

23 (6.6B) Breathing Air

23.1 Functions, Basic Configuration, and Interfaces

23.1.1 Functions

The primary function performed by the breathing air system is to supply and distribute "breathing quality" compressed air (as defined in section 23.2.1.8) to enable personnel wearing plastic suits or respirators to enter and work in contaminated or potentially contaminated areas of the ITER plant. With plastic suits, about 80 percent of air is used for suit cooling with the balance used for respiration. Breathing air is also used by workers wearing respirators when entering enclosed work locations having inadequate ventilation. The function is accomplished by compressors, air receivers, air dryers, air distribution, filters and other equipment needed to meet the requirements detailed in this document. The breathing air system is required to perform this function during normal plant operating and shut-down conditions.

A mandatory requirement for the function of the breathing air system is that it must not be connected in any way to the plant compressed air systems which are covered separately in chapter 23 (6.6.A).

23.1.2 Basic Configuration

Breathing air is supplied on an entire ITER plant basis at nominal pressure of 520 kPa(g). The single, centralized system of compressors with a distribution system is justified on an economic basis. The duplication of breathing air system components and controls is minimized. The breathing air system equipment is located in the site services building (building 61). The main distribution headers distribute breathing air to the complex of buildings which are the tokamak, hot cell, radwaste and tritium buildings. Each of these buildings are supplied by a separate distribution system from the main distribution header.

For access to areas that are too far away to connect into the distributed breathing air system, or for when the air compressors are not running, bottled breathing air supply is provided in addition to the plastic suits.

23.1.3 Interfaces

The breathing air subsystems have interfaces with the following WBS elements:

WBS Title

- 2.6.O Component Cooling System
- 4.3 Steady State Electrical Power Network
- 6.2.A Tokamak Buildings
- 6.2.G Radwaste and Personnel Building

23.2 Requirements

The requirements for the breathing air system are derived from DRG1, and the GSSR (annex to PDD1) and the ITER plant breathing air needs.

The design requirements listed below are the design parameters and other criteria which are

used for system sizing, layout determination of system reliability and selection of major components for the compressed air system.

23.2.1 Specific

23.2.1.1 Breathing Air Suits Capacity

Each suit requires 51 m³ /h.

23.2.1.2 Tokamak Building Subsystem

The breathing air to the tokamak building shall be supplied from the main distribution header of the breathing air system. A maximum of fifty (50) workers in plastic suits shall be provided breathing air for operation and maintenance activities.

23.2.1.3 Tritium Building Subsystem

The breathing air to the tritium building shall be supplied from the main distribution header of the breathing air system. A maximum of twenty (20) workers in plastic suits shall be provided breathing air for operation and maintenance activities.

23.2.1.4 Hot Cell Building Subsystem

The breathing air to the hot cell building shall be supplied from the main distribution header of the breathing air system. A maximum of twenty (20) workers in plastic suits shall be provided breathing air for operation and maintenance activities.

23.2.1.5 Radwaste Building Subsystem

The breathing air to the radwaste building shall be supplied from the main distribution header of the breathing air system. A maximum of five (5) workers in plastic suits shall be provided breathing air for operation and maintenance activities.

23.2.1.6 Bottled Breathing Air

Bottled breathing air shall be provided for work areas which are not covered by permanent breathing air manifolds. Each bottle shall have 510 m³/h capacity.

23.2.1.7 System Air Connections

23.2.1.7.1 Connections to the Breathing Air System

The breathing air system shall be used solely for personnel protection. Connection to any other system could affect the quality, condition and availability of breathing air and therefore jeopardize personnel safety.

23.2.1.7.2 Location of Breathing Air Stations

The breathing air stations shall be permanently installed in the potentially contaminated areas (i.e., areas contaminated with tritium, radioactive or other hazardous particles) and near

enclosed work locations without adequate ventilation.

23.2.1.8 Air Quality Requirements

The quality requirements for breathing air are specified in each country by regulatory authorities, but the following specifications from ANSI/CGA G-7.1-19 89 shall be applied until site selection occurs:

- Breathing air shall be oil and dust free with a dew point temperature of +2 °C at 520 kPa(g) to minimize corrosion and bacterial growth. To meet this dew point, a refrigerated air dryer will be required.
- Oxygen content: $21 \pm 1\%$
- CO limit: < 10 ppm
- CO₂ limit: $< 1,000$ ppm
- Condensed oil: < 5 mg/m³ at STP

23.2.1.9 Breathing Air System

23.2.1.9.1 Total System Capacity

The system capacity shall be sized to supply the breathing air at 3,570 m³/h to the entire ITER plant for 70 personnel wearing plastic suits at the same time. An additional 10% margin over the minimum air requirement shall be provided to cover leakage losses at breathing air stations.

23.2.1.9.2 Air Temperature to End-User

The temperature of the breathing air supplied to the end user shall be within the normal comfort zone of 22°C ± 3°C. Transients in air temperature shall be tolerable, however, only for short periods as follows:

- (i) 26°C to 29°C for maximum period of 15 minutes.
- (ii) 30°C to 34°C for maximum period of 5 minutes.

The end user air supply temperature shall not exceed 35°C at any time to ensure operating personnel comfort.

23.2.1.10 Breathing Air Stations

To allow for proper access, the breathing air stations shall be located in or near potentially contaminated areas and the maximum distance between the breathing air stations shall be 12.3 m. This permits the user to carry only short air hoses, and allows the user to disconnect from one station and re-connect at the next one in a reasonable time.

23.2.1.11 Air Receiver

23.2.1.11.1 Receiver Air Storage Capacity

Sufficient air storage capacity shall be provided to supply the air requirements of 70 personnel for a period of 5 minutes following a total loss of class IV power to the compressor. The nominal air flow to each individual suit shall be 51 m³/h (14.2 ℓ/s), but not be less than 26 m³/hr at the end of the 5 minute period.

23.2.1.11.2 Pressure Set points

The breathing air system shall operate compressors and issue alarms according to the pressure set points in Table 23 (6.6.B) –1.

Table 23 (6.6.B) -1 Air Pressure Set Points

Function	Pressure Switch Setting (kPa Gauge)
Compressors Shutdown	690
1st Compressor Starts	650
2nd Compressor Starts	610
3rd Compressor Starts	570
Nominal System Pressure (Reg. Set point)	520
System Low Pressure Annunciation	< 450

This is further elaborated in the section on instrumentation and control (section 23.2.2.10).

23.2.2 General

23.2.2.1 Equipment Layout

23.2.2.1.1 Maintenance Space

The equipment (i.e. compressor, dryers, receivers, filters etc.) shall be so arranged so as 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 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

Utility drains shall be provided to collect compressor cooling water discharge and condensate

from equipment and piping automatic drain traps. Floor drains shall be provided which shall be connected to the oil-contaminated water drainage and treatment system (oil spills may occur during compressor servicing i.e. lubricating oil changes etc.).

23.2.2.1.5 Receiver Orientation

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

23.2.2.2 Thermohydraulic

Component cooling water (CCW) shall be used to cool the intercooler, bypass coolers, oil coolers and aftercoolers. The CCW system distribution line shall terminate immediately upstream of the compressors cooling water valves. The quantity, maximum and minimum temperature(s) and pressure(s) of the cooling water shall be in accordance with the compressor manufacturer's installation, operational and maintenance manual.

23.2.2.3 Mechanical

23.2.2.3.1 Breathing Air Pressure

The nominal operating pressure at the breathing air station shall be 520 kPa(g) as required by plastic suit design. The minimum operating pressure shall be 450 kPa(g).

23.2.2.3.2 Safety Valves

Safety valves shall be provided on each air receiver and on piping where necessary to protect equipment according to ASME section VIII, part UG-125 and power piping code ANSI B31.1, sections 102 and 107. The safety valves shall be located so as not to be a hazard to personnel. Belt guards and coupling guards shall be provided on all rotating equipment.

23.2.2.4 Electrical

23.2.2.4.1 Power Supplies

The breathing air compressor and dryers shall have class IV power supply because their long term shutdown would not affect equipment or personnel safety. If practical, each compressor shall be supplied from a different 11 kV bus.

23.2.2.4.2 Control Power

Control power shall be supplied from class IV power supplies, because all controls are designed to go to a safe condition during power failures.

23.2.2.4.3 Equipment Voltage

Equipment voltage requirements shall conform to IEC standard nominal voltages. In order to limit the number of step-down transformers, preference shall be given to 11 kV for large equipment (> 500 kW) and to 3.3 kV for (100-500 kW).

23.2.2.4.4 Wireless Communication

Each breathing air station shall incorporate wireless communication connections to be used by workers wearing plastic suits.

23.2.2.5 Nuclear

23.2.2.5.1 Elemental Tritium and Activation Products Resistance

Plastic suits for protection against elemental tritium and neutron activation products shall provide inhalation and absorption protection for the life of the suit which is reusable after surface decontamination.

23.2.2.5.2 Tritium Oxide (Vapor or Liquid Contact)

Plastic suits for protection against tritium oxide (vapor or liquid) shall provide inhalation and absorption protection for a minimum of 30 minutes when contacted with water at 10 Ci/kg tritium oxide concentration. These plastic suits shall be one-time use only and shall have a distinctive color to differentiate them from reusable plastic suits.

23.2.2.6 Environmental

23.2.2.6.1 Air Compressor Intake Environment

The compressor air intake shall be located in an area free of contaminants from engine exhausts, vacuum system discharge, paint and solvent fumes, water treatment chemical fumes, etc. to ensure the air supplied is safe and high quality.

23.2.2.6.2 Air Compressor Noise Emission

Noise emission from each compressor or dryer shall be such that the average sound pressure levels at a distance of 1 m from the compressor or dryer shall not exceed 85 dB(A), or conform to the local standards, whichever is the more stringent condition.

23.2.2.7 Seismic

23.2.2.7.1 Seismic Design

Breathing air system distribution piping shall be safety importance class (SIC) requiring SL-1 seismic qualification.

23.2.2.7.2 Seismic Anchors

Breathing air compressor components and air bottles shall be evaluated for their potential to become missiles under SL-1 seismic loads and if such component missiles are possible under design basis seismic conditions, the components shall be anchored to prevent such missile action.

23.2.2.8 Construction

The air receivers shall be designed, fabricated, tested, inspected and registered in compliance with the ASME "Unfired Pressure Vessels Code".

23.2.2.9 Testing - Field Performance Tests

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

23.2.2.10 Instrumentation and Control

23.2.2.10.1 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 shall be designed so that the compressors can run in a 'manual' mode.
- (c) The controls shall be designed to allow manual rotation of the each compressor to distribute wear.
- (d) The control system shall automatically turn on or off all compressor services, such as service water for cooling, as required.
- (e) The control system shall include instrumentation to provide indication of compressor parameters.

23.2.2.10.2 Compressor Protection System

A compressor protection system shall be provided which shall monitor parameters and protect the compressors from electrical and mechanical damage.

23.2.2.10.3 Dryer Control System

The dryer control shall be designed as follows:

- (a) One (1) dryer shall be started manually and operate for six hours. The second dryer shall start when two or more compressors are running.
- (b) The second dryer shall stop when the lag compressors stop.
- (c) The lead and lag dryer shall alternate automatically every six hours.

23.2.2.10.4 Flow Monitoring

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

23.2.2.10.5 Air Purity Monitoring

Air purity test connections shall be provided in breathing air system distribution piping. The air samples shall be analyzed in accordance with breathing air specification ISO 8573-10.

23.2.2.11 Grounding/Insulation

The breathing air system equipment shall be well-connected to the building and site ground system.

23.2.2.12 Materials

23.2.2.12.1 Pipes and Vessels

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 the possibility of corrosion.

23.2.2.12.2 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.B) -2 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

23.2.2.13 HVAC

The room where the breathing air system is located shall be provided with an adequate ventilation system. The ventilation system shall be sized to remove excessive heat from compressors and dryers when supplying the maximum breathing air flow requirements.

23.2.3 **Operation and Maintenance**

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

23.2.3.1 Accessibility

The breathing air system shall be designed such that operation and maintenance personnel are able to perform their duties with reasonable accessibility to the equipment.

23.2.3.2 Maintainability

The breathing air system shall be designed so that isolation and access to components for maintenance is available.

- (a) Adequate floor space for equipment laydown and adequate withdrawal area for equipment removal shall be provided.
- (b) 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.
- (c) Manholes shall be provided to allow internal inspection of air receivers.

23.2.3.3 Loss of Class IV Electrical Power

Receivers, compressors and related equipment shall be designed to provide breathing air, at or above the minimum specifications, for at least 15 minutes following loss of electrical power.

23.2.4 Surveillance and In-service Inspection

The breathing air system design shall take into consideration the following surveillance and in-service inspection requirements.

23.2.4.1 Periodic Inspection

Air purity test connections shall be provided in breathing air system distribution piping.

23.2.4.2 Visual Inspection

All breathing 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 (QA)

The compressor quality specification shall be ANSI Q92 and the breathing air system quality specification shall be ISO 8573-10. Further, the ITER QA manual shall be considered for the supply of this equipment.

23.2.6 Reliability Assurance

23.2.6.1 Reliability

The failure of the breathing air system does not directly impact the operation of the tokamak. However, the breathing air system must be sufficiently reliable such that the probability of excessive radiation dose to the user as the result of system failure will be reduced to an acceptable minimum.

23.2.6.2 Compressor Redundancy

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 will be provided.

23.2.6.3 Passive Exit Reliability

The most likely total failure mode for the breathing air system is a failure of all compressors through an interruption in the electrical power supply. These interruptions are tolerable because workers can remove the suits and exit the hazardous areas within 15 minutes of air supply provided by the receivers. As a result, the reliability requirement is that the total failure of the breathing air supply system which exceeds 15 minutes duration does not endanger workers and only extends the outage work by the duration of the power outage.

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 and shall be free from possible common-mode-type failures.

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

The breathing air system shall meet the following codes and standards (or their equivalents):

- (a) All piping material shall be designed and constructed in accordance with the power piping code ANSI B31.1. All pressure welding shall meet the requirements of the ASME code section IX;
- (b) 1.9.2 ISO 8573 - 10, compressed breathing air, or the ITER site equivalent;
- (c) 1.9.3. ANSI Q92, compressor, or the ITER site equivalent;
- (d) ASME performance test code PTC-9-1970, or equivalent;
- (e) ANSI/CGA G-7.1-19 89 or equivalent, for breathing air quality;
- (f) ASME section VIII, part UG-125;
- (g) ANSI B31.1, section 102 and 107 (piping code), or equivalent;
- (h) ASME "Unfired Pressure Vessels Code" (for air receivers);

- (i) the ITER QA manual.