# TRANSPORT FOR NSW (TfNSW)

# SPECIFICATION D&C R164

# TUNNEL JET FANS

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## REVISION REGISTER

| Ed/Rev Number | Clause Number | Description of Revision | Authorised By | Date |
|---|---|---|---|---|
| Ed 1/Rev 0 | | First issue. | GM, CB | 16.02.17 |
| Ed 1/Rev 1 | | Updated to accord with base (non-D&C) Specification R164 Ed 1/Rev 1. | MCQ | 27.10.17 |
| Ed 1/Rev 2 | Global | References to "Roads and Maritime Services" or "RMS" changed to "Transport for NSW" or "TfNSW" respectively.<br>References to "RMS Representative" changed to "Principal". | DCS | 22.06.20 |
| Ed 1/Rev 3 | | Updated to accord with base (non-D&C) Specification R164 Ed 1/Rev 3. | MCQ | 20.11.20 |
| Ed 1/Rev 4 | | Updated to accord with base (non-D&C) Specification R164 Ed 1/Rev 4. | DT-M&E | 24.04.24 |

Transport for NSW

# SPECIFICATION D&C R164

# TUNNEL JET FANS

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# FOREWORD

## TFNSW COPYRIGHT AND USE OF THIS DOCUMENT

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## BASE SPECIFICATION

This document is based on Specification TfNSW R164 Edition 1 Revision 4.

# TfNSW SPECIFICATION D&C R164

# TUNNEL JET FANS

# 1 GENERAL

## 1.1 SCOPE

This Specification sets out the requirements for the supply of tunnel jet fans and related items such as casing, instrumentation, inlet and outlet silencers, anti-vibration mounts, fan mounting frame and installation cradle, including their design, manufacture, factory testing, documentation and delivery.

This Specification excludes requirements for installation of the jet fan equipment, supply and installation of anchor bolts, and supply and installation of all cabling (power and communications) beyond the jet fan terminal boxes.

## 1.2 STRUCTURE OF THE SPECIFICATION

This Specification includes a series of annexures that detail additional requirements.

### 1.2.1 Project Specific Requirements

Project specific details of work are shown in Annexure R164/A.

The types of jet fan and the number of each fan type required under the Project Deed are stated in Annexure R164/A. The number of maintenance cradles required under the Project Deed is also stated in Annexure R164/A.

### 1.2.2 (Not Used)

### 1.2.3 Schedules of HOLD POINTS, WITNESS POINTS and Identified Records

The schedules in Annexure R164/C list the **HOLD POINTS** and **WITNESS POINTS** that must be observed. Refer to Specification TS 01572.2 (TfNSW D&C Q6) for definitions of **HOLD POINTS** and **WITNESS POINTS**.

The records listed in Annexure R164/C are **Identified Records** for the purposes of TS 01572.2 (TfNSW D&C Q6) Annexure Q/E.

### 1.2.4 Planning Documents

The PROJECT QUALITY PLAN must include each of the documents and requirements listed in Annexure R164/D and must be implemented.

### 1.2.5 Referenced Documents

Standards, specifications and test methods are referred to in abbreviated form (e.g. AS 1234). For convenience, the full titles are given in Annexure R164/M.

## 1.3 DEFINITIONS AND ACRONYMS

### 1.3.1 Definitions

The terms "you" and "your" mean "the Contractor" and "the Contractor's" respectively.

The following definitions apply to this Specification:

| | |
|---|---|
| **Critical speed** | Speed at which the natural frequency is generated |
| **Flow reversal** | Change in the operating direction of fan flow, i.e. from flow in one direction to flow in the opposing direction |

### 1.3.2 Acronyms

| | |
|---|---|
| **DOL** | Direct on line |
| **ITP** | Inspection and Test Plan |
| **MTBF** | Mean Time Between Failure |
| **MTTR** | Mean Time To Repair |
| **NDE** | Non-destructive examination |
| **RTD** | Resistance temperature detector |
| **VSD** | Variable speed drive |

# 2 TENDER SUBMISSION AND FAN SELECTION

## 2.1 GENERAL

Submit in your tender the following information under Clauses 2.2 to 2.4 for consideration by the Principal of the jet fan(s) proposed.

The Principal will select the make and model for each type of jet fan required under the Project Deed using the tender submissions received. When assessing the proposed jet fan submitted, the Principal will give preference to jet fans (including motors) that can be serviced locally.

## 2.2 MANUFACTURER'S QUALIFICATIONS

Submit documentation demonstrating that:

(a) The jet fan manufacturer has at least 10 years of recent experience in the manufacture of jet fans of the type, size and capacity described in this Specification.

(b) Comparable jet fans and drive systems have been in satisfactory operation for a minimum of five years in at least three projects.

## 2.3 MANUFACTURER'S QUALITY SYSTEM

### 2.3.1 Quality System Certification

The jet fan manufacturer must have a quality management system independently certified as fully complying with AS/NZS ISO 9001, by an organisation accredited by JAS-ANZ or an affiliated international certification organisation. Submit current documentation as proof of this certification.

### 2.3.2 Documentation Submission

Submit also the following quality system documentation from the jet fan manufacturer:

(a) List of all technical procedures, work instructions and processes used for the manufacture and assembly of the jet fans.

(b) Typical Inspection and Test Plan (ITP) used for manufacture and assembly of jet fans, detailing inspection and testing methods and their applicable standards.

(c) Contact details of a third party certifier, whom the Principal may use to verify compliance of manufacturing and testing of the jet fans with this Specification, in the case where the jet fans are manufactured overseas.

### 2.3.3 Standards and Specifications

Where any of the standards or specifications used or proposed by the manufacturer for any material, manufacturing or testing method is different to what is specified in this Specification, submit details of such standard or specification with your tender for assessment by the Principal.

### 2.3.4 Audits and Inspections

The Project Verifier may conduct its own audits and inspections, or alternatively where the fans are to be manufactured overseas, may require you to engage a third party certifier to undertake the audits and inspections of the manufacturer's procedures and processes, including during the course of the contract.

## 2.4 TECHNICAL INFORMATION

Submit the following technical information:

(a) General arrangement and detailed drawings, showing all components of the proposed jet fan assembly. The drawings must show the overall dimensions of the fan assembly, the mounting frame and the mounting arrangement. The drawings must also show details of the installation cradle and proposed lifting methodology.

(b) General information about the proposed jet fan including type, size, thrust rating, performance, motor rating and operational parameters including estimated Mean Time Between Failure (MTBF) and Mean Time To Repair (MTTR).

(c) Data sheets showing jet fan performance in the forward flow direction and reverse flow direction if specified.

(d) Anticipated sound power spectrum at the specified forward and reverse operating thrust.

(e) Catalogue(s) of the proposed jet fans and their instrumentation sensors.

(f) General assembly and detailed drawings for jet fans of the same or similar design as that proposed including impeller and motor mount details. The drawings must include a list of system components, stating for each component the name of supplier, the material used and applicable manufacturing standards and drawing reference.

(g) Details of standards for material, welding, manufacturing and testing for use in the design and manufacture of the fans and supports, where they are not referenced or are different from that which is specified in this Specification.

(h) Proposed corrosion protection treatment regimes.

(i) Sample copies of recent test reports showing compliance of various materials, components and manufacturing procedures with their respective standards and associated ITPs.

(j) Proposed non-destructive examination (NDE) methods for all fan blades, hubs and welded connections in the fans and mounting frames.

(k) Evidence that fans of the same or similar design as that proposed are capable of operating at the elevated temperature specified in Annexure R164/A and resisting thermal shock.

Such evidence may be in the form of copies of certificates of tests carried out in accordance with ISO 21927-3 on comparable fans of the same manufacture and using the same components, at a date no longer than two years prior.

(l) Contact details and experience of proposed maintenance service provider who must have at least five years recent experience in maintaining fans similar to those proposed.

# 3 DESIGN AND PERFORMANCE

## 3.1 PERFORMANCE REQUIREMENTS

### 3.1.1 Operating Conditions

The jet fans and fan mounting frame must be suitable for operation in a tunnel environment, taking into consideration the following conditions under which they will be operating:

(a) continuous operation in polluted air, including but not limited to high concentrations of carbon monoxide, oxides of nitrogen, volatile organic compounds and particulate matter

(b) 24-hour operation

(c) water ingress from high pressure washing and water seepage

(d) normal operating temperature ranging from 0 to 55°C

(e) attack by vermin and insects

(f) subjected to vandalism.

The jet fans must also be suitable for operation using the electrical power supply stated in Annexure R164/A.

### 3.1.2 Fan Performance

The jet fans must be capable of meeting the minimum thrust requirements stated in Annexure R164/A.

In the design of the jet fan, take into consideration vehicle induced pressure transients.

The nominal absorbed power of the jet fans is stated in Annexure R164/A.

### 3.1.3 Reversibility

Where so specified in Annexure R164/A, the jet fans must be capable of reversible flow operation.

Such fans must be capable of changing from full flow in one direction to full flow in the opposing direction, with a de-energised period in between, within 90 seconds. Three flow reversals must be possible during a 20 minute period. (Refer Clause 1.3.1 for definition of "flow reversal".)

### 3.1.4 Aerodynamic Efficiency

Design the jet fan to operate at maximum aerodynamic efficiency for flow in the forward direction.

If reversible fans are required, the thrust generated in the reverse flow direction must not be less than 90% of that in the forward direction.

### 3.1.5 Stalling

Jet fans must be able to operate with the flow in the same or opposite direction to that of vehicle travel without stalling.

### 3.1.6 Elevated Temperature Operation

Design the jet fans and all components required for a fully functioning fan assembly, to continue to operate at the elevated temperature specified in Annexure R164/A.

### 3.1.7 Design Life

Design the jet fans and other components for the design life specified in Annexure R164/A.

### 3.1.8 Static and Dynamic Design Loads

Design all structural and mechanical parts of the jet fan assembly for strength, serviceability, fatigue and durability as required by the applicable design standard.

Apply a minimum factor of safety of 1.5 to all loads, or higher factors of safety where such higher factors of safety are specified by the design codes (e.g. AS 4100). Loads must include, but are not limited to:

(a) gravity, including any lateral components

(b) thrust, vibration and aerodynamic loads from fan operation

(c) torque reaction loads, including fan start-up torque reaction loads

(d) fan/motor imbalance loads

(e) loads generated during any flow reversal operations

(f) loads generated by air flows within the tunnel

(g) loads generated by traffic flows within the tunnel.

### 3.1.9 Balancing

Design the jet fan so that they are balanced both statically and dynamically.

### 3.1.10 Accessibility for Maintenance

Design the jet fans to be accessible for maintenance in a safe manner.

Jet fans must be removable from the mounting frame.

### 3.1.11 Lifting Points

Provide lifting points to lift the complete jet fan assembly in accordance with the methodology shown in the general arrangement drawings stated in Clause 2.4.

### 3.1.12 Dimensions

The nominal diameter of the fan impeller is stated in Annexure R164/A.

The dimensions of the jet fans and their supports must be such that, when installed, they do not encroach into the clearance envelope of the tunnel shown in the Design Documentation drawings.

## 3.2 DOCUMENTATION SUBMISSION

Prior to commencement of manufacture of the jet fans for the contract, submit the following information:

(a) Completed equipment schedule for the jet fan system as set out in Annexure R164/E.

(b) Fan performance data sheet, based on an air density of 1.2 kg/$m^3$.

If reverse flow is required, provide data for both forward and reverse flow.

(c) Workshop drawings of the jet fans and mounting frames. The drawings must include information about the material of each component and applicable standard, characteristics of finished surfaces and tolerances and their respective standards.

(d) General arrangement drawings showing the complete jet fan assembly, and details of their interface points with the tunnel structure.

(e) Fan mounting frame structural design calculations. Include any proposed modifications to the structural and mechanical design interface.

(f) Fan lifting methodology and lifting design calculations.

(g) Design load factors.

(h) Certification that the design complies with this Specification and the relevant standards.

(i) Details of the fan instrumentation sensors, including details on the output to the control system.

(j) Details of the fan motor and its components including workshop drawings, motor winding and insulation details, manufacturer's operating and maintenance instructions and part lists.

(k) Nominated corrosion rate classifications in accordance with AS 4312, and corresponding nominated corrosion protection treatment schemes for the various fan components in accordance with AS/NZS 2312. The nominated treatment must be based on the installation conditions and the corrosion rate classification specific to the equipment location.

(l) Nominated standards or procedures for the fabrication of all steel components, where these are not in accordance with Specification TS 01744.2 (TfNSW D&C B201). In particular, provide details of the welding standards for fabrication of all steel components, including fan casings and support frames.

(m) Nominated standards or procedures for the fabrication of all non-steel components.

(n) ITP for manufacture of the jet fans detailing inspection and testing methods and their applicable standard, including NDE procedures.

(o) Welding and material procurement plan that includes proposed material standards, welding procedure specifications, procedure qualification records, welder qualification records, weld maps and fatigue life enhancement methods.

(p) Evidence that the materials selected and the assembled product will meet the required design life with a reasonable level of maintenance.

(q) Proposed product identification nameplates, which must be in accordance with Clause 5.5.3.

(r) Manufacturing and delivery programme.

(s) Installation and commissioning manual(s).

(t) Operations and maintenance manual(s).

For items (s) and (t) above, a preliminary version containing only outline content is acceptable at this stage of the submission. The final manuals submitted must include the details specified in Clauses 8.3 and 9.5 respectively.

# 4 MATERIALS AND COMPONENTS

## 4.1 IMPELLER

### 4.1.1 Materials

Select materials for the impeller that are suitable for the specified temperature, anticipated pollution conditions, speeds, dynamic loads and fatigue loads throughout the design life.

### 4.1.2 Impeller Blade Section

For unidirectional jet fans, provide blades that are of true aerofoil section. If reversible fans are required, provide blades that are of symmetrical section to maximise efficiency in both directions.

### 4.1.3 Critical Speed

Design the shaft impeller motor assembly such that the first critical speed is at least 50% higher than the design maximum operating speed.

### 4.1.4 Stresses at Over-speed

Design the impeller to withstand stresses generated from 125% of the nominal operating speed.

## 4.2 MOTOR

### 4.2.1 Operating Characteristics

Jet fan motors must have the following characteristics:

(a) conformity with AS 60034

(b) single speed or variable speed as per duty specified in Annexure R164/A

(c) direct on line (DOL), using soft starter or variable speed drive (VSD) control, as specified in Annexure R164/A

(d) operate at maximum motor efficiency under normal operating conditions

(e) of a minimum power factor of 0.85

(f) housed in a “totally enclosed, air over” enclosure of IP65 rating to AS 60529 or IEC 60529

(g) fitted with anti-condensation heaters. Heaters to be turned on automatically when motors are not operating

(h) capable of being run in an inclined position of up to 15 degrees from the horizontal

(i) capable of operating at the elevated temperature where so specified in Annexure R164/A for the fan

(j) able to accelerate from standstill to full forward running speed in not more than 30 seconds for DOL or soft starters and 60 seconds for VDS operated

(k) for reversible fans, compliance with the flow reversal requirement specified in Clause 3.1.3

(l) capable of six starts per hour, or for reversible fans, six starts per hour in either direction including at least three reversals within 20 minutes

(m) minimum motor efficiency in accordance with IEC 60034-30-1 Class IE3 or equivalent

(n) motors connected to VSD in accordance with IEC TS 60034-25.

### 4.2.2 Motor Power Terminal Box

Fit a motor power terminal box, of IP65 rating to AS 60529, external to each fan casing, easily accessible from a platform below the fan.

### 4.2.3 Motor Voltage Rating

Where the fans are installed with VSDs, voltage impulses generated by the VSDs do not exceed the fan motor insulation voltage rating. Ensure that the motor voltage rating is suitable for the installation with respect to the locations of the VSDs, the length and types of cables between the VSDs and the fans, and overvoltage limiting devices such as dV/dt filters.

Submit an engineering analysis report to the Principal demonstrating that the suitable motor impulse voltage insulation class (IVIC) is selected and VSDs comply with the motor insulation capability. The report must include calculations and measurement methodologies, testing procedures, testing outcomes, and measurements of switching amplitudes, peak voltage, voltage rise and dV/dt at motor terminals.

## 4.3 BEARINGS

### 4.3.1 Basic Rating Life

Provide fan and motor bearings with a minimum basic rating life ($L_{10}$) in accordance with ISO 281 of either 40,000 hours or 10 years, depending on which is reached first operationally.

### 4.3.2 Damage to Stationary Fans

Design the bearings to avoid permanent damage when the jet fans are not operating, over the design life of the jet fan.

### 4.3.3 Lubrication

Equip the fans with "sealed for life" bearings.

You may submit for approval use of non-sealed lubricated bearings and include a lubrication system with lubrication points external to the fan casing at a location that is accessible from a platform below a suspended jet fan. Fix covers to lubrication points to prevent water and dust ingress.

Lubrication lines must be able to be cleared to eliminate blockages during lubrication.

Lubricants must be available locally, within Australia, throughout the design life of the fan.

### 4.3.4 Elevated Temperature Performance

Bearing lubricant must be capable of operating at the same elevated temperature as that for the fan where so specified in Annexure R164/A.

## 4.4 INSTRUMENTATION

### 4.4.1 Vibration Sensor

Equip each jet fan with permanent sensors to measure and report out of balance vibration from every bearing (including the bearings at both drive end and non-drive end), the impeller, and the motor. These sensors must monitor the jet fan continuously while it is running, and generate an alarm condition to the control system if the vibration exceeds a pre-set design limit.

Connect the sensors to the instrumentation terminal box.

### 4.4.2 Resistance Temperature Detector (RTD)

Equip each jet fan motor with motor bearing RTDs and motor winding RTDs or motor winding intelligent motor protection relays (IMPRs), connected to the instrumentation terminal box on the jet fan casing. These sensors must generate an alarm condition to the control system when bearing or winding over-temperature is detected.

### 4.4.3 Instrumentation Terminal Box

Provide an instrumentation terminal box, IP65 rating to AS 60529, external to the fan casing and separate from the motor terminal box, easily accessible from a platform below the fan.

### 4.4.4 Elevated Temperature Performance

All wiring and cabling within the air stream must be capable of operating at the same elevated temperature conditions, in accordance with AS/NZS 3013, as that for the fan where so specified in Annexure R164/A.

## 4.5 FAN CASING

### 4.5.1 Material

Manufacture jet fan casings of welded mild steel with a minimum thickness of 6 mm and with spun or continuously welded flanged ends for connection to silencers.

### 4.5.2 Lifting Points

Provide lifting points on the fan casing to allow the fan to be lifted in a stable manner whilst orientated in its final installed layout.

## 4.6 SILENCERS

### 4.6.1 General

Supply all jet fans complete with inlet and outlet silencers such that after the jet fans have been installed and with all jet fans operating at synchronous speed, the noise level does not exceed the requirement specified in Annexure R164/A.

### 4.6.2 Self-draining

Silencers must be self-draining cylindrical type silencers with drain points at each end of each silencer compartment such that water is not able to form a pool inside each compartment.

### 4.6.3 Elevated Temperature Performance

Silencers must be capable of operating at the same elevated temperature as that for the fan where so specified in Annexure R164/A.

### 4.6.4 Acoustic Lining Protection

Provide measures such as scrim cloth or equivalent to protect the acoustic lining from deterioration over the life of the silencers.

## 4.7 ANTI-VIBRATION MOUNTS

### 4.7.1 General

Mount each jet fan on anti-vibration spring mounts designed to isolate the fan vibration from the supporting structure under the dynamic design load expected during operation and outlined in Clause 3.1.8.

### 4.7.2 Failure of Anti-vibration Mounts

Design the mounts such that a complete failure of the anti-vibration elements would not allow the jet fan to fall.

### 4.7.3 Elevated Temperature Performance

Anti-vibration mounts must be capable of withstanding the same high temperature as that for the fan where so specified in Annexure R164/A.

## 4.8 FAN MOUNTING FRAME

### 4.8.1 General

Provide each jet fan with a mounting frame to independently support or suspend the fan assembly (comprising the fan, silencers, connectors, etc) from the tunnel structure.

### 4.8.2 Interface with Tunnel Structure

The interface between the fan mounting frame and the tunnel structure must fully comply with the Design Documentation drawings submitted under Clause 3.2.

### 4.8.3 Supports

Provide all jet fans with independently mounted safety chains or cables, capable of supporting the jet fan in the event of failure of the fan supports, and withstanding the dynamic shock loads that may occur during that failure.

Under normal operating conditions (i.e. non-failure), the safety chains or cables must not carry any equipment loads or abrasively contact any part of the fan or silencer casings.

Provide adequate bracing to the mounting frame so that it remains stable during start up, operation, testing and shut down.

Provide additional supports for silencers if such supports are required.

### 4.8.4 Elevated Temperature Performance

Design the mounting frame to be capable of withstanding the same elevated temperature as that specified for the fan in Annexure R164/A.

## 4.9 FASTENERS

### 4.9.1 General

Supply all fasteners (e.g. nuts, bolts, spacers, washers, seals, packers, etc) necessary for the complete assembly and mounting of the fans and other components which are supplied together with the fans, such as silencers.

All bolts, nuts, screw and washers provided must be in accordance with the Design Documentation drawings and Specification TS 01744.2 (TfNSW D&C B201) and TS 00033.

### 4.9.2 Corrosion Protection

All fasteners must be hot-dip galvanized.

Care must be taken to avoid galvanic and other corrosion of fasteners.

### 4.10 CRADLES

#### 4.10.1 Installation Cradles

Supply the number of installation cradles required for the fan installation in accordance with your installation methodology submitted in Clause 3.2.

You may propose changes to the installation arrangements, including changes to the number of cradles, from those submitted in Clause 3.2.

#### 4.10.2 Maintenance Cradles

To facilitate maintenance and servicing of the jet fans, supply the minimum number of maintenance cradles specified in Annexure R164/A.

## 5 MANUFACTURE

### 5.1 GENERAL

#### 5.1.1 Hold Point

| **HOLD POINT** | |
|---|---|
| Process Held | Manufacture of each type of jet fans and their supports. |
| Submission Details | At least 20 working days prior to commencement of fabrication, submit to the Principal the documentation detailed in Clause 3.2. |
| Release of Hold Point | The Principal will examine the submitted items prior to authorising the release of the Hold Point. |

#### 5.1.2 Third Party Certifier

Where jet fans are to be manufactured overseas, the Principal may order that you engage a third party certifier approved by the Principal to verify compliance of the manufacture of the fans with this Specification.

### 5.2 FANS

#### 5.2.1 General

Carry out the fabrication of fan assembly, including its individual components and associated items such as the mounting frame, in accordance with the approved standards and/or procedures submitted under Clause 3.2.

#### 5.2.2 Dynamic Balance

Balance each jet fan dynamically to balance quality grade G 2.5 in accordance with ISO 21940-11 and/or ANSI/AMCA 204 to fan application category BV-4 in ISO 14694. Once balanced, the maximum vibration measured of the fan must not exceed 4.5 mm/s rms.

## 5.3 NON-DESTRUCTIVE EXAMINATION

In addition to the visual inspection in accordance with AS/NZS 5131, carry out ultrasonic and/or radiographic (x-ray), magnetic particle and/or penetrant non-destructive examination (NDE) of all components and welds in accordance with AS/NZS 5131, AS/NZS 1554.1, AS/NZS 1554.4, AS/NZS 1554.5, AWS D1.1, ASTM E 164 and ISO 15614.

Welds must be able to withstand dynamic loading and high level fatigue condition. The type and minimum extent of NDE for welds subject to fatigue must conform to the acceptance criteria specified in above standards.

Carry out radiographic (x-ray) NDE of all fan blades and hubs in accordance with EN 12681 and/or ASTM E 155 for detection of discontinuities including cracks, porosity, inclusions, and cavities.

Submit NDE regimes, including the method, extent for each part and acceptance criteria, for approval by the Principal prior to manufacturing.

## 5.4 SURFACE CORROSION PROTECTION AND FINISH

### 5.4.1 General

Apply corrosion protection treatment to all fan assembly components, including the mounting frames, in accordance with your nominated treatment schemes submitted under Clause 3.2. The fan casing including all flanges must be hot-dip galvanized in accordance with AS/NZS 4680, ASTM A123M and/or ISO 1461.

### 5.4.2 Seal All Crevices

Weld fully or otherwise seal all crevices in the fan casing or at the connection to flanges, to protect against crevice corrosion.

### 5.4.3 Prevent Galvanic Corrosion

Provide measures to prevent galvanic corrosion of fan components and supports due to contact between dissimilar metals.

### 5.4.4 Painting

Paint all jet fan and silencer casings matt black to match or blend in with the tunnel soffit. Painting schemes must be in accordance with AS/NZS 2312. Use paint that is suitable for the tunnel environment including the elevated temperature requirements specified in Clause 3.1.6.

## 5.5 PRODUCT IDENTIFICATION

### 5.5.1 General

Identification plates must be fabricated from stainless steel and permanently attached to the motor housing or fan outer casing, as appropriate.

### 5.5.2 Motor Identification Plate

Fix to each motor an identification plate showing the following:

(i) name and address of the motor manufacturer

(ii) serial number of the motor

(iii) model number

(iv) motor speed in revolutions per minute

(v) nominal power rating

(vi) electrical characteristics of the motor.

### 5.5.3 Fan Identification Plate

Fix to each jet fan an identification plate showing the following:

(a) name and address of the fan manufacturer

(b) serial number of the fan

(c) model number

(d) maximum safe rotational speed of the fan in revolutions per minute

(e) design operating thrust of the fan

(f) asset identifier.

## 5.6 MATERIAL AND COMPONENT CERTIFICATION

Submit the following documentation prior to delivery of the fans in accordance with Clause 7.1:

(a) certified inspection and test reports for fan materials verifying compliance in accordance with the ITP submitted by the fan manufacturer

(b) certified welding inspection test results and non-destructive examination results verifying compliance for fan components and frames in accordance with the ITP submitted by the fan manufacturer.

# 6 FACTORY TESTING

## 6.1 GENERAL

Factory testing under this Specification comprises acceptance testing and production testing.

### 6.1.1 Hold Point

| **HOLD POINT** | |
|---|---|
| Process Held | Acceptance and production testing of each type of jet fans. |
| Submission Details | Details of the testing setups, testing procedures and acceptance criteria at least 10 working days prior to commencement of acceptance and/or production testing. |
| Release of Hold Point | The Nominated Authority will examine the submitted items prior to authorising the release of the Hold Point. |

The above Hold Point applies wherever different testing setups, testing procedures or acceptance criteria are proposed, and the required details have not been previously submitted.

### 6.1.2 Witness Point

| **WITNESS POINT** | |
|---|---|
| Process to be Witnessed: | Each acceptance and production testing of fans. |
| Submission Details: | Notification in writing of testing, at least 10 working days prior to the date of testing. Allow for this lead time in your delivery programme. |

### 6.1.3 Third Party Certifier

Where factory testing is to be carried out overseas, the Principal may order that you engage a third party certifier approved by the Principal to verify compliance of the fan testing with this Specification. Factory testing not witnessed by the approved certifier or another party delegated by the Principal for this purpose will not be accepted for compliance verification purposes.

## 6.2 ACCEPTANCE TESTING – JET FANS

### 6.2.1 Number of Tests

Carry out acceptance testing on 10% of the jet fans of each type. Where the 10% value is a fraction, round it up to the next higher integer.

### 6.2.2 Details of Tests

Carry out the following tests as part of acceptance testing:

(a) **Thrust performance** to ISO 13350 giving measurements of developed thrust, in both forward and reverse directions (where applicable). Test the fan assembly complete with silencers for thrust performance.

Take measurements of the **thrust**, **speed of rotation**, and **electrical power input** at the duty point for the proposed system.

Record the **motor performance characteristics** including voltage, current, input power and power factor.

(b) Noise tests to ISO 13350 Section 8 “Determination of sound level”.

(c) Validate the time taken for the fan to reach full forward running speed from standstill and the capability of six starts per hour. For reversible fans, prove the reversing cycle including six starts per hour in either direction with at least three reversals within 20 minutes.

(d) Prove the instrumentation operation including the output from the vibration sensors and the RTDs or IMPRs when the fan is operating at the design duty point.

(e) Over-speed test on the fan impeller, at 125% of nominal operating speed for three minutes. Examine for loose components, damage, excessive vibration, or adverse behaviour and carry out radiographic (x-ray) or dye penetrant inspection of all fan blades for detection of defects or cracks.

(f) Validate the structural design with strain gauge measurements, including but not limited to the motor mounting frame.

(g) If the fan is required to operate at the elevated temperature as specified in Annexure R164/A, and the Principal has ordered acceptance testing, prove the fan at this **elevated temperature** and verify its resistance to thermal shock in accordance with ISO 21927-3 and/or EN 12101-3.

In lieu of carrying out acceptance testing at the elevated temperature, the Principal may accept certificates of such tests carried out on comparable fans of the same manufacture and using the same components, submitted under Clause 2.4.

## 6.3 ACCEPTANCE TESTING – CRADLE

### 6.3.1 Number of Tests

Carry out acceptance testing on at least one installation cradle and one maintenance cradle.

### 6.3.2 Details of Tests

Carry out the following tests as part of acceptance testing:

**(a) Functionality:**

Demonstrate the capabilities of the cradle to perform all functions of the cradle using a production jet fan complete with silencers and mounting brackets.

**(b) Lifting capacity:**

Test the cradle for lifting capacity using a test load of at least twice the intended working load.

## 6.4 PRODUCTION TESTING

### 6.4.1 Number of Tests

Carry out production testing on all fans to be delivered.

### 6.4.2 Details of Tests

Carry out the following test as part of production testing:

**Maximum speed test**, at 100% of maximum rated speed for three minutes. Examine for loose components, damage, excessive vibration or adverse behaviour.

## 6.5 FAN CERTIFICATION

Prior to delivery of the jet fans and cradles, submit certificates of compliance for the following:

(a) acceptance testing for jet fans

(b) production testing for jet fans

(c) acceptance testing for installation/maintenance cradles

(d) certification to EN 12101-3 and ISO 21927-3.

# 7 TRANSPORT AND DELIVERY

## 7.1 GENERAL

### 7.1.1 Hold Point

| HOLD POINT | |
|---|---|
| Process Held | Dispatch of jet fans, supporting frames, cradles and other ancillary items. |
| Submission Details | NDE test results (refer Clause 5.3), certification documents (refer Clauses 5.6 and 6.5), installation and commissioning manual(s) (refer Clause 8.3), warranty (refer Clause 9.1), and operations and maintenance manual(s) (refer Clause 9.5) at least 10 working days prior to dispatch. |
| Release of Hold Point | The Nominated Authority will examine the submitted items prior to authorising the release of the Hold Point. |

### 7.1.2 Delivery Location

Deliver the jet fans, supporting frames, cradles and other ancillary items to the Site unless stated otherwise in Annexure R164/A.

## 7.2 TRANSPORT

### 7.2.1 General

Load and transport the fans and associated ancillary items and provide protection during sea and road transportation and long-term storage requirements where applicable in a manner that avoids any distortion or damage to the fans, components and their protective coatings.

### 7.2.2 Labelling

Clearly label each packed item with the contract reference number, description and quantity of the contents. Include details of the handling requirements.

### 7.2.3 Packing Protection

Protect the jet fans from heavy vibration during transport.

In the packing of the fans and ancillary items, use padding materials appropriate for the mode of transport to prevent damage to the fans or to their protective coatings during handling, storage and transport.

### 7.2.4 Corrosion Inhibitor

Protect any machined and unpainted surfaces with a temporary corrosion inhibitor compound prior to dispatch.

# 8 INSTALLATION SUPERVISION AND SITE ACCEPTANCE TESTING

Installation and commissioning of the jet fans is not within the scope of this Specification.

## 8.1 ATTENDANCE AT SITE DURING INSTALLATION AND COMMISSIONING

Provide a representative of the jet fan manufacturer who will be in attendance at the Site to supervise the installation, site acceptance testing and commissioning of the jet fans.

## 8.2 FAN INSTALLATION WITH VSDS

Where fans are installed with VSDs, the VSDs must be located at close proximity to the fans wherever possible. If dV/dt filters are required to limit the voltage impulses generated by VSDs, the filters must also be located as close as possible to the fan motor terminals.

Prior to running the fans, representative of the fan manufacturer in attendance at the Site must inspect the electrical installation and verify that the motor and VSD manufacturers' recommendations have been followed with respect to the locations of the VSDs, the length and types of cables between the VSDs and the fans, and the types and locations of overvoltage limiting devices such as dV/dt filters.

## 8.3 INSTALLATION AND COMMISSIONING MANUAL(S)

### 8.3.1 Number of Copies

Provide three paper copies and an electronic copy of the final installation and commissioning manual(s), written in the English language, for the fans.

### 8.3.2 Contents

The manual(s) must include as a minimum the following:

(a) installation methodology

(b) site acceptance testing (SAT) procedures

(c) procedures for field testing of fans using their instrumentation sensors, in accordance with ISO 5802

(d) commissioning procedures

(e) factory acceptance test (FAT) records.

# 9 POST-COMMISSIONING AND MAINTENANCE

## 9.1 WARRANTY

Provide a written performance warranty from the manufacturer of the jet fans, for the warranty period stated in Annexure R164/A from the date of commissioning completion of the fans.

The warranty must be in the name of Transport for NSW and must cover the repair or replacement of parts to the same standard as that required under this Specification.

## 9.2 DEFECTS RECTIFICATION

Rectify any defects, including replacing as necessary any defective parts, during the warranty period at no cost to TfNSW.

Attend to any notification of defect within 24 hours, and complete the required rectification work within the minimum time period agreed with the Principal.

## 9.3 ROUTINE MAINTENANCE

The maintenance service provider must carry out routine maintenance of the fans in accordance with the submitted schedule in Clause 9.5, for the period stated in Annexure R164/A from the date of commissioning completion of the fans.

## 9.4 SPARE PARTS AND CONSUMABLES

Supply all parts and consumables required for defect rectification and routine maintenance over the warranty and routine maintenance period.

All replacement parts used must be new and of the same make and model as the original.

## 9.5 OPERATION AND MAINTENANCE MANUAL(S)

### 9.5.1 Number of Copies

Provide three paper copies and an electronic copy of the operation and maintenance manual(s), written in the English language, for the fans.

### 9.5.2 Contents

The manual(s) must include, but are not limited to, the following:

(a) operation procedures, including measures to maximise bearing life

(b) detailed drawings showing the complete fan assembly, details of interface points with the frame and any connected components

(c) routine maintenance/servicing procedures

(d) routine maintenance schedules and recommended refurbishment schedules

(e) all design parameters

(f) schedule of fan and components models, serial numbers and suppliers

(g) designation, part numbers and commercial sources of spare parts

(h) recommended list of spare parts to be carried

(i) storage and maintenance requirements for the fans and ancillary items

(j) supplier local contact details and maintenance partners.

## 9.6 TOOLS AND ACCESSORIES

Provide two sets of all special tools and accessories required for operation and maintenance of equipment provided.

# ANNEXURE R164/A – PROJECT SPECIFIC REQUIREMENTS

Refer to Clause 1.2.1.

*NOTES TO TENDER DOCUMENTER: (Delete this boxed text after customising Annexure R164/A)*

*Complete the tables below by deleting whichever option is not applicable and filling in the required details. Some items may be covered elsewhere in the Project Deed or their requirements may not be known at the time of tender. For such items, either delete them or leave them blank. For advice on how to complete the tables, contact the Tunnel Technology Unit.*

## A1 GENERAL REQUIREMENTS

*NOTES TO TENDER DOCUMENTER: (Delete this boxed text after customising Annexure R164/A)*

*In the table below, the routine maintenance period should normally be the same as the warranty period.*

| Clause | Description | Requirements |
|---|---|---|
| 3.1.1 | Electrical power supply (ph/V/Hz) | ….. / ….. / ….. |
| 3.1.7 | Design life | 25 years [3] |
| 4.6.1 | In-tunnel noise level | ….. dBA or NR ….. |
| 7.1.2 | Delivery location [1] | |
| | Jet fans | ……. |
| | Maintenance cradles | ……. |
| 9.1 | Warranty period | 5 years [2, 4] |
| 9.3 | Routine maintenance period | ….. years [2] |

**Notes:**

[1] Delivery location is the Site unless stated otherwise above.

[2] Starting from the date of commissioning completion.

[3] Default design life is 25 years.

[4] Default warranty period is five years.

## A2 FAN TYPE AND QUANTITY

*The table below is intended for use by the Contractor during the tunnel ventilation procurement stage.*

*In the table below, "Fan designation" refers to an identifying code number for the particular fan type (e.g. JFN-01) shown on the Design Documentation drawings.*

*Additional specific details may also be nominated within section A2 if required. This may include motor size, fan efficiency if there are known and project specific limitations with respect to power availability.*

*Where there is more than one fan type, insert additional columns in the table.*

| Clause | Parameter | Details |
|---|---|---|
| 1.2.1 | Fan designation | ……. |
| | Installation location | ……. |
| | Type | ……. |
| | Quantity required: | |
| | Jet fans | ….. |
| | Maintenance cradles | ….. |
| 3.1.2 | Forward thrust, nominal (N) | ….. |
| 3.1.3 | Flow direction | Unidirectional/Reversible |
| 3.1.6 | Elevated temperature operation | …..°C for ….. hours |
| 3.1.12 | Impeller diameter, nominal (mm) | ….. |
| 4.2.1 | VSD operation | Yes/No |

Note:
(1) If requirement is "No", then motor starter must be DOL or soft starter.

# ANNEXURE R164/B – (NOT USED)

# ANNEXURE R164/C – SCHEDULES OF HOLD POINTS, WITNESS POINTS AND IDENTIFIED RECORDS

Refer to Clause 1.2.3.

## C1 SCHEDULE OF HOLD POINTS AND WITNESS POINTS

| Clause | Type | Description |
|---|---|---|
| 5.1.1 | Hold | Manufacture of each type of jet fan |
| 6.1.1 | Hold | Acceptance and production testing of each type of jet fan |
| 6.1.2 | Witness | Each acceptance and production testing of jet fans |
| 7.1.1 | Hold | Dispatch of jet fans and ancillary items. |

## C2 SCHEDULE OF IDENTIFIED RECORDS

The records listed below are Identified Records for the purposes of TS 01572.2 (TfNSW D&C Q6) Annexure Q/E.

| Clause | Description of Identified Record |
|---|---|
| 2.4 | Details of proposed fan system maintenance service provider |
| 3.2 | Design Documentation drawings and other technical information of fans |
| 5.3 | NDE test reports |
| 5.6 | Material and component certification |
| 6.4 | Fan acceptance and production testing certification |
| 8.3 | Installation and commissioning manual(s) |
| 9.1 | Warranty |
| 9.5 | Operation and maintenance manual(s) |

# ANNEXURE R164/D – PLANNING DOCUMENTS

Refer to Clause 1.2.4.

The following documents are a summary of documents that must be included in the PROJECT QUALITY PLAN. The requirements of this Specification and others included in the Project Deed must be reviewed to determine additional documentation requirements.

| Clause | Description of Document |
|---|---|
| 3.2 | Inspection and Test Plan (ITP) for manufacture of fans |
| 5.3 | NDE procedures |
| 6.2 | Acceptance testing procedures |
| 6.4 | Production testing procedures |

# ANNEXURE R164/E – EQUIPMENT SCHEDULE

Complete the schedule shown below with details of the jet fan proposed for the contract and submit it in accordance with Clause 3.2 prior to commencement of manufacture of the fans.

| Description | Details |
|---|---|
| Designation | |
| Location | |
| Make | |
| Model | |
| Quantity | |
| Rated thrust, minimum (N) | |
| Forward | |
| Reverse | |
| Exit velocity (m/s) | |
| Speed (rpm) | |
| Absorbed power (kW) | |
| Efficiency ($N_{thrust}/kW_{power}$) | |
| Impeller diameter (mm) | |
| Pitch angle (degrees) | |
| Motor type | |
| Motor frame size, L x W x D (m) | |
| Motor power input (kW) | |
| Electrical power supply (ph/V/Hz) | |
| Power factor | |
| Start-up amperage (A) | |
| Resistance temperature detector (Yes/No) | |
| Elevated temperature operation | …..°C for ….. hours |
| Variable speed drive capable (Yes/No) | |
| Direct on line capable (Yes/No) | |
| Corrosion protection type | |
| Bearing type | |
| Bearing life (hours) | |
| Jet fan fall protection (Yes/No) | |
| Anti-vibration mounting type | |
| Bearing over temperature (°C) | |
| Motor rating | |

| Description | Details |
|---|---|
| Silencer length (m) | |
| Total weight including silencers (tonne) | |
| Unweighted sound power spectrum (dBW) | |
| 63 Hz | |
| 125 Hz | |
| 250 Hz | |
| 500 Hz | |
| 1000 Hz | |
| 2000 Hz | |
| 4000 Hz | |
| 8000 Hz | |
| Sound pressure @ 3m dBA | |
| MTBF (hours) | |
| MTTR (hours) | |

# ANNEXURES R164/F TO R164/L – (NOT USED)

# ANNEXURE R164/M – REFERENCED DOCUMENTS

Refer to Clause 1.2.5.

### TfNSW Specifications

| | |
|---|---|
| TS 01744.2 (TfNSW D&C B201) | Steelwork for Bridges |
| TS 00033 | Supply of Bolts, Nuts and Washers, ATS 5420-20, Ed 1.0 MOD |
| TS 01572.2 (TfNSW D&C Q6) | Quality Management (Major Works) |

### Australian Standards

| | |
|---|---|
| AS/NZS 1554 | Structural steel welding |
| AS/NZS 1554.1 | Welding of steel structures |
| AS/NZS 1554.4 | Welding of high strength quenched and tempered steels |
| AS/NZS 1554.5 | Welding of steel structures subject to high levels of fatigue loading |
| AS 2207 | Non-destructive testing – Ultrasonic testing of fusion welded joints in carbon and low alloy steel |
| AS/NZS 2312 | Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings – Parts 1 & 2 |
| AS/NZS 3013 | Electrical installations – Classifications of the fire and mechanical performance of wiring system elements |
| AS 4100 | Steel structures |
| AS 4312 | Atmospheric corrosivity zones in Australia |
| AS/NZS 4680 | Hot-dip galvanised (zinc) coatings on fabricated ferrous articles |
| AS/NZS 5131 | Structural steelwork – Fabrication and erection |
| AS/NZS ISO 9001 | Quality management system – Requirements |
| AS 60529 | Degrees of protection provided by enclosures (IP Code) |
| AS 60034 | Rotating electrical machines (series) |

### Overseas and International Standards

| | |
|---|---|
| ANSI/AMCA 204 | Balance Quality and Vibration Levels for Fans |
| ANSI/AMCA 210 | Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating |
| ASTM A123M | Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products |
| ASTM E 155 | Standard Reference Radiographs for Inspection of Aluminum and Magnesium Castings |
| ASTM E 164 | Standard Practice for Contact Ultrasonic Testing of Weldments |
| AWS D1.1 | Structural Welding – Steel |
| EN 1993 | Design of Steel Structures |
| EN 1993.1 | Eurocode 3: Design of steel structures |

| | |
|---|---|
| EN 12101-3 | Smoke and Heat Control Systems – Part 3: Specifications for Powered Smoke and Heat Control Ventilators (fans) |
| EN 12681 | Founding – Radiographic examination |
| EN 12681-1 | Founding – Radiographic Testing – Part 1: Film Techniques |
| IEC 60034 | Rotating Electrical Machines (series) |
| IEC TS 60034-25 | Rotating electrical machines – Part 25: AC electrical machines used in power drive systems – Application guide |
| IEC 60034-30-1 | Rotating electrical machines – Part 30-1: Efficiency classes of line operated AC motors |
| IEC 60529 | Degrees of protection provided by enclosures (IP Code) |
| ISO 281 | Rolling bearings – Dynamic load ratings and rating life |
| ISO 1461 | Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods |
| ISO 3744 | Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering methods for an essentially free field over a reflecting plane |
| ISO 5136 | Acoustics – Determination of sound power radiated into a duct by fans and other air-moving devices – In-duct method |
| ISO 5801 | Industrial fans – Performance testing using standardised airways |
| ISO 5802 | Industrial fans – Performance testing in situ |
| ISO 12944 | Paints and varnishes – Corrosion protection of steel structures by protective paint systems |
| ISO 12944-2 | Classification of Environments |
| ISO 12944-5 | Protective Paint Systems |
| ISO 13350 | Fans – Performance testing of jet fans |
| ISO 14694 | Industrial fans – Specifications for balance quality and vibration levels |
| ISO 14713 | Zinc coatings – Guidelines and recommendations for the protection against corrosion of iron and steel in structures |
| ISO 15614 | Specification and qualification of welding procedures for metallic materials |
| ISO 21927-3 | Smoke and heat control systems – Part 3: Specification for powered smoke and heat exhaust ventilators |
| ISO 21940-11 | Mechanical vibration – Rotor balancing – Part 11: Procedures and tolerances for rotors with rigid behaviour |