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D 1 Special instructions for safe operation

CAUTION

Should you intend to start the turbo machines after it had been out of operation for a longer period of time, you are obliged to check all items as you did during first commissioning.

The turbo machines must be operated only by trained staff to rule out any and all gross negligence. Please pay close attention to the safety instructions included in chapter Safety.

The general work place of the machine operators is the control room; only in exceptional cases, e.g. to start up the turbomachine, are they required to stay in close vicinity to the machine for a short time.

When machines can be started and stopped only locally, i.e. on the machine itself, the immediate surrounding of the machine is regarded as work place.

WARNING

Danger by noise.

The communication may be disturbed by noise. This causes danger for the staff.

- Never operate the compressor when doors or covers, e.g. of silencing hoods, if any, are still open.

Always wear ear protection

WARNING

Danger by insufficient safety devices.

Might lead to lethal injuries.

- Check proper operation of alarm and safety devices prior to any compressor start-up. Your are obliged to immediately report any irregularities that you yourself are not in a position to eliminate to your company senior.
- Never inactivate safety devices.
- Check that the guards of live, rotating, hot or cold parts have been properly mounted.
- Make sure that valves or flaps cannot be involuntarily opened or closed (by signs, mechanical interlocks).
- Turbo machines must not be started up, if the start-up conditions do not comply with plant data or the plant process and if plant data have not been expressly checked.
- The CE Declaration of Conformity issued for the compressor must be available.

WARNING

Danger by escaping compressed process gas.

May lead to lethal injuries.

During operation of the turbomachine

- Maintenance work must not be carried out
- Valves or plugs must not be opened

WARNING

Danger by fire.

May lead to poisoning, severe burns and overload of machine components.

- Implement sufficient fire protection and prevention measures.
- Provide adequate fire extinguishing equipment and measures to protect your staff.

D 2 Impermissible operation

WARNING

Danger by bursting impellers and casings

Might lead to severe injuries.

- The turbo machine must not be operated at speeds above its maximum operating speed; when overspeed has been reached/exceeded, the impeller might burst which in turn might lead to major damage. The casing might burst on account of the high kinetic energy.
- Critical speed ranges, if any are specified in the data sheets, must be run through quickly. The compressor must not be operated at critical speeds to avoid damage by resonance vibrations.
- The turbo machine must not be operated at pressures and temperatures other than those specified. The suction temperature must not be fallen below to avoid the formation of condensate which will enter the compressor and thus damage it.

CAUTION

Danger by component overload might severely damage the machine.

- The turbo machine must not be operated at ambient conditions otherthan those stipulated in applicable specifications. In such cases, the AC Parts & Service Centre must be contacted, as materials, clearances etc. might be insufficient for these conditions.
- The gas must not be polluted by solid, liquid or gaseous particles.
- The turbo machine must not be allowed to start surging as this represents an excess dynamic load to components on account of increased temperatures and axial thrust.
  Damage to the machine - in particular to impellers and bearings - cannot be ruled out. (refer to the chapter "Instruments")
- After commisioning the start up strainers in the inlet pipes of centrifugal compressor have to be removed.

CAUTION

Danger of damage to plant parts caused by frost.

Proceed as follows to ensure that plant parts such as pipes, coolers, and measuring pipes cannot freeze in winter:

- Vent coolers
- Drain condensate
- Switch on water supply
- Install trace heater
- Provide oil tanks and pipes with sufficient insulation
- Isolate oil system, heat it.

D 3 Permissible operation

The compressor has been designed to compress process gas at the operating conditions specified in chapter „Plant description".

D 4 Maintenance during operation

Good supervision of operation is ascertained by close observation of the compressor while it is operating, of the correctly operating measuring instruments and controlling devices and by continuous and regular registration of measured values.

We recommend to register and record measured values stating date and time:

- Any start-up
- Any shutdown
- Any overhaul, repair, revision
- Any cleaning of filters and coolers
- Operating data

The subsequent maintenance plan is to be regarded as recommendation, as binding maintenance plans have to reflect factory-specific requirements. Therefore, they should be set up by the plant user.

D 4.1 Maintenance schedule during operation

CAUTION

Should deviations from normal operation be detected in the course of the daily centrifugal compressor check-ups, corrective action must be taken immediately. Depending on the nature of the deviation we recommend to contact expert staff or the AC Service personnel.

Maintenance work	by	when				
Functional test of safety devices	W	In regular intervals, e.g. to the regulations for the prevention of and after modifications or inspections				
		every 4 hours	daily	monthly	annually	every 2 years
Check function of control mechanism (IGV/DGV)				X		
Register operating data	B	X				
Check oil level (oil tanks) **	B		X			
Check oil supply motor*	B		X			
Check oil filter for fouling	B		X			
Drain water and foam from oil tank	B		X			
Check condensate trap, drain condensate (unless done automatically)	B		X			
Check centrifugal compressor for irregular noise, loose screw and cable connections, etc.	B		X			
Check plant for gas, water and oil leakage	B		X			
Oil inspection.	B	according to lubrication schedule				
Compare thermodynamic data	AC				X	
Inspect plant	AC					X

AC = AC personnel, B = customer experts, W = maintenance staff
* For further information refer to sub-suppliers manuals
**If the oil level in the oil tank increases, the oil cooler must be check for cooling water leakage

For more detailed information on lubricants to be used and detailed preventive maintenance, refer also to chapter „Maintenance“ and “Workstandards”.

D 5 Operating instructions

The subsequent instructions include the prerequisites and the sequence of activities required for the provided operating mode.

Listed operating modes and starting sequences are to be regarded as examples; they may be used as basis for job-specific procedures.

WARNING

Danger by faulty operation

Whenever the control system is provided by the customer, the specified alarms and trips must be considered.

Whenever the centrifugal compressor will be operated at different operating modes which require different activities for operation, the customer shall be obliged to describe these operating modes on his own in the following chapters.

The operating instructions have to be completed by an operating concept and a detailed description of all operating modes.

D 5.1 Auxiliaries

The following description includes all steps required for operation of all auxiliaries which can be started and stopped individually and independently.

We recommend to use the following symbols to define the locations of action:
Explanation of symbols:

(öS) = local control panel (W) = control room, (M) = on machine, (S) = control board

(?) = not defined or optionally useable

D 5.1.1 Cooling water system

Start-up

Target:
To supply the gas and oil coolers and the motor (if necessary) with the required amount of cooling water.

Prerequisites:	**Status:**
Cooling water	available
Cooling water supply/return pipe	open

Action to be carried out:

Cooling water supply	
Pumps	switch ON
Shut-off devices	open, if any

Result:

The required amount of cooling water is being supplied to gas and oil cooler and the motor.

Measuring place/signal	Value
Cooling water pressure and flow	≥ alarm value if applicable, normally not provided!

Shutdown

Target:
Shut down the cooling water supply. After this has been accomplished, the compressor cannot be re-started.

Prerequisites:	**Status:**
Compressor	standing still, should not be re-started

Action to be carried out:

Cooling water supply	switch OFF

Result:

The supply of cooling water is being interrupted.

Measuring place/signal	Value
Cooling water pressure and flow	≥ alarm value, if applicable

D 5.1.2 Lubricating oil system

Start-up

Target:

After the lubricating oil system has been started up, all bearing places and gears are supposed to be supplied the amount of oil required for lubrication.

The oil is supplied by the auxiliary oil pump, until the compressor has reached its operating speed. Oil cooling is effected in the oil cooler, cleaning in the oil filter.

Prerequisites:	**Status:**
Compressor	standing still
Oil tank	filled
Oil tank	drained of water
Cooling water supply/outlet pipe, if required	open
Main switch	ON

Action to be carried out:

Oil demister	switch ON
Oil heating	switch ON
Auxiliary oil pump	switch ON

On actuation of the main switch, the oil heating and the oil demister may be automatically started.

Results:

The lubricating oil system is now supplying oil to all bearings and gears.

Measuring place/signal	Value
Oil pressure	> alarm value

Shutdown

Target:

Shut down the lubricating oil system. The supply of oil to bearing places and gears is interrupted. The compressor cannot be started up.

Prerequisites:	**Status:**
Compressor	is standing still, should not be re-started
Auxiliary oil pump	re-lubricating time has elapsed

Action to be carried out:	
Auxiliary oil pump	switch OFF
Oil heating	switch OFF
Oil demister	switch OFF

Result:

The lubricating oil supply is being interrupted.

Measuring place/signal	Value
Oil pressure	< alarm value

To keep the compressor in ready-for-operation-state, the lubricating oil system should be left on stand-by.

D 5.2 Compressor

D 5.2.1 Start-up

Target:

After start-up, the compressor will deliver process gas to the consumer. Until process gas is delivered into the process, the compressor will be operated in blow-off mode.

In case of automatic start-up:

WARNING

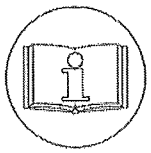
Prior to automatic start-up

May lead to lethal injuries.

Turbomachinery provided with a remote start-up option must be equipped with a signal to indicate readiness for machine start-up. Such machinery may be started up at any time. Leave the hazardous area at once.

Prerequisites:	Status
Plant-side shut-off devices	open
Condensate	drained
Suction flap	open *
Discharge flap	open *
Oil system	operating
Oil level	above minimum level (at sight glass)
Oil pressure	> alarm value
Oil temperature	in between alarm values
Diffuser/ Inlet guide vanes	min. position
Bypass valve	open
Coastdown time	elapsed
Trips	none

- *) If any. Basic position: closed. These two flaps must be opened immediately prior to compressor start-up, unless this is effected automatically during start-up. Normally equipped with spring-loaded non-return flap.



E-motors must only be commissioned in strict compliance with the corresponding instructions issued by the motor manufacturer.

Never re-start electric motors during coastdown.

Observe the number of permissible start-ups per hour and year applicable to electric motors.

Action to be carried out:

Compressor	start up

Now, the following action is supposed to be triggered automatically :

- Vibration alarms	The alarm value will be inactivated for 60 seconds. There is no trip during this time
- Suction flap	is opened
- Discharge flap/bypass valve	is opened

Only then will the motor be started.

- Maximum compressor run-up time is 30 seconds. During this time, the auxiliary oil pump cannot be manually stopped.
- The compressor can be started up in the presence of alarms, not, however, in the presence of trips.

Result:

Process gas will be blown off the recycle line.

D 5.2.2 Operation:

Target:

After compressor start-up, the process gas is to be compressed to the required discharge pressure and then to be delivered to the consumer.

Prerequisites:	Status
Compressor	started
Suction pressure	> alarm value
Piping	checked for tightness
Operating behaviour (noise, etc.)	normal
Auxiliary oil pump after approx. 30 seconds	shut off
Vibration monitoring equipment	adjusted to normal operation

The compressor has been adjusted to the desired operating point (e.g. by means of adjusting the inlet and diffuser guide vanes and by closing the bypass valve).

Whenever the oil pressure falls below the alarm value, the auxiliary oil pump is started. It must be stopped manually after the interference has been eliminated. The compressor is tripped, whenever the oil pressure falls below the trip value.

Result:

The compressor is now building up the required discharge pressure and is delivering process gas to the consumer.

- **Alarms**

Various alarm functions are provided in the turbino machinery plant. Whenever one of the set alarm values is exceeded or fallen below, an alarm message is triggered (see set point list in the annex). Action for remedy must be taken, refer to chapter "Possible faults, causes and correction".

CAUTION

Danger of severe damage to the turbo machine

Whenever turbo machinery has been tripped on account of high shaft vibrations, it may only be re-started, after the reason for the trip has been found and assessed to be non-hazardous by expert staff. The company senior must be informed prior to any re-start.

Potential reasons for such trips might be:

- Measurement errors,
- Surging (of compressors),
- Instantaneous unbalance or
- Severe damage to the rotor,

Refer to the end of the chapter.

If it turns out to be impossible to find the reason for the trip, we recommend to inspect the turbine.

- **Trips**

Trips will directly shut the compressor down. For the associated set points refer to the list of set point.

The reasons for trips must be eliminated prior to re-starting the compressor.

Operation during Winter

We recommend that you protect your plant against frost. Any required trace heater for water pipes, measuring pipes, instruments etc. must be installed by the customer.

D 5.2.3 Shutdown

Target:

After compressor shutdown, an immediate re-start is not scheduled.

Prerequisites:	Status:
Consumer	no demand for process gas

Action to be carried out:

Compressor	switch OFF

If it is planned to immediately re-start the compressor, the shutdown procedure must be immediately cancelled. Remember to consider the coastdown time of the motor for any re-start.

Auxiliary oil pump	switch OFF (after 60 minutes)
Main switch	OFF (after standstill of auxiliary oil pump)
Shut-off valves	close (if applicable)

The following sequences are effected automatically:

Auxiliary oil pump	is switched ON for 60 minutes
Diffuser / inlet guide vanes	are closed
Bypass valve	is opened
Re-start	is interlocked (during the coastdown time)

It is prohibited to shut the auxiliary oil pump down during the re-lubricating time of 60 minutes.

Result:

The compressor is standing still. The auxiliary devices are out of operation.

CAUTION

Overly frequent starts of the driver motor will lead to damage.

- Comply with the permissible number of starts per hour and year.

CAUTION

If the emergency off is actuated the main switch is adjusted to „0", the compressor is immediately shut down. The auxiliary devices are in stand-by modus.

During commissioning, the EMERGENCY STOP function is tested after which the counter is reset to zero.

After the turbomachine has been tripped eight times via EMERGENCY STOP during operation, the gearbox and the bearings have to be inspected (see chapter Commissioning) to see whether the trips and the resulting lack of lubricating oil have led to signs of wear.

If the inspection shows that neither gears nor bearings have suffered any damage, these parts can be further used and the EMERGENCY STOP counter starts again at zero.

Any subsequent re-starting sequence will be initiated by starting the lubricating oil system.

D 6 Shut-down for a longer period of time

If it is planned to shut the plant down for a longer period of time, please observe instructions for normal shut-down for conservation.

The plant must be re-started as described in section "Preparing for first start-up".

D 7 Possible faults, causes and correction

Various trip functions are provided in the turbo machinery plant. In the event of any of the trip criteria being exceeded in the respective direction, the plant is shut down automatically.

Several instrument points are equipped to actuate an alarm signal in advance of the trip point being reached. This permits early recognition of an imminent fault condition or malfunction, making it possible in many instances to intervene positively in the control process and restore the compressor plant to normal operating conditions and thus avoid shutdown.

Additional help is afforded by the following troubleshooting chart, which assists quick and reliable location of the cause of compressor tripping and any defective parts. Beyond that, the originally stable operation of the compressor might change due to other, external influences. In such an instance, vibration measurements should be made immediately. This often enables the cause of vibration to be ascertained in its early phase, this again preventing the occurrences of any more serious damage to the machine.

Depending on the scope of supply some of the following items are not installed in your machine..

WARNING

Prior to automatic start-up.

May lead to lethal injuries.

Removal of faults only after the compressor had been stopped and secured against restart.

Fault	Possible cause	Elimination	By *)	Note
*) AC = AC staff	B = expert customer staff		W = maintenance staff	
Oil pressure too low	Oil temperature too high	Check fan	W	only possible if oil cooler is air-cooled
		Increase oil cooler water throughput or clean oil cooler	B	Only possible, if oil cooler is water-cooled
	Oil filter fouled	Replace filter cartridge	W	Change over oil filter before (if dual filter is installed)
	Pressure gauge defective	Replace pressure gauge	W	Check against pressure indicator
	Leaky oil pipe	Eliminate leakage	W	
	Use of wrong oil	Use specified oil	W	
	Spill valve defective	Replace spill valve	B	
	Oil pump failed	Clean and repair pump	B	
	Excessive bearing clearance	Replace bearing	AC	
Oil level in tank too low	Leaky oil pipe	Check all pipes, eliminate leakage	W	
	Oil cooler defective	Remove cooler bundle, if possible, and pressure-test	W	Only if oil cooler is water-cooled
		Replace oil cooler	W	
	Level switch defective	Check level switch	W	
Bearing temperature too high	Filter fouled	Change over filter and clean fouled filter cartridge.	W	
	Change in water supply temperature	Increase water flow rate to oil cooler. If unsuccessful, inspect oil cooler	W	
	Temperature probe defective	Replace	W	If applicable
	Cooling water controller defective	Repair or replace controller.	W	If applicable

Fault	Possible cause	Elimination	By *)	Note
*) AC = AC staff	B = expert customer staff		W = maintenance staff	
	Oil temperature controller defective	Repair or replace controller.	W	
	Oil system incorrect	Check oil system	W	
	Bearing damaged	Remove and replace bearing	AC	
Suction temperatures in any stage too high	Climatically induced	-	-	Contact AC staff to review operating conditions
	Insufficient interstage cooling	Increase water throughput. If valve is open, check water inlet temperature. If okay, check cooler and clean if necessary.	W	
	Measuring sensor defective	Replace	W	
Suction flow too low	Suction temperature too high	-	-	See suction temperature too high
	Suction filter fouled	Clean or replace suction filter	W	
	Suction pipe and controlling devices highly contaminated	Clean suction pipes and controlling devices	W	
	High internal and external leakage losses	Check, then eliminate internal and external leakage	AC	
	Guide vanes misadjusted	Check adjusting mechanism and auxiliary energy. Check setting.	AC	
	Impeller contaminated	Engage water wash system. Remove rotor, clean impeller, then check rotor balancing state and re-install	B/W	if any

Fault	Possible cause	Elimination	By *)	Note
*) AC = AC staff	B = expert customer staff		W = maintenance staff	
Centrifugal compressor discharge pressure too low	Flow supplied to process too high	Reduce demand	B	Centrifugal compressor has reached its capacity limit
	Discharge pressure controller defective	Check transmitter and/ or PLC	AC	
	Suction flow drops	Check inlet guide vanes or diffuser guide vanes and their setting	AC	
	Guide vanes changed position on their own	Check adjusting mechanism and auxiliary energy. Check setting	AC	
Centrifugal compressor discharge temperature too high	Suction temperature increased		-	Refer to item: suction temperature in any stage too high
	Thermometer defective	Change thermometer	W	
	Impeller contaminated	Engage water wash system. Remove rotor, clean impeller and check rotor balancing state. If necessary, install spare rotor	AC	If any
Vibration and noise level too high	Coupling worn	Replace wear parts	W	
	Coupling misaligned	Re-align coupling	AC	
	-	Vibration analysis, determine frequency and amplitude	AC	
	Driver operation rocky	Vibration analysis, check driver	AC	
	Mechanical unbalance of driver	Re-balance rotor	-	Contact driver supplier
	Magnetic unbalance of driver		-	Contact driver supplier

Fault	Possible cause	Elimination	By *)	Note
*) AC = AC staff	B = expert customer staff		W = maintenance staff	
Vibration and noise level too high	Compressor/gear and/or plant misaligned	Check foundation. Then re-align centrifugal compressor and plant.	AC	
	Bearings damaged	Remove bearings and install spare bearings	AC	
	Impeller contaminated	Engage water wash system. Remove rotor, clean impeller and check rotor balancing state. If necessary, install spare rotor.	AC	If any
	Gears damaged	install spare wheel, if necessary	AC	
	Foundation vibrating	Foundation calculation to be checked		AC/Engineering company
Centrifugal compressor surging	Control system defective	Check controlling devices and auxiliary energy	AC	
	Blow-off or bypass valve defective	Check valve, replace if necessary	W	
Centrifugal compressor reverses	Non-return valve failure	Close discharge valve in gas pipe. Check non-return valve, replace, if necessary.	W	If any
Auxiliary oil pump running	Main oil pump failure	Clean and repair pump.	W	
	Wrong setting of oil pressure control valve	Correct settings	W	