EMBASSY OF THE UNITED STATES OF AMERICA

Via Veneto 119/A
0187 Rome, Italy

U.S. EMBASSY ROME

AIR CONDITIONING REPLACEMENT AT SERVER ROOMS

FAC Engineering
01/26/2026

FOREWORD

The Embassy of the United States in Rome needs to award a contract for the replacement of an existing air conditioning system serving two IT rooms located at the Mel Sembler Building and Chancery building, Via Sallustiana 49, Rome.

GENERAL

- The contractor shall supply all the installation materials and equipment, skilled and unskilled labor, technical supervision, as well as logistic and administrative support. The contractor shall also supply all accessory services such as: transportation, leasing, equipment and tools, disposal of debris, cleaning the work area and anything else necessary to complete the project in compliance with the present specifications

- The COR may schedule some of the operations to be performed after-hours or during the weekend. These activities shall be performed at no extra cost for the Embassy.

- Maximum attention is required for the safety of personnel at work on the site. The workers shall operate in compliance with standard codes. In view of the fact that the work site consists of crucial technical installations, temporary safety protection measures towards third parties and workers shall be installed with care and attention, especially for the hours when site is closed.

- The Contractor shall be responsible for submitting, for approval by the COR, samples of materials and supplies to be used.

- It shall be Contractor's responsibility to verify all the quantities and dimensions.

DEFINITIONS

A glossary of terms and relative equivalents used in the drawing up of the tender documents are indicated hereunder:

Client, Administration, Project Supervisor, COR, CO: all these denominations identify the technical administrative staff, predisposed to handle the contract on behalf of the embassy of the United States of America.

Contracting Company, Contractor: all these denominations identify the subject that undertakes to carry out the work described in the contract.

Contract, Purchase Order (P.O.), Work Order: these terms identify the contract document with which the project is awarded. The Client at his indisputable judgment shall make the formal selection of the different types of documents.

PARKING

No parking is allowed inside Embassy grounds. The Contractor's vehicles shall be allowed to enter only for loading and unloading materials.

Loading and unloading operations shall be carried out using only one vehicle at a time.

Consequently, during the accomplishment of the project the Contractor shall ensure that its vehicles are parked at its own expense outside the Government property.

SAFETY STANDARDS

The Contractor shall comply with all the applicable health and safety obligations provided by Legislative Decree No. 81/2008 (Consolidated Law on Occupational Health and Safety). The main objective is to eliminate or, where not possible, to reduce to the minimum any exposure of workers to risks arising from work-related activities. To this end, the Contractor is required, when applicable, to submit the Risk Assessment Document (Documento di Valutazione dei Rischi – DVR) or the Operational Safety Plan (Piano Operativo di Sicurezza – POS), to provide adequate and documented training to workers, to supply appropriate individual and collective protective equipment (PPE and CPE), and to fully comply with all the other obligations set forth under Legislative Decree 81/2008.

Submission of the Operational Safety Plan (POS)

Within 10 calendar days after receiving the Notice to Proceed, the awarded Contractor must submit a detailed Operational Safety Plan (POS). The POS must clearly identify the following key professional figures:

Site Technical Director (Direttore Tecnico di Cantiere):

The individual responsible for managing the construction site on behalf of the Contractor. This role may be fulfilled by either an internal employee or an external professional formally appointed by the company. This figure is not to be confused with the Construction Supervisor (Direttore dei Lavori), who is appointed by the Client and is responsible for verifying that the works are carried out in compliance with thedesign and technical specifications.

Supervisor (Preposto):

An individual who, by the nature of their duties, supervises the work of others (e.g., site manager, workshop head, department chief). The Supervisor must be adequately trained to fulfill the responsibilities assigned under Art. 19, paragraph 1, letter g) and in accordance with the objectives of Art. 37 of Legislative Decree 81/2008. The Supervisor shall ensure, continuously and effectively, that:

1. Workers comply with safety instructions and the provisions of the safety plan;
2. Personal protective equipment (PPE) is used as required;
3. Any deficiencies in procedures, tools, PPE, or persistent non-compliance are promptly reported to the employer or manager.

The contractor has to send the list of personnel who will work on site. The workers have to be regularly registered and if there is a subcontractor this has to present the documents requested too. All workers have to understand and speak Italian.

DESCRIPTION OF WORK

PROJECT MANAGER SITE PRESENCE AND REPORTING

The Project Manager shall be present on site on a daily basis for the entire duration of the works. Prior to each site visit, the Project Manager shall notify the Contracting Officer's Representative (COR) of his/her presence. At the end of each working day, the Project Manager shall submit to the COR a written daily inspection report in English, documenting the activities carried out, the number and roles of personnel on site, the status of materials and equipment deliveries, any issues or non-conformities identified, and any actions taken or planned to address them. The daily inspection report shall be submitted in a format approved by the COR and shall constitute an official record of the progress of the works. Failure to maintain the required site presence or to submit the daily inspection report may be considered a material breach of contract obligations.

MEL SEMBLER BUILDING SERVER ROOM

The server room at the Mel Sembler Building is currently served by an existing Computer Room Air Conditioning (CRAC) system composed of three units make Emerson HPM S20.
The contractor shall replace the existing system with two new packaged floor mounted a/c unit and two new remote condensers. New units shall have a rated total cooling capacity of 20.0 kW each and shall be equipped with a BACnet IP module.
The two units shall be part of a sole system and they must be managed by a PLC controller (HIPRO).
Contractor shall supply and install new CAT6 cable to connect the indoor units to the BAS control panel.

The work consists of:

- Site preparation, including installation of fences, temporary staging areas, and protection of materials, furniture, floors, and walls.
- Removal and storage of all furniture that may interfere with the work, as directed by the COR.
- Draining of refrigerant circuits from the units and remote condensers, with recovery and disposal of R407c gas in accordance with regulations.
- Removal of the existing A/C outdoor and indoor units and transportation to authorized landfill
- Removal of existing pipes and of electrical and communication cables
- Wall finishing and painting of the walls to restore them to their original conditions
- Demolition by cut of the masonry walls to run pipes and cables. All pass through-holes in structural masonry and floors, will be reinforced with metal frames in order to maintain structural integrity. if the walls are to be fireproof, additional fireproof plating is to be foreseen with products that guarantee same fireproof characteristics of the walls.
- Supply and installation of a new A/C system as described in the drawings. Air conditioning system includes indoor packaged unit, drainpipes, remote condensers, bus cables, wall mounted control units, fixtures, brackets, additional refrigerant charge (100g each meter) and additional oil charge (50g each siphon), etc. The new A/C units shall be equipped with

the “long distance kit”, the check valve on the supply and the solenoid valve on the liquid line. Refrigerant lines shall be 3/4"- 1/2". Provide 3 siphon traps on the vertical section. Oil addition: mod. FV68S: + 100g

- Connect and configure the new A/C system to the existing Building Automation System.
- Supply and installation of new electrical and communication cables to feed all the internal units and the remote condensers.
- Supply and installation of new drain lines for the units. The new drain line shall connect to the existing ones and shall be realized with sufficient slope (at least 1,5%) to allow condensate drain by gravity.
- Install a new electrical panel to be connected to an existing 40 A circuit breaker on the PM/D2 through a Cu/EPR-XLPE 5G4. The new electrical panel shall be wall mounted, 36 modules, with terminals and transparent door. Supply and install the new electrical cables as described below. The new panel shall be composed of:
    - Magneto thermic, DP main breaker: 4 poles 32A, Ith:32A, Im:320A, Icu/Icn: 6kA
    - Magneto thermic and GFCI serving the A/C unit 1: 4 poles 20A, Ith:20A, Idn: 0.3 (B type), Im:200A, Icu/Icn: 6kA – electrical cable: Cu/EPR-XLPE 5G2.5 (FG16OM16)
    - Magneto thermic and GFCI serving the A/C unit 2: 4 poles 20A, Ith:20A, Idn: 0.3 (B type), Im:200A, Icu/Icn: 6kA – electrical cable: Cu/EPR-XLPE 5G2.5 (FG16OM16)
- Start up of the system by Manufacturer authorized technicians.

CHANCERY SERVER ROOM

The server room at the Mel Sembler Building is currently served by an existing Computer Room Air Conditioning (CRAC) system composed of two units make Emerson HPM S07.
The contractor shall replace the existing system with two new packaged floor mounted a/c unit and two new remote condensers. New units shall have a rated total cooling capacity of 8.0 kW each and shall be equipped with a BACnet IP module.
The two units shall be part of a sole system and they must be managed by a PLC controller (HIPRO).
The contractor will test the existing refrigerant piping for leaks. Locate and repair any leak found during this process. Existing pipes shall be cleaned, flushed and prepared for reuse with new R410A units. This includes recovery on residual refrigerant, internal chemical flushing with approved flushing agent, nitrogen blowing, deep vacuum drying, replacement of filters driers and preparation of piping for R410A operation.
Contractor shall supply and install new CAT6 cable to connect the indoor units to the BAS control panel.

The work consists of:

- Site preparation, including installation of fences, temporary staging areas, and protection of materials, furniture, floors, and walls.
- Removal and storage of all furniture that may interfere with the work, as directed by the COR.
- Draining of refrigerant circuits from the units and remote condensers, with recovery and disposal of R407c gas in accordance with regulations.
- Removal of the existing A/C outdoor and indoor units and transportation to authorized landfill

- Removal of the electrical and communication cables
- Wall finishing and painting of the walls to restore them to their original conditions
- Supply and installation of a new A/C system as described in the drawings. Air conditioning system includes indoor packaged unit, drainpipes, remote condensers, bus cables, wall mounted control units, fixtures, brackets, additional refrigerant charge (100g each meter), etc. The new A/C units shall be equipped with the "long distance kit", the check valve on the supply and the solenoid valve on the liquid line. Refrigerant lines shall be 3/4"- 1/2". Provide 3 siphon traps on the vertical section. Oil addition: mod. FV68S: + 100g
- Connect and configure the new A/C system to the existing Building Automation System.
- Supply and installation of new electrical and communication cables to feed all the internal units and the remote condensers.
- Supply and installation of new drain lines for the units. The new drain line shall connect to the existing ones and shall be realized with sufficient slope (at least 1,5%) to allow condensate drain by gravity.
- Install a new electrical panel to be connected to an existing 40 A circuit breaker on the PM/D1 through a Cu/EPR-XLPE 5G2.5. The new electrical panel shall be wall mounted, 36 modules, with terminals and transparent door. Supply and install the new electrical cables as described below. The new panel shall be composed of:
    - Magneto thermic, DP main breaker: 4 poles 40A, Ith:40A, Im:400A, Icu/Icn: 6kA
    - Magneto thermic and GFCI serving the A/C unit 1: 4 poles 20A, Ith:20A, Idn: 0.3 (B type), Im:200A, Icu/Icn: 6kA – electrical cable: Cu/EPR-XLPE 5G2.5 (FG16OM16)
    - Magneto thermic and GFCI serving the A/C unit 2: 4 poles 20A, Ith:20A, Idn: 0.3 (B type), Im:200A, Icu/Icn: 6kA – electrical cable: Cu/EPR-XLPE 5G2.5 (FG16OM16)
- Start up of the system by Manufacturer authorized technicians.

MEL SEMBLER BUILDING UPS ROOM

The UPS room at the Mel Sembler Building is currently cooled by a residential split unit (12000BTU). The contractor shall replace the existing system with a split unit dedicated to IT equipment.

The work consists of:

- Site preparation, including installation of fences, temporary staging areas, and protection of materials, furniture, floors, and walls.
- Removal and storage of all furniture that may interfere with the work, as directed by the COR.
- Draining of refrigerant circuits from the units and remote condensers, with recovery and disposal of R410a gas in accordance with regulations.
- Removal of the existing A/C outdoor and indoor units and transportation to authorized landfill
- Removal of the existing piping and electrical and communication cables
- Wall finishing and painting of the walls to restore them to their original conditions
- Supply and installation of a new A/C system as described in the drawings. Air conditioning system includes indoor unit, refrigerant lines, drainpipes, outdoor unit, bus cables, wall mounted control units, fixtures, brackets, additional refrigerant charge (100g each meter). Refrigerant lines shall be 1/2"- 5/16". Provide 3 siphon traps on the vertical section. Oil

addition: mod. RB68A: + 50g. Outdoor unit will need to be installed in the MSB courtyard and new refrigerant lines to be installed on the façade protected by a conduit.

- Connect and configure the new A/C system to the existing Building Automation System.
- Supply and installation of new electrical and communication cables to feed the unit.
- Supply and installation of new drain lines for the units. The new drain line shall connect to the existing ones and shall be realized with sufficient slope (at least 1,5%) to allow condensate drain by gravity.
- Start up of the system by Manufacturer authorized technicians.

MATERIAL EQUIVALENTS

The Contractor shall verify and ensure that all the materials supplied are new and without defects and that their use and/or installation is carried out using the best techniques and fully respecting the instructions supplied by the manufacturers.

Special parts shall be manufactured solely by workshops that are highly qualified in that specific sector.

The makes indicated in this SOW (Scope of Work) are intended as a point of reference and therefore, the words *or approved equivalent* are implicit.

Different selections implemented by the Contractor shall be approved in advance by Client after submission of samples and technical cards.

AC INDOOR UNIT
HIREF
www.hiref.com
Chancery - 10JAUR0060_F10
MSB - 10JAUR0190_F30

REMOTE CONDENSER
HIREF
www.hiref.com
Chancery - PEC3N-212 H010M0Q00 0
MSB - PEC3N-423 H010M0Q00 0

SPLIT UNIT
HIREF
www.hiref.com
20HTI00351_F1 W0

MAINTENANCE PLAN

At completion of project, the contractor shall submit the preventive maintenance plan of all the equipment installed within the scope of the project, as follows.

List in detail the new equipment installed and submit the list to the COR.
The COR shall review the list and will give the contractor the standard inventory card for each type of equipment. Also, the COR will give the contractor the "Check list" detailing the standard OBO preventive maintenance activity for each type of equipment together with the required schedule, i.e. monthly, semiannual or annual schedule.

The contractor shall fill in the inventory cards for all equipment and shall submit to the COR the entire maintenance plan on paper.

SECTION 024116
STRUCTURE DEMOLITION

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 024119 – Selective Demolition
2. Section 033000 – Cast-in-Place Concrete (for new structural elements after demolition)
3. Section 134813 – Acoustic Equipment Enclosures

1.2 SUMMARY

A. Scope: Complete demolition of existing structures as shown on drawings; including reinforced concrete frames, masonry walls, floor slabs, foundations, and all embedded services within the demolition envelope.

B. Work includes:

1. Pre-demolition survey and structural assessment
2. Disconnection and capping of all utilities within demolition zone
3. Controlled demolition of structural elements
4. Removal and disposal of all demolition debris
5. Controlled demolition methods for reinforced concrete with diamond wire saw, hydraulic splitter, or other controlled technique where vibration or noise limits apply
6. Environmental protection and dust/noise control throughout

C. Do not demolish elements shown to remain. Verify demolition limits with Engineer before commencing each phase.

1.3 DEFINITIONS

A. PSC (Site Safety and Coordination Plan): mandatory safety and coordination plan per D.Lgs. 81/2008 art. 91; prepared by CSP (Design Safety Coordinator).

B. POS (Piano Operativo di Sicurezza): contractor's operational safety plan; per art. 96 D.Lgs. 81/2008.

C. Exclusion from Demolition (Keep): elements, finishes, or structures designated to remain; shown with hatching on demolition drawings.

D. Debris: demolished material; shall be sorted on site into waste streams (concrete, steel rebar, masonry, timber, mixed) for regulated disposal.

E. CER (European Waste Code): EU waste classification code per D.Lgs. 152/2006; demolition contractor to classify all waste streams before transport.

1.4 APPLICABLE STANDARDS

Key Applicable Standards	
EN 13670	Execution of concrete structures
EN 1992-1-1	Eurocode 2 – Design of concrete structures
DM 17/01/2018	Norme Tecniche per le Costruzioni (NTC 2018)
UNI EN 12111	Tunnelling machines – road headers, continuous miners and impact rippers
EN ISO 4413	Hydraulic fluid power – general rules and safety requirements for systems
D.Lgs. 81/2008	Consolidated Safety Act – Title IV (Temporary and Mobile Worksites)
D.Lgs. 152/2006	Management of demolition waste – classification and disposal
UNI 11716	Demolition and deconstruction of buildings – guidelines

EN 474-1	Earth-moving machinery – safety – general requirements
EN 791	Drill rigs – safety
ISO 9613-2	Acoustics – attenuation of sound during outdoor propagation
UNI EN 1992-1-1	Eurocode 2 – Design of concrete structures
UNI EN 206	Concrete – specification and performance
DM 17/01/2018	Norme Tecniche per le Costruzioni (NTC 2018) – Italian technical standards for construction
Circ. 21/01/2019 n.7	NTC 2018 application instructions
D.M. 37/2008	Building systems – installer qualifications and requirements
D.Lgs. 192/2005 e s.m.i.	Energy performance of buildings
D.Lgs. 81/2008	Consolidated Workplace Safety Act
D.P.R. 380/2001	Consolidated Building Code

1.5 SUBMITTALS

A. Pre-demolition structural survey: signed by structural engineer; identifying condition of elements, asbestos/hazardous materials survey, and demolition sequence recommendation.

B. Demolition plan (Piano di Demolizione): per D.Lgs. 81/2008 Allegato IX; phased sequence; shoring and propping requirements; vibration and noise predictions.

C. POS (Piano Operativo di Sicurezza): specific to demolition contractor activities; before commencement.

D. Waste management plan: CER codes for each waste stream; licensed carrier details; disposal facility acceptance certificates.

E. Vibration monitoring plan: sensor placement, threshold levels, and response protocol; where demolition is within 20 m of existing structures to remain.

F. Noise management plan: where works are within 200 m of noise-sensitive receptors; per D.P.C.M. 01/03/1991.

1.6 QUALITY ASSURANCE

A. Demolition contractor: qualified with evidence of prior RC demolition projects of comparable size; submit references.

B. Safety: D.Lgs. 81/2008 Titolo IV governs all site operations; PSC and POS mandatory; CSE (Coordinator for Execution) to be appointed by Client.

C. Asbestos: if asbestos-containing materials are identified, stop demolition; notify authority (ASL) per D.Lgs. 81/2008 art. 246; engage specialist asbestos removal contractor before resuming.

D. Vibration limits: peak particle velocity (PPV) per DIN 4150-3 at retained structures; limit as noted or ≤ 5 mm/s at foundations of structures to remain.

E. Dust: wet suppression or screening mandatory when demolishing masonry or concrete; no dry sweeping of debris on or near access routes.

1.7 UTILITY DISCONNECTION

A. Before demolition commences: identify, isolate, test dead, and cap or remove all utilities within demolition envelope.

B. Sequence: electricity (cut and cap at distribution board); gas (cap at service); water (drain and cap); telecoms (cut and cap); district heating/cooling (drain and cap).

C. Obtain written confirmation from each utility company that services are disconnected before starting demolition near service routes.

PART 2 – PRODUCTS

2.1 DEMOLITION METHODS AND EQUIPMENT

A. Mechanical demolition: hydraulic excavator with breaker or crusher jaw; for unrestricted demolition areas away from retained structures.

B. Controlled demolition – RC: diamond wire saw, wall saw, floor saw, or hydraulic rock splitter; where vibration must be minimised (< 5 mm/s PPV at adjacent structures).

C. Hand tools: electric or pneumatic demolition hammers for small-scale and precision work; concrete saws for cutting openings in slabs.

D. Craneage: where large elements are to be cut and lowered by crane; structural calculations for lifting weights required.

E. Prohibition: explosive demolition not permitted without written approval from Engineer and local authority.

2.2 SHORING AND PROPPING

A. Provide temporary shoring to all retained structural elements that may be affected by removal of adjacent structure.

B. Design: temporary works engineer to design all shoring systems; calculations submitted before installation.

C. Materials: steel props, acrow props, or structural timber; rated for imposed loads; no improvised propping.

D. Maintain shoring until permanent structure can take loads; do not remove until directed by Engineer.

2.3 PROTECTIVE MEASURES

A. Hoarding: solid timber or steel hoarding around demolition zone; 2.4 m minimum height; warning signs and site lighting.

B. Debris netting: scaffold with fine-mesh debris netting on all open faces of demolition; prevent projectiles.

C. Dust suppression: continuous water misting during breaking; site water supply and pump as required.

D. Vibration monitoring: continuous monitoring at nearest retained structure during all breaking; automatic alarm at 80% of limit; stop work at 100%.

PART 3 – EXECUTION

3.1 EXAMINATION AND PRE-DEMOLITION SURVEY

A. Carry out comprehensive visual survey of all elements to be demolished; note condition, structural system, and any deviation from drawings.

B. Survey adjacent retained structures for pre-existing cracks and defects; photographically document condition before demolition.

C. Test all utility isolations before commencing; use voltage detector and pressure gauge as appropriate.

3.2 DEMOLITION SEQUENCE

A. Demolish in reverse order of construction: remove fit-out and secondary elements first; then non-structural partitions; then structural floors from top down; then frames; finally foundations.

B. Maintain stability of remaining structure at all phases; do not create cantilever conditions not accounted for in demolition plan.

C. At each phase boundary: pause, inspect, consult with structural engineer if any concern, confirm next phase before proceeding.

D. Do not allow overloading of floors or slabs with demolition debris; remove debris progressively.

3.3 REINFORCED CONCRETE DEMOLITION

A. Breaking: hydraulic breaker where vibration is not restricted; diamond sawing where vibration must be controlled.

B. Rebar: cut flush with concrete surface where adjacent to retained structure; bend and cap protruding rebar if left in place during construction phase.

C. Foundations: break to full depth shown; remove all concrete from foundation pit; clean base for new construction.

D. Dust from cutting: diamond saw blade with integral water cooling; apply dust suppression at all cutting locations.

3.4 WASTE MANAGEMENT

A. Sort demolished materials on site into CER-classified streams:

1. Concrete and masonry: CER 17 01 01 (concrete) – inert; suitable for licensed inert landfill or recycled aggregate
2. Mixed metals (rebar, steel sections): CER 17 04 05 – recyclable; to licensed metal recycler
3. Timber: CER 17 02 01 – if untreated, compostable; if painted/treated, hazardous waste stream
4. Mixed demolition waste: CER 17 09 04 – to licensed non-hazardous construction waste facility
5. Asbestos (if encountered): CER 17 06 05 – hazardous; specialist contractor only; notify ASL

B. Maintain waste transfer records (Formulario di Identificazione Rifiuti – FIR) for all transported waste; retain for 5 years.

C. Maximum re-use of demolition materials on site (recycled aggregate for sub-base, fill) where quality permits; document in waste management plan.

3.5 COMPLETION AND SITE CLEARANCE

A. Remove all temporary shoring only after permanent structure can carry loads (written Engineer instruction).

B. Clear site of all demolition debris; wash down hardstanding with water; clean drainage gullies.

C. Survey retained structures for new damage; repair any damage attributable to demolition operations.

D. Submit waste disposal records to Engineer before final payment.

END OF SECTION 024116

SECTION 221316
SANITARY, SEWER, AND HVAC CONDENSATE DRAINAGE PIPING

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 232113 – Hydronic Piping (water piping; NOT drainage)
2. Section 232116 – Hydronic Specialties (backflow preventer at fill connection)
3. Section 237300 – Air Handling Units (AHU condensate drain pan and outlet)
4. Section 238216 – Fan-Coil Units (FCU drain pan, condensate lift pump, drain outlet)
5. Section 238143 – Air-Source Heat Pumps (defrost water and condensate discharge)
6. Section 233113 – Metal Ducts (duct moisture drainage where applicable)
7. Section 230716 – HVAC Thermal Insulation (condensate drain insulation against sweating)

1.2 SUMMARY

A. Scope: Furnish and install all gravity drainage piping for the project, comprising:

1. Sanitary waste and vent piping serving plumbing fixtures (WCs, basins, sinks, urinals, floor drains)
2. Building drainage discharge from inside the building envelope to the external sewer connection
3. Site sewer extension from building envelope to public sewer or on-site treatment
4. HVAC condensate drainage from fan-coil units, air-handling units, heat-pump indoor sections, dehumidifiers, and humidifier blowdown
5. Defrost / drip-pan drainage from outdoor heat-pump units
6. Storm/rainwater drainage where indicated on architectural drawings
7. Cleanouts, traps, vents, and inspection access provisions

B. Design code precedence: International Plumbing Code (ICC IPC 2021) is the primary design reference for sizing, slope, materials, and termination of all drainage piping and HVAC condensate disposal (per Engineer's directive). Italian / European standards (UNI EN 12056 series, UNI EN 752, D.Lgs. 152/2006) apply concurrently; where conflict arises, the more stringent requirement governs.

1.3 DEFINITIONS

A. Sanitary drainage: piping system removing wastewater from plumbing fixtures (greywater + blackwater) to the building sewer connection.

B. Building drain: the lowest piping inside the building envelope that receives discharge from soil, waste, and other drainage pipes and conveys it to the building sewer.

C. Building sewer: the piping extending from the end of the building drain to the public sewer, septic tank, or other approved disposal point.

D. HVAC condensate: water condensed from atmospheric moisture on cooling coils (FCU, AHU, heat pump), or produced during defrost cycles; pH typically 6.5–8 but may be slightly acidic on some materials.

E. Indirect waste pipe: waste pipe that does not connect directly to the sanitary drainage system, but discharges through an air gap into a fixture, receptor, or interceptor that is so connected — per ICC IPC Chapter 8. **HVAC condensate is classified as indirect waste** and shall discharge through an air gap.

F. Air gap: unobstructed vertical distance, through the free atmosphere, between the lowest opening of any pipe supplying water or waste to a receptor and the flood-level rim of that receptor; minimum 25 mm or twice the effective pipe diameter, whichever is greater (ICC IPC 802.2).

G. Trap: fitting providing a liquid seal that prevents back-passage of air and odours without materially affecting flow.

H. Trap seal depth: vertical distance between the dip and the crown weir of the trap; minimum 50 mm, maximum 100 mm (ICC IPC 1002.4 / UNI EN 12056-2).

I. Cleanout: access opening in a drainage piping system used for clearing obstructions.

1.4 APPLICABLE STANDARDS

Key Applicable Standards	
ICC IPC 2021	International Plumbing Code – Chapter 3 (General Regulations), Chapter 7 (Sanitary Drainage), Chapter 8 (Indirect/Special Waste), and Section 314 (Condensate Disposal)
ICC IPC Section 314	Condensate Disposal – HVAC equipment condensate piping size, materials, slope, and termination
ICC IPC Section 314.2.3	Condensate drain pipe minimum size based on coil capacity (≤ 20 ton: DN 20; 21–40 ton: DN 25; 41–90 ton: DN 32; 91–125 ton: DN 40; 126–250 ton: DN 50)
UNI EN 12056-1	Gravity drainage systems inside buildings – general and performance requirements
UNI EN 12056-2	Gravity drainage systems inside buildings – sanitary pipework, layout and calculation
UNI EN 12056-3	Gravity drainage systems inside buildings – roof drainage, layout and calculation
UNI EN 12056-5	Gravity drainage systems inside buildings – installation and testing
UNI EN 752	Drain and sewer systems outside buildings – sewer system management
UNI EN 1610	Construction and testing of drains and sewers (trench backfill, joint testing)
UNI EN 877	Cast iron pipes and fittings for sanitary drainage (SML-type)
UNI EN 1329-1	PVC-U piping systems for soil and waste discharge inside building
UNI EN 1451-1	Polypropylene (PP) piping systems for soil and waste
UNI EN 1453-1	Structured-wall PVC-U pipes for soil and waste discharge
UNI EN 12200	PVC-U rainwater piping systems
UNI 9183	Sistemi di scarico delle acque usate – design criteria
D.Lgs. 152/2006	Environmental Code – Part III (water protection, discharge of treated wastewater)
D.M. 37/2008	Building systems – installer qualifications (plumbing systems)
Reg. (UE) 305/2011 (CPR)	Construction Products Regulation – CE marking for piping products
D.M. 37/2008	Building systems – installer qualifications and requirements
D.Lgs. 192/2005 e s.m.i.	Energy performance of buildings
D.Lgs. 81/2008	Consolidated Workplace Safety Act

1.5 SUBMITTALS

A. **Drainage layout drawings:** plans and isometrics showing all drainage piping; sizes, slopes, cleanouts, vents, traps, and termination points; coordinated with structural and architectural drawings.

B. **Sizing calculations:** drainage fixture unit (DFU) calculations per ICC IPC Chapter 7 (Tables 709.1, 710.1) and concurrent verification per UNI EN 12056-2 for all building drains; condensate-line sizing per ICC IPC 314.2.3 based on cooling-equipment tonnage.

C. **Product data:** pipe and fitting manufacturers' data sheets; CE marking and Declaration of Performance per CPR; material standard compliance (EN 877 / EN 1329 / EN 1451 / EN 1453 / EN 12200).

D. Hydrostatic test plan: plan for water/air testing per ICC IPC 312 and UNI EN 1610.

E. Condensate route drawing: drawing showing the route of every HVAC equipment condensate line from drain pan outlet, through trap, to indirect-waste termination; trap geometry detail.

1.6 QUALITY ASSURANCE

A. Installer: licensed plumbing contractor per **D.M. 37/2008** (impianti idrici e sanitari, lett. d); minimum 5 years' experience on comparable projects.

B. Pipe and fittings: CE marked per CPR (Reg. UE 305/2011); DoP submitted at procurement.

C. Codes governing installation: ICC IPC 2021 is the primary installation code for this project. UNI EN 12056 (inside buildings) and UNI EN 752 (outside buildings) apply concurrently. D.Lgs. 152/2006 governs the quality of any wastewater discharged off-site.

D. No cross-connection between potable water and drainage; backflow protection per Section 232116; air-gap separation per ICC IPC 802.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Deliver pipes and fittings in manufacturer's original packaging; protect ends with caps.

B. Store horizontally on level supports; protect from UV (PVC/PP); do not stack above manufacturer's limit.

C. Inspect on delivery for damage, ovalisation, or fitting deformation; reject non-conforming items.

1.8 WARRANTY

A. All drainage piping and fittings: **5 years** from Substantial Completion.

B. HVAC condensate lift pumps: **1 year**.

PART 2 – PRODUCTS

2.1 PIPE MATERIALS — INSIDE BUILDING

A. Cast iron (SML — soil, manhole, lead-free) per EN 877: preferred for vertical stacks in multi-storey buildings and where acoustic performance is required; centrifugal cast or sand cast; with EPDM gaskets and stainless-steel clamps; ≥ 1.5 mm internal epoxy lining for chemical resistance.

1. Diameter range: DN 50 – DN 300
2. Use: vertical waste/soil stacks in occupied buildings (sound absorption), and any application where higher fire performance (A1 non-combustible per EN 13501-1) is required

B. Polypropylene (PP) per EN 1451-1: standard for in-building waste and vent piping where acoustic performance is not the principal criterion; mineral-reinforced PP for sound-attenuating ranges; socket fittings with integrated EPDM lip seal.

1. Diameter range: DN 32 – DN 160
2. Temperature: continuous 90 °C, short-burst 95 °C — suitable for kitchen and dishwasher waste
3. Fire class: B-s1,d0 minimum per EN 13501-1; A2-s1,d0 for sound-rated/fire-rated branches

C. PVC-U per EN 1329-1: acceptable for non-acoustic in-building waste piping, condensate lines, and laboratory waste; socket joints with elastomeric seal or solvent cement; do not use above 60 °C.

1. Diameter range: DN 32 – DN 160
2. Fire class: B-s1,d0 minimum; not used where A2 required

D. Copper per EN 1057 (for condensate only, optional): half-hard tube acceptable for short condensate runs where corrosion resistance and small bore are advantageous (e.g., from FCU drain pan to nearest trap).

2.2 PIPE MATERIALS — OUTSIDE BUILDING (BURIED)

A. Vitrified clay per EN 295: preferred for buried gravity sewer in commercial projects; sulphate-resistant; long life; lockable spigot-socket joints with elastomeric seal.

B. Structured-wall PVC-U per EN 1453-1 or HDPE per EN 12666-1: acceptable for buried sewer lines; minimum SN 8 ring stiffness (or as required by burial depth and traffic load); EN 1610 installation.

C. **Reinforced concrete pipe per EN 1916:** for large-diameter (DN ≥ 400) buried sewer lines or where traffic loading and durability so require.

D. **Cast iron per EN 877 (buried):** acceptable for buried sections immediately exiting the building, transitioning to alternative material at the first inspection chamber.

2.3 HVAC CONDENSATE DRAIN PIPING — DEDICATED

A. **Code reference:** ICC IPC Section 314 (Condensate Disposal). All HVAC condensate piping shall conform to IPC 314 sizing, slope, material, and termination requirements.

B. **Material — preferred:** PVC-U per EN 1329-1 (Schedule 40 or equivalent wall) or polypropylene (PP) per EN 1451-1; copper EN 1057 acceptable; **galvanised steel is NOT recommended** for condensate (mild acidity attacks zinc coating).

C. **Minimum size per ICC IPC 314.2.3 (based on cooling-equipment nominal capacity, USRT = US refrigeration tons; 1 USRT = 3.517 kW):**

1. Equipment ≤ 20 USRT (≤ 70 kW): minimum **DN 20** (¾")
2. Equipment 21–40 USRT (74–141 kW): minimum **DN 25** (1")
3. Equipment 41–90 USRT (144–317 kW): minimum **DN 32** (1¼")
4. Equipment 91–125 USRT (320–440 kW): minimum **DN 40** (1½")
5. Equipment 126–250 USRT (443–880 kW): minimum **DN 50** (2")

D. **Minimum slope:** 1% (10 mm per metre) toward indirect-waste termination per ICC IPC 314.2.2; never level or back-slope.

E. **Trap geometry — mandatory:** P-trap or U-trap at each drain-pan outlet, with trap depth (water seal) at least equal to the negative static pressure (mm w.g.) the fan develops downstream of the cooling coil + 25 mm safety margin; this prevents the fan suction from holding water in the pan (drain-pan flooding) on draw-through AHU configurations. **No exception** — every drain-pan outlet has its own trap.

F. **Vent (where required by IPC 314.2.5):** open vent (air-admittance valve or open pipe to atmosphere) upstream of the trap where condensate-line static head could break the trap seal.

G. **Termination — indirect waste per ICC IPC 802:** condensate pipe shall terminate at an air gap above a tundish, floor drain, mop-sink, hub drain, or approved indirect-waste receptor. **Direct connection to sanitary drainage is NOT permitted.**

H. **Insulation:** all condensate lines passing through occupied spaces shall be insulated against surface condensation (sweating) per Section 230716 — minimum 13 mm FEF closed-cell elastomeric foam, vapour-tight at all joints.

I. **Cleanout / rod-out access:** provide cleanout tee at the start of each horizontal condensate run, at every change of direction > 45°, and at maximum 15 m intervals; cleanout caps accessible without dismantling adjacent insulation.

2.4 CONDENSATE LIFT PUMPS (WHERE GRAVITY DRAINAGE IS NOT FEASIBLE)

A. **Application per ICC IPC 314.2.4:** where the drain-pan outlet elevation does not permit gravity flow to an indirect-waste receptor with the minimum 1% slope, install a condensate lift pump.

B. **Type:** factory-assembled lift pump unit comprising tank (≥ 0.5 L), float switch, centrifugal or peristaltic pump (≥ 6 L/h at 3 m discharge head), check valve, high-water alarm contacts.

C. **Materials:** ABS or polycarbonate tank; PP impeller; FKM seal compatible with mild-acid condensate; brass or stainless discharge connection.

D. **Electrical:** 230 VAC 50 Hz fused supply; volt-free high-water alarm contact wired to BMS via Section 230900; pump fault contact wired to BMS.

E. **Safety interlock:** high-water level shall interrupt the cooling-coil control loop (close chilled water valve or stop heat-pump compressor) preventing further condensate generation until alarm clears. Wire interlock through Section 230900 DDC.

F. **Discharge pipe:** soft copper or flexible PE tube; minimum DN 8 (5/16"); rises vertically to maximum 3 m, then to gravity drain with continuous slope; terminate at indirect waste per Article 2.3.

2.5 TRAPS, CLEANOUTS, AND VENTS

A. Traps: every plumbing fixture and floor drain provided with a P-trap (preferred), S-trap or bottle trap as appropriate; trap seal depth 50–100 mm; trap material to match upstream piping.

B. Cleanouts (ICC IPC 708):

1. Every horizontal branch ≥ DN 75: cleanout at upstream terminus
2. Every change of direction > 45°
3. Maximum 30 m intervals on straight runs ≤ DN 150; 22.5 m for DN > 150 (ICC IPC 708.1.5)
4. Every base of soil/waste stack
5. At entrance of building drain to building (within 1.5 m of the wall penetration)

C. Vents (ICC IPC Chapter 9): size and arrange vent piping to limit pressure deviation in any plumbing fixture trap to ±25 mm water column; main vent through-roof termination minimum DN 75; cap with rodent screen.

D. Air-admittance valves (AAV): acceptable per ICC IPC 917 where through-roof venting is impractical (e.g., island fixtures, retrofit); approved AAV per ASSE 1051; do not use as substitute for primary system vent.

2.6 FLOOR DRAINS AND TUNDISHES

A. Floor drains: stainless steel AISI 304 body and grating (AISI 316 in coastal/swimming-pool areas); load class K3 (300 kN) per EN 1253-1 for plant rooms; integral P-trap with self-priming feature where exposed to evaporation.

B. Trap primer: install trap primer line on floor drains in mechanical rooms and other areas subject to evaporation; supply from potable water with backflow preventer.

C. Tundishes / hub drains for HVAC condensate termination: stainless steel or PP-with-elastomeric-seal tundish with visible air gap, sized for combined condensate and safety-valve discharge flows.

2.7 SUMPS AND LIFT STATIONS (WHERE REQUIRED)

A. Sewage ejector / lift station: factory-packaged duplex pump unit in cast-iron or HDPE chamber; alternate-duty pumps; high-water alarm; vent to atmosphere; per ICC IPC Section 712.

B. Storm-water sump pump (where applicable): submersible pumps with float control; discharge to building storm-water system; do not connect storm sump discharge to sanitary system.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Verify structural openings, sleeves, and penetrations are correctly positioned and sized for drainage piping; report discrepancies before commencing installation.

B. Confirm location of building sewer connection, invert level, and minimum cover with site survey before commencing buried drainage works.

C. Verify condensate drain elevation at each HVAC equipment outlet permits gravity drainage with required slope; identify locations requiring lift pumps before equipment installation.

3.2 INSTALLATION — IN-BUILDING DRAINAGE

A. Install all drainage piping per ICC IPC Chapter 7 and UNI EN 12056-5; coordinate with structural and architectural penetrations.

B. Slope (ICC IPC 704.1):

1. Building drain and horizontal branches DN ≤ 80: minimum 2% (20 mm/m)
2. Building drain DN 90 – DN 150: minimum 1% (10 mm/m)
3. Building drain DN > 150: minimum 0.8% per ICC IPC Table 704.1; verify per local authority
4. Condensate drain: minimum 1% per ICC IPC 314.2.2

C. Joints: elastomeric-seal socket joints (preferred); solvent-cemented joints for PVC-U where elevated temperatures and chemical content allow; mechanical clamp couplings for cast iron (EN 877); never mix jointing methods within a single run.

D. Hangers and supports: size and space per Section 230529 and manufacturer's data; cast-iron DN 100: maximum 2.0 m horizontal spacing; PVC-U DN 100: maximum 1.0 m horizontal spacing; sound-attenuating clamps required on vertical stacks within occupied spaces.

E. Penetrations: sleeve all drainage pipes through walls, floors, and slabs; fire-stop per Section 078413 at fire-rated barriers; acoustic seal at acoustic-rated barriers; flexible coupling at structural movement joints.

F. Cleanouts (ICC IPC 708): install at all locations specified in Article 2.5; orient access cap toward unobstructed working space; cap with brass plug; thread-lock not permitted.

G. Vent piping: rise to roof penetration at minimum 1:50 slope; terminate not less than 150 mm above roof line and not less than 3 m horizontally from openable windows / air intakes (ICC IPC 904).

3.3 INSTALLATION — HVAC CONDENSATE DRAIN

A. Connect to drain-pan outlet of each FCU, AHU, heat pump, and dehumidifier per equipment manufacturer's instructions.

B. Trap fabrication: P-trap or U-trap immediately at drain-pan outlet; height of trap seal = fan negative static pressure (mm w.g.) + 25 mm; document trap depth in commissioning record.

C. Slope: continuous 1% minimum (10 mm/m) toward indirect-waste termination; no upward sections in gravity portion.

D. Indirect waste termination (ICC IPC 802): terminate at tundish, floor drain, hub drain, or mop-sink with **visible air gap** ≥ 2 × pipe diameter (minimum 25 mm). Engineer or Owner shall be able to verify air gap during inspection.

E. Insulation: apply 13 mm FEF closed-cell foam over entire condensate run within insulated/occupied spaces; vapour-tight at all joints; do not leave any portion of cold condensate pipe uninsulated within finished ceiling voids.

F. Cleanouts: at start of run, at every change of direction > 45°, every 15 m on straight runs.

G. No connection of condensate drain to roof gutter, rainwater leader, or sanitary stack without air-gapped intermediate receptor.

3.4 INSTALLATION — BURIED SEWER

A. Install per **UNI EN 1610** and ICC IPC Chapter 7; minimum cover 800 mm in landscape, 1000 mm in traffic-loaded areas.

B. Bedding: 150 mm compacted granular fill (sand or 4/8 mm gravel) below pipe; haunching and surround to spring line; selected excavated material as backfill above; warning tape at 300 mm above pipe.

C. Slope: minimum 1% (10 mm/m) for DN ≤ 200; 0.5% acceptable for DN > 200 per local authority.

D. Inspection chambers (manholes): at every change of direction, junction, or invert change, and at maximum 30 m intervals; sizes per UNI EN 476.

E. Connection to public sewer: per local utility authority's approval and connection specification; coordinate elevation and any required backwater valve.

3.5 TESTING

A. Sanitary drainage water test (ICC IPC 312.2): plug downstream end; fill to overflow at highest point or apply 3 m water column at lowest point; maintain ≥ 15 minutes; no visible leakage permitted.

B. Air test (ICC IPC 312.3): alternative to water test; pressurise system to 35 kPa (5 psi); maintain ≥ 15 minutes; pressure drop ≤ 7 kPa permitted.

C. Buried sewer joint test (UNI EN 1610): water-fill test or air-pressure test per EN 1610; document each manhole-to-manhole section result before backfill closure.

D. Condensate drain test: pour 2 L of clean water into each drain pan; verify free flow to indirect-waste termination without backup or overflow; verify trap holds water seal after fan shutdown.

E. Lift pump test: simulate high-water condition with float manually raised; verify pump operation, discharge, alarm signal to BMS, and cooling-coil interlock shut-off.

F. Submit signed test reports for all drainage works before concealment by ceilings, walls, or backfill.

3.6 COMMISSIONING

A. Operate each HVAC cooling unit for minimum 1 hour at design conditions; verify continuous condensate flow at indirect-waste termination; verify trap retains water seal; record observations.

B. Verify lift-pump high-water alarm transmits to BMS supervisor; verify cooling-coil shut-off interlock disables cooling on high-water signal.

C. Photographically document each air-gap termination for the project record.

3.7 IDENTIFICATION

A. Label all drainage piping per Section 230553:

1. Sanitary waste: brown
2. Storm/rainwater: blue with white stripe
3. HVAC condensate: blue (cold-water family) with 'CONDENSATE' text label every 5 m and at each change of direction

B. Tag lift pumps, sumps, and main cleanouts with stainless tag showing function and reference number.

END OF SECTION 221316

SECTION 230529
HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 232113 – Hydronic Piping
2. Section 232116 – Hydronic Specialties
3. Section 233113 – Metal Ducts
4. Section 237300 – Air Handling Units
5. Section 238216 – Fan Coil Units
6. Section 232123 – Hydronic Pumps
7. Section 230716 – HVAC Thermal Insulation
8. Section 230553 – Identification for HVAC Systems

1.2 SUMMARY

A. Scope: Furnish and install all hangers, supports, anchors, guides, seismic braces, and associated hardware for HVAC piping, ductwork, and mechanical equipment.

B. Included work:

1. Pipe hangers and rods for all hydronic piping systems (heating, cooling, condenser water, glycol)
2. Duct hangers, trapeze frames, and lateral braces for rectangular and circular sheet metal ducts
3. Equipment support bases, inertia pads, and anti-vibration mounts for AHUs, pumps, and fans
4. Seismic restraints and lateral bracing per NTC 2018 for all piping ≥ DN 65 and ducts with longest side ≥ 600 mm
5. Pipe anchors, guides, and expansion loops to control thermal movement
6. Insulation protection saddles and shields at all support points on insulated piping

1.3 DEFINITIONS

A. Hanger: support that suspends pipe or duct from overhead structure by means of rods, straps, or chains; carries load in tension.

B. Support: structure that bears pipe or equipment weight from below; carries load in compression; includes floor stands, base plates, and structural frames.

C. Anchor: rigid restraint that prevents pipe movement in all directions; absorbs thermal expansion forces; located at fixed points in expansion loop design.

D. Guide: restraint that allows axial pipe movement but prevents lateral/vertical movement; directs thermal expansion toward expansion loops or flexible joints.

E. Trapeze: horizontal structural member (angle or channel section) spanning between two hanger rods; supports multiple parallel pipes or a wide duct.

F. Seismic brace: lateral restraint system (rod, angle, or sway brace) designed to resist inertial forces from seismic events; required by NTC 2018 §7.2.3.

G. Insulation protection saddle (sella): curved steel plate between pipe support and insulation; prevents crushing of insulation at support points; mandatory on insulated pipes.

H. MSS SP-58 type number: industry-standard catalogue designation for hanger and support components; referenced throughout this Section.

1.4 APPLICABLE STANDARDS

Key Applicable Standards	
MSS SP-58	Pipe Hangers and Supports – Materials, Design, Manufacture, Selection, Application, and Installation
MSS SP-69	Pipe Hangers and Supports – Selection and Application Guide

MSS SP-89	Pipe Hangers and Supports – Fabrication and Installation Practices
MSS SP-90	Guidelines on Terminology for Pipe Hangers and Supports
EN 13480-3	Metallic industrial piping – Design and calculation; Annex J – pipe support spacing
UNI EN ISO 3506-1	Mechanical properties of corrosion-resistant stainless steel fasteners – bolts
UNI EN 10025-2	Hot-rolled structural steel products – technical delivery conditions
NTC 2018 §7.2.3	Norme Tecniche per le Costruzioni – non-structural elements (seismic bracing of systems)
Circ. 21/01/2019 n.7	NTC 2018 application instructions
SMACNA HVAC Duct Construction Standards	Duct hanger types, spacing, and loading – Chapter 4 (Hangers and Supports)
EN 12237	Ventilation for buildings – ductwork – strength and leakage of circular sheet metal ducts
D.Lgs. 81/2008	Consolidated Workplace Safety Act
D.P.R. 380/2001	Consolidated Building Code

1.5 SUBMITTALS

A. Shop drawings: hanger and support layout drawings at 1:50 minimum; showing type, location, rod size, and load for each support; seismic brace locations and directions highlighted.

B. Product data: manufacturer's load tables for all hanger types; rod pull-out strength for all insert types; seismic load resistance data for all bracing components.

C. Calculations: structural calculations for all trapeze hangers carrying pipes ≥ DN 100 or total load > 500 kg per trapeze; seismic brace calculations per NTC 2018 signed by a registered structural engineer.

D. Material certificates: material test reports (MTC) for hanger rods and structural steel; stainless steel grade certification where specified.

E. Anchor approvals: manufacturer's technical approval (ETA or equivalent) for all cast-in or post-installed anchors into concrete; anchor design calculations.

1.6 QUALITY ASSURANCE

A. All hanger and support components shall be of a recognised manufacturer specialising in pipe support systems (Hilti, Sikla, Unistrut, Flamco, or equal approved).

B. Hanger rod sizes and spacing shall comply with MSS SP-69 Tables and EN 13480-3 Annex J; no field-fabricated rod or strap without Engineer approval.

C. Seismic bracing design: NTC 2018 §7.2.3; calculations signed and stamped by a registered structural or civil engineer licensed per DM 17/01/2018 – NTC 2018. Installer follows Engineer-approved drawings and installation instructions; installer shall not modify brace layout without written Engineer approval.

D. All post-installed anchors into concrete: ETA-approved expansion or chemical anchors; installed per manufacturer's instructions; torque-tested at 10% of installed anchors (minimum 3 per system).

1.7 WARRANTY

A. All hanger and support systems: **1 year** from Substantial Completion.

B. Seismic bracing system: **5 years** — structural integrity of all restraint connections and anchors.

PART 2 – PRODUCTS

2.1 MATERIALS — GENERAL

A. **Standard material:** carbon steel, hot-dip galvanised (HDG) per EN ISO 1461; minimum coating 45 µm (85 µm for outdoor or humid locations).

B. **Stainless steel:** AISI 316 (1.4401) for all hangers and rods in contact with stainless steel piping; for outdoor, coastal, or chemically aggressive environments; for pool plant rooms.

C. **Threaded rods:** DIN 975 / ISO 4029; carbon steel class 4.6 galvanised (standard); class 8.8 galvanised where specified for heavy loads; stainless A4-70 where SS required.

D. **Nuts and washers:** matching grade and material to rod; double-nut locking at all adjustable rod connections.

E. **Unistrut / channel sections:** zinc-electrogalvanised (minimum 12 µm) for indoor dry; HDG or stainless for all other locations.

F. **Dissimilar metals:** where copper or stainless steel piping contacts carbon steel support, use dielectric isolation pad (neoprene or EPDM, 3 mm minimum) to prevent galvanic corrosion.

G. **Insulating pipe collars and clamps:** All pipe clamps, rings, and clevis hangers in direct contact with HVAC piping shall incorporate a continuous elastomeric liner (neoprene, EPDM, or reinforced rubber, minimum 3 mm thickness). Bare metal-to-pipe contact is not permitted on any HVAC service. Purpose: prevent galvanic corrosion at dissimilar-metal interfaces; eliminate thermal bridging and surface condensation at hanger contact points on chilled water, cold glycol, and other sub-ambient circuits; attenuate structure-borne vibration transmission from pipe to building structure. Accepted products: Hilti MFP / MI-F with neoprene insert, Flamco Fixothem, Sikla Isoflex, or equal approved by Engineer.

2.2 PIPE HANGER TYPES (MSS SP-58)

A. **Type 5 – Clevis hanger:** adjustable; standard for horizontal piping up to DN 150; sized per pipe OD including insulation where applicable.

B. **Type 9 – Adjustable band hanger:** for smaller pipes DN 15–50 where rod hanger is impractical; maximum load per manufacturer's table.

C. **Type 12 – Pipe clamp:** for close-to-wall horizontal pipe; where vertical rod hanger cannot be used; load limit per manufacturer.

D. **Type 26 – Adjustable pipe roll support:** for long runs with significant thermal expansion; allows axial pipe movement via steel roller; galvanised steel body; locate at calculated guide points in expansion loop design. Where low-friction sliding support is required (large diameter piping), use PTFE slide plate assembly (separate product; specify PTFE pad minimum 5 mm thick, stainless steel backing) in lieu of Type 26 roller.

E. **Type 36 / 37 – Adjustable swivel clevis hanger:** two-bolt adjustable clevis; for horizontal piping where angular adjustment is required; not a spring hanger.

F. **Type 51 / 54 – Spring hangers:** Type 51 = variable spring; Type 54 = constant-load spring; for pump suction/discharge piping and connections subject to vibration or thermal settlement; spring rate and travel calculated by Engineer; load and travel stamped on unit.

G. **Trapeze hanger:** fabricated from back-to-back angles or channel (Unistrut/Sikla); for multiple parallel pipes ≤ 2 m width; span and section sized per loading calculations.

NOTE: All hanger types shall be adjustable after installation to permit final alignment of piping. One-piece clamps or fixed types without adjustment mechanism are not permitted as primary pipe supports.

2.3 PIPE ANCHORS AND GUIDES

A. **Anchors:** welded or bolted anchor brackets on pipe; resist axial, lateral, and vertical forces; designed by Engineer to absorb expansion forces from thermal loops.

B. **Guides:** allow axial pipe movement only; lateral and vertical movement restrained; spacing per expansion loop design; maximum spacing = 40 × pipe OD.

C. **Anchor and guide materials:** carbon steel galvanised; welded to pipe with full penetration weld where pipe material allows; bolted type (split collar) for copper and stainless pipe.

2.4 INSULATION PROTECTION SADDLES

A. Requirement: mandatory at every support point on insulated piping; prevents compression of insulation; maintains thermal continuity through support.

B. Material: carbon steel sheet ≥ 3 mm; galvanised or painted; arc-welded saddle enclosing lower 180° of pipe circumference; length ≥ 150 mm (small bore) to 300 mm (large bore); no contact between support structure and pipe.

C. Insulation thickness: saddle height = full insulation thickness + 10 mm clearance; pipe insulation continuous through saddle zone.

D. High-temperature piping (> 60°C): high-density calcium silicate or foam glass insert within saddle to bridge support point.

2.5 DUCT HANGERS AND SUPPORTS

A. Rectangular duct hangers: trapeze type using back-to-back 40×40×4 mm angles (or Unistrut channel) spanning duct width + 50 mm each side; suspended by two threaded rods; rod size per spacing table below.

B. Circular duct hangers: adjustable band hanger or clevis-type ring at diameter; rod size per spacing table.

C. Duct support at AHU connections: independent support within 300 mm of AHU casing; ductwork weight shall not bear on AHU connections.

D. Maximum hanger spacings and minimum rod diameters for ductwork:

Parameter	BACnet Object / Modbus Reg.	R/W	Notes
Duct type / size	Max spacing	Rod Ø min	Notes
Rectangular – longest side ≤ 400 mm	2 400 mm	Ø 8 mm	SMACNA Table 4-1
Rectangular – longest side 401–800 mm	1 500 mm	Ø 10 mm	SMACNA Table 4-1
Rectangular – longest side 801–1500 mm	1 200 mm	Ø 12 mm	SMACNA Table 4-1
Rectangular – longest side > 1500 mm	900 mm	Ø 12 mm + mid-support	SMACNA Table 4-1
Circular / oval – Ø or minor ≤ 500 mm	3 000 mm	Ø 8 mm	SMACNA Table 4-1
Circular / oval – Ø or minor > 500 mm	2 000 mm	Ø 10 mm	SMACNA Table 4-1

2.6 MAXIMUM PIPE HANGER SPACING

A. Hanger spacing shall not exceed the values below; actual spacing may be reduced by the Engineer where concentrated loads, valves, or fittings require closer support.

Parameter	BACnet Object / Modbus Reg.	R/W	Notes
Nominal pipe size	Steel / GI / Fe (m)	Copper (m)	Pre-insulated (m)
DN 15 - DN 20 (1/2 in - 3/4 in)	2.0 m	1.8 m	2.0 m
DN 25 - DN 32 (1 in - 1-1/4 in)	2.5 m	2.0 m	2.5 m
DN 40 - DN 50 (1-1/2 in - 2 in)	3.0 m	2.5 m	3.0 m
DN 65 - DN 80 (2-1/2 in - 3 in)	3.5 m	3.0 m	3.5 m

DN 100 - DN 125 (4 in - 5 in)	4.0 m	3.5 m	4.0 m
DN 150 (6 in)	4.5 m	--	4.5 m
DN 200 and above (>= 8 in)	5.0 m	--	5.0 m

NOTE: Spacings are for straight horizontal runs of water-filled pipe. Reduce by 20% for vertical runs without intermediate restraints, for steam piping, or for pipes with external insulation > 80 mm thickness. Copper pipe (EN 1057) is not commercially available in HVAC applications above DN 108 (4 in); columns marked '--' indicate copper is not applicable at that diameter. Steel pipe spacing per EN 13480-3 Annex J; copper pipe spacing per MSS SP-69 Table 3 (which governs where more restrictive).

2.7 SEISMIC RESTRAINTS

A. Applicability: all piping ≥ DN 65 and all ductwork with longest side ≥ 600 mm shall be provided with seismic lateral bracing per NTC 2018 §7.2.3.

B. Lateral brace spacing: maximum 6 m centres for piping; maximum 6 m for ductwork; braces at each change of direction.

C. Brace types: four-way (longitudinal + transverse) sway braces using steel angle or rod diagonals; Hilti MI or equivalent modular seismic system acceptable.

D. Design loads: horizontal seismic force per NTC 2018 §7.2.3 formula $F_a = S_a \times W_a \times \gamma_a / q_a$; seismic coefficient Sa and site parameters (ag, S, Categoria d'uso) defined by the structural engineer for the specific project location. For preliminary design and where project-specific seismic calculation is not yet available, use the conservative estimate $F_a = 0.3 \times g \times W$ (W = weight of pipe/duct including fluid and insulation); this value shall be confirmed or replaced by the structural engineer's project-specific calculation before detailed design.

E. Anchors: ETA-approved expansion anchors or chemical anchors into concrete structure; anchor design per manufacturer's ETA and seismic load calculations.

F. Seismic isolators for equipment: AHUs, pumps, and fan coils on spring or neoprene mounts to limit seismic force transmission to structure; spring mounts for equipment > 5.5 kW with steel cage housing, NTC 2018 rated.

2.8 ANTI-VIBRATION MOUNTS FOR EQUIPMENT

A. Pumps and fans ≤ 5.5 kW: neoprene anti-vibration pads; Shore A hardness 40–60; minimum 20 mm static deflection under operating load.

B. Pumps and fans > 5.5 kW, AHUs: spring isolators with steel housing/cage; minimum 25 mm static deflection; NTC 2018 seismic rated; natural frequency ≤ 4 Hz.

C. Fan coil units (ceiling suspended): spring hangers rated for FCU weight + service load (including full water content and filter); minimum **25 mm** static deflection; natural frequency ≤ 4 Hz; neoprene-only hangers not permitted for ceiling-suspended FCUs.

D. Inertia bases: reinforced concrete inertia pad, mass = 1.5 × (pump + motor) assembly weight, for all base-mounted pumps > 5.5 kW; spring mounts between inertia base and floor slab.

NOTE: All anti-vibration mounts shall be loaded to 60–80% of rated capacity at operating weight to achieve stated natural frequency. Overloaded or underloaded mounts do not achieve the specified isolation.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Verify structural elements (beams, slabs, walls) are available and adequate for support loads before installing hangers.

B. Do not attach hangers to metal decking, sprinkler piping, electrical conduit, or other mechanical/electrical systems.

C. Confirm anchor type is appropriate for concrete compressive strength and slab thickness; minimum embedment per ETA.

3.2 INSTALLATION — PIPE SUPPORTS

A. Rod plumb: hanger rods shall be plumb within 1°; angled rods without lateral brace are not permitted.

B. Adjustment: set hanger nuts to maintain designed pipe elevation; re-adjust after system fill and pressurisation.

C. Isolation: install neoprene or EPDM pad between pipe clamp and copper or stainless steel pipe; between galvanised support and copper pipe.

D. Insulated pipe: install insulation protection saddle before closing hanger; do not compress insulation; maintain full insulation thickness at support.

E. Vertical pipe: support at each floor penetration and at maximum 4 m intervals on vertical risers; use riser clamps (MSS SP-58 Type 8) with load transferred to slab.

F. No support to piping itself: piping shall not support the weight of valves, strainers, or instruments without independent support within 300 mm of the fitting.

3.3 INSTALLATION — DUCT SUPPORTS

A. Install trapeze hangers level to ± 2 mm across span; verify duct sits level on trapeze before fastening.

B. Support flexible duct connections at AHU and fan coil independently — do not use flexible connection to carry duct weight.

C. All penetrations through fire-rated floors and walls: provide independent support on each side of penetration; fire-rated collars or intumescent blanket as required.

3.4 INSTALLATION — SEISMIC BRACING

A. Install lateral braces before completing pipe or duct connections; do not wait until system is complete.

B. Four-way braces at maximum 6 m spacing and at all changes of direction ≥ 45°; longitudinal and transverse braces may be combined at the same location.

C. Anchor torque: tighten to manufacturer's specified installation torque; record torque values on installation record.

D. Submit completed seismic brace installation record (Dichiarazione di corretta posa) signed by installer before system commissioning.

3.5 FIELD QUALITY CONTROL

A. Hanger inspection: 100% visual inspection of all hangers before insulation is applied; check rod size, spacing, plumb, and nut tightening.

B. Load test (spot check): 5% of all post-installed anchors to be torque-tested to 120% of installation torque; no pull-out or cracking permitted.

C. Anti-vibration mount check: measure static deflection under operating load; verify within 10% of specified value.

D. As-built record: submit as-built hanger schedule showing actual hanger type, rod size, and spacing at each support point; update seismic brace layout drawing.

END OF SECTION 230529

SECTION 230553
IDENTIFICATION FOR HVAC SYSTEMS

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 232113 – Hydronic Piping (pipe labelling at completion)
2. Section 233113 – Metal Ducts (duct labelling)
3. Section 230529 – Hangers and Supports for HVAC Piping and Equipment
4. Section 230900 – Instrumentation and Controls for HVAC (BMS point labelling)
5. Section 232123 – Hydronic Pumps
6. Section 237300 – Air Handling Units
7. Section 260518 – Low-Voltage Electrical Power Conductors and Cables (cable marking)

1.2 SUMMARY

A. Scope: Furnish and install a complete identification system for all HVAC piping systems, ductwork, mechanical equipment, valves, and control panels.

B. Included work:

1. Pipe labels with colour band, fluid name, flow direction arrow, and pressure/temperature where required
2. Equipment name plates (targhe) for all AHUs, pumps, fan coil units, heat pumps, and major plant items
3. Valve identification tags (targhette valvole) keyed to valve schedule
4. Duct labels at each air terminal and at each major branch
5. Control panel labels and zone identification for BMS field devices
6. Safety and hazard signs at refrigerant plant, gas train, and high-temperature equipment

C. Identification shall be installed **after** pressure testing, flushing, and final painting of piping and equipment, but **before** final inspection and handover.

1.3 DEFINITIONS

A. Equipment tag (targa): permanent stainless steel or anodised aluminium nameplate affixed to each item of mechanical plant; carries tag number, description, and duty data.

B. Valve tag (targhetta valvola): numbered disc (brass, aluminium, or engraved stainless) hung from valve handwheel or stem; cross-referenced to valve schedule in O&M manual.

C. Pipe label (etichetta tubazione): adhesive or banded label showing colour stripe, fluid name, and flow arrow; applied to pipe or pipe insulation at regular intervals and at key locations.

D. Flow arrow: directional arrow on pipe label indicating normal flow direction; both directions shown where flow is reversible.

E. Circuit code: abbreviated service code used consistently throughout drawings, schedules, and tags (e.g., HW = heating water; CHW = chilled water; CW = condenser water; GLY = glycol; DHW = domestic hot water).

1.4 APPLICABLE STANDARDS

Key Applicable Standards	
ANSI/ASME A13.1	Scheme for the Identification of Piping Systems – colour and label requirements
UNI 5634:1965	Pipe identification for fluids – withdrawn; no current regulatory force; cited for historical reference only; superseded in this project by ASME A13.1
UNI EN ISO 20560-1:2021	Identification of contents of piping systems – graphical symbols for labels and signs (current ISO reference)

ISO 7010	Graphical symbols – safety signs – registered safety signs
UNI EN ISO 7000	Graphical symbols for use on equipment – registered symbols
CEI EN 60445	Basic and safety principles – identification of equipment terminals and conductor terminations
CEI 64-8	Electrical systems – conductor identification colours
UNI 7543-1	Colours and safety signs – safety colours
D.Lgs. 81/2008 All. XXV	Safety signage – minimum provisions
D.Lgs. 81/2008	Consolidated Workplace Safety Act

1.5 SUBMITTALS

A. Identification schedule: complete list of all pipes, equipment, valves, and ducts to be identified; tag numbers, circuit codes, label text, and colours; submitted for Engineer approval before fabrication.

B. Valve schedule (registro valvole): tabulated list of all valves; columns: tag number, service, location, type, size, normal position (open/closed), fail position; to be included in O&M manual.

C. Sample labels and tags: physical samples of each label type and tag material for Engineer approval before full production.

D. Equipment tag drawings: drawings showing tag content for each major item; submitted concurrently with equipment submittals.

1.6 QUALITY ASSURANCE

A. All labels, tags, and signs shall be produced by a specialist identification manufacturer; field hand-written labels are not acceptable.

B. Tag numbers shall match exactly the numbers shown on Contract drawings, BMS point schedules, and O&M manuals; no variation without Engineer approval.

C. Colours shall match the project colour schedule (Art. 2.2) and ASME A13.1 where applicable; verify colour under project lighting conditions before full installation.

1.7 WARRANTY

A. All identification materials: **1 year** from Substantial Completion; labels shall not peel, fade, or become illegible under normal plant room conditions within warranty period.

PART 2 – PRODUCTS

2.1 PIPE LABELS

A. Label type: self-adhesive vinyl labels or wrap-around band labels; UV-resistant and chemical-resistant inks; suitable for –20°C to +120°C continuous service.

B. Label size: per pipe / insulation OD:

1. OD ≤ 50 mm: minimum 50 mm × 200 mm label
2. OD 51–150 mm: minimum 70 mm × 300 mm label
3. OD 151–300 mm: minimum 90 mm × 400 mm label
4. OD > 300 mm: stencilled directly on pipe insulation lagging

C. Label content:

1. Background colour band: full width of label, per colour schedule (Art. 2.2)
2. Fluid name: abbreviated circuit code + full Italian description (e.g., 'CHW – Acqua refrigerata')
3. Flow direction arrow: minimum 50 mm tall; black or white for contrast; both arrows for reversible flow
4. Pressure and temperature where required by PED Dir. 2014/68/UE (piping systems > 110°C or > PN16)

D. Label spacing:

1. Straight runs: maximum 5 m between labels in plant rooms; maximum 10 m in ceiling voids
2. At every branch, riser, floor/wall penetration (both sides), valve, and access panel
3. At every change of direction > 45°
4. Minimum one label in each room or zone served

2.2 PIPE COLOUR IDENTIFICATION SCHEDULE

A. The following colour schedule applies to all HVAC piping systems on this project, based on ASME A13.1 and common Italian HVAC practice:

Parameter	BACnet Object / Modbus Reg.	R/W	Notes
Service	Background	Text	RAL approx.
Heating hot water (HW)	Orange	Black	RAL 2010
Low-temp. heating (LTHW)	Orange	Black	RAL 2010
Chilled water – supply (CHW-S)	Blue	White	RAL 5015
Chilled water – return (CHW-R)	Blue	White	RAL 5015
Condenser water (CW)	Grey	Black	RAL 7001
Domestic hot water (DHW)	Orange	Black	RAL 2010
Domestic cold water (DCW)	Green	White	RAL 6024
Glycol / antifreeze circuit	Violet	White	RAL 4005
Compressed air	Pastel blue	Black	RAL 5024
Natural gas (where present)	Yellow	Black	RAL 1021
Drain / condensate	Grey	Black	RAL 7035
Refrigerant (high-pressure side)	Orange	Black	RAL 2004
Refrigerant (low-pressure side)	Light orange	Black	RAL 2003
Fire-protection water	Red	White	RAL 3000

NOTE: Where pipe insulation cladding (lagging) is present, the colour band label is applied to the cladding surface. Self-adhesive labels shall not be applied directly to mineral wool or foam insulation without a vapour-barrier cladding layer. Natural gas (yellow RAL 1021) is the only fluid retaining a yellow label on this project; all water-based services use orange, blue, green, or grey to avoid confusion with the gas hazard colour. Supply air ducts (light blue RAL 5012) are differentiated from compressed air piping (pastel blue RAL 5024) by both RAL shade and label format (duct labels are significantly larger). Condenser water (CW, grey RAL 7001) is intentionally differentiated from domestic cold water (DCW, green RAL 6024) to prevent cross-connection risk.

2.3 EQUIPMENT NAME PLATES (TARGHE)

A. Material: 1.5 mm anodised aluminium (natural or black anodised); or 1.5 mm brushed stainless AISI 304; engraved text filled with black or white enamel.

B. Size: minimum 150 mm × 80 mm; larger as required to accommodate all tag information.

C. Fixing: stainless steel self-tapping screws or rivets to equipment casing; adhesive fixing only where screw fixing would damage equipment warranty.

D. Tag content format:

Parameter	BACnet Object / Modbus Reg.	R/W	Notes
Field	Content	Example	Status
Line 1 (top)	Equipment tag number	e.g. P-01-HW-001	Mandatory
Line 2	Equipment description (Italian)	e.g. Pompa acqua calda - circuito primario	Mandatory
Line 3	Duty point or capacity	e.g. Q = 8 m3/h H = 18 m 3.0 kW	Mandatory
Line 4 (bottom)	Service circuit code	e.g. HW / LTHW / CHW / CW / GLY	Mandatory

E. Colour coding of tags:

1. Heating system equipment: yellow tag with black text
2. Cooling / chilled water equipment: blue tag with white text
3. Ventilation / AHU equipment: grey tag with black text
4. Domestic water equipment: green tag with white text
5. Refrigerant / heat pump equipment: red tag with white text
6. General / mixed service: aluminium natural anodised tag with black text

2.4 VALVE TAGS (TARGHETTE VALVOLE)

A. Material: 2 mm brass disc or 1.5 mm anodised aluminium disc; minimum Ø 50 mm.

B. Stamped or engraved: tag number per valve schedule; circuit code; normal position (NA = normally open; NC = normally closed).

C. Attachment: stainless steel 'S'-hook to valve handwheel spindle or identification ring on actuated valve; wire attachment not acceptable.

D. Colour:

1. Manual isolation valves: brass (natural) or yellow anodised aluminium
2. Pressure-reducing valves and safety relief valves: red disc
3. Motorised / actuated control valves: blue disc
4. Drain and vent valves: grey disc

E. Valve schedule: provide complete valve schedule in O&M manual; include: valve tag, service, pipe size, type, location description, normal position (open/closed), fail-safe position, and actuator/BMS point reference where applicable.

NOTE: All valves, including drain cocks, automatic air vents, and fill points, shall be tagged. No valve shall be left unidentified at handover. The valve schedule is a mandatory O&M document.

2.5 DUCT LABELS

A. Supply air ducts: label background light blue (RAL 5012); text black; content: 'MANDATA – [zone or AHU tag]'.

B. Return / extract air ducts: label background yellow (RAL 1003); text black; content: 'RIPRESA / ESTRAZIONE – [zone or AHU tag]'.

C. Fresh air intake ducts: label background green (RAL 6024); text white; content: 'ARIA ESTERNA'.

D. Exhaust air ducts: label background grey (RAL 7035); text black; content: 'ARIA ESPULSA'.

E. Label spacing: at each branch from main; at each AHU connection; at each zone served; at every access panel; minimum one label per room or zone served by the duct.

F. Airflow arrow: printed on label; direction of normal flow.

G. Label size: minimum 100 mm × 300 mm for ducts ≥ 200 mm side; label applied to duct or duct insulation lagging; stencilled directly on large ducts > 1000 mm.

2.6 CONTROL PANEL AND BMS FIELD DEVICE LABELS

A. **Control panels:** engraved panel fascia label; text: panel tag, description, served zone; minimum 10 mm text height; label material per equipment nameplate (Art. 2.3).

B. **BMS sensors and actuators:** adhesive polyester label on each sensor, transmitter, and actuator; text: BMS point tag (as per BMS point schedule in Section 230900); minimum 12 pt font.

C. **VFD / frequency drive:** label on door: drive tag, motor it serves, BACnet Device Instance number.

D. **Terminal strips:** label each terminal with wire number per wiring diagram; CEI EN 60445 compliant numbering.

2.7 SAFETY AND HAZARD SIGNS

A. **Refrigerant plant room:** ISO 7010 / D.Lgs. 81/2008 mandatory signs: 'RISCHIO ASFISSIA – REFRIGERANTE'; 'VIETATO FUMARE E USARE FIAMME LIBERE'; emergency ventilation switch label.

B. **High-temperature piping (> 60°C):** 'ATTENZIONE – SUPERFICIE CALDA' warning label per ISO 7010-W017 at accessible locations.

C. **Gas (where present):** mandatory sign 'GAS – PERICOLO DI ESPLOSIONE / VIETATO FUMARE E USARE FIAMME LIBERE' per D.Lgs. 81/2008 All. XXV (sign text legally required in Italian); non-residential gas systems: UNI 11528; residential gas systems: UNI 7129.

D. **Pressurised equipment (PED):** pressure vessel CE plate per PED Dir. 2014/68/UE; stamped PS, TS, V, year, and Notified Body number.

E. **Emergency stops:** red/yellow emergency stop labels per ISO 13850 (safety of machinery – emergency stop) and D.Lgs. 81/2008 All. XXV at each emergency stop push button and at plant room entry points; wording: 'ARRESTO DI EMERGENZA'.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Confirm all piping, ductwork, and equipment painting and insulation is complete before applying identification labels.

B. Verify tag numbers against as-built drawings and BMS point schedules; report and resolve any discrepancies before label production.

3.2 INSTALLATION

A. **Surface preparation:** clean pipe or duct surface with isopropyl alcohol before applying self-adhesive labels; ensure surface is dry and free of dust, grease, and condensation.

B. **Label alignment:** apply labels horizontally on horizontal pipes and ducts; readable from the floor or from the main access aisle; labels on vertical pipes shall be readable from below or from the nearest walkway.

C. **Insulated pipes:** apply labels after final cladding is installed; where cladding is PVC or GRP, apply self-adhesive label directly; where cladding is canvas or mineral wool, use stainless steel banding with label clip.

D. **Equipment plates:** fix name plates before painting of equipment is complete so that paint does not obscure text; re-apply if plate is painted over.

E. **Valve tags:** hang tag after valve is installed and before system fill; confirm tag number matches valve schedule before hanging.

3.3 INSPECTION AND ACCEPTANCE

A. **100% check:** Engineer or Clerk of Works to inspect all labels, tags, and signs before handover; sign off on identification checklist.

B. **Valve schedule verification:** walk all systems with valve schedule; confirm each valve tag is in place, readable, and matches schedule.

C. **Illegible or damaged labels:** replace before handover; no acceptance of faded, peeling, paint-covered, or incorrectly positioned labels.

D. Submit completed identification checklist with as-built documentation; include photographic record of each plant room's labelling.

END OF SECTION 230553

SECTION 230593
TESTING, ADJUSTING, AND BALANCING FOR HVAC

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 230519 – Meters and Gauges for HVAC Piping (instruments used as reference)
2. Section 230523 – General-Duty Valves for HVAC Piping (balancing valves, PICV)
3. Section 230900 – Instrumentation and Controls for HVAC (BMS commissioning)
4. Section 232113 – Hydronic Piping (flushing, prerequisite to TAB)
5. Section 232123 – Hydronic Pumps (operating-point verification)
6. Section 233113 – Metal Ducts (leakage testing, prerequisite to TAB)
7. Section 237300 – Air Handling Units (fan SFP verification)
8. Section 238143 – Air-Source Heat Pumps (waterside flow/duty verification)
9. Section 238216 – Fan-Coil Units (zone-level balancing)
10. Section 134813 – Acoustic Equipment Enclosures (post-TAB sound measurements)

1.2 SUMMARY

A. Scope: Provide complete testing, adjusting, and balancing (TAB) of all HVAC air and water distribution systems, including measurement, verification, balancing, and documentation, by an independent specialist TAB contractor; followed by acceptance testing witnessed by the Engineer.

B. Included works:

1. Pre-TAB system readiness verification (flushing, leak testing, BMS point checkout)
2. Air-side balancing of all supply, return, and exhaust ductwork to design airflows
3. Waterside balancing of all hydronic circuits (primary, secondary, tertiary, terminal) to design flow rates
4. Fan and pump operating-point verification, SFP/SPP measurement
5. Coil duty verification on representative units
6. Sound and vibration measurement (post-balancing)
7. Final TAB report and as-balanced documentation

C. Procedural reference: UNI EN 12599 (acceptance testing), BSRIA BG 1/2009 (air systems), BSRIA BG 2/2009 (water systems), and CIBSE Commissioning Codes A and W. Where US procedures and tolerances apply, AABC / NEBB / ASHRAE Std. 111 are referenced concurrently.

1.3 DEFINITIONS

A. TAB: Testing, Adjusting, and Balancing — the systematic process of (1) testing equipment performance, (2) adjusting controls and dampers/valves, and (3) balancing flows to design values.

B. Total flow: the sum of all branch / terminal flows in a system; shall equal the design system flow within tolerance.

C. Proportional balancing: technique where all branches of a system are simultaneously adjusted to maintain their designed proportional flow share, regardless of the absolute total.

D. SFP (Specific Fan Power): electrical power consumed by the fan per unit of volumetric airflow, W/(L/s) or W/(m³/s); per Reg. (UE) 1253/2014.

E. SPP (Specific Pump Power): equivalent metric for pumps, W/(L/s) of water moved at design head.

F. TAB Agency: independent specialist firm engaged to perform TAB; **not** the mechanical installation contractor.

G. As-balanced: the final state of the system after all adjustments are recorded; the basis for warranty operation and BMS reference values.

1.4 APPLICABLE STANDARDS

Key Applicable Standards

UNI EN 12599	Ventilation for buildings – test procedures and measurement methods for installed HVAC systems
UNI EN 14336	Heating systems in buildings – installation and commissioning
UNI EN 15378-1	Heating systems and DHW – inspection of boilers and heating systems
UNI EN 16798-17	Energy performance of buildings – Module M5-11 – inspection of ventilation and AC systems
UNI EN ISO 5167	Measurement of fluid flow by means of pressure differential devices
BSRIA BG 49/2024	Commissioning of HVAC systems – best-practice guide
BSRIA BG 2/2009	Commissioning Water Systems – application procedures
BSRIA BG 1/2009	Commissioning Air Systems – application procedures
CIBSE Commissioning Code A	Air distribution systems
CIBSE Commissioning Code W	Water distribution systems
CIBSE Commissioning Code R	Refrigerating systems
AABC National Standards 2016	Total system balance – measurement & verification (US reference for procedures and tolerances)
NEBB Procedural Standards 2019	Testing, Adjusting and Balancing of Environmental Systems
ASHRAE Std. 111-2008(R2017)	Measurement, Testing, Adjusting, and Balancing of Building HVAC Systems
ISO 5801	Fans – performance testing using standardised airways
ISO 10816-3 / ISO 20816-3	Mechanical vibration – evaluation by measurement on non-rotating parts
UNI EN 16430:2014	Fan coil units – testing and rating
UNI EN 14511	Air conditioners and heat pumps – rating
UNI EN 14825	Heat pumps – part load (SCOP/SEER)
UNI EN 15232	Energy performance – impact of controls
D.M. 37/2008	Building systems – installer qualifications and requirements
D.Lgs. 192/2005 e s.m.i.	Energy performance of buildings
D.Lgs. 81/2008	Consolidated Workplace Safety Act

1.5 SUBMITTALS

A. **TAB Agency qualification:** company profile; list of completed projects (minimum 5 comparable in the past 5 years); CVs of lead engineer and lead technician; AABC, NEBB, or BSRIA-equivalent certification.

B. **TAB Plan (draft):** submitted minimum 60 days before TAB start; covers procedures, sequence of operations, instruments to be used (with calibration certificates), point-by-point measurement list, and tolerances.

C. **Instrument calibration certificates:** for every instrument used during TAB — pitot tubes, anemometers, differential-pressure meters, flow meters, sound level meters, vibration meters, multimeters — calibration not older than 12 months, traceable to national metrology standards.

D. Pre-TAB checklist: signed checklist confirming each prerequisite (flushing complete, leak test passed, BMS controls operational, set-points configured) before TAB commences.

E. Final TAB Report: complete bound report with all readings, system schematics, balanced flow tables, deviation summary, and TAB Agency stamp.

1.6 QUALITY ASSURANCE

A. TAB Agency independence: the TAB Agency shall be an independent third party, with no commercial relationship to the mechanical installation contractor or to the equipment manufacturers used on the project. Engineer reserves the right to reject any proposed TAB Agency for conflict of interest.

B. Certification: AABC firm certification, NEBB firm certification, or BSRIA TAB certification scheme; alternative accreditation subject to Engineer approval.

C. Instrument accuracy minimum requirements:

1. Air velocity (hot-wire / vane anemometer): ±3% of reading
2. Air volume by pitot traverse: ±5% of reading
3. Differential pressure (water): ±0.25% full scale
4. Water flow at balancing valve (manufacturer's Kv curve): ±5%
5. Water flow by installed flow meter (verified): ±2%
6. Temperature: ±0.3 °C for water, ±0.5 °C for air
7. Sound level meter: Class 1 per IEC 61672
8. Vibration meter: per ISO 2954

1.7 COORDINATION

A. TAB commencement requires:

1. All HVAC equipment installed and energised
2. Hydronic systems flushed, pressure-tested, and dosed with inhibitor (Section 232113, 232500)
3. Ductwork leakage tested (Section 233113)
4. BMS DDC points checked out (Section 230900)
5. All filters installed in clean condition; no temporary commissioning filters
6. Building substantially complete with weather-tight envelope

B. Conflict resolution: any deviation from design that prevents balancing within tolerance shall be reported to the Engineer in writing within 24 hours; the TAB Agency does not modify design without written authorisation.

1.8 WARRANTY AND POST-OCCUPANCY

A. Re-balance during warranty: TAB Agency shall return to site once during the warranty period (recommended at 9 months post-handover) to verify that as-balanced flows are maintained and to perform any seasonal re-balance required.

B. Documentation retention: TAB report stored in project O&M manual and on BMS server as PDF.

PART 2 – INSTRUMENTS AND DOCUMENTATION

2.1 TAB INSTRUMENTS

A. Air-side instruments:

1. Pitot-tube and digital manometer for duct traverses (range 0–2500 Pa, 0.5% accuracy)
2. Hot-wire anemometer for low-velocity grilles (0.1–30 m/s)
3. Rotating-vane anemometer for diffuser and grille flow (≥ 80 mm head)
4. Flow hood (powered or unpowered) for terminal device measurement up to 1000 L/s
5. Tachometer (optical and contact) for fan speed verification

B. Water-side instruments:

1. Differential pressure meter with manifold and pressure-test-point fittings (range 0–500 kPa)
2. Portable ultrasonic flow meter (clamp-on, ±1%) as primary verification tool

3. Magnetic flow meter (insertion type) for permanent installations

C. Environmental / safety instruments:

1. Sound level meter Class 1 per IEC 61672 with octave-band analyser
2. Vibration meter per ISO 2954 / ISO 10816-3
3. Multimeter (true RMS, CAT III) for motor current verification
4. Thermal imaging camera (FLIR or equivalent) for trend/qualitative analysis

2.2 DOCUMENTATION FORMATS

A. TAB readings to be recorded on standardised reporting forms (NEBB / AABC standard sheets or equivalent BSRIA forms) for each system, including:

1. System identification (tag, location, design parameters)
2. Equipment performance data (fan/pump speed, current, power, suction/discharge pressure or static pressure)
3. Distribution data (flow at each branch, valve/damper setting, measured ΔP)
4. Terminal device data (flow, valve setting, room temperature observed)
5. Date of measurement, ambient conditions, instrument used, technician initials

B. Final TAB report in PDF and editable spreadsheet format; deposited with Engineer and uploaded to BMS server documentation folder.

PART 3 – EXECUTION

3.1 PRE-TAB VERIFICATION

A. Before commencing measurements, the TAB Agency shall verify and document the following on the Pre-TAB Checklist:

1. Mechanical installation complete per drawings
2. Ductwork leakage test report submitted and accepted (Section 233113)
3. Hydronic flushing and chemical dosing complete (Sections 232113, 232500)
4. All filters installed, clean, factory specification
5. Fan and pump rotation correct; safety devices operational
6. VFDs commissioned with motor nameplate data loaded (Section 262913)
7. BMS points checkout signed off (Section 230900) — sensors reading correctly, valve/damper actuators stroking through full range
8. All access doors operational; all dampers/valves accessible

B. Deficiencies identified during pre-TAB are reported to the General Contractor; TAB does not proceed until each item is closed.

3.2 AIR-SIDE BALANCING — PROCEDURE

A. Per UNI EN 12599 and BSRIA BG 1/2009:

1. 1. Set all volume control dampers to 100% open
2. 2. Start each AHU and operate at design speed; record initial fan total static pressure, current, and power
3. 3. Perform pitot traverse on each main duct branch using ≥ 24 readings per ISO 3966 / EN 12599 Annex A; calculate volumetric flow
4. 4. Identify the highest-resistance (index) branch; this becomes the design reference
5. 5. Apply proportional balancing: simultaneously close branch dampers to match each branch's ratio of design flow to total
6. 6. Fine-adjust to bring each terminal device within tolerance
7. 7. Adjust fan speed (VFD) to minimum required to satisfy index branch + 10% margin
8. 8. Re-verify all terminals within tolerance; lock damper settings; record

B. Tolerance for air-side balancing per EN 12599 Table 5 / Class B:

1. Total system airflow: −5% / +10% of design

2. Individual zone / terminal: ±10% of design
3. Outdoor air flow (critical): −0% / +10% of design (no less than design)

C. SFP verification: measure fan power and total airflow at final balanced state; calculate SFP; compare to design SFP and Reg. (UE) 1253/2014 minima; report any exceedance.

3.3 WATER-SIDE BALANCING — PROCEDURE

A. Per BSRIA BG 2/2009 and CIBSE Commissioning Code W:

1. 1. Verify pump operating point: measure suction and discharge pressure, calculate developed head, compare to pump curve
2. 2. Verify total system flow by ultrasonic flow meter at pump discharge or by installed flow meter
3. 3. Set all manual balancing valves wide open (or PICVs to maximum preset)
4. 4. Identify the most-hydraulically-remote (index) terminal; this becomes the reference
5. 5. Measure flow at each terminal using ΔP across balancing valve and the manufacturer's Kv chart (or PICV setting verification)
6. 6. Proportionally balance: close branch valves to match design ratios; lock memory stops
7. 7. Adjust VFD set-point (proportional pressure or constant pressure) to minimum required to satisfy index terminal + 10% margin
8. 8. Verify final flows at each terminal; record measured flow, valve opening, ΔP

B. Tolerance for water-side balancing per BSRIA BG 2/2009:

1. Total system flow: ±10% of design
2. Branch and terminal flow: ±10% of design (Class A) or ±15% (Class B) per project category

C. PICV verification: where pressure-independent control valves are installed, verify preset against the design flow chart; measure actual flow at minimum and maximum ΔP across the PICV body to confirm flow independence.

3.4 COIL DUTY VERIFICATION (SAMPLE BASIS)

A. On minimum 10% of installed coils (selected by Engineer to include all coil types), verify duty:

1. Measure air ΔT across coil (supply and return air temperatures)
2. Measure air volume by flow hood or duct traverse
3. Measure water ΔT across coil (supply and return water temperatures)
4. Measure water flow by ultrasonic flow meter
5. Calculate sensible and latent (cooling) or sensible (heating) duty from each side
6. Compare air-side and water-side duty calculations (energy balance check)
7. Compare to scheduled duty; deviation > 10% triggers further investigation

3.5 ACOUSTIC AND VIBRATION VERIFICATION

A. Sound level measurement at representative occupied positions: with HVAC at full and part-load operation; A-weighted LpA in dB(A) and unweighted octave-band SPL; compared to project NR or NC targets.

B. Outdoor heat-pump LpA at 7 m verification per Section 238143 Article 3.3.

C. Vibration measurement at each pump and fan bearing housing per ISO 10816-3 / ISO 20816-3; maximum 2.8 mm/s RMS for Class II (HVAC) machinery in 'good' band; record three orthogonal axes.

3.6 BMS POINT VERIFICATION (PARALLEL CHECK)

A. For each measurement made by the TAB Agency at a location where the BMS also has a sensor, compare TAB instrument reading against BMS reading; flag deviations > 2× sensor accuracy class for re-calibration by the controls contractor (Section 230900).

B. Verify alarm setpoints with BMS commissioned values: high/low temperature, high/low pressure, filter Δp, flow no-flow.

3.7 TAB REPORT

A. Submit final TAB report within 15 working days of completion; report shall include:

1. Executive summary: systems balanced, tolerance achieved, outstanding issues
2. Equipment data sheets: each pump, fan, coil, AHU as-balanced
3. Distribution tables: each balanced flow with valve/damper setting and reference ΔP
4. Terminal device tables: each grille, diffuser, FCU, and terminal unit
5. SFP and SPP calculations
6. Acoustic and vibration measurements
7. Identified deviations, mitigations, and any items not yet within tolerance with proposed plan to close
8. Instrument calibration certificates appendix
9. Signed and stamped by TAB Agency Project Manager

B. Engineer review and acceptance of the TAB Report is a precondition for Substantial Completion of HVAC works.

3.8 ACCEPTANCE TESTING (WITH ENGINEER WITNESS)

A. After TAB Report acceptance, conduct witnessed acceptance test:

1. Engineer selects minimum 10% of balanced terminals at random
2. TAB Agency re-measures in Engineer's presence
3. All sampled readings shall fall within previously-reported values ±5% of design
4. Any sampled point failing acceptance triggers full re-verification of the affected system at TAB Agency's cost

3.9 SEASONAL RE-BALANCE

A. Where TAB is completed outside the operating season of a given mode (e.g., heating-mode TAB conducted in summer), schedule a seasonal re-balance at the appropriate time of year; coordinated with Owner's facility manager and Engineer.

B. 9-month return visit during warranty period to verify maintained balance and address any seasonal observation; document any field adjustments in a TAB Addendum filed with the O&M manual.

END OF SECTION 230593

SECTION 230716
HVAC THERMAL INSULATION

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 232113 – Hydronic Piping
2. Section 233113 – Metal Ducts
3. Section 237300 – Air Handling Units
4. Section 232123 – Hydronic Pumps
5. Section 336316 – Pre-Insulated Underground Piping Systems

1.2 SUMMARY

A. Scope: Furnish and install thermal insulation on all HVAC piping, ductwork, and equipment as shown on drawings and specified herein.

B. Included applications:

1. Hydronic piping – heating, chilled water, condenser water, domestic hot water
2. Refrigerant suction and liquid lines (where not factory-insulated)
3. Ductwork – supply, return, and exhaust ducts in unconditioned spaces
4. Air handling unit casings and plenums
5. Equipment – pump casings, valve bodies, expansion vessels (where noted)

C. Design conditions: ambient temperature range –10°C to +40°C; pipe operating temperatures –15°C to +120°C.

1.3 DEFINITIONS

A. Lambda (λ): thermal conductivity [W/(m·K)] of insulation material at declared mean temperature.

B. Mu (μ): water vapour resistance factor; higher μ = better vapour barrier.

C. Reaction to fire class: EN 13501-1 classification (Euroclass A1, A2, B, C, D, E, F); minimum class B-s2,d0 required for all HVAC insulation exposed inside buildings.

D. Cladding: outer protective jacket over insulation; aluminium sheet, PVC, GRP, or self-adhesive aluminium foil laminate.

E. Condensation control thickness: minimum insulation thickness preventing surface condensation; governs cold-pipe insulation design.

1.4 APPLICABLE STANDARDS

Key Applicable Standards	
EN ISO 12241	Thermal insulation for building equipment and industrial installations – calculation rules
EN ISO 10456	Building materials and products – thermal performance
EN 13162	Thermal insulation products – factory made mineral wool (MW) products
EN 13163	Thermal insulation products – factory made expanded polystyrene (EPS)
EN 13165	Thermal insulation products – factory made polyurethane foam (PUR/PIR)
EN 13166	Thermal insulation products – factory made phenolic foam (PF)
EN 13167	Thermal insulation products – factory made cellular glass (CG)
EN 14303	Thermal insulation – flexible foam rubber products (FEF)
EN 15499	Thermal insulation – elastomeric foam rubber products

EN 13501-1	Fire classification of construction products – reaction to fire
EN ISO 9229	Thermal insulation – vocabulary
D.Lgs. 311/2006	Amendments to D.Lgs. 192/2005 – energy efficiency in buildings
D.P.R. 59/2009	Energy performance of buildings – implementing regulation
UNI 10847	Thermal insulation for buildings – single layer and multilayer systems on flat roofs
D.M. 37/2008	Building systems – installer qualifications and requirements
D.Lgs. 192/2005 e s.m.i.	Energy performance of buildings
D.Lgs. 81/2008	Consolidated Workplace Safety Act

1.5 SUBMITTALS

A. Product Data: manufacturer's technical data sheets for each insulation type; thermal conductivity (λ) vs. temperature curves, reaction-to-fire classification, vapour resistance (μ).

B. Fire certificates: EN 13501-1 test reports; certificates valid and issued by accredited laboratory.

C. Insulation schedule: tabulated schedule showing pipe or duct service, operating temperature, insulation type, thickness, and cladding for all systems.

D. Thermal calculations: condensation risk calculations per EN ISO 12241 for all cold-pipe applications; submitted prior to purchase.

1.6 QUALITY ASSURANCE

A. All insulation materials exposed within occupied or accessible spaces: minimum Euroclass **B-s2,d0** per EN 13501-1.

B. Thermal conductivity values used in thickness calculations must be certified by manufacturer and tested per EN 12667 or EN 12939.

C. Cold-pipe insulation must prevent surface condensation under design conditions (indoor RH ≤ 70%, ambient 30°C).

D. D.M. 37/2008: insulation of HVAC piping is part of the plant installation; the licensed installer (impresa abilitata per D.M. 37/2008 lett. c) shall certify compliance.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Deliver insulation in original sealed packaging clearly marked with product name, lambda value, and fire class.

B. Store in dry, covered location; protect from moisture, direct sunlight, and physical damage.

C. Do not compress pre-formed pipe sections during storage.

1.8 WARRANTY

A. All insulation materials and installation: **1 year** from Substantial Completion.

B. Pre-insulated pipe systems (Section 336316) warranted separately.

PART 2 – PRODUCTS

2.1 GENERAL REQUIREMENTS

A. Select insulation type based on operating temperature, fire classification requirement, exposure (indoor/outdoor), and vapour control need.

B. All adhesives, sealants, and tapes shall be **compatible** with the base insulation material and rated for the service temperature.

C. No insulation containing HCFC or HFC blowing agents shall be used.

2.2 FLEXIBLE ELASTOMERIC FOAM (FEF) INSULATION

A. Application: chilled water piping, refrigerant lines, cold-water pipes, condensate drains; wherever vapour diffusion control is critical.

B. Standard: EN 14303 and EN 15499.

C. Material: closed-cell nitrile-rubber or EPDM foam; λ ≤ 0.040 W/(m·K) at 0°C; μ ≥ 10,000.

D. Fire class: Euroclass **B-s3,d0** minimum; B-s2,d0 preferred and required in escape routes and plant rooms.

E. Form: pre-formed pipe sections (slit lengthwise) for pipe insulation; sheets/rolls for flat surfaces and ductwork.

F. Joining: all longitudinal seams and butt joints sealed with manufacturer's contact adhesive; no gaps, voids, or bridged seams.

G. Thickness – chilled water piping: minimum per condensation calculation; typical values:

1. DN15–DN25: 25 mm
2. DN32–DN65: 32 mm
3. DN80–DN150: 40 mm
4. DN > 150: 50 mm or per thermal calculation

H. Cladding outdoors: aluminium foil facing (factory) or GRP cloth and vapour-barrier paint; FEF not left exposed to UV outdoors without protection.

2.3 MINERAL WOOL (MW) INSULATION

A. Application: heating piping (>60°C), AHU casings, ductwork in fire-rated shafts; where non-combustibility (A1/A2) is required.

B. Standard: EN 13162.

C. Material: glass wool or rock wool; λ ≤ 0.040 W/(m·K) at 50°C mean temperature; fire class **A1** (non-combustible).

D. Form: pre-formed pipe sections with integrated foil facing (glass wool) or jacketed rock wool sections.

E. Jacket: aluminium self-adhesive foil tape or aluminium sheet cladding.

F. Thickness – heating pipes (80–120°C):

1. DN15–DN25: 40 mm
2. DN32–DN65: 50 mm
3. DN80–DN150: 60 mm
4. DN > 150: 80 mm or per thermal calculation

G. Vapour barrier: not required for hot-pipe service; foil facing for appearance and mechanical protection only.

H. Finishing for exposed surfaces: aluminium sheet cladding (0.6 mm minimum); stainless steel banding at 400 mm centres.

2.4 POLYURETHANE / POLYISOCYANURATE (PUR/PIR) FOAM INSULATION

A. Application: complex geometries, flat surfaces, equipment insulation; where thin profile and low λ are needed.

B. Standard: EN 13165.

C. Material: rigid closed-cell PUR/PIR foam; λ ≤ 0.028 W/(m·K) at 10°C; fire class **B-s2,d0** minimum.

D. Form: factory-made pipe sections or boards with factory facings; spray-applied PUR only where noted on drawings.

E. Finishing: aluminium foil facing or aluminium sheet cladding; no exposed foam permitted in finished spaces.

2.5 CELLULAR GLASS (CG) INSULATION

A. Application: pipes in contact with soil or embedded in concrete (pre-insulated systems excluded); cryogenic service.

B. Standard: EN 13167.

C. Material: closed-cell glass foam; λ ≈ 0.038 W/(m·K) at 10°C; **completely vapour-proof** (μ = ∞); fire class **A1**.

D. Joining: bitumen or hot-applied adhesive; joints staggered; sealed with bituminous mastic.

2.6 DUCTWORK INSULATION

A. Supply air ducts in unconditioned spaces: 50 mm mineral wool blanket, foil-faced, secured with pins and speed-clips at 300 mm centres; seams sealed with aluminium tape.

B. Return and exhaust ducts (unconditioned): 25 mm mineral wool blanket, foil-faced.

C. Chilled-water supply ducts / supply air in humid zones: 25 mm FEF sheet, all seams glued; vapour barrier maintained.

D. Fire-rated ducts: ductwork in fire shafts shall have non-combustible (A1 class) insulation; verify fire resistance period required with fire engineer.

E. Duct casing – external: apply insulation after leak test; use self-adhesive FEF or MW blanket with aluminium facing; cladding with 0.6 mm aluminium sheet in mechanical rooms.

2.7 VALVE AND FITTING INSULATION

A. Insulate valve bodies, flanges, and fittings with removable / reusable insulation jackets (soft fabric-covered PUR) on valves DN ≥ 50.

B. Smaller fittings (elbows, tees, DN < 50): preformed FEF or PUR mitre-cut sections; glued and taped; no gaps.

C. Leave valve stems, actuators, and gauge connections accessible; do not insulate over handwheels or actuators.

D. Safety valve bodies and discharge pipes: not insulated; leave bare for visual inspection.

2.8 CLADDING AND FINISHES

A. Aluminium sheet cladding: 0.6 mm thickness; smooth or corrugated; secured with stainless steel banding.

B. Self-adhesive aluminium foil tape: minimum 50 mm wide; for sealing FEF and MW joints in plant rooms.

C. PVC cladding: permitted in dry, unexposed locations only; not for outdoor or high-humidity applications.

D. Outdoor service: use aluminium cladding or GRP jacketing; seal all seams with silicone sealant to prevent water ingress.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Install insulation only after piping and ductwork have been pressure-tested, cleaned, and accepted.

B. Pipe surface must be clean, dry, and free of corrosion before insulation is applied.

C. Ambient temperature during application: FEF adhesive above +10°C; MW not below –5°C.

3.2 INSTALLATION – PIPING INSULATION

A. Install pre-formed pipe sections with longitudinal seam on the upper quadrant or on opposite sides for symmetry; glue all seams continuously.

B. Butt joints: staggered 100 mm minimum from pipe fittings and hangers; sealed with adhesive and tape.

C. Hangers: use over-insulation hangers or pre-insulated support shields; do not compress insulation at support points.

D. Penetrations: seal annular space between insulation and sleeve with mineral wool packing (hot pipes) or FEF with vapour-barrier sealant (cold pipes).

E. Flanges: insulate after pressure test; removable boxes or split shells acceptable at flanges requiring periodic maintenance access.

F. Continuity: insulation shall be continuous through hangers, sleeves, and penetrations; no thermal bridges.

3.3 VAPOUR BARRIER INTEGRITY (COLD PIPE)

A. All cold-pipe insulation is a **vapour barrier system**: any puncture, gap, or bridged seam will cause condensation and insulation failure.

B. **Pipe hangers:** use hanger inserts (same material, same or greater density) glued into the insulation; no metal-to-pipe contact through insulation.

C. **End caps:** install manufacturer-approved end caps at valves, flanges, and equipment connections; no raw foam exposed.

D. After insulation complete: inspect under raking light for surface imperfections; repair any visible defects before cladding.

3.4 DUCTWORK INSULATION

A. Install insulation after ductwork leak test (Section 233113); start at AHU connections and work toward terminals.

B. Secure blanket insulation with mechanical pins at maximum 300 mm grid; apply before adhesive sets.

C. Seal all seams, corners, and overlaps with 75 mm aluminium tape; apply with roller for full adhesion.

D. Finish exposed ductwork insulation in plant rooms with aluminium sheet cladding; snap-lock or S-joint seams.

3.5 FIELD QUALITY CONTROL

A. **Thickness verification:** sample-check insulation thickness at 10% of all pipe segments; measure with calibrated pin probe; record results.

B. **Vapour barrier inspection:** inspect all cold-pipe insulation seams with damp-test kit or visual inspection in humid conditions after 48 hours; no condensation on surface permitted.

C. **Thermal imaging (optional):** infrared survey of insulated piping at design conditions to verify no thermal bridges.

D. Submit field quality control report listing checked locations, measured thicknesses, and any deficiencies corrected.

3.6 PROTECTION AND LABELING

A. Where insulated pipes are subject to mechanical damage (floor level, accessible areas): protect with 1.5 mm aluminium sheet or GRP jacket.

B. Label insulated pipes per Section 232113 colour coding; apply labels over outer cladding, not directly on insulation.

END OF SECTION 230716

SECTION 232300
REFRIGERANT PIPING

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 238143 – Air-Source Heat Pumps (refrigerant equipment served by this piping)
2. Section 230716 – HVAC Thermal Insulation (insulation of suction and liquid lines)
3. Section 230529 – Hangers and Supports for HVAC Piping and Equipment
4. Section 230553 – Identification for HVAC Systems (refrigerant pipe labelling)
5. Section 230900 – Instrumentation and Controls for HVAC (refrigerant leak detection)
6. Section 260518 – Low-Voltage Electrical Power Conductors and Cables (interconnect cables routed with refrigerant pipework)

1.2 SUMMARY

A. Scope: Furnish and install all field-erected refrigerant piping connecting split-type heat pumps and air-conditioning systems, including suction, discharge (hot gas), liquid, and equalisation lines, insulation, supports, and refrigerant charge.

B. Applies to:

1. Split-type air-source heat pumps (Section 238143) where outdoor and indoor sections are interconnected by field-erected refrigerant pipework
2. VRF/VRV systems where field-installed refrigerant headers are used
3. Any refrigerant circuit not factory pre-charged and pre-piped (monoblock units are excluded — covered entirely by Section 238143)

C. Excluded: factory-sealed refrigerant circuits within monoblock units (no field refrigerant work).

1.3 DEFINITIONS

A. Refrigerant: working fluid that absorbs heat at the evaporator and rejects heat at the condenser; classified by safety group (A1, A2, A2L, A3, B1, B2, B2L, B3) per EN 378-1.

B. A1: non-toxic, non-flammable (e.g., R410A, R134a). Higher-GWP A1 refrigerants are subject to phase-down under Reg. (UE) 2024/573 on a date-and-equipment-category schedule; R410A remains legal and acceptable on this project for circuits with per-circuit charge > 6.5 kg per the project refrigerant policy (Article 1.6).

C. A2L: non-toxic, mildly flammable, low burning velocity ≤ 10 cm/s (e.g., R32, R454B, R1234yf) — preferred class for new HVAC heat pumps.

D. A3: non-toxic, highly flammable (e.g., R290 propane) — requires special installation precautions per EN 378-3.

E. GWP (Global Warming Potential): CO_2-equivalent climate-warming effect per kg of refrigerant over 100 years.

F. MWP / PS (Maximum Working Pressure / Maximum Allowable Pressure): the refrigerant-circuit pressure rating used as the reference for strength and tightness tests per EN 378-2 and EN 14276-2; PS is the term defined by PED 2014/68/UE, MWP is the equivalent term used in manufacturer catalogues; both refer to the same design pressure limit of the circuit.

G. Brazing: joining process using a filler metal melted above 450 °C without melting the base metals; standard joint type for refrigerant copper pipework.

H. Pressure test (strength): pressurisation to 1.43 × MWP (or higher per PED) to verify mechanical strength.

I. Tightness test (leak): pressurisation to test pressure with traceable leak detection (electronic detector, bubble method, or vacuum decay).

J. Triple evacuation: evacuation to deep vacuum (≤ 500 µmHg), break with dry nitrogen, repeat ≥ 3 times to remove non-condensables and moisture.

1.4 APPLICABLE STANDARDS

Key Applicable Standards	
EN 378-1	Refrigerating systems and heat pumps – safety and environmental requirements – Part 1: basic requirements, definitions, classification, selection criteria
EN 378-2	Refrigerating systems and heat pumps – Part 2: design, construction, testing, marking and documentation
EN 378-3	Refrigerating systems and heat pumps – Part 3: installation site and personal protection
EN 378-4	Refrigerating systems and heat pumps – Part 4: operation, maintenance, repair and recovery
EN 12735-1	Copper and copper alloys – seamless round copper tubes for air conditioning and refrigeration – Part 1: tubes for piping systems
EN 12735-2	Copper and copper alloys – Part 2: tubes for equipment
EN 14276-1	Pressure equipment for refrigerating systems and heat pumps – Part 1: vessels (PED interface)
EN 14276-2	Pressure equipment for refrigerating systems and heat pumps – Part 2: piping
EN ISO 14903	Refrigerating systems and heat pumps – qualification of tightness of components and joints
EN 1044	Brazing – filler metals (silver-phosphorus and silver-copper-phosphorus)
EN ISO 9606-1	Qualification testing of welders – fusion welding – Part 1: steels
EN ISO 13585	Brazing – qualification testing of brazers and brazing operators
Reg. (UE) 517/2014	F-Gas regulation (in force; partially superseded by Reg. (UE) 2024/573)
Reg. (UE) 2024/573	New F-Gas regulation – HFC phase-down and stricter GWP limits (in force from 11 March 2024)
D.P.R. 146/2018	Italian implementation of F-Gas regulation (replaces D.P.R. 43/2012)
Dir. 2014/68/UE (PED)	Pressure Equipment Directive – refrigerant circuits classified by group 2 fluid, fluid category, and volume
D.M. 37/2008	Building systems – installer qualifications and requirements
D.Lgs. 192/2005 e s.m.i.	Energy performance of buildings
D.Lgs. 81/2008	Consolidated Workplace Safety Act

1.5 SUBMITTALS

A. **Refrigerant piping layout drawings:** routes, lengths, vertical lifts, oil trap and inverted trap locations, expansion provisions, and accessory components; coordinated with structural and architectural drawings.

B. **Pipe sizing calculations:** per equipment manufacturer's table for the chosen refrigerant, equivalent length, and capacity; show pressure drop on suction (target ≤ 1 K saturated-temperature equivalent) and liquid (≤ 0.5 K).

C. **Equipment manufacturer's compatibility statement:** confirming the proposed piping arrangement complies with the manufacturer's published limits (length, lift, oil-trap intervals, branch fitting geometry).

D. **Refrigerant safety analysis per EN 378-1:** charge per zone-volume calculation; occupancy classification; safety class verification; ventilation requirements where required by EN 378-3.

E. **Brazer / installer qualification:** EN ISO 13585 brazer qualifications; F-Gas certification (categoria I, II, III, or IV per D.P.R. 146/2018) for each technician handling refrigerant.

F. **PED documentation:** classification of the refrigerant circuit per PED 2014/68/UE Annex II; design and manufacture documentation if circuit falls in Category I or higher.

G. **Strength and tightness test reports:** documented per Article 3.5.

H. **Refrigerant charging log:** type, GWP, mass charged, mass of nitrogen used for purging, F-Gas technician certificate number, date.

1.6 QUALITY ASSURANCE

A. **Brazers:** qualified per EN ISO 13585 for the brazing process (manual oxy-fuel, induction, or orbital), filler material group, and base material; qualification certificates not older than 3 years.

B. **F-Gas certification:** every technician handling refrigerant shall hold valid F-Gas certification per Reg. (UE) 517/2014 and D.P.R. 146/2018; certification category appropriate to the task and refrigerant charge size; certificate number recorded in installation logbook.

C. **PROJECT REFRIGERANT POLICY — selection by per-circuit charge:** the choice between low-GWP A2L refrigerants and R410A on this project is governed by a **6.5 kg per-circuit charge threshold** related to Italian fire-prevention (CPI) obligations and EN 378-3 additional safety measures for flammable refrigerants:

1. **Per-circuit charge ≤ 6.5 kg → GWP ≤ 750 mandatory (A2L preferred):** use R32 (GWP 675), R454B (GWP 466), R1234yf, or equivalent A2L refrigerant. At small charges the A2L flammable classification does not trigger fire-prevention assessment beyond the EN 378-1 charge-per-volume check, so the GWP benefit is taken without regulatory penalty. **R410A is NOT acceptable** at this charge level where an A2L alternative is technically available.
2. **Per-circuit charge > 6.5 kg → R410A acceptable (and project-preferred for large systems):** above the practical 6.5 kg threshold, A2L refrigerants trigger Italian fire-prevention (CPI) obligations, EN 378-3 additional safety measures (mechanical ventilation of plant rooms, fixed A2L leak detection, restricted-access zone, ATEX-related considerations) whose regulatory and capital-cost burden outweighs the GWP saving on a project-economics basis. R410A (A1 non-flammable, GWP 2088) is therefore the project-preferred refrigerant for large VRF banks, large heat-pump banks, and larger DX CRAC units where charge per circuit exceeds 6.5 kg. R410A remains legally available under Reg. (UE) 2024/573 phase-down for the equipment categories specified on this project, with the GWP < 750 mandate applying to specific monoblock/small-split categories at later dates.
3. **Submittal requirement:** the Contractor shall submit, with the equipment shop drawings, the per-circuit refrigerant charge calculation (factory pre-charge + additional charge for the field-erected pipework per manufacturer's formula) confirming compliance with the refrigerant selection specified on the drawings and in this Section.
4. **R290 (propane, A3):** only where specifically selected for sustainability or low-temperature application; follow EN 378-3 strict installation requirements (mechanical ventilation, explosion-proof equipment in classified zone, A3-certified technicians) regardless of charge size; not a default option on this project.

D. **Safety group considerations:**

1. **A2L refrigerants (R32, R454B, R1234yf):** verify charge per zone-volume against EN 378-1 limits; provide leak detection where charge exceeds practical limit in any conditioned space
2. **A3 refrigerants (R290):** stricter charge limits per EN 378-1 Annex C; mechanical ventilation of plant enclosure required; warning signage per EN 378-3; only F-Gas-certified A3 technicians; no electrical equipment within hazardous zone

E. **PED classification:** refrigerant circuits with PS × V > 50 bar·L typically fall in Category I+ and require CE marking; verify and document.

F. **No-venting policy:** under no circumstance shall refrigerant be vented to atmosphere; all removed refrigerant shall be recovered to dedicated cylinder for disposal via authorised waste channel.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Deliver copper tubes with both ends factory-capped; remove caps only immediately before joint assembly.

B. Store copper tubes horizontally on level supports, off the ground, indoors or under cover; do not store outdoors uncovered.

C. Inspect every length before installation; reject any tube with internal contamination (oxidation, oil, moisture), surface scratches > 0.2 mm deep, or fitting deformation.

D. Refrigerant cylinders: store upright, secured against falling, ventilated area, away from heat sources and ignition sources (especially for A2L and A3); do not store above 50 °C.

1.8 WARRANTY

A. **Field-erected refrigerant piping system: 5 years** from Substantial Completion, including absence of refrigerant leakage.

B. **Refrigerant charge:** free top-up for normal leakage during warranty (defined as ≤ 5% of charge per year, measured at annual leak check); above this rate, leak investigation and rectification at installer's cost.

PART 2 – PRODUCTS

2.1 COPPER TUBE

A. **Standard:** EN 12735-1 (piping systems) — refrigeration-grade seamless copper tube; deoxidised, low residual oxygen content; internal surface clean and free of mill scale, oil, or moisture.

B. **Material:** Cu-DHP (CW024A); minimum tensile strength 220 MPa (R250 half-hard) or 290 MPa (R290 hard).

C. **Dimensions:** OD per equipment manufacturer's sizing; wall thickness per EN 12735-1 Table 2 / Series K or Series L, sized for refrigerant working pressure with safety factor per EN 14276-2.

D. **Form:**

1. Hard-drawn straight lengths (R290) for runs ≥ DN 12; preferred for visible/exposed sections
2. Annealed soft tube (R220) in coils ≤ DN 22; permitted only where bends and routing cannot use hard tube
3. Internally cleaned and capped at factory; CFC-/HCFC-free oil residue per EN 12735-1 Annex A

E. **Inspection at delivery:** end-cap intact; no visible contamination inside tube; manufacturer's batch identification on each length.

2.2 FITTINGS AND JOINTS

A. **Capillary brazed fittings:** wrought copper to EN 1254-1 or EN 12449; matching the connected tube series; clean internal surfaces; supplied end-capped.

B. **Brazing filler:** silver-phosphorus alloy per EN 1044, type CP105 (≥ 5% Ag, P 6%, balance Cu) for copper-to-copper joints; **silver-bearing alloy ≥ 30% Ag** (BAg-1 or equivalent) for copper-to-brass joints.

C. **Flux:** not required for copper-to-copper brazing with phosphorus-bearing filler; use only manufacturer-approved low-residue flux for copper-to-brass joints; remove flux residue with hot water after brazing.

D. **Mechanical fittings (limited use):**

1. Manufacturer's proprietary press-fit refrigeration fittings (e.g., RLS, Lokring or equivalent) — acceptable for refrigerant pressure rating and refrigerant type; submit type-approval documentation; Engineer approval required
2. Flared joints — permitted only at equipment terminations where manufacturer's instructions so specify; SAE 45° flare with brass nut; torque per equipment manufacturer's value
3. Threaded fittings — not permitted on refrigerant pressure-bearing joints

E. **Service valves and ports:** factory-fitted on outdoor and indoor sections; Schrader-type charging port; ball-type service valve with backseat for stem replacement.

F. Sight glass and moisture indicator: install on liquid line of each refrigerant circuit upstream of the EEV; moisture indicator with colour-change dot.

G. Filter drier: install on liquid line; solid-core type sized for circuit refrigerant mass; replaceable cartridge; isolation valves both sides for service.

2.3 INSULATION

A. Suction line: insulate with closed-cell elastomeric (FEF) foam per Section 230716; **continuous and vapour-tight** to prevent condensation and surface frost in cooling mode.

B. Liquid line: insulate only where required to prevent flash gas under high ambient (outdoor exposed runs, mechanical room with high ambient); minimum 13 mm FEF.

C. Discharge (hot-gas) line: insulate where personnel could come into contact (≥ 60 °C surface) and where heat loss is undesirable; minimum 19 mm FEF or mineral wool with vapour-tight cladding.

D. Insulation thickness — suction line:

1. Indoor concealed (ceiling void, conditioned space): 13 mm FEF minimum
2. Indoor exposed (plant room, humid): 19 mm FEF minimum
3. Outdoor exposed: 25 mm FEF with UV-resistant cladding (aluminium foil + GRP jacket or paint)

E. Joints: all longitudinal seams and butt joints sealed with manufacturer's contact adhesive; no gaps; no bridged seams (cold-bridge guarantee failure).

F. Suction/liquid pair: where suction and liquid lines run together, insulate separately — never inside a single foam jacket — to prevent heat exchange and flash gas.

2.4 SUPPORTS

A. Support and brace refrigerant piping per Section 230529; spacing per copper-pipe table (typically 1.5 m for DN ≤ 18 horizontal, 1.0 m vertical).

B. Insulated clamp / collar: mandatory at every support point on insulated refrigerant pipe — same requirement as for HVAC water piping (see Section 230529 Article 2.1).

C. Differential expansion provisions: for runs > 15 m, provide L-shape or Z-shape directional change to absorb thermal expansion; refrigerant temperatures span +60 °C (hot-gas discharge) to −15 °C (evaporator suction).

2.5 ACCESSORIES

A. Oil trap (P-trap): at base of every vertical riser carrying suction gas, and at maximum 6 m intervals on vertical lifts, sized per manufacturer's instructions; ensures return of compressor oil entrained in suction gas.

B. Inverted trap: at top of every vertical riser to prevent reverse oil flow during compressor off-cycles.

C. Service valves at indoor unit: suction and liquid service valves with brazed connection on system side, flared connection on equipment side, integrated Schrader access port.

D. High/low pressure switches: factory-fitted in heat-pump equipment per Section 238143; verify wiring during commissioning.

E. Refrigerant leak detector (A2L/A3 systems where required by EN 378-3): dedicated electrochemical or NDIR sensor with alarm to BMS; trip threshold per refrigerant LFL/4 (lower flammability limit / 4) or manufacturer's published value; tested per EN 14624.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Confirm the refrigerant piping layout matches equipment manufacturer's published limits — total length, vertical lift, branch arrangement, oil-trap intervals.

B. Verify all sleeves, openings, and supports are in place before commencing piping.

C. For A2L and A3 systems: verify the planned charge against EN 378-1 charge-per-room-volume limits for all occupied zones the pipework traverses; report exceedances before installation.

3.2 PIPE PREPARATION AND CUTTING

A. Cut copper tube square with a sharp tube cutter (no hacksaw — leaves debris); deburr internal edge with reamer; clean cut end with lint-free cloth.

B. Do not allow swarf, water, or foreign material to enter pipe; cap any open end of tube whenever not actively being worked.

C. **Bending:** use proprietary tube bender; minimum bending radius 4 × OD for hard tube; do not heat-bend; reject any tube showing kinks, ovalisation > 5%, or wall thinning.

3.3 BRAZING

A. **Brazer qualification:** verify EN ISO 13585 certification on file for each brazer; current within 3 years; matching process and material range.

B. **Nitrogen purge (mandatory) — to prevent internal scale (cupric oxide) formation:**

1. Connect oxygen-free dry nitrogen (OFN) cylinder to one end of the pipe section being brazed
2. Flow nitrogen continuously through pipe at low rate (1–3 L/min) during heating and brazing
3. Continue purge until joint cools below 200 °C
4. Internal scale (black oxide) is cause for rejection — circulating scale damages compressor and EEV; rejected pipe section to be cut out and re-brazed

C. **Brazing technique:** heat the joint uniformly (not the filler); apply filler at joint gap when copper reaches dull red colour; allow capillary action to draw filler fully; do not over-fill or over-heat (over-heating burns out phosphorus, embrittling joint).

D. **Joint inspection:** visual check for full circumferential fillet; no pinholes, blow-through, or cold joints; mark accepted joints with permanent ink for traceability.

E. **Joint identification:** maintain brazing log: joint number, brazer ID, date, filler material batch, inspection result.

3.4 INSTALLATION

A. Route piping per approved drawings; maintain manufacturer's required clearances and lengths.

B. **Slope (suction line):** minimum 1% (10 mm/m) toward compressor; ensures oil return.

C. **Oil traps:** install at the base of every vertical riser, at the top (inverted), and at intermediate spacings per manufacturer's instructions.

D. **Routing through walls and floors:** sleeve all penetrations; protect insulation from compression; fire-stop at fire-rated barriers per Section 078413.

E. **Electrical interlock cable:** route alongside refrigerant pipework in separate conduit; do not share conduit with refrigerant pipe.

F. **Insulation:** apply after pressure and tightness test; complete and vapour-tight before system fill.

3.5 STRENGTH TEST, TIGHTNESS TEST, EVACUATION, CHARGE

A. **Strength (pressure) test per EN 378-2:**

1. Test pressure: 1.43 × maximum allowable pressure (PS) of the high-pressure side, or per PED requirements, whichever higher
2. Test medium: oxygen-free dry nitrogen (OFN); helium permitted; never use oxygen, hydrogen, or compressed air
3. Duration: minimum 1 hour at full test pressure; no pressure drop permitted other than that explainable by ambient temperature change
4. Verify with calibrated gauge (Class 1.0 or better)

B. **Tightness (leak) test per EN ISO 14903:**

1. After strength test, reduce pressure to 90% of MWP
2. Check every brazed joint with electronic leak detector (sensitivity ≤ 5 g/year of refrigerant equivalent) or pressure-decay over 24 hours
3. Maximum acceptable leak rate per EN ISO 14903 Class A: ≤ 3 g/year
4. Repair any leak found; re-test until clean

C. **Triple evacuation:**

1. Vacuum to ≤ 500 μmHg (0.667 mbar) absolute — measured with calibrated thermistor or pirani vacuum gauge
2. Break vacuum with dry nitrogen to ~1 bar; hold ≥ 15 minutes
3. Repeat evacuation–break cycle minimum 3 times (final evacuation to ≤ 250 μmHg held ≥ 30 minutes without pressure rise > 100 μmHg)
4. Standing-vacuum test: after final evacuation, isolate vacuum pump; pressure rise ≤ 0.5 mbar in 30 minutes indicates dry, tight system

D. Refrigerant charging:

1. Charge by mass (scale) per equipment manufacturer's table — never by sight glass alone
2. Charge into liquid line (with compressor off) or as vapour into suction (with compressor running)
3. Verify superheat (suction) and subcooling (liquid) at full-load operation against manufacturer's target
4. Record: refrigerant type, GWP, mass charged, F-Gas technician name and certificate number, date, equipment serial number
5. Affix F-Gas charge label to outdoor unit per Reg. (UE) 517/2014 Article 12

3.6 COMMISSIONING

A. Start system per equipment manufacturer's commissioning checklist; record operating data: ambient, leaving water temperature, suction and discharge pressure, superheat, subcooling, current, power, COP.

B. Leak detection: re-check all field-brazed joints with electronic detector after first 24 hours of operation; record results.

C. Verify high-/low-pressure switch trip values match manufacturer specification.

D. Test refrigerant leak detector (where installed) by exposing sensor to simulant gas; verify alarm to BMS.

3.7 F-GAS LOGBOOK AND LABELLING

A. Establish F-Gas logbook for each refrigerant circuit per D.P.R. 146/2018; entries include:

1. Equipment identification (model, serial, location)
2. Refrigerant type, GWP, charge mass at commissioning
3. Charge in CO_2-equivalent tonnes (for determining leak-test schedule)
4. Initial leak check result; subsequent leak check dates and results
5. Any addition/recovery of refrigerant (date, mass, technician certificate)
6. End-of-life recovery records

B. Affix permanent label to outdoor unit per Reg. (UE) 517/2014 Article 12: refrigerant type, GWP, charge mass, CO_2-eq tonnes; in indelible ink; visible without dismantling.

END OF SECTION 232300

SECTION 233113
METAL DUCTS

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 237300 – Air Handling Units
2. Section 230716 – HVAC Thermal Insulation
3. Section 230900 – Instrumentation and Controls for HVAC
4. Section 134813 – Acoustic Equipment Enclosures

1.2 SUMMARY

A. Scope: Fabricate and install all low-pressure and medium-pressure ventilation and air conditioning ductwork, including supply, return, exhaust, and outdoor air ducts, complete with all fittings, supports, access doors, dampers, and accessories.

B. Duct types included:

1. Rectangular galvanised steel ductwork (low- and medium-pressure)
2. Circular (spiral-wound) galvanised steel ductwork
3. Flexible ductwork connections at AHU and terminal units
4. Stainless steel ductwork for exhaust systems with moisture/chemical content
5. Fire-rated ductwork in fire compartment penetrations

1.3 DEFINITIONS

A. Pressure class: classification per EN 15727 or SMACNA based on operating static pressure (Pa); typical HVAC classes: Low (< 500 Pa), Medium (500–1000 Pa), High (> 1000 Pa).

B. Leakage class: EN 15727 classification A, B, C, D (A = tightest); leakage expressed as $L \cdot s^{-1} \cdot m^{-2}$ at reference pressure.

C. Transverse joint: joint connecting two duct sections end-to-end; must resist longitudinal forces and limit air leakage.

D. Access opening: door or removable panel in duct allowing access for cleaning, inspection, or damper operation.

E. Fire damper: fusible-link or motorised damper installed at fire compartment penetrations; rated to EN 1366-2 for fire resistance period.

1.4 APPLICABLE STANDARDS

Key Applicable Standards	
EN 1505	Ventilation for buildings – sheet metal air ducts and fittings with rectangular cross-section
EN 1506	Ventilation for buildings – sheet metal air ducts and fittings with circular cross-section
EN 12237	Ventilation for buildings – ductwork – strength and leakage of circular sheet metal ducts
EN 1507	Ventilation for buildings – sheet metal air ducts with rectangular cross-section – requirements for strength and leakage
EN 13403	Ventilation for buildings – non-metallic ducts
EN 12599	Ventilation for buildings – test procedures and measurement methods to hand over installed ventilation and air conditioning systems

EN 13779	Ventilation for non-residential buildings – performance requirements for ventilation and room-conditioning systems
EN 15727	Ventilation for buildings – ducts and duct components – classification and determination of leakage characteristics
EN 13501-1	Fire classification of construction products and building elements – reaction to fire
UNI 10339	Air-handling systems – quality requirements and classification
EUROVENT 2/2	Classification of air leakage of duct systems
SMACNA HVAC Duct Construction Standards	Sheet Metal and Air Conditioning Contractors' National Association
D.M. 37/2008	Building systems – installer qualifications and requirements
D.Lgs. 192/2005 e s.m.i.	Energy performance of buildings
D.Lgs. 81/2008	Consolidated Workplace Safety Act

1.5 SUBMITTALS

A. Shop drawings: ductwork layout on floor plans and sections; show duct sizes, pressure class, insulation, access doors, dampers, hangers, and clearances from structure and other services.

B. Duct leakage test reports: submitted after installation and before insulation; signed by test technician.

C. Fire damper certificates: EN 1366-2 fire resistance certificates for all fire dampers; test reports from accredited laboratory.

D. Acoustic data: octave-band noise generation and attenuation data for all ductwork and fittings where noise calculations are required.

1.6 QUALITY ASSURANCE

A. Ductwork fabricated to SMACNA HVAC Duct Construction Standards or EN 1505/1506/12237/1507.

B. Leakage class minimum **Class B** per EN 15727 for all supply and return ducts; Class A for clean rooms and pharmaceutical applications.

C. All ductwork materials: minimum Euroclass **A2-s1,d0** (non-combustible) or **B-s2,d0**; check local fire authority requirements.

1.7 WARRANTY

A. Ductwork fabrication and installation: **1 year** from Substantial Completion.

PART 2 – PRODUCTS

2.1 GENERAL DUCT MATERIALS

A. Galvanised steel sheet: hot-dip galvanised per EN 10346; coating class Z275 (275 g/m² total both sides) minimum.

B. Sheet thickness (rectangular, low-pressure): per EN 1505 or SMACNA Table 1-1:

1. Longest side ≤ 750 mm: 0.6 mm
2. Longest side 751–1500 mm: 0.8 mm
3. Longest side 1501–2250 mm: 1.0 mm
4. Longest side > 2250 mm: 1.2 mm minimum

C. Spiral (circular) duct: continuously formed spiral lock-seam; 0.5–1.0 mm sheet thickness depending on diameter; per EN 1506.

D. Stainless steel ductwork: AISI 304 for kitchen exhaust and moisture-laden exhaust; AISI 316L where chemical resistance required; welded seams; 1.0 mm minimum thickness.

2.2 SEALING AND JOINTS

A. All transverse joints and longitudinal seams sealed with **mastic sealant** (non-hardening, elastomeric, temperature-rated for service) applied to both mating faces before assembly.

B. **Slip-on joints (low-pressure):** S-lock or Pittsburgh seam; sealed with mastic.

C. **Flanged joints (medium/high-pressure):** flanged frame (TDF or DUCTMATE equivalent); with EPDM gasket; sealed with mastic; bolted at maximum 150 mm centres.

D. **Spiral duct joints:** push-fit spigot with snap ring and mastic band seal; or flanged coupling.

E. **Sealant type:** water-based acrylic or solvent-based elastomeric; rated for –20°C to +120°C; UL-listed or EN-tested.

2.3 STIFFENERS AND CROSS-BREAKING

A. Rectangular ducts 450 mm longest side and above: diagonal cross-break or bead stiffeners at maximum 1220 mm centres per SMACNA.

B. Duct panels 1500 mm and above on longest side: external angle-iron frame stiffeners.

C. Stiffeners welded or riveted; no sharp edges exposed inside duct.

2.4 FITTINGS

A. **Elbows:** use turning vanes in rectangular elbows with aspect ratio > 4:1 or where radius < 1× duct width; turning vanes: single-thickness curved galvanised steel, spaced 50 mm centres.

B. **Transitions:** converging and diverging transitions at maximum included angle 15° on each side to limit pressure loss.

C. **Tees and branch take-offs:** conical tees preferred for circular ductwork; 45° entry saddle tees for rectangular; provide volume control damper at each branch take-off.

D. **Reducers:** minimum length 150 mm; symmetric where possible.

2.5 ACCESS DOORS AND OPENINGS

A. Provide access doors at the following locations:

1. Each fire damper (on both sides)
2. Each motorised volume control damper (on downstream side)
3. Each control sensor or transmitter
4. Each coil connection for inspection and cleaning
5. At maximum 3 m intervals on main supply and return ducts in accessible spaces

B. **Access door construction:** same-gauge sheet as duct; insulated where duct is insulated; hinged (larger than 300 mm); removable screw panel (smaller than 300 mm); sealed with continuous foam gasket.

C. **Fire-rated access doors:** at fire dampers in fire-rated ductwork; same fire-resistance period as the duct/damper assembly; certified per EN 1366-2.

2.6 DAMPERS

A. **Volume control dampers (VCD):** single-blade (round < 400 mm) or multi-blade opposed-blade (rectangular); galvanised steel; blade seals; maximum leakage per EN 1751.

B. **Balancing dampers:** manual quadrant-lock type; installed at each branch duct; 25% adjustment range minimum at design setting.

C. **Fire dampers:** fusible-link (FM type) or motorised (M type) per EN 15650; fire resistance EI90 (60-minute) or as noted; CE marked per EN 15650.

D. **Smoke dampers:** motorised with 24 VAC spring-return actuator; fail-safe closed; position feedback; connected to fire detection system.

E. **Motorised dampers (BMS-controlled):** 24 VAC actuator; 0–10 V position command; spring-return fail-safe open (exhaust) or closed (supply); position feedback signal.

2.7 DUCT HANGERS AND SUPPORTS

A. **Rectangular ducts:** trapeze support with threaded rod and angle iron; spacing per SMACNA Table 4-1.

1. Duct longest side ≤ 800 mm: support at 1200 mm centres maximum
2. Duct longest side > 800 mm: support at 900 mm centres maximum

B. Circular ducts: band hanger or bracket; 1500 mm centres maximum for ≤ DN400; 900 mm for DN > 400.

C. Threaded rod: minimum M8 galvanised; M10 for ducts longer than 1200 mm per hanger.

D. Seismic restraint: provide lateral and longitudinal bracing per SMACNA Seismic Restraint Manual where indicated or required by NTC 2018.

E. Anti-vibration hangers: spring or neoprene isolation at connections to AHU and in noise-sensitive areas.

2.8 FLEXIBLE DUCT CONNECTIONS

A. Application: connections between duct and AHU, FCU, or terminal unit fans; maximum 150 mm length.

B. Material: fire-rated flexible fabric (Euroclass B-s2,d0); not plain canvas; not corrugated aluminium foil.

C. Clamps: stainless steel worm-drive clamps; tightened uniformly.

D. Do not use flexible connections as elbows, offsets, or to compensate for misalignment.

PART 3 – EXECUTION

3.1 FABRICATION

A. Fabricate ductwork in workshop conditions; cut sheets with clean edges; remove all burrs and sharp edges.

B. Apply sealant to all joints and seams before assembly; verify seams are fully closed before sealant cures.

C. Label each duct section with section number and pressure class.

3.2 INSTALLATION

A. Install ductwork per approved shop drawings; maintain minimum clearances per local code (typically 50 mm from structure, 100 mm from electrical trunking).

B. Slope: pitch horizontal ducts 1:250 minimum toward drain points for moisture-laden exhaust and kitchen extract.

C. Supports: install hangers before connecting duct sections; do not hang duct from other services.

D. Penetrations: use collars or sleeves; seal annular gap with mineral wool and fire-rated sealant where penetrating fire-rated walls/floors.

E. Fire dampers: installed flush with fire wall/floor face; access door on both sides; fusible link accessible for replacement.

3.3 LEAKAGE TESTING

A. Test ductwork before insulation; isolate sections using blanking plates at AHU connections.

B. Method: EN 15727 pressure decay or flow measurement test; class B target leakage ≤ 0.027 × $L \cdot s^{-1} \cdot m^{-2}$ at 400 Pa.

C. Test each system zone separately; test pressure: 400 Pa for low-pressure systems, 1000 Pa for medium-pressure.

D. Seal any identified leaks with mastic; re-test failed sections; submit signed test record.

3.4 BALANCING

A. Set all volume control dampers to design airflow; measure and record flow at each branch and terminal.

B. Submit air balancing report per EN 12599 signed by testing agency.

C. Final balancing performed after AHU commissioning and all dampers are in operational positions.

END OF SECTION 233113

SECTION 238123
COMPUTER ROOM AIR CONDITIONERS (CRAC / CRAH)

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 232113 – Hydronic Piping (CHW circuit for CRAH units)
2. Section 232116 – Hydronic Specialties
3. Section 232123 – Hydronic Pumps
4. Section 232300 – Refrigerant Piping (DX CRAC split installations)
5. Section 232500 – HVAC Water Treatment (CHW and humidifier supply water)
6. Section 230900 – Instrumentation and Controls for HVAC (data-centre BMS integration)
7. Section 230593 – Testing, Adjusting, and Balancing for HVAC
8. Section 230553 – Identification for HVAC Systems
9. Section 221316 – Sanitary, Sewer, and HVAC Condensate Drainage Piping (ICC IPC reference)
10. Section 230716 – HVAC Thermal Insulation
11. Section 233113 – Metal Ducts (where ductwork connects CRAC to plenum)
12. Section 134813 – Acoustic Equipment Enclosures
13. Section 260518 / 260534 / 262913 – Electrical distribution
14. Section 238143 – Air-Source Heat Pumps (where dual-fluid/free-cooling chillers feed CRAH units)

1.2 SUMMARY

A. Scope: Furnish and install precision close-control air-conditioning units for server rooms, data centres, network rooms, MDF/IDF rooms, UPS rooms, and other IT/electronic-equipment spaces requiring tight temperature and humidity control with high reliability.

B. Unit types covered (selected per drawings):

1. **CRAC (Computer Room Air Conditioner) — DX (direct-expansion):** integral refrigerant circuit; remote air-cooled condenser; for small to medium server rooms
2. **CRAH (Computer Room Air Handler) — CHW (chilled water):** chilled-water cooling coil; no on-board refrigerant; for medium to large data centres connected to central chiller plant
3. **InRow / In-Row coolers:** row-mounted close-coupled units serving hot/cold aisle architecture
4. **Overhead / suspended units:** for ceiling-installation in small IT rooms where floor space is at premium
5. **Dual-coil / hybrid units:** DX + CHW combined for free-cooling integration

C. Configurations covered: downflow (under-floor air distribution), upflow (overhead supply), and room-flow (in-room mixing).

D. Key performance characteristics distinguishing CRAC from comfort AC:

1. **Sensible Heat Ratio (SHR) ≥ 0.9** — designed for nearly-all-sensible IT loads; minimal latent removal (which would inadvertently lower humidity)
2. **Continuous 24/7/365 operation** with N+1 or higher redundancy
3. **Tight humidity control** (typical 30–60% RH per ASHRAE TC 9.9 Class A1)
4. **High airflow per kW** (typical 150–250 L/s per kW vs ~50 L/s per kW for comfort AC)
5. **Programmable supply-air or return-air temperature control** with rapid response and PID loop tuning
6. **Multi-unit teamwork / lead-lag rotation** with seamless capacity transfer

1.3 DEFINITIONS

A. CRAC (Computer Room Air Conditioner): precision close-control AC with on-board refrigerant compressor; rejects heat to an external (typically rooftop) air-cooled condenser.

B. CRAH (Computer Room Air Handler): precision air handler with a chilled-water coil; no refrigerant on-board; chilled water supplied from a central chiller plant (typically via Section 232113 piping).

C. **SHR (Sensible Heat Ratio):** sensible cooling / total cooling; for CRAC/CRAH, target ≥ 0.9 (≥ 0.95 preferred) — IT load is nearly all sensible.
D. **ASHRAE TC 9.9 Class A1:** recommended environmental envelope 18–27 °C, 5.5 °C dew-point to 60% RH; design target for general data-centre cooling.
E. **ASHRAE TC 9.9 Class A1–A4:** allowable envelopes ranging from tight (A1) to wide (A4 — up to 45 °C inlet) reflecting IT equipment tolerance; modern equipment supports A2 or wider, allowing higher supply-air setpoints and increased free-cooling hours.
F. **Hot aisle / cold aisle:** server-rack arrangement separating IT equipment exhaust ('hot aisle') from IT equipment intake ('cold aisle') for thermodynamic efficiency.
G. **Containment (hot or cold aisle):** physical separation (curtains, doors, ceilings) of hot and cold aisles to prevent mixing — increases efficiency and allows higher supply-air temperatures.
H. **N+1 / N+2 / 2N redundancy:** N = number of units required to meet design load; +1 = one spare; 2N = full duplicate; per Uptime Institute Tier classification.
I. **Free cooling:** operating mode using outdoor air or chilled cooling tower water below threshold ambient to provide all or part of cooling without mechanical refrigeration; major data-centre energy lever.
J. **PUE (Power Usage Effectiveness):** total facility energy / IT equipment energy; the lower the better (1.0 is ideal); CRAC/CRAH efficiency directly impacts PUE.

1.4 APPLICABLE STANDARDS

Key Applicable Standards	
EN 14511-1/2/3/4	Air conditioners, liquid chilling packages and heat pumps – rating and performance
EN 14825	Heat pumps and air conditioners – testing at part load
UNI EN 16573	Energy performance of computer-room air conditioning units (CRAC) – test methods and rating (EU reference for CRAC)
EN 12102-1	Acoustics – sound power level of heat pumps and air conditioners
EN 378-1/2/3/4	Refrigerating systems and heat pumps – safety and environmental requirements
EN 14276-2	Pressure equipment for refrigerating systems – piping
EN ISO 16890	Air filters for general ventilation – classification (ePM)
EN 60529	Degrees of protection (IP rating)
EN 60204-1	Safety of machinery – electrical equipment of machines
ASHRAE 90.4-2022	Energy standard for data centers (mechanical load component / DCiE-equivalent metrics)
ASHRAE TC 9.9	Thermal Guidelines for Data Processing Environments – ASHRAE Classes A1, A2, A3, A4 envelope
ASHRAE Std. 127	Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners
EN 50600-2-3	Information technology – data centre facilities and infrastructures – environmental control
EN 50600-1	Information technology – data centre facilities – general concepts
Uptime Institute Tier I–IV	Data centre availability tier classification (referenced for redundancy criteria)

Reg. (UE) 517/2014 + Reg. (UE) 2024/573	F-Gas regulations applicable to DX CRAC units
D.P.R. 146/2018	Italian implementation of F-Gas regulation
D.M. 37/2008	Building systems – installer qualifications and requirements
D.Lgs. 192/2005 e s.m.i.	Energy performance of buildings
D.Lgs. 81/2008	Consolidated Workplace Safety Act
D.P.R. 380/2001	Consolidated Building Code
Dir. 2014/68/UE (PED)	Pressure equipment

1.5 SUBMITTALS

A. **Unit selection schedule:** unit tag, location, type (CRAC-DX / CRAH-CHW / InRow / Hybrid), nominal sensible cooling kW, total cooling kW, SHR at design conditions, EER/SEER, airflow (L/s), external static pressure (Pa), fan SFP, sound power LWA, electrical FLA, refrigerant type and charge (DX), CHW design flow (CHW).

B. **Capacity at design conditions:** manufacturer's certified performance at the design return-air condition (typically 27 °C dry-bulb, 50% RH) and at high-density data-centre return condition (32–35 °C dry-bulb) with associated SHR.

C. **Free-cooling performance:** for units with integrated free-cooling, performance curves showing transition points and partial-load efficiency at relevant ambient temperatures.

D. **Redundancy and lead-lag scheme:** description of unit teamwork mode (parallel duty/standby; cascade; lead-lag rotation); failover sequence; expected response time on unit failure.

E. **Acoustic data:** sound power LWA octave bands; sound pressure LpA in equipment room and at adjacent occupied spaces.

F. **BMS integration:** BACnet PICS (or Modbus map as legacy); object list / register list for unit status, alarms, setpoints, capacity demand, sub-component data (compressor stage, EEV opening, fan speed).

G. **Refrigerant safety (DX units) per EN 378-1:** GWP, charge per unit, leak-detection plan, room ventilation calculations.

H. **Vibration isolation and seismic anchorage:** detail per Section 230529; calculations stamped by structural engineer.

1.6 QUALITY ASSURANCE

A. **EN 16573 compliance:** CRAC/CRAH units shall be tested and rated per EN 16573 (EU CRAC reference standard) where applicable; manufacturer's test report submitted at procurement.

B. **EN 14511 + ASHRAE 127:** as concurrent rating references; EER/SEER reported per both.

C. **ASHRAE TC 9.9 envelope class:** unit selected to meet at least Class A1; preferred selection allowing Class A2 operation (higher supply-air setpoint) to maximise free-cooling hours and reduce PUE.

D. **EN 50600-2-3 compliance:** environmental control system performance for the data-centre availability class specified on drawings.

E. **Manufacturer qualification:** dedicated precision-cooling product line with minimum 10 years' market presence; spare-parts guarantee minimum 10 years from product purchase.

F. **Refrigerant (DX units) — selection by per-circuit charge threshold (see Section 232300 Article 1.6 for the project master policy):**

1. **Per-circuit charge ≤ 6.5 kg (small to medium CRAC, typically up to 30–40 kW DX):** GWP ≤ 750 mandatory — R32 preferred for compact units; R454B for medium units; R513A acceptable where manufacturer offers it.
2. **Per-circuit charge > 6.5 kg (large DX CRAC, multi-compressor units, typically > 40 kW DX): R410A acceptable and project-preferred** — large DX CRAC compressor circuits frequently exceed 6.5 kg refrigerant, at which point Italian fire-prevention (CPI) obligations and EN 378-3

measures for A2L refrigerants in IT-room environments (where occupied space is continuously present and where electrical-ignition sources from servers are abundant) significantly outweigh the GWP saving. R410A (A1 non-flammable) is the appropriate selection for large DX CRAC, with manufacturer reliability proven over decades on this duty.

3. **CRAH (chilled-water) units:** no on-board refrigerant; this threshold does not apply; chilled-water plant refrigerant policy governed separately by the central chiller specification or by Section 238143 if heat-pump chillers are used.
4. **Contractor shall submit** with shop drawings: per-DX-circuit refrigerant charge (factory pre-charge + field additional charge); confirmation of refrigerant selection compliance with the threshold above; EN 378-1 charge-per-IT-room-volume verification.

G. F-Gas compliance: D.P.R. 146/2018; logbook from commissioning.

1.7 WARRANTY

A. Complete CRAC/CRAH unit: **3 years** parts and labour from Substantial Completion.

B. Compressor (DX units): **5 years** from date of manufacture (compressor OEM warranty).

C. EC fans: **5 years**.

D. Refrigerant charge: free top-up for normal leakage (≤ 5% of charge per year measured at scheduled F-Gas leak check).

E. Spare-parts availability: manufacturer commits to supply spare parts for **minimum 10 years** post-installation.

PART 2 – PRODUCTS

2.1 GENERAL UNIT CONSTRUCTION

A. Casing: double-skin panel; outer skin pre-coated galvanised steel; inner skin galvanised steel; mineral-wool or PUR insulation infill; thermal break frame; T2/TB2 class per EN 1886.

B. Panel finish: RAL 7035 (light grey) standard; alternative manufacturer colour where coordinated with IT-room finishes.

C. Doors and access: front-access doors for filter, fan, and electrical panel; full-height hinged doors with locking handles; LED interior light activated by door switch.

D. Frame: structural galvanised steel; designed for floor or roof mounting; lifting lugs.

E. Footprint and clearances: unit dimensions to fit data-centre rack pitch (typical 1.8/2.4 m wide, 600/900 mm deep); manufacturer's minimum service clearances respected on installation drawings.

F. Drain pan: stainless steel AISI 304 (preferred for data-centre cleanliness) or ABS; sloped to outlet; condensate sensor and high-water alarm.

2.2 FANS

A. Fan type: EC (electronically commutated) plug fans; backward-curved aerofoil impeller; direct-drive; permanent-magnet motor; integrated controller.

B. Multiple fans: unit shall include multiple smaller EC fans in parallel (typical 4–8 fans) rather than a single large fan; provides:

1. Inherent N+1 fan redundancy within each unit
2. Continuous capacity modulation 20–100% via speed control
3. Lower noise levels at part load
4. Reduced bearing wear (lower individual fan speeds)

C. External static pressure: minimum 150 Pa for downflow units serving raised-floor plenum; minimum 80 Pa for upflow units; consult equipment schedule for specific values.

D. Fan failure: any single fan failure shall not reduce total unit airflow below 80% of design; fan fault alarm to BMS via BACnet/IP.

E. Acoustic: target LpA ≤ 60 dB(A) at 1 m in front of unit at design speed; ≤ 65 dB(A) at maximum speed.

2.3 COOLING — DX (DIRECT EXPANSION) — CRAC UNITS

A. **Compressor:** inverter-driven scroll; minimum 25% capacity turndown; permanent-magnet BLDC motor; vibration isolation mounts.

B. **Multi-compressor option:** two-circuit redundancy preferred for ≥ 30 kW units; independent refrigerant circuits with separate compressors and EEVs; failure of one circuit maintains 50% capacity.

C. **Refrigerant:** selection follows the project per-circuit charge policy (Article 1.6 of this Section and Section 232300 Article 1.6):

   1. Per-circuit charge ≤ 6.5 kg → GWP ≤ 750 (R32 preferred; R454B; R513A) — small/medium CRAC compressor circuits
   2. Per-circuit charge > 6.5 kg → R410A acceptable and project-preferred — large DX CRAC, multi-compressor large units, where the 6.5 kg fire-prevention (CPI) threshold for A2L flammable refrigerants is exceeded
   3. Charge labelled per Reg. (UE) 517/2014 (refrigerant type, GWP, mass, CO_2-eq tonnes)

D. **EEV (Electronic Expansion Valve):** stepper-motor type per circuit; BMS-readable position.

E. **Remote air-cooled condenser:** rooftop or external-grade mount; EC variable-speed condenser fans for head pressure control and low-ambient operation; minimum operating ambient −20 °C; coastal/aggressive site = epoxy-coated coil + stainless casing.

F. **Refrigerant piping:** field-erected per **Section 232300**; pre-charge in compressor section; additional charge for field pipework as required; F-Gas certified technician charge documentation.

2.4 COOLING — CHW (CHILLED WATER) — CRAH UNITS

A. **CHW coil:** copper tubes, aluminium fins (hydrophilic coating); minimum 6 rows for design Δt = 6 K; **fin spacing ≥ 2.5 mm** (preferred 3 mm) to facilitate cleaning and reduce fouling in dusty IT environments.

B. **Design CHW flow and Δt:** 6/12 °C (Δt 6 K) standard; some high-density installations specify 10/15 °C (Δt 5 K) — confirm per schedule.

C. **Control valve: PICV (Pressure-Independent Control Valve)** at coil supply; sized per design flow; modulating actuator with 0–10 V command from CRAH controller; see Section 230523 Article 2.8.

D. **Bypass valve (where free-cooling/economiser provided):** 3-way diverter routing CHW between coil and bypass per controller demand.

E. **Coil pressure rating:** PN16 minimum; flanged or threaded connection per coil size.

F. **Drain provisions:** isolation valves and drain cocks at coil headers for system isolation and drain-down.

2.5 REHEAT (WHERE REQUIRED FOR HUMIDITY CONTROL)

A. **Function:** reheat is used to maintain RH setpoint when cooling load alone would reduce air temperature below dewpoint and inadvertently dehumidify the room; rarely needed in modern data centres with high SHR ≥ 0.95, but specified where required by IT-room humidity tolerance.

B. **Type — preferred:** hot-gas reheat (DX units) — uses compressor discharge gas; no extra energy cost.

C. **Type — alternative:** electric resistive reheat — multiple SCR-controlled stages; only when hot-gas option not available; energy-inefficient — minimise use via setpoint widening.

D. **Reheat avoidance:** prefer to widen room humidity tolerance (ASHRAE A1 allowable 8–60% RH) and disable reheat entirely; significant energy saving.

2.6 HUMIDIFICATION (WHERE REQUIRED)

A. **Type — preferred:** ultrasonic humidifier — atomises water using piezoelectric crystals; minimal energy (water provides its own latent heat via cooling-coil heat absorption); demineralised water required (conductivity < 30 µS/cm).

B. **Type — alternative:** isothermal steam humidifier — electrode or resistive; sterilises water via steam temperature; preferred when potable water supply is the only option and demineralisation is not provided.

C. **Capacity:** sized per maximum credible water-vapour deficit; typically 2–5 kg/h per CRAH unit; multi-stage proportional control.

D. **Where humidification is NOT installed:** humidity control is achieved by widening the allowable RH range per ASHRAE TC 9.9 A1 (8–60%); confirm IT equipment manufacturer tolerance before omitting humidification.

E. **Water supply:** demineralised (ultrasonic) or potable (steam) — confirm material compatibility; backflow preventer per EN 1717 / Section 232116.

2.7 AIR FILTERS

A. **Pre-filter:** ePM10 ≥ 50% per EN ISO 16890 (equivalent to G4 per old EN 779); washable.

B. **Main filter:** ePM1 ≥ 50% (equivalent to F7 per old EN 779); bag or compact filter; pressure drop ≤ 120 Pa initial.

C. **Differential-pressure sensor:** factory-fitted across filter bank; alarm at 2× initial Δp.

D. **MERV equivalence:** comparable to MERV 13 / ISO 16890 ePM1 50% for general data-centre IT-equipment protection.

E. **No HEPA** for typical CRAC; HEPA only specified for cleanroom adjacent applications.

2.8 REDUNDANCY AND TEAMWORK

A. **Redundancy class:** as specified on schedule, typically:

1. **N+1:** one spare unit; loss of any one unit does not affect total capacity
2. **N+2:** two spare units; for higher-availability rooms
3. **2N:** full duplicate system; for Tier III/IV-equivalent data centres

B. **Teamwork mode (unit-to-unit communication via dedicated network):**

1. All connected units share return-air temperature and humidity readings
2. Capacity dispatched to operating units to equalise load
3. Lead/lag rotation at programmable interval (typical weekly)
4. Automatic failover: standby unit starts within ≤ 60 seconds of operating-unit fault
5. Discharge-air or supply-air temperature control coordinated across units to prevent hunting and short-cycling

C. **Fault tolerance:** any single unit failure, fan failure, or compressor failure shall result in alarm to BMS within 30 seconds and automatic re-distribution of load to remaining units without manual intervention.

2.9 FREE COOLING / ECONOMISER INTEGRATION

A. **Free-cooling modes (where specified on schedule):**

1. **Direct outdoor-air economiser:** uses filtered outdoor air below setpoint to cool IT room directly; suitable for dry climates; humidity control critical
2. **Indirect air-side economiser (heat exchanger):** outdoor air via plate or rotary heat exchanger cools recirculated IT air; no outdoor air enters IT room; preferred for humid climates
3. **Water-side economiser (chiller free-cooling):** dry-cooler or cooling-tower CHW below threshold ambient; chiller off; coordinated with central chiller plant
4. **Dual-coil hybrid:** unit includes both DX coil and free-cooling coil (water from dry cooler); seamless transition controlled by unit controller based on ambient

B. **Switchover setpoints:** programmable per ambient and load; record switchover hours in BMS for verification.

C. **Expected free-cooling hours:** ≥ 4000 h/year for Italian Po Valley climate when free-cooling switchover ≥ 18 °C ambient dry-bulb is achievable; manufacturer to confirm projection in submittal.

2.10 CONTROLS AND BMS INTEGRATION

A. **On-board controller:** colour touch-screen interface (≥ 5" diagonal); local set-point adjustment with password protection; real-time display of all sensor readings, capacity demand, fan speed, compressor stage / EEV opening, filter Δp, alarm history.

B. **Control modes:**

1. Return-air temperature control (legacy default)

2. Supply-air temperature control (preferred for modern data centres — directly controls cold-aisle temperature)
3. Cold-aisle temperature control (with remote sensor in the cold aisle)
4. Selectable per project schedule

C. **BMS / DCIM gateway — BACnet/IP standard:** native BACnet/IP support per ASHRAE 135 / EN ISO 16484-5; PICS submitted; objects per unit (minimum):
   1. AV: return-air temperature, supply-air temperature, room temperature, return-air humidity, setpoints (R/W)
   2. AI: compressor stage(s), EEV opening %, fan speed %, CHW valve position %, filter Δp, refrigerant suction/discharge pressure (DX)
   3. BV: unit enable / disable, free-cooling mode active (R/W)
   4. BI: unit fault, compressor fault (DX), fan fault, filter alarm, water leak alarm, condensate high-water
   5. MV: operating mode (Cool, Free-Cool, Hybrid, Standby, Fault)

D. **SNMP support (where required by data-centre DCIM):** optional SNMP v3 trap output to data-centre management system in parallel with BACnet/IP.

E. **Modbus RTU/TCP:** accepted as legacy alternative only where BACnet not available from manufacturer; written Engineer approval required.

2.11 LEAK DETECTION

A. **Water-leak detection cable:** spot or cable-type water-leak sensor under each unit and along CHW pipework in the IT room; alarm to BMS; trigger unit shutdown if water detected within unit footprint.

B. **Refrigerant-leak detection (A2L DX units, where required by Section 232300 / Article 1.6):** in-room sensor; alarm to BMS; interlock to shut down affected unit and initiate room ventilation.

C. **Condensate high-water sensor:** factory-fitted in drain pan; alarm and unit shutdown.

2.12 ELECTRICAL

A. **Power supply:** 400 V ± 10%, 3-phase + neutral + earth, 50 Hz; single-phase for units < 5 kW only.

B. **Inrush current:** inverter compressors limit inrush; document FLA and starting current.

C. **EMC:** EN 61000-3-2 / -3-12; built-in EMC filter.

D. **Dual electrical feed (where redundancy requires):** ATS (Automatic Transfer Switch) within unit cabinet for A/B power-feed switching without operational interruption; only for units intended for 2N facility power architecture.

E. **UPS-backed control circuit:** unit control board powered via small internal UPS or external 24 V battery to allow orderly shutdown on main-power loss and to maintain BMS communication during transient.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Verify IT-room layout (rack positions, hot/cold aisle orientation, raised-floor plenum depth where applicable) matches unit air distribution scheme.

B. Confirm structural support of raised floor (where used as supply plenum) and floor slab loading for unit weight (typically 800–1500 kg per unit).

C. Verify electrical distribution sized for unit FLA + future expansion; confirm A/B feeds where 2N redundancy is required.

D. Verify CHW supply at correct flow and Δt at design conditions (CRAH units).

E. Verify make-up water supply with demineralisation system (ultrasonic humidifier) or potable water with backflow preventer (steam humidifier).

3.2 INSTALLATION

A. Install on level concrete pad or raised-floor support frame; level to ±2 mm/m.

B. Anti-vibration isolation: neoprene pads or steel-housing spring mounts per Section 230529; selected by manufacturer; static deflection ≥ 25 mm for units with rotating compressors.

C. Air distribution:

1. **Downflow units:** mount on raised-floor cut-out or floor-plenum frame; verify floor-plenum static pressure design
2. **Upflow units:** connect supply to overhead duct distribution per Section 233113; provide acoustic attenuator where required
3. **InRow units:** mount on level floor; align with hot/cold aisle containment per data-centre architectural drawings

D. Refrigerant piping (DX CRAC): install per **Section 232300**; field-erected; brazed; N_2-purged; triple-evacuated; charged per F-Gas certified technician.

E. CHW piping (CRAH): install per Section 232113; thermally insulate against condensation per Section 230716 (CHW lines are very cold; sweating in IT room is unacceptable — full vapour barrier essential).

F. Condensate drain: install per Section 221316 (ICC IPC 314); P-trap depth = fan static + 25 mm; insulated; air-gap indirect waste termination; **no condensate may discharge inside the IT-room raised-floor plenum** — route to outside the IT room.

G. Make-up water (humidifier): dedicated supply with isolation valve, backflow preventer, and demineralisation cartridge as applicable; pressure regulator if mains pressure > 4 bar.

H. Electrical connection: dedicated MCC feeder per Section 262913; A/B feeds where redundancy requires; SPD (surge protective device) at unit incomer for IT-environment protection.

3.3 COMMISSIONING

A. Pre-commissioning checks: electrical insulation; supply voltage; refrigerant charge (DX) or CHW flow (CHW); fan rotation; condensate drain free-flowing; humidifier water supply pressure.

B. Capacity verification at design conditions (in heated server room or with simulated IT load):

1. Measure return-air dry-bulb and wet-bulb temperatures
2. Measure supply-air dry-bulb
3. Measure airflow by traverse or factory-fitted flow meter
4. Calculate sensible cooling kW (mass flow × Cp × ΔT)
5. Compare to schedule; deviation > 10% triggers investigation

C. Free-cooling switchover test: force-trigger switchover by adjusting setpoint; verify mode transition without supply-air temperature excursion > 2 K; record switchover hours in BMS dashboard.

D. Redundancy / failover test: simulate failure of one unit (controlled shutdown); verify standby unit picks up load within 60 seconds; document temperature excursion at IT inlet (target ≤ 2 K from setpoint within transient).

E. Teamwork test: verify all units communicate; verify lead/lag rotation per schedule; verify capacity dispatch balances unit run-hours within ±5%.

F. BMS integration test: confirm every BACnet object discoverable from project BMS supervisor; force alarms (fan fault, filter, refrigerant) and verify notification chain to facility-management system.

G. Acoustic measurement: LpA inside IT room ≤ 75 dB(A) (worker exposure limit per D.Lgs. 81/2008); LpA at adjacent occupied rooms ≤ project NR target.

H. Submit full commissioning report with all measurements, BACnet point checkout, redundancy test results.

3.4 TRAINING AND DOCUMENTATION

A. Provide minimum 4 hours operator training: daily monitoring, alarm response, filter replacement, condensate-drain inspection, humidifier maintenance, lead/lag rotation review.

B. Provide minimum 4 hours facility-engineer training: BACnet integration, teamwork configuration, free-cooling setpoint tuning, F-Gas logbook, refrigerant troubleshooting.

C. O&M documentation: complete control schematic, BACnet object list, refrigerant circuit diagrams, P&ID for CHW circuits, spare-parts list, F-Gas logbook (DX).

D. As-built dashboard: custom BMS / DCIM dashboard showing all CRAC/CRAH units, current operating mode, capacity %, alarm status, lead-lag rotation, free-cooling hours, calculated mechanical-load PUE contribution.

3.5 IDENTIFICATION

A. Label each unit with stainless tag per Section 230553: tag number, type (CRAC-DX / CRAH-CHW / InRow / Hybrid), nominal sensible kW, refrigerant type and charge (DX), unit role (lead 1 / standby / etc.).

B. Mark IT-room floor with cold-aisle / hot-aisle designation aligned to unit air-distribution scheme.

C. Label CHW supply and return piping per Section 230553 colour codes; label condensate drain per Section 221316.

END OF SECTION 238123

SECTION 260518
LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 260534 – Raceways and Boxes for Electrical Systems
2. Section 262913 – Motor-Control Centers
3. Section 230900 – Instrumentation and Controls for HVAC
4. Section 232123 – Hydronic Pumps
5. Section 238143 – Air-Source Heat Pumps

1.2 SUMMARY

A. Scope: Furnish and install all low-voltage power cables, control cables, and signal cables for HVAC mechanical and electrical systems.

B. Standard cable types:

1. Power and control cables **FG16OM16** – 0.6/1 kV, HEPR insulation compound 16, rubber outer sheath OM16, halogen-free; **standard for all HVAC power and control circuits**
2. Flexible cables **H07RN-F** – 450/750 V, EPR insulated, polychloroprene outer sheath; final connections to motors and equipment within LFMC
3. Fire-resistant cables **FTG10(O)M1** – circuit integrity ≥ 90 min in fire conditions; safety-critical circuits only
4. Data/signal cables – Cat6 F/UTP for BACnet/IP; screened twisted pair for BACnet MS/TP and sensors

NOTE: FG16OR and FG16R (HEPR insulation, PVC outer sheath) are permitted only as substitution where FG16OM16 is not commercially available in the required configuration; written approval from the Engineer is required before substitution. FG16OR is not standard and shall not be used as the default cable type.

NOTE: All cables installed in building construction works must carry CPR marking (Reg. (UE) 305/2011) with declared Euroclass per EN 50575. The minimum required Euroclass depends on the installation location — see Article 1.6.

1.3 DEFINITIONS

A. FG16OM16: CEI 20-13; standard cable for all HVAC power and control circuits; F = copper conductor; G = elastomeric insulation; 16 = HEPR (Hard Ethylene Propylene Rubber) compound 16, conductor temperature 90 °C; O = multicore unarmoured; M = rubber outer sheath; 16 = rubber compound M16, oil-resistant, halogen-free, flexible to −40 °C; 0.6/1 kV. Advantages over FG16OR: halogen-free rubber sheath (no HCl in case of fire); better resistance to ageing and chemicals in plant rooms; greater flexibility at low temperatures.

B. FG16OR / FG16R: CEI 20-13 (CPR designation); CPR-era renaming of pre-CPR types FG7OR and FG7R; F = copper conductor; G = elastomeric insulation; 16 = HEPR compound 16 (updated CPR classification of the former EPR 7 compound); O = multicore unarmoured; R = PVC compound R outer sheath; 0.6/1 kV; acceptable substitute where FG16OM16 is not available.

C. H07RN-F: harmonised European flexible cable (CENELEC HD 22.4 S4 / EN 50525-3-21); H = harmonised type; 07 = 450/750 V rated voltage; R = vulcanised elastomeric (EPR/EPDM) insulation; N = polychloroprene (neoprene) outer sheath; F = fine-strand flexible class 5 copper conductor per EN 60228; for final connections from LFMC conduit to motor terminal boxes and equipment.

D. FTG10(O)M1: CEI 20-45 fire-resistant cable; mineral-insulated or fire-resistant EPR; LSOH outer sheath; maintains circuit integrity ≥ 90 min per IEC 60331; required for safety-critical circuits.

E. CPR (Construction Products Regulation): Reg. (UE) 305/2011 requires all cables permanently installed in building structures to carry CE marking with declared Euroclass fire performance. Mandatory in all EU member states since 1 July 2017.

F. CPR Euroclass: fire classification per EN 13501-6 / EN 50575; classes from Aca (best — non-combustible) down to Fca (no performance declared). Sub-classes: s1/s2/s3 (smoke), d0/d1/d2 (flaming droplets), a1/a2/a3 (acidity of gases).

G. **DoP (Declaration of Performance):** mandatory document from cable manufacturer declaring the Euroclass and other CPR performance characteristics; required at submittal.

H. **Sheathed cable:** cable with an overall outer jacket enclosing all conductors; provides mechanical protection, chemical resistance, and identification; mandatory for single-core cables > 6 mm² on cable tray.

I. **CCA (Copper Clad Aluminium):** not permitted; all conductors shall be annealed copper per EN 60228.

1.4 APPLICABLE STANDARDS

Key Applicable Standards	
CEI 64-8	Electrical systems – user installations at nominal voltage ≤ 1000 V
CEI 20-13	Cables with elastomeric insulation and sheath – FG16R/FG16OR/FG16OM16 family (CPR designations)
CEI 20-38	Rubber-insulated cables – nominal voltage 450/750 V (H07RN-F)
CEI 20-22	Cables not propagating fire in bunched installations – IEC 60332-3
CEI 20-35	Flame non-propagation test – IEC 60332-1
CEI 20-37	Gas emission – halogen-free (zero-halogen) cables
CEI 20-45	Fire-resistant cables – IEC 60331
EN 60228	Conductors of insulated cables – cross-section classes (class 2 solid, class 5 flexible)
EN 50525-2-31	Electric cables – general applications – halogen-free thermoplastic insulated
EN 50525-3-21	Electric cables – rubber insulated – H07RN-F flexible cables
IEC 60502-1	Power cables with extruded insulation – rated voltages 1 kV to 30 kV
Reg. (UE) 305/2011	Construction Products Regulation (CPR) – mandatory CE marking for cables in buildings
EN 50575	Power, control, and communication cables – CPR fire performance classification
EN 13501-6	Fire classification of construction products – cables (Euroclass Aca to Fca)
CEI 64-8	Electrical systems – user installations (≤ 1000 V)
UNI EN 60364	Electrical systems in buildings (series)
CEI EN 60529	Degrees of protection (IP rating)
IEC 61158 / 61784	Modbus RTU/TCP fieldbus
D.M. 37/2008	Building systems – installer qualifications and requirements
D.Lgs. 192/2005 e s.m.i.	Energy performance of buildings
D.Lgs. 81/2008	Consolidated Workplace Safety Act

1.5 SUBMITTALS

A. **Cable schedule:** listing each cable run; tag number, from/to, cable type, CPR Euroclass, conductor size (mm²), length, routing, and conduit reference.

B. **Product data:** manufacturer's data sheets for each cable type; voltage rating, insulation compound, fire performance Euroclass, temperature rating, and bending radius.

C. DoP (Declaration of Performance): mandatory for every cable type per Reg. (UE) 305/2011; declaring CPR Euroclass per EN 50575; submitted before procurement.

D. Test certificates: fire performance (IEC 60331/60332), halogen content (CEI 20-37) from accredited laboratory; traceable to EN 50575 / EN 13501-6.

E. Cable drawings: single-line diagram showing power distribution; block diagram showing control and BMS wiring.

1.6 QUALITY ASSURANCE AND CPR REQUIREMENTS

A. CPR mandatory marking: all cables shall be CPR-marked per Reg. (UE) 305/2011; Euroclass per EN 50575 / EN 13501-6 declared on cable sheath and in DoP. Cables without valid CPR marking shall not be installed.

B. Minimum Euroclass by installation zone:

1. Escape routes, stairwells, corridors used for evacuation: **B2ca-s1,d1,a1** minimum
2. Plant rooms, technical risers, general HVAC areas: **Cca-s1,d1,a1** minimum
3. Fire-resistant circuits (FTG10(O)M1): **B2ca-s1,d0,a1** or **Aca** minimum per local fire authority requirements
4. Class Eca and Fca: NOT permitted in any permanent building installation

C. Conductor material: annealed copper class 2 (rigid) or class 5 (flexible) per EN 60228; no aluminium conductors for cross-sections < 25 mm²; no CCA.

D. CEI 64-8 compliance: installation methods, cable sizing, overcurrent protection coordination.

E. Installation by qualified electricians; certification per D.M. 37/2008 for all HVAC electrical connections.

1.7 WARRANTY

A. All cables and accessories: **1 year** from Substantial Completion.

PART 2 – PRODUCTS

2.1 POWER CABLES — FG16OM16 (STANDARD)

A. Type FG16OM16 — standard for all HVAC power circuits: CEI 20-13; 0.6/1 kV; copper class 2 conductor; HEPR insulation compound 16 (90°C conductor temperature); rubber outer sheath compound OM16 (oil-resistant, halogen-free, flexible to –40°C); unarmoured for conduit/tray installation.

1. Conductor sizes: 1.5, 2.5, 4, 6, 10, 16, 25, 35, 50, 70, 95 mm² multi-core and single-core as designed
2. Temperature rating: +90°C conductor; –40°C installation; outer sheath oil-resistant (IEC 60811)
3. CPR Euroclass: minimum **Cca-s1,d1,a1** per EN 50575; DoP from manufacturer required

B. Type FG16OR (substitution only — not standard): CEI 20-13; HEPR compound 16 insulation; PVC outer sheath compound R (CPR-era renaming of the pre-CPR FG7OR designation); permitted only where FG16OM16 is not commercially available in the required size or core count; written Engineer approval required before use.

1. CPR Euroclass: minimum Cca-s1,d1,a1 per EN 50575
2. Limitation: PVC outer sheath releases halogen gases (HCl) in fire; not acceptable in escape routes, areas requiring LSOH cables, or as a default cable type

C. Type FG16R (armoured — specific applications only): CEI 20-13; HEPR insulation + galvanised steel wire armour (CPR-era renaming of the pre-CPR FG7R designation); for direct burial, exposed external runs, or where additional mechanical protection is required; Engineer approval required.

D. Minimum conductor sizes:

1. Lighting circuits: 1.5 mm² minimum
2. Power socket circuits: 2.5 mm² minimum
3. Motor feeders: FLA × 1.25 per CEI 64-8; minimum 2.5 mm²
4. Main distribution feeders: sized by voltage drop; maximum 3% feeder to board; 5% total

E. Single-core cables > 6 mm² — sheathing rule:

1. On cable tray: single-core conductors > 6 mm² **shall be of the sheathed type** (FG16OM16 or FG16OR single-core with overall outer sheath); bare insulated conductors on open tray are not permitted above 6 mm²
2. In metallic conduit (EMT/IMC/RMC): sheathed cables are **strongly preferred**; individual insulated conductors without overall sheath are acceptable inside fully enclosed metallic conduit only

NOTE: The sheathing requirement for single-core cables > 6 mm² provides mechanical protection against installation damage, abrasion in conduit, oil exposure, and rodent damage in plant rooms. FG16OM16 single-core with rubber sheath is the standard solution for distribution feeders and motor circuits. FG16OR single-core (ex FG7OR) is acceptable as alternative.

2.2 FLEXIBLE CABLES — H07RN-F (EQUIPMENT FINAL CONNECTIONS)

A. **Type H07RN-F:** CENELEC HD 22.4 S4 / EN 50525-3-21; 450/750 V; EPR rubber insulation; polychloroprene (neoprene) outer sheath; flexible class 5 copper conductors; for final connections from LFMC conduit termination to motor terminal box and HVAC equipment.
   1. Voltage: 450/750 V
   2. Temperature: –25°C to +60°C continuous; peak +85°C
   3. Use: within LFMC flexible conduit at equipment connection (see Section 260534 Art. 2.3); length ≤ LFMC length
   4. CPR Euroclass: minimum Eca-s2; DoP from manufacturer required
   5. Conductor sizes: 1.5 to 35 mm² as required for motor FLA

B. **Not for:** fixed conduit runs, cable trays, or any routed installation; H07RN-F is exclusively for the equipment connection point within LFMC flexible conduit.

C. **Slack:** leave 200 mm slack at equipment connection box to allow maintenance disconnection without disturbing the conduit system.

2.3 FIRE-RESISTANT CABLES

A. **Application:** fire alarm circuits, emergency lighting, smoke damper actuators, fire pump circuits, pressurisation fans, emergency ventilation, and all circuits required to function under fire conditions.

B. **Type FTG10(O)M1:** CEI 20-45; fire-resistant EPR insulation; copper class 2 conductor; LSOH outer sheath (CEI 20-37 zero-halogen); circuit integrity ≥ **90 minutes (FE90)** per IEC 60331-11.
   1. CPR Euroclass: **B2ca-s1,d0,a1** minimum; Aca where required by local fire authority
   2. Flame retardant: IEC 60332-1 (single) and IEC 60332-3 (bundle)
   3. Minimum size: 1.5 mm² for control circuits; 2.5 mm² for power circuits under fire conditions

C. **Colour code:** red outer sheath for all fire-resistant cables; maintain red consistently throughout project.

D. **Segregation:** fire-resistant cables in dedicated metallic conduit or cable tray; do not share raceway with standard cables.

2.4 LSOH / HALOGEN-FREE CABLES

A. **Application:** underground car parks, tunnels, public areas, escape routes, and locations where halogen gas release in fire endangers occupants or sensitive equipment.

B. **Type:** CEI 20-37 Class 1 (zero-halogen content); CEI 20-35 (flame retardant); LSZH outer sheath.

C. **CPR Euroclass:** minimum **Cca-s1,d1,a1** for general areas; **B2ca-s1,d1,a1** for escape routes.

D. **Note:** FG16OM16 rubber-sheathed cables inherently have low halogen content; verify manufacturer's halogen declaration against CEI 20-37 limits when using FG16OM16 in LSOH-required areas.

2.5 CONTROL AND SIGNAL CABLES

A. **Multi-core control cables:** FG16OM16 multi-core; 0.6/1 kV; 0.75, 1.0, 1.5 mm² per core; for valve and damper actuators, sensor wiring, and 230 V control circuits. FG16(O)R multi-core only as Engineer-approved substitution where FG16OM16 is unavailable in the required core count.
   1. Number of cores: as required; minimum 20% spare cores in each cable
   2. Screen: overall aluminium/polyester tape screen with drain wire for control cables in VFD-noisy environments

3. CPR Euroclass: minimum Cca-s1,d1,a1

B. BACnet/IP network cable (standard): Cat6 F/UTP or S/FTP; 250 MHz bandwidth; in dedicated metallic conduit segregated from 230 V power cables; connect to building BACnet VLAN or dedicated BMS LAN.

C. BACnet MS/TP cable (RS-485 field bus): shielded twisted pair (STP); 0.5 mm² minimum; Belden 9842 or equivalent; characteristic impedance 100–120 Ω; drain shield at one end only.

D. Modbus RTU cable (legacy): same specification as BACnet MS/TP cable; use only where BACnet is unavailable from the field device manufacturer.

E. 4–20 mA analogue signal: shielded twisted pair 0.5–1.0 mm²; screen drained at receiving end only.

2.6 CABLE IDENTIFICATION AND MARKING

A. Colour coding — Italian CEI 64-8 standard:

1. Phase L1: brown; Phase L2: black; Phase L3: grey (3-phase circuits)
2. Neutral (N): blue
3. Protective earth (PE): green/yellow
4. Control 230 VAC: any colour except green/yellow and blue
5. Control 24 VAC/VDC: violet or grey recommended
6. Fire-resistant circuits: red outer sheath

B. CPR marking: all cable sheaths shall display CPR Euroclass marking (e.g., Cca-s1,d1,a1), CE mark, EN 50575 reference, and manufacturer name; visible without unsheathing.

C. Cable markers: heat-shrink or clip-on markers at each end and at all junction boxes; marker shows cable tag number matching cable schedule.

D. Core markers: insulated bootlace ferrules at each core end; core number per cable schedule.

2.7 CABLE ACCESSORIES

A. Cable glands: IP-rated per enclosure IP rating; nickel-plated brass or stainless steel; nylon only for light-duty indoor dry locations; ATEX certified in classified hazardous areas.

B. Terminations: crimped compression lugs for conductors ≥ 10 mm²; insulated bootlace ferrules for all stranded conductor ends ≤ 6 mm²; no bare strands; no soldering as primary connection method.

C. Junction boxes: IP54 minimum in plant rooms; DIN rail terminal blocks; earth bar; size to allow 150 mm cable loop inside.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Verify conduits and metallic trunking (Section 260534) are installed, secured, and clean before pulling cables.

B. Confirm cable type and CPR Euroclass match the approved cable schedule and installation zone.

C. Verify segregation between power and signal/BACnet cables from conduit installation stage.

3.2 INSTALLATION

A. Cable fill: maximum 40% of conduit cross-sectional area (single cable); 33% for three or more cables per CEI 64-8.

B. Bending radius: minimum 8× cable diameter for FG16OM16 and FG16OR; 10× for armoured cables (FG16R); 5× for data cables.

C. Cable pulling: use lubricant compatible with cable sheath material; maximum pulling tension per manufacturer; pull rope attached to conductor bundle via pulling eye — never to core insulation ends.

D. Mechanical protection: all cables below 2.4 m in plant rooms must be in conduit or metallic trunking; no bare cable runs at accessible height.

E. Segregation: minimum 300 mm between power cables (230 V and above) and signal/control/BACnet cables; metallic barrier or separate conduit where 300 mm not achievable.

F. Earth continuity: maintain PE throughout; connect PE at every junction box; test continuity before energising.

G. Fire stopping: seal all cable penetrations through fire-rated walls and floors with intumescent putty or collars maintaining the rated fire period; record every penetration.

H. Terminations: identify each core with ferrule before terminating; tighten terminals to manufacturer's specified torque; no insulation under terminal clamp; no exposed bare conductor outside terminal.

3.3 TESTING AND COMMISSIONING

A. Insulation resistance test: each cable core to earth and between cores; minimum 1 MΩ at 500 V DC for 0.6/1 kV cables; minimum 100 MΩ at 500 V DC for control cables; record results per cable tag.

B. Continuity test: PE and neutral conductors; maximum 1 Ω end-to-end for circuits < 100 m.

C. Polarity test: confirm L, N, PE correct at all outlets and equipment terminals.

D. Loop impedance test: measure earth fault loop impedance at all power outlets and motor terminals; verify overcurrent device disconnects within required time per CEI 64-8.

E. Submit signed electrical inspection and test report (Rapporto di Verifica per D.M. 37/2008) before energising; signed by a qualified electrician licensed per D.M. 37/2008.

3.4 IDENTIFICATION AT HANDOVER

A. Provide complete as-built cable schedule: cable tags, types, CPR Euroclasses, routes, lengths, and test results.

B. Mark cable routes on as-built drawings; update BIM model where applicable.

C. File all DoPs (Declarations of Performance) in the project O&M manual.

END OF SECTION 260518

SECTION 260534
RACEWAYS AND BOXES FOR ELECTRICAL SYSTEMS

Technical Specification — Coordinated with Italian / EU Standards
FAC ENGINEERING ROME | May 23, 2026 | Rev. 0

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

B. Related Sections:

1. Section 260518 – Low-Voltage Electrical Power Conductors and Cables
2. Section 262913 – Motor-Control Centers
3. Section 230900 – Instrumentation and Controls for HVAC
4. Section 232123 – Hydronic Pumps (vibration isolation at equipment connections)

1.2 SUMMARY

A. Scope: Furnish and install all conduit systems, metallic cable trays, metallic trunking, and junction/outlet boxes for HVAC electrical and control wiring.

B. Permitted raceway types (metallic only):

1. EMT (Electrical Metallic Tubing) — standard for all indoor HVAC runs
2. IMC (Intermediate Metal Conduit) — for exposed, outdoor, and heavy-duty zones
3. RMC (Rigid Metal Conduit) — for direct burial and highest mechanical protection
4. LFMC (Liquidtight Flexible Metal Conduit) — final connections to vibrating equipment only
5. Perforated metallic cable trays and cable ladders — for main power and control runs
6. Metallic trunking (cable duct) — for surface-mounted runs in plant rooms and finished areas
7. Junction boxes, pull boxes, and outlet boxes — pressed steel or die-cast aluminium

*NOTE: Plastic (PVC/HDPE) conduit and nonmetallic flexible conduit (LFNC) are NOT permitted anywhere in this project. Primary basis: **CEI 64-8** for general installation methods and **EN 13501-1** for reaction-to-fire performance in air-handling spaces. NFPA 70 Art. 300.22 (plenum cabling) and NFPA 90A (HVAC materials) are referenced as concurrent best practice but are not cogent in Italy.*

1.3 DEFINITIONS

A. EMT (Electrical Metallic Tubing): thin-wall galvanised steel conduit per NFPA 70 Art. 358 and EN 61386-21 Class 3; connected with compression or set-screw fittings (no threads); standard wiring method for all indoor commercial HVAC electrical runs.

B. IMC (Intermediate Metal Conduit): medium-wall galvanised steel conduit per NFPA 70 Art. 342; threaded fittings; used for exposed outdoor runs, mechanical protection zones, and locations requiring greater crush resistance than EMT.

C. RMC (Rigid Metal Conduit): heavy-wall galvanised steel conduit per NFPA 70 Art. 344; threaded; for direct burial, concrete encasement, and highest mechanical protection requirements.

D. LFMC (Liquidtight Flexible Metal Conduit): helically wound galvanised steel strip with liquidtight PVC outer jacket per NFPA 70 Art. 350; used exclusively for the final 300–600 mm connection to vibrating HVAC equipment (motors, compressors, AHUs); provides vibration absorption while maintaining metallic ground continuity and liquidtight IP67 rating.

E. PE (Protective Earth Conductor) / EGC (Equipment Grounding Conductor): dedicated green/yellow protective conductor ensuring fault current returns to source. On this project, per **CEI 64-8 Section 543**, a separate green/yellow PE conductor shall be installed in every circuit alongside the live conductors; the metallic conduit alone is NOT relied upon as the protective earth conductor. The metallic raceway itself shall additionally be bonded to earth at terminations and at suitable intervals for mechanical fault path and EMC purposes, but does not replace the dedicated PE conductor required by CEI 64-8.

F. Plenum space: air-handling space above suspended ceilings or below raised floors used as return-air path; per NFPA 70 Art. 300.22 and NFPA 90A, only metallic conduit or plenum-rated cable permitted.

G. Cable tray: open metallic support system (perforated tray or ladder) for grouped cable runs; provides mechanical support but not a closed conduit; cables not individually protected from mechanical damage — use in accessible locations only.

1.4 APPLICABLE STANDARDS

Key Applicable Standards	
CEI 64-8	Electrical systems – user installations ≤ 1000 V (Italian transposition of HD 60364); primary cogent standard
EN 61386-1	Conduit systems for cable management – general requirements
EN 61386-21	Conduit systems – rigid metallic conduits (rigid steel conduit equivalent to IMC/RMC)
EN 61386-22	Conduit systems – pliable metallic conduits
EN 61386-23	Conduit systems – flexible metallic conduits (equivalent to LFMC)
EN 50085-1	Cable trunking and cable ducting systems – general requirements
EN 50085-2-1	Cable trunking systems intended for mounting on walls and ceilings
EN 61537	Cable management – cable tray systems and cable ladder systems
CEI EN 60529	Degrees of protection (IP) – boxes and enclosures
EN 60423	Conduit systems – outside diameters and threads
EN 13501-1	Fire classification – reaction to fire for cable management systems
NTC 2018 §7.2.3	Norme Tecniche per le Costruzioni – seismic bracing of non-structural elements
Circ. 21/01/2019 n.7	NTC 2018 application instructions
NFPA 70 (NEC)	National Electrical Code – US standard, referenced here only for terminology (EMT/IMC/RMC/LFMC) and plenum-space best practice; **not cogent in Italy** — grounding/earthing follows CEI 64-8
NFPA 90A	Standard for the Installation of Air-Conditioning and Ventilating Systems – US standard; referenced for plenum-space material guidance only
CEI 64-8	Electrical systems – user installations (≤ 1000 V)
UNI EN 60364	Electrical systems in buildings (series)
CEI EN 60529	Degrees of protection (IP rating)
D.M. 37/2008	Building systems – installer qualifications and requirements
D.Lgs. 192/2005 e s.m.i.	Energy performance of buildings
D.Lgs. 81/2008	Consolidated Workplace Safety Act

1.5 SUBMITTALS

A. **Product data:** manufacturer's data sheets for each raceway type; material, wall thickness, IP rating, fire class, and load capacity.

B. **Raceway layout drawings:** conduit and tray routing on structural drawings; hanger spacing; penetration schedules; EMT/IMC/RMC designation by zone.

C. **Seismic bracing plan:** lateral and longitudinal bracing per NTC 2018 §7.2.3 (non-structural elements) and Circolare 21/01/2019 n.7.

D. **Plenum compliance statement:** written confirmation that all wiring methods in air-handling spaces comply with NFPA 70 Art. 300.22 and NFPA 90A.

1.6 QUALITY ASSURANCE

A. All metallic raceway systems: CE marked per applicable EN standard; listed per UL 797 (EMT), UL 1242 (IMC), or UL 6 (RMC) where NFPA 70 compliance is required.

B. Metallic raceways bonded to earth throughout; continuity tested per CEI 64-8 and NFPA 70 Art. 250.

C. **Plastic conduit and LFNC are not permitted** — verify at inspection; non-compliant installations to be removed and replaced at Contractor's cost.

D. **D.M. 37/2008 and CEI 64-8 are the primary cogent standards** for installation methods. EN 61386 series and EN 50085 series apply to product conformity. NFPA 70 / NFPA 90A are referenced as best-practice for terminology and plenum-space guidance; where NFPA imposes a more stringent requirement than the European standards on a topic explicitly cited in this Section, the more stringent shall apply.

1.7 WARRANTY

A. All raceway systems: **1 year** from Substantial Completion.

PART 2 – PRODUCTS

2.1 EMT — ELECTRICAL METALLIC TUBING (STANDARD INDOOR CONDUIT)

A. **Standard:** NFPA 70 Art. 358; EN 61386-21 Class 3; UL 797 listed.

B. **Material:** cold-drawn carbon steel; electrolytic zinc-coated (galvanised) inside and outside.

C. **Diameter range:** 16, 20, 25, 32, 40, 50, 63 mm nominal (metric); or ½", ¾", 1", 1¼", 1½", 2" trade size (inch-series) as shown on drawings.

D. **Fittings:** steel compression couplings and connectors (raintight type outdoors); set-screw type for concealed dry locations only; steel locknuts; steel insulated bushings at all conduit terminations in enclosures.

E. **Use:** all indoor HVAC electrical and control cable runs — in plant rooms, ceiling voids, wall chases, and above suspended ceilings (plenum spaces).

F. **Earth bonding of raceway:** ensure all compression / set-screw fittings are fully tightened so that the metallic raceway itself remains electrically continuous and bonded to the earthing system at terminations. This bonding is **in addition to** the dedicated green/yellow PE conductor required inside the raceway per CEI 64-8; it does not replace it.

NOTE: EMT is the default conduit type for all indoor runs. Use IMC or RMC only where EMT does not provide sufficient mechanical protection (e.g., areas exposed to physical damage, below 2.4 m in plant rooms, outdoor, or direct burial).

2.2 IMC AND RMC — INTERMEDIATE AND RIGID METAL CONDUIT

A. **IMC standard:** NFPA 70 Art. 342; UL 1242; EN 61386-21 Class 4; threaded fittings.

B. **RMC standard:** NFPA 70 Art. 344; UL 6; EN 61386-21 Class 4 (heavy); threaded fittings.

C. **Material:** hot-dip galvanised steel; stainless AISI 316 or PVC-coated galvanised for coastal / chemical environments.

D. **Fittings:** malleable iron or steel; galvanised; threaded couplings; weatherproof threaded hubs at enclosures; drain fittings at low points on outdoor runs.

E. **Use of IMC:** areas exposed to physical damage (below 2.4 m in plant rooms), outdoor runs, conduit on building exterior.

F. **Use of RMC:** direct burial (minimum 450 mm cover per NFPA 70 Table 300.5); concrete-encased runs; areas with highest mechanical impact risk.

G. **Earth bonding of raceway:** threaded joints provide reliable mechanical and electrical continuity; bond raceway to earthing system at terminations. As for EMT (Article 2.1), the metallic raceway bonding is supplemental to — and does not replace — the dedicated green/yellow PE conductor required inside the raceway per CEI 64-8.

2.3 LFMC — LIQUIDTIGHT FLEXIBLE METAL CONDUIT

A. **Standard:** NFPA 70 Art. 350; UL 360; EN 61386-23.

B. Construction: helically-wound galvanised steel strip with outer liquidtight PVC jacket; metallic core provides mechanical bonding continuity for the raceway.

C. Application: final **300–600 mm** connections to all vibrating HVAC equipment — motors, compressors, AHUs, fan-coil units, heat pumps; connections to panel-mounted equipment requiring flexibility for maintenance removal.

D. IP rating: IP67 when assembled with LFMC liquidtight fittings (threaded steel with sealing gland).

E. Maximum length: 1800 mm per NFPA 70 Art. 350.30 (or shorter per voltage drop calculation); not to be used as a substitute for properly routed rigid conduit.

F. Minimum bend radius: 7× nominal conduit diameter.

G. Grounding: a dedicated green/yellow PE conductor shall be run inside LFMC per CEI 64-8 Section 543; the LFMC casing shall additionally be bonded to earth at both termination glands to ensure mechanical continuity of the raceway.

NOTE: Liquidtight Flexible NONmetallic Conduit (LFNC / FNMC, NFPA 70 Art. 356) is NOT permitted on this project. All flexible conduit connections to HVAC equipment shall be LFMC only.

2.4 METALLIC CABLE TRAYS AND LADDERS

A. Perforated cable tray: hot-dip galvanised steel; 1.5 mm thickness for trays ≤ 300 mm wide; 2.0 mm for wider; perforation ≥ 30% of base area for cable ventilation.

B. Cable ladder: for heavy power feeders; galvanised steel; rung spacing 300 mm maximum; side rails minimum 50 mm deep.

C. Width: as shown on drawings; minimum 150 mm; size for design cable fill + 30% spare capacity.

D. Supports: wall brackets or trapeze hangers; maximum 1500 mm centres on straight runs; 600 mm either side of bends and tees.

E. Covers: mandatory in plenum spaces (NFPA 90A); in all areas exposed to dripping water or mechanical damage.

F. Seismic bracing: lateral and longitudinal bracing per NTC 2018 §7.2.3 and Circolare n.7/2019 at maximum 6 m intervals.

G. Segregation: separate trays for power cables (230 V and above) and signal/control/BACnet cables; minimum 300 mm separation or metallic divider; never share a tray with different voltage classes without a fixed metallic divider.

H. Earthing: bond across every joint with proprietary earth bonding links; test continuity of complete tray run before cable installation.

2.5 METALLIC TRUNKING (CABLE DUCT / WIREWAY)

A. Standard: EN 50085-1; NFPA 70 Art. 376 (Metal Wireways).

B. Material: galvanised steel or powder-coated steel; snap-lid or hinged-lid cover; IP40 standard; IP54 with sealed covers for plant rooms.

C. Use: surface-mounted runs in plant rooms, finished office areas, and anywhere plastic trunking would otherwise be specified.

D. Fill: maximum 20% of cross-sectional area for conductors (NFPA 70 Art. 376.22); 75% for a single conductor.

E. Partitioned trunking: two-compartment metallic trunking where power and signal cables must share the same duct; metallic divider fixed throughout full length.

F. EMC-screened trunking: fully sealed metallic trunking (no perforations) for BACnet/IP, control, and sensor cable runs adjacent to VFD power cables.

NOTE: PVC (plastic) trunking is NOT permitted. All cable ducting shall be metallic, consistent with the all-metallic raceway policy of this project.

2.6 JUNCTION BOXES AND OUTLET BOXES

A. Standard junction boxes: pressed steel; IP54 in plant rooms and above ceiling voids; IP44 in dry finished areas; knock-outs all four sides and base; earthing lug inside.

B. Weatherproof boxes (outdoor): die-cast aluminium or GRP (glass-reinforced polyester); IP65; stainless steel screws; neoprene gasket.

C. HVAC-specific pull boxes: where cable changes direction or pull length exceeds 30 m; minimum 300 mm × 300 mm × 100 mm deep; hinged lid; accessible at all times — no permanent concealment behind fixed structure.

D. Terminal boxes at equipment: IP54 minimum; DIN rail terminal blocks; earth bar; wiring diagram laminated inside lid.

E. Marking: label all junction and pull boxes with permanent markers showing circuit numbers and distribution board reference.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Confirm structural elements are complete before installing conduit supports; identify all penetrations through rated walls and floors and obtain structural engineer approval before coring.

B. Confirm that all specified conduit types in the submitted raceway drawings are metallic; reject any non-metallic conduit specified in error.

3.2 INSTALLATION — EMT / IMC / RMC CONDUIT

A. Install conduit to neat, parallel, and plumb lines; parallel to building grid; no diagonal runs unless unavoidable and approved.

B. Support spacing: EMT maximum 1500 mm and within 900 mm of each box, fitting, or cabinet per NFPA 70 Art. 358.30; IMC/RMC maximum 3 m and within 900 mm of terminations.

C. Bends: use factory or hydraulic-bender-formed bends; minimum bending radius 6× conduit diameter; no kinking, flattening, or heat-formed bends.

D. Expansion joints: install conduit expansion couplings where conduit crosses structural expansion joints.

E. Metallic raceway earth bonding: bond every metallic raceway run to the building earthing system at terminations; ensure all compression / threaded fittings are wrench-tight to maintain mechanical-continuity bonding of the raceway; test raceway continuity (≤ 0.5 Ω end-to-end) before cable installation. This bonding is in addition to the dedicated green/yellow PE conductor required inside the raceway per CEI 64-8.

F. Concrete-embedded conduit: IMC or RMC only; secure to rebar at 600 mm centres; protect open ends with foam plugs; minimum cover 40 mm concrete.

G. Plenum spaces: all conduit runs in ceiling voids used as air-handling return plenum shall be EMT minimum; verify classification with mechanical engineer before installation.

H. Fire stopping: seal all conduit penetrations through fire-rated walls and floors with intumescent putty or collars maintaining the rated fire period; document all penetrations with photo record.

3.3 INSTALLATION — LFMC FLEXIBLE CONDUIT

A. Install LFMC only at equipment termination points — not as a routing method over distances.

B. Cut LFMC square with a hacksaw; remove burrs; install liquidtight fittings hand-tight plus ¾ turn with wrench.

C. Support LFMC within 300 mm of each fitting; no unsupported spans greater than 900 mm.

D. Verify that LFMC maintains sufficient slack to absorb equipment vibration without tensioning the conduit; provide a single loop or offset where necessary.

NOTE: Inspect all flexible connections after 6 months of operation; replace any conduit showing outer jacket cracking or inner core corrosion. Record in maintenance log.

3.4 INSTALLATION — CABLE TRAY AND METALLIC TRUNKING

A. Install cable tray continuous and level; butt-joint with matching couplers and earth bonding straps across every joint.

B. Provide purpose-made radius fittings at all direction changes; no site-cut sharp-edge bends in tray base.

C. Do not support other services from cable tray or trunking.

D. Secure cables on open tray with cable ties at 300 mm centres on horizontal runs; 200 mm on vertical runs.

E. Test earth continuity of complete tray/trunking run before cable installation; document results.

3.5 INSTALLATION — BOXES

A. Mount junction boxes flush with finished wall in finished spaces; surface-mounted in plant rooms.

B. Install weatherproof gaskets on all outdoor box lids; seal conduit entries with appropriate LFMC fittings or compound.

C. Leave minimum 150 mm spare cable coiled inside each junction box; tag each cable with marker sleeve at entry point.

D. Plug all unused knock-outs with IP-rated plugs matching box IP rating; no open knock-outs permitted.

3.6 TESTING AND INSPECTION

A. **Conduit continuity:** test metallic conduit earth continuity on each run; maximum 0.5 Ω end-to-end; record results per circuit.

B. **Visual inspection:** verify 100% metallic raceways — no plastic conduit or LFNC installed anywhere; non-conformances to be corrected before cable pull.

C. **Raceway integrity:** verify all box covers secured; all penetrations sealed; IP rating maintained; LFMC fittings wrench-tightened.

D. **Plenum compliance check:** before ceiling closure, confirm all wiring in air-handling ceiling void is in metallic conduit or plenum cable; sign off on NFPA 90A compliance checklist.

E. Submit signed raceway inspection report; include in electrical commissioning report per Section 260518.

END OF SECTION 260534