance job is carried out)
- Ensure that blinding & deblinding is done for Normal Running condition.
- Take Clearance for Steam from TPS.
- Ensure HHP steam main valves, bypass valves, control valve and trip valve are closed
- Ensure backpressure LP Steam line main valves & bypass valves are closed.
- Open condensate drain valve in SHH line and dry the steam upto main B/V
Open condensate drain valve in SL line and dry the steam upto main B/V



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STEPS DURING STARTUP

ESTABLISH COOLING WATER

Commission cooling water in following systems

- Ejector condenser of Gland System
- LO cooler.
- Turbine steam condenser
- LO pump bearing house

Precautions:

- Remove air pockets.
- Ensure TSV/PSVs are in line
- Ensure TG, PG are working



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STEPS DURING STARTUP

ESTABLISH SEPARATION SEAL BUFFER

- Line up the Nitrogen supply Filter.
- Ensure DP across filter is in normal range,
- Service the filter if PDG shows high.
- Set pressure of separation seal buffer.
- Line up separation seal buffer valves

Precautions:

- Ensure TSV/PSVs are in line
- Ensure TG, PG are working
- Confirm the flow of nitrogen

STEPS DURING STARTUP

ESTABLISH LUBE OIL SYSTEM

- Ensure that sufficient oil level is there in the reservoir or else Top-up
- Heat oil if necessary
- Prepare accumulators ready.
- Prepare the LOP(T) and start the pump
- Circulate oil through various circuits
- Remove air pockets from TSV, impulse lines, filters, accumulators etc.
- Fill the rundown tank , commission it and check through sight glass
- Ensure flow through all the Oil return lines.
- Run the mist eliminator
- Run Centrifuge

Precautions:

- Ensure that leaks are not there,
- Stabilize the pressure, temperature level readings
- Check the auto start of the standby pump



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STEPS DURING STARTUP

ESTABLISH SEAL GAS SYSTEM

- Keep the discharge PSV bypass open.
- Line up Flush gas supply to the seal.
- Set the flow of flush gas on both DE and NDE .
- Establish primary buffer

Precautions:

- Ensure there is not pressure buildup in the compressor casing that will damage the seal
- Ensure that the filter DP is normal and there is no condensate in the system.

TAKING TURNING GEAR IN LINE

- Initial operation of turning gear should be done manually to ensure that breakaway of the turbine train is possible without exceeding the torque capability of the Turning Gear. This will be done by Maintenance.
- Start turning gear system (approx. one hour prior to start-up for cold start up)
- Disable lock out function of turning gear by selecting handle position on turning gear before turning motor start.
- Confirm that the turning gear is in disengage position and start the motor.
- Check for shaft rotation and proper operation of turning gear. Adjust the Seal gas system flows after turning gear is put in operation.

Precautions:

- Ensure shaft rotation physically and from field instruments
- Check the axial displacement and vibration probe readings

STEPS DURING STARTUP

START LIVE STEAM PIPING & STEAM TURBINE CHEST VALVE INITIAL WARM-UP

- Admit LP Steam(exhaust steam) for approximately 3 hours by opening bypass valve of NRV with opening casing drain and other drains to remove condensate.
- Ensure that SSH steam is superheated by at least 30°C
- Open the b/v's in the drain including TTV drains and warm-up lines to allow the removal of condensate arising during warm-up.
- Warm up inlet piping system simultaneously up to the recommended superheat condition as shown in table. TTV warm up will be part of Inlet piping system.
- TTV drain line shall be kept open during warm up.
- Continue warming-up casing with exhaust steam until temperatures are climbing very slowly. Increase casing metal temperature to (SL Temp - 30) °C approx. at deep temperature sensors (If necessary open TTV valves and admit steam into casing.

Precautions:

- Thoroughly remove the condensate forming.
- Follow the heating curve.

STEPS DURING STARTUP

LINEUP THE GLAND STEAM CONDENSER

- Ensure cooling water is Charged
- Check the CW pressures and temperatures on the gland steam condenser.
- Ensure that the goose neck sealed by filling with water Take inline the condensate trap in the SM line.
- Charge steam slowly and establish vacuum.
- Ensure that no steam escapes at the rotor ends of the steam turbine,
- In case of steam escape have the malfunction corrected.

Precautions:

- If steam turbine is in hot condition during turbine trip break the vacuum till the time steam is charged, ingress of air into gland will cause shaft

STEPS DURING STARTUP

PREPARATION OF COMPRESSOR

- Ensure Blinding/ Deblinding is done as per list.
- Purge the suction lines with Nitrogen purge provided, to remove air from the circuit Pressurise the casing to 0.5kg/cm² and vent to atmosphere and Depressurise using LPDs in suction, discharge and spill back line.
- Repeat this till sample from casing reads oxygen <0.2%.
- Open anti-surge valves to full open condition and free from hand wheel.
- Open Inventory isolation valves.
- Lineup tracing steam of suction lines of the Compressor.
- Once Compressor is floating with suction close the PSV bypass that are opened. Drain compressor casing free of any liquid.

Precautions:

- Discharge PSVs can now be closed



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STEAM TURBINE - STARTUP

PERMISSIVES FOR STARTING STEAM TURBINE

- Normally unless certain conditions of the compressor are met as mentioned typical of FCC WGC below, the compressor start is not allowed by the ESD system
- WGC Start Permissive:

I305	STARTPERMISSIVE FOR WGC FROM 1ST AS VALVE OPEN FEEDBACK	FSH0182	SP
I305	STARTPERMISSIVE FOR WGC FROM 2ND AS VALVE OPEN FEEDBACK	FSH0135	SP
I305	LO COOLER O/L TEMP NOT LOW	TT4402	SP
I305	LO SUPPLY HDR PRESSURE COMP PERMISSIVE NOTLOW	PT4201	SP
I305	DP BETWEEN FLUSH N2 AND PRIMARY BUFFER	PDT4203	SP
I305	ESV CLOSE FEED BACK	ZSL4302	SP
I305	OVERHEAD TANK LEVEL HIGH	LIA4200	SP
I305	CONTROL OIL HDR PRESSURE NOT LOW	PT4303	SP



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STEAM TURBINE - STARTUP

Start the Turbine (Typical of FCC WGC by Elliot Ebara)

- Check if Ready to start is achieved.
- Keep the governor valve full open.
- Slowly open the TTV valve manually to increase the RPM @ 10rpm/sec
- Bring the rpm to low idle speed of 600rpm.
- If any noise is observed reduce speed to previous step and wait till noise gets reduced
- Monitor (SI-4300/2) and control speed at low Idle speed #1 using the T&T valve (023-TOV-401).And confirm that the all mechanical conditions are satisfactory.
- Confirm that the bearing temperatures (T1-4350/1/2/3/4/5/6/7) and vibration levels (VIX-4350/2, VIY-4351/4) are stabilized before making speed changes, And confirm that all the mechanical conditions are satisfactory.

Start the Turbine (Typical of FCC WGC by Elliot Ebara)

- Confirm that the bearing temperatures (T1-4350/1/2/3/4/5/6/7) and vibration levels (VIX-4350/2, VIY-4351/4) are stabilized before making speed changes, And confirm that all the mechanical conditions are satisfactory.
- Bring the RPM to low Idle speed#2 of 1500rpm @ 10 rpm/sec by throttling 023-TOV-401 manually with governor valves (SV-4302) wide open for equalized casing warming and keep at that RPM for 80 min
- Confirm that the Deep casing metal temp (TI4302-TI4304) < 80 °C and shallow casing metal temp (TI4303-TI4305) < 80 °C and Temp diff (TI4306-TI4307) < 125 °C.
- Rise the deep casing metal temperatures to 150 °C at (TI-4302/4) at end of low idle#2 1500 rpm.

Start the Turbine (Typical of FCC WGC by Elliot Ebara)

- Gradually open T&T valve fully. Then governor will control train speed a little bit above low Idle speed#2 of 1500. Confirm that governor is controlling speed (once the speed exceeds reference speed (SI-4301/3) a
- Now press acceleration start (HS4321), the train will be brought to high Idle speed of 2400 rpm by Auto Acceleration Logic. and then back to reference speed).
- There is a critical speed band (1600-2100), in this band the acceleration will be 20 rpm/sec
- Allow the deep casing temperatures to rise above 150 °C
- Increase the speed to minimum governing speed.



STEAM TURBINE - STARTUP

Loading the Turbine (Typical of FCC WGC by Elliot Ebara)

- Check the process readiness
- Put anti-surge controllers in auto.
- Slowly increase the load and allow the anti-surge to close.
- Put the speed controller in auto cascade.
- While loading watch for level increase in compressor KODs and turbine condensate well.



NORMAL RUNNING AND MONITORING

- During normal running condition the operating parameter of both process and machine are to be monitored.
- The monitoring interfaces are DCS panel, SRR, LCP.

Parameters to monitor

- Process P/T/F
- Anti-surge controller deviation
- Compressor discharge pressure controller.
- Compressor KOD levels and Auto Run of condensate pumps.
- LO system filter DP/ Temp, LO quality level
- Vibration/compressor temp/ axial displacement readings.
- Seal system health(DP, Nitrogen pressure, seal gas leak flow.)
- Cooling water flow
- Gland leak and Gland system
- Physical verification of compressor for integrity and coherence with instrument readings



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TRIP / EMERGENCY SHUTDOWN

- Trip is executed by ESD system when any of the process/ machine parameters crosses healthy values and bring the machine to safe shutdown
- Below is the Typical of FCC-INDMAX WGC

IZ302	LO TO BEARINGS HDR PRESSURE TO TRIP WGC 2/3	PZT4200A/B/C	TRIP
IZ304	WGC SEAL NITROGEN PRESSURE LOW	PZT4295A/B/C	TRIP
IZ306	DP BETWEEN FLUSH N2 AND PRIMARY BUFFER TO TRIP WGC	PDZT4202A/B/C	TRIP
IZ311	RPM INDICATION TO TRIP CONFIRM SOURCE (SA4302)		TRIP
IZ312	SPEED SIGNAL FROM GOVERNOR OVERSPEED TRIP	(2/3)	TRIP
IZ313	OVERSPEED PROTECTION PROTECH203	SSHH4351 (2/3)	TRIP
IZ314	EMERGENCY STOP PUSH BUTTON	(HSZ4306)	TRIP
IZ321	ZZS4250A/B/C 2/3		TRIP
IZ322	VZX4250/4251 1/2		TRIP
IZ323	VZX4252/4253 1/2		TRIP
IZ324	VZX4350/4351 1/2		TRIP
IZ325	VZX4352/4353 1/2		TRIP
IZ326	ZZS4350A/B/C 2/3		TRIP
IZ327	TZ4250/4251 1/2		TRIP
IZ328	TZ4252/4253 1/2		TRIP
IZ329	TZ4254/4255 1/2		TRIP
IZ330	TZ4256/4257 1/2		TRIP
IZ331	TZ4350/4351 1/2		TRIP
IZ332	TZ4352/4353 1/2		TRIP
IZ333	TZ4354/4355 1/2		TRIP
IZ334	TZ4356/4357 1/2		TRIP
IZ341	CONTROL OIL HEADER PRESSURE LOW	PZT4304A/B/C (2/3)	TRIP
IZ371	ASC FAILURE 1ST STG FIC4100A/B		TRIP
IZ372	ASC FAILURE 2ND STG FIC4101A/B		TRIP
IZ373	TRIP ON EXCESSIVE SURGE RECEIVING FROM ASC 1ST STG	XA4100A/B	TRIP
IZ374	TRIP ON EXCESSIVE SURGE RECEIVING FROM ASC 2ND STG	XA4101A/B	TRIP



TRIP / EMERGENCY SHUTDOWN

Usual Trip conditions

Process side

- High KOD level
- High discharge temperature
- Inventory valve accidental closure

Machine side

- High vibrations
- High axial displacement
- High temperature in bearings
- LO pressure low
- Low control oil pressure
- Excessive surge
- Seal failure detected by high seal gas flow
- Over speed trip
- Emergency stop

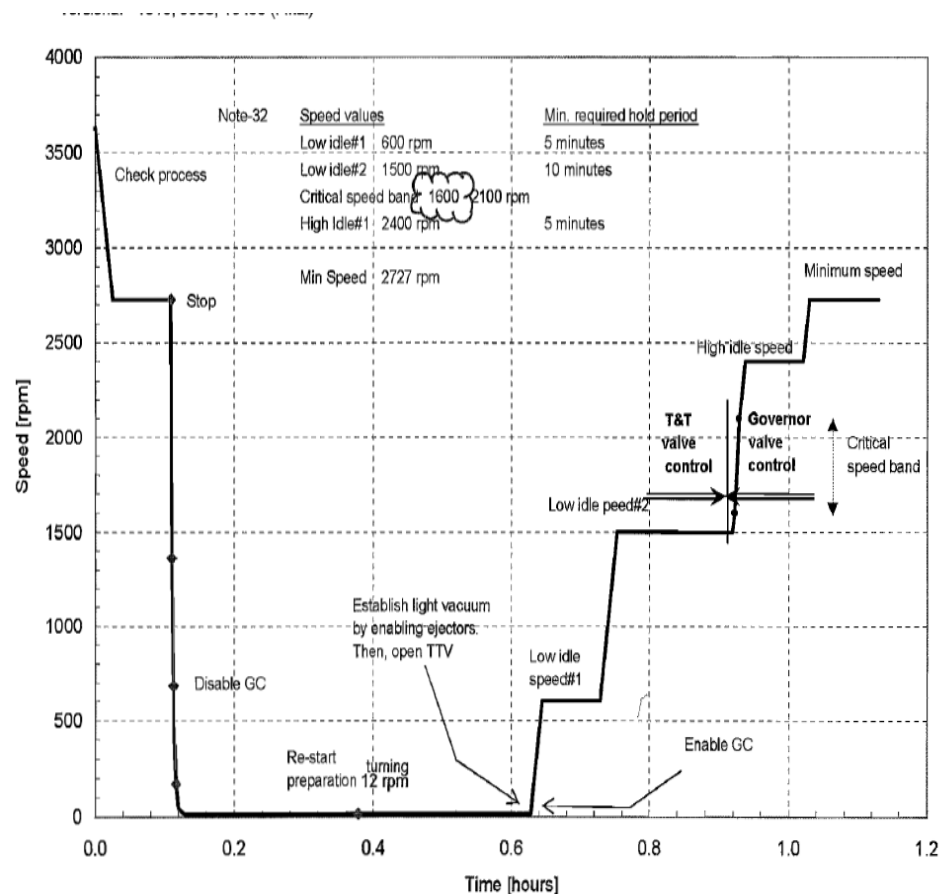
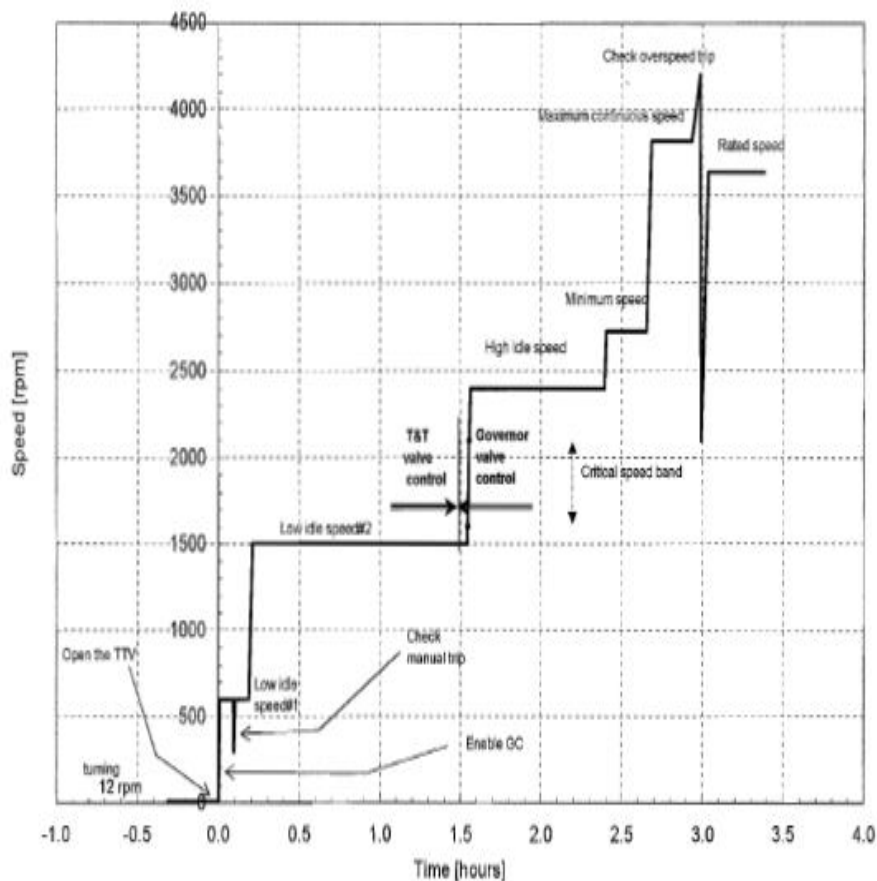
AFTERMATH OF TRIP & HOT COLD START-UP

Effects of activation of trip

- TTV will close
- Control oil to governor will stop
- Inventory valve will close
- Machine train will coast down to barring condition
- Barring will be activated

COLD START UP (WGC-FCC)

HOT STARTUP





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SHUTDOWN & HANDOVER TO MAINTENANCE

- Switch the Speed control and the Anti-surge valves to manual.
- Gradually reduce load by reducing the turbine speed to minimum governing speed and open the anti-surge valve fully.
- Press the “Stop” Gov stop: This will eventually close the Governor Valve and the T & T Valve.
- Monitor the vibration levels, particularly when approaching the unit critical speeds. In the event that severe vibration is encountered when approaching the critical speed, decelerate as quickly as possible.
- Shut down the gland condenser leak off system before rotor comes to a stop.



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SHUTDOWN & HANDOVER TO MAINTENANCE

- Close the exhaust block valve and release the casing internal pressure as quickly as possible. Confirm zero speed for a while and confirm that there is no possibility of reverse rotation.
- Then select ratcheting position (not lockout position) of the lever on the turning gearbox. And start the turning gear.
- The recommended turning period is minimum 14 hrs after turbine shut down. When turning period is over, stop the turning motor. And select lockout position (not ratcheting position) of the lever on the turning gearbox before rotor complete stop.
- Be sure that no steam can enter the turbine from any source when idle. Open the turbine casing drains once unit is entirely blocked-in
- Ensure closing of the compressor suction and discharge valve (XZV0026/0369/0370/0371)

SHUTDOWN & HANDOVER TO MAINTENANCE

- Open the compressor drains and drain off any liquid.
- Depressurise and purge with nitrogen and blind the suction and discharge

General Precaution

- Allow the auxiliary oil pump to operate until the bearings have reached temp. of oil leaving the cooler.
- Shutdown the gas seal system after the compressor has been depressurized. Shut down the separation seal buffer after oil system has been shutdown
- If an unusual amount of liquid is drained from the compressor, it should be analyzed to determine the source. Steps should be taken immediately to prevent liquid from entering into the compressor.
- Handover to maintenance for blinding.
- After blinding purge the system and handover to maintenance only when gas test is passed



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LIST OF MAJOR CENTRIFUGAL COMPRESSORS

UNIT	COMPRESSOR	VENDOR	SERVICE	DRIVE
UNIT - 23 FCC	WGC (WETGAS COMPRESSOR)	ELLIOT EBARA	HYDROCARBON	STEAM TURBINE DRIVEN
UNIT - 23 FCC	MAB (MAIN AIR BLOWER)	MAN TURBO	AIR	STEAM TURBINE DRIVEN
UNIT - 70 PRU	VRC (VAPOR RECOVERY COMPRESSOR)	ELLIOT EBARA	HYDROCARBON	MOTOR DRIVEN
UNIT-40 NHT	40K001 (NHT RECYCLE GAS COMPRESSOR)	HITACHI	HYDROCARBON	MOTOR DRIVEN
UNIT-42 CCR	42K001 (CCR RECYCLE GAS COMPRESSOR)	DRESSOR RAND	HYDROCARBON	STEAM TURBINE DRIVEN
UNIT-42 CCR	42K002 (NET GAS COMPRESSOR-1)	HITACHI	HYDROCARBON	MOTOR DRIVEN
UNIT-42 CCR	42K003 (NET GAS COMPRESSOR-2)	HITACHI	HYDROCARBON	MOTOR DRIVEN
UNIT-20/21/22 VGO-HDT	RECYCLE GAS COMPRESSOR	BHEL	HYDROGEN	STEAM TURBINE DRIVEN
UNIT- 13/14/15 DHDT	RECYCLE GAS COMPRESSOR	BHEL	HYDROGEN	STEAM TURBINE DRIVEN
UNIT-24 ALKYLATION	REFRIERIGATION GAS COMPRESSOR	HITACHI	C3-C4	MOTOR DRIVEN
UNIT- 30 DCU	WET GAS COMPRESSOR	BHEL	HYDROCARBON	STEAM TURBINE DRIVEN



WHAT CAN GO WRONG?

During startup

- Not Properly drying the steam/ faulty Steam Traps
- Not Giving sufficient time for idling
- Not ensuring LO quality/quantity
- Improper lineup of process valves
- Bypassing Safety Interlocks
- Improper Inertisation
- Restriction in discharge circuit
- Improper Draining of KOD/Casing



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SAFETY ASPECTS

- **Strictly Avoid Assumptions**
- **Follow SOPs provided**
- **Communication between field and panel**
- **Keen observation for leaks with gas monitors**
- **Ear Muffs along with other safety gear**
- **Ensure that all the online gas detectors in the vicinity are functioning**
- **Checking of the Safety Interlock systems**
- **Test Run/Surge Test should be done before commissioning**

QUERIES



