

Part 1 General**1.1 RELATED REQUIREMENTS**

- .1 Section 23 05 93 - Testing, Adjusting and Balancing for HVAC.

1.2 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
 - .1 Submit manufacturer's instructions, printed product literature and data sheets. Include product characteristics, performance criteria, physical size, finish and limitations.
- .3 Shop Drawings:
 - .1 Indicate on drawings:
 - .1 Mounting arrangements.
 - .2 Operating and maintenance clearances.
 - .2 Shop drawings and product data accompanied by:
 - .1 Detailed drawings of bases, supports, and anchor bolts.
 - .2 Acoustical sound power data, where applicable.
 - .3 Points of operation on performance curves.
 - .4 Manufacturer to certify current model production.
 - .5 Certification of compliance to applicable codes.
 - .3 In addition to transmittal letter referred to in Section 01 33 00 - Submittal Procedures: use MCAC "Shop Drawing Submittal Title Sheet". Identify section and paragraph number.

1.3 CLOSEOUT SUBMITTALS

- .1 Submit in accordance with Section 01 78 00 - Closeout Submittals.
- .2 Operation and Maintenance Data: submit operation and maintenance data for incorporation into manual.
 - .1 Operation and maintenance manual approved by, and final copies deposited with, Departmental Representative before final inspection.
 - .2 Operation data to include:
 - .1 Control schematics for systems including environmental controls.
 - .2 Description of systems and their controls.
 - .3 Description of operation of systems at various loads together with reset schedules and seasonal variances.
 - .4 Operation instruction for systems and component.
 - .5 Description of actions to be taken in event of equipment failure.
 - .6 Valves schedule and flow diagram.
 - .7 Colour coding chart.
 - .3 Maintenance data to include:
 - .1 Servicing, maintenance, operation and trouble-shooting instructions for each item of equipment.
 - .2 Data to include schedules of tasks, frequency, tools required and task time.
 - .4 Performance data to include:
 - .1 Equipment manufacturer's performance datasheets with point of operation as left after commissioning is complete.
 - .2 Equipment performance verification test results.
 - .3 Special performance data as specified.
 - .4 Testing, adjusting and balancing reports as specified in Section 23 05 93 - Testing, Adjusting and Balancing for HVAC.

- .5 Approvals:
 - .1 Submit 2 copies of draft Operation and Maintenance Manual to Departmental Representative for approval. Submission of individual data will not be accepted.
 - .2 Make changes as required and re-submit as directed by Departmental Representative.
- .6 Additional data:
 - .1 Prepare and insert into operation and maintenance manual additional data when need for it becomes apparent during specified demonstrations and instructions.
- .7 Site records:
 - .1 Departmental Representative will provide 1 set of reproducible mechanical drawings. Provide sets of white prints as required for each phase of work. Mark changes as work progresses and as changes occur. Include changes to existing mechanical systems, control systems and low voltage control wiring.
 - .2 Transfer information weekly to reproducibles, revising reproducibles to show work as actually installed.
 - .3 Use different colour waterproof ink for each service.
 - .4 Make available for reference purposes and inspection.
- .8 As-built drawings:
 - .1 Prior to start of Testing, Adjusting and Balancing for HVAC, finalize production of as-built drawings.
 - .2 Identify each drawing in lower right hand corner in letters at least 12 mm high as follows:
- "AS BUILT DRAWINGS: THIS DRAWING HAS BEEN REVISED TO SHOW MECHANICAL SYSTEMS AS INSTALLED" (Signature of Contractor) (Date).
 - .3 Submit to Departmental Representative for approval and make corrections as directed.
 - .4 Perform testing, adjusting and balancing for HVAC using as-built drawings.
 - .5 Submit completed reproducible as-built drawings with Operating and Maintenance Manuals.
- .9 Submit copies of as-built drawings for inclusion in final TAB report.

1.4 DELIVERY, STORAGE AND HANDLING

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements and with manufacturer's written instructions.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
 - .1 Store materials off ground, indoors, and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
 - .2 Store and protect , from nicks, scratches, and blemishes.
 - .3 Replace defective or damaged materials with new.

Part 2 Products

2.1 NOT USED

- .1 Not used.

Part 3 Execution

3.1 REPAIRS AND RESTORATION

- .1 Prime and touch up marred finished paintwork to match original.
- .2 Restore to new condition, finishes which have been damaged.

3.2 SYSTEM CLEANING

- .1 Clean interior and exterior of all systems including strainers. Vacuum interior of ductwork and air handling units.

3.3 DEMONSTRATION

- .1 Supply tools, equipment and personnel to demonstrate and instruct operating and maintenance personnel in operating, controlling, adjusting, trouble-shooting and servicing of all systems and equipment during regular work hours, prior to acceptance.
- .2 Use operation and maintenance manual, as-built drawings, and audio visual aids as part of instruction materials.

3.4 CLEANING

- .1 Progress Cleaning:
 - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment.
- .3 Waste Management: separate waste materials for reuse and recycling

3.5 PROTECTION

- .1 Protect equipment and systems openings from dirt, dust, and other foreign materials with materials appropriate to system.

END OF SECTION

Part 1 General**1.1 SUMMARY**

- .1 Section Includes:
 - .1 Electrical motors, drives and guards for mechanical equipment and systems.
 - .2 Supplier and installer responsibility indicated in Motor, Control and Equipment Schedule on electrical drawings and related mechanical responsibility is indicated on Mechanical Equipment Schedule on mechanical drawings.
 - .3 Control wiring and conduit is specified in Division 26 except for conduit, wiring and connections below 50 V which are related to control systems specified in Division 22 and 23. Refer to Division 26 for quality of materials and workmanship.

1.2 REFERENCES

- .1 American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE)
 - .1 ASHRAE 90.1-2016, Energy Standard for Buildings Except Low-Rise Residential Buildings (IESNA cosponsored; ANSI approved; Continuous Maintenance Standard).
- .2 Electrical Equipment Manufacturers' Association Council (EEMAC)
- .3 Health Canada/Workplace Hazardous Materials Information System (WHMIS)
 - .1 Material Safety Data Sheets (MSDS).
- .4 National Electrical Manufacturers Association (NEMA)
 - .1 NEMA MG 1-2016, Motors and Generators.

1.3 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Submittals: in accordance with Section 01 33 00 - Submittal Procedures.

Part 2 Products**2.1 GENERAL**

- .1 Motors: high efficiency, in accordance with local Hydro company standards and to ASHRAE 90.1.

2.2 MOTORS

- .1 Provide premium efficiency motors for mechanical equipment to NEMA MG 1 Part 31.
- .2 Motors under 373 W (½ HP): speed as indicated, continuous duty, built-in overload protection, resilient mount, single phase, 120 V, unless otherwise specified or indicated.
- .3 Motors 373 W (½ HP) to 14.92 kW (20 HP): EEMAC Class B/F, squirrel cage induction, speed as indicated, continuous duty, drip proof, ceramic ball bearing, maximum temperature rise 45°C/60°C over ambient of 30°C, 3 phase, 600 V, unless otherwise specified or indicated.
- .4 Motors 18.65 kW (25 HP) and larger: EEMAC Class B/F, squirrel cage induction, speed as indicated, continuous duty, drip proof, ceramic ball bearing, maximum temperature rise 45°C/60°C over ambient of 30°C, 3 phase, 600 V, c/w integral thermistor protection, unless otherwise specified or indicated. Thermistors shall be factory installed, copper RTD type, one on each phase, wired to identified terminals in motor terminal box and wired to starter/VFD (wiring, conduit & connections by Div. 26).

- .5 Two speed motors shall be double winding type.
- .6 Motors coupled with VFD shall be premium efficiency, inverter duty type to NEMA MG 1 Part 31 and shall have as a minimum EEMAC Class F insulation. Inverter ready motors shall not be acceptable.
- .7 Motors coupled with VFD's shall include ceramic bearings.
- .8 Motors located outside to be TEFC type, unless located in insulated weatherproof enclosure.

2.3 BELT DRIVES

- .1 Fit reinforced belts in sheave matched to drive. Multiple belts to be matched sets.
- .2 Use cast iron or steel sheaves secured to shafts with removable keys unless otherwise indicated.
- .3 For motors 7.5 kW and over: sheave with split tapered bushing and keyway having fixed pitch unless specifically required for item concerned. Provide sheave of correct size to suit balancing.
- .4 Correct size of sheave determined during commissioning.
- .5 Minimum drive rating: 1.5 times nameplate rating on motor. Keep overhung loads within manufacturer's design requirements on prime mover shafts.
- .6 Motor slide rail adjustment plates to allow for centre line adjustment.
- .7 Supply one set of spare belts for each set installed in accordance with Section 01 78 00 - Closeout Submittals.

2.4 DRIVE GUARDS

- .1 Provide guards for unprotected drives.
- .2 Guards for belt drives:
 - .1 Expanded metal screen welded to steel frame.
 - .2 Minimum 1.2 mm thick sheet metal tops and bottoms.
 - .3 38 mm dia holes on both shaft centres for insertion of tachometer.
 - .4 Removable for servicing.
- .3 Provide means to permit lubrication and use of test instruments with guards in place.
- .4 Install belt guards to allow movement of motors for adjusting belt tension. -
- .5 Guard for flexible coupling:
 - .1 "U" shaped, minimum 1.6 mm thick galvanized mild steel.
 - .2 Securely fasten in place.
 - .3 Removable for servicing.
- .6 Unprotected fan inlets or outlets:
 - .1 Wire or expanded metal screen, galvanized, 19 mm mesh.
 - .2 Net free area of guard: not less than 80% of fan openings.
 - .3 Securely fasten in place.
 - .4 Removable for servicing.

Part 3 Execution**3.1 MANUFACTURER'S INSTRUCTIONS**

- .1 Compliance: comply with manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheet.

3.2 INSTALLATION

- .1 Fasten securely in place.
- .2 Make removable for servicing, easily returned into, and positively in position.

3.3 FIELD QUALITY CONTROL

- .1 Manufacturer's Field Services:
 - .1 Obtain written report from manufacturer verifying compliance of Work, in handling, installing, applying, protecting and cleaning of product and submit Manufacturer's Field Reports.
 - .2 Provide manufacturer's field services consisting of product use recommendations and periodic site visits for inspection of product installation in accordance with manufacturer's instructions.

END OF SECTION

Part 1 General**1.1 REFERENCES**

- .1 National Electrical Manufacturers Association (NEMA)
 - .1 NEMA MG 1-2016, Motors and Generators, Part 31.
- .2 Institute of Electrical and Electronics Engineers (IEEE)
 - .1 IEEE 519-2014, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.
- .3 Canadian Standards Association (CSA).
- .4 Underwriters Laboratories (UL)
 - .1 UL 508C, Standard for Power Conversion Equipment.

1.2 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Submittals: in accordance with Section 01 33 00 - Submittal Procedures.

1.3 GENERAL DESIGN CHARACTERISTIC

- .1 The VFD shall be of the Pulse Width Modulated (PWM) voltage source type, utilizing fixed diode bridge input rectification and Insulated Gate Bipolar Transistor (IGBT) / Intelligent Power Module (IPM) technology.
- .2 The VFD's digital electronic control board(s) shall be manufactured using Surface Mount Technology (SMT).
- .3 The VFD shall be dual rated for variable torque applications, with the continuous duty output current on the nameplate. The overload rating shall be 110% for 60 seconds. The VFD shall be selected such that the continuous duty current rating shall be equal to or greater than the connected motor full load current rating.
- .4 All VFD's shall be factory CSA/CUL certified.
- .5 All packaged drive systems shall be CSA certified.
- .6 The VFD shall have the capability of operating multiple motors. The minimum VFD continuous current rating shall be the sum of the full load current ratings of the connected motors.
- .7 The VFD shall be capable of operating in an open circuit mode i.e. with the motor(s) disconnected, for start-up and test purposes.
- .8 The VFD shall have a minimum displacement power factor of 0.96 or higher at all output frequencies.
- .9 The VFD and all options (e.g. line and load reactors, filters, bypass, etc.) must be manufacturer wired & warrantied as an assembly in NEMA 1 use NEMA 3R for outdoors enclosures. The enclosures may be of a Wall or Floor mount design, depending on the rating, and be supplied with forced ventilation complete with cleanable air filters in enclosures where components produce excessive heat.

1.4 QUALITY ASSURANCE

- .1 Regulatory Requirements: work to be performed in compliance with CEPA, CEAA, TDGA, and applicable Provincial /Territorial regulations.

Part 2 Products**2.1 STANDARD VFD DESIGN FEATURE**

- .1 Microprocessor Logic: The VFD shall include a 32 bit microprocessor and DSP (Digital Signal Processor). A digital display keypad shall be provided for input of parameter setting and operating commands. The digital display shall indicate output frequency, motor RPM, output current, as well as fault history information.
- .2 Digital Inputs: The VFD shall include a minimum of five (5) digital inputs programmable for function. Each input shall also be programmable to operate as a normally open (n/o) or normally closed (n/c) contact.
- .3 Analog Inputs: The VFD shall accept an analog speed reference input signal of 0-5 V DC, 0-10 V DC, and/or 4-20 mA). If both inputs are active, the 0-10V DC (or 0-5 V DC) or 4-20 mA signals shall be selectable by a digital input.
- .4 Digital Outputs: The VFD shall include two (2) digital outputs each programmable for drive run, frequency arrival (at set speed) or over torque. Each output shall also be programmable to operate as a normally open (n/o) or normally closed (n/c) contact.
- .5 Analog Output: The VFD shall provide an analog pwm output signal (0-10 V DC, @ 1 ma) proportional to the output frequency or output current.
- .6 Alarm Relay Outputs: The VFD shall provide an alarm relay which activates during a fault condition. The relay contacts shall include a set of normally open/normally closed (form c) contacts.
- .7 Auto Restart: The VFD shall have the capability to automatically restart the motor after an interruption in input power.
- .8 Critical Frequency Rejection: The VFD shall provide a minimum of three (3) selectable jump frequency points used to avoid critical resonance of the mechanical system. Frequency bandwidth for each jump frequency shall be programmable from 0 to +/- 9.9 Hz.
- .9 DC Injection Braking: The VFD DC braking control shall be capable of automatic initiation prior to all start commands to stop a "wind-milling" fan motor before issuing a run command. The duration and amplitude of this setting is to be programmable through the operator interface.
- .10 Acceleration/Deceleration Control: The VFD shall provide independent programmable settings for accel/decel time (0-999 seconds). The VFD shall also include a setting to allow the motor to coast to a stop. Acceleration and deceleration shall be programmable for linear, S-Curve, U-Curve or Reverse-U-Curve output.
- .11 Carrier Frequency: The carrier frequency shall be programmable from 3 kHz up to a maximum of 16 kHz in 0.1 increments.
- .12 Energy Savings:
 - .1 The VFD shall be programmable for variable torque V/F curves to optimize energy consumption.
 - .2 The VFD shall include an Automatic Energy Savings feature to further reduce energy consumption by minimizing the current demand of the motor for a given load, automatically.
- .13 Automatic Voltage Regulation: The VFD shall maintain the rated starting torque independent of the input voltage tolerance of +/-10%.
- .14 Power Loss Ride-through: The VFD shall have a ride-through capability during an intermittent loss of power for up to 15 mSec.
- .15 Min/Max Speed: Minimum and maximum speed settings shall be adjustable from 0 - 100%.

- .16 Fault Log: A fault log will record the total number of faults and display details of the last three faults, including reason for fault, frequency at time of fault, current at time of fault, and DC Bus Voltage at time of fault.
- .17 Pre-set Speeds: Using the digital inputs a minimum of 7 programmable pre-set speeds shall be selectable.
- .18 Safety Interlocks: Terminals to be provide for connection of safety interlocks such as motor thermistors. These interlocks shall shutdown operation in either the Drive or Bypass operating modes.
- .19 Door Mounted Operator Controls/Indicators: The basic operator controls shall consist of the following:
 - Hand - Off - Auto Selector Switch
 - Potentiometer for setting speed in "Hand"
 - Indicating Lights for:
 - Power On
 - Run
 - Fault
 - Keypad for setting parameters, control and viewing of Speed, Current, and Alarms
 - Bypass
- .20 Provide Profibus connectivity for all VFD's.

2.2 OUTPUT RATINGS

- .1 The VFD shall operate within the following rated values.
 - .1 Output Frequency Range: 0.1 to 400 Hz.
 - .2 Frequency Accuracy: +/- 0.01% with respect to digital input setting.
 - .3 Overload Rating: VT - 125% for 60 seconds.

2.3 INPUT POWER

- .1 Voltage: 3 phase (3 wire) 575 V +/- 10%
- .2 Frequency: 60 Hz +/- 5%

2.4 ENVIRONMENTAL RATINGS

- .1 The VFD shall operate within the following parameters without the need for derating:
 - .1 Temperature: -10 to 40°C.
 - .2 Humidity: 20 - 90% RH non-condensing.
 - .3 Altitude: up to 1,000 meters.
 - .4 Vibration of 0.2 G or less.

2.5 PROTECTIVE FEATURES

- .1 The VFD shall be designed to include the following protective functions and displays for maintainability:
 - .1 All control circuits (5, 12, & 24 V DC) shall be physically and electrically isolated from the power circuit voltages to ensure safety to maintenance personnel.
 - .2 Instantaneous Over Current Protection: The output of the VFD shall automatically be turned off if the operating current exceeds the specified level.
 - .3 Motor Overload Protection: The VFD shall include electronic thermal overload protection for automatic reduction of the overload limit at reduced operating speed, overload protection shall be provided in both VFD and bypass operation. The output of the VFD shall be disabled if the motor's thermal rating is exceeded.

- .4 External Trip: The VFD shall have the capability to accept an external trip input and the input shall be programmable for either N/O or N/C operation.
- .5 Phase Loss Protection: Phase loss detection shall be provided to prevent single phasing of the VFD input.
- .6 Unattended Start Protection: The VFD shall include a user selectable function to prevent an automatic restart after an interruption in input power.
- .7 Over Voltage Protection: The output of the VFD shall be automatically cut off if the DC Bus voltage exceeds the specified level due to regenerative energy from the motor.
- .8 Ground Fault Protection: The VFD shall have the capability to sense current imbalance during motor start-up for protection of the power circuit in the event of a ground fault.
- .9 Software Lock The VFD shall include a software function which prevents changes to the user defined settings.
- .10 Power Module Protection: The IPM shall incorporate thermal and short circuit protection circuits.
- .11 CPU or EEPROM Error: VFD shall automatically be turned off in the event of an error in the CPU or EEPROM.
- .12 Option board communication error: VFD will automatically be turned off in the event of an option board error.

2.6 RELIABILITY

- .1 A complete description of the manufacturer's quality assurance and testing program shall be provided.
- .2 Printed Circuit Boards / Pre-assembly: All blank circuit boards shall be checked for appearance, dimensions and continuity as per specification. All electronic components shall be subjected to a visual and functional test. Circuit board components shall be stored at 15-30°C @ 5 % humidity.
- .3 Printed Circuit Board Inspection: All surface-mount devices shall be subjected to microscopic inspection for component alignment and solder joint integrity. All completed circuit boards shall undergo a thermal stress test with temperatures cycled between -5 to 65°C.
- .4 All VFD's of a series shall use one common logic printed circuit board for all units supplied.

2.7 INPUT FILTERING

- .1 All VFD's shall be furnished with the following protective devices as a minimum: All 575 volt systems require 5% impedance harmonically compensated Line reactors rated to carry 150% total RMS current continuously for the reduction of line harmonics and to limit line voltage transients.

2.8 OUTPUT FILTERING

- .1 All VFD's shall be furnished with DV/DT output filter to match load. DV/DT output filter to be factory wired and shipped to site as complete assembly with VFD or if DV/DT filters are shipped loose must be wired on site by supplier.

2.9 INTEGRAL BYPASS

- .1 Provide Bypass package in a NEMA 1 enclosure. Bypass shall include three (3) contactors for manual switching from the VFD to line and from Line to VFD. Control Transformer, Class J fuses relay and:
 - .1 Provide an Operator station consisting of:
 - Hand-Off-Auto Selector Switch
 - VFD-Off-Bypass Selector Switch
 - Auto Bypass Enable Switch
 - Test Mode Switch
 - Manual Speed Potentiometer
 - Power On Light

- External Trip On Light
- Hand Operation Light
- Auto Operation Light
- VFD On Light
- VFD Run Light
- VFD Fault Light
- Frequency Arrival (at set speed) Light
- Bypass On Light
- Bypass Fault Light
- Auto Bypass Enable Light
- Test Mode Light

- .2 When in Bypass Mode the VFD shall be isolated from the line and motor to enable servicing by qualified personnel. The Drive output contactor and the bypass contactor must be mechanically interlocked to prevent simultaneous closure.
- .3 Provide dry contacts for Fault, Run Status, and Frequency arrival to the building automation system.
- .4 Provide a 24 VDC power supply.
- .5 The Drive output contactor and the bypass contactor must be mechanically interlocked to prevent simultaneous closure.
- .6 Provide overload protection in the bypass circuit.

2.10 DISCONNECT SWITCH

- .1 Provide fusible Input Disconnect complete with Class J 200 kA interrupt fuses (sized per CEC tables), for all VFD installations. The Fusible disconnect shall be integrally mounted and wired within the VFD NEMA 1 enclosure and be provided with a door interlock mechanism to prevent unauthorized entry with the power on. In addition the disconnect must have provision for padlocking in the off position. Service personnel shall be open the door when the system is operating.

2.11 DIGITAL KEYPAD

- .1 Provide a multi-line display (minimum 4 lines) (68 characters) digital backlit keypad that employs words and numbers for easy operator interface. Keypad shall be capable of monitoring, programming, and operating the VFD.

2.12 OVERLOAD RELAY

- .1 Provide a separately mounted Class 20 overload relay for each motor. Provide door mounted overload reset buttons.

Part 3 Execution

3.1 START-UP AND COMMISSIONING SERVICES

- .1 The manufacturer shall provide start-up and commissioning of the variable frequency drive and its optional circuits by a factory certified service technician who is experienced in start-up and repair services. The commissioning personnel shall be the same personnel that will provide the factory service and warranty repairs at the customer site. Sales personnel and other agents who are not factory certified technician shall not be acceptable as commissioning agents. The manufacturer shall have the ability to repair his products within 24 hours of notification of failure.

- .2 Start-up services shall include checking for verification of proper operation and installation of the VFD, its options and its interface wiring to the building automation system. Included in this service shall be as a minimum:
 - .1 Verification of contractor wire terminations and conduit runs to and from the VFD.
 - .2 One hour of customer operator training on the operation and service diagnostics at the time of commissioning.
 - .3 Measurement for verification of proper operation of the following:
 - .1 Motor voltage and frequency. Verification of proper motor operation.
 - .2 Control input for proper building automation system interface and control calibration.
 - .3 Calibration check for the following set-points:
 - .1 minimum speed
 - .2 maximum speed
 - .3 acceleration and deceleration rates.
- .3 Commissioning agent to verify the programming of the VFD and to provide a written copy of the settings to the Departmental Representative.
- .4 Commissioning agent to lock out critical frequencies throughout the operating curve of the equipment as identified and required by the Departmental Representative. The agent shall record amperages at six (minimum) different frequencies from minimum to maximum speed.

3.2 EXAMINATION

- .1 The contractor is to verify that the job site conditions for installation meet the factory recommended and code required conditions for the VFD installation prior to start-up. These shall include as a minimum:
 - .1 Clearance spacing.
 - .2 Compliance with environmental ratings of the VFD system.
 - .3 Separate conduit installation of the input wiring, the motor wiring, and control wiring. At no time does any of this wiring run in parallel with each other.
 - .4 All power and control wiring is complete.
- .2 The VFD is to be covered and protected from installation dust and contamination until the environment is cleaned and ready for operation. The VFD system shall not be operated while the unit is covered.
- .3 Power shall not be applied until the manufacturer has started up his equipment.

END OF SECTION

Part 1 General**1.1 RELATED REQUIREMENTS**

- .1 Section 23 05 49.01 - Seismic Restraint Systems (SRS) - Type P2 Buildings.

1.2 REFERENCE STANDARDS

- .1 American Society of Mechanical Engineers (ASME)
 - .1 ASME B31.1-07, Power Piping.
- .2 ASTM International
 - .1 ASTM A125-96(2013)e1, Standard Specification for Steel Springs, Helical, Heat-Treated.
 - .2 ASTM A307-14, Standard Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength.
 - .3 ASTM A563-15, Standard Specification for Carbon and Alloy Steel Nuts.
- .3 Manufacturer's Standardization Society of the Valves and Fittings Industry (MSS)
 - .1 MSS SP 58-2009, Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application and Installation.
- .4 National Research Council Canada (NRC)
 - .1 National Plumbing Code of Canada 2015 (NPC).

1.3 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Provide submittals in accordance with Section 01 33 00 - Submittal Procedures.

Part 2 Products**2.1 SYSTEM DESCRIPTION**

- .1 Design Requirements:
 - .1 Construct pipe hanger and support to manufacturer's recommendations utilizing manufacturer's regular production components, parts and assemblies.
 - .2 Base maximum load ratings on allowable stresses prescribed by ASME B31.1 or MSS SP 58.
 - .3 Ensure that supports, guides, anchors do not transmit excessive quantities of heat to building structure.
 - .4 Design hangers and supports to support systems under conditions of operation, allow free expansion and contraction, prevent excessive stresses from being introduced into pipework or connected equipment.
 - .5 Provide for vertical adjustments after erection and during commissioning. Amount of adjustment in accordance with MSS SP 58.
- .2 Performance Requirements:
 - .1 Design supports, platforms, catwalks, hangers to withstand seismic events as specified in section 23 05 49.01 - Seismic Restraint Systems (SRS) - Type P2 Buildings.

2.2 GENERAL

- .1 Fabricate hangers, supports and sway braces in accordance with MSS SP 58. ANSI B31.1 and
- .2 Use components for intended design purpose only. Do not use for rigging or erection purposes.

2.3 PIPE HANGERS

- .1 Finishes:
 - .1 Pipe hangers and supports: galvanized after manufacture.
 - .2 Use electro-plating galvanizing process.
 - .3 Ensure steel hangers in contact with copper piping are copper plated epoxy coated.
- .2 Upper attachment structural: suspension from lower flange of I-Beam:
 - .1 Cold piping NPS 2 maximum: malleable iron C-clamp with hardened steel cup point setscrew, locknut and carbon steel retaining clip.
 - .1 Rod: 9 mm UL listed.
 - .2 Cold piping NPS 2 1/2 or greater, hot piping: malleable iron beam clamp, eye rod, jaws and extension with carbon steel retaining clip, tie rod, nuts and washers, UL listed to MSS-SP 58.
- .3 Upper attachment structural: suspension from upper flange of I-Beam:
 - .1 Cold piping NPS 2 maximum: ductile iron top-of-beam C-clamp with hardened steel cup point setscrew, locknut and carbon steel retaining clip, UL listed to MSS SP 58.
 - .2 Cold piping NPS 2 1/2 or greater, hot piping: malleable iron top-of-beam jaw-clamp with hooked rod, spring washer, plain washer and nut UL listed.
- .4 Upper attachment to concrete:
 - .1 Ceiling: carbon steel welded eye rod, clevis plate, clevis pin and cotters with weldless forged steel eye nut. Ensure eye 6 mm minimum greater than rod diameter.
 - .2 Concrete inserts: wedge shaped body with knockout protector plate UL listed to MSS SP 58.
- .5 Shop and field-fabricated assemblies:
 - .1 Sway braces for seismic restraint systems: to Section 23 05 49.01 - Seismic Restraint Systems (SRS) - Type P2 Buildings.
- .6 Hanger rods: threaded rod material to MSS SP 58:
 - .1 Ensure that hanger rods are subject to tensile loading only.
 - .2 Provide linkages where lateral or axial movement of pipework is anticipated.
 - .3 Do not use 22 mm or 28 mm rod.
- .7 Pipe attachments: material to MSS SP 58:
 - .1 Attachments for steel piping: carbon steel black.
 - .2 Attachments for copper piping: copper plated black steel.
 - .3 Use insulation shields for hot pipework.
 - .4 Oversize pipe hangers and supports.
- .8 Adjustable clevis: material to MSS SP 58 UL listed, clevis bolt with nipple spacer and vertical adjustment nuts above and below clevis.
 - .1 Ensure "U" has hole in bottom for riveting to insulation shields.
- .9 Yoke style pipe roll: carbon steel yoke, rod and nuts with cast iron roll, to MSS SP 58.
- .10 U-bolts: carbon steel to MSS SP 58 with 2 nuts at each end to ASTM A563.
 - .1 Finishes for steel pipework: black.
 - .2 Finishes for copper, glass, brass or aluminum pipework: black, with formed portion epoxy coated.
- .11 Pipe rollers: cast iron roll and roll stand with carbon steel rod to MSS SP 58.

2.4 RISER CLAMPS

- .1 Steel or cast iron pipe: black carbon steel to MSS SP 58, type 42, UL listed.
- .2 Copper pipe: carbon steel copper plated to MSS SP 58, type 42.
- .3 Bolts: to ASTM A307.

- .4 Nuts: to ASTM A563.

2.5 INSULATION PROTECTION SHIELDS

- .1 Insulated cold piping:
 - .1 64 kg/m³ density insulation plus insulation protection shield to: MSS SP 58, galvanized sheet carbon steel. Length designed for maximum 3 m span.
- .2 Insulated hot piping:
 - .1 Curved plate 300 mm long, with edges turned up, welded-in centre plate for pipe sizes NPS 12 and over, carbon steel to comply with MSS SP 58.

2.6 CONSTANT SUPPORT SPRING HANGERS

- .1 Springs: alloy steel to ASTM A125, shot peened, magnetic particle inspected, with +/-5% spring rate tolerance, tested for free height, spring rate, loaded height and provided with Certified Mill Test Report (CMTR).
- .2 Load adjustability: 10% minimum adjustability each side of calibrated load. Adjustment without special tools. Adjustments not to affect travel capabilities.
- .3 Provide upper and lower factory set travel stops.
- .4 Provide load adjustment scale for field adjustments.
- .5 Total travel to be actual travel +20%. Difference between total travel and actual travel 25 mm minimum.
- .6 Individually calibrated scales on each side of support calibrated prior to shipment, complete with calibration record.

2.7 VARIABLE SUPPORT SPRING HANGERS

- .1 Vertical movement: 13 mm minimum, 50 mm maximum, use single spring pre-compressed variable spring hangers.
- .2 Vertical movement greater than 50 mm: use double spring pre-compressed variable spring hanger with 2 springs in series in single casing.
- .3 Variable spring hanger complete with factory calibrated travel stops.
- .4 Steel alloy springs: to ASTM A125, shot peened, magnetic particle inspected, with +/-5 % spring rate tolerance, tested for free height, spring rate, loaded height and provided with CMTR.

2.8 EQUIPMENT ANCHOR BOLTS AND TEMPLATES

- .1 Provide templates to ensure accurate location of anchor bolts.

Part 3 Execution

3.1 MANUFACTURER'S INSTRUCTIONS

- .1 Compliance: comply with manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheet.

3.2 INSTALLATION

- .1 Install in accordance with:
 - .1 Manufacturer's instructions and recommendations.

- .2 Vibration Control Devices:
 - .1 Install on piping systems at pumps, boilers, chillers, cooling towers, and as indicated.
- .3 Clamps on riser piping:
 - .1 Support independent of connected horizontal pipework using riser clamps and riser clamp lugs welded to riser.
 - .2 Bolt-tightening torques to industry standards.
 - .3 Steel pipes: install below coupling or shear lugs welded to pipe.
 - .4 Cast iron pipes: install below joint.
- .4 Clevis plates:
 - .1 Attach to concrete with 4 minimum concrete inserts, one at each corner.
- .5 Provide supplementary structural steelwork where structural bearings do not exist or where concrete inserts are not in correct locations.
- .6 Use approved constant support type hangers where:
 - .1 Vertical movement of pipework is 13 mm or more,
 - .2 Transfer of load to adjacent hangers or connected equipment is not permitted.
- .7 Use variable support spring hangers where:
 - .1 Transfer of load to adjacent piping or to connected equipment is not critical.
 - .2 Variation in supporting effect does not exceed 25% of total load.

3.3 HANGER SPACING

- .1 Plumbing piping: to Provincial Code & authority having jurisdiction.
- .2 Fire protection: to applicable fire code.
- .3 Gas and fuel oil piping: up to NPS 1/2: every 1.8 m.
- .4 Copper piping: up to NPS 1/2: every 1.5 m.
- .5 Flexible joint roll groove pipe: in accordance with table below for steel, but not less than one hanger at joints. Table listings for straight runs without concentrated loads and where full linear movement is not required.
- .6 Within 300 mm of each elbow.

Maximum Pipe Size : NPS	Maximum Spacing Steel	Maximum Spacing Copper
up to 1¼	2.4 m	1.8 m
1½	3.0 m	2.4 m
2	3.0 m	2.4 m
2½	3.7 m	3.0 m
3	3.7 m	3.0 m
3½	3.7 m	3.3 m
4	3.7 m	3.6 m
5	4.3 m	
6	4.3 m	
8	4.3 m	
10	4.9 m	
12	4.9 m	

- .7 Pipework greater than NPS 12: to MSS SP 58.

3.4 HANGER INSTALLATION

- .1 Install hanger so that rod is vertical under operating conditions.
- .2 Adjust hangers to equalize load.
- .3 Support from structural members. Where structural bearing does not exist or inserts are not in suitable locations, provide supplementary structural steel members.

3.5 HORIZONTAL MOVEMENT

- .1 Angularity of rod hanger resulting from horizontal movement of pipework from cold to hot position not to exceed 4 degrees from vertical.
- .2 Where horizontal pipe movement is less than 13 mm, offset pipe hanger and support so that rod hanger is vertical in the hot position.

3.6 FINAL ADJUSTMENT

- .1 Adjust hangers and supports:
 - .1 Ensure that rod is vertical under operating conditions.
 - .2 Equalize loads.
- .2 Adjustable clevis:
 - .1 Tighten hanger load nut securely to ensure proper hanger performance.
 - .2 Tighten upper nut after adjustment.
- .3 C-clamps:
 - .1 Follow manufacturer's recommended written instructions and torque values when tightening C-clamps to bottom flange of beam.
- .4 Beam clamps:
 - .1 Hammer jaw firmly against underside of beam.

END OF SECTION

Part 1 General**1.1 DEFINITIONS**

- .1 Priority Two (P2) Buildings: buildings in which life safety is of paramount concern. It is not necessary that P2 buildings remain operative during or after earthquake activity.
- .2 SRS: acronym for Seismic Restraint System.

1.2 DESCRIPTION

- .1 SRS fully integrated into, and compatible with:
 - .1 Noise and vibration controls specified elsewhere.
 - .2 Structural, mechanical, electrical design of project.
- .2 Systems, equipment not required to be operational during and after seismic event.
- .3 During seismic event, SRS to prevent systems and equipment from causing personal injury and from moving from normal position.
- .4 Designed by Professional Engineer specializing in design of SRS and registered in Province of Ontario.

1.3 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Submittals: in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Shop drawings: Submit drawings stamped and signed by professional engineer registered or licensed in Ontario, Canada.

Part 2 Products**2.1 SRS MANUFACTURER**

- .1 SRS from one manufacturer regularly engaged in SRS production.

2.2 GENERAL

- .1 SRS to provide gentle and steady cushioning action and avoid high impact loads.
- .2 SRS to restrain seismic forces in every direction.
- .3 Fasteners and attachment points to resist same load as seismic restraints.
- .4 SRS of Piping systems compatible with:
 - .1 Expansion, anchoring and guiding requirements.
 - .2 Equipment vibration isolation and equipment SRS.
- .5 SRS utilizing cast iron, threaded pipe, other brittle materials not permitted.
- .6 Attachments to RC structure:
 - .1 Use high strength mechanical expansion anchors.
 - .2 Drilled or power driven anchors not permitted.
- .7 Seismic control measures not to interfere with integrity of firestopping.

2.3 SRS FOR STATIC EQUIPMENT, SYSTEMS

- .1 Floor-mounted equipment, systems:
 - .1 Anchor equipment to equipment supports.
 - .2 Anchor equipment supports to structure.
 - .3 Use size of bolts scheduled in approved shop drawings.
- .2 Suspended equipment, systems:
 - .1 Use one or combination of following methods:
 - .1 Install tight to structure.
 - .2 Cross-brace in every direction.
 - .3 Brace back to structure.
 - .4 Slack cable restraint system.
 - .2 SCS to prevent sway in horizontal plane, "rocking" in vertical plane, sliding and buckling in axial direction.
 - .3 Hanger rods to withstand compressive loading and buckling.

2.4 SRS FOR VIBRATION ISOLATED EQUIPMENT

- .1 Floor mounted equipment, systems:
 - .1 Use one or combination of following methods:
 - .1 Vibration isolators with built-in snubbers.
 - .2 Vibration isolators and separate snubbers.
 - .3 Built-up snubber system approved by Departmental Representative, consisting of structural elements and elastomeric layer.
 - .2 SRS to resist complete isolator unloading.
 - .3 SRS not to jeopardize noise and vibration isolation systems. Provide 4-8 mm clearance between seismic restraint snubbers and equipment during normal operation of equipment and systems.
 - .4 Cushioning action: gentle and steady by utilizing elastomeric material or other means in order to avoid high impact loads.
- .2 Suspended equipment, systems:
 - .1 Use one or combination of following methods:
 - .1 Slack cable restraint system.
 - .2 Brace back to structure via vibration isolators and snubbers.

2.5 SLACK CABLE RESTRAINT SYSTEM (SCS)

- .1 Use elastomer materials or similar to avoid high impact loads and provide gentle and steady cushioning action.
- .2 SCS to prevent sway in horizontal plane, "rocking" in vertical plane, sliding and buckling in axial direction.
- .3 Hanger rods to withstand compressive loading and buckling.

Part 3 Execution**3.1 MANUFACTURER'S INSTRUCTIONS**

- .1 Compliance: comply with manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheet.

3.2 INSTALLATION

- .1 Attachment points and fasteners:
 - .1 To withstand same maximum load that seismic restraint is to resist and in every direction.

- .2 Slack Cable Systems (SCS):
 - .1 Connect to suspended equipment so that axial projection of wire passes through centre of gravity of equipment.
 - .2 Use appropriate grommets, shackles, other hardware to ensure alignment of restraints and to avoid bending of cables at connection points.
 - .3 Piping systems: provide transverse SCS at 10 m spacing maximum, longitudinal SCS at 20 m maximum or as limited by anchor/slack cable performance.
 - .4 Small pipes may be rigidly secured to larger pipes for restraint purposes, but not reverse.
 - .5 Orient restraint wires on ceiling hung equipment at approximately 90 degrees to each other (in plan), tie back to structure at maximum of 45 degrees to structure.
 - .6 Adjust restraint cables so that they are not visibly slack but permit vibration isolation system to function normally.
 - .7 Tighten cable to reduce slack to 40 mm under thumb pressure. Cable not to support weight during normal operation.
- .3 Install SRS at least 25 mm from equipment, systems, services.
- .4 Miscellaneous equipment not vibration-isolated:
 - .1 Bolt through house-keeping pad to structure.
- .5 Co-ordinate connections with other disciplines.
- .6 Vertical tanks:
 - .1 Anchor through house-keeping pad to structure.
 - .2 Provide steel bands above centre of gravity.
- .7 Horizontal tanks:
 - .1 Provide at least two straps with anchor bolts fastened to structure.

3.3 FIELD QUALITY CONTROL

- .1 Inspection and Certification:
 - .1 SRS: inspected and certified by Seismic Engineer upon completion of installation.
 - .2 Provide written report to Departmental Representative with certificate of compliance stamped by Seismic Engineer.

END OF SECTION

Part 1 General**1.1 REFERENCE STANDARDS**

- .1 Canadian General Standards Board (CGSB)
 - .1 CAN/CGSB-24.3-92, Identification of Piping Systems.

1.2 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Product Data:
 - .1 Submittals: in accordance with Section 01 33 00 - Submittal Procedures.

Part 2 Products**2.1 MANUFACTURER'S EQUIPMENT NAMEPLATES**

- .1 Metal or plastic laminate nameplate mechanically fastened to each piece of equipment by manufacturer.
- .2 Lettering and numbers raised or recessed.
- .3 Information to include, as appropriate:
 - .1 Equipment: manufacturer's name, model, size, serial number, capacity.
 - .2 Motor: voltage, Hz, phase, power factor, duty, frame size.

2.2 SYSTEM NAMEPLATES

- .1 Colours:
 - .1 Hazardous: red letters, white background.
 - .2 Elsewhere: black letters, white background (except where required otherwise by applicable codes).
- .2 Construction:
 - .1 3 mm thick laminated plastic, matte finish, with square corners, letters accurately aligned and machine engraved into core.
- .3 Sizes:
 - .1 Conform to following table:

Size #	Sizes (mm)	No. of Lines	Height of Letters (mm)
1	10 x 50	1	3
2	13 x 75	1	5
3	13 x 75	2	3
4	20 x 100	1	8
5	20 x 100	2	5
6	20 x 200	1	8
7	25 x 125	1	12
8	25 x 125	2	8
9	35 x 200	1	20

- .2 Use maximum of 25 letters/numbers per line.
- .4 Identification for Health Canada and PSPC Preventive Maintenance Support System (PMSS):
 - .1 Use arrangement of Main identifier, Source identifier, Destination identifier.
 - .2 Equipment in Mechanical Room:
 - .1 Main identifier: size #9.

- .2 Source and Destination identifiers: size #6.
- .3 Terminal cabinets, control panels: size #5.
- .3 Equipment elsewhere: sizes as appropriate.

2.3 EXISTING IDENTIFICATION SYSTEMS

- .1 Apply existing identification system to new work.
- .2 Where existing identification system does not cover for new work, use identification system specified this section.
- .3 Before starting work, obtain written approval of identification system from Departmental Representative.

2.4 IDENTIFICATION DUCTWORK SYSTEMS

- .1 50 mm high stencilled letters and directional arrows 150 mm long x 50 mm high.
- .2 Colours: back, or co-ordinated with base colour to ensure strong contrast.

2.5 CONTROLS COMPONENTS IDENTIFICATION

- .1 Identify all systems, equipment, components, controls, sensors with system nameplates specified in this section.
- .2 Inscriptions to include function and (where appropriate) fail-safe position.

2.6 LANGUAGE

- .1 Identification in English and French.
- .2 Use one nameplate and label for both languages.

Part 3 Execution

3.1 MANUFACTURER'S INSTRUCTIONS

- .1 Compliance: comply with manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheet.

3.2 INSTALLATION

- .1 Perform work in accordance with CAN/CGSB-24.3 except as specified otherwise.
- .2 Provide ULC and/or CSA registration plates as required by respective agency.
- .3 Identify systems, equipment to conform to PSPC PMSS.

3.3 NAMEPLATES

- .1 Locations:
 - .1 In conspicuous location to facilitate easy reading and identification from operating floor.
- .2 Standoffs:
 - .1 Provide for nameplates on hot and/or insulated surfaces.
- .3 Protection:
 - .1 Do not paint, insulate or cover.

3.4 LOCATION OF IDENTIFICATION ON DUCTWORK SYSTEMS

- .1 On long straight runs in open areas in boiler rooms, equipment rooms, galleries, tunnels: at not more than 17 m intervals and more frequently if required to ensure that at least one is visible from any one viewpoint in operating areas and walking aisles.
- .2 Adjacent to each change in direction.
- .3 At least once in each small room through which piping or ductwork passes.
- .4 On both sides of visual obstruction or where run is difficult to follow.
- .5 On both sides of separations such as walls, floors, partitions.
- .6 Where system is installed in pipe chases, ceiling spaces, galleries, confined spaces, at entry and exit points, and at access openings.
- .7 At beginning and end points of each run and at each piece of equipment in run.
- .8 At point immediately upstream of major manually operated or automatically controlled valves, and dampers. Where this is not possible, place identification as close as possible, preferably on upstream side.
- .9 Identification easily and accurately readable from usual operating areas and from access points.
 - .1 Position of identification approximately at right angles to most convenient line of sight, considering operating positions, lighting conditions, risk of physical damage or injury and reduced visibility over time due to dust and dirt.

END OF SECTION

Part 1 General**1.1 RELATED REQUIREMENTS**

- .1 Section 23 05 93.13 - Testing, Adjusting and Balancing of Fume Hoods.

1.2 PURPOSE OF TAB

- .1 Test to verify proper and safe operation, determine actual point of performance, evaluate qualitative and quantitative performance of equipment, systems and controls at design, average and low loads using actual or simulated loads.
- .2 Adjust and regulate equipment and systems to meet specified performance requirements and to achieve specified interaction with other related systems under normal and emergency loads and operating conditions.
- .3 Balance systems and equipment to regulate flow rates to match load requirements over full operating ranges.

1.3 CO-ORDINATION

- .1 Schedule time required for TAB (including repairs, re-testing) into project construction and completion schedule to ensure completion before acceptance of project.
- .2 Do TAB of each system independently and subsequently, where interlocked with other systems, in unison with those systems.
- .3 Co-ordinate work with controls contractor and fume hood certifier.

1.4 PRE-TAB REVIEW

- .1 Review Contract Documents before project construction is started and confirm in writing to Departmental Representative adequacy of provisions for TAB and other aspects of design and installation pertinent to success of TAB.
- .2 Review specified standards and report to Departmental Representative in writing proposed procedures which vary from standard.
- .3 During construction, co-ordinate location and installation of TAB devices, equipment, accessories, measurement ports and fittings.

1.5 START-UP

- .1 Follow start-up procedures as recommended by equipment manufacturer unless specified otherwise.
- .2 Follow special start-up procedures specified elsewhere in Division 23.

1.6 OPERATION OF SYSTEMS DURING TAB

- .1 Operate systems for length of time required for TAB and as required by Departmental Representative for verification of TAB reports.

1.7 START OF TAB

- .1 Notify Departmental Representative 7 days prior to start of TAB.
- .2 Start TAB when construction is essentially completed, including:

- .3 Provisions for TAB installed and operational.
- .4 Start-up, verification for proper, normal and safe operation of mechanical and associated electrical and control systems affecting TAB including but not limited to:
 - .1 Proper thermal overload protection in place for electrical equipment.
 - .2 Air systems:
 - .1 Filters in place, clean.
 - .2 Duct systems clean.
 - .3 Ducts, air shafts, ceiling plenums are airtight to within specified tolerances.
 - .4 Correct fan rotation.
 - .5 Fire, smoke, volume control dampers installed and open.
 - .6 Coil fins combed, clean.
 - .7 Access doors, installed, closed.
 - .8 Outlets installed, volume control dampers open.

1.8 APPLICATION TOLERANCES

- .1 Do TAB to following tolerances of design values:
 - .1 Laboratory HVAC systems: plus 10%, minus 0%.

1.9 ACCURACY TOLERANCES

- .1 Measured values accurate to within plus or minus 2 % of actual values.

1.10 INSTRUMENTS

- .1 Prior to TAB, submit to Departmental Representative list of instruments used together with serial numbers.
- .2 Calibrate in accordance with requirements of most stringent of referenced standard for either applicable system or HVAC system.
- .3 Calibrate within 3 months of TAB. Provide certificate of calibration to Departmental Representative.

1.11 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Submit, prior to commencement of TAB:
- .2 Proposed methodology and procedures for performing TAB if different from referenced standard.

1.12 TAB REPORT

- .1 Format in accordance with referenced standard.
- .2 TAB report to show results in SI units and to include:
 - .1 Project record drawings.
 - .2 System schematics.
- .3 Submit electronic copy of TAB Report to Departmental Representative for verification and approval, in English, complete with index tabs.

1.13 VERIFICATION

- .1 Reported results subject to verification by Departmental Representative.
- .2 Provide personnel and instrumentation to verify up to 30 % of reported results.
- .3 Number and location of verified results as directed by Departmental Representative.
- .4 Pay costs to repeat TAB as required to satisfaction of Departmental Representative.

1.14 SETTINGS

- .1 After TAB is completed to satisfaction of Departmental Representative, replace drive guards, close access doors, lock devices in set positions, ensure sensors are at required settings.
- .2 Permanently mark settings to allow restoration at any time during life of facility. Do not eradicate or cover markings.

1.15 COMPLETION OF TAB

- .1 TAB considered complete when final TAB Report received and approved by Departmental Representative.

1.16 AIR SYSTEMS

- .1 Standard: TAB to most stringent of this section or TAB standards of AABC, NEBB, SMACNA or ASHRAE.
- .2 Qualifications: personnel performing TAB qualified to standards of AABC or NEBB.
- .3 Quality assurance: perform TAB under direction of supervisor qualified to standards of AABC or NEBB.
- .4 Measurements: to include as appropriate for systems, equipment, components, controls: air velocity, static pressure, flow rate, pressure drop (or loss), temperatures (dry bulb, wet bulb, dewpoint), duct cross-sectional area, RPM, electrical power, voltage, noise, vibration.
- .5 Locations of equipment measurements: to include as appropriate:
 - .1 Inlet and outlet of dampers, filter, coil, humidifier, fan, other equipment causing changes in conditions.
 - .2 At controllers, controlled device.
- .6 Locations of systems measurements to include as appropriate: main ducts, main branch, sub-branch, run-out (or grille, register or diffuser).

1.17 OTHER TAB REQUIREMENTS

- .1 General requirements applicable to work specified this paragraph:
 - .1 Qualifications of TAB personnel: as for air systems specified this section.
 - .2 Quality assurance: as for air systems specified this section.
- .2 Laboratory fume hoods:
 - .1 Refer to Section 23 05 93.13 - Testing, Adjusting and Balancing of Fume Hoods.

Part 2 Products**2.01 NOT USED**

- .1 Not used.

Part 3 Execution**3.1 NOT USED**

- .1 Not used.

END OF SECTION

Part 1 General**1.1 REFERENCE STANDARDS**

- .1 American National Standards Institute (ANSI)
 - .1 ASHRAE 110-2016, Method of Testing Performance of Laboratory Fume Hoods.
- .2 Public Works and Government Services Canada (PSPC)
 - .1 PSPC MD15128-2013, Laboratory Fume Hoods.

1.2 QUALITY ASSURANCE

- .1 Test Agency: fume hood tests to be performed by qualified independent testing agency with proven experience in Work of this Section and in accordance with PSPC MD15128-2013.
- .2 Test Agency Qualification: submit proof of qualifications to Departmental Representative to demonstrate:
 - .1 Minimum 3 years' experience in testing of fume hoods.
 - .2 Attendance at laboratory HVAC design course, by US Eagleson Institute or equivalent.
 - .3 Attendance at ASHRAE 110 Testing Workshop, by US Eagleson Institute or equivalent.

Part 2 Products**2.1 TESTING EQUIPMENT**

- .1 Test equipment to and PSPC MD 15128-2013.
- .2 Data logger:
 - .1 Speed: 10 Hz or better.
 - .2 Memory: sufficient to allow data collection for duration of test.
- .3 In-duct flow sensor to measure flow response:
 - .1 Speed: 10 Hz.
 - .2 Range: 95 L/s to 950 L/s.
 - .3 Accuracy: $\pm 5\%$.
- .4 Thermal anemometer:
 - .1 Mounting: on stand with probe fixed at each traverse grid location.
 - .2 Include: averaging function over twenty second period for each location or output recorded for 20 seconds minimum at a rate of one reading/second on data logger.
 - .3 Accuracy:
 - .1 Below 0.50 m/s: ± 0.025 m/s.
 - .2 0.50 m/s and over: $\pm 5\%$.
- .5 Detector for tracer gas containment:
 - .1 Type: continuous reading.
 - .2 Minimum Detectable Level (MDL): 0.01 ppm.
 - .3 Accuracy: concentrations below 0.1 ppm: $\pm 25\%$; concentrations above 0.1 ppm: $\pm 10\%$.
- .6 Smoke generator:
 - .1 Use smoke generator and diffuser complying with PSPC MD15128-2013.

Part 3 Execution**3.1 AS INSTALLED (AI) AND INTEGRATED SYSTEMS TESTS**

- .1 Perform AI and integrated systems tests as follows:
 - .1 After entire laboratory HVAC and exhaust systems have been tested and balanced (TAB), and TAB and Performance Verification (PV) reports have been submitted and accepted.
 - .2 HVAC and exhaust systems are in full operation.
 - .3 Room temperatures are maintained between 22 degrees C and 24.5 degrees C., recorded and submitted with fume hood test documentation.
 - .4 At specified laboratory space pressurization.
 - .5 Under deviation of space pressurization due to laboratory door opening and closing, change of laboratory operating modes, upset conditions, and other causes of change in laboratory air pressure.
 - .6 As part of commissioning of integrated HVAC and exhaust systems and laboratory space pressurization tests included in commissioning process.
- .2 After installation, test each fume hood to PSPC MD15128-2013 at design sash position to ensure compliance with design criteria in PSPC MD15128-2013.

3.2 "AI" TESTS FOR VAV HIGH PERFORMANCE FUME HOODS

- .1 Cross draft tests:
 - .1 Test air currents external to fume hood to PSPC MD15128-2013.
 - .2 Ensure velocity of cross draft does not exceed 50% of average face velocity.
 - .3 Record measurements as follows:
 - .1 Using thermal anemometer take readings 1.5 m above floor, 500 mm from sash, at centre, and left and right posts of fume hood.
 - .2 Take readings at 1 reading/second, recorded to obtain average, and maximum and minimum values over a duration of 20 seconds at each location.
 - .3 Ensure that project authority reduces excessive values to less than 50% of average face velocity before proceeding with further fume hood testing.
- .2 Visualization (smoke) tests:
 - .1 Extent of tests and performance criteria: to PSPC MD15128-2013.
- .3 Face velocity and flow response test pass ratings: to PSPC MD15128-2013.
 - .1 VAV face velocity and flow response tests:
 - .1 Average face velocity at design sash position: 0.5 m/s
 - .2 Average face velocity with sash at 66% of design sash position: 0.5 m/s \pm 0.025 m/s
 - .1 Variation allowed for individual readings: \pm 20%
 - .3 Average face velocity with sash at 33% of design sash position: 0.5 m/s \pm 0.025 m/s.
 - .1 Variation allowed for individual readings: \pm 20%
 - .4 Response time: time to reach 90% of the average steady state value: within 5 seconds of initial sash movement
 - .5 Test for VAV minimum flow with sash closed.
- .4 Tracer Gas tests:
 - .1 Performance criteria: to PSPC MD15128-2013.
 - .2 Conduct tests at target average face velocity.
 - .3 Use approved tracer gas.
 - .4 Perform tests with probe at height of 560 mm above work surface.
 - .5 Leakage with sash at normal operating position:
 - .1 Average leakage: 0.05 ppm maximum.
 - .2 Peak reading: 0.25 ppm.
 - .6 Peripheral scan:
 - .1 Record significant peak readings and their locations.
 - .2 Record 30 second rolling averages.
 - .3 Maximum 0.25 ppm for any 30 second rolling average.

- .4 Include readings in test report.
 - .7 Sash Movement Effect (SME), to determine potential for escape after movement of sash:
 - .1 Maximum 45 second rolling average: 0.05 ppm.
- .5 Conduct VAV Response Tests, Stability Tests and SME simultaneously for VAV fume hoods.

3.3 FUME HOOD MONITOR AND ALARM TESTS

- .1 Fume Hood Monitor:
 - .1 Provide 3 point calibration.
 - .2 Ensure each monitor initiates alarms (audible, visual, and BMS) when unsafe velocity conditions occur.
 - .3 Ensure monitor readings are displayed in metres per second, to 2 decimal places.
- .2 Fume Hood Monitor/Alarm testing:
 - .1 Monitor accuracy test: ensure monitor is accurate within 5% of average face velocity.
 - .2 Alarm enunciation test: ensure alarm occurs beyond $\pm 20\%$ of design flow set point.
 - .3 Alarm response enunciation test: ensure alarm delay is 10 seconds maximum.

3.4 VERIFICATION LABELS

- .1 Affix label to front of fume hood indicating verification, name of testing agency, and date.

3.5 COMMISSIONING - INTEGRATED SYSTEMS TESTS

- .1 Fume hood testing to commence only after laboratory HVAC systems are fully commissioned, including calibration of airflow controls, calibration of automatic temperature controls, balance of air supply, completion of duct traverse on each fume hood exhaust duct, and completion of an air balance of the total exhaust flow.
- .2 Test fume hoods in conjunction with complete laboratory integrated HVAC and exhaust systems commissioning testing including, room air flow patterns, temperature, humidity, pressurization, noise, and vibration.
- .3 Co-ordinate work with balancing and controls contractor.

3.6 REPORTS

- .1 Ensure test reports are signed by testing agency before submitting to Departmental Representative.

3.7 PROTECTION

- .1 Protect adjacent materials from work associated with testing and maintenance of fume hoods.

END OF SECTION

Part 1 General**1.1 RELATED REQUIREMENTS**

- .1 Section 23 05 29 - Hangers and Supports for HVAC Piping and Equipment.

1.2 REFERENCE STANDARDS

- .1 ASTM International Inc.
 - .1 ASTM C335/C335M-10e1, Standard Test Method for Steady State Heat Transfer Properties of Pipe Insulation.
 - .2 ASTM C449-07(2013), Standard Specification for Mineral Fiber-Hydraulic-Setting Thermal Insulating and Finishing Cement.
 - .3 ASTM C553-13, Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications.
 - .4 ASTM C612-14, Standard Specification for Mineral Fiber Block and Board Thermal Insulation.
 - .5 ASTM C921-10(2015), Standard Practice for Determining the Properties of Jacketing Materials for Thermal Insulation.
- .2 Canadian General Standards Board (CGSB)
 - .1 CGSB 51-GP-52Ma, Vapour Barrier, Jacket and Facing Material for Pipe, Duct and Equipment Thermal Insulation.
- .3 Thermal Insulation Association of Canada (TIAC): National Insulation Standards (2005).
- .4 Underwriters Laboratories of Canada (ULC)
 - .1 CAN/ULC-S102-10, Method of Test for Surface Burning Characteristics of Building Materials and Assemblies.

1.3 DEFINITIONS

- .1 For purposes of this section:
 - .1 "CONCEALED" - insulated mechanical services and equipment in suspended ceilings and non-accessible chases and furred-in spaces.
 - .2 "EXPOSED" - means "not concealed" as previously defined.
 - .3 Insulation systems - insulation material, fasteners, jackets, and other accessories.
- .2 TIAC Codes:
 - .1 CRD: Code Round Ductwork,
 - .2 CRF: Code Rectangular Finish.

1.4 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Provide submittals in accordance with Section 01 33 00 - Submittal Procedures.

Part 2 Products**2.1 SUSTAINABLE REQUIREMENTS**

- .1 Materials and products in accordance with Section 01 47 15 Sustainable Requirements: Construction.

2.2 FIRE AND SMOKE RATING

- .1 To CAN/ULC-S102:
 - .1 Maximum flame spread rating: 25.
 - .2 Maximum smoke developed rating: 50.

2.3 INSULATION

- .1 Mineral fibre: as specified includes glass fibre, rock wool, slag wool.
- .2 Thermal conductivity ("k" factor) not to exceed specified values at 24 degrees C mean temperature when tested in accordance with ASTM C335/C335M.
- .3 TIAC Code C-1: Rigid mineral fibre board to ASTM C612, with or without factory applied vapour retarder jacket to CGSB 51-GP-52Ma (as scheduled in PART 3 of this Section).
- .4 TIAC Code C-2: Mineral fibre blanket to ASTM C553 faced with or without factory applied vapour retarder jacket to CGSB 51-GP-52Ma (as scheduled in PART 3 of this section).
 - .1 Mineral fibre: to ASTM C553.
 - .2 Jacket: to CGSB 51-GP-52Ma.
 - .3 Maximum "k" factor: to ASTM C553.

2.4 JACKETS

- .1 Canvas:
 - .1 220 gm/m² cotton, plain weave, treated with dilute fire retardant lagging adhesive to ASTM C921.
- .2 Lagging adhesive: compatible with insulation.

2.5 ACCESSORIES

- .1 Vapour retarder lap adhesive:
 - .1 Water based, fire retardant type, compatible with insulation.
- .2 Indoor Vapour Retarder Finish:
 - .1 Vinyl emulsion type acrylic, compatible with insulation.
- .3 Insulating Cement: hydraulic setting on mineral wool, to ASTM C449.
- .4 ULC Listed Canvas Jacket:
 - .1 220 gm/m² cotton, plain weave, treated with dilute fire retardant lagging adhesive to ASTM C921.
- .5 Tape: self-adhesive, aluminum, reinforced, 75 mm wide minimum.
- .6 Contact adhesive: quick setting.
- .7 Tie wire: 1.5 mm stainless steel.
- .8 Banding: 19 mm wide, 0.5 mm thick stainless steel.
- .9 Facing: 25 mm galvanized steel hexagonal wire mesh stitched on one face of insulation.
- .10 Fasteners: 2 mm diameter pins with 35 mm diameter clips, length to suit thickness of insulation.

Part 3 Execution**3.1 APPLICATION**

- .1 Manufacturer's Instructions: comply with manufacturer's written recommendations, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 PRE-INSTALLATION REQUIREMENTS

- .1 Pressure test ductwork systems complete, witness and certify.

- .2 Ensure surfaces are clean, dry, free from foreign material.

3.3 INSTALLATION

- .1 Install in accordance with TIAC National Standards.
- .2 Apply materials in accordance with manufacturer's instructions and as indicated.
- .3 Maintain uninterrupted continuity and integrity of vapour retarder jacket and finishes.
- .1 Ensure hangers, and supports are outside vapour retarder jacket.
- .4 Hangers and supports in accordance with Section 23 05 29 - Hangers and Supports for HVAC Piping and Equipment.
- .1 Apply high compressive strength insulation where insulation may be compressed by weight of ductwork.
- .5 Fasteners: install at 300 mm on centre in horizontal and vertical directions, minimum 2 rows each side.

3.4 DUCTWORK INSULATION SCHEDULE

- .1 Insulation types and thicknesses: conform to following table:

	TIAC Code	Vapour Retarder	Thickness (mm)
Rectangular cold and dual temperature supply air ducts	C-1	yes	50
Round cold and dual temperature supply air ducts	C-2	yes	50
Round warm air ducts	C-1	no	25

- .2 Exposed round ducts 600 mm and larger, smaller sizes where subject to abuse:

- .1 Use TIAC code C-1 insulation, scored to suit diameter of duct.

- .1 Finishes: conform to following table:

	TIAC Code	
	Rectangular	Round
Indoor, concealed	none	none
Indoor, exposed within mechanical room	CRF/1	CRD/2
Indoor, exposed elsewhere	CRF/2	CRD/3
Outdoor, exposed to precipitation	CRF/3	CRD/4
Outdoor, elsewhere	CRF/4	CRD/5

END OF SECTION

Part 1 General**1.1 RELATED REQUIREMENTS**

- .1 Section 23 05 29 - Hangers and Supports for HVAC Piping and Equipment.

1.2 REFERENCE STANDARDS

- .1 ASTM International
- .1 ASTM A480/A480M-16a, Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet and Strip.
 - .2 ASTM A653/A653M-15e1, Standard Specification for Steel Sheet, Zinc Coated (Galvanized) or Zinc-Iron Alloy Coated (Galvannealed) by the Hot-Dip Process.
- .2 National Fire Protection Association (NFPA)
- .1 NFPA (Fire) 90A, Standard for the Installation of Air-Conditioning and Ventilating Systems, 2015 Edition.
 - .2 NFPA (Fire) 90B, Standard for the Installation of Warm Air Heating and Air-Conditioning Systems, 2015 Edition.
- .3 Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)
- .1 SMACNA 016-2012, HVAC Air Duct Leakage Test Manual, 2nd Edition.

Part 2 Products**2.1 SEAL CLASSIFICATION**

- .1 Classification as follows:

Maximum Pressure Pa	SMACNA Seal Class
500	A
250	A
125	A

- .2 Seal classification:
- .1 Class A: longitudinal seams, transverse joints, duct wall penetrations and connections made airtight with sealant and tape.

2.2 SEALANT

- .1 Sealant: oil resistant, water borne, polymer type flame resistant duct sealant. Temperature range of minus 30 degrees C to plus 93 degrees C.

2.3 DUCT LEAKAGE

- .1 In accordance with SMACNA 016.

2.4 FITTINGS

- .1 Fabrication: to SMACNA.
- .2 Radiused elbows:
- .1 Rectangular: standard radius: 1.5 times width of duct.
 - .2 Round: 1.5 times diameter.

- .3 Mitred elbows, rectangular:
 - .1 To 400 mm: with single thickness turning vanes.
 - .2 Over 400 mm: with double thickness turning vanes.
- .4 Branches:
 - .1 Rectangular main and branch: with 45 degrees entry on branch.
 - .2 Round main and branch: enter main duct at 45 degrees with conical connection.
 - .3 Provide volume control damper in branch duct near connection to main duct.
- .5 Transitions:
 - .1 Diverging: 20 degrees maximum included angle.
 - .2 Converging: 30 degrees maximum included angle.
- .6 Offsets:
 - .1 Full radiused elbows.
- .7 Obstruction deflectors: maintain full cross-sectional area.
 - .1 Maximum included angles: as for transitions.

2.5 FIRE STOPPING

- .1 Retaining angles around duct, on both sides of fire separation.
- .2 Fire stopping material and installation must not distort duct.

2.6 GALVANIZED STEEL

- .1 Lock forming quality: to ASTM A653/A653M, Z90 zinc coating.
- .2 Thickness, fabrication and reinforcement: to SMACNA.
- .3 Joints: to SMACNA.

2.7 STAINLESS STEEL

- .1 To ASTM A480/A480M, Type 304.
- .2 Finish: number 4.
- .3 Thickness, fabrication and reinforcement: to SMACNA.
- .4 Joints: to SMACNA and be continuous inert gas welded.

2.8 HANGERS AND SUPPORTS

- .1 Hangers and Supports: in accordance with Section 23 05 29 - Hangers and Supports for HVAC Piping and Equipment.
 - .1 Strap hangers: of same material as duct but next sheet metal thickness heavier than duct.
 - .1 Maximum size duct supported by strap hanger: 500.
 - .2 Hanger configuration: to SMACNA.
 - .3 Hangers: black steel angle with black steel rods to SMACNA and following table:

Duct Size (mm)	Angle Size (mm)	Rod Size (mm)
up to 750	25 x 25 x 3	6
751 to 1050	40 x 40 x 3	6
1051 to 1500	40 x 40 x 3	10
1501 to 2100	50 x 50 x 3	10
2101 to 2400	50 x 50 x 5	10
2401 and over	50 x 50 x 6	10

- .4 Upper hanger attachments:
 - .1 For concrete: manufactured concrete inserts.
 - .2 For steel joist: manufactured joist clamp or steel plate washer.
 - .3 For steel beams: manufactured beam clamps.

Part 3 Execution

3.1 GENERAL

- .1 Do work in accordance with NFPA (Fire) 90A, NFPA (Fire) 90B and SMACNA.
- .2 Do not break continuity of insulation vapour barrier with hangers or rods.
 - .1 Insulate strap hangers 100 mm beyond insulated duct. Ensure diffuser is fully seated.
- .3 Support risers in accordance with SMACNA.
- .4 Install breakaway joints in ductwork on sides of fire separation.
- .5 Install proprietary manufactured flanged duct joints in accordance with manufacturer's instructions.
- .6 Manufacture duct in lengths and diameter to accommodate installation of acoustic duct lining.

3.2 HANGERS

- .1 Strap hangers: install in accordance with SMACNA.
- .2 Angle hangers: complete with locking nuts and washers.
- .3 Hanger spacing: in accordance with SMACNA and as follows:

Duct Size (mm)	Spacing (mm)
to 1500	3000
1501 and over	2500

3.3 SEALING

- .1 Apply sealant in accordance with SMACNA and to manufacturer's recommendations.

3.4 LEAKAGE TESTS

- .1 In accordance with SMACNA 016.
- .2 Do leakage tests in sections.
- .3 Make trial leakage tests as instructed to demonstrate workmanship.
- .4 Do not install additional ductwork until trial test has been passed.
- .5 Test section minimum of 30 m long with not less than three branch takeoffs and two 90 degrees elbows.
- .6 Complete test before performance insulation or concealment Work.

END OF SECTION

Part 1 General**1.1 RELATED REQUIREMENTS**

- .1 Section 23 05 29 - Hangers and Supports for HVAC Piping Equipment.

1.2 REFERENCE STANDARDS

- .1 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- .2 ASTM International
 - .1 ASTM A653/A653M-15e1, Standard Specification for Steel Sheet, Zinc Coated (Galvanized) or Zinc-Iron Alloy Coated (Galvannealed) by the Hot-Dip Process
- .3 Sheet Metal Air Conditioning Contractors' National Association (SMACNA)
 - .1 SMACNA 016-2012, HVAC Air Duct Leakage Test Manual, 2nd Edition.

Part 2 Products**2.1 DUCTWORK**

- .1 Material:
 - .1 Galvanized steel with Z90 designation zinc coating lock forming quality: to ASTM A653/A653M.
 - .2 Thickness: to SMACNA.
- .2 Construction: round and oval.
 - .1 Ducts: factory fabricated, spiral wound, with matching fittings and specials to SMACNA.
 - .2 Transverse joints up to 900 mm: slip type with tape and sealants.
 - .3 Transverse joints over 900 mm: Vanstone.
 - .4 Fittings:
 - .1 Elbows: smooth radius. Centreline radius: 1.5 x diameter.
 - .2 Branches: conical transition with conical branch at 45 degrees and 45 degrees elbow.
- .3 Construction: rectangular:
 - .1 Ducts: to SMACNA.
 - .2 Transverse joints: welded proprietary duct joints or SMACNA seal Class A.
 - .3 Fittings:
 - .1 Elbows: smooth radius; centreline radius 1.5 x width of duct. No vanes.
 - .2 Branches: with conical branch at 45 degrees and 45 degrees elbow.
- .4 Fire stopping:
 - .1 50 x 50 x 3 mm retaining angles around duct, on both sides of fire separation.
 - .2 Fire stopping material must not distort duct.

2.2 STAINLESS STEEL (LAB EXHAUST)

- .1 Material: type 316 L stainless steel sheets with longitudinal joints. Passivate and anneal stainless steel sheets before welding. For round ducts, roll sheets circular and weld flush.
- .2 Continuously weld all joints using Inert Gas Metal Arc process without burning parent metal, using filler rods type ER 316 L to CSA W48.2. Grind smooth and polish all joints.
- .3 Construction:
 - .1 Construct ductwork from the following thickness of stainless steel sheet.
 - .1 Rectangular ducts: 1.31 mm thick.
 - .2 Round ducts up to 500 mm diameter: 0.853 mm thick.

- .3 Round ducts over 500 mm diameter: 1.01 mm thick
- .2 Reinforce rectangular ducts with galvanized angle frames at 120 mm on centres, 25 mm x 25 mm x 3 mm up to 800 mm maximum dimensions and 50 mm x 50 mm x 6 mm for larger ducts.
- .4 Flexible connectors: neoprene coated glass fibre, coated both sides, minimum mass 1.33 kg/m², secured to ducts and fans with 25 mm x 25 mm x 3 mm stainless steel type 316 L flat bars and bands using type 316 L stainless steel screws or bolts at 100 mm intervals.

2.3 SEAL CLASSIFICATION

- .1 Classification as follows:

Maximum Pressure Pa	SMACNA Seal Class
2500	A
1500	A
1000	A
750	A

- .2 Seal classification:
 - .1 Class A: longitudinal seams, transverse joints, duct wall penetrations and connections made airtight with sealant and tape.

2.4 SEALANT

- .1 Oil resistant, polymer type flame resistant high velocity duct sealing compound.
 - .1 Temperature range of minus 30 degrees C to plus 93 degrees C.

2.5 HANGERS AND SUPPORTS

- .1 Hangers and supports: in accordance with Section 23 05 29 - Hangers and Supports for HVAC Piping Equipment.
 - .1 Band hangers: use on round and oval ducts up to 500 mm diameter, of same material as duct but next sheet metal thickness heavier than duct.
 - .2 Trapeze hangers: ducts over 500 mm diameter or longest side, to SMACNA.
 - .3 Hangers: black steel angle with black steel rods to SMACNA and following table:

Duct Size (mm)	Angle Size (mm)	Rod Size (mm)
up to 750	25 x 25 x 3	6
751 to 1050	40 x 40 x 3	6
1051 to 1500	40 x 40 x 3	10
1501 to 2100	50 x 50 x 3	10
2101 to 2400	50 x 50 x 5	10
2401 and over	50 x 50 x 6	10
 - .4 Upper hanger attachments:
 - .1 For concrete: manufactured concrete inserts.
 - .2 For steel joist: manufactured joist clamp or steel plate washer.
 - .3 For steel beams: manufactured beam clamps:

Part 3 Execution

3.1 GENERAL

- .1 Do work in accordance with SMACNA.
- .2 Do not break continuity of insulation vapour barrier with hangers or rods.
 - .1 Insulate band hangers 100 mm beyond insulated duct.
 - .2 Ensure diffuser is fully seated.

- .3 Support risers in accordance with SMACNA.
- .4 Install breakaway joints in ductwork on sides of fire separation.

3.2 HANGERS

- .1 Band hangers: install in accordance with SMACNA.
- .2 Angle hangers: complete with locking nuts and washers.
- .3 Hanger spacing: in accordance with SMACNA and as follows:

Duct Size (mm)	Spacing (mm)
to 1500	3000
1501 and over	2500

3.3 SEALING

- .1 Apply sealant in accordance with SMACNA and to manufacturer's recommendations.

3.4 LEAKAGE TESTS

- .1 In accordance with SMACNA 016.
- .2 Perform leakage tests in sections.
- .3 Perform trial leakage tests, as instructed to demonstrate quality of work.
- .4 Do not install additional ductwork until trial tests have been achieved.
- .5 Test section minimum of 30 m long with not less than 3 branch takeoffs and two 90 degrees elbows.
- .6 Complete tests before performing insulation or concealment Work.

END OF SECTION

Part 1 General**1.1 RELATED REQUIREMENTS**

- .1 Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)
 - .1 SMACNA 1966, HVAC Duct Construction Standards - Metal and Flexible, 3rd Edition.

Part 2 Products**2.1 GENERAL**

- .1 Manufacture in accordance with SMACNA 1966.

2.2 TURNING VANES

- .1 Factory or shop fabricated single thickness & double thickness with trailing edge, to recommendations of SMACNA.

2.3 INSTRUMENT TEST

- .1 1.6 mm thick steel zinc plated after manufacture.
- .2 Cam lock handles with neoprene expansion plug and handle chain.
- .3 28 mm minimum inside diameter. Length to suit insulation thickness.
- .4 Neoprene mounting gasket.

2.4 SPIN-IN COLLARS

- .1 Conical galvanized sheet metal spin-in collars with lockable butterfly damper.
- .2 Sheet metal thickness to co-responding round duct standards.

Part 3 Execution**3.1 INSTALLATION**

- .1 Instrument Test Ports:
 - .1 General:
 - .1 Install in accordance with recommendations of SMACNA and in accordance with manufacturer's instructions.
 - .2 Locate to permit easy manipulation of instruments.
 - .3 Install insulation port extensions as required.
 - .4 Locations:
 - .1 For traverse readings:
 - .1 Ducted inlets to roof and wall exhausters.
 - .2 Inlets and outlets of other fan systems.
 - .3 Main and sub-main ducts.
 - .4 And as indicated.
 - .2 For temperature readings:
 - .1 At outside air intakes.
 - .2 In mixed air applications in locations as approved by Departmental Representative.
 - .3 At inlet and outlet of coils.

- .4 Downstream of junctions of two converging air streams of different temperatures.
 - .5 And as indicated.
- .2 Turning Vanes:
 - .1 Install in accordance with recommendations of SMACNA and as indicated.

END OF SECTION

Part 1 General**1.1 REFERENCE STANDARDS**

- .1 Sheet Metal and Air Conditioning National Association (SMACNA)
 - .1 SMACNA 1966, HVAC Duct Construction Standards, Metal and Flexible, 3rd Edition.

Part 2 Products**2.1 GENERAL**

- .1 Manufacture to SMACNA standards.

2.2 SINGLE BLADE DAMPERS

- .1 Fabricate from same material as duct, but one sheet metal thickness heavier. V-groove stiffened.
- .2 Size and configuration to recommendations of SMACNA, except maximum height 100 mm.
- .3 Locking quadrant with shaft extension to accommodate insulation thickness.
- .4 Inside and outside nylon end bearings.
- .5 Channel frame of same material as adjacent duct, complete with angle stop.

2.3 MULTI-BLADED DAMPERS

- .1 Factory manufactured of material compatible with duct.
- .2 Opposed blade: configuration, metal thickness and construction to recommendations of SMACNA.
- .3 Maximum blade height: 100 mm.
- .4 Bearings: self-lubricating nylon.
- .5 Linkage: shaft extension with locking quadrant.
- .6 Channel frame of same material as adjacent duct, complete with angle stop.
- .7 Maximum leakage : 0.07% at 750 Pa.

Part 3 Execution**3.1 INSTALLATION**

- .1 Install where indicated.
- .2 Install in accordance with recommendations of SMACNA and in accordance with manufacturer's instructions.
- .3 Locate balancing dampers in each branch duct, for supply, return and exhaust systems.
- .4 Runouts to registers and diffusers: install single blade damper located as close as possible to main ducts.
- .5 Dampers: vibration free.

- .6 Ensure damper operators are observable and accessible.
- .7 Corrections and adjustments conducted by Departmental Representative.

END OF SECTION

Part 1 General**1.1 REFERENCE STANDARDS**

- .1 National Fire Protection Association (NFPA)
 - .1 NFPA (Fire) 90A, Standard for the Installation of Air-Conditioning and Ventilating Systems, 2015 Edition.
 - .2 NFPA (Fire) 90B, Standard for Installation of Warm Air Heating and Air-Conditioning Systems, 2015 Edition.
- .2 Sheet Metal and Air-Conditioning Contractors' National Association (SMACNA)
 - .1 SMACNA 1966, HVAC Duct Construction Standards - Metal and Flexible, 3rd Edition.
- .3 Underwriters' Laboratories (UL)
 - .1 UL 181, Standard for Factory-Made Air Ducts and Air Connectors.
- .4 Underwriters' Laboratories of Canada (ULC)
 - .1 CAN/ULC-S110-07, Standard Methods of Tests for Air Ducts.

1.2 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
 - .1 Indicate:
 - .1 Acoustical loss.
 - .2 Leakage.
 - .3 Fire rating.
- .3 Test and Evaluation Reports:
 - .1 Catalogue or published ratings to be those obtained from tests carried out by manufacturer or independent testing agency signifying adherence to codes and standards.

Part 2 Products**2.1 GENERAL**

- .1 Factory fabricated to CAN/ULC-S110.
- .2 Pressure drop coefficients listed below are based on relative sheet metal duct pressure drop coefficient of 1.00.
- .3 Flame spread rating not to exceed 25. Smoke developed rating not to exceed 50.

2.2 METALLIC - INSULATED

- .1 Spiral wound flexible aluminum with factory applied, 37 mm thick flexible glass fibre thermal insulation with vapour barrier and vinyl jacket.
- .2 Performance:
 - .1 Factory tested to 2.5 kPa without leakage.
 - .2 Maximum relative pressure drop coefficient: 3.
 - .3 Maximum length: 1.5 m.

Part 3 Execution

3.1 DUCT INSTALLATION

- .1 Install in accordance with: CAN/ULC-S110, UL 181, NFPA (Fire) 90A, NFPA (Fire) 90B & SMACNA.

END OF SECTION

Part 1 General**1.1 REFERENCE STANDARDS**

- .1 ASTM International
 - .1 ASTM C177-13, Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus.
 - .2 ASTM C916-14, Standard Specification for Adhesives for Duct Thermal Insulation.
 - .3 ASTM C1071-16, Standard specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material).
 - .4 ASTM C1338-14, Standard Test Method for Determining Fungi Resistance of Insulation Materials and Facings.
 - .5 ASTM G21-15, Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi.
- .2 National Fire Protection Association (NFPA)
 - .1 NFPA (Fire) 90A, Standard for the Installation of Air Conditioning and Ventilating Systems, 2015 Edition.
 - .2 NFPA (Fire) 90B, Standard for the Installation of Warm Air Heating and Air Conditioning Systems, 2015 Edition.
- .3 Sheet Metal and Air Conditioning Contractor's National Association (SMACNA)
 - .1 SMACNA 1966, HVAC Duct Construction Standards, Metal and Flexible 3rd Edition.
- .4 Underwriter's Laboratories of Canada (ULC)
 - .1 CAN/ULC-S102-10, Standard Method of Test for Surface Burning Characteristics of Building Materials and Assemblies.

1.2 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.

Part 2 Products**2.1 DUCT LINER**

- .1 General:
 - .1 Mineral Fibre duct liner: air surface coated mat facing.
 - .2 Flame spread rating shall not exceed 25. Smoke development rating shall not exceed 50 when tested in accordance with CAN/ULC-S102.
 - .3 Fungi resistance: to ASTM C1338 & ASTM G21.
- .2 Rigid:
 - .1 Use on flat surfaces where indicated.
 - .2 25 mm thick, to ASTM C1071 Type 2, fibrous glass rigid board duct liner.
 - .3 Density: 48 kg/m³ minimum.
 - .4 Thermal resistance to be minimum 0.76 (m². degrees C)/W for 25 mm thickness when tested in accordance with ASTM C177, at 24 degrees C mean temperature.

2.2 ADHESIVE

- .1 Adhesive: to NFPA (Fire) 90A, NFPA (Fire) 90B and ASTM C916.
- .2 Flame spread rating shall not exceed 25. Smoke development rating shall not exceed 50. Temperature range minus 29 degrees C to plus 93 degrees C.

- .3 Water-based fire retardant type.

2.3 FASTENERS

- .1 Weld pins 2 mm diameter, length to suit thickness of insulation. Metal retaining clips, 32 mm square.

2.4 JOINT TAPE

- .1 Poly-Vinyl treated open weave fiberglass membrane 50 mm wide.

2.5 SEALER

- .1 Meet requirements of NFPA 90A and NFPA 90B.
- .2 Flame spread rating shall not exceed 25. Smoke development rating shall not exceed 50. Temperature range minus 68 degrees C to plus 93 degrees C.

Part 3 Execution

3.1 GENERAL

- .1 Do work in accordance with SMACNA 1966.
- .2 Line inside of ducts where indicated.
- .3 Duct dimensions, as indicated, are clear inside duct lining.

3.2 DUCT LINER

- .1 Install in accordance with manufacturer's recommendations, and as follows:
 - .1 Fasten to interior sheet metal surface with 100% coverage of adhesive to ASTM C916.
 - .1 Exposed leading edges and transverse joints to be factory coated or coated with adhesive during fabrication.
 - .2 In addition to adhesive, install weld pins not less than 2 rows per surface and not more than 425 mm on centres to compress duct liner sufficiently to hold it firmly in place.
 - .1 Spacing of mechanical fasteners in accordance with SMACNA 1966.

3.3 JOINTS

- .1 Seal butt joints, exposed edges, weld pin and clip penetrations and damaged areas of liner with joint tape and sealer. Install joint tape in accordance with manufacturer's written recommendations, and as follows:
 - .1 Bed tape in sealer.
 - .2 Apply 2 coats of sealer over tape.
- .2 Replace damaged areas of liner at discretion of Departmental Representative.
- .3 Protect leading and trailing edges of duct sections with sheet metal nosing having 15 mm overlap and fastened to duct.

END OF SECTION

Part 1 General**1.1 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.

Part 2 Products**2.1 SYSTEM DESCRIPTION**

- .1 Performance Requirements:
 - .1 Catalogued or published ratings for manufactured items: obtained from tests carried out by manufacturer or those ordered by manufacturer from independent testing agency signifying adherence to codes and standards.

2.2 GENERAL

- .1 To meet capacity, pressure drop, terminal velocity, throw, noise level, neck velocity as indicated.
- .2 Frames:
 - .1 Full perimeter gaskets.
 - .2 Plaster frames where set into plaster or gypsum board and as specified.
 - .3 Concealed fasteners.
- .3 Concealed manual volume control damper operators.

2.3 MANUFACTURED UNITS

- .1 Grilles, registers and diffusers of same generic type, products of one manufacturer.

2.4 LAMINAR SUPPLY AIR DIFFUSERS

- .1 Type SD1: existing 600 x 300 to remain or be relocated as indicated.
- .2 Type SD2: 600 x 600, painted aluminum and painted steel to inhibit corrosion, perforated face plate 1 mm thick, off-white finish.
- .3 Type SD3: 1200 x 600, painted aluminum and painted steel to inhibit corrosion, perforated face plate 1 mm thick, off-white finish.

2.5 RETURN AND EXHAUST GRILLES AND REGISTERS

- .1 Type RG-1: aluminum, 25 x 25 mm egg crate type face bars. Finish: off-white.

Part 3 Execution**3.1 INSTALLATION**

- .1 Install in accordance with manufacturer's instructions.
- .2 Install with flat head cadmium plated screws in countersunk holes where fastenings are visible.

END OF SECTION