23 (6.6.A) Compressed Air

23.1 Functions, Basic Configuration, and Interfaces

23.1.1 Functions

The primary function performed by the compressed air system is to provide instrument air and service air to each ITER building. Instrument air is used for control valve actuators, power operators, pneumatic controllers, etc., and for special purposes (such as in the laboratories and for other users) where the quality of service air is not acceptable. Service air is used for operation of air-powered tools, cleaning and other building needs.

23.1.2 Basic Configuration

The function is accomplished by compressors, receivers, dryers, prefilters, afterfilters and other equipment needed to meet the requirements detailed in this document.

The compressed air system covers the entire ITER plant. Therefore, a single, centralized system of compressors with a distribution system is neither practical nor cost effective. The compressed air system equipment is located strategically at various ITER buildings (listed below) as stand-alone subsystems. This reduces the distribution costs, and compressed air specifications for specific equipment can be met cost effectively. Instrument air comprises 90% of capacity. The remaining capacity is allocated to the service air system which is not dried and filtered. The service air does not have to meet instrument air quality standards. Service air is used for the operation of pneumatic tools and blast cleaning. The service air usage is categorized as a non-safety-related air requirement. Each compressed air subsystem is independent with separate interface controls.

An important exclusion for the function of the compressed air system is that it does not include "breathing air" which is covered separately in WBS 6.6.B.

23.1.3 Interfaces

In order to assist with interfaces, the locations of the independent subsystems are identified in the general section of the design requirements and this nomenclature is used consistently throughout the document. If a requirement does not specify the subsystem name, then it is understood to apply to all subsystems. The compressed air subsystems have interfaces with the following WBS elements:

Building	WBS Element	
Tokamak Building	1.8	Fueling and Wall Conditioning
	2.6	Cooling Water System
	3.1	Vacuum Pumping & Leak Detection Systems
	3.2.A	Tokamak Exhaust Processing
	5.1	IC H&CD
	5.3	NB H&CD System
	5.5	Diagnostics
	6.2.A	Tokamak Buildings
Tritium Building	1.8	Fueling and Wall Conditioning
	3.1	Vacuum Pumping & Leak Detection Systems
	3.2	Tritium Plant
	5.1	IC H&CD
	5.2	EC H&CD
	6.2.A.02	Tritium Building
Hot Cell & Radwaste Buildings	6.2.B	Hot Cell Building
	6.2.G	Radwaste and Personnel Building
	6.3.A	Hot Cell Docking and Storage
	6.3.B	Hot Cell Waste Processing and Storage
	6.3.C	Hot Cell Component Repair
	6.3.D	Low Level Waste Processing
Cryoplant Buildings	3.4.A	Cyoplant
	3.4.B	Cryodistribution
	4.3.C	Steady-State Electrical Power Distribution
	6.2.J	Cryoplant Buildings
Emergency Power Supply	4.3.A	Steady-State HV Substation
	4.3.C	Steady-State Electrical Power Distribution
	6.2.L	Emergency Power Supply Building
Auxiliary Buildings	4.1	Coil Power Supply (PS) and Distribution
	4.2.A	IC H&CD System Power Supplies
	4.2.B	EC H&CD System Power Supplies
	4.2.C	NB H&CD System Power Supplies
	6.2.E	Auxiliary Buildings
Site Services Building	2.6.L	Circulating Water System
	2.6.M	Cooling Tower System
	2.6.O	Component Cooling System
	2.6.P	Chilled Water Systems
	6.2.M	Site Services Building
	6.3.F	Non-Radioactive Waste Systems
	6.5.C	Potable & Fire Water
	6.5.D	Sewage (Sanitary & Industrial)
	6.5.E	Steam/Condensate/Demineralized Water

23.2 Design Requirements

23.2.1 Specific

The requirements for the compressed air system are derived from DGR1 and from an evaluation of the ITER plant compressed air needs. Instrument and service air shall be supplied at a nominal pressure of 690 kPa(g).

The instrument air system is required to provide 'instrument quality' compressed air for the following application:

(a) Operation of pneumatically-operated instrumentation and controls.
(b) Special purposes - laboratory/plant processes where the quality of service air is unacceptable.

The service air system is required to provide compressed air to all areas in the building for various maintenance and operational functions such as the operation of pneumatic tools and air blast cleaning.

23.2.1.1 Compressed Air System Capacities

The compressed air system is comprised of the following subsystems listed in Table 23 (6.6.A) - 1. The subsystem capacity is allocated 90% to instrument air which is dried and filtered and the remaining 10% capacity is allocated for the service air system which is not dried and filtered.

Table 23 (6.6.A) -1 List of Subsystems and System Capacity

Subsystem Name	**Instrument Air Capacity** m^3/hr	**Service Air Capacity** m^3/hr
Tokamak Building	4,050	450
Tritium Building	1,080	120
Hot Cell Building	1,080	120
Cryoplant Building	1,080	120
Emergency Power Supply Building	1,080	120
Auxiliary Buildings	4,050	450
Site Services Building	1,080	120

23.2.1.1.1 Instrument Air

All subsystems providing compressed air to instruments and similar components ("instrument air") shall have a dew point of -40°C at 860 kPa(g) to prevent line freezing and maximum oil vapor content of 1 ppm (condensable). A desiccant type dryer will be required to achieve a dew point of -40°C.

23.2.1.1.2 Standard Instrument and Service Compressed Air Units

The subsystem capacities shall be standardized for two compressor units which are 4,500 m^3/hr and 1,200 m^3/hr. This will minimize the spare parts cost and reduce the capital cost on the basis of repeat units. The additional capacity will serve for any unknown users

and future use.

23.2.1.2 Air Receiver Requirements

23.2.1.2.1 Receiver Air Storage Capacity

Sufficient air storage capacity shall be provided to supply the maximum air requirements of the system without make-up for 5 minutes, during the transfer from class IV to class III electric power on a failure of the class IV electric power system. The residual pressure in the air receivers shall not be less than 410 kPa(g).

23.2.1.2.2 Pressure Set points
The compressed air system shall operate compressors and issue alarms according to the pressure set points in Table 23 (6.6.A) –2.

Table 23 (6.6.A) -2 Pressure Set Points for the Compressed Air System

Function	Pressure Switch Setting (kPa Gauge)
Compressors Shutdown	860
1st Compressor Starts	827
2nd Compressor Starts	799
3rd Compressor Starts	771
Pressure (Reg.) Set point	690
System Low Pressure Annunciation	< 590

23.2.2 General

23.2.2.1 Equipment Layout

23.2.2.1.1 Maintenance Space

The equipment (compressors, dryers, receivers, filters etc.) shall be arranged to facilitate maintenance and inspection of the equipment, and if necessary to remove the equipment or their major components. A laydown area shall be provided where the equipment may be loaded onto a cart or trailer for workshop servicing.

23.2.2.1.2 Lifting Beams

Lifting beams shall be provided for the installation and servicing of the air compressor. The beams shall be designed to carry a maximum load of 1700 kg (weight of an oil–free 4500 m^3/hr screw compressor).

23.2.2.1.3 Compressor Installation

The air compressors and receivers shall be installed on concrete plinths approximately 150 to 200 mm high to allow sufficient slope on the equipment drain trap discharge lines to the utility drains. The concrete plinths shall extend a short distance (~ 75 mm) outwards from the compressors or receivers fabricated steel base to allow for separation of the equipment from

personnel, and to allow for barriers to be set up to protect personnel, and to avoid interference with the equipment by passing maintenance vehicles. Equipment anchor bolts may be either poured in place or cinched-anchored at the time of installation.

23.2.2.1.4 Utility and Floor Drains

The compressed air system shall specify the number, characteristics and capacity of utility drains needed to collect compressor cooling water discharge, oil and condensate from equipment and piping automatic drain traps.

23.2.2.1.5 Receiver Orientation

All air receivers shall be of the vertical type to minimize the floor space requirements.

23.2.2.2 Thermohydraulic - Heat Removal

Component cooling water (CCW) shall be used to cool the air compressor intercooler, bypass coolers, oil coolers and aftercoolers. The compressor cooling water block valves are part of the compressed air system and shall be the interface point with the CCW system distribution line.

23.2.2.3 Mechanical

23.2.2.3.1 High Pressure Service

Unless otherwise specified all subsystems shall provide "high pressure" compressed air at a nominal pressure of 690 kPa (a minimum of 590 kPa, and a maximum of 860 kPa).

23.2.2.3.2 Low Pressure Service
Unless otherwise specified all subsystems shall provide "low pressure" compressed air at a nominal pressure of 350 kPa (minimum of 270 kPa and a maximum of 450 kPa). The low pressure system is not a separate system and simply uses additional regulators to deliver air at reduced pressure.

23.2.2.3.3 Very High Pressure Instrument Air

Compressed air service for pressures that must be continuously greater than about 720 kPa shall be provided from high pressure compressed air cylinders with appropriate regulators. If volume requirements exceed that which is practical from gas bottles, the component requiring the very high pressure service shall provide the specialized compressors for this service because they are outside the scope of this WBS item.

23.2.2.4 Electrical

All compressor units that provide service for safety importance class (SIC) equipment shall be supplied from class III power supplies. On a loss of class IV power the unit air receiver shall have sufficient capacity to provide at least five minutes of air service during the transfer from class IV to class III power while maintaining a minimum pressure of 460 kPa(g). Each compressor shall be supplied from a different 11 kV bus if this arrangement does not significantly increase cost. Compressors providing service to non-SIC equipment will not be

connected to class III power unless it is justified for investment protection.

23.2.2.5 Seismic

23.2.2.5.1 Seismic Design

Compressed air subsystems shall have the same seismic classification as the equipment that is serviced. Failure of the subsystem shall not impair the function of SIC equipment.

23.2.2.5.2 Seismic Anchors

Compressed air components shall be evaluated for their potential to become missiles under seismic loads and if such component missiles are possible under design basis seismic conditions, the components shall be anchored to prevent such missile action.

23.2.2.6 Testing

Field performance tests for air compressors shall be in accordance with ASME performance test code PTC-9-1970 or the ITER site equivalent.

23.2.2.7 Instrumentation and Control

23.2.2.7.1 Compressor Control System

The compressor control system shall be designed to perform the following:

(a) The control system (sequencing system) shall monitor system demand and control the number of compressors running to meet demand. Each compressor shall start unloaded and be automatically loaded after twenty (20) seconds.
(b) If a compressor runs unloaded for twenty (20) minutes, it shall be shutdown. The control system shall be designed so that compressors can run in a "manual mode".
(c) The control system shall be designed to allow manual rotation of each compressor to distribute wear.
(d) The control system shall automatically turn on or off all compressor services, such as component cooling water, as required.
(e) The control system shall include instrumentation to provide indications of compressor parameters.

23.2.2.7.2 Compressor Protection System

A compressor protection system shall be provided with sensors which monitor and protect the compressors against off-normal operating conditions such as high temperature, pressure, motor current, and other potentially damaging conditions.

23.2.2.7.3 Dryer Control System

The dryer control shall be designed as follows:

(a) Each dryer shall have controls to allow manual and automatic operation. Two dryers shall operate on a lead-lag basis and shall automatically alternate from lead to lag every 24 hours. There shall be provision to manually alternate from lead to lag operation. The second dryer shall start when the third compressor starts.

(b) When a compressor starts, the controls shall start the lead dryer. Whenever a compressor stops, the control shall continue regeneration of the desiccant tower so that a fresh tower is available for the next start-up.
(c) If the differential pressure across a dryer and filter set exceeds 138 kPa(d) the standby dryer shall start-up and there shall be annunciation locally and in the main control room. Indication of the cause of high differential pressure shall be provided.
(d) If the desiccant tower fails to switch over there shall be annunciation locally and in the building control room.
(e) Condensate dump valves on the pre-filter shall be opened for up to 15 seconds every 30 minutes of dryer operation.
(f) The controls shall automatically cycle the dryer between its two desiccant towers so that one tower is regenerating while the other is drying.

23.2.2.7.4 Additional Annunciation

In addition to the control system annunciation, the following additional events shall cause annunciation both locally and in the building control room:
(a) Failure of a compressor to reach 860 kPa(g) within three (3) minutes after starting.
(b) System pressure less than 590 kPa(g) and no compressors are running.

23.2.2.7.5 Isolation Valves

Two seismically qualified isolation valves shall be provided in the tokamak building compressed air subsystem. The purpose of the isolation valves is to seal the containment in the event of a pipe rupture and prevent overpressurization of the TCWS vault and other pressure sensitive rooms and equipment due to the compressed air system inleakage.

23.2.2.7.6 Instrument Indication

Instrument indications for process parameters shall be provided to monitor compressed air subsystems as follows:
(a) Pressure: inlet water, intercooler air, discharge air, inlet filter oil.
(b) Temperature: oil, discharge water, aftercooler outlet air, aftercooler inlet air, aftercooler outlet water and aftercooler inlet water.
(c) Location: pressure gauges inside each unit compressor control panel, at each compressor air receiver, in the building control room, on the prefilter and afterfilter, on each dryer, for each pressure regulating valve and on the main header; differential pressure gauges across the prefilter and afterfilter for each dryer.

23.2.2.7.7 Air Quality Monitoring

Unless otherwise specified, all subsystems shall provide local air quality instrumentation as appropriate for the service delivered.

23.2.2.8 Materials

23.2.2.8.1 Main Headers

Unless otherwise specified, the main distribution header, the branch distribution headers and the small bore distribution piping are constructed of stainless steel piping. Stainless steel is selected over carbon steel to prevent corrosion.

23.2.2.8.2 Electrical

All cables will be made with copper and should have the 15 kV, 6 kV and 0.6 kV rated insulation voltage for 11 kV. Cable insulation should meet the following requirements:

- insulation material XLPE preferred, PVC not accepted;
- max. permissible temperature of conductor:
  - continuous 90°C,
  - under short circuit conditions 250°C;
- acid gas content zero halogen, according to IEC-754;
- fire retardancy according to IEC-332

Table 23 (6.6.A) -3 IEC Relevant Material

IEC #	Technical Committee	Title
332-1 to 3	SC 20C	Test on electric cables under fire conditions
728	SC 12G	Cable distribution systems
754	SC 20C	Tests on gases involved during combustion of electric cables
840	SC 20A	Test on electric cables 30 kV to 150 kV

23.2.3 Operations and Maintenance

The operations and maintenance (O&M) requirements for the compressed air system are derived from DRG1 and the functions of the compressed air loads.

23.2.3.1 Accessibility

All compressed air subsystems shall be designed such that operations and maintenance personnel are able to perform their duties with reasonable accessibility to the equipment.

23.2.3.2 Maintainability

The compressed air system shall be designed so that isolation and access to components for maintenance is provided as follows:

(a) Provision shall be made to segregate parts of the system requiring maintenance or repairs without interruption to the air distribution;
(b) Adequate floor space for equipment laydown and withdrawal area for equipment removal shall be provided.
(c) Sufficient primary temperature and pressure indicators shall be provided for the compressors and dryers to facilitate the locating of faults so that maintenance can be initiated as soon as possible.

(d) Manholes shall be provided to allow the internal inspection of air receivers.

23.2.4 Surveillance and In-service Inspection

Surveillance and in-service inspection requirements (including features which provide information on the condition of the compressed air subsystems) are identified below:

23.2.4.1 Periodic Inspections

The design shall permit periodic inspection of the air compressors and air dryers. The inspection procedures will be described in their respective operational and maintenance manuals.

23.2.4.2 Visual Inspection

All compressed air components shall provide visual inspection access for surface corrosion, cracks and other signs of degradation on the outer surfaces of components.

23.2.4.3 Corrosion Control

Components which are vulnerable and exposed to corrosive conditions shall have features which control corrosion or make allowances for corrosion over the expected life of the component.

23.2.5 Quality Assurance

The compressors shall be procured to ANSI Q92 quality specifications, or the ITER site equivalent. Air receivers and dryer towers shall be designed and constructed to "Code for the Construction of Boiler and Pressure Vessels" and the latest revision of ASME section VIII or the ITER site equivalent. The pressure vessel shall be registered with the local jurisdiction authority. The ITER QA manual shall be used as a guide to other QA requirements.

23.2.6 Reliability Assurance

There shall be a sufficient number of compressors to ensure at least 50 percent supply when one compressor is out for maintenance. No standby compressor shall be required. In addition, the following shall be provided at the ITER site as spare parts:

(a) Two (2) spare compressors each with a capacity of 4,500 m^3/hr and 1,200 m^3/hr shall be provided so that the outage of any compressor would not affect the total required compressed air capacity.
(b) Two (2) dryers each with a capacity of 4,500 m^3/hr and 1,200 m^3/hr shall be provided so that the failure of a dryer would not cause subsystem shutdown.

23.2.7 Cooling Water Supply

The design of cooling water supplies to air compressors and auxiliaries, i.e. aftercoolers, may seriously effect the operational reliability of the various compressed air systems. The cooling water system provided shall have a high reliability.

23.2.8 Other

The compressor shall be of the oil-free type to ensure that no oil contamination of the system occurs. The oil-free requirement applies only to the final stage of the compressor. Other parts of the compressor may use oil provided the oil cannot be present in the high pressure air discharge from the compressor.

23.3 Codes and Standards

23.3.1 Piping Standards

All piping materials shall be designed and constructed in accordance with the power piping code ANSI B31.1 or the ITER site equivalent.

23.3.2 Compressor Standards

Compressor systems shall meet the following standards;

- ISO 8573 - 10, Compressed air system, or the ITER site equivalent
- ANSI Q92, Compressor or the ITER site equivalent

23.3.3 Other Codes

- ASME Performance test code PTC-9-1970
- ASME Code for the construction of boiler and pressure vessels
- ASME Section VIII or the ITER site equivalent. The pressure vessel shall be registered with the local jurisdiction.