INSTRUMENT/ PLANT AIR SYSTEM

1. General

A compressed air system may consist essentially of one or more compressors with a power source, control system, intake air filter, aftercooler and separator, air receiver, air dryer, and inter connecting piping, plus a distribution system to carry the air to points of application.

Atmospheric Air is sucked by air Compressor which basically contains water vapor & dust. Besides, in lubricated type Air Compressors, oil is present in the air compression chamber, traces of which are present, in compressed air in Liquid / Vapor form, which condenses into a heavy gummy oil varnish.

Condensed moisture together with dust and oil in compressed air leads to emulsion formation causing following troubles:

- Formation of rust & scale, clogging orifices, resulting in malfunctioning of tools, controls & instruments.
- Freezing in air lines causes malfunctions & damages to process Equipments.
- Increased resistance to flow.
- By corrosion of air or gas the instruments can give false reading disrupting product quality.
- Rust & scale contaminates products when compressed air is used in mixing and processing.
- Bubbling effect in spray painted / Powder coated items.
- Sluggish operation of pneumatic equipments.

The object of installing a compressed air system shall be to provide air to the various points of application in sufficient quantity and quality and with adequate pressure for efficient operation of air tools or other pneumatic devices.

The total air requirement is the sum of the plant air and instrument air inclusive of contingency for each category.

1.1 Plant Air

The plant air requirements should not be designed for coincident operation. Optimum schedule for overhaul, regeneration, decoking, etc. shall be considered when arriving at the total capacity of the complex.

Plant air consumption is intermittent and difficult to estimate at early project stages.

For initial estimate add 130-170 Sm^3/h to compressor capacity.

2. Instrument Air Quality and Quantity [1]

The instrument air shall be dust-free, oil-free and dry.

To prevent condensation in the supply piping or in the instruments, the dew point of the air at operating pressure after drier shall always be at least 10°C lower than the lowest ambient temperature ever recorded in the area (Fig. 1.).

Under normal operation the instrument air shall have a pressure of at least 8 barg in the buffer vessel, and a pressure of 7 barg in the supply piping.

The required quantity of instrument air shall be estimated as accurately as possible, taking into account the requirements for:

- Pneumatically operated instrumentation, based on the data stated by the manufacturers or suppliers of such equipment.
- Pressurizing the enclosures of electrical instruments located in hazardous areas.
- Continuous dilution for enclosures of process stream analyzers, etc.
- Regeneration of air drier, especially for heatless type as the required quantity is about 15-20% of drier outlet.

The consumption thus obtained shall be multiplied by 1.3 to account for uncertainties in the data used for the estimate and for the installation of additional instruments during the first years of plant operation.

The total air requirement for pneumatic devices should not be the total of the individual maximum requirement but the sum of the average air consumption of each.

Sufficient air storage to meet short-term high demands should also be available.

Determination of the average air consumption is faciliated by the use of the concept of the load factor.

The ratio of actual air consumption to the maximum continuous full-load air consumption, each measured in cubic meter of air per hour, is known as the load factor.

The instrument air requirement customarily, should be considered about 1.6 Sm3/h of dry air for each instrument pilot in process units.

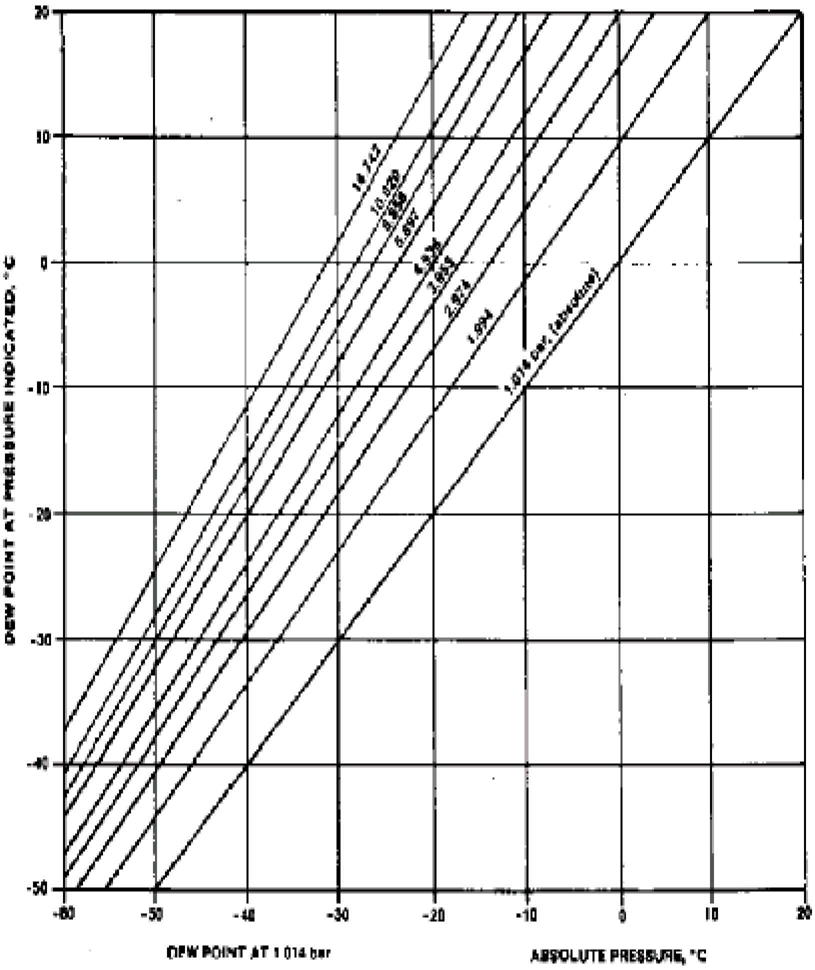


Fig. 1) Change In Dew Point-Conversion Chart (Metric Units)

Table 1 represents a typical air requirement for various instruments.

Table 1) Air Requirement Of Various Instruments At Steady State Conditions

a) Normal pneumatic actuated control valve with diaphragm actuator operating on 20-100 kPa (0.2-1.0 bar) signal.

If fitted with pneumatic positioner: 0.4 Sm3/h.

If fitted with electro-pneumatic positioner: 0.49 Sm3/h.

b) Normal pneumatic actuated control valve with diaphragm actuator operating on 40-200 kPa (0.4-2.0 bar) signal.

If fitted with pneumatic positioner: 0.57 Sm3/h.

If fitted with electro-pneumatic positioner: 0.68 Sm3/h.

c) Under steady state conditions an on/off valve would not use any air, when the valve is operated the volume of air used will be equal to (diaphragm area × valve stroke).

d) I/P converter: 0.22 Sm3/h.

3. Air Supply Plant

An instrument air supply plant shall be provided, comprising:

- Compressors
- Buffer vessel
- Air drier

In addition, independent facilities may be required to ensure the continuation of instrument air supply to the utility supply plants and/or essential process instrumentation in emergency cases.

These facilities shall then comprise an automatically starting emergency compressor with associated buffer vessel and air drier.

The air supply plant shall be located in a non-hazardous area.
All piping interconnecting the compressors, buffer vessel and air drier shall be so arranged that each major piece of equipment can be taken out of operation without interrupting the air supply.
In cold climates this piping as well as the bottom part of the buffer vessel, shall be heat traced and insulated [1].

The piping between the compressor discharge, buffer vessel and drier inlet shall have automatic condensate draining facilities at all low points.
A by-pass line with an automatic pressure control valve shall be installed between the inlet and the outlet of the air drier. The valve shall open at a low downstream pressure, e.g. 5 barg, and shall have a valve position switch which shall initiate an alarm on the main panel when the valve starts to open.
The main air supply line shall be provided with a flow measuring element and on the main panel a pressure recorder and a low-pressure alarm.

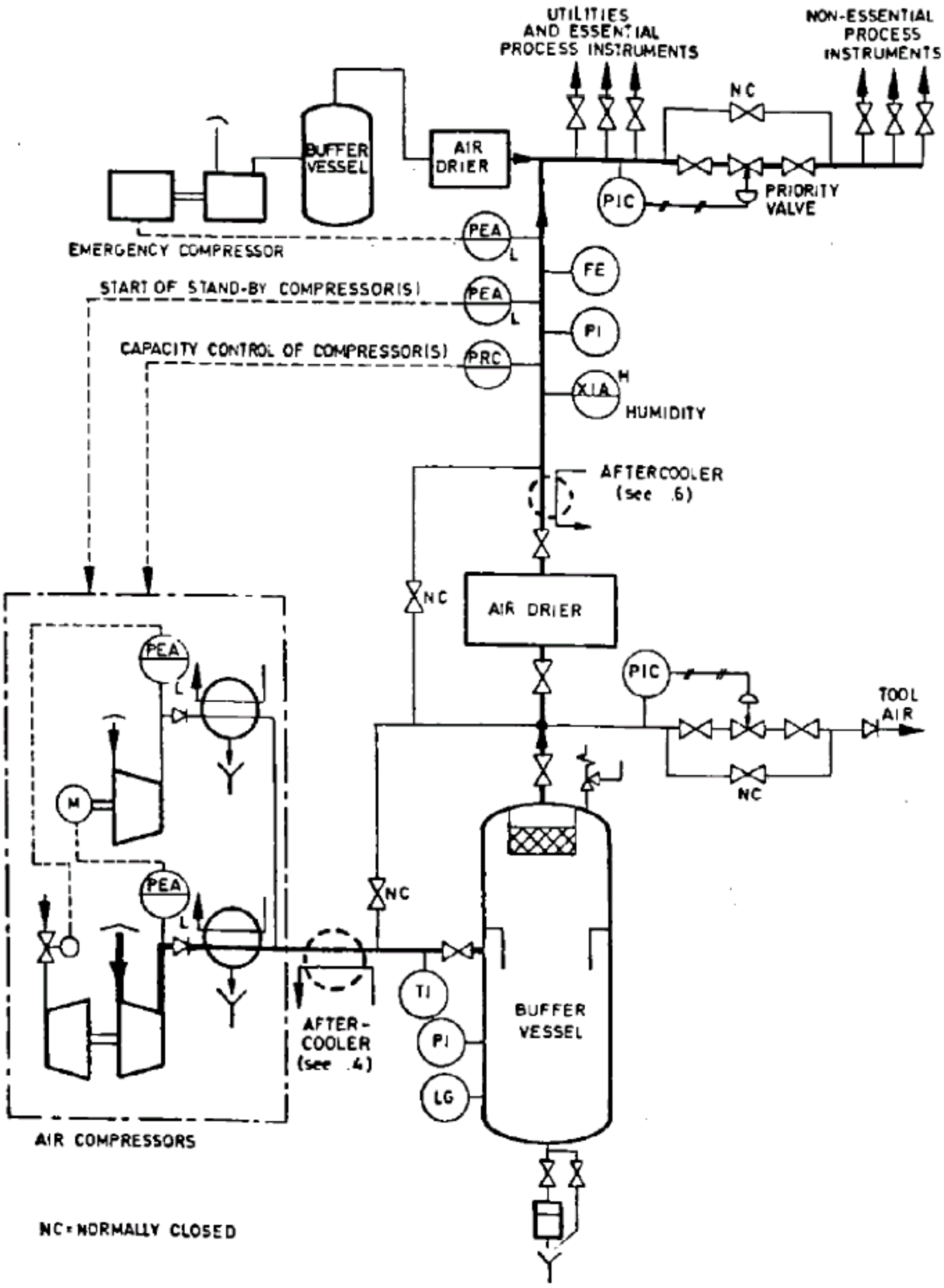


FIG. 2) TYPICAL AIR SUPPLY PLANT

The humidity shall be measured with a water-content analyzer of the lithium chloride type (or equivalent), with a local indication and with a high-humidity alarm on the main panel.

Safety/relief valves shall be provided when required by statutory regulations and/or by the relation between maximum compressor discharge pressure and the maximum allowable working pressure of vessels and piping.

4. Air Compressors

To ensure maximum reliability of the instrument air supply, at least two compressors shall be installed. Each compressor shall be arranged for normal operation and for stand-by, and shall be capable of supplying the designed quantity of instrument air, plus the required quantity of plant air, and, if applicable, the required quantity of regeneration air.

Where it is essential to have stand-by also if one of the two compressors is not operational, e.g. because of repairs or maintenance, the installation of a third compressor shall be considered.

The installation of more than two compressors may also be considered for other reasons, e.g. where the fluctuations in air consumption are greater than the range ability of one compressor, or where purchasing and maintaining a number of compressors each with relatively low capacity is more attractive than a (small) number of compressors each with relatively large capacity.

In any case, the total capacity of the compressors driven by the most reliable utility shall be sufficient to supply the design quantity of instrument air.

Note:

In addition to the above compressors for normal plant operation, an independent emergency air compressor may be required.

4.1 Selecting the size and number of compressors

In sizing and number of compressors, the following features shall be considered:

1) Total actual air requirement;

2) Estimated leakage of the air system;

3) Spare & operational philosophy;

4) Criticality of air supply;

5) Energy management;

6) Optimum size based on market availability.

Air compressors of the rotary design usually require less downtime and should be considered when making selection.

Air leakage of the compressed air system, customarily should be considered about 10 percent to the estimated amount of consumption.

4.2 Non lubricated air compressors

Reciprocating, nonlubricated air compressors substitute low friction or self lubricating materials such as carbon or Teflon for piston and packing rings, where the piston is usually supported on wear rings of similar materials.

Oil free rotary screw and lobe-type compressors are available, having a design that does not require lubrication in the compression chamber for sealing and lubrication.

Centrifugal air compressors are inherently nonlubricated due to their configuration.

Generally, nonlubricated compressors have a higher initial cost due to the special design and materials.

Nonlubricated reciprocating air compressors also tend to have higher operating costs due to higher maintenance cost associated with shorter valve and ring life.

4.3 Compressor selection

Compressor selection shall be as per CHAGALESH Standard, "Process Design of Compressors".

4.4 Compressor Specification

The compressor shall be of the dry type cylinder and shall supply oil-free air, and be complete with non-return valves, intercoolers, after coolers, condensate draining facilities, etc.

The compressors and their drives shall satisfy the requirements for running equipment as specified by the user.

Electric motors shall be suitable for installation in a non-hazardous area.

4.5 Compressor Controls

Each compressor shall have facilities for manual and automatic starting in the case of failure of the other compressor(s).

The automatic starting system shall be so arranged that stopping of a compressor is only possible by manual control.

Automatic starting of the stand-by compressor(s) shall be as quick as possible; in addition to an initiator on the piping downstream of the air drier. Initiators shall be provided at each compressor discharge upstream of the non-return valve and/or on the compressor oil system. Starting of each stand-by compressor shall be indicated by an alarm on the main panel.

The electric motor(s) shall have local start /stop controls and be protected against repetitive starting. Electric controls supplied as integral parts of the compressor, as for oil filter, oil pump, oil heater, shall be interlocked with the start/stop controls and shall be located in a weatherproof housing on, or close to, the compressor.

4.6 Compressor Piping

The inlet of the compressors shall be so located that the instrument air is free from toxic, obnoxious or flammable gases, and is free from dust.

The inlet opening shall be fitted with a wire mesh cage. The cage shall be of adequate size to prevent flying papers, etc., from completely blocking the compressor inlet; the wire mesh shall be adequate to prevent flying objects from entering the compressor and to prevent plugging by frost or hoar-frost.

Where the compressor inlet cannot be located in a completely dust-free area, consideration may be given to dust filters in the inlet piping.

To reduce the load on the air drier, the air from the compressors shall be cooled to a temperature of 5 to 10°C above the cooling medium inlet temperature. Where the after coolers supplied as an integral part of the compressors are suspected of having only marginal capacity, the installation of additional after coolers shall be considered.

5 Air storage (air receiver)

The receiver serves several important functions. It damps pulsations from the discharge line, resulting in essentially steady pressure in the system. It serves as a reservoir to take care of sudden or unusually heavy demands in excess of compressor capacity. It prevents too frequent loading and unloading of the compressor. In addition, it serves to precipitate some of the moisture that may be present in the air, as it comes from the compressor or that may be carried over from the aftercooler.

The horizontal receiver should be so sloped that the collected water in the receiver moves toward the pot under the receiver for better drainage. The slope should be 2 mm/m.

The time interval which receiver can supply air without excessive drop in pressure shall be found from the equation:

$$T = V\frac{P_1 - P_2}{C\,P_0} \qquad (1\text{-}1)$$

T	time	hr
P_1	initial receiver pressure	kPa (ga)
P_2	final pressure	kPa (ga)
P_0	atmospheric pressure	kPa (abs)
C	air requirement	Sm^3/hr
V	receiver capacity	m^3

This equation assumes that the temperature of the receiver is constant at standard atmospheric temperature and that P_0 is standard atmospheric pressure. It also assumes that no air is supplied to the receiver during the time interval. If air is being supplied steadily to the receiver at a rate of S cubic meters of free air per hour, then C in the equation should be replaced by C minus S.

The buffer vessel shall be sized to maintain the air supply between the moments of compressor failure caused by mechanical failure of one compressor or failure of one utility supply for the compressor(s) normally in operation, and the moment that the stand-by compressor(s) is or are operating.

The period between these moments shall be taken as the time required for starting the stand-by compressor(s) manually if automatic starting is unsuccessful, and shall be determined by plant operations in connection with mechanical engineering and utility engineering, but shall be at least (15) minutes.

During this period, the instrument air pressure shall not drop below the minimum value required for proper operation of the instruments (especially control valves) and other services depending on instrument air. This minimum pressure can usually be taken as (3.0 barg), but may be higher for some special cases.

Note:

The sizing of the air receiver shall be based on the design quantity of instrument air consumption for the period required to bring the emergency compressor into service. The minimum of 15 min. should be selected if not time period specified for this purpose. The capacity should also be sufficient for condensate collection and removal [1].

Alternatively, consideration may be given to bottled high-pressure air or nitrogen as emergency supply for such equipment.

The sizing of the buffer vessel shall be based on the design quantity of instrument air, plus the plant air consumption until the safeguarding device closes.

The buffer vessel shall have automatic draining facilities. The wall thickness shall have a 3 mm corrosion allowance, and the lower part of the vessel shall be provided internally with a protective coating.

The vessel shall be installed between the compressors and the drier. Where limited space makes it impossible to install the buffer vessel in this place, part of the required buffer volume may be located downstream of the drier, provided the buffer vessel between compressor and drier remains of sufficient size for condensate separation.

6. Air Drier

This equipment will dry compressed air having 100% relative humidity to the stipulated dew point, and shall be durable for continuous operation under the specified pressure, humidity and flow rate. The design dew point for instrument air shall be more than 10°C below the lowest recorded outside temperature under the line pressure. The design dew point for plant air shall be of lowest ambient recorded outside temperature under the line pressure.

Compressed air may be dried by [2]:

1) Absorption;

2) Adsorption;

3) Compression;

4) Cooling;

5) Combination of compression and cooling.

The air drier shall normally be of the twin-vessel adsorption type with regeneration. Switching of the vessels shall be either manual or automatic.

The air drier shall have a sight glass for indication of outlet air humidity.

The selected methods of drying, regeneration and switching are usually specified by the user; where this has not been done the contractor shall submit a proposal for approval by the user.

6.1 The Desiccant

The desiccant shall normally be activated alumina or silica gel or molecular sieve in beaded form. When silica-gel is used, a bottom layer (approx. 10%) of activated alumina shall be provided to achieve a better resistance to entrained water. The quantity of desiccant shall be such that adequate drying capacity is still available after the desiccant activity has deteriorated.

The continuous operating time of one desiccant drum shall not be less than 8 hours under the specified conditions. However, based on ultimate life and other parameters, the operating time shall be optimized.

The dryer has two desiccant drums, regeneration equipment, instrumentation, piping and other accessories. While one desiccant drum is being operated, the other drum will be automatically regenerated.

When using an electric heater for regeneration integrated into the desiccant drum, this heater shall be capable of being maintained without affecting dryer operation.

6.2 Regeneration

The regeneration for heater type drier shall be at elevated temperature either at atmospheric pressure or at operating pressure.

Regeneration for heatless air drier shall be at ambient temperature and atmospheric pressure.

The heat required for regeneration shall be supplied by electric heaters or steam heaters.

Notes:

1) When selecting electric heaters, it should be realized that these are large consumers of electric energy (approximately 30 kW for a drier of 0.5 m3/s capacity at 15°C and 1.013 bar abs.), and this power must be available from emergency generators during prolonged power failures, e.g. for more than 1 hour.

2) Heatless regeneration is preferable (See fig. 3).

Steam heaters shall be of good mechanical construction to avoid leakage into the desiccant vessel.

For regeneration of heater type drier at atmospheric pressure the water vapor is removed by means of air which can either be taken from the outlet of the drier (2-3 wt %) or be provided by a separate blower; see fig. 4.

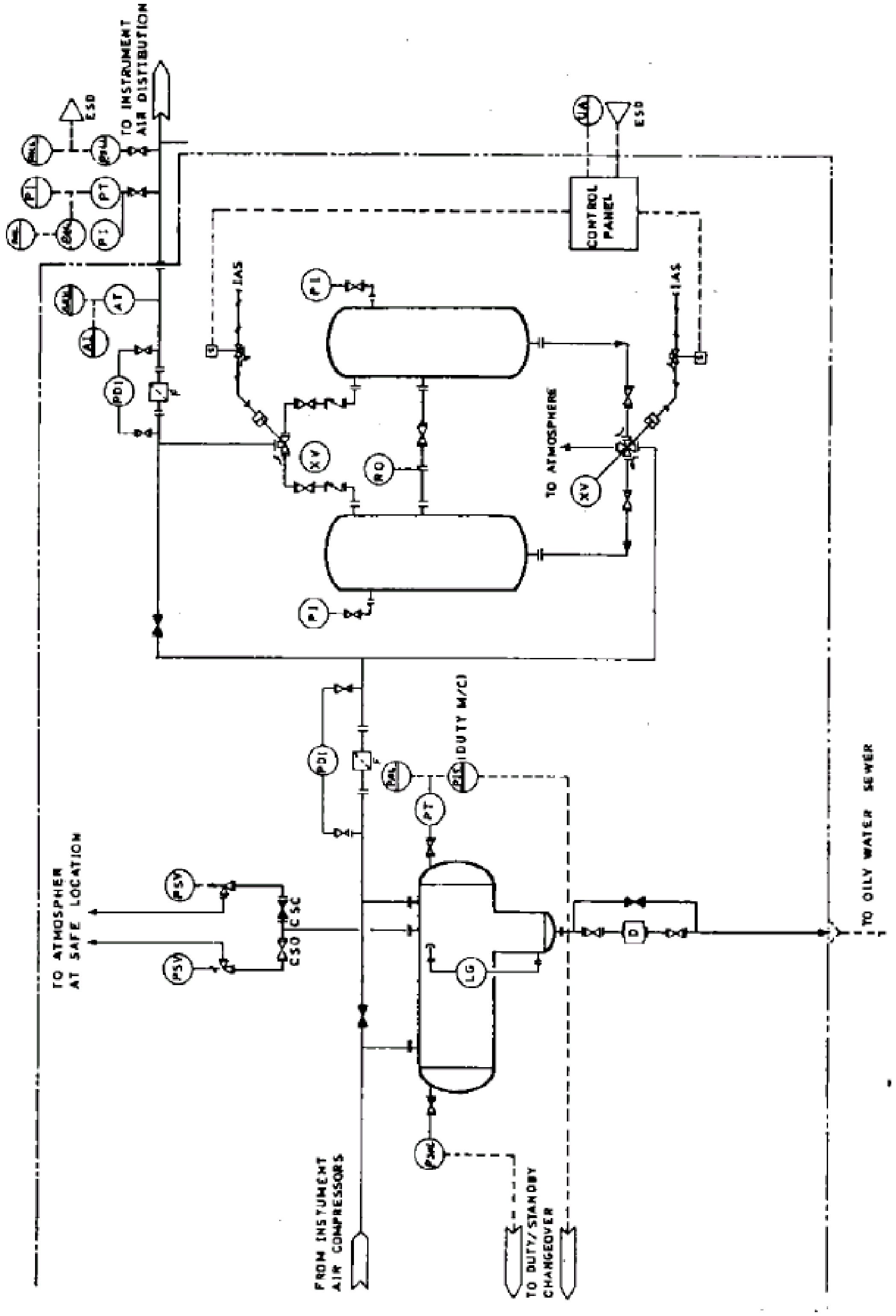


Fig. 3) typical Drier With Heatless Regeneration

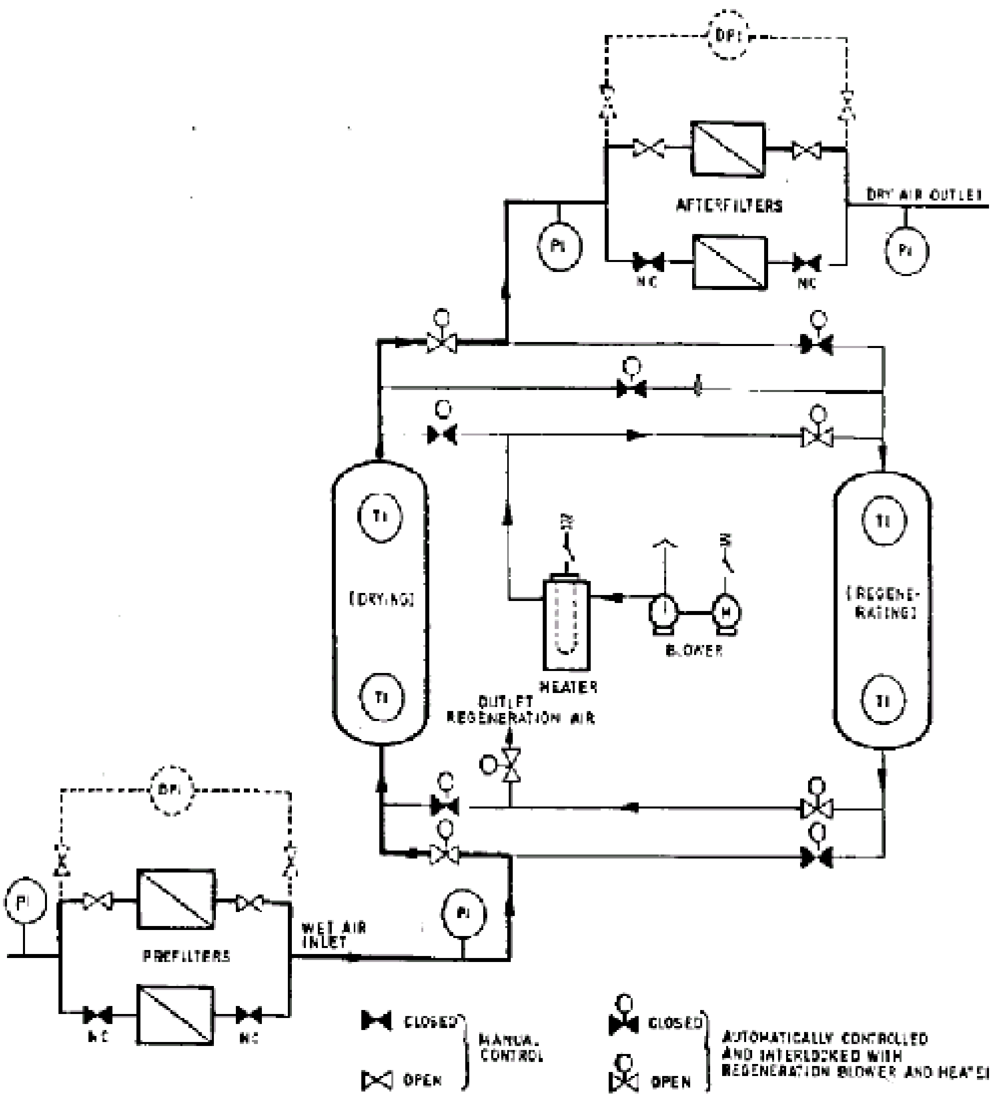


Fig.4)Typical Drier With Regeneration At Elevated Temperature And Atmospheric Pressure

Where separate blower is used, the heater shall be external to the vessel; otherwise each vessel may be internally heated.

Where internal electric heaters are applied, these should preferably be removable during operation of the drier.

Where regeneration at atmospheric pressure is used, the vessel shall be depressurized slowly to prevent blowing out and/or fragmentation of the desiccant and to reduce exhaust noise. After the desiccant has been regenerated, the vessel shall be pressurized slowly before switch-over.

For regeneration of heater type drier at operating pressure, the regeneration air is taken upstream of a restriction in the drier inlet piping, heated by an electric or steam heater, passed through the desiccant to be regenerated, cooled and (after separation of condensed water) returned to the drier inlet piping downstream of the restriction (see fig. 5).

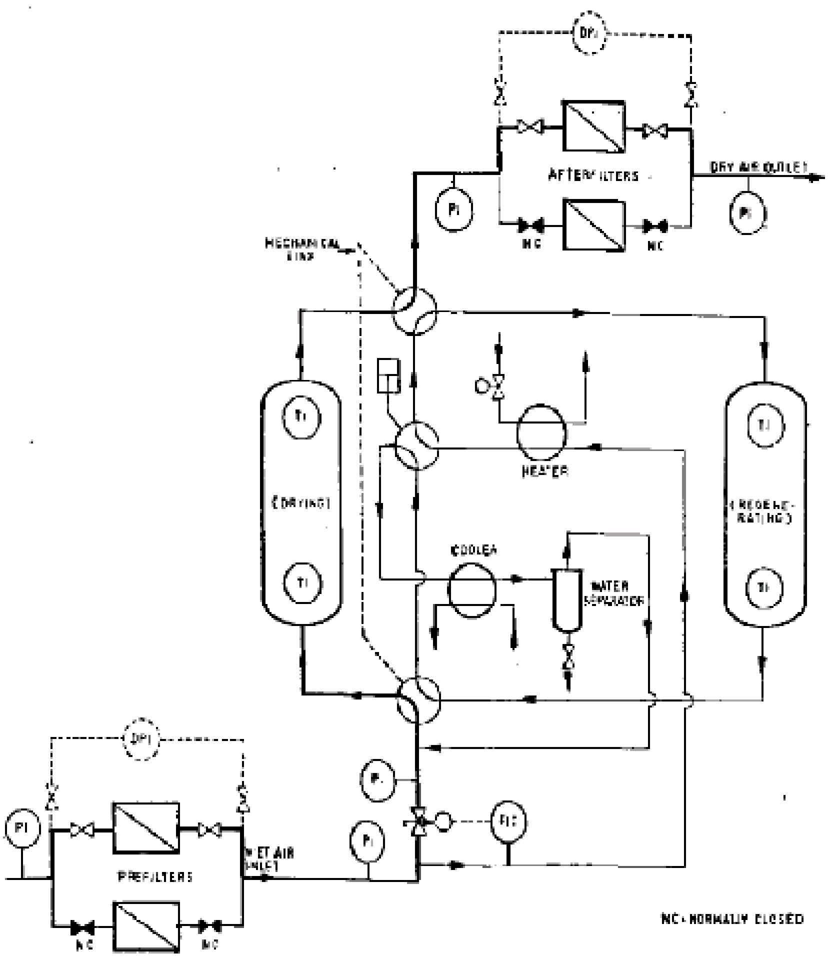


Fig. 5) Typical Drier With Regeneration At Elevated Temperature And Operating Pressure

Cooler and water separator shall be adequately sized. Quantity control for the regeneration air shall be by means of a local flow indicating controller with low-flow interlock on the heater and a pneumatically operated control valve with mechanical limit stop.

After the desiccant has been regenerated, it shall be cooled by a flow of cold air (For heater type only).

For regeneration of heatless type drier, the water vapor is removed by means of air which shall be taken from the outlet of drier (15-20 wt% as purge air to desorb the desiccant and carry the moisture to atmosphere).

6.3 Filters

An air prefilter with a drain trap shall be installed at the entrance of the desiccant drum.

An air after-filter with a drain valve shall be installed at the exit of the dryer system.

For the desiccant type dryer, the filter mesh shall be less than 3 micrometers (microns).

Measures shall be provided so that the flow of air will not stop even in the case of replacement or cleaning of the filter elements.

All filters shall be in duplicate and have isolating valves.

6.4 After cooler (For heater type only)

Because of the adsorption heat generated during the drying cycle, the outlet temperature of the drier may rise to 60°C. If the air cannot cool down to approximately 40°C before reaching the consumers, an after cooler shall be installed.

6.5 Instrumentation

Operation control of the dryer shall be fully automatic control. Switching valves should not block the air flow in their failure unless an automatic back-up bypass valve across the dryer is installed.

Control panels shall be provided as follows:

a) A local control panel for the air dryer shall be employed;

b) The control panel shall be equipped with necessary instrument for monitoring operation of the air dryer.

6.6 Drier Specification

The specification of the drier shall contain all data necessary to ensure the supply of a suitable unit. Wherever possible a construction in accordance with the manufacturer's standard should be accepted.

The following characteristics shall be guaranteed:

- Inlet/outlet air flow rate.
- Dew point of outlet air.
- Drying and regeneration cycle time.
- Pressure drop through the dryer including air filters.

7 Calculation

7.1 Compressor capacity

The air compressor capacity is summation of plant air+wet air for instrument air.

10 percent over design shall be added to compressor capacity for air leakage of the compressed air system.

7.1.1 Plant air

Please refer to item 1.1

7.1.2 Instrument air

The required instrument air shall be determined by instrument Department.

Process department also can estimate the required instrument air by considering table 1.

The consumption thus obtained above shall be multiplied by 1.3 to account for uncertainties in the data used for the estimate and for the installation of additional instruments during the first years of plant operation.

For regeneration of air drier, especially for heatless type as the required quantity is about 20% of drier outlet.

The wet air required for dryer to add to compressor capacity is obtained from the following procedure:

Relative Humidity (RH)	40	%	
max. amb. Temp	52.6	°C	
$Q_{dry\ air}$	918	Sm^3/hr	
$V_{H2o\ @\ max.\ amb.\ Temp.}$	2.02	Psia	from steam table
P_{H2o}	0.808	Psia	$RH * V_{H2o}$
$V_{dry\ air}$	13.892	Psia	$14.7 - P_{H2o}$
$Q_{wet\ air}$	971.4	Sm^3/hr	$Q_{dry\ air} * 14.7 / V_{dry\ air}$

- Determine vapor pressure water at max. ambient temperature from steam table or software.
- Use the above equations to determine $Q_{wet\ air}$.

7.2 Air Receiver

Air receiver dimension will be determined by equation 1-1.

The following assumption can be used for sizing of air receiver:

AIR RECEIVER SIZING

T	time	15	min.
P_1	initial receiver pressure	900	kPa (ga)
P_2	final pressure	600	kPa (ga)
P_0	atmospheric pressure	100	kPa (abs)
C	air requirement	50	Sm^3/hr

V	receiver capacity	4.17	m^3

$$T = V \frac{P_1 - P_2}{C\, P_0}$$

D	receiver diameter	1210	mm
L	receiver height (L=3D)	3630	mm

- Use hold up time (T) based on design criteria, else assume 15 minutes.
- Consider Initial receiver pressure based on design criteria (max. compressor discharge press.), else assume 9 barg.
- L/D=3

7.3 Process data sheet

Chagalesh process data sheets for air drier and compressor is as below

CHAGALESH CONSULTING ENGINEERS	INSTRUMENT AIR COMPRESSOR PROCESS DATA SHEET	REV.	ORIG.	1	2	3	4
		PREP'D					
		CHK'D					
		APPR'D					
		DATE					

ITEM NO.:	SERVICE: AIR COMPRESSOR PACKAGE
NO.REQUIRED :	PROJECT NO.:
SITE:	UNIT:

TYPE OF MACHINE:

ROTARY ☐ CENTRIFUGAL ☐ NONLUB.RECIP ☐ LUBRICATED RECIP ☐

NO. OF STAGE: BY VENDOR

NO. OF IDENTICAL MACHINE REQUIRED:

OPERATING: SPARE:

TYPE OF DRIVER: OPERATING: SPARE:

PROCESS REQUIREMENTS PER MACHINE

OPERATING CASE					DESIGN CONDITIONS
GAS HANDLED		AIR			
CAPACITY (1)	SM^3/HR				
GAS DEW POINT	^oC				
HUMIDITY					
VOLUME AT SUCTION COND.	M^3/HR				
MASS FLOW	KG / HR				
SUCTION TEMPERATURE	^oC				
MAX.SUCTION PRESS.	BARA				
SUCTION PRESSURE	BARA				
SETTLING OUT PRESSURE (2)	BARA				
DISCHARGE PRESSURE	BARA				
DIFFERENTIAL PRESSURE	BAR				
COMPRESSION RATIO					
COMPRESSIBILITY FACTOR AT SUC.(2)					
CP/CV AT SUCTION	(2)				
MOLECULAR WEIGHT					
TURN DOWN RATIO	%				
START-UP GAS					
GHP	KW				

SITE DATA

DESCRIPTION	UNIT	CONDITION	REMARK
ALTITUDE	M		
BAROMETER	BARA		
MIN./MAX/AMB. TEMPERATURE	^oC		

WINTERIZATION REQUIRED ☐ TROPICALIZATION REQUIRED ☐

UNUSUAL CONDITION:

DUST ☐ FUME ☐ OTHERS:

NOTES :

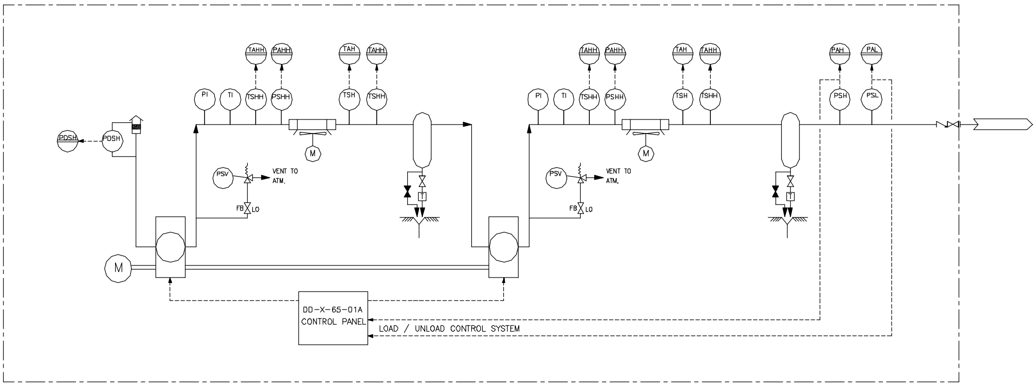
1-STANDARD CONDITION:PRESSURE @ 1ATM & TEMPERATURE @15.5 ^oC

PROJECT:	PAGE: OF:	OWNER:	DOC. NO. :

DISTRIBUTION TO: 1.PROCESS DEPT. 2.MECHANICAL DEPT.

			REV.	ORIG.	1	2	3	4
	CHAGALESH CONSULTING ENGINEERS	**INSTRUMENT AIR COMPRESSOR PROCESS DATA SHEET**	PREP'D					
			CHK'D					
			APPR'D					
			DATE					

ITEM NO.:	SERVICE: AIR COMPRESSOR PACKAGE
NO.REQUIRED :	PROJECT NO.:
SITE:	UNIT:



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DISTRIBUTION TO: 1.PROCESS DEPT. 2.MECHANICAL DEPT.

			REV.	ORIG.	1	2	3	4
CHAGALESH CONSULTING ENGINEERS		**INSTRUMENT AIR DRYER PROCESS DATA SHEET**	PREP'D					
			CHK'D					
			APPR'D					
			DATE					

ITEM NO.:	SERVICE: AIR DRYER PACKAGE
NO. REQ'D :	PROJECT NO.:
SITE:	UNIT:

DESCRIPTION	***UNIT***	***OPERATING CONDITION***	***REMARKS***
CAPACITY	SM^3/HR		
MAX. INLET TEMPERATURE	^oC		
MAX. INLET PRESSURE	BARG		
MIN. INLET PRESSURE	BARG		
MAX. ALLOWABLE PRESSURE DROP	BAR		
DESIGN PRESSURE	BARG		
DESIGN TEMPERATURE	^oC		
INLET AIR MOISTURE CONTENT (SATURATED)	%		
OUTLET DEW POINT (@DISCHARGE CONDITION)	^oC		
CORROSION ALLOWANCE (BY VENDOR)	MM		
SITE CONDITION	***UNIT***	***OPERATING CONDITION***	***REMARKS***
MIN. AMBIENT TEMPERATURE	^oC		
MAX. AMBIENT TEMPERATURE	^oC		
ELEVATION	M		

NOTE :

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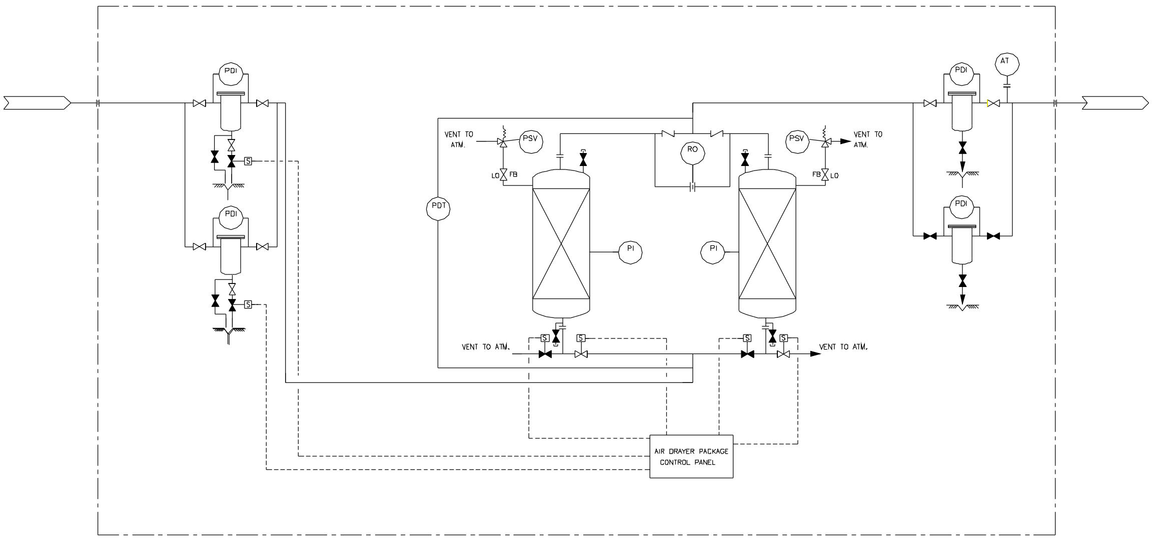
DISTRIBUTION TO: 1.PROCESS DEPT. 2. MECHANICAL DEPT.

CHAGALESH CONSULTING ENGINEERS	**INSTRUMENT AIR DRYER PROCESS DATA SHEET**	REV.	ORIG.	1	2	3	4
		PREP'D					
		CHK'D					
		APPR'D					
		DATE					

ITEM NO.:	SERVICE: AIR DRYER PACKAGE
NO. REQ'D :	PROJECT NO.:
SITE:	UNIT:



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8 References:

1. IPS-E-IN-200
2. IPS-E-PR-905
3. IPS-E-PR-905
4. Total Operating Manual
5. Chagalesh Compressor Design Guide