ISHRAE

Sheet Metal HVAC Duct Construction and Installation Standard

ISHRAE Standard – 20003:2025

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Indian Society of Heating, Refrigerating and Air Conditioning Engineers

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Email : info@ishraehq.in
Web : www.ishrae.in

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Fort, Mumbai - 400 001, India.

ISHRAE Standards Development Committee

Name	Organization	Email	Position in SC
Ms. Nivedita Jadhav	Aeon Integrated Building Design Consultants	nivedita.jadhav@aeonconsultants.in	Chair
Mr. Yusuf Bhetasiwala	Encon Expertise Pvt Ltd	yusuf_bhetasi@yahoo.com	Member
Dr. Shivraj Dhaka	Confederation of Indian Industry	shivraj.dhaka@cii.in	Member
Mr. Anurag Goyal	Indian Institute of Technology, New Delhi	agoyal@mech.iitd.ac.in	Member
Mr. Achyut R Kulkarni	Trane Technologies India P Ltd	Achyut.Kulkarni@trane.com	Member
Mr. Goutham Pichikala	Eskayem Consultants Pvt. Ltd.	goutham148@gmail.com	Member

ISHRAE Duct Standard:
List of Standards Technical Committee Members

Name	Organization	E Mail ID	Position in STC
Mr. Gidvani Pratap	Founder CEO, Rolastar (Retd)	pgidvani@gmail.com	Chair
Mr. Ramachandran K	Consulting Engineer, Mumbai	ram@ramachandran.net.in	Coordinator
Mr. Bhetasi Yusuf	Encon Expertise Pvt Ltd	yusufbhetasi@gmail.com	Member
Mr. Desai Prashant	Elm Enterprises P Ltd	prashant960@gmail.com	Member
Dr. (Mrs) Easow Roshini	Prof - Mechanical Engg. (Retd)	roshinieasow@gmail.com	Member
Mr. Gupta Nishant	Degree Day P Ltd	nishant@degreeday.in	Member (Chair-ITC)
Ms. Jadhav Nivedita	Aeon Integrated Building Design	nivedita.jadhav@aeonconsultants.in	Member (Chair-Standards)
Dr. Kapilan N	Nitte Meenakshi Institute of Technology	kapil@krecmech@yahoo	Member
Mr. Kazi Ajaz	Reliance Industries Ltd	ajazkazi2000@yahoo.com	Member
Mr. Maheshkumar KR	KRI Ducts HVAC Ancillaries P Ltd	maheshkumar.kr@kriducts.com	Member
Mr. Manjunath V	Octolife Climate Solutions P Ltd	manjunath@octolife.in	Member
Mr. Mehta Bhavesh	Asawa Insulation P Ltd	Bhavesh.mehta@asawainsulation.com	Member
Mr. Mishra Rajesh Kumar	BARC, Mumbai	Rmishra11@gmail.com	Member
Mr. Naik Amit	Stellar ADP P ltd	amit@stellaradp.com	Member
Dr. Rane Milind	IIT, Bombay.	ranemv@iitb.ac.in	Member
Dr. Singh HK	Design to Occupancy Services LLC	dr.hksingh37@gmail.com	Member
Mr. Sonawane B Swapnil	Blue Star Ltd	swapnilsnwne@gmail.com	Member

Foreword

The duct system, which carries air from the fan system to terminal units, is a very important part of any air conditioning, heating and/or ventilation system. Since ducts have to be designed, fabricated and installed to suit specific project needs, this activity almost always falls on the critical path of the HVAC project.

Important performance parameters are: amount of leakage, vibration and noise, efficiency and turbulence of the airflow, dimensional accuracy, physical appearance, goodness of fit with other building services, speed of assembly and installation and, most importantly, pressure drop offered by the system which translates into energy consumed for operation of the system.

Since the turn of this century, duct factories using computer-controlled cutting and bending machines capable of manufacturing ducts from coil stock with consistent quality, minimal wastage and vastly improved productivity have been established around the country, and technology is steadily replacing the earlier practice of site fabrication which is heavily dependent on the skill of the workmen.

While this Standard is not meant to exclude any products or methods that can be demonstrated to be equivalent in performance for the application, methods of construction detailed in the Standard which are essentially process-agnostic require compliance.

This Standard, which covers sheet metal ducting for carrying air, has been attempted to be state-of-the-art and largely in line with International Standards.

It is expected that by specifying duct fabrication and installation to this Standard, users and specifiers will take advantage of getting consistently well-engineered products in their HVAC projects.

This Standard has been developed by ISHRAE through a consensus process with balanced stake-holder participation in a Standards Technical Committee (STC) and giving due consideration to comments received from the public after wide circulation of the draft on ISHRAE website.

Pratap Gidvani
Chair
Duct Standards Committee

K. Ramachandran
Coordinator
Duct Standards Committee

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ISHRAE Sheet Metal HVAC Duct Construction and Installation Standard

1.0 Scope

This Standard covers the materials, constructional details and installation requirements for sheet metal ducts used in air conditioning and ventilation systems. Informative Annexure A to the Standard has certain design guidelines, and Informative Annexure B deals with duct accessories and duct construction practices. Informative Annexure C deals with methods of measurement with a few illustrative examples.

1.1 Exclusions: This Standard does not cover sheet metal ducting used for fume extraction, kitchen exhaust and laundry area ventilation. The Standard also excludes welded construction of ducts.

2.0 References

Annexure D to this Standard is a list of Indian and International Standards that are referenced here. All references shall mean the edition of those standards as on date of publication of this Standard.

3.0 Definitions

For the purpose of this Standard, the following definitions shall apply (listed in alphabetical order):

3.1 Air Flow: Air flow within a duct system is the result of the pressure differential between two points in the system and may be expressed as cubic meters per second (m^3/s).

3.2 Air Flow – Velocity of: Is expressed in meters per second (m/s) and is numerically equal to the speed of air within the duct.

3.3 Air Density: Weight of unit volume of air expressed as kg/m^3. Standard air is defined as having density of 1.201 kg/m^3. Heating and humidifying increase the specific volume of air and hence decreases its density. Lower density requires higher volume flow rate to maintain the same mass flow rate. However, in normal air conditioning or ventilation applications (4 to 38°C and altitudes up to 305 m), density correction is not necessary. Fan capacity is not affected by changes in air density.

3.4 Pressure – Gauge and Absolute: Gauge pressure at any point is the pressure at that point above atmospheric pressure, and absolute pressure at that point is the gauge pressure plus atmospheric pressure. Gauge pressure may be expressed as kg/cm^2 (G) and absolute pressure as kg/cm^2 (A).

3.5 Pressure – Static: Static pressure is the pressure that propels air to flow within the duct. It represents the resistance encountered by the air as it moves within the duct. Static pressure acts uniformly in all directions and remains unaffected by the air velocity. It is expressed in mm of water column or in pascals.

3.6 Pressure – Velocity: Velocity pressure is the resultant of air movement. Vp=Density (kg/m^3)×Velocity (m/s)^2/2

3.7 Pressure – Total: Total pressure in a duct system is the sum of the static pressure and velocity pressure both expressed in identical units.

3.8 Pressure – Limit: Limit pressure in a duct system is the maximum pressure at which safety of the duct is not compromised.

4.0 Classification of Ducts

4.1 Based on internal pressure

Table 1: Pressure classification of ducts

Classification by Pressure	Normal Service – Positive Pa	Normal Service – Negative Pa	Limit Pressure – Positive Pa	Limit Pressure – Negative Pa
Low Pressure	<500	<(500)	1000	(750)
Medium Pressure	501 to 1000	(501) to (1000)	1500	(1500)
High Pressure	1001 to 2500	(1001) to (2500)	3000	(2500)

4.2 Based on material of construction

Sheet metal ducts covered under this standard shall be constructed out of:

- Galvanized steel sheets
- Cold rolled cold annealed (CRCA) sheets – coated/pre-painted
- Aluminum sheets
- Stainless steel sheets

4.3 Based on cross-sectional shape

- Rectangular (includes also square shape)
- Round (plain and spiral)
- Flat Oval (plain and spiral)

4.4 Based on jointing technique

- Angle flange joints
- Corner bolt with same sheet flange
- Corner bolt with slide-on flange

5.0 Materials of Construction

5.1 Galvanized steel sheets shall conform to Class 4 of IS 277 for indoor ducts and insulated outdoor ducts, and Class 3 of IS 277 for uninsulated outdoor ducts. Zinc coating shall be minimum 120 g/m^2 unless specifically agreed between OWNER and CONTRACTOR. Sheets shall be of lock forming quality.

5.2 Stainless steel sheets shall conform to IS 6911.

5.3 CRCA sheets shall conform to IS 513. In case of pre-painted/coated CRCA sheets, the requirement of painting/coating shall be agreed between OWNER and CONTRACTOR.

5.4 Aluminum sheets shall conform to IS 737.

5.5 Steel jointing flanges, steel bars and flats used for support shall conform to IS 2062.

5.6 Light gauge steel sections shall conform to IS 811.

5.7 Steel tubes used for support shall conform to IS 3601.

5.8 Hexagonal head bolts and nuts shall conform to IS 1363 Part 1 and Part 3 respectively.

5.9 Flange gaskets shall be of fiber, rubber or a resin system. Gaskets shall be non-scatter type and shall provide good air-tightness with compressibility, flexibility and durability.

5.10 Duct tape shall be resin adhesive coated on one side of aluminum foil; minimum 0.05 mm thick.

5.11 Sealing materials for seams and duct corners shall be silicone rubber, nitryl rubber or butyl rubber and shall be fire retardant and smoke free.

6.0 Duct Design

6.1 For guidelines on duct design, please refer to Informative Annexure A to this Standard.

6.2 Air velocities within a duct system may vary from 5 m/s to 15 m/s or more, and velocity in the main and branch ducts of the same system may also be different. While noise, vibration and friction loss are more related to velocity than to pressure, duct strength, deflection and leakage are functions of pressure. Since the pressure in a ducting system reduces from the fan outlet pressure to the pressure at air terminals, it is essential that each portion is assigned a pressure classification by the designer. Duct pressure class in relation to the operating pressure shall be as given in *Table 2*.

Table 2: Operating pressure range with respect to pressure class

Duct Pressure Class (Pa)	Operating Pressure (Pa)
125	Up to 125
250	126 to 250
500	251 to 500
750	501 to 750
1000	751 to 1000
1500	1001 to 1500
2500	1501 to 2500

7.0 Information Required for Duct Construction

7.1 Duct layout with routings, sizes, air flow rates, pressure class, type of fittings such as turning vanes, splitter vanes, access doors, volume control and balancing dampers, types and locations of air terminals and insulation requirements, if any.

7.2 Locations and types of all fire protection devices.

8.0 Method of Construction

8.1 General

8.1.1 Method of duct construction primarily depends on the cross-sectional shape of duct. Three cross sectional shapes are covered in this Standard:

- Rectangular
- Circular
- Flat oval

Circular ducts may again be classified as rolled ducts and spiral ducts.

Construction methodology and jointing techniques are different for the different cross-sectional shapes.

8.1.2 It is recommended that sheet metal duct sections be fabricated at suitably equipped ducting factories having CNC controlled machines to provide accuracy in construction and thereafter be transported to project site for installation. Where this is not feasible as in the case of “suit-at-site” pieces as well as in cases where factory fabrication is not feasible due to commercial or logistic reasons, duct pieces may be fabricated at site by skilled labor strictly complying with sections 8.2, 8.3 and 8.4 of this Standard. If the ducts are fabricated at site and the overall ducting quantity exceeds 600 m^2 or when the pressure class exceeds 250 Pa, lock forming machines shall be used for fabrication.

8.1.3 When pressure class is not specified in the drawings, 250 Pa pressure class shall be considered for all ducting other than those ducts upstream of VAV boxes for which 500 Pa pressure class shall be considered.

8.1.4 Direction of airflow in the duct is considered to be its longitudinal direction and the direction perpendicular to it is the transverse direction.

8.1.5 In India, rolled sheets are available in coils 1220/1250 mm wide and when folded in an auto-fold machine the length of each section will be 1220/1250 mm less the applicable flange height. Cut sheets for fabrication at site are available with the same width and in lengths of 2400 mm and it would be possible to fabricate sections 2400 mm long from cut sheets. However, this will require multiple longitudinal seam joints when the circumference exceeds 1250 mm, which is best avoided. Hence, it is suggested that the length of each duct section be limited to maximum 1250 mm and all transverse joint and reinforcement information in this Standard considers Standard duct sections of 1250 mm length.

8.1.6 Size of duct shall refer to its internal dimensions. For rectangular duct, it may be expressed as 'longitudinal dimension × transverse dimension', and for circular duct by its internal diameter. Tolerance in dimensions of rectangular duct shall be -0, +4 mm and for circular ducts the tolerance on diameter shall be +/- 2.5 mm.

8.1.7 Thickness of sheets shall be chosen based on pressure class as well as jointing and reinforcement details. Nominal thickness of galvanized steel sheets and the allowable tolerances as per IS 1730 are given in *Table 3*. Sheet thickness for galvanized steel of lock forming quality to IS 277 with zinc coating of 120 gsm minimum (or as specified by user) for various pressure classes are given in *Tables 6* to *12*. In all cases, prime material of lock forming grade shall be used.

8.1.7.1 For stainless steel and CRCA sheets, the minimum base metal thickness as specified in these tables may be maintained.

8.1.7.2 Aluminum has significantly less yield strength and modulus of elasticity as compared to steel. Hence, aluminum sheets used for duct fabrication require to be thicker than GI sheets selected for the same application. Similarly, reinforcements fabricated out of aluminum require to be thicker than those made of GI. *Table 4* gives Equivalent thickness of aluminum sheets and *Table 5* gives equivalent thickness for aluminum angles used for reinforcement. These sizes are applicable for pressure class of 750 Pa or lower.

Table 3: Nominal thickness and allowable tolerances of GS sheets (Refer IS 1730)

Sheet Thickness (mm)	Tolerance (mm)	Min T (mm)	Max T (mm)	Weight/m²	Weight/m²
0.5	±.06	0.44	0.56	3.94	3.87
0.63	±.08	0.55	0.71	4.96	4.95
0.8		0.72	0.88	6.27	6.24
1	±.09	0.91	1.09	7.84	7.86
1.25	±.12	1.13	1.38	9.82	9.79

Table 4: Equivalent sheet thickness for aluminum

S. No.	Steel Sheet Thickness – mm	Equivalent Aluminum sheet Thickness – mm
1	0.5	0.69
2	0.63	0.86
3	0.8	1.09
4	1.0	1.32
5	1.25	1.70

Table 5: Equivalent reinforcement thickness for aluminum based on minimum sizes

S. No.	Steel Angle Size, mm	Equivalent Aluminum Angle Size, mm
1	25 x 25 x 1.6	32 x 32 x 3.2
2	25 x 25 x 3	38 x 38 x 3.2
3	32 x 32 x 3	45 x 45 x 3.2
4	38 x 38 x 3.2	63 x 63 x 3.2
5	40 x 40 x 5	50 x 50 x 6.4
6	50 x 50 x 3.2	64 x 64 x 4.8
7	50 x 50 x 5	64 x 64 x 8.0
8	50 x 50 x 6.4	64 x 64 x 8.0
9	64 x 64 x 4.8	76 x 76 x 8.0
10	Steel bar 25 x 3.2	Al bar 32 x 4.8
11	Steel bar 38 x 3.2	Al bar 32 x 4.8

8.2 Construction of Rectangular Ducts

8.2.1 Longitudinal Seams: Seams shall be appropriate to the material used, pressure classification and other construction details. Seams shall be formed and assembled to ensure tightness of the joint and notching shall be minimum.

Configuration of seam in rectangular ducts shall be as indicated in *Figure 1* to *Figure 4*.

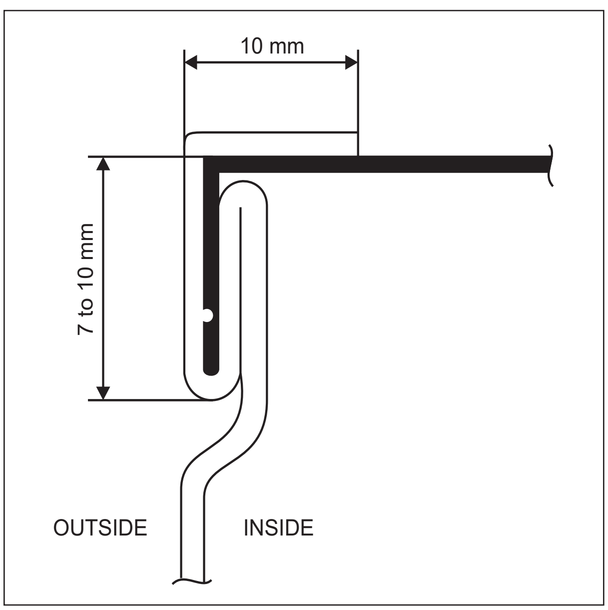


Figure 1: Pittsburgh lock seam

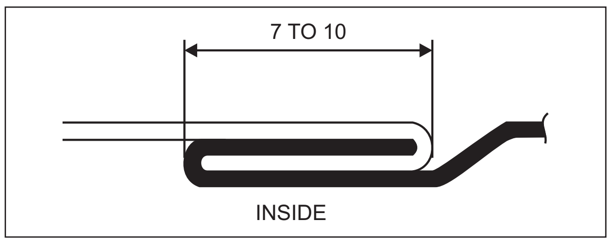


Figure 2: Grooved lock seam

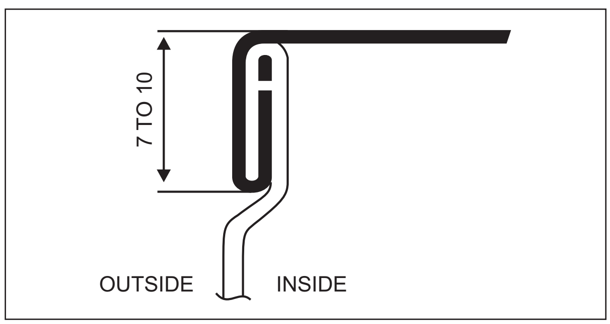


Figure 3: Grooved corner lock seam

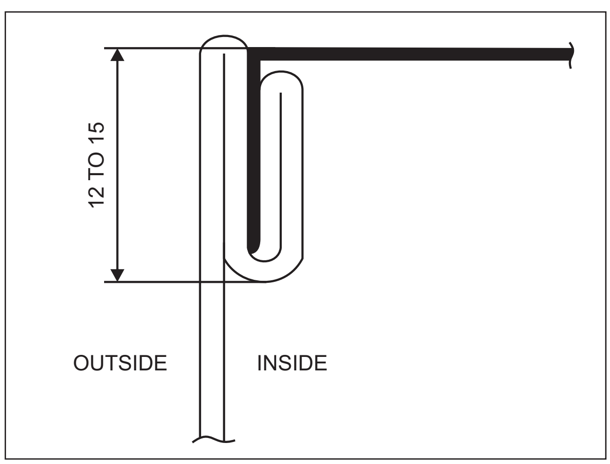


Figure 4: Pittsburgh punch snap lock seam

Longitudinal seams in a rectangular duct may be positioned at one or more of the duct corners. Number of seams shall be minimum and may be limited to maximum four.

8.2.2 Transverse joints: Transverse joints in rectangular ducts shall be consistent with pressure class, sealing requirements, jointing materials and support intervals. Bars or angles used in a joint shall be secured. Where intermediate type reinforcements are used as supplement for joints, they shall be attached to the duct wall with in 75 mm of the joint by weld, bolt, screw or blind rivet fastening within 50 mm of duct corners and at intervals not exceeding 300 mm. Transverse joints in sheet metal duct may be formed by one of the following three techniques, and are illustrated in *Figure 5*.

- Angle Flange
- Rolled-on Flange
- Slip-on Flange

8.2.2.1 Angle Flange: Connection of ducts shall be carried out by tightening the flanges attached to both ends of ducts using bolts and nuts. Gaskets shall be inserted between joining faces to keep the joint air tight. Flanges shall be made in such a way that the four corners are welded at outside and assembled so that contacting surfaces are flat and smooth with bolt holes (for hangers) drilled in. End folds of ducts shall be minimum 6 mm. Typical configuration is given in *Figure 6*.

8.2.2.2 Rolled-on Flange: Flange is produced by bending of the same sheet as the duct and joint is made of corner bolts, clips and gaskets. In addition to corner bolts, the flanges may be tightened with metal clips and the flanges may be reinforced with mounting fittings with bolts. Metal clips for jointing shall have a minimum width of 150 mm and shall be located within 150 mm from the duct

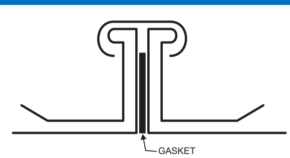
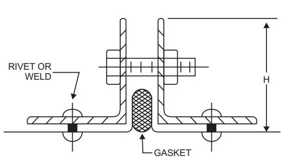
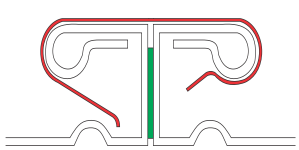
Transverse Joint Type	Typical Section	Remarks
Slip-on Flange		• Thickness of slip shall be minimum of 0.4mm higher than the duct panel thickness • Minimum thickness of slip shall be 0.6 mm and minimum flange height shall be 20 mm • Shall have provision for built-in sealant if asked by user
Angle Flange		• End fold of duct shall be minimum 6 mm • Angle shall have welded corners. L-shaped angles may be used • Angles must be tack welded, bolted or screwed to the duct wall at 50 mm maximum from the ends and at 300 mm maximum intervals • Refer *Table 12* for Dimension H
Rolled-on Flange		• In addition to bolts/nuts, flanges shall be tightened with clamps/clips. These shall have minimum 150 mm width and located within 150 mm of duct edge with spacing less than 200 mm • Gasket to be located to form an effective seal • Refer *Table 12* for Dimension H

Figure 5: Typical sections of transverse joints

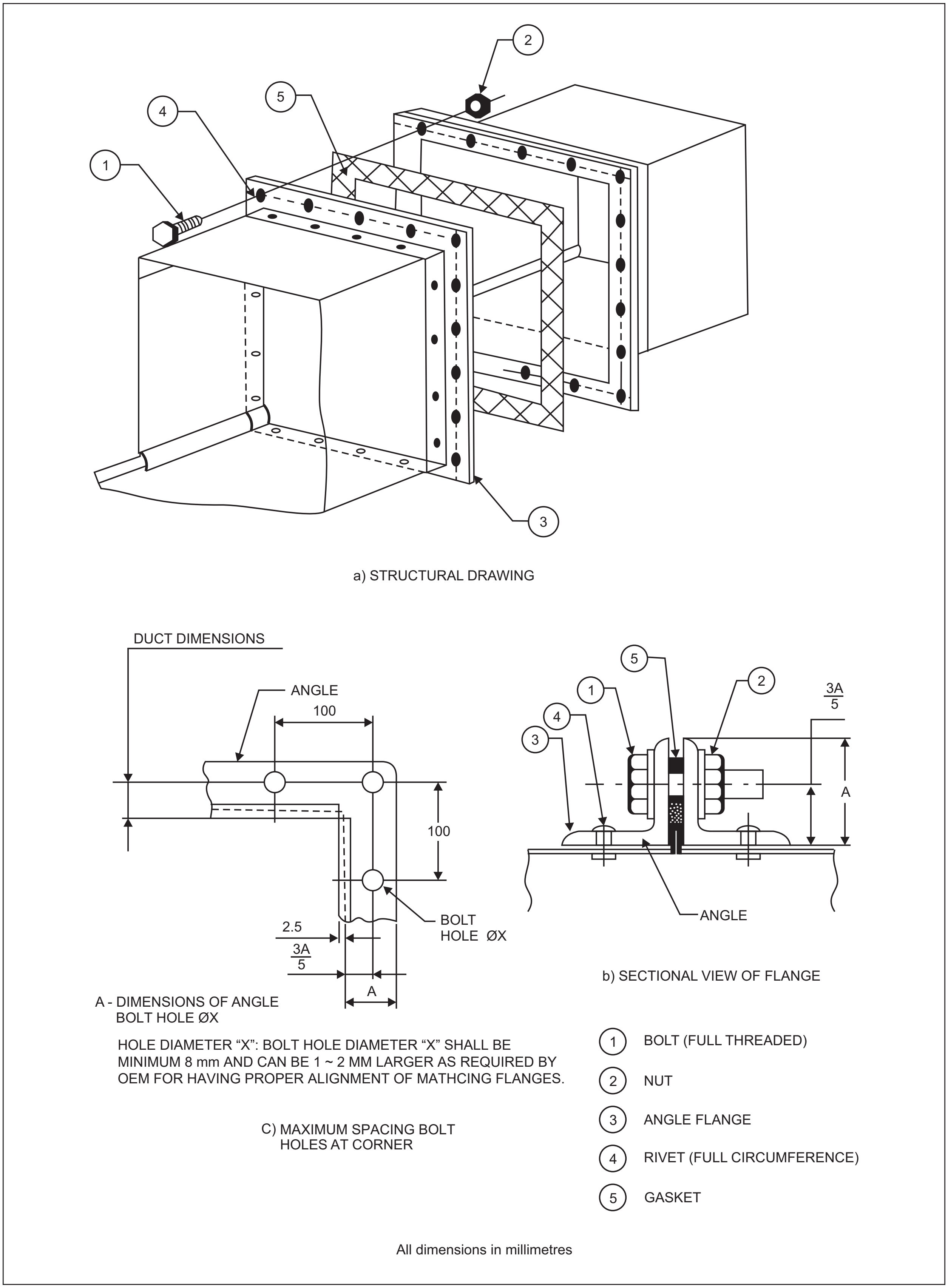


Figure 6: Typical configuration, angle flange

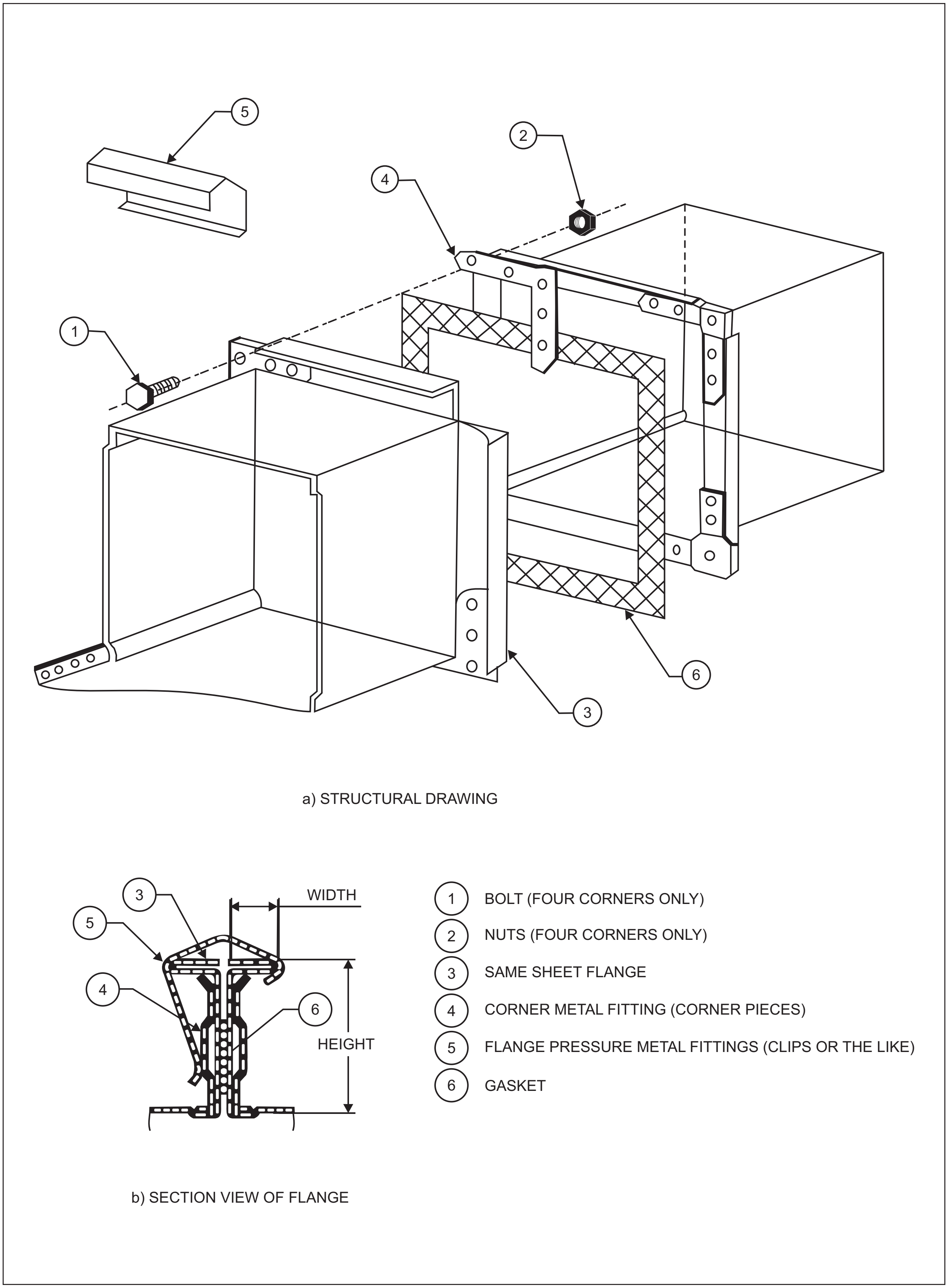


Figure 7: Configuration – rolled-on flange

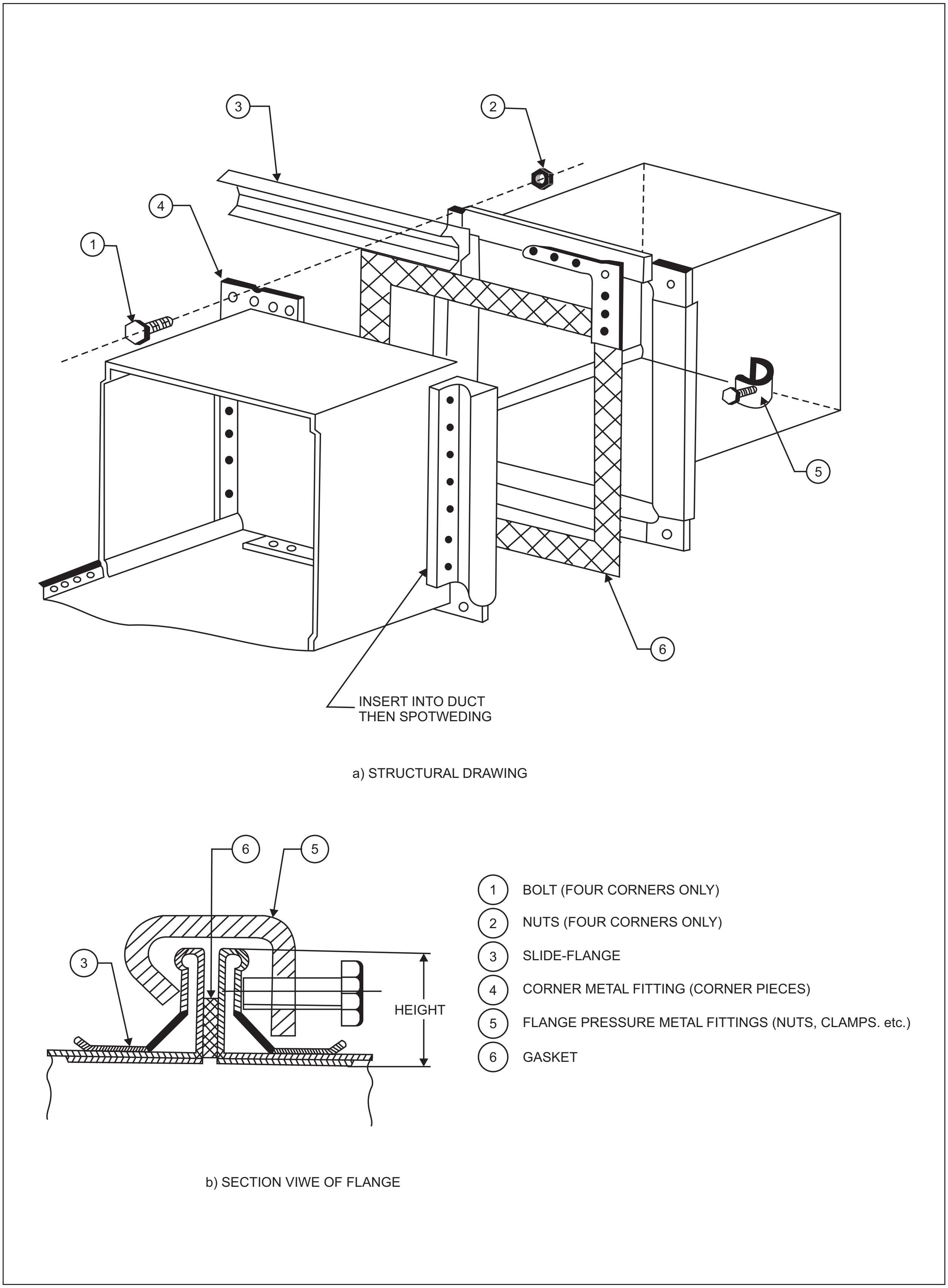


Figure 8: Typical configuration – slip-on flange

edge, and spacing between the clips shall not exceed 200 mm. Typical configuration is given in *Figure 7*.

8.2.2.3 Slide-on/Slip-on Flange: Joint is made of corner metal fittings, corner bolts, slide-on flanges, nuts, clamps, clips and gasket. Flange shall be double folded and shall be made of minimum 0.6 mm thick sheets and shall be minimum 20 mm high. Thickness of the sheet for corner metal fittings shall be adequate. In addition to bolts flanges shall be fitted with clamps/clips. Flange shall be mounted to the duct by electric spot welding with spacing of 100 mm or less. Typical configuration is given in *Figure 8*.

8.2.3 Rectangular ductwork using GI Sheets shall be constructed in accordance with the details given in *Table 6* to *12*.

8.2.3.1 Duct wall thickness, joints, seams, and reinforcements must be coordinated to provide proper assembly.

Table 6: Transverse joint details for 125 Pa pressure class

Transverse Joints for Standard Duct Section Length of 1250 mm – 125 Pa Pressure Class			
Duct Dimension, mm	Duct Pressure, Pa		
	125		
	Rolled-on flanges	Slip-on Flanges	Angle Flanges
<200	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
200-250	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
251-300	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
301-350	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
351-400	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
401-450	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
451-500	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
501-550	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
551-600	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
601-650	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
651-700	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
701-750	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
751-900	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
901-1000	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
1001-1200	0.5 mm	0.5 mm–F	0.63 mm–25 x 25 x 3
1201-1300	0.63 mm	0.5 mm–F	0.63 mm–25 x 25 x 3
1301-1500	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
1501-1800	0.8 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
1801-2100	0.8 mm – JTR/1.0 mm	0.63 mm–I	0.63 mm–32 x 32 x 3
2101-2400	0.8 mm – JTR	0.8 mm-I	0.8 mm–40 x 40 x 5
2401-2700	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
2701-3000	1.6 mm – JTR or 1.2 mm – JTR & bracing at 600 mm of 40 x 40 x 5 mm	1.6 mm–I or 1.2 mm – I (JTR) & bracing at 600 mm of 40 x 40 x 5 mm	1.6 mm–50 x 50 x 5

Table 7: Transverse joint details for 250 Pa pressure class

Transverse Joints for Standard Duct Section Length of 1250 mm – 250 Pa Pressure Class			
Duct Dimension, mm	Duct Pressure, Pa		
	250		
	Rolled-on flanges	Slip-on Flanges	Angle Flanges
<200	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
200-250	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
251-300	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
301-350	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
351-400	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
401-450	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
451-500	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
501-550	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
551-600	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
601-650	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
651-700	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
701-750	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
751-900	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
901-1000	0.63 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
1001-1200	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
1201-1300	0.8 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
1301-1500	0.8 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
1501-1800	0.8 mm – JTR	0.8 mm–I	0.8 mm–40 x 40 x 5
1801-2100	1.0 mm – JTR	1.0 mm–I	1.0 mm–40 x 40 x 5
2101-2400	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
2401--2700	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
2701-3000	1.6 mm-JTR or 1.2 mm JTR & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm-J or 1.2 mm I (JTR) & bracing at 600 mm of 50 x 50 x 5 mm	1.2 mm–50 x 50 x 5 with 50 x 50 x 5 reinforcement at 900 mm spacing

Table 8: Transverse joint details for 500 Pa pressure class

Transverse Joints for Standard Duct Section Length of 1250 mm – 500 Pa Pressure Class			
Duct Dimension, mm	Duct Pressure, Pa		
	500		
	Rolled-on flanges	Slip-on Flanges	Angle Flanges
<200	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
200-250	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
251-300	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
301-350	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
351-400	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
401-450	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
451-500	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
501-550	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
551-600	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
601-650	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
651-700	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
701-750	0.63 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
751-900	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
901-1000	0.8 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
1001-1200	0.8 mm – JTR/1.0 mm	0.8 mm–I	0.8 mm–40 x 40 x 5
1201-1300	1.0 mm – JTR	1.0 mm–I	1.0 mm–40 x 40 x 5
1301-1500	1.0 mm – JTR	1.0 mm–I	1.0 mm–40 x 40 x 5
1501-1800	1.0 mm – JTR	1.0 mm–I	1.0 mm–40 x 40 x 5
1801-2100	1.0 mm – JTR	1.0 mm–I	1.0 mm–40 x 40 x 5
2101-2400	1.2 mm – JTR	1.2 mm–J	1.2 mm–50 x 50 x 5
2401-2700	1.6 mm – JTR or 1.2 mm JTR & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm - J or 1.2 mm - I (JTR) & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm–50 x 50 x 5
2701-3000	1.2 mm – JTR & bracing at 600 mm of 50 x 50 x 5 mm	1.2 mm - I (JTR) & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm–50 x 50 x 5 with 50 x 50 x 5 mm reinforcement at 900 mm spacing

Table 9: Transverse joint details for 750 Pa pressure class

Transverse Joints for Standard Duct Section Length of 1250 mm – 750 Pa Pressure Class			
Duct Dimension, mm	Duct Pressure, Pa		
	750		
	Rolled-on flanges	Slip-on Flanges	Angle Flanges
<200	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
200-250	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
251-300	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
301-350	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
351-400	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
401-450	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
451-500	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
501-550	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
551-600	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
601-650	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
651-700	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
701-750	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
751-900	0.8 mm	0.8 mm–F	0.8 mm–25 x 25 x 3
901-1000	0.8 mm – JTR/1.0 mm	0.8 mm–I	0.8 mm–40 x 40 x 5
1001-1200	1.0 mm – JTR	1.0 mm–I	1.0 mm–40 x 40 x 5
1201-1300	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
1301-1500	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
1501-1800	1.2 mm – JTR	1.2 mm–J	1.2 mm–50 x 50 x 5
1801-2100	1.6 mm – JTR or 1.00 mm JTR, 2 MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm-J or 1.00 mm–I (JTR), 2 MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm–50 x 50 x 5 with 50 x 50 x 5 mm reinforcement at 900 mm spacing
2101-2400	1.6 mm – JTR or 1.00 mm JTR, 2 MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm-J or 1.00 mm I (JTR), 2 MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm–50 x 50 x 6 with 50 x 50 x 6 mm reinforcement at 900 mm spacing
2401--2700	1.2 mm – JTR, 2 MPT & bracing at 600 mm of 65 x 65 x 5 mm	1.20 mm I (JTR), 2 MPT & bracing at 600 mm of 65 x 65 x 5 mm	1.2 mm–65 x 65 x 6 with 65 x 65 x 6 mm reinforcement at 900 mm spacing
2701-3000	1.20 mm JTR, 2 MPT & bracing at 600 mm of 65 x 65 x 6 mm	1.20 mm I (JTR), 2 MPT & bracing at 600 mm of 65 x 65 x 5 mm	1.2 mm–65 x 65 x 6 with 65 x 65 x 6 mm reinforcement at 900 mm spacing

Table 10: Transverse joint details for 1000 Pa pressure class

Transverse Joints for Standard Duct Section Length of 1250 mm – 1000 Pa Pressure Class			
Duct Dimension, mm	Duct Pressure, Pa		
	1000		
	Rolled-on flanges	Slip-on Flanges	Angle Flanges
<200	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
200-250	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
251-300	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
301-350	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
351-400	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
401-450	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
451-500	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
501-550	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
551-600	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
601-650	0.8 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
651-700	0.8 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
701-750	0.8 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
751-900	0.8 mm – JTR/1.0 mm	0.8 mm–I	0.8 mm–40 x 40 x 5
901-1000	1.0 mm- JTR/ 1.2 mm	1.0 mm–I	1.0 mm–40 x 40 x 5
1001-1200	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
1201-1300	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
1301-1500	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
1501-1800	1.6 mm – JTR or 1.00 mm JTR, MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm-J or 1.00 mm I (JTR), MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm–50 x 50 x 5 with 50 x 50 x 5 mm reinforcement at 900 mm spacing
1801-2100	1.20 mm JTR, MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.20 mm I (JTR), MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.2 mm–50 x 50 x 5 mm with 65 x 65 x 5 mm reinforcement at 750 mm spacing
2101-2400	1.20 mm JTR, 2 MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.20 mm I (JTR), 2 MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.2 mm–65 x 65 x 5 with 65 x 65 x 5 mm reinforcement at 750 mm spacing
2401--2700	1.20 mm JTR, 2 MPT & bracing at 600 mm of 65 x 65 x 5 mm	1.20 mm I (JTR), 2 MPT& bracing at 600 mm of 65 x 65 x 5 mm	1.2 mm–65 x 65 x 6 mm with 65 x 65 x 6 mm reinforcement at 750 mm spacing
2701-3000	1.20 mm JTR, 2 MPT & Bracing at 600 mm of 65 x 65 x 5 mm	1.20 mm I (JTR), 2 MPT& bracing at 600 mm of 65 x 65 x 5 mm	1.2 mm–65 x 65 x 6 mm with 65 x 65 x 6 mm reinforcement at 750 mm spacing

Table 11: Transverse joint details for 1500 Pa pressure class

Transverse Joints for Standard Duct Section Length of 1250 mm – 1500 Pa Pressure Class			
Duct Dimension, mm	Duct Pressure, Pa		
	1500		
	Rolled-on flanges	Slip-on Flanges	Angle Flanges
<200	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
200-250	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
251-300	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
301-350	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
351-400	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
401-450	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
451-500	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
501-550	0.8 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
551-600	0.8 mm	0.8 mm–F	0.8 mm–25 x 25 x 3
601-650	0.8 mm	0.8 mm–F	0.8 mm–25 x 25 x 3
651-700	1.0 mm	0.8 mm–I	0.8 mm–40 x 40 x 5
701-750	1.0 mm	0.8 mm–I	0.8 mm–40 x 40 x 5
751-900	1.0 mm – JTR /1.2 mm	1.0 mm–I	1.0 mm–40 x 40 x 5
901-1000	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
1001-1200	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
1201-1300	1.60 mm JTR, or 1.0 mm JTR MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm or 1.00 mm I (JTR), MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm–50 x 50 x 5
1301-1500	1.60 mm JTR, or 1.00 mm JTR MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.60 mm or 1.0 mm I (JTR), MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm–50 x 50 x 5
1501-1800	1.20 mm JTR, MPT & bracing at 600 mm of 50 x 50 x 5 mm	1.20 mm I (JTR), & bracing at 600 mm of 50 x 50 x 5 mm	1.2 mm–50 x 50 x 5 mm with 50 x 50 x 5 mm reinforcement at 750 mm spacing
1801-2100	1.20 mm JTR, 2 MPT & bracing at 600 mm of 65 x 65 x 5 mm	1.20 mm I (JTR), 2 MPT & bracing at 600 mm of 65 x 65 x 5 mm	1.2 mm–65 x 65 x 6 with 65 x 65 x 6 mm reinforcement at 750 mm spacing
2101-2400	1.20 mm JTR, 2 MPT & bracing at 600 mm of 65 x 65 x 6 mm	1.20 mm I (JTR), & bracing at 600 mm of 50 x 50 x 5 mm	1.2 mm–with 65 x 65 x 6 mm reinforcement at 750 mm spacing
2401--2700	1.20 mm JTR, 2 MPT & bracing at 600 mm of 65 x 65 x 6 mm	1.20 mm I (JTR), 2 MPT & bracing at 600 mm of 65 x 65 x 6 mm	1.2 mm–65 x 65 x 6 mm with 65 x 65 x 6 mm reinforcement at 600 mm spacing
2701-3000	1.20 mm JTR, 2 MPT & bracing at 600 mm of 65 x 65 x 5 mm with Tie Rod	1.20 mm I (JTR), & bracing at 600 mm of 65 x 65 x 5 mm with Tie Rod	1.2 mm–65 x 65 x 5 mm with 65 x 65 x 5 mm reinforcement at 600 mm spacing

Table 12: Transverse joint details for 2500 Pa pressure class

Transverse Joints for Standard Duct Section Length of 1250 mm – 2500 Pa Pressure Class			
Duct Dimension, mm	Duct Pressure, Pa		
	2500		
	Rolled-on flanges	Slip-on Flanges	Angle Flanges
<200	0.5 mm	0.5 mm–F	0.5 mm–25 x 25 x 3
200-250	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
251-300	0.63 mm	0.63 mm–F	0.63 mm–25 x 25 x 3
301-350	0.8 mm	0.8 mm–F	0.8 mm–25 x 25 x 3
351-400	1.0 mm	1.0 mm–F	1.0 mm–25 x 25 x 3
401-450	1.0 mm	1.0 mm–F	1.0 mm–25 x 25 x 3
451-500	1.0 mm	1.0 mm–F	1.0 mm–25 x 25 x 3
501-550	1.0 mm	1.0 mm–I	1.0 mm–40 x 40 x 5
551-600	1.0 mm -JTR/1.2 mm	1.0 mm–I	1.0 mm–40 x 40 x 5
601-650	1.0 mm -JTR/1.2 mm	1.0 mm–I	1.0 mm–40 x 40 x 5
651-700	1.0 mm -JTR/1.2 mm	1.2 mm–I	1.2 mm–40 x 40 x 5
701-750	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
751-900	1.2 mm – JTR	1.2 mm–I	1.2 mm–40 x 40 x 5
901-1000	1.2 mm – JTR	1.2 mm–J	1.2 mm–50 x 50 x 5
1001-1200	1.6 mm – JTR or 1.00 mm JTR and bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm-J or 1.00 mm I(JTR) & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm–50 x 50 x 5
1201-1300	1.6 mm – JTR or 1.00 mm JTR and bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm-J or 1.00 mm I(JTR) & bracing at 600 mm of 50 x 50 x 5 mm	1.6 mm–50 x 50 x 6
1301-1500	1.20 mm JTR and bracing at 600 mm of 50 x 50 x 5 mm	1.20 mm I(JTR) & bracing at 600 mm of 50 x 50 x 5 mm	1.2 mm–65 x 65 x 5 with 65 x 65 x 5 mm reinforcement at 750 mm spacing
1501-1800	1.20 mm JTR and bracing at 600 mm of 65 x 65 x 6 mm	1.20 mm I(JTR) & bracing at 600 mm of 65 x 65 x 6 mm	1.2 mm–65 x 65 x 6 mm with 65 x 65 x 6 mm reinforcement at 750 mm spacing
1801-2100	1.20 mm JTR and bracing at 600 mm of 65 x 65 x 6 mm	1.20 mm I(JTR) & bracing at 600 mm of 65 x 65 x 6 mm	1.2 mm–65 x 65 x 6 mm with 65 x 65 x 6 mm reinforcement at 600 mm spacing
2101-2400	1.6 mm – JTR or 1.00 mm JTR and bracing at 600 mm of 65 x 65 x 6 mm with Tie Rod	1.6 mm-J (JTR) & bracing at 600 mm of 65 x 65 x 6 mm with Tie Rod	1.6 mm–65 x 65 x 6 with Tie Rod and 65 x 65 x 6 mm reinforcement at 600 mm spacing
2401--2700	1.6 mm – JTR and bracing at 600 mm of 65 x 65 x 6 mm with Tie Rod	1.6 mm-J (JTR) & bracing at 600 mm of 65 x 65 x 6 mm with Tie Rod	1.6 mm–65 x 65 x 6 with Tie Rod & 65 x 65 x 6 mm reinforcement at 600 mm spacing
2701-3000	1.6 mm – JTR and bracing at 600 mm of 65 x 65 x 6 mm with Tie Rod	1.6 mm-J (JTR) & bracing at 600 mm of 65 x 65 x 6 mm with Tie Rod	1.6 mm–65 x 65 x 6 mm with Tie Rod & 65 x 65 x 6 mm reinforcement at 600 mm spacing

Notes Common to *Table 6* through *12*:
JTR – Joint Tie Rod; MPT – Mid Panel Tie Rod; 2 MPT – 2 # MPTs required; Suffixes F, I, J, etc., for slip-on flanges refer Reinforcement Class (Refer SMACNA 006-2020, *Table 2-32*)

8.2.4 Reinforcement of Rectangular Duct

8.2.4.1 Reinforcements may be in transverse (lateral) direction perpendicular to air flow or they may be in longitudinal direction parallel to the air flow.

8.2.4.2 Joint spacing on unreinforced ducts is unlimited. On ducts that require reinforcement, joint spacing is unrestricted except that the joint itself must qualify for the minimum reinforcement code associated with the reinforcement spacing. Exceptions can be made for rolled on flange and angle flange transverse joints provided the connections are mechanically fastened or welded and the joint is not credited towards the reinforcement requirements.

Table 13: Reinforcement and joint types

Reinforcement & Joint Types	Joint–to–Joint (Transverse)
	Joint–to–Intermediate
	Intermediate–to–Intermediate

8.2.4.3 The flange junction made in the duct by any one of the three methods illustrated in Section 8.2.2 shall be considered as the lateral reinforcement provided the sheet thickness and fitting details specified here are met.

8.2.4.4 Unless otherwise specified, reinforcement may be of galvanized steel.

8.2.4.5 Sides of ducts over 500 mm and with sheet thickness of 1.00 mm or less and with more than 1 m^2 of panel area shall be cross-broken or beaded as indicated in *Figure 6*. However, ducts that are lined on the inside or insulated on the outside shall be exempt from this requirement. Beading or cross-breaking shall not affect reinforcement spacings. See *Figure 9*.

8.2.4.6 Fittings shall be reinforced same as sections of straight duct and where the size changes from one end to the other, the higher size shall be considered.

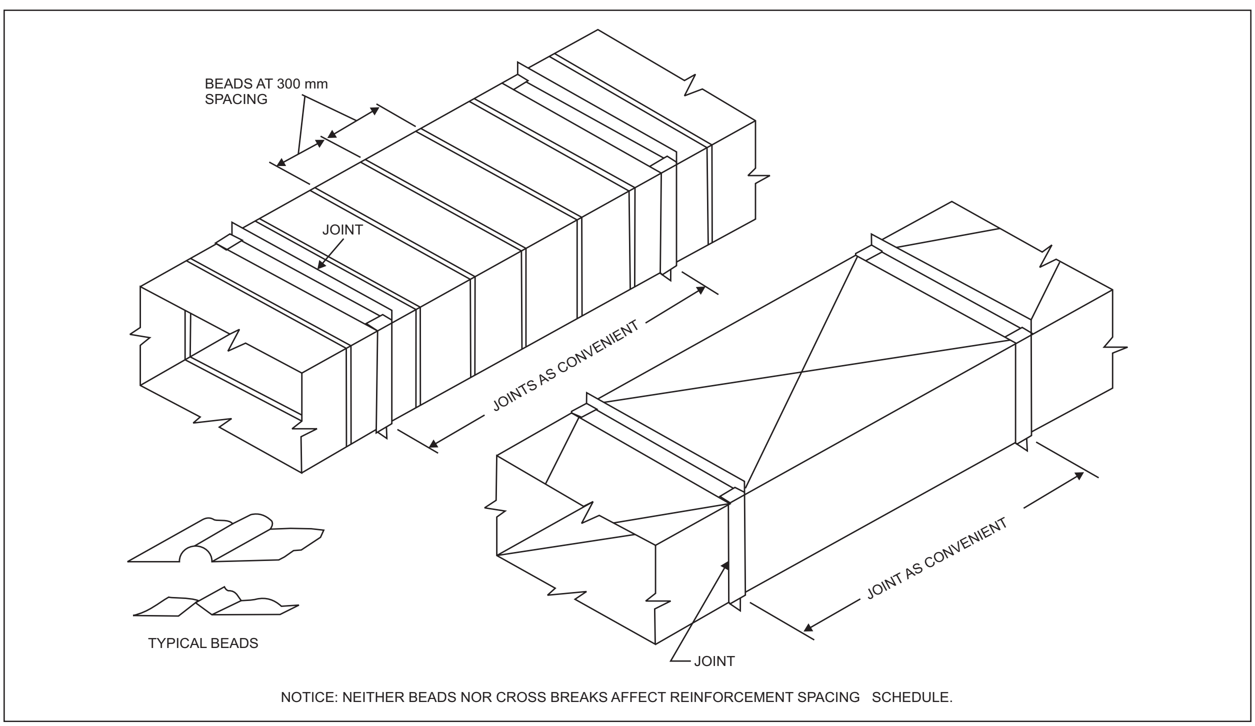
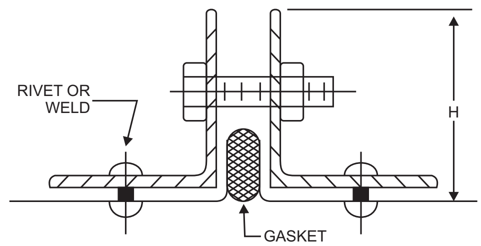


Figure 9: Beading and cross-breaking of duct

8.2.4.7 Fasteners shall be steel with zinc or cadmium coating. If blind rivets are used, the holes shall be sealed to reduce air leakage. Fasteners shall not project into the duct interior by more than 20 mm. Self-tapping screws shall not be used.

8.2.5 Joint to Joint Reinforcement
Angle flanges shall be fitted on bare ducts by riveting. Arc welding may also be done, if agreed by OWNER.

Table 14: Transverse reinforcement – angle flange (dimensions in mm); see also Figure 10

<table>
<tr><th colspan="6">Transverse Joint Reinforcement</th></tr>
<tr><th colspan="6">Angle Flange Technique</th></tr>
<tr><td colspan="6">
</td></tr>
<tr><th></th><th colspan="2">Rivet Mounting</th><th colspan="3">Connecting Bolt</th></tr>
<tr><th>H x H x T</th><th>Dia
(a)</th><th>Max. Rivet Spacing
(b)</th><th>Dia.
(c)</th><th>Spacing from
Corner (d)</th><th>Spacing Between Bolts
(e)</th></tr>
<tr><td>25 x 25 x 3</td><td rowspan="7">4.5</td><td rowspan="7">100</td><td rowspan="4">M6</td><td rowspan="7">100</td><td rowspan="3">150</td></tr>
<tr><td>32 x 32 x 3</td></tr>
<tr><td>40 x 40 x 3</td></tr>
<tr><td>40 x 40 x 5</td><td rowspan="4">100</td></tr>
<tr><td>50 x 50 x 3</td><td rowspan="3">M8 for 50 x 50 x 3
M10 for 5 & 6</td></tr>
<tr><td>50 x 50 x 5</td></tr>
<tr><td>50 x 50 x 6</td></tr>
</table>

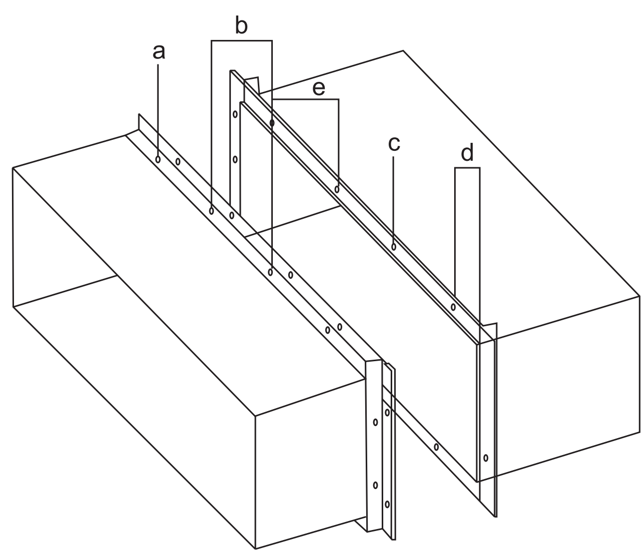
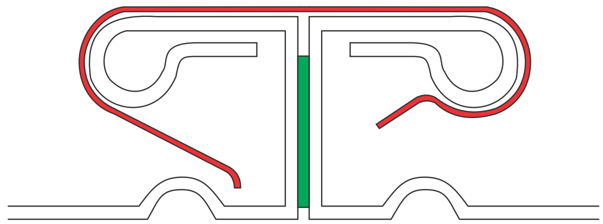


Figure 10: Details of transverse joint with angle flange

Table 15: Transverse reinforcement – rolled-on flange (dimensions in mm); see also Figure 11

Transverse Joint – Rolled-on Flange



H = 35 mm with gasket

Pressure Class	Sheet Thickness	Cleat/Flange Presser W x T (a)	Corner Thickness (b)	Cleat Edge from Corner (c)	Spacing Between Cleat Edges (d)	Gasket W*T (e)	Carriage Bolt Dia. (f)
	0.50	150 x 0.6	1				
	0.60	150 x 0.8	1				
< 750	0.80	150 x 1	1		250	10*3	
	1.00	150 x 1.2	1.2				
	1.25	150 x 1.2	1.6	150			M8
	0.50	150 x 1	1				
	0.60	150 x 1	1.2				
> 750	0.80	150 x 1	1.2		150	12*5	
	1.00	150 x 1.2	1.2				
	1.25	150 x 1.2	1.6				

The L corner shall be of the same material composition as duct sheets.

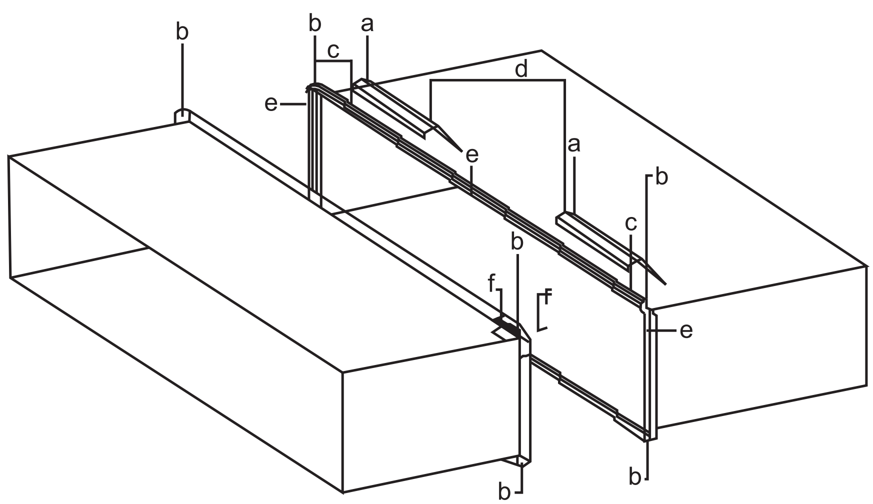


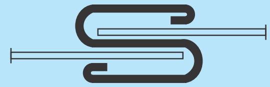
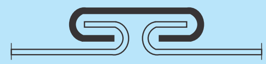
Figure 11: Details of transverse joint with rolled-on flange

Transverse joint reinforcement with slip-on flanges shall be as per *Figure 5* (Typical sections of transverse joints). Thickness of slip shall be 0.4 mm higher than duct panel thickness. Minimum flange height shall be 20 mm. Manufacturer shall be consulted for ratings established by documented performance.

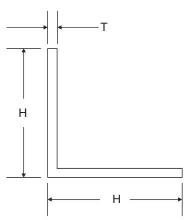
8.2.6 Flat drive joint with C/S Cleat

Where transverse joints with flange cannot be accommodated due to height restrictions or for any other reasons, a flat drive Joint with C/S cleats may be used. Limitations for use of this joint shall be as specified in *Table 16*. In the absence of gaskets and sealants, these joints are prone to heavy leakage and shall be used only with specific approval of user.

Table 16: Flat drive joint with C/S Cleat

Joint Type	**Flat Drive Joint - With C/S Cleat**						
Duct Wall	**0.63 mm**		**0.8 mm**		**1.00 mm and above**		**Remarks**
Static Pressure	**Maximum Duct Width (W) and Minimum Reinforcement Spacing (RS)**						
Pascals	**W**	**RS**	**W**	**RS**	**W**	**RS**	
125	500 mm	NR	500 mm	NR	500 mm	NR	0.63 mm panels shall be minimum. Any length at 500 Pa. 900 mm max. length at 750 Pa. 750 mm max length at 1000 Pa. Not permitted above 1000 Pa.
250	500 mm	2500 mm	500 mm	3000 mm	500 mm	NR	
	360 mm	NR	460 mm	NR			
500	460 mm	2500 mm	460 mm	3000 mm	460 mm	NR	
	300 mm	NR	360 mm	NR			
750	460 mm	1500 mm	460 mm	1500 mm	460 mm	1800 mm	
	250 mm	NR	305 mm	NR	360 mm	NR	
1000	400 mm	1500 mm	300 mm	1800 mm	300 mm	NR	
	200 mm	NR	200 mm	NR			
Note: NR - No reinforcement is required. Flat drive joint may be used as specified							

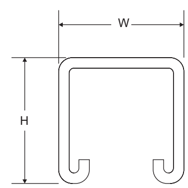
8.2.7 Intermediate to intermediate reinforcement



Angle

- Refer *Table 17* for assembling and reinforcement class specifications
- Refer *Figure 10* for assembling of bolts, rivets on the angle flange

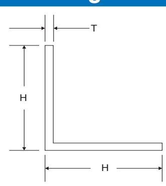
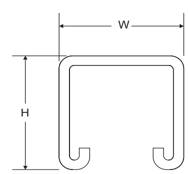
Channel frame



- Refer *Table 17* for reinforcement class specifications

Figure 12: Intermediate to intermediate reinforcements

Table 17: Intermediate reinforcement (dimensions in mm)

Intermediate Reinforcement			
Angle	**Framing Channel (Strut)**		
			
H x H x T	**H**	**W**	**T**
25 x 25 x 3	20	20	1
32 x 32 x 3	20	40	1.8
40 x 40 x 3	35	40	2.5
40 x 40 x 5	60	40	2.5
50 x 50 x 5	60	40	2.5
50 x 50 x 6	60	40	2.5

Notes on Table 17: Angle mentioned in the table is hot-rolled MS angle. Framing channels having the same physical dimensions as those listed above, but fabricated from thicker steel may be used at the reinforcement class assigned to the lighter version. Strut with holes or slots may be used. Consult manufacturer's literature to adjust reinforcement class.

8.2.8 Reinforcement of Rectangular Duct by Tie Rod

8.2.8.1 When ducts are joined by slip-on or rolled-on flanges, additional reinforcement may be made by means of Tie Rods. Tie Rods shall be located at a position where lateral and longitudinal reinforcements intersect. Nominal diameter of tie rods shall be 9 mm minimum when rod is one on each side and 12 mm minimum when two or more rods are placed on each side.

8.2.8.2 For ducts with slip-on or rolled-on flanges, tie rod reinforcement details are given *Table 18*. (Refer also *Figure 13*).

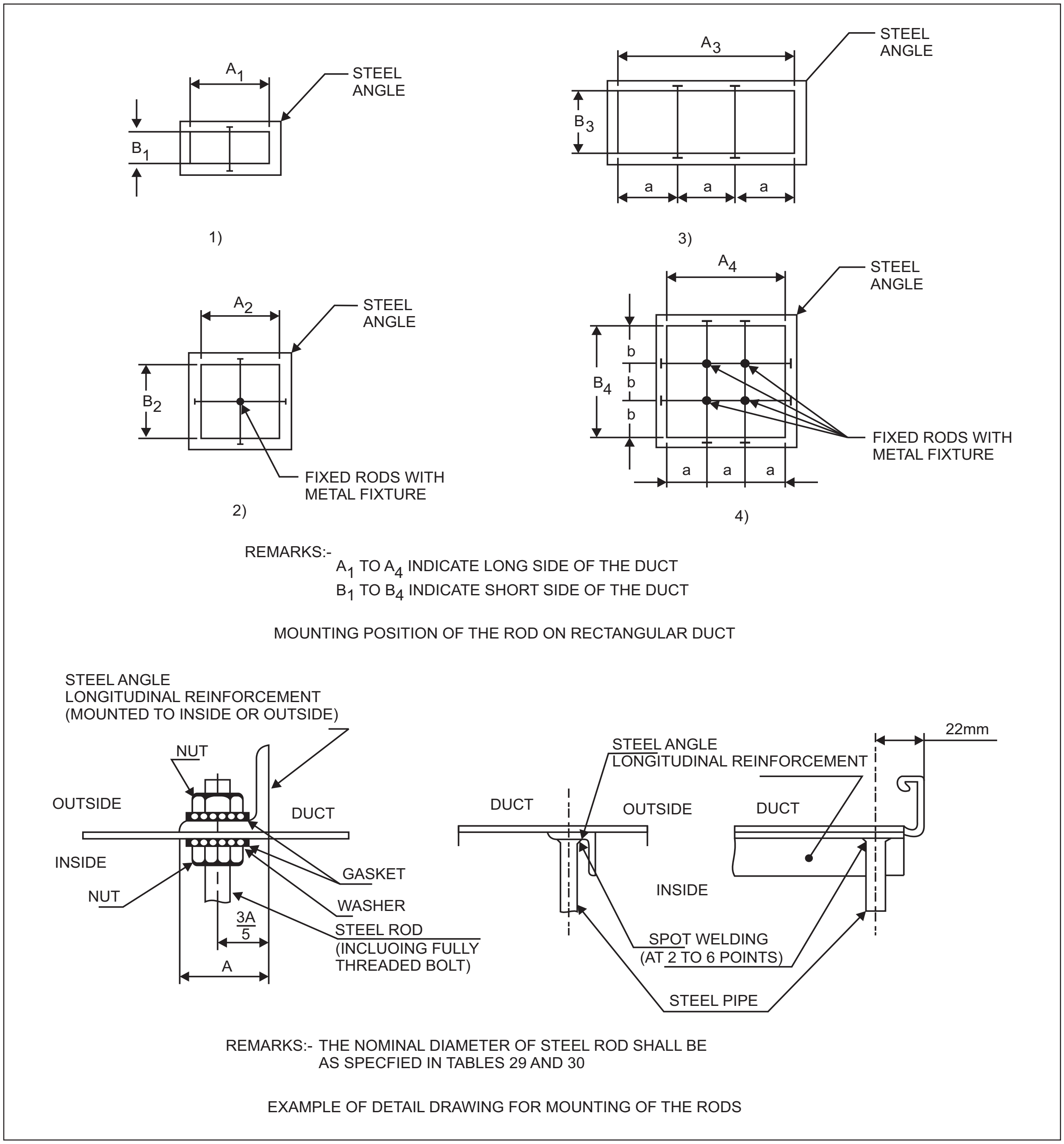


Figure 13: Mounting positions and details of mounting of tie rods

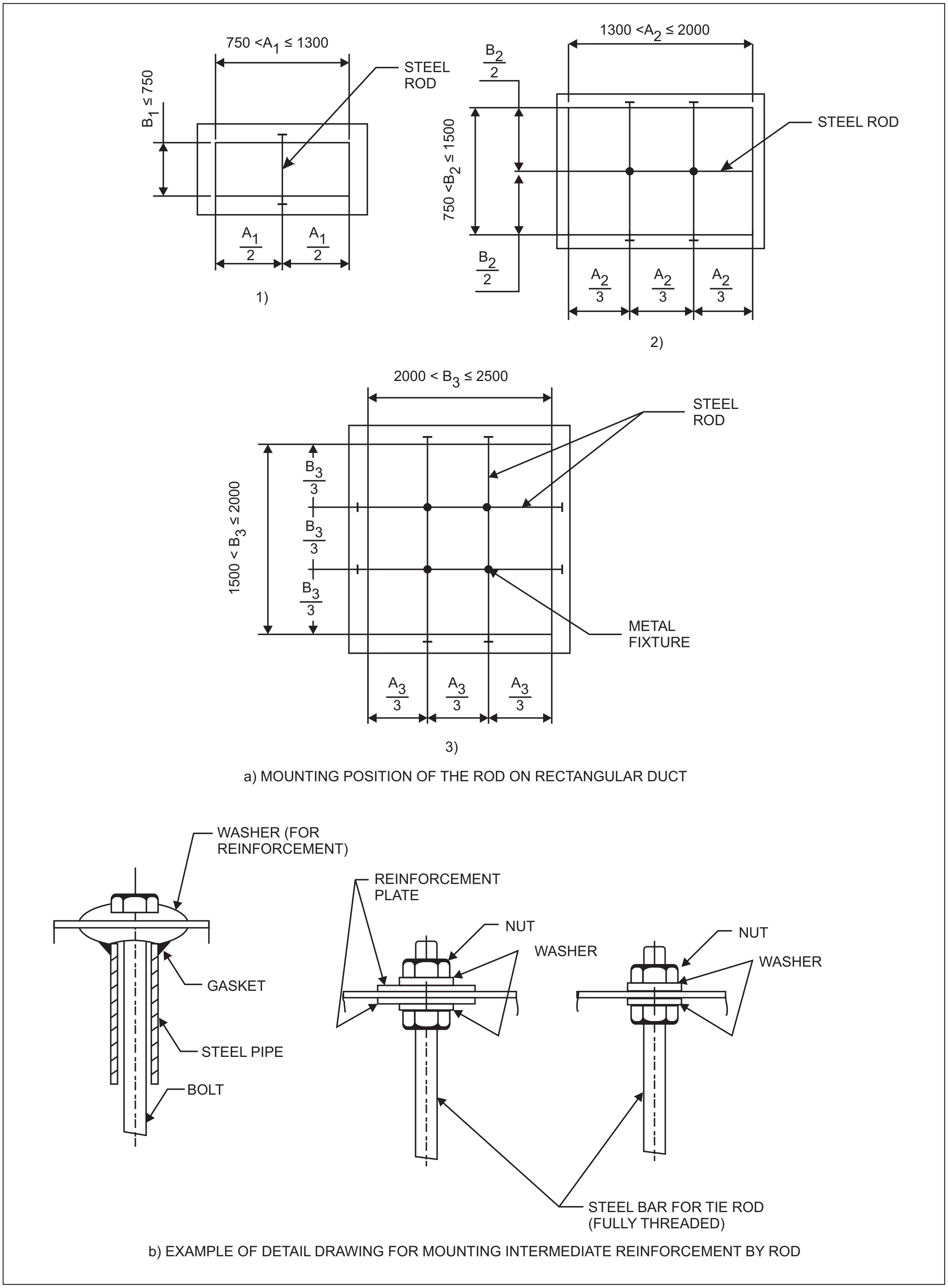


Figure 14: Mounting positions and details of intermediate reinforcement by tie rods

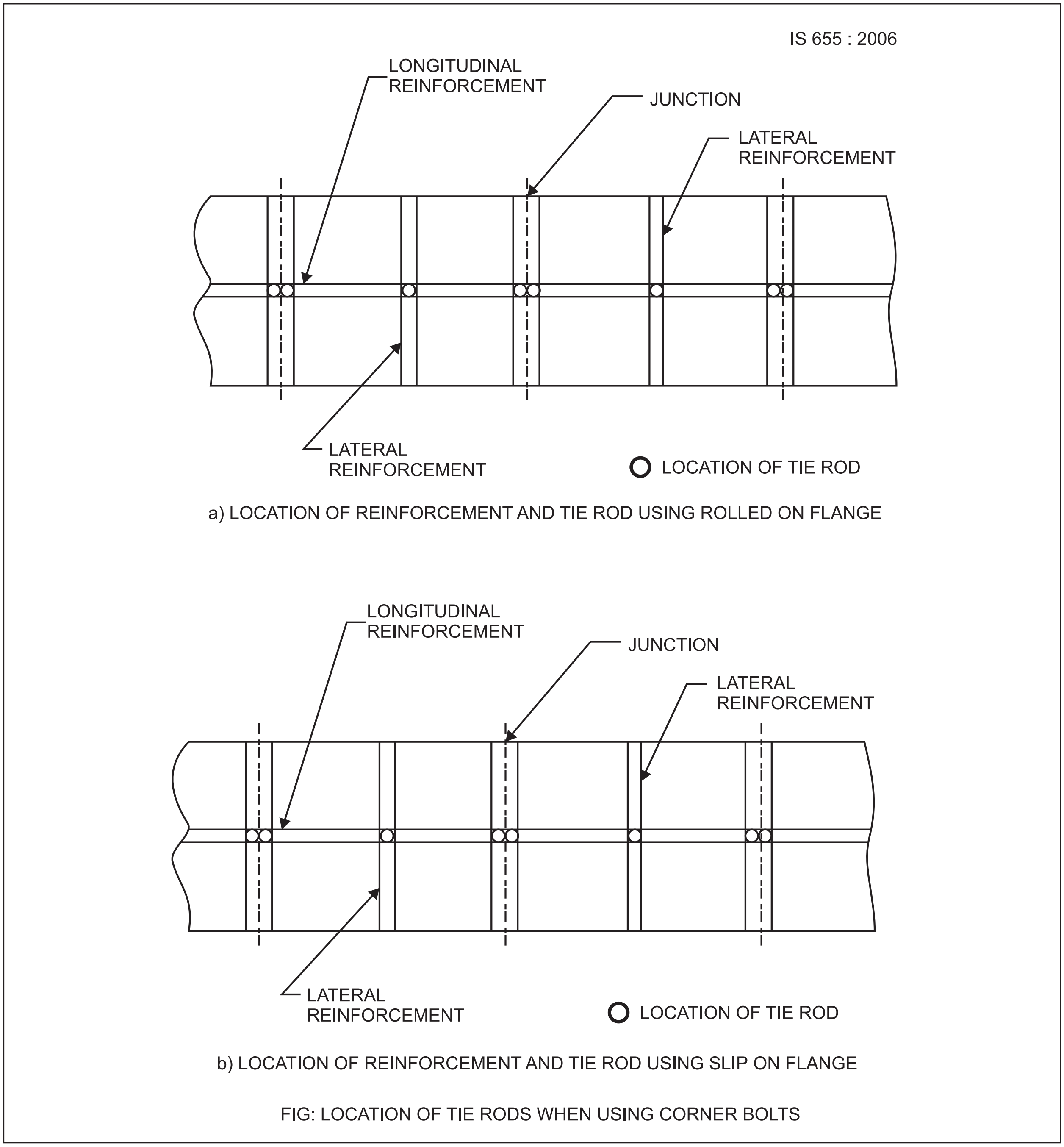


Figure 15: Location of reinforcements and tie rods

Table 18: Tie rod reinforcement details

Pressure Class	*Figure 11* Reference	Duct Dimension Side A, mm	Duct Dimension Side B, mm	Tie Rod Spacing, mm	Tie Rod Nominal Dia, mm
<500 Pa	1	1500 to 2200	<1500	One at center of side A	9
<500 Pa	2	1500 to 2200	1500 to 2200	One each at center of side A and Side B	9
<500 Pa	3	>2200	<1500	Max 1100 C to C	12
<500 Pa	4	>2200	>2200	Max 1100 C to C	12
>500 Pa	1	1200 to 1800	<1200	One at center of side A	12
>500 Pa	2	1200 to 1800	1200 to 1800	One each at center of side A and Side B	12
>500 Pa	3	>1800	<1200	Max 900 C to C	12
>500 Pa	4	>1800	>1800	Max 900 C to C	12

8.3 Round and Spiral Ducts

8.3.1 Round ducts may be fabricated out of GS, CRCA, stainless steel or aluminum. Following are the joining options:

- Continuously welded or brazed. (Not in scope of this Standard.)
- Tack or spot welded. (Not in scope of this Standard.)
- Seam locked.
- Screwed or riveted.

8.3.2 Sheet thickness for round and spiral ducts.

8.3.3 Configuration of longitudinal seam in GS/SS Circular duct with flange joints shall be as per *Figure 16*.

Table 19: Round ducts – sheet thickness

Pressure	Internal Diameter, mm	Sheet Thickness, mm
<500 Pa	<500	0.5
<500 Pa	500 to 630	0.63
>500 Pa	<450	0.8
>500 Pa	450 to 630	1.0

Table 20: Spiral ducts galvanized steel – sheet thickness

Pressure	Internal Diameter, mm	Sheet Thickness, mm
<500 Pa	<450	0.5
<500 Pa	450 to 710	0.63
<500 Pa	710 to 1000	0.8
<500 Pa	>1000	1.0
>500 Pa	<200	0.5
>500 Pa	200 to 560	0.6
>500 Pa	560 to 800	0.8
>500 Pa	800 to 1000	1.0
>500 Pa	>1000	1.2

Table 21: Spiral ducts stainless steel – sheet thickness.

Pressure	Internal Diameter, mm	Sheet Thickness, mm
<500 Pa	<560	0.5
<500 Pa	560 to 800	0.6
<500 Pa	800 to 1000	0.8
<500 Pa	>1000	1.0
>500 Pa	<250	0.5
>500 Pa	250 to 560	0.6
>500 Pa	560 to 800	0.8
>500 Pa	800 to 1000	1.0
>500 Pa	>1000	1.2

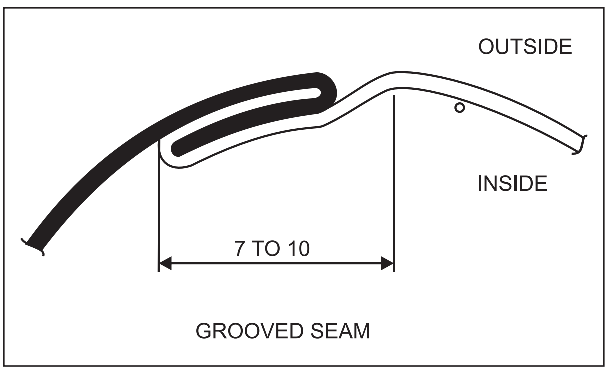


Figure 16: Configuration of longitudinal seam in GS/SS circular duct with flange joints

For circular duct with socket joints, the seam shall be as per *Figure 17*.

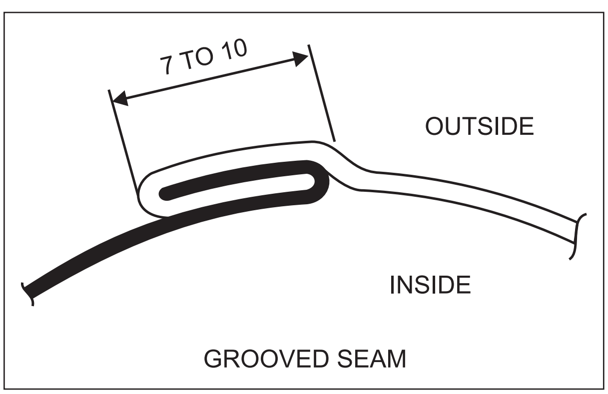


Figure 17: Configuration of longitudinal seam in circular duct with socket joints

For circular spiral duct, seam shall be as per *Figure 18*.

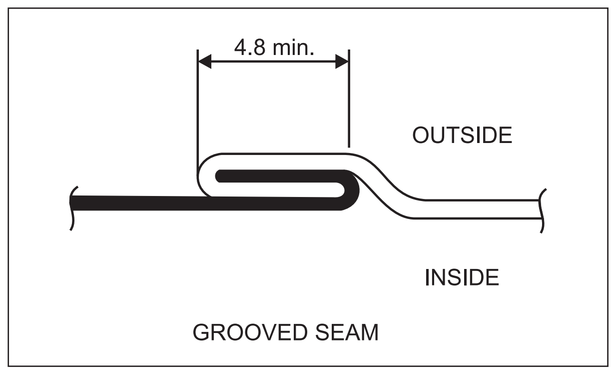


Figure 18: Configuration of longitudinal seam in circular spiral duct

8.3.4 In circular spiral ducts, pitch of the seam shall be as per *Table 22*.

Table 22: Pitch of seam in spiral ducts

Duct Internal Dia, mm	Maximum Pitch of Seam, mm
<100	125
100 to 1250 mm	150

8.3.5 Transverse joints in circular ducts.

8.3.5.1 Flange joints: Joint is illustrated in *Figure 19* and connecting material details shall be as per *Table 23* and *Table 24*.

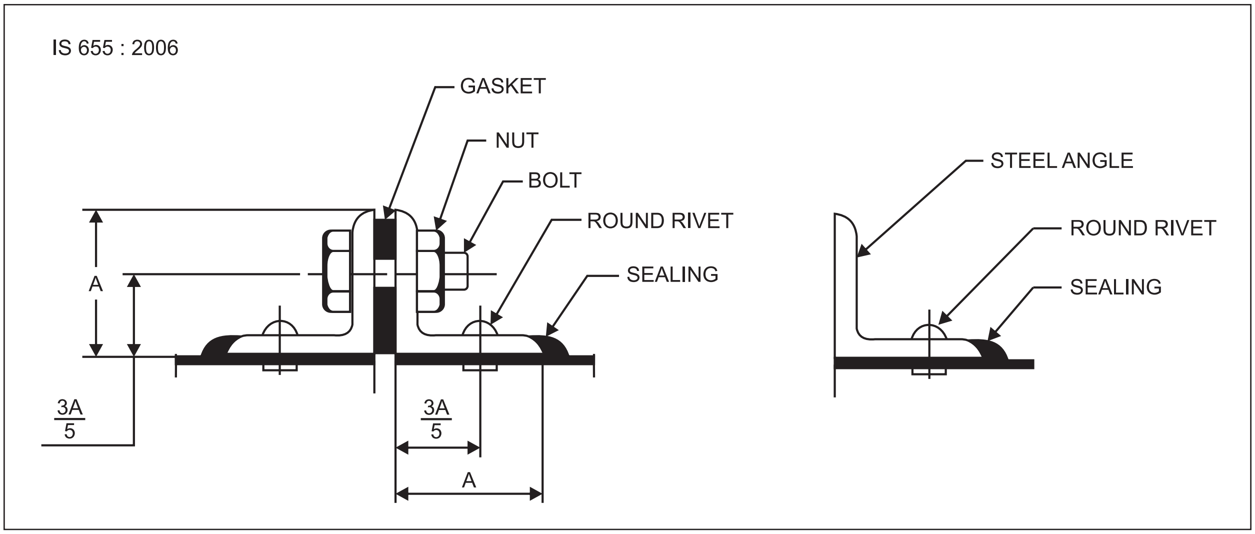


Figure 19: Flange joint in circular duct

Table 23: Connecting materials for flange joint

Internal Dia of Duct, mm	Joint Flange Min Angle Size	Joint Flange Max Spacing, mm	Flange Mounting Rivet Min Nominal Dia, mm	Flange Mounting Rivet Max Spacing, mm	Connecting Bolt Min Nominal Dia, mm	Connecting Bolt Max Spacing, mm
< 700 mm	25x25x3	1820	4.5	65	M8	100
701 mm – 1000 mm	30x30x3	1820	4.5	65	M8	100
1001 mm – 1250 mm	40x40x3	1820	4.5	65	M8	100

Table 24: Number of flange connecting bolts

Internal Diameter of Duct, mm	Minimum Number of Bolts
<160	6
161 to 250	8
251 to 355	12
356 to 500	16
501 to 630	20
631 to 700	24
701 to 1000	32
1001 to 1250	40

8.3.5.2 Socket joints: Socket is externally coated with a sealing compound and then inserted into the straight duct and connected to the duct at periphery by machine screws. Engaged part is wound with two layers of duct tape. Socket joint is illustrated in *Figure 20* and sheet thickness; length of insertion and number of machine screws are given in *Table 25*.

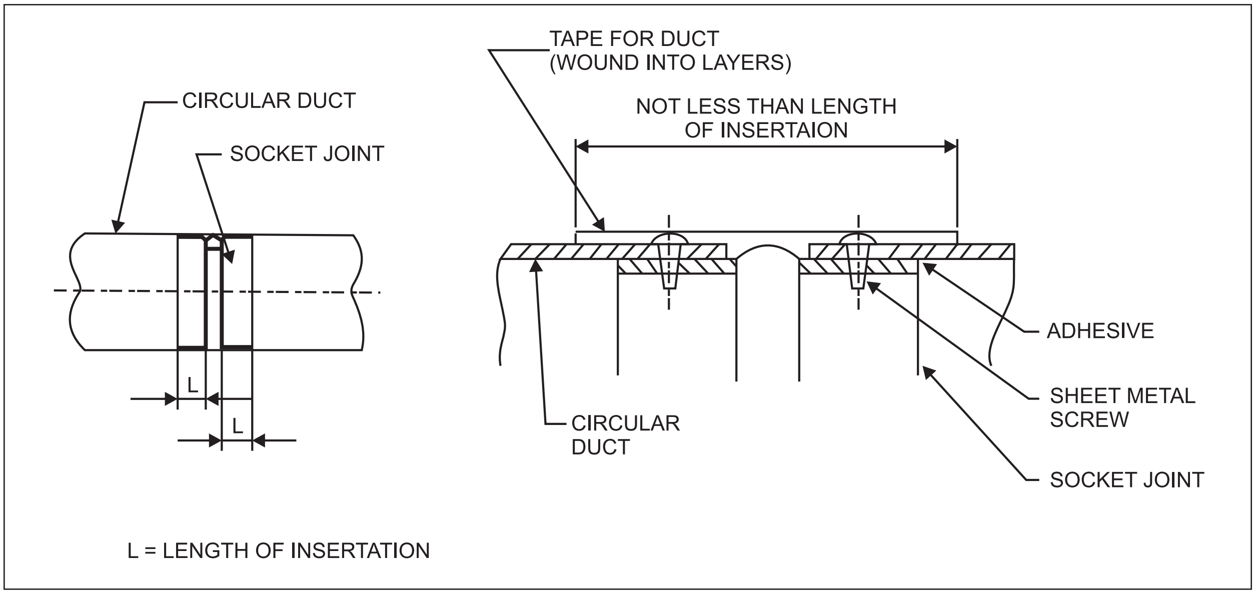


Figure 20: Socket joint in circular duct

Table 25: Details of socket joint for circular ducts

Internal Diameter of Duct, mm	Minimum Sheet Thickness, mm	Minimum Insertion Length, mm	Minimum Number of Bolts on Each Side
<315	0.6	25	4
316 to 560	0.8	50	6
561 to 800	1.0	50	8
801 to 1250	1.2	100	12

Table 26: Reinforcement details of circular duct (GS and SS)

Thickness of Sheet, mm	Min Size of Steel Angle, mm	Minimum Spacing, mm	Nominal Dia of Rivet, mm (Min)	Rivet Spacing, mm (Max)
0.6	25 x 25 x 3	2400	4.5	100
0.8	30 x 30 x 3	1800	4.5	100
1.0	40 x 40 x 3	1800	4.5	100
1.2	40 x 40 x 5	1200	4.5	100

8.3.6 Reinforcement of GS/SS Circular Duct

Reinforcement shall be carried out by means of steel angles as per *Table 26*.

8.4 Flat Oval Ducts

8.4.1 In cases where round ducts are unable to fit in a given space, duct of flat oval shape can be an option. Deflection of flat oval duct under pressure is related to its flat span rather than the overall width.

8.4.2 Flat oval ducts are machine made from round spiral lock seam ducts. They can also be made with longitudinal seams.

8.4.3 Minimum wall thickness for flat oval ducts with longitudinal seams shall be as per *Table 27*.

Table 27: Longitudinal seam flat oval duct for positive pressure up to 1000 Pa

S. No.	Major Dimension – Duct Width, mm	Longitudinal Seam, mm	Sheet Thickness, mm
1	Up to 900 mm	1.00	1.00
2	900 to 1500 mm	1.3 mm	1.3 mm
3	1501 and above	1.60	1.60

8.4.4 Reinforcement for flat sides of longitudinal flat oval duct shall be the same size and spacing interval as specified for rectangular duct of identical dimension.

8.4.5 For spiral flat oval duct, joints and seams shall be similar to those indicated for round ducts. Fittings used in conjunction with spiral seam flat oval duct shall be 0.4 mm thicker than the duct thickness.

8.4.6 Duct construction shall be capable of withstanding 50 % greater pressure than the design pressure

9.0 Duct Supporting and Hanging Systems

9.1 Duct hanging system shall have 3 parts – upper attachment to the building, the hanger and lower attachment to duct.

9.1.1 Upper attachments shall be concrete inserts which are cast into the structure, threaded concrete fasteners which are inserted into the cast slab or structural steel fasteners. Upper attachment method shall be selected with care and a safety factor of 5 is recommended. In case of steel structure careful selection of primary and secondary supporting shall be done on case to case basis.

9.1.2 Hangers shall be strips of galvanized steel or threaded round steel rods. Threaded portion of the rods shall be painted after installation. Alternatively, fully threaded and galvanized rods may be used. Projection of the rod through the bottom support shall not exceed twice the thickness of the securing nut. Alternatively, slotted galvanized brackets attached to the top two bolts of the four-bolt duct connector shall be used. Engineered wire ropes is also an option and can be used subject to proper engineering calculation as per manufacturer recommendations.

9.1.3 Lower attachment is the connection between the hanger and duct section. Fasteners that penetrate the duct shall be sheet metal screws or rivets. All nuts, bolts and washers shall be zinc plated steel. Rivets shall be galvanized or made of magnesium-aluminum alloy.

9.1.4 Where ducts cannot be supported from the ceiling, wall brackets or other suitable support arrangements may be used.

9.1.5 Neoprene or other vibration isolation material of minimum 6 mm thickness shall be inserted between the ducts and the angle iron supports/brackets. Vertical ductwork shall be supported at each floor by suitable structural steel members.

Support details for rectangular, flat oval and circular ducting are given in *Table 28*.

Table 28: Support details for rectangular, flat oval and circular ducts

Larger Side of Rectangular Duct/ Major Axis of Flat Oval duct/ Dia of Circular Duct (mm)	Supporting Angle (mm)	Vertical Rod Diameter (mm)	Maximum Spacing between Supports (mm)
Up to 900	40 x 40 x 3	8	At transverse joints or support length not exceeding 2400 mm
901 to 1500	40 x 40 x 3	10	--- do ---
1501 to 2400	40 x 40 x 6	12	--- do ---
2401 and above	65 x 65 x 5	12	--- do ---

Angle support is illustrated in *Figure 21* and bottom bearer supports for rectangular ducts are shown in *Figure 22, 23,* and *24*. Typical support arrangements for Flat oval ducts are shown in *Figure 25* and *26*. Typical support arrangement for circular ducts are shown in *Figure 27, 28, 29* and *30*.

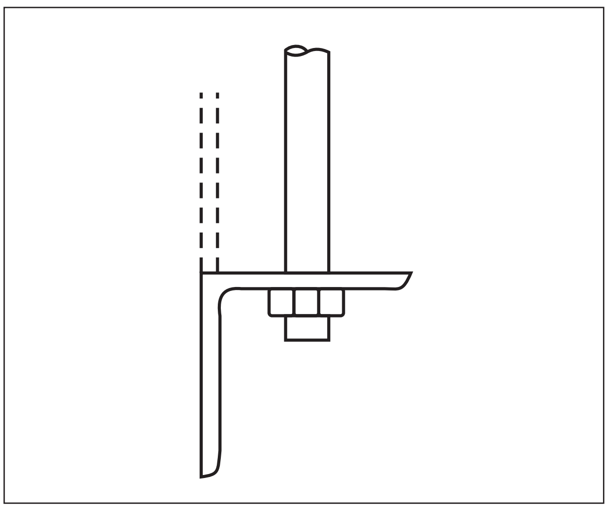


Figure 21: Rolled steel angle

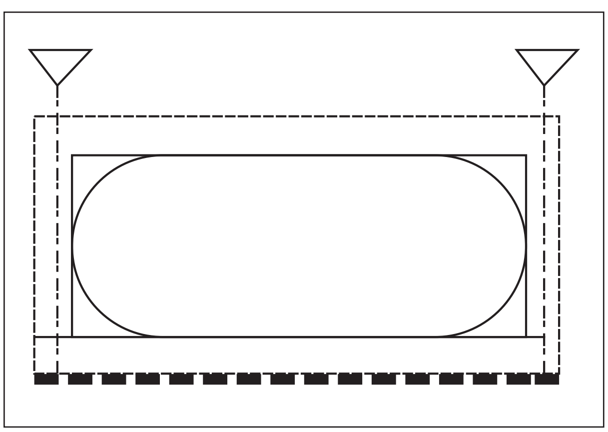


Figure 22: Rolled or profiled bearer

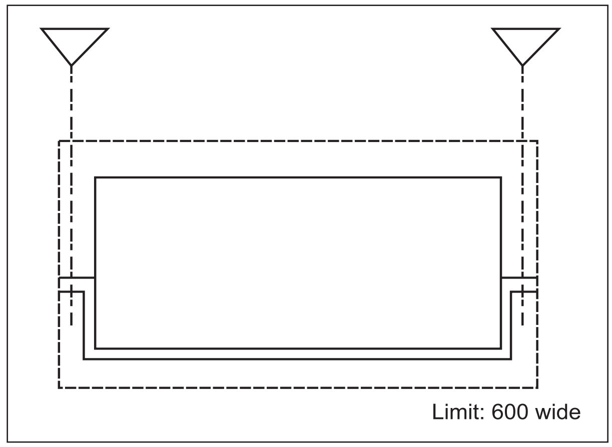


Figure 23: Stirrup, limit 600 wide

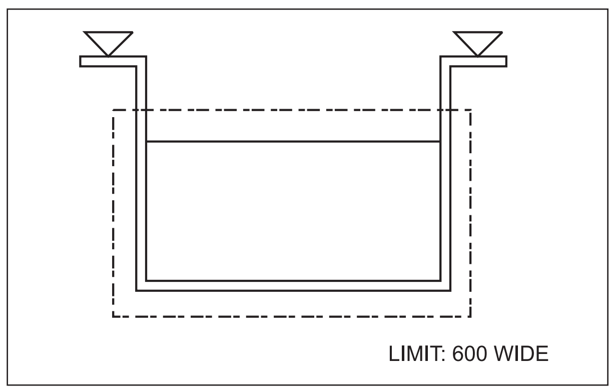


Figure 24: Flat strap hanger, limit: 600 wide

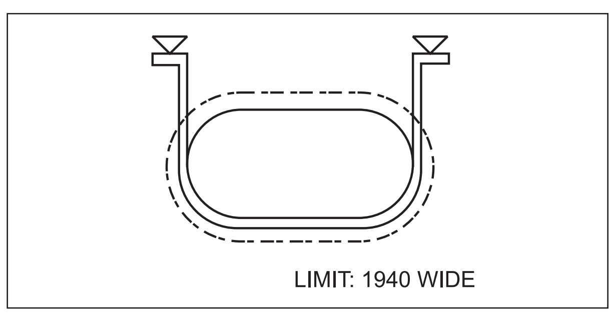


Figure 25: Flat strap hanger, limit: 1940 wide

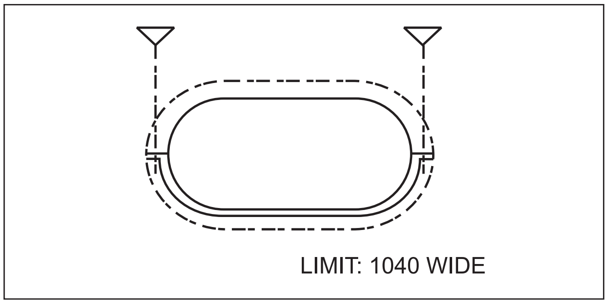


Figure 26: Stirrup, limit 1040 wide

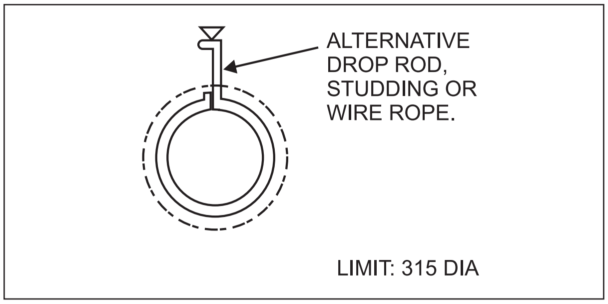


Figure 27: Wrap-round hanger

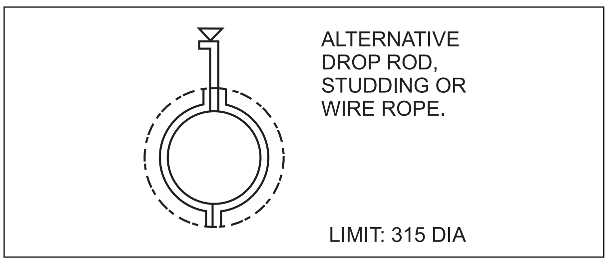


Figure 28: Flat strap hanger and split clips

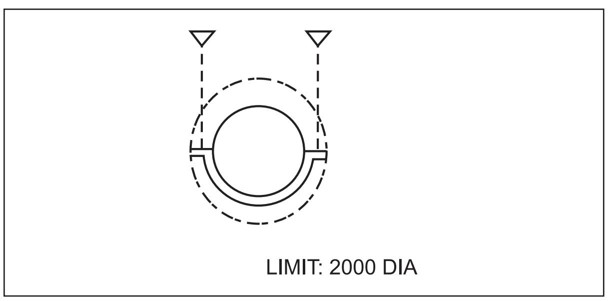


Figure 29: Stirrup, limit 2000 dia.

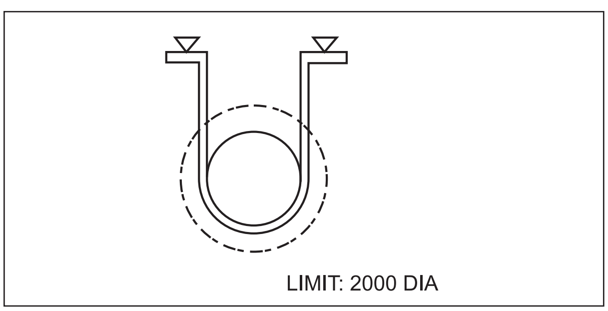


Figure 30: Flat strap hanger, limit: 2000 dia.

10.0 Sealing of Ducts

10.1 Sealing requirements for ducts shall be prescribed by the designer considering the pressure loss and system performance objectives. The seal classes as per *Table 29* may be used as a guideline. Duct sealing shall be carried out by adhesives, liquid sealants, heavy mastic sealants, gaskets, tape systems or a combination of all these.

Table 29: Seal classes and sealing requirements

Sl. No.	Seal Class	Sealing Requirement	Applicable Static Pressure
1	C	Transverse joints only	Up to 500 Pa
2	B	Transverse joints and longitudinal seams	501 to 1000 Pa
3	A	Transverse joints, longitudinal seams and duct wall penetrations	Above 1000 Pa

10.2 Type of seal application shall depend on the position of the duct.

N Type seal shall be applied to four corners of the transverse joint as illustrated in *Figure 31*.

A Type seal shall be applied to longitudinal seams as illustrated in *Figure 32*.

B Type seal shall be applied at the junction of transverse joints. Illustrated in *Figure 33*.

C Type seal shall be used to seal duct penetrations by rivets, tie rods, etc. Illustrated in *Figure 34*.

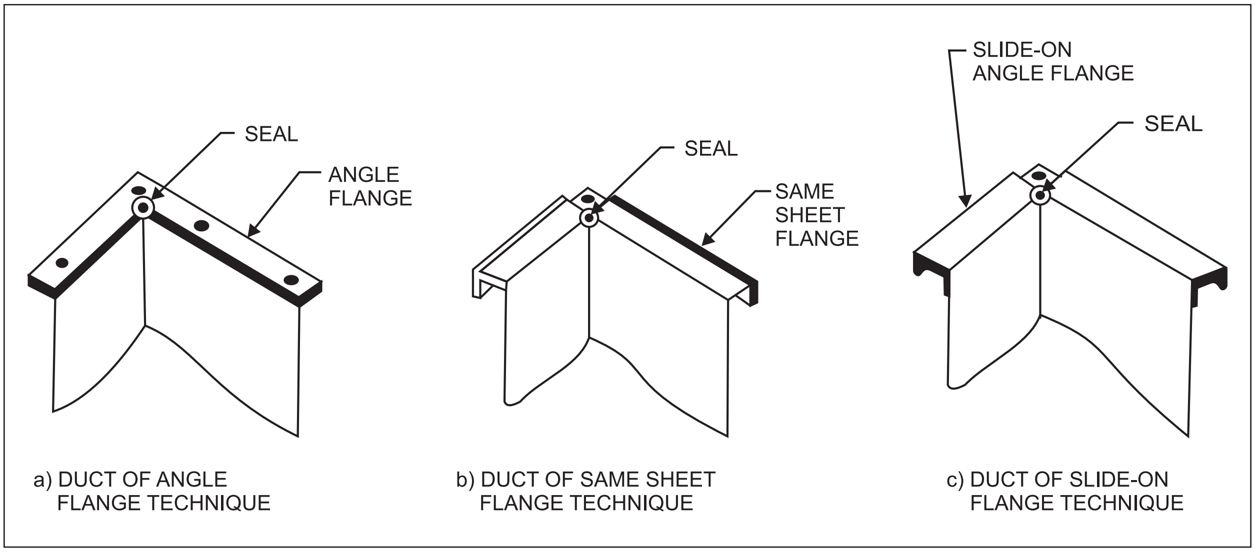


Figure 31: Example of 'N' seal position for transverse joints

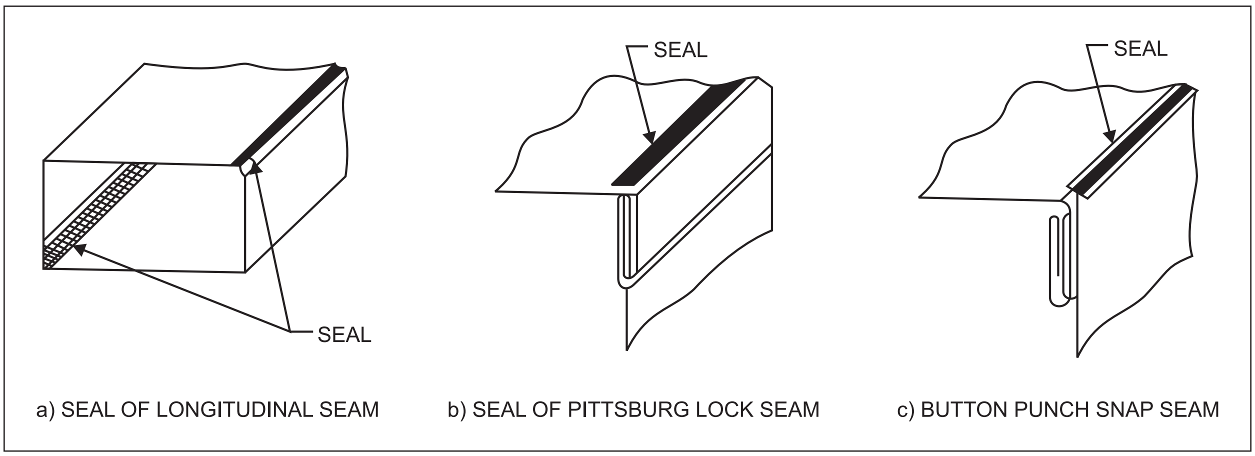


Figure 32: Example of 'A' seal position for longitudinal seams

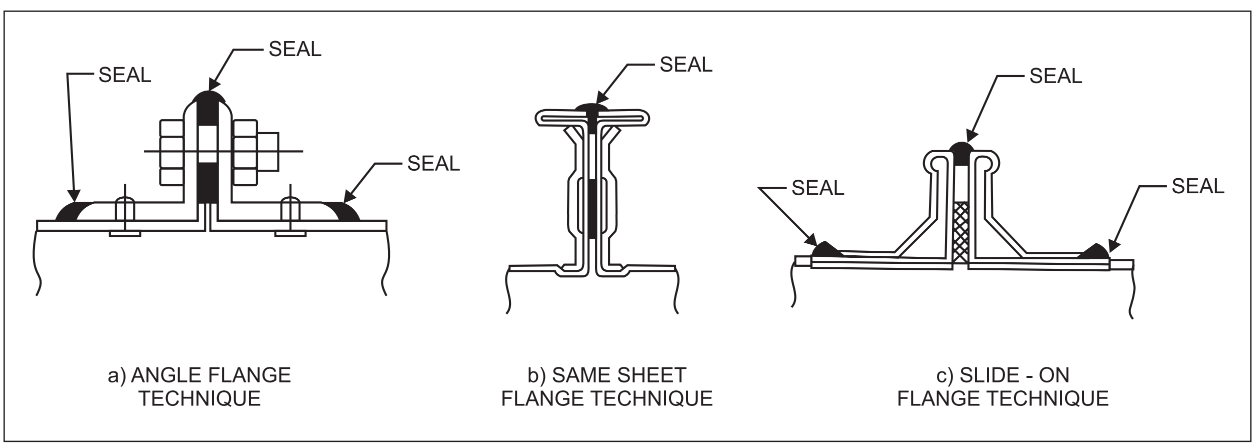


Figure 33: Example of 'B' seal position at transverse joints

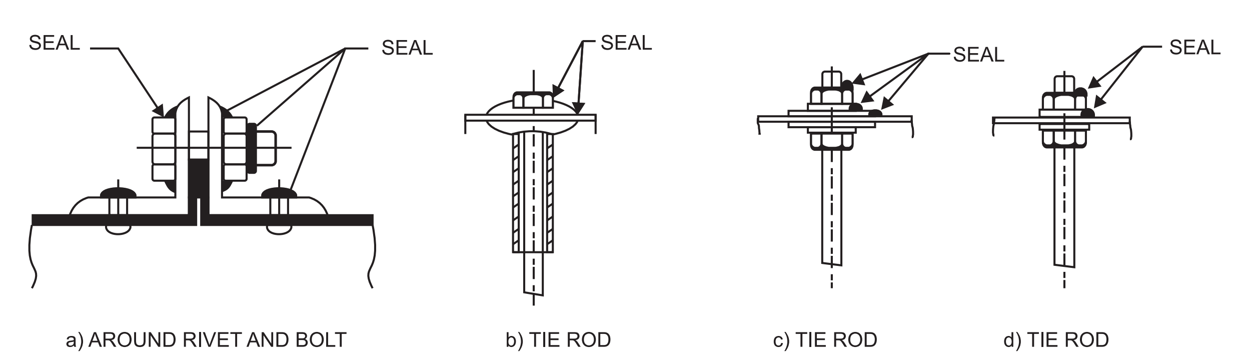


Figure 34: Example of 'C' seal position for duct penetrations

10.3 For details of duct sealing please refer to Informative Annexure A and B.

11.0 Duct Leakages and Leakage Testing

11.1 Leakage control by field testing is not recommended for pressure class up to 750 Pa. For 1000 Pa and above, designer may determine if testing is required and shall clearly specify the portions of the system which shall be tested and the appropriate test methods.

11.2 For details of leakage classes, permissible leakages and leakage testing, please refer Informative Annexure A.

12.0 Duct Identification and Measurement

12.1 All fabricated ducting shall be represented in a Measurement Sheet, which shall show its tag number, dimensions, external surface area and sheet thickness. For ducts fabricated in a factory and dispatched to site, the tag number which shall be shown in the drawing will be the basis of identification and adhesive labels indicating the drawing number and tag number shall be fixed to two opposing sides of each duct section.

12.2 Measurement of ducting shall be on the following basis:

Ductwork shall be measured based on external surface area by measuring the perimeter comprising overall width and depth at the center of each duct section and multiplying the perimeter so obtained by the overall length from flange face to flange face. Plenum shall also be measured on the same basis. Measurements shall be taken before any insulation is applied.

For tapered rectangular ducts, the average width and depth at both the ends shall be considered for calculating the perimeter. For tapered circular ducts, the circumference of the section midway between both ends shall be considered as the perimeter.

For special pieces such as bends, tees, reducers, branches and collars the external surface area shall be the average perimeter multiplied by the centerline distance between the flanges of the duct section.

Informative Annexure C may be referred to for illustrative formulae and worked out examples.

Informative Annexure A: Duct Design

1.0 Duct Design for HVAC Systems

An efficiently designed ductwork system is required to ensure designed comfort conditions while minimizing operating expenses, and maintaining high indoor air quality. When creating an HVAC duct system, certain key requirements need to be met:

Air Flow: The duct system shall effectively transport air at specified rates to designated areas. Proper air flow distribution is essential for achieving uniform temperature control and ventilation throughout the space.

Cost-effectiveness: The duct system shall strike a balance between initial costs, operating expenses, and efficient use of building space. A cost-effective design considers factors such as duct size, materials, and layout to minimize both installation and long-term energy costs.

Noise Reduction: It is crucial to prevent the transmission or generation of excessive noise within the ductwork system. Unwanted noise can disrupt the overall comfort and tranquility of indoor spaces. By appropriately sizing the ducts and properly designing branches and take-offs, noise can be substantially reduced. Additionally, acoustic insulation as well as other noise reduction techniques can be employed.

One of the primary considerations is the trade-off between the upfront cost of the duct system and the energy expenses associated with air distribution. While larger ducts may require a higher initial investment, they tend to result in lower fan energy costs over the system's lifespan. On the other hand, inadequately designed ducts lead to discomfort, increased energy consumption, poor air quality, and elevated noise levels.

2.0 Duct Design Principles

This section covers key concepts necessary for designing duct systems.

2.1 Air Flow Principles

Air flow within HVAC duct system is a result of the pressure differential that exists between two points. This fundamental principle governs the movement of air, as it naturally flows from areas of higher energy or pressure to areas of lower energy.

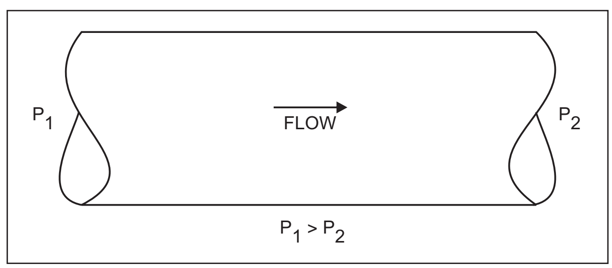


Figure A1: Air flow within duct

The movement of air within ductwork follows three fundamental laws of physics: conservation of mass, conservation of energy, and conservation of momentum.

1. *Conservation of Mass:* The total air mass within a duct system remains constant. This means that the amount of air entering a junction in the ductwork system is equal to the amount

of air leaving the junction. Although ductwork carries incompressible air, neglecting the changes in air density resulting from pressure loss and flow, the law of conservation of mass allows for calculating the duct size based on air velocity using the equation: V2 = (V1*A1)/A2 where V represents velocity and A represents area

2. *Conservation of Energy:* Energy can only be converted from one form to another. As per Bernoulli's equation, pressure loss between two points in a duct system will be equal to the pressure difference between the two points. (Pressure loss)1-2 = (total pressure)1 - (total pressure)2.

3. *Conservation of Momentum:* Newton's law, which states that an object will maintain its state of rest or uniform motion unless acted upon by an external force.

2.2 Velocity, Static and Total Pressure

Air flow within a duct system gives rise to two distinct pressures: static pressure and velocity pressure.

1. *Static pressure:* Static pressure refers to the pressure that propels air to flow within the ducts. It represents the resistance encountered by the air as it moves through the ductwork. Measured in cm of water column (cm-wc), static pressure acts uniformly in all directions and remains unaffected by air velocity.

2. *Velocity pressure:* Velocity pressure arises from the movement of air. It is determined by multiplying the air density by the square of the velocity and dividing the result by 2. The equation for velocity pressure is as follows:

$$VP = 0.5 \times \rho \times v^2$$

Where,
VP represents velocity pressure,
ρ denotes air density,
and v symbolizes the velocity of the air.

3. *Total pressure:* Total pressure is the sum of velocity pressure and static pressure. It is calculated by adding the two pressures algebraically. Mathematically, total pressure can be expressed as: TP = VP + SP, where TP denotes total pressure, VP represents velocity pressure, and SP represents static pressure.

2.3 Air Flow Characteristics in Ducts

In a duct system, the total pressure can be determined by adding the static pressure and the velocity pressure. This means that the total pressure at any given point is the combined effect of both these pressures.

By accurately measuring and analyzing static pressure, velocity pressure,

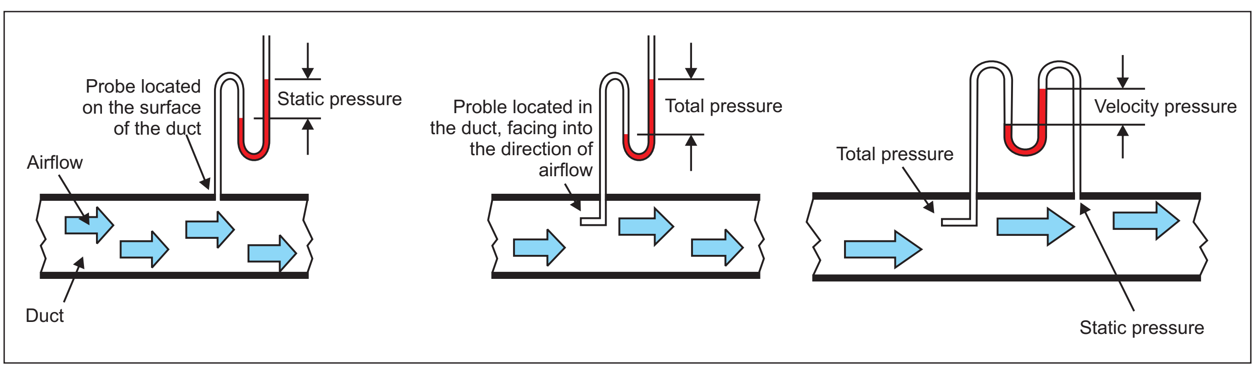


Figure A2: Schematic representation of static, velocity, and total pressure

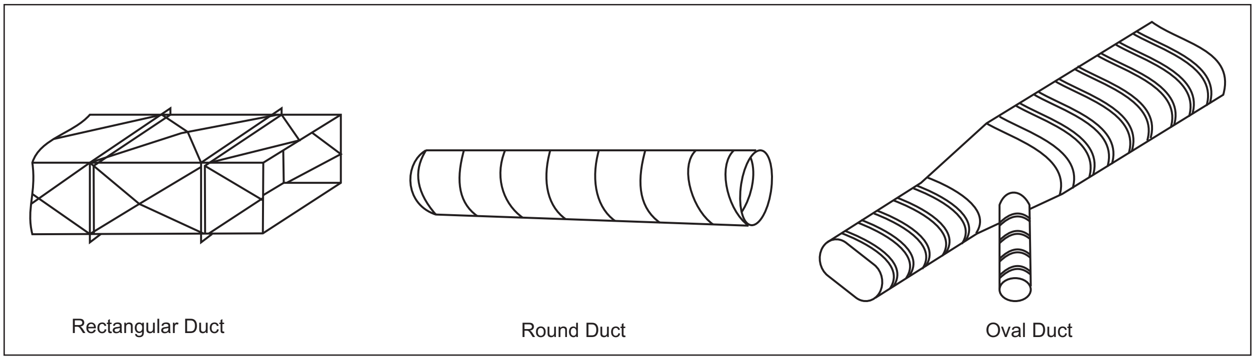


Figure A3: Commonly used duct shapes

and total pressure, one can assess the performance of the duct system and make necessary adjustments to optimize air flow and ensure efficient operation. The velocity pressure (VP) can be calculated by subtracting the static pressure from the total pressure (TP).

Static pressure and velocity pressure are interrelated and can be converted from one to another. The magnitude of each pressure component depends on the local cross-section of the duct, which determines the flow velocity. The following pressure changes occur within the ducts:

1. *Constant cross-sectional areas:* When the duct maintains a constant size, the total pressure loss is equal to the static pressure loss.
2. *Diverging sections (increase in duct size):* In sections where the duct size increases, the velocity pressure decreases. As a result, both the total pressure and static pressure decrease. However, in certain cases, the static pressure may increase due to a phenomenon known as static regain.
3. *Converging sections (decrease in duct size):* Conversely, in sections where the duct size decreases, the velocity pressure increases in the direction of flow. Consequently, both the total pressure and static pressure decrease.

Overall, the total pressure tends to decrease along the air flow path due to the combined effects of frictional losses and turbulence. These losses occur as a result of air friction against the duct walls and the turbulence caused by changes in direction or obstructions within the duct system.

2.4 Duct Shapes

Ducts are commonly employed to transport air in various settings, and they come in different shapes such as round, flat oval, or rectangular. Each shape has its own set of advantages and disadvantages.

2.4.1 Round Ducts

The most efficient shape for conveying moving air in ductwork is the round duct. This is because it offers the least resistance due to its larger cross-sectional area and minimal contact surface compared to square or rectangular ducts. For the same volume of air handled, a round duct requires less material, resulting in cost savings.

To illustrate, a 0.45 m diameter round duct has the same air-carrying capacity as a 0.66 × 0.27 m^2 rectangular duct. The round duct has a cross-sectional area of 0.164 m^2 and a perimeter of 1.432 m, while the rectangular duct has a cross-sectional area of 0.1845 m^2 and a perimeter of 1.889 m. Hence, the rectangular duct requires 32% more material leading to higher costs.

Round ductwork offers several advantages:

- *Lower pressure drops: The round shape minimizes pressure drops, reducing the amount of fan* horsepower needed to move air. This can result in smaller fan sizes as well as energy savings.
- *Reduced surface area and insulation requirements:* The round shape has less surface area, requiring less insulation when externally wrapped.
- *Longer lengths and fewer joints:* Round ducts are available in longer lengths, eliminating costly field joints. Spiral lock-seams add rigidity, allowing lighter gauge fabrication. Spiral ducts have better sealing capabilities and lower leakage compared to rectangular ducts.
- *Improved acoustic performance:* Round and oval ducts have superior acoustic performance due to their curved surfaces, which reduce breakout noise and contain low-frequency sound.
- *Better indoor air quality:* The round shape, absence of corners, and improved air flow reduce the accumulation of dirt and grime inside the ducts, minimizing the potential for bacterial growth and promoting a healthier indoor environment.

However, round ducts have a drawback in that they require more clear height for installation. In spaces with limited vertical clearance, such as furred spaces above suspended ceilings, a 45 cm diameter round duct may not fit. In such cases, a combination of a rectangular plenum and round branches can be a compromise.

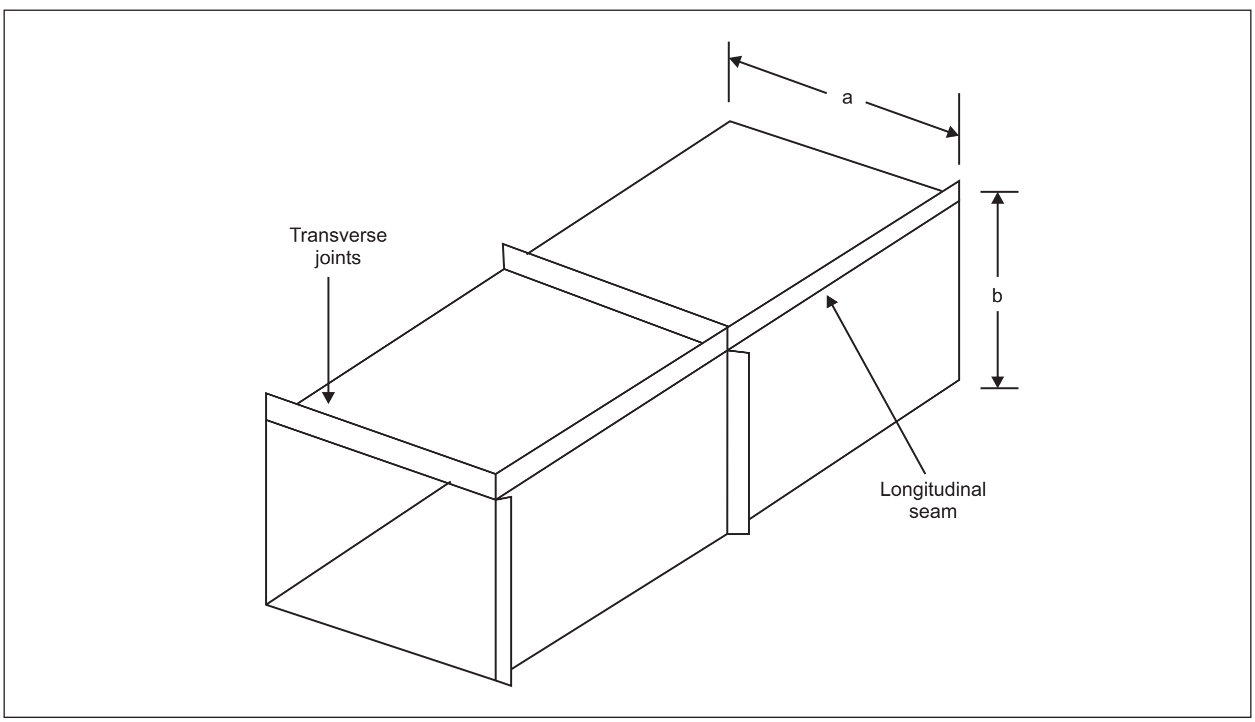


Figure A4: Schematic illustration of rectangular duct

2.4.2 Rectangular Ducts

Rectangular ducts are often preferred for building construction due to their better fit in various spaces. They can easily be installed above ceilings, within walls, and between joists and studs. When using rectangular ducts due to space limitations, it is recommended to maintain a low width-to-height ratio (aspect ratio).

Rectangular ducts with an aspect ratio close to 1 are the most efficient in terms of conveying air. Ducts with aspect ratios above 4 are less efficient, leading to greater pressure losses and material usage. Aspect ratios ranging from 2 to 3 strike a balance between added duct cost, fan energy, and headroom savings.

However, rectangular ducts have certain disadvantages:

1. *Higher pressure drop*: Rectangular ducts create higher pressure drops compared to round ducts.
2. *Increased material usage*: Rectangular ducts require more metal by weight to achieve the same air-flow rate as round ducts.
3. *Limited joint length*: The length of joints in rectangular ducts is restricted to the widths of the sheets available for fabrication
4. *Difficult sealing*: Sealing rectangular duct joints can be more challenging compared to other shapes.
5. *Noise transmission*: Rectangular ducts with high aspect ratios can transmit excessive noise if not properly supported.

It is important to consider these factors when choosing between square, rectangular, and round ducts to ensure efficient air flow, minimize pressure losses, and meet specific space requirements.

2.4.3 Flat Oval Ducts

Flat oval ducts offer the advantage of smaller height requirements compared to round ducts while still retaining many of the benefits of round ducts. However, there are some disadvantages associated with flat oval ducts:

1. *Handling and shipping challenges*: Larger sizes of flat oval ducts can be more difficult to handle and transport, requiring extra care during the logistics process.
2. *Round shape tendency*: Flat oval ducts have a tendency to become more rounded under pressure, which can affect their performance and overall efficiency.
3. *Assembly difficulties*: Assembling oval slip joints in flat oval ducts, particularly in cases of large aspect ratios, can pose challenges in terms of fitting and joining the duct sections effectively.

2.5 Equivalent Diameter of Ducts

As round and rectangular ducts are commonly used in air conditioning systems, it is not uncommon for contractors to consider substituting one for the other during construction

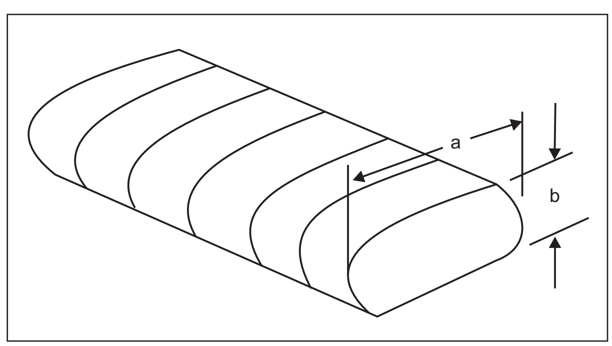


Figure A5: Schematic illustration of flat oval duct or system modifications. However, it is important to note that directly substituting the cross-sectional areas of round and rectangular ducts can have a negative impact on the performance of the air distribution system.

To address this issue, the concept of equivalent diameter (D_{eq}) is introduced. The equivalent diameter represents the diameter of a circular duct that would produce the same pressure drop at the same air flow as the rectangular duct. This allows for a proper comparison and conversion between round and rectangular ducts.

Following are the equations that can be utilized to convert between rectangular, flat oval, and round ducts, ensuring accurate sizing and performance. By employing these conversion equations, contractors can effectively navigate between different duct shapes, ensuring optimal air distribution system performance for the specific project requirements.

Rectangular ducts : $D_{eq} = \dfrac{1.30\,(ab)^{0.625}}{(a+b)^{0.250}}$

Flat oval ducts : $D_{eq} = \dfrac{1.55\,A^{0.625}}{p^{0.250}}$

$$A = \frac{\pi b^2}{4} + b(a-b)$$

$$A = \pi b + 2(a-b)$$

Where,

- P represents the perimeter of the oval duct, measured in m
- A denotes the cross-sectional area of the oval duct, measured in m²
- a corresponds to the length of the major axis of the oval duct, measured in m
- b signifies the length of the minor axis of the oval duct, also measured in m.

2.5.1 Equivalent Diameter vs. Equivalent Cross-sectional Area Approach

When comparing different duct options for a given air flow rate, two approaches can be used: the equivalent diameter approach and the equivalent cross-sectional area approach.

2.5.1.1 Equivalent Diameter Approach

For a given air flow rate of 3.5 m³/s, consider a 76 cm diameter round duct as the reference. To determine the dimensions of equivalent rectangular and flat oval ducts, we need to use the equations mentioned earlier. By fixing the minor axis at 0.40 m and applying the equations, we find that the equivalent rectangular duct dimensions are 0.40 × 1.29 m², while the equivalent flat oval duct dimensions are 0.40 x 1.34 m². Using this approach, we can conclude that all three duct options 0.76 m round, 0.40 × 1.29 m² rectangular, and 0.40 x 1.34 m² flat oval will result in the same friction loss for the given air flow rate of 3.5 m³/s. *Table A1* provides a summary of the equivalent diameter approach and its findings.

Table A1: Equivalent diameter approach

Duct Shape	Area (m²)	Velocity (m/s)	Friction Loss mm-wc/100 m
Round	π*(0.76)²/4	776.22	250
Flat Oval	0.40 x 1.34	691.38	250
Rectangular	0.40 x 1.29	691.89	250

Based on the above analysis, it can be observed that all three duct options – round, rectangular, and oval – exhibit the same friction loss factors.

Table A2: Equivalent cross-sectional area approach

Duct Shape	Air Flow (Q) m^3/s	Area A (m^2)	Velocity Q/A (m/s)	Friction Loss mm-wc/100 m
Round	3.54	$\pi*(0.76)^2/4$	7.76	254
Flat Oval	3.54	0.40×1.34	7.69	305
Rectangular	3.54	0.40×1.29	7.79	356

This implies that they have equivalent pressure drop per unit length. It is important to note that rectangular and oval ducts will always have larger cross-sectional areas compared to round ducts with the same equivalent diameter.

2.5.1.2 Equivalent Cross-sectional Area Approach

Under this approach and using the same data as in 2.5.1.1,

Cross-sectional area of round duct:

Diameter of the duct = 0.76 cm

Cross-sectional area of the 76 cm diameter duct = 3.14*0.76*0.76/4 = 0.453 m^2

Cross-sectional area of rectangular duct:

A = a*b

Assuming a minor axis 'b' of 0.40 m

The major axis 'a' will be: 0.453/0.40 = 1.133 m

Cross-sectional area of oval duct:

Assuming a minor axis 'b' of 0.40 m

The major axis 'a' will be = 1.21 m.

Velocity in the duct can be calculated using the formula:

$$v = Q / A$$

Where:

v = air velocity in meter per second (m/s)

Q = air flow through the duct in cubic meter per second (m^3/s)

A = cross-section of the duct in m^2

Friction loss is estimated from the duct friction charts based on the air flow rate and velocity.

Table A2 provides a summary of the equivalent cross-sectional area approach, including the calculated velocities and friction losses based on the given data. It is evident that as the velocity increases and the cross-sectional area decreases, the frictional loss increases. This observation highlights the inverse relationship between cross-sectional area and frictional loss in duct systems.

Using the equivalent diameter approach ensures that the pressure drop remains constant, but it leads to larger cross-sectional areas for rectangular and oval ducts in comparison to round ducts. On the other hand, the equivalent area approach maintains the same cross-sectional area but results in increased pressure drop along the duct run.

2.6 Duct Sizing

2.6.1 Equal Friction Method

The equal friction method is widely used for sizing ducts in HVAC systems. The equal friction method involves designing the ducts based on a constant 'friction rate', which represents the average pressure drop per unit length of duct length in the system. A typical friction rate for a well-designed system is 8.29 mm per 100 m of duct length.

By following the equal friction method, duct sizes are optimized to achieve a balanced pressure drop throughout the system. This approach allows for efficient air flow and helps in reducing fan energy consumption. It is important to note that using reduced friction rates can increase duct sizes but also reduce pressure drop and consequently fan energy. For example, designing the duct for a 4.49 mm pressure drop per 100 m, (as against 8.29 mm per 100 m) can increase duct size and costs by 16%, but it also cuts the portion of total pressure drop in the ductwork by 48%, resulting in energy savings of 16% to 22%.

Please refer to the chart and calculation tools available to determine the appropriate duct sizes based on the equal friction method for the specific HVAC system design.

Procedure

To apply the equal friction method, the following procedure is followed (refer *Figure A6*):

a. Determine the maximum air velocity in the main duct after the fan outlet.

b. Using a duct slide rule, duct calculator, or friction rate chart, find the relationship between duct size and air flow, based on the determined velocity. This will help determine the appropriate duct diameter. (Refer *Table A3*)

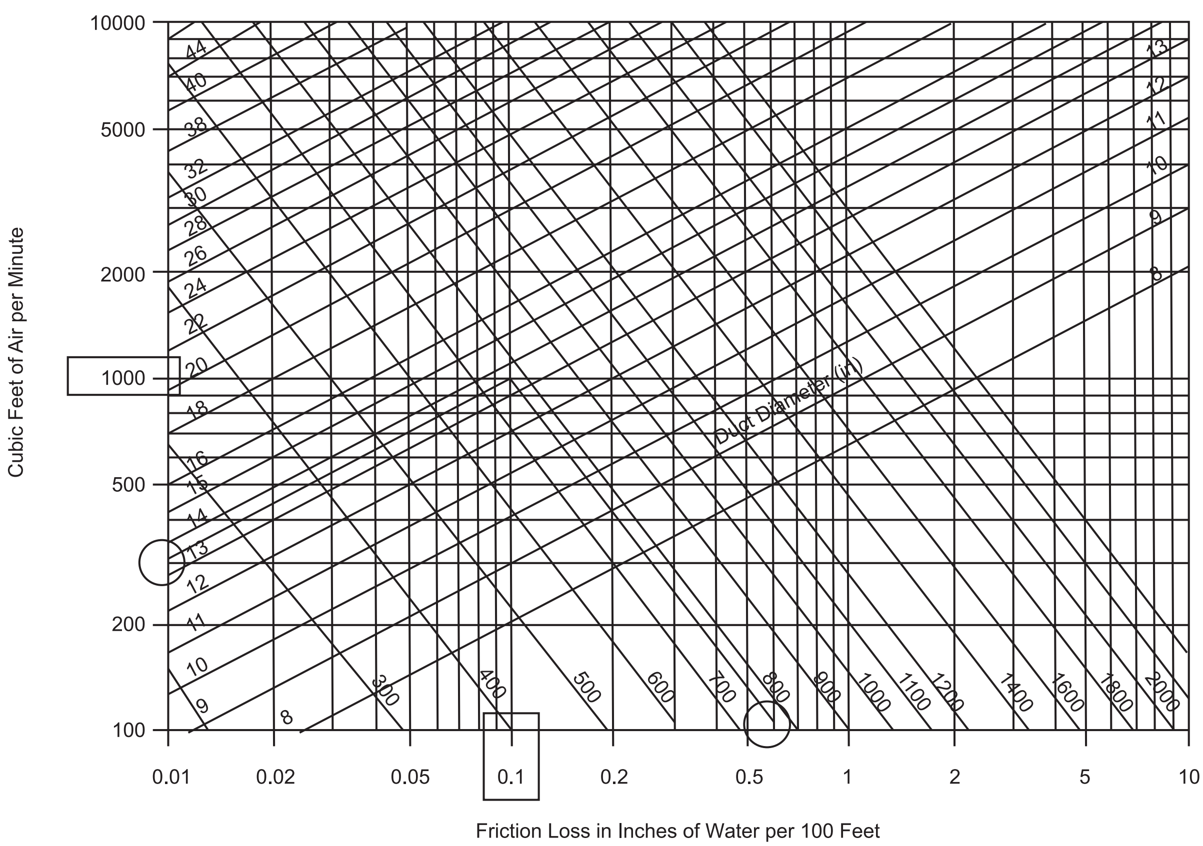


Fig. A6: Friction of Air in Straight Duct.

Source: Carrier duct design; Chart-friction loss for round duct. part 2. Air Distribution, Chapter2, Air Duct Design.

Figure A6: Friction of air in straight duct

Source: Carrier Duct Design; Chart: Friction loss for round duct; Part 2. Air Distribution, Chapter2, Air Duct Design

c. Once the friction rate is obtained from the previous step, use the same value to determine the diameters for all other sections of the ductwork.

d. Total friction loss (of the system) is obtained by multiplying friction loss per unit length by equivalent length of the duct work.

Example

Determine the diameter and the velocity of air through a duct carrying 0.471 m^3/s of air. Assume a friction loss of 8.29 mm of wc per 100 m of duct length. Determine the pressure drop and velocity on the selected duct size.

Solution

Based on the information provided, it can be observed that the 8.29 mm per 100 m friction line intersects the 0.471 m^3/s line at a round duct diameter of 0.343 m. However, since the next available round duct size is 0.356 m, it is recommended to select the 0.356 m diameter for this scenario.

When using the 0.356 m round duct, the pressure loss will be approximately 7.49 mm per 100 m, and the velocity of air through the duct will be approximately 4.1 m/s. Please note that the chart depicted above is approximate and may not be accurately scaled.

To ensure accurate duct sizing, there are several commercially available duct calculator tools, often referred to as ductulators. These tools provide an easy and precise way to size ducts based on the desired flow rate, friction loss, or velocity. It is recommended to consult such tools and adhere to the provided friction loss guidelines when sizing ducts for optimal performance.

Table A3: Friction loss guidelines for sizing ducts

System Type	Friction Loss in mm per 100 m of Duct
Supply run-out	6.67
Supply trunk or plenum	4.17
Return Duct	1.67

2.6.1.1 Advantages of the Equal Friction Method

The equal friction method offers has the following advantages:

i) Simplicity: This method is simple and easy to understand.

ii) Noise Reduction: By automatically reducing air velocities along the duct system, the equal friction method helps mitigate potential noise generated by the air flow.

iii) The equal friction method is well-suited for constant volume air systems where a consistent air flow rate is desired. It ensures that the ducts are sized appropriately to maintain the desired air volume throughout the system.

2.6.1.2 Disadvantages of the Equal Friction Method

i) Pressure drops in different duct branches will be different (based on their lengths). For equalizing pressure drop across branches, balancing dampers are needed.

ii) Not suitable for VAV systems where terminal units need pressure-independent control.

iii) Cannot easily be adapted to changes in layout.

2.6.2 Velocity Reduction Method

The velocity reduction method is employed to size ducts by adjusting the air velocity in both

Table A4: Recommended velocity limits

Type of Duct	Comfort System Velocity (m/s)	Industrial Systems Velocity (m/s)	High Speed System Velocity (m/s)
Main Duct	5-7	7-12	10-18
Main Branch Duct	3-5	5-8	6-12
Round Duct	2-3	3-4	4-5

the main and branch ducts. The following steps are involved:

Determine suitable velocity limits for the main and branch ducts based on established guidelines. *Table A4* presents commonly used velocity ranges:

- Main Duct Velocity: 3-4 m/s
- Branch Duct Velocity: 2-3 m/s

Calculate the diameters of the main and branch ducts using the given air flow rates and velocities. The velocity in the duct can be determined using the formula:

$$A = Q / V$$

Where:

- A represents the duct area in square meter (m^2)
- Q is the air flow rate in cubic meter per second (m^3/s)
- V denotes the air velocity in meter per second (m/s)

With the obtained velocities and duct dimensions from the previous step, determine the frictional pressure drop for both the main and branch ducts by referring to the provided friction chart.

2.6.3 Static Regain Method

Static regain is a duct sizing technique that involves converting velocity pressure (VP) into static pressure (SP). As discussed in previous sections, the total pressure (TP) in a duct system is the sum of static pressure and velocity pressure (TP = SP + VP). When the TP is given, a higher VP (usually resulting from smaller duct areas) corresponds to a lower SP. SP is responsible for air flow within the duct, while VP arises from the movement of air. Therefore, it is desirable to have a higher static pressure relative to the total pressure generated by the fan.

The static regain method of duct sizing relies on Bernoulli's equation, which postulates that a decrease in velocity leads to the conversion of velocity pressure into static pressure. This approach systematically reduces duct velocities along the distribution layout, allowing velocity pressure to transform into static pressure. As a result, the static pressure offsets friction losses in subsequent duct sections. Consequently, the static pressure remains consistent near all branches and diffusers, minimizing the need for system balancing during design.

2.6.3.1 Advantages of Static Regain Method

i) *Uniform Static Pressure:* In a duct system designed using the Static Regain Method, all duct sections maintain a consistent static pressure at branches and outlets. This uniform pressure distribution simplifies the selection of outlets and ensures the correct air quantity is delivered to each outlet. By eliminating pressure variations, this method helps achieve desired air distribution throughout the system.

ii) *Balanced System:* The Static Regain Method ensures that losses and gains in the duct system are proportional to the velocities. This feature makes it particularly suitable for designing variable air volume (VAV) systems where air flow requirements vary. By maintaining a balanced system, the method promotes optimal air distribution, reduces pressure fluctuations, and facilitates efficient operation of VAV systems.

iii) *Material Efficiency and Noise Reduction:* The Static Regain Method requires less quantity of sheet metal compared to other duct sizing approaches. By systematically reducing velocities and converting velocity pressure into static pressure, the method minimizes the need for oversized ducts. This not only reduces material costs but also contributes to a quieter operation by mitigating the potential for air movement noise.

2.6.3.2 Disadvantages of Static Regain Method.

i) *Potential Velocity Reduction:* In duct networks where there is a significant pressure drop in a section near the fan outlet; the velocity may decrease to a minimum level within a few sections. As a result, all downstream ductwork would be sized based on this minimum velocity, potentially leading to inefficient air flow distribution. It is important to carefully assess the pressure drop and velocity distribution to avoid such limitations.

ii) *Risk of Oversized Ducts:* When specifying a very low minimum velocity for the system, there is a possibility that ducts at the end of long branch runs may become excessively large. The Static Regain Method primarily focuses on balancing static pressure and does not directly account for the total mechanical energy supplied by the fan. Consequently, without proper consideration, oversized ducts may be present at the ends of lengthy branch sections, which could lead to unnecessary material usage and increased costs.

2.7 Pressure Losses in Duct System

2.7.1 The resistance encountered by air flow within ductwork can be attributed to three main factors:

i) *Friction Loss:* Friction loss occurs due to various factors such as the size of the duct, the roughness of its walls, and the velocity of the air. As the air flows through the duct, it encounters resistance, resulting in a loss of pressure and energy.

ii) *Dynamic Loss:* Dynamic loss refers to the resistance caused by changes in air velocity and direction. When the air flow undergoes changes in speed or encounters bends, turns, or transitions within the duct system, additional pressure losses occur.

iii) *Equipment Pressure Loss:* Equipment pressure loss is the resistance to air flow caused by components integrated into the duct system, including diffusers, coils, filters, and other devices. These components introduce additional obstacles to the air flow, leading to pressure drops.

2.7.1.1 Duct Friction Losses

Frictional resistance is an inherent characteristic of any duct system, impeding the smooth movement of air. The extent of this resistance is influenced by several factors, including:

a) *Velocity of air:* The speed at which air flows through the duct affects the level of frictional resistance encountered. Higher velocities result in increased friction.

b) *Size of duct:* The diameter of the duct also plays a role in determining the frictional resistance. Smaller diameter ducts tend to have higher levels of friction compared to larger ones.

c) *Roughness of the material:* The texture or roughness of the duct's inner surface affects the amount of frictional resistance experienced by the air flow. Smoother surfaces result in lower friction.

d) *Length of the duct:* The overall length of the duct impacts the total frictional resistance encountered. Longer ducts tend to have higher levels of friction.

It is important to note that the frictional resistance of a supply duct is directly proportional to the square of the velocity ratio. This means that as the velocity increases, the frictional resistance grows exponentially. For example, if two supply ducts carry the same air volume of 2.4 m^3/s but at velocities of 5 m/s and 10 m/s respectively, the second duct will have four times the frictional resistance per unit length of duct $(10/5)^2$. Additionally, the power required to overcome this increased frictional resistance will be eight times greater $(10/5)^3$.

Frictional loss per unit length, may be calculated from *Figure A7*.

Example

• For a 100 m length of a 0.254 m diameter duct with an air flow rate of 0.19 m^3/s, the friction loss would be estimated at 7.49 mm of water column.

• Similarly, for a 100 m length of a 0.254 m diameter duct carrying 0.28 m^3/s, the friction loss would be approximately 16.66 mm of water column.

• If we consider a longer duct length of 200 m length of a 0.254 m diameter duct carrying 0.28 m^3/s, we can estimate the friction loss by multiplying the friction loss per 100 m (16.66 mm of water column) by the length ratio: $(200/100) \times 16.66 = 33.32$ mm of water column.

It is important to note that these estimates are approximations and can vary depending on specific conditions and factors within the duct system.

Worked out Example

Calculate the friction head loss in mm of water column for moving 9 m^3/s of air through 200 m of a 0.86 m diameter duct.

Solution

According to *Figure A7*, the friction loss for a 0.86 m duct at an air flow rate of 9 m^3/s is 24.99 mm of water column per 100 m of duct. Therefore, the total loss can be calculated by multiplying the friction loss by the length: (24.99 mm of wc/100 m duct) $\times$ 200 m of duct = 49.98 mm of water column.

2.7.2 Duct Fitting Dynamic Losses

Dynamic losses in duct systems occur due to various

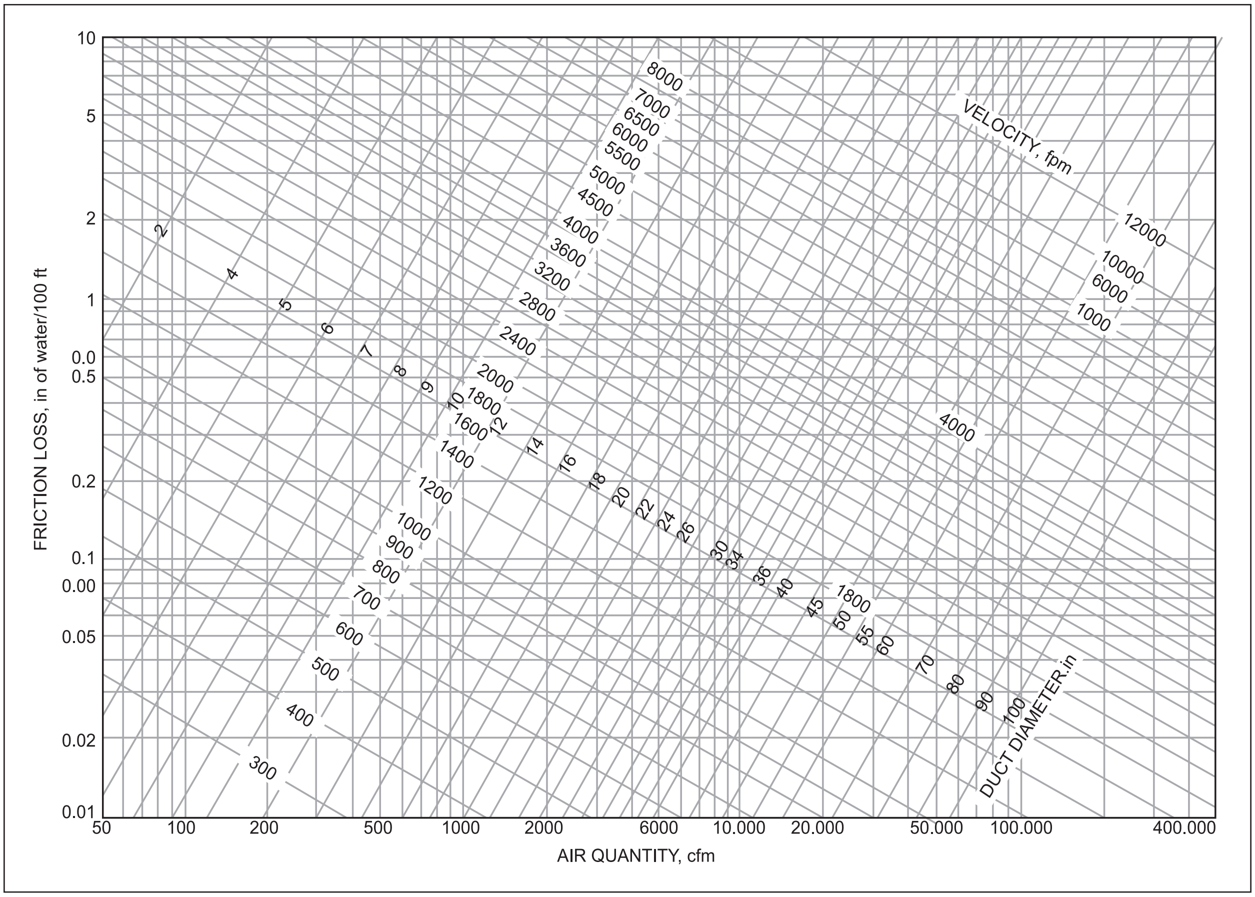


Figure A7: Equivalent area and duct class of rectangular duct for equal friction
Source: Carrier Air-Conditioning Manual; 1960

factors, including changes in air direction, restrictions or obstructions in the air flow, and variations in air velocity caused by changes in duct size.

• The change in air direction from elbows, offsets, and take-offs

• Restrictions or obstructions in the air stream such as dampers, filters, and coils

• Changes in air velocity because of changes in duct size.

Note: The computation of energy losses associated with different types of fittings is based on information provided in the ASHRAE Handbook of Fundamentals or can be determined using loss-coefficient charts developed by the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).

The total pressure loss resulting from friction through fittings is directly proportional to the velocity pressure (VP). The specific constant of proportionality depends on the type of fitting. Therefore, the total pressure loss caused by friction through a fitting can be calculated using the following equation:

$$F_{fitting} = K * VP$$

$$F_{fitting} = K\left(\frac{V}{4005}\right)^2$$

The dynamic loss coefficient (K) is determined through empirical measurements conducted by fitting manufacturers. To simplify calculations, an 'equivalent length' method is often employed. This method involves assigning a numerical value to a fitting, such as a T-wye or elbow, which represents the length of straight duct that would cause an equal pressure-drop. For instance, a T-wye may be assigned an equivalent length of 3 m, while a ninety-degree elbow might have an equivalent length of 4 m. In the case of a round start collar connected to a sheet metal supply plenum, the equivalent lengths can reach 9 m or more. These additional lengths are then added to the straight length of the duct to determine the overall effective length.

2.7.2.1 The Concept of Duct Equivalent Length

Equivalent length refers to the length of straight duct that would create the same level of air resistance as a specific fitting. To illustrate this concept, consider a blower duct system depicted in the accompanying diagram. Static pressure measurements can be taken before (P1) and after (P2) the elbow, and a third gauge (P3) can be positioned anywhere along the duct. In this scenario, the duct system consists of 170 mm dia. round pipe, including the elbow.

When a flow rate of 0.118 m³/s is maintained in the system, the pressure loss across the elbow (measured as the difference between gauge readings P1 and P2) is approximately 1.37 mm of water gauge (WG). To achieve an equivalent pressure loss in the straight pipe section between gauges P2 and P3, gauge P3 needs to be positioned 7 m away from gauge P2. Therefore, in this specific case, the pressure loss caused by the 0.17 m round elbow is equivalent to the pressure loss incurred by a 7 m length of 0.17 m round duct.

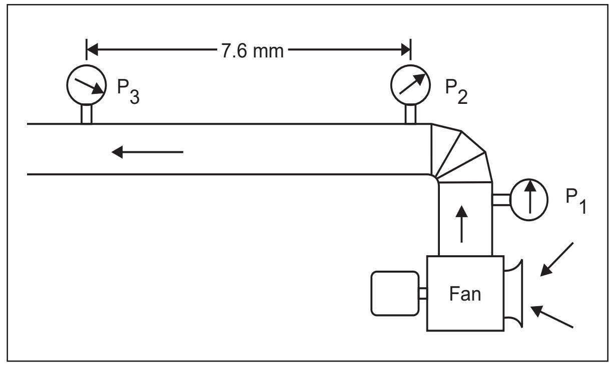


Figure A8: Schematic depiction of equivalent length for duct system

If the air flow rate is increased, it would require placing gauge P3 at a greater distance from gauge P2 to maintain equal pressure loss readings. For instance, if the flow rate is raised to 0.165 m³/s, gauge P3 might need to be positioned 7 or 8 m away from P2 to achieve the same pressure loss as observed across the elbow. Conversely, decreasing the flow rate would allow for a narrower distance between P2 and P3 to maintain equivalent pressure loss.

Note: The pressure loss caused by a fitting can be expressed in terms of an equivalent length of straight duct. These equivalent lengths are numerical values that can be found in resources such as ACCA Manual D, ASHRAE, or

SMACNA guides. It is important to note that the equivalent length of a fitting should not be confused with the effective length. The effective length is the combined measurement of the actual length of the duct and the sum of the equivalent lengths of all the fittings within the duct system.

2.8 Aspect Ratio

Aspect ratio represents the relationship between the width (w) and height (h) of the duct and is expressed as the ratio of w/h. When the aspect ratio is increased, both the initial installation cost and the ongoing operational cost of the system tend to rise. On the other hand, a rectangular duct with an aspect ratio closer to 1 requires less sheet metal, offering advantages such as lower frictional resistance, reduced weight of materials, and decreased expenses for insulation and installation.

Example

A duct with a cross-sectional area of 0.36 m^2 and a length of 30 m can be constructed with dimensions of 0.6 m by 0.6 m or 0.3 m by 1.2 m.

- In the first case, with dimensions of 0.6 m by 0.6 m, the perimeter of the duct is 2.4 m, resulting in a total sheet metal requirement of 2.4 m^2/m of duct length. Therefore, the total sheet metal required for a 30 m length is $2.4 \times 30 = 72\ m^2$.
- In the second case, with dimensions of 0.3 m by 1 m, the perimeter of the duct is 2.6 m, leading to a total sheet metal requirement of 2.6 m^2/m of duct length. Thus, the total sheet metal required for a 30 m length is $2.6 \times 30 = 78\ m^2$.

As the aspect ratio increases from 1:1 to 1:4, there is a 11% increase in the surface area and consequently higher insulation requirements for the duct.

3.0 Duct System Air Leakage

Duct leakage refers to the unintended escape of air from the ductwork of an air distribution system. This leakage can occur at various points such as joints, seams, and penetrations. The presence of duct leakage gives rise to two main issues:

1. Inadequate air flow: Leakage can result in certain areas at the end of the duct run receiving insufficient air flow, leading to compromised comfort levels or reduced performance of the HVAC system.
2. Increased energy consumption: Duct leakage also impacts the energy efficiency of the system. The fan, which is responsible for circulating the air, needs to compensate for the lost air due to leakage. The energy required by the fan increases exponentially with the amount of air leakage. For instance, consider a system with 10% leakage and an originally designed fan motor of 20 horsepower (hp). To account for the 10% loss, the new motor required would be 20 hp $\times (1.1)^3 = 26.6$ hp. This means that the owner would end up paying for an additional 6.6 hp in fan energy throughout the lifespan of the building.

To sum up, duct leakage not only results in inadequate air distribution to certain areas but also contributes to increased energy consumption by the HVAC system, impacting both comfort and operational costs.

Note: The amount of air duct leakage can be quantified based on factors such as the surface area of the duct, the specific leakage class, and the static pressure within the duct system. The leakage class is determined by following the guidelines and standards outlined in the ANSI/SMACNA HVAC duct construction standards.

3.1 Duct Leakage Tests

This document presents guidelines for assessing and testing ducts to ensure compliance with specified air leakage limits outlined in project specifications. While this document acknowledges the importance of proper assembly and sealing methods in achieving a reasonably airtight duct system, it recognizes the need for allowances as no duct can be completely airtight.

Duct leakage can lead to reduced air quantities at terminal points unless compensatory adjustments are made to maintain the desired air flow. Leakage should be treated as a transmission loss within duct systems, with the extent of leakage being influenced by several key variables.

- Static pressure, rather than velocity pressure, plays a significant role in determining the amount of leakage. Higher static pressure levels generally result in increased leakage.
- Additionally, the overall length of the duct system contributes to the potential for leakage, as more ductwork provides more opportunities for air to escape. The openings in the duct surface, such as joints, seams, access doors, rod penetrations, and fastener penetrations, are major contributors to leakage.
- Furthermore, the quality of workmanship during construction plays a crucial role in minimizing leakage. Poor workmanship undermines even the best construction standards and can lead to increased air leakage.

To evaluate system leakage, it is practical to consider the duct surface area as a parameter. While it is possible to evaluate leakage rates per unit length of seam, per diameter of a hole, or per dimension of a crack, using duct surface area offers a simpler approach. Research conducted in Europe and independently in the United States have provided insights into establishing acceptable tolerances and identifying a duct surface leakage factor based on this relationship.

$$L_{max} = (C_L)*(P)^N$$

Where,

- L_{max} represents the maximum allowable leakage in cubic meter per second per 100 m² of duct surface area.
- C_L denotes the duct leakage class, indicating the leakage rate in m³/s per 100 m² of duct surface area at a static pressure of 25 mm of water column (250 Pa). Leakage classes defined by *SMACNA* include 24, 12, and 6, which correspond to the expected leakage rates at 250 Pa pressure.
- P refers to the test pressure, which should match the design duct pressure class rating. The test pressure is measured in mm of water column.
- N is an exponent typically set at 0.69, although it may vary between 0.5 and 0.9 depending on the specific circumstances.

For ductwork designed to operate at static pressures below 750 Pa and located outdoors or in unconditioned spaces, it is necessary to perform leak testing using the procedures outlined in the *SMACNA HVAC Air Duct Leakage Test Manual.* This manual provides guidelines and instructions for conducting appropriate leakage tests to assess the duct system's integrity and adherence to acceptable leakage standards.

3.2 Leakage Classifications

The DW/143 guidelines provide leakage classifications, ranging from 3 to 48, as indicated in *Figure A9* for pressures up to 2200 Pa. These classifications are associated with specific duct types, seal classes, and construction pressure classes outlined in *Table A5*. The table serves as the reference for evaluating duct systems in accordance with the DW/143 duct construction standards which are used here as an illustration.

To determine compliance, two criteria are considered based on the specified test pressure:

1. If the leakage factor (F) determined through testing is equal to or lower than the value associated with the specified leakage class, the duct is considered compliant.

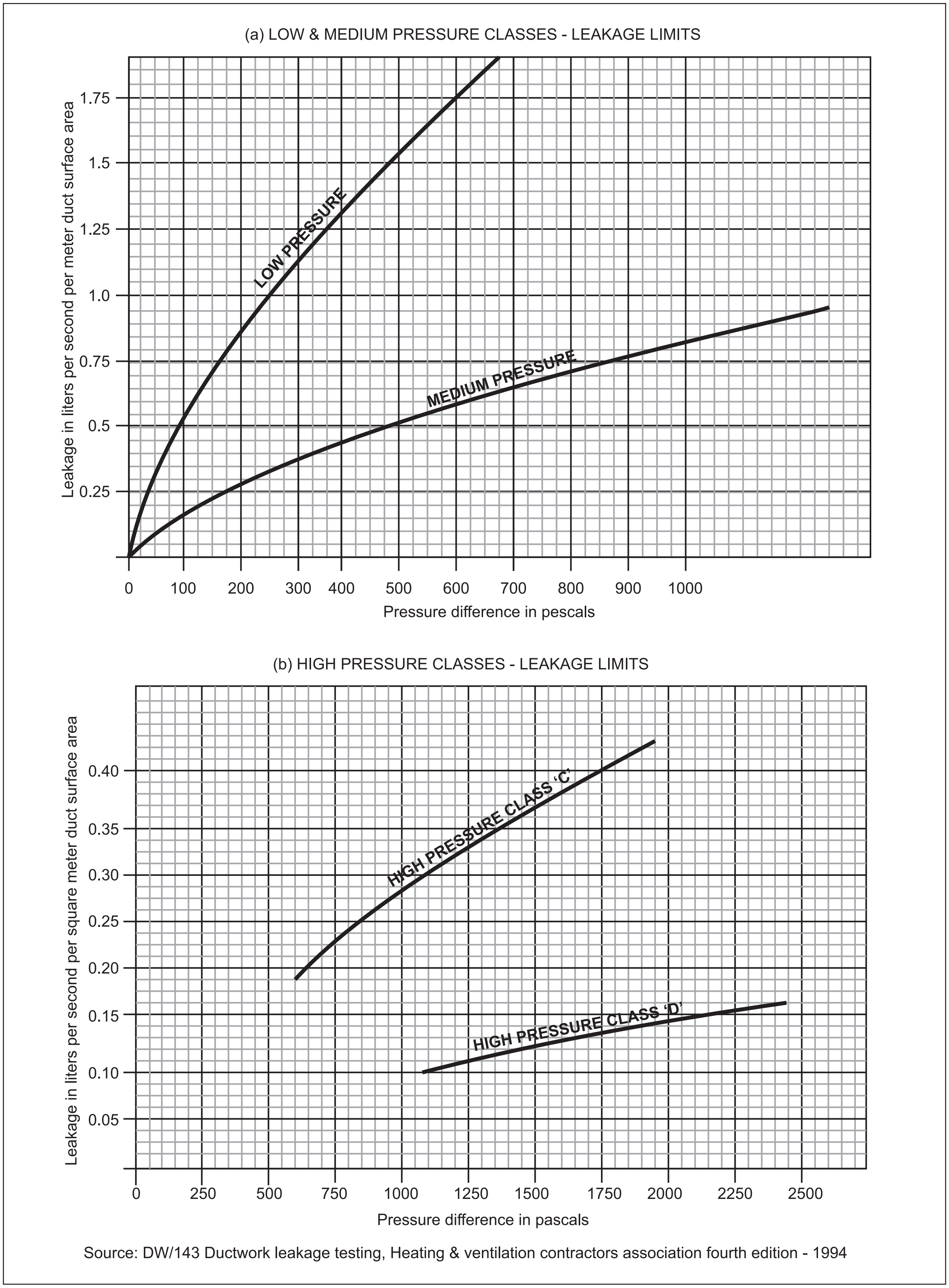
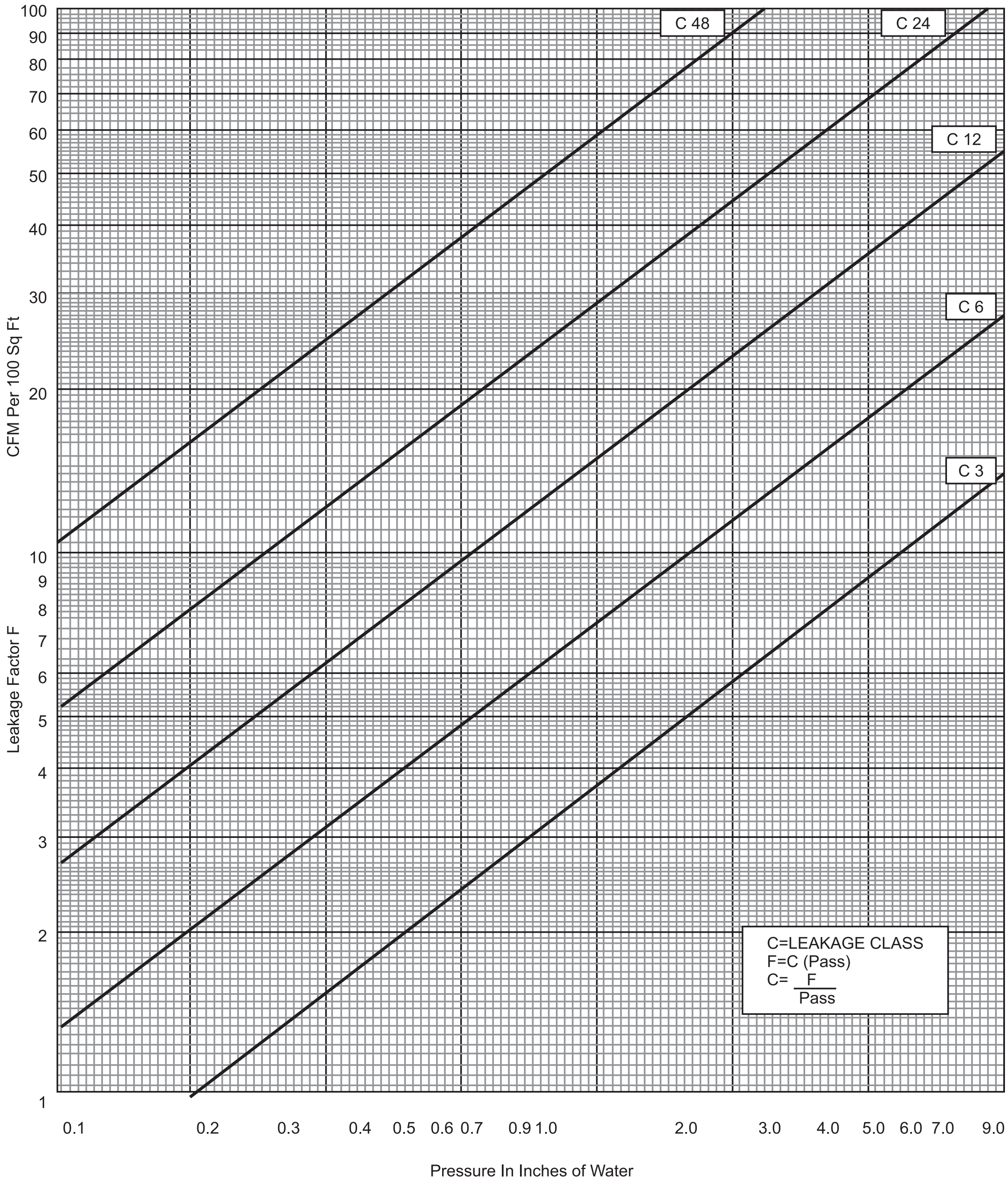


Figure A9: Permitted leakage at various pressures



Source: DW/143 Ductwork leakage testing, Heating & ventilation contractors association forth addicion - 1994

Figure A10: Duct leakage classification

2. *Alternatively*, if the leakage constant (C) derived from tests is equal to or lower than the specified leakage class, the duct is considered compliant.
   Assigning appropriate leakage classes requires careful consideration of factors such as system size, duct location, sealing methods, and construction class. Arbitrary assignment of allowable leakage percentages without considering these factors can lead to unachievable results.

As an example, selecting a construction pressure class of 2500 Pa for a system operating at 250 Pa solely to achieve leak class 3 for rectangular ducts would not be cost-effective. Assigning a leak class 3 to a 250 Pa rectangular duct system may seem achievable, but the associated difficulties and costs would be excessive.

Table A5 illustrates the expected leakage rates using Seal Classes A, B, and C for the specified duct construction types typically chosen for each pressure class. It is possible to apply Seal Class B or A at construction pressure classes lower than those indicated in the table. However, without prequalification through tests or a proven track record at higher pressures, the predictability of leakage rates becomes less certain, considering factors such as joint type, seam type, duct wall thickness, and specific sealing methods.

When considering setting lower allowable leakage rates than those presented in *Table A5*, the benefits should be carefully evaluated against the associated costs of achieving them.

Table A5: Expected leakage classes with respect to seal classes

Duct Class	125, 250, 500 Pa	750 Pa	1000, 1500, 2500 Pa
Seal Class	**C**	**B**	**A**
Sealing Applicable	Transverse Joints Only	Transverse Joints and Seams	Joints, Seams and all Wall Penetrations
Leakage Class			
Rectangular Metal	24	12	6
Round Metal	12	6	3

3.3 Leakage factors

3.3.1 Leakage in unsealed ducts can vary significantly depending on factors such as the type of fabricating machinery used, assembly methods, and the quality of installation workmanship. On the other hand, sealed ducts offer a range of sealing methods and products to minimize leakage. It has also been observed that for the same type of construction, leakage rates do not significantly differ between negative and positive air pressure modes.

Table A6 provides a range of leakage rates for longitudinal seams commonly employed in metal duct construction. It is worth noting that the longitudinal seam leakage for unsealed or unwelded metal ducts typically accounts for approximately 10 to 15% of the total duct leakage. These findings highlight the importance of proper sealing practices to minimize overall duct leakage and ensure efficient air flow within the system.

Table A6: Unsealed longitudinal seam leakage, metal ducts

Leakage in (m^3/h)/m of Seam Length at 250 Pa Static Pressure		
Type of Duct/Seam	**Range**	**Average**
Rectangular		
Pittsburgh Lock	0.05 to 3.13	0.90
Button Punch		
Snap Lock	0.05 to 0.90	0.36
Round		
Snap Lock	0.22 to 0.80	0.61
Grooved	0.61 to 1.08	0.68

3.3.2 To determine system leakage rates, it is recommended to refer to *Table A7* as a guideline for specifying the ductwork leakage class or to specify a duct seal level as suggested by *Table A8* and *Table A9*.

Table A7: Recommended leakage class by duct type

Duct Type	Leakage Class	Leakage Rate L/(s·m²) at 250 Pa
Rectangular	8	0.29
Flat Oval	4	0.14
Round	4	0.14

Table A8: Recommended ductwork seal levels

Duct Location	Supply <500 Pa	Supply >500 Pa	Exhaust	Return
Outdoor	A	A	A	A
Unconditioned Space	B	A	B	B
Conditioned Space-Concealed duct	C	B	B	C
Conditioned Space – Exposed Duct	A	A	B	B

Table A9: Duct seal levels

Seal Level	Sealing Requirements
A	All transverse joints, longitudinal seams and all penetrations
B	All transverse joints and longitudinal seams
C	Transverse joints only

3.3.3 The designer shall consider the attainable leakage rates for each duct type and also take into account that casings of volume-controlling air terminal units may have a leakage of 1 to 2% of their maximum flow. The potential impact of such leakage shall be anticipated, and the ductwork shall not be solely relied upon to compensate for equipment leakage.

3.3.4 When a system leakage class is specified by the designer, it is a performance requirement that should not be compromised by strictly prescriptive sealing methods. It is possible for a portion of the system to exceed its leakage class as long as the overall system leakage remains within the allowable rate. To estimate the system's percentage of leakage based on the system's design leakage class and the total duct surface area, *Table A10* can be used. It is important to consider an average of upstream and downstream pressures when using *Table A10*, as relying solely on the highest pressure may result in artificially inflated leakage rates. In cases where multiple duct pressure classifications are present within a system, the ductwork in each pressure class should be assessed independently to determine the aggregate system leakage

3.3.5 Each duct system must be constructed according to the specified duct pressure classifications specified by designer. In cases where the designer has not specified any pressure classes, the compliance with these standards shall be based on the 250 Pa pressure class, irrespective of the duct velocity, except for variable volume ducts. For variable volume ducts upstream of Variable Air Volume (VAV) boxes, the basis of compliance shall be 500 Pa.

Table A10: Leakage as percentage of air flow

Leakage Class	Leakage (L/s·m²)	Static Pressure (Pa)	Static Pressure (Pa)	Static Pressure (Pa)	Static Pressure (Pa)	Static Pressure (Pa)	Static Pressure (Pa)
		125	**250**	**500**	**750**	**1000**	**1500**
68	10	15	24	38	49	59	77
68	12.7	12	19	30	39	47	62
68	15	10	16	25	33	39	51
68	20	7.7	12	19	25	30	38
68	25	6.1	9.6	15	20	24	31
34	10	7.7	12	19	25	30	38
34	12.7	6.1	9.6	15	20	24	31
34	15	5.1	8.0	13	16	20	26
34	20	3.8	6.0	9.4	12	15	19
34	25	3.1	4.8	7.5	9.8	12	15
17	10	3.8	6.0	9.4	12	15	19
17	12.7	3.1	4.8	7.5	9.8	12	15
17	15	2.6	4.0	6.3	8.2	9.8	13
17	20	1.9	3.0	4.7	6.1	7.4	9.6
17	25	1.5	2.4	3.8	4.9	5.9	7.7
8	10	1.9	3.0	4.7	6.1	7.4	9.6
8	12.7	1.5	2.4	3.8	4.9	5.9	7.7
8	15	1.3	2.0	3.1	4.1	4.9	6.4
8	20	1.0	1.5	2.4	3.1	3.7	4.8
8	25	0.8	1.2	1.9	2.4	3.0	3.8
4	10	1.0	1.5	2.4	3.1	3.7	4.8
4	12.7	0.8	1.2	1.9	2.4	3.0	3.8
4	15	0.6	1.0	1.6	2.0	2.5	3.2
4	20	0.5	0.8	1.3	1.6	2.0	2.6
4	25	0.4	0.6	0.9	1.2	1.5	1.9

Note: Percentage applies to the average upstream and downstream pressures of air flow entering a duct section.

3.3.6 Limits for Each Pressure Class

The allowable air leakage is determined based on four standards of airtightness, as indicated in *Table A11*.

Table A11: Leakage limits for pressure and sealing class

Air Leakage Class	Leakage Limit in L/(s·m²) of Duct Surface Area
Low pressure – Class A	$0.027 \times p^{0.65}$
Medium pressure – Class B	$0.009 \times p^{0.65}$
High pressure – Class C	$0.003 \times p^{0.65}$
High pressure – Class D	$0.001 \times p^{0.65}$

Note: p is the differential pressure in Pa

By referring to the prescribed limits outlined in *Table A11*, one can determine the permissible amount of leakage at various pressure levels within each class. *Table A10* illustrates the relationship between pressure and leakage.

3.3.7 Leakage Points in Ductwork, and Measuring Leakage in Ducts.

3.3.7.1 Air leakage within installed ductwork predominantly takes place at the longitudinal seams and cross joints. These areas, especially the corners and the points where the seams and cross joints intersect, are the primary locations where air leakage occurs.

3.3.7.2 In practical terms, the extent of leakage can be considered proportional to the surface area of the ductwork, regardless of whether it is rectangular or circular in shape. Although there may be variations in different sections of a complete duct system due to variations in duct sizes and the presence of various fittings, the surface area provides a straightforward measure that can be calculated as part of the design process.

3.3.7.3 *Table A12* provides the allowable leakage values corresponding to different pressure levels within each class. These leakage limits are specified to ensure compliance with the desired airtightness standards. Additionally, the relationship between pressure and leakage is depicted in *Figure A9*, offering a graphical representation of the pressure-leakage correlation.

Table A 12: Air leakage values corresponding to pressure class (leakage expressed in L/s per m² of surface area)

Static Pressure Differential Pa	Max. Leakage Low Pressure Class A	Max. leakage Medium Pressure Class B	Max. Leakage High Pressure Class C	Max. Leakage High Pressure Class D
100	0.54	0.18		
200	0.84	0.28		
300	1.10	0.37		
400	1.32	0.44		
500	1.53	0.51		
600		0.58	0.19	
700		0.64	0.21	
800		0.69	0.23	
900		0.75	0.25	
1000		0.80	0.27	
1100			0.29	0.10
1200			0.30	0.10
1300			0.32	0.11
1400			0.33	0.11
1500			0.35	0.12
1600			0.36	0.12
1700			0.38	0.13
1800			0.39	0.13
1900			0.40	0.14
2000			0.42	0.14
2100				0.14
2200				0.15
2300				0.15
2400				0.16
2500				0.16

3.3.7.4 The relationship between air leakage and the surface area of ductwork suggests that it cannot be predetermined as a percentage of total air flow, and using a percentage loss as a performance standard would not be appropriate. However, extensive analysis of various ductwork systems applying the specified leakage limits has shown that, under normal operating conditions, air losses typically range within 6% of total air flow for the low-pressure class, 3% for the medium-pressure class, and between 2% and 0.5% for the high-pressure class, depending on the specific leakage limit being applied. These observations provide valuable insights into the expected air loss within different pressure classes.

3.3.7.5 The mentioned percentages are applicable to typical ratios of duct area to air flow. However, in cases where the ratio is high, such as long runs of small ducts, it may be necessary for the designer to specify a higher standard of airtightness in order to ensure that the actual leakage remains within an acceptable limit.

To address this, designers are required to perform specific calculations. These calculations involve:

(a) Determining the pressure class for the ductwork based on design requirements.

(b) Calculating the surface area of the ductwork and estimating the average system pressure difference for the entire ductwork system or a specific section of the system.

The mean pressure (P_m) is defined as the average pressure and can be calculated using the formula:

$$P_m = (P1 + P2)/2$$

Where:

- P_m represents the mean or average pressure.
- P1 denotes the operating pressure at the beginning of the ductwork system or the relevant section.
- P2 represents the operating pressure at the end of the ductwork system or the relevant section.

It is important to note that when determining the maximum test pressure and leakage rates, *Table A13* shall be referenced

Table A13: *Recommended maximum test pressures (with leakage rates)*

Static Pressure Differential	Maximum Leakage of Ductwork			
	Low Pressure Class A	Medium Pressure Class B	High Pressure	
			Class C	Class D
1	2	3	4	5
kg/m^2	m^3/h per m^2 of surface area			
20	3.02	-	-	-
40	4.75	1.58	-	-
80	-	2.48	-	-
120	-	-	1.08	
150	-	-	1.26	0.43
200	-	-	-	0.50

and followed as a guide. This will aid in ensuring accurate calculations and appropriate standards for the ductwork system.

4.0 Duct Sealing

4.1 Ensuring adequate airtightness in ducts is essential for the efficient and quiet functioning of HVAC systems. While absolute airtightness, as required in water piping systems, is not necessary for ducts, it is important to maintain a reasonable level of airtightness. Building codes typically specify that ducts should be reasonably airtight. Energy conservation, humidity control, temperature regulation, air circulation, ventilation, and maintenance considerations all contribute to the need for regulating duct leakage through construction standards.

4.2 It is recommended that all ducts constructed for the 125 and 250 Pa pressure classes meet Seal Class C requirements. However, there are cases where designers may exempt certain ducts from sealing, such as small systems, residential buildings, ducts located within the zones they serve, short duct runs from volume control boxes to diffusers, or specific return air ceiling plenum applications.

4.3 There are seven Pressure Classes available (125, 250, 500, 750, 1000, 1500 and 2500 Pa). In cases where the Pressure Class is not specified, 250 Pa may be assumed for normal ducting and 500 Pa for ducting upstream of VAV boxes.

4.4 It is important to note that certain sealants may adversely affect the function of breakaway connections to fire dampers. Therefore, it is advisable to consult the damper manufacturer for any installation restrictions or guidelines.

4.5 Duct sealing involves the application of approved materials or sealants at specific locations prone to air leakages. These locations typically include the supply and return plenums, starting collars where ducts connect to the plenums, fittings within the duct runs, splices along the ducts, and terminations where the ducts connect to the supply registers. Proper sealing at these points helps minimize air leakage and ensure the optimal performance of the HVAC system.

4.6 Approved Sealants

To ensure effective duct sealing, it is recommended to use sealants that meet certain criteria. The sealants should be UL 181 listed, which ensures their compliance with industry standards. They should also be water-based, non-toxic, and have water-resistant properties. It is preferable for the sealants to have a high solids content.

Approved sealants for duct sealing include flexible gaskets, fiber-reinforced mastic, and mastic used in combination with mesh tape. Duct systems that are sealed with mastics generally demonstrate lower levels of leakage.

4.6.1 It is important to note that certain types of tapes, such as foil tapes, cloth-backed duct tapes, or pressure-sensitive tapes, are not suitable for duct sealing purposes. These tapes may not provide the necessary durability and longevity required for effective sealing. Similarly, oil-based caulking and glazing compounds should be avoided as they are not designed for duct sealing applications and may not provide reliable and long-lasting seals.

Both *ASHRAE* and *SMACNA* standards provide guidelines for duct sealing, categorizing sealing requirements into Seal Classes A, B, and C. These standards define the specific criteria and performance levels for duct sealing based on factors such as air leakage and pressure resistance. Following these standards (mentioned in *Table A14*) ensures that the appropriate sealing materials and methods are employed to achieve the desired level of airtightness and system performance.

Table A14: *Ductwork seal classes*

Seal Level	Sealing Requirements
Seal Class A	All transverse joints and longitudinal seams, and duct wall penetrations. Pressure-sensitive tape shall not be used as the primary sealant.
Seal Class B	All transverse joints and longitudinal seams. Pressure-sensitive tape shall not be used as the primary sealant.
Seal Class C	All transverse joints only.

- Seal Class A: This class permits 2 to 5 percent total system leakage, which includes leakage from transverse joints, longitudinal seams, and duct penetrations.
- Seal Class B: Class B allows for 3 to 10 percent total system leakage, covering leakage from transverse joints and longitudinal seams.
- Seal Class C: Class C specifies 5 to 20 percent total system leakage, which includes leakage from transverse joints.
- Unsealed: The unsealed category indicates a higher level of leakage, allowing for 10 to 40 percent total system leakage.

4.6.2 These percentages serve as guidelines for acceptable levels of leakage in duct systems, with each class representing a different level of airtightness. Designers and contractors shall adhere to these standards to ensure appropriate sealing practices and maintain the desired system performance. Failure to adhere to these guidelines compromises the effectiveness of seals. For achieving low leakage, factors such as Section of joints to be sealed as well as workmanship of sealing are very important. It is also important to select the correct sealant considering the position of joint to be sealed, application conditions, direction of air pressure during operation, etc.

5.0 Leakage Testing of ducts

5.1 Verification of leakage control through field testing is unnecessary when proper assembly and sealing methods are employed. Conducting leakage tests adds extra expenses to the installation process. It is generally not cost-effective to test duct systems constructed to a 750 Pa class or lower. For duct systems constructed to a 1000 Pa class or higher, the designer should evaluate the need for testing and clearly specify the portions of the system to be tested and the appropriate test methods.

5.2 A ten percent drop in pressure between fan delivery point and air flow at terminals may be accepted considering possible reading errors, instrument accuracy, etc. Where terminals are at quite a distance from the fan outlet (more than 100 m), more effective sealing is called for.

Contractors should carefully choose construction details that align with sealing requirements, air pressure direction, and adequate sealing methods. The cost of rectifying systems that have not been properly sealed can far exceed the modest expense of applying proper sealing. Contractors utilizing slip and drive connection systems shall ensure control over connector length and notch depth on rectangular duct ends to facilitate effective sealing.

5.3 Duct system leakage test, if specified, shall be carried out as per SMACNA System Air Leakage Test Standard – 2020.

Informative Annexure B: Duct Accessories and Construction Practices

1.0 General

Ductwork, to efficiently perform its duty of transporting air from one point to another, requires various accessories and attachments. Some of these accessories impose pressure loss on the moving air and sometimes also facilitate air leakage. This section deals with judicious use of such accessories. Only those accessories for sheet metal ducts covered under ISHRAE Sheet Metal HVAC Duct Construction and Installation Standard (ISHRAE Standard 20003: 2025) is covered here. This Annexure is only for guidance and is not a part of the Standard.

2.0 Construction Practices

2.1 Duct supports shall be designed to handle the load without bulging or buckling. Where seismic considerations are specified, they shall be followed. Support material shall be galvanized or coated steel or aluminum angle sections, threaded rods and wire supports using stud anchors provided in the ceiling slab or by threaded fasteners. Care shall be taken to ensure that the slab or structural members are not damaged. Where false ceiling is provided, ducts and false ceiling shall be supported separately. Collar Off-takes for supply air outlets shall be constructed and installed only after the false ceiling/boxing framework is done and frames for fixing supply air outlets and return air Inlets are installed. Flexible ducts may be used for terminal connections.

2.2 Where duct penetrates brickwork or masonry openings, wooden framework shall be provided within the opening and the duct shall have flanged collars on either side of the wooden frame. Alternatively, the duct section passing through the structure may be suitably wrapped so that vibration is not transmitted to the structure. Where duct passes through a fire compartment partition, a fire barrier shall be created by installing a fire or combination fire and smoke damper as specified.

2.3 When fans feed into a duct system, uniform straight flow conditions shall be ensured. Fan manufacturer's recommendation in regard to straight length of connecting duct both at inlet and outlet of the fan to obtain optimum fan performance shall be followed. Pressure loss in a duct elbow or a volume control damper is minimum when air approaching the elbow or damper has a uniform velocity profile and positioning the elbow or damper after an adequate straight piece of duct is recommended. All elbows shall have adequate number of turning or guide vanes to ensure uniform air flow over the entire cross-section.

2.4 When duct is connected to an air handler or a fan, flexible connections (see section 3.8 below) shall be used between duct and AHU/fan to reduce transmission of vibration from equipment to duct work. Such connection shall be securely bonded and bolted to the unit casing as well as the duct to prevent air leakage.

2.5 Turning vanes shall be provided at supply air outlet collars and at branch take-offs. (See section 3.2.)

2.6 Take-offs allow air from main duct to be diverted to branch ducts and take-offs are fitted into circular or rectangular openings cut into the wall of the main duct and small metal tabs cut at the start of the take-off are bent to connect the take off to main duct. Alternatively, a snap-in attachment with an adhesive foam gasket can be used. Outlet of the take-off connects to branch duct.

2.7 Dampers in a duct system allow control of airflow to different sections and are necessary to balance air flows in the system. Dampers shall be manually controlled or automatic. Dampers shall be rated for operation against 1.5 times the rated pressure class of ducting. Links, levers and quadrants shall be provided for proper operation, control and setting of the dampers. Linkages shall be blade-to-blade and concealed in a jamb out of the airstream. Every damper shall have an indicating device showing the damper position and a locking device. Where dampers are operated via an external gear train, these are to be constructed out of engineering polymers with self-lubricating properties, and, located out of the air stream. Leak resistant access doors next to the dampers will not only facilitate attending to the dampers but also duct cleaning. (Refer Section 3.3 for details of dampers.)

2.8 Electrical heaters either tubular or strip shall not be mounted inside ducts except in locations clearly identified and approved.

2.9 Variable Air Volume (VAV) boxes shall be installed at specified locations. They may be supported from floor, wall or ceiling as specified and may be mounted in vertical or horizontal direction. VAV shall be factor- set for minimum airflow of 10 % and maximum airflow of 110% of design flow. Access to the box shall be from below and shall be completely sealed but easily removable. Power point with an isolator shall be provided and step-down transformer shall be part of the unit.

2.10 Grilles, diffusers and registers act as terminal units for supplying air from the duct system to the room or for collecting back air from the room either to exhaust or for return to AHU/fan. Terminal units may be fitted with air filters. Square or rectangular wall outlets shall have a flanged frame. Outer edge of the frame shall be curved to a radius of 5 to 10 mm. A flexible gasket shall be fitted between the wall and the frame. Supply air registers shall have front louvres in the horizontal direction and back louvres in the vertical direction. Horizontal front louvres shall allow a deflection of up to 25 degrees (to the vertical), and vertical louvres shall allow a deflection of up to 45 degrees (to the horizontal).

2.10.1 Same as wall outlets, ceiling outlets shall also have a flexible gasket between the flange and the ceiling. Core assembly shall be removable. Inner as well as outer rings shall be minimum 1.1 mm thick and diffuser assembly shall be 0.8 mm thick extruded aluminum section. Circular ceiling outlets shall have the option to have an outer cone in which case the lower edge of the cone shall not be more than ½ mm below the finished ceiling. Dirt deposit on the ceiling adjacent to the outlet/inlet is a common problem and care should be taken in design to avoid this.

2.10.2 Linear diffusers shall have a flanged frame with the outer edge turned 3.5 mm and shall have 1 to 8 slots as specified in the design. These shall be constructed out of 1.6 mm thick extruded aluminum sheet. All supply air outlets shall have volume control device made of extruded aluminum.

2.10.3 All air outlets and inlets shall be reflected in drawings.

2.11 For details of fresh air intakes and exhaust air outlets on the facia, please refer section 3.6.

3.0 Duct Accessories

3.1 Sealing Gaskets

3.1.1 Gaskets are needed to seal transverse joints of ducts. Gaskets of various materials and in various forms are available. Unless otherwise specified, gaskets 3 mm thick may be used. Gasket material shall be soft and pliant so that after being located, they expand in the flanging gaps to arrest leakages. However, they should not be overly soft to get compressed and leave gaps when the flange joint is tightened. Gasket material shall not be porous nor shall it be of closed cell composition. It is suggested that the joints in which gasket is inserted be

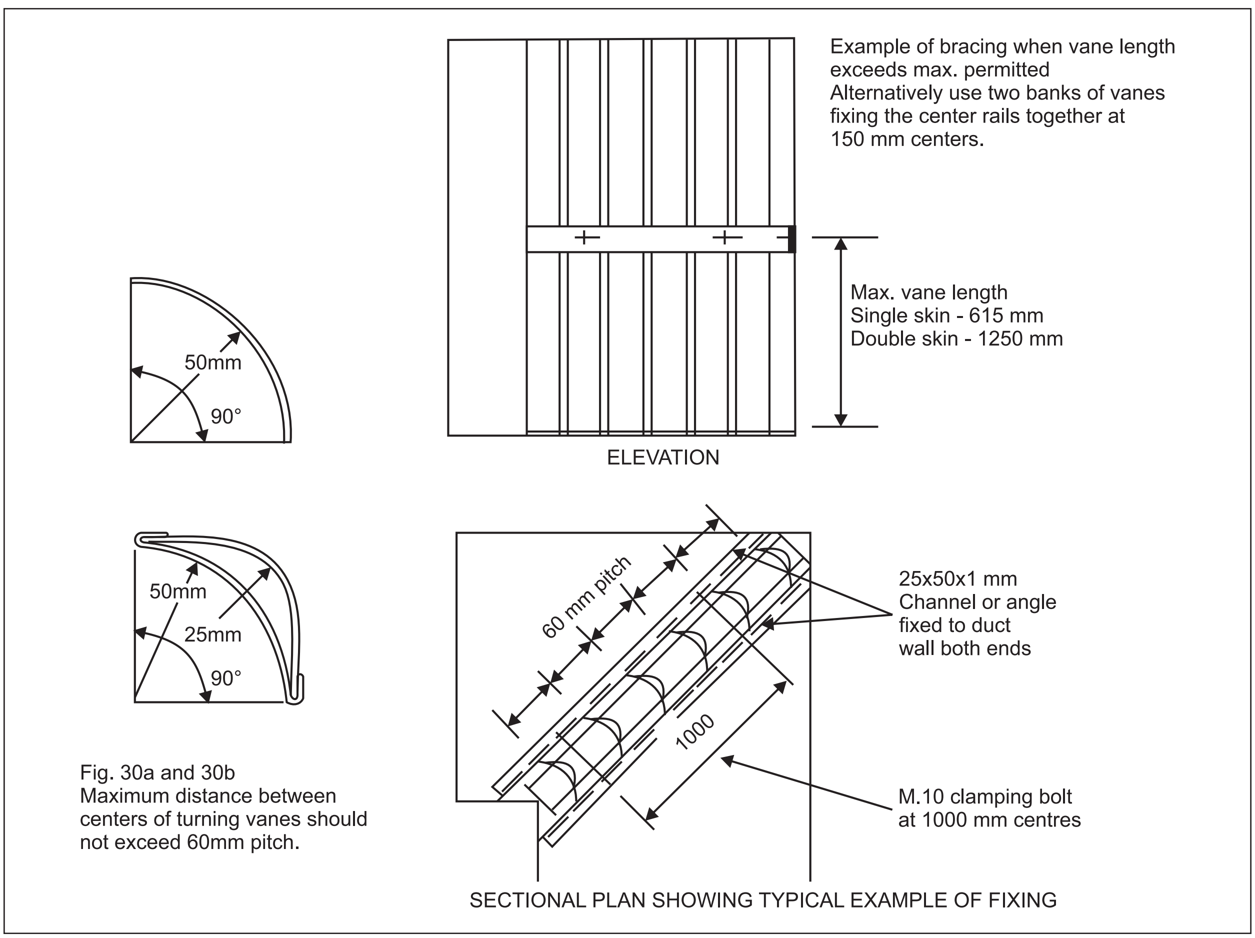


Figure B1: Turning vane details

either inclined or of tongue-and-groove type. Gaskets, while applying, shall have as few joints as possible and shall not be stretched while applying. Since some amount of shredding over time cannot be avoided, use of food grade material is recommended. A non-exhaustive list of gasketing material is given below:

- Polyethylene foam
- Neoprene sponge
- PVC Foam
- High density polyurethane
- Vinyl nitrile
- EPDM foam
- Butyl rubber
- Silicone sponge

3.2 Turning Vanes

Turning vanes may be provided at a few (say, first four) outlet collars, after an elbow and at branch takeoffs. Blades of the vanes shall be minimum 1 mm GI sheet. They shall be equally spaced on the runner side and the runner shall be riveted to the duct. For details, please refer *Figure B1*.

3.3 Dampers

3.3.1 Dampers – General

Dampers are generally constructed out of the same material as the duct work. Construction shall take care to prevent distortion and jamming during operation. Blades shall be rigid enough to prevent movement in locked position. Blades shall be securely fixed and spindles shall be housed in synthetic or roller bearings. Balancing and control dampers shall have a locking device located outside the casing with clear indication of blade position. Damper casings shall meet the minimum leakage limits of the ductwork on which they are installed.

3.3.2 Splitter Dampers

In branches where split takes place, splitter dampers shall be provided. These dampers are hinged at their downstream edge. Device for operating the damper shall project outside the duct and insulation (if provided). It shall be possible to lock the damper in position. Blade thickness shall be minimum 1.5 mm. Double thickness aerofoil blades are recommended. The splitter damper assembly shall be a separate unit with flanges at both ends aligning with the main duct. The enclosure shall be made of sheet thickness one size higher than the upstream duct.

3.3.3 Louvre Dampers

Louvre dampers shall be provided in all branches. Any duct feeding more than four outlets shall be regarded as a branch and louver dampers provided.

Louvre dampers shall be multi-blade type with opposed blades or parallel blades of aerofoil construction rotating in permanently lubricated ball or roller bearings. Blades shall be 1200 × 250 maximum mounted in a channel frame. Blades shall be connected with suitable linkage for gang operation by an operating rod extending beyond the frame and insulation if any and terminating in a locking quadrant with damper position indicator. Dampers larger than 1200 mm in width shall be furnished in multiple sections. Dampers shall be enclosed in a sheet steel box with flanges at both ends. Thickness shall be one size larger than the upstream duct.

Dampers shall be manual or motorized as specified and actuators shall be rated for operation against static pressure of 650 Pa unless specified otherwise.

3.3.4 Balancing and Control Dampers, Shut-off Dampers

3.3.4.1 Balancing and control dampers in duct systems are used to modify airflow rate. Shut-off dampers, allow closure of the airflow.

Damper blades shall be 1.5 mm galvanized steel 3V type with three longitudinal grooves for reinforcement. Blades shall be completely symmetrical relative to their axle pivot point, presenting identical resistance to airflow and operation in either direction through the damper. Blade seals shall be made of thermoplastic elastomer (TPE). Linkage shall be blade-to-blade concealed in jamb (out of the airstream) to protect linkage and reduce pressure drop and noise.

3.3.4.2 Single blade dampers shall consist of a single pivoted blade adjustable through 90° by means of a quadrant. Spindle of the quadrant may be extended to connect to a power actuator. Single skin blades may be used for a maximum duct width of 300 mm and double skin single blade dampers may be used for a maximum duct width of 1250 mm; in both cases, the maximum duct height being 300 mm.

3.3.4.3 Multiblade dampers shall be either parallel or opposed blade and single skin or double skin. They shall consist of a number of pivoted blades contained in a casing and operable through 90°. There is no restriction on size of duct but when damper blade length exceeds 1250 mm, suitable reinforcement or support shall be provided. Damper blade width shall not exceed 200 mm.

3.3.4.4 Backdraft dampers are air pressure actuated or gravity actuated and are uni-directional. Such dampers shall be used in horizontal ducts or in vertical ducts where the flow is upwards. For downward flow in vertical ducts, calibrated spring assisted gravity louvres may be used. Backdraft dampers may also be used for pressure relief duty, in which case the louvres shall be provided with adjustable counterbalance weights or with tension adjustable springs.

3.3.5 Fire Dampers

3.3.5.1 Fire dampers shall be provided in all the supply air ducts and return air passages and at all floor crossings and fire compartment crossings. Access door shall be provided in the duct for each set of fire dampers.

Fire dampers shall be multi-blade louver type. The blade should remain in the air stream in open position and shall allow maximum free area to reduce pressure drop and noise in the air passage. The blades and frame shall be constructed with minimum 1.6 mm thick galvanized sheet and shall be factory-fitted in a sleeve made out of 1.6 mm galvanized sheet, minimum 400 mm long. It shall be complete with locking device, motorized actuator and control panel. Where specified, fusible links may be used in place of motorized actuator. In respect of motorized actuator, an electric signal shall cut off air supply immediately on receipt of fire alarm signal. Where the operation is through fusible link, an electric limit switch shall also be operated by the closing of fire damper, which in turn shall switch off power supply to AHU blower motor.

Fire dampers shall be Central Building Research Institute (CBRI) tested and certified for 90 minutes rating against collapse and flame penetration as per UL Standard 555: 1995.

3.3.6 Combination Fire and Smoke Damper

Combination fire and smoke dampers shall comply with dynamic fire damper requirements of UL Standard 555 and with smoke damper requirements of UL Standard 555S.

All fire dampers and combination fire and smoke dampers shall meet requirements with

A) NFPA 80, 90A, 92, 101 and 105 (latest edition)

B) National Building Code of India.

3.3.7 Fire and combination dampers shall be tested, rated and labeled in accordance with

A) UL Standard 555

B) UL Standard 555S.

3.3.8 Dampers shall bear the AMCA certified rating seal for air performance in accordance with the latest editions of AMCA 511 and AMCA 500-D.

3.3.9 Dampers shall have a UL standard 555 fire resistance ratings of 2 hours and a UL Standard 555 S elevated temperature rating of 250°C.

3.3.10 Combination dampers shall be equipped with factory installed heat responsive device rated to close the damper where the temperature at the damper reaches 70°C to 80°C.

3.3.11 Dampers shall have a UL Standard 555S leakage rating of leakage class I, velocity rating of 21.25 m/s and differential pressure rating of 100 mm WG (minimum). AMCA certified (AMCA 500-D) pressure drop shall not exceed 2.5 mm WG.

3.3.12 Construction of frame shall be 1.6 mm thick galvanized steel; damper blade shall be 2 mm thick galvanized steel.

3.3.13 Electric actuator shall be external mounting type with 230 V AC, 2-position or modulating. An access door shall be provided as per NFPA 80 and 105 requirement.

3.3.14 Damper shall be installed such that the fire integrity of the partition is maintained. Sleeves, if any, used for mounting the damper shall be designed for the rated fire resistance and the opening in the partition fire sealed with an appropriate and approved sealant.

3.3.15 All fire, smoke and combination fire and smoke dampers shall be suitable to be installed either in horizontal or vertical direction. Damper assemblies shall include built-in clearance frames to allow for expansion of the casing in the event of fire. Integrity of fire barrier shall be maintained either by metal-to-metal contact or by fire resistant packing. They are illustrated in Figure B2.

3.4 Constant Air Flow Regulator

3.4.1 Constant airflow regulators (CAR) shall automatically regulate airflows in ductwork to constant levels. Operation shall

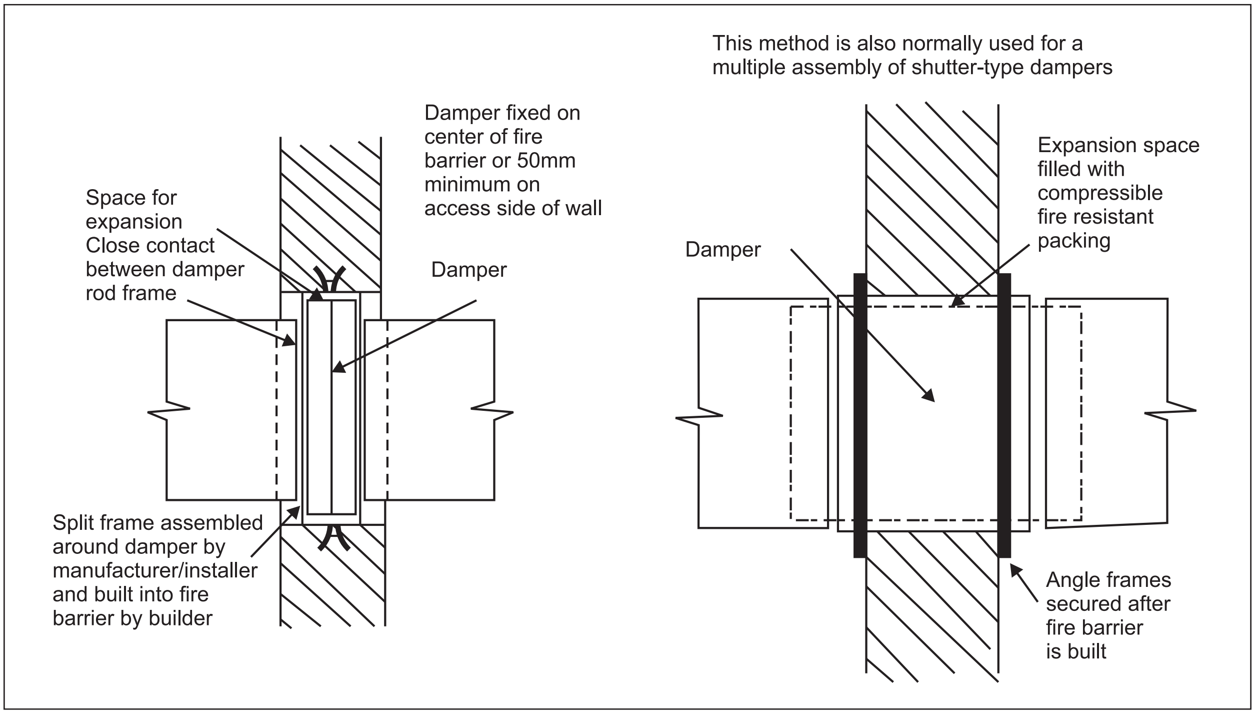


Figure B2: Details of fixing damper assembly

be completely passive where no electric or pneumatic sensors are needed.

3.4.2 The active element of the CAR shall be a flexible silicone bulb that will inflate and deflate in response to the static pressure difference to maintain the airflow.

3.4.3 The CAR's sub-assembly consisting of the silicone bulb and its housing shall be mounted on a rolled galvanized steel sleeve. The total assembly shall be designed to fit inside standard rigid round ducting as well as duty fittings such as tees. A seal shall be provided around the circumference to ensure a tight fit.

3.5 Access Panels and Inspection Covers

3.5.1 Access panels shall be provided adjacent to in-line equipment requiring intermittent access. Openings shall be 450 × 450 mm and shall provide hand or arm access only.

3.5.2 Inspection openings shall be provided next to in-line equipment that need only visual inspection from outside. They shall be 100 mm square or round. Access panels next to fire dampers shall provide access to both blades as well as actuator/fusible link. Panels next to filters, coils, fans shall be located upstream of device.

3.5.3 Inspection covers shall be provided next to regulating dampers where the control linkage is mounted with in the duct.

3.5.4 Handholes to permit proper joining of duct sections, if provided, shall be sealed and securely fastened after use.

3.5.5 Test holes 15 mm dia with a removable seal shall be provided at the outlet of fans and before and after cooling/heating coils. These may be provided at site during commissioning activity. Test probes shall be of heavy-duty zinc alloy casting. Expansion plugs shall made of be neoprene and capable to withstand 80°C and 300 kPa pressure.

3.5.6 Access doors for internal cleaning of ductwork may be provided as directed by the specialized cleaning contractor. It is a good practice to have access doors at 10 m intervals.

3.5.7 Opening in the ductwork as well as access doors shall be adequately reinforced to prevent distortion. Suitable sealing gasket shall be provided along with sufficient clamping type latches to ensure an airtight seal between the duct and access door.

3.6 Air Outlets and Inlets

3.6.1 Fixing devices shall be visible from the face of the frame. Where louvers are to be fixed in masonry or concrete, fixing shall be with either expanding plugs or rawl plugs. Where the louvers are to be fixed in steel or wood, non-ferrous screws or bolts shall be used. The fresh air intakes and exhaust outlets shall be anodized or powder coated aluminum. Fresh air intake grills shall be made of extruded aluminum sections.

3.6.2 A flanged frame using rolled steel sections shall be provided on the front face to conceal the gap between the louvers and the adjoining wall face. Corners of frame shall be welded. The frame shall be made structurally rigid. Louvers made from extruded aluminum section shall be in modular panel form for ease of handling. These shall be free from waves and buckles. Butt joints in blades shall not be accepted. Additional intermediate equally spaced supports and stiffeners shall be provided to prevent sagging or vibrating of the louvers, at no more than 750 mm centers where the louver's length is more than 750 mm.

3.6.3 A bird wire screen made of 12 mm mesh in 1.6 mm steel wire held in angle or channel frame shall be fixed to the rear face of the louver frame by screens. Unless specified otherwise, louvers shall be made of 3 mm thick 100 mm wide extruded aluminum sections fixed in an extruded aluminum frame. Louvers shall be fixed at 45° to vertical and provide 60% minimum net opening.

3.6.4 The entire assembly shall be fitted into the clear opening in the wall and the edges sealed with a polysulphide or silicone sealant. All frames and clamps used shall be hot dip galvanized or extruded aluminum.

3.7 Flexible Ducts

3.7.1 Flexible duct connections shall be used to connect ducting to equipment such as fan coils and to terminal units such as grills and diffusers. Flexible ducts shall be of metal or fabric.

3.7.2 Metal flexible ducts may be made of coated steel, stainless steel or aluminum, helically wound with a lock seam to form a corrugated duct capable of being bent without losing its circular shape. These ducts shall be mechanically fastened at both ends maintaining air tightness of the system. Permitted fastenings in flexible ducts shall be the same as in the case of circular ducts and sealing shall be as per section 4.0 of Annexure A to the Standard.

3.7.3 Non-metallic flexible ducts may be of PVC or polyester laminate encasing a high tensile steel wire helix. They shall be securely fastened at each end by a suitable band assuring the required air-tightness.

3.7.4 Flexible duct lengths shall be kept to a minimum and shall be supported in such a way that excessive sagging and kinking is avoided. It is not advisable to have test holes in flexible ducts and these shall be restricted to regular metal ducts.

3.8 Flexible Connections

3.8.1 Flexible connections are typically used to connect ducts to AHU, fan, etc., and they may also be used at building expansion joints. They shall be kept as short as possible and under reasonable compression but shall not be taut. When they are connected to flanged rectangular ducts, they shall be attached to the flanges with flat bar strips not less than 2 mm thick with suitable fittings. Connection to circular and oval ducts with flanges shall be with flat bar rings with screw or toggle fittings. Careful consideration shall be given to sealing and air tightness.

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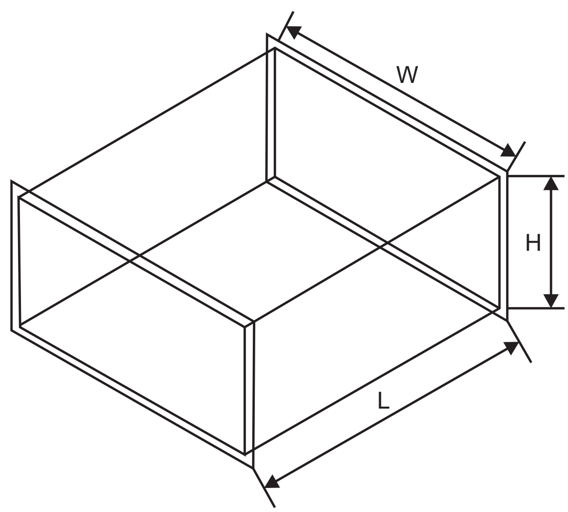
Informative Annexure C: Finished Duct Measurement Formulae

1.0 Rectangular Straight Duct Piece

Duct area (m^2) = Perimeter (m) × Length* (m)

Perimeter (m) = [W (m) + H (m)] × 2



Where,

W = Width

H = Height

Example:

If duct width (W) = 1 m, height (H) = 0.5 m and length (L) = 1.2 m, find duct area.

Perimeter (m) = [W (m) + H (m)] × 2
= [1.0 (m) + 0.5 (m)] × 2
= 1.5 (m) × 2
= 3.0 (m)

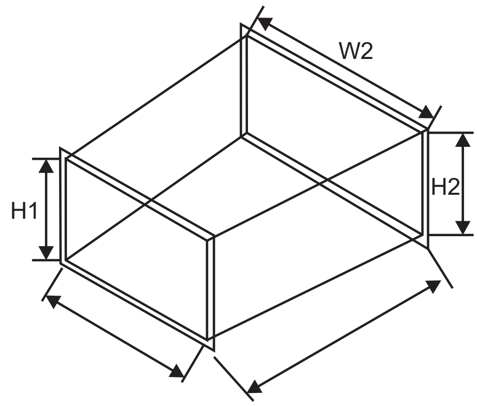
Duct area (m^2) = Perimeter (m) × Length (m)
= 3.0 (m) × 1.2 (m)
= 3.6 (m^2)

*Length of duct shall be without flange.

2.0 Rectangular Taper Piece

Taper piece area (m^2) = Perimeter (m) × Length* (m)

Perimeter (m) = [W1 (m) + H1 (m) + W2 (m) + H2 (m)]



Where,

W1 = Width one end

H1 = Height one end

W2 = Width other end

H2 = Height other end

Example:

If taper one end width (W1) = 0.8 m, one end height (H1) = 0.5 m, other end width (W2) = 1.0 m, other end height (H2) = 0.5 m and length (L) = 1.2 m, find taper piece area.

Perimeter (m) = [W1 (m) + H1 (m) + W2 (m) + H2 (m)]
= [0.8 (m) + 0.5 (m) + 1.0 (m) + 0.5 (m)]
= 2.8 (m)

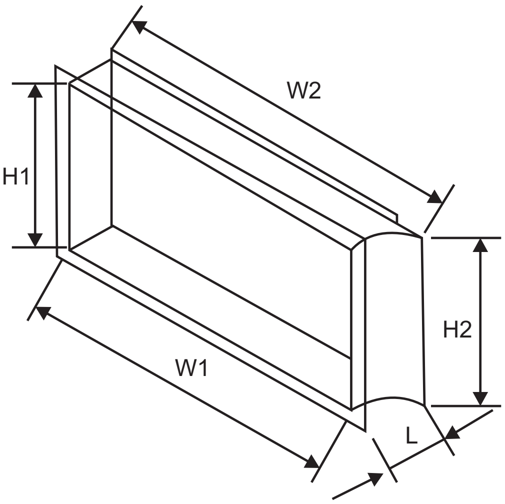
Duct area (m^2) = Perimeter (m) × Length (m)
= 2.8 (m) × 1.2 (m)
= 3.36 (m^2)

* Length of duct shall be without flange.

3.0 Rectangular Shoe Piece

Shoe piece area (m^2) = Perimeter (m) × Length* (m)

Perimeter (m) = [W1 (m) + H1 (m) + W2 (m) + H2 (m)]



Where,

W1 = Width one end

H1 = Height one end

W2 = Width other end

H2 = Height other end

Example:

If shoe piece one end width (W1) = 1.0 m, one end height (H1) = 0.5 m, other end width (W2) = 1.1 m, other end height (H2) = 0.5 m and length (L) = 0.15 m. Find shoe piece area.

Perimeter (m) = [W1 (m) + H1 (m) + W2 (m) + H2 (m)]

= [1.0 (m) + 0.5 (m) + 1.1 (m) + 0.5 (m)]

= 3.1 (m)

Duct area (m^2) = Perimeter (m) × Length (m)

= 3.1 (m) × 0.15 (m)

= 0.465 (m^2)

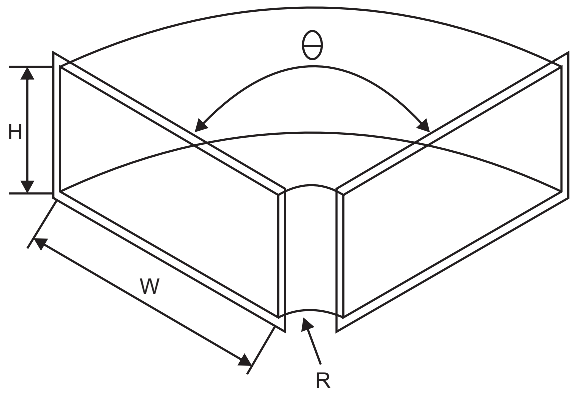
* Length of duct shall be without flange.

4.0 Rectangular Elbow Piece

Elbow area (m^2) = Perimeter (m) × Length (m)

Perimeter (m) = [W (m) + H (m)] × 2

Length (m) = 3.14 × [R+(W/2)] × (θ/180)



Where,

W = Width

H = Height

R = Elbow throat radius

θ = Elbow angle

Example:

If elbow piece width (W) = 1 m, height (H) = 0.5 m, elbow throat radius (R) = 0.15 m and elbow angle (θ) = 90° Find elbow piece area.

Perimeter (m) = [W (m) + H (m)] × 2

= [1.0 (m) + 0.5 (m)] × 2

= 3.0 (m)

Length (m) = 3.14 × [R+(W/2)] × (θ/180)

= 3.14 × [0.15+(1.0/2)] × (90/180)

= 3.14 × 0.65 × 0.5

= 1.0205 (m)

Duct area (m^2) = Perimeter (m) × Length (m)

= 3.0 (m) × 1.0205 (m)

= 3.0615 (m^2)

5.0 Rectangular Y Piece

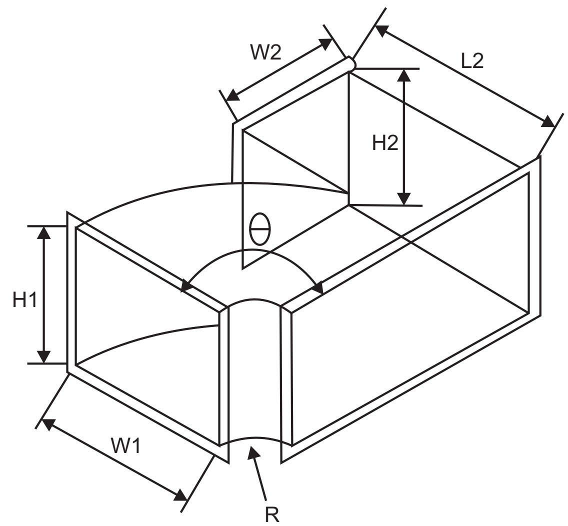
Y piece area (m^2) = [Perimeter-1 (m) × L1 (m)]+[Perimeter-2 (m) × L2*(m)]

Perimeter-1 (m) = [W1 (m) + H1 (m)] × 2

L1 (m) = 3.14 × [R+(W1/2)] × (θ/180)

Perimeter-2 (m) = [W2 (m) + H2 (m)] × 2

L2 (m) = Straight Length (m)



Where,

R	=	Elbow throat radius	θ	=	Elbow angle
W1	=	Width elbow side	H1	=	Height elbow side
L1	=	Length elbow side	W2	=	Width straight side
H2	=	Height straight side	L2	=	Length straight side

Example:

If Y piece elbow side width (W1) = 0.6 m, elbow side height (H1) = 0.5 m, straight side width (W2) = 0.4 m, straight side height (H2) = 0.5 m and straight side length (L2) = 0.75 m. Find Y piece area.

Perimeter-1 (m) = [W1 (m) + H1 (m)] × 2
= [0.6 (m) + 0.5 (m)] × 2
= 1.1 × 2
= 2.2 m

L1 (m) = 3.14 × [R+(W1/2)] × (θ/180)
= 3.14 × [0.15+(0.6/2)] × (90/180)
= 3.14 × 0.45 × 0.5
= 0.7065 (m)

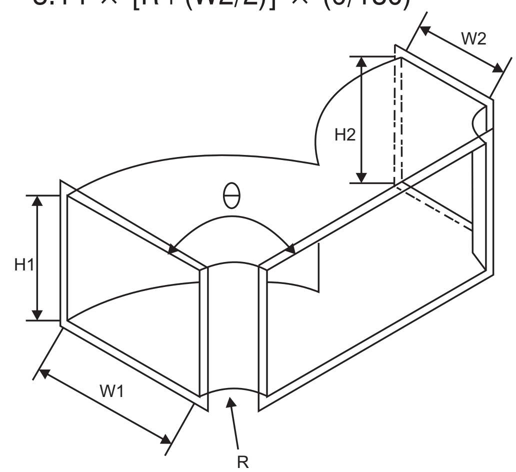
Perimeter-2 (m) = [W2 (m) + H2 (m)] × 2
= [0.4 (m) + 0.5 (m)] × 2
= 0.9 × 2
= 1.8 m

Y piece area (m^2) = [Perimeter-1 (m) × L1 (m)]+[Perimeter-2 (m) × L2 (m)]
= [2.2 (m) × 0.7065 (m)]+[1.8 (m) × 0.75 (m)]
= 1.5543 (m^2) + 1.35 (m^2)
= 2.9043 (m^2)

* Length of duct shall be without flange.

6.0 Rectangular Y Piece (Tee Type)

Y piece area (m^2) = [Perimeter-1 (m) × L1 (m)]+[Perimeter-2 (m) × L2 (m)]
Perimeter-1 (m) = [W1 (m) + H1 (m)] × 2
L1 (m) = 3.14 × [R+(W1/2)] × (θ/180)
Perimeter-2 (m) = [W2 (m) + H2 (m)] × 2
L2 (m) = 3.14 × [R+(W2/2)] × (θ/180)



Where,

R	= Elbow throat radius	θ	= Elbow angle
W1	= Width one side elbow	H1	= Height one side elbow
L1	= Length one side elbow	W2	= Width other side elbow
H2	= Height other side elbow	L2	= Length other side elbow

Example:

If Y piece elbow side width (W1) = 0.6 m, elbow side height (H1) = 0.5 m, straight side width (W2) = 0.4 m, straight side height (H2) = 0.5 m. Find Y piece area.

Perimeter-1 (m) = [W1 (m) + H1 (m)] × 2
= [0.6 (m) + 0.5 (m)] × 2
= 1.1 × 2
= 2.2 m

L1 (m) = 3.14 × [R+(W1/2)] × (θ/180)
= 3.14 × [0.15+(0.6/2)] × (90/180)
= 3.14 × 0.45 × 0.5
= 0.7065 (m)

Perimeter-2 (m) = [W2 (m) + H2 (m)] × 2
= [0.4 (m) + 0.5 (m)] × 2
= 0.9 × 2
= 1.8 m

L2 (m) = 3.14 × [R+(W2/2)] × (θ/180)
= 3.14 × [0.15+(0.4/2)] × (90/180)
= 3.14 × 0.35 × 0.5
= 0.5495 (m)

Y piece area (m^2) = [Perimeter-1 (m) × L1 (m)]+[Perimeter-2 (m) × L2 (m)]
= [2.2 (m) × 0.7065 (m)]+[1.8 (m) × 0.5495 (m)]
= 1.5543 (m^2) + 0.9891 (m^2)
= 2.5434 (m^2)

7.0 Rectangular Dummy Piece

Dummy piece area (m^2) = [W (m) + 0.032 (m)] × [H (m) + 0.032 (m)]

Annexure D:
List of Referenced Standards

S No	Standard No	Description	Remarks
1	IS 655	BIS Standard for Air Ducts	
2	SMACNA	HVAC Duct Construction Standard	
3	SMACNA	System air leakage test standard	
4	ASHRAE	Standard 90.13	
5	DW 144	Specification for Sheet Metal Ductwork	
6	UL 181	Standard for factory made air ducts and air connectors	
7	IS 277	Galvanized Steel Strips and Sheets	
8	IS 6911	Stainless Steel Plates, Sheets and Strips	
9	IS 513 Part 1	Cold reduced carbon steel sheet and strip	Cold forming and drawing purpose
10	IS 737	Wrought Aluminum and Aluminum alloy Sheets and Strips for general engineering purposes	
11	IS 811	Cold formed light gauge structural steel sections	
12	IS 3601	Steel tubes for mechanical and general engineering purposes	
13	IS 1363 Part 1	Hexagonal head bolts, screws and nuts of product grade C	Hexagon head bolts size range M5 to M64
14	IS 1730	Steel plates, sheets, strips and flats for structural and general engineering purposes	Dimensions
Note: All Standards referred above shall mean the latest on the date of publication of this Standard			

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About ISHRAE

The Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) was founded in 1981 at New Delhi by a group of eminent HVAC&R professionals. ISHRAE has over 13, 000 HVAC&R professionals as its members today along with 10, 000 student members, and operates from over 50 Chapters and sub-Chapters spread all over India, with its HQ in Delhi. It is led by a team of elected officers who are members of the Society working on a voluntary basis, collectively called the Board of Governors. In pursuance of its objectives, ISHRAE works in the areas of Research, Standards, Education and Training, and Publication of Technical Books and a Journal. It also organizes world-class annual exhibitions ACREX and REFCOLD, besides hosting technical seminars and conferences. ISHRAE is a responsible and socially-conscious Technical Society.

Objective

- Advancement of the Arts and Sciences of Heating, Ventilation, Air Conditioning and Refrigeration Engineering and Related Services.
- Continuing education of members and other interested persons in the said sciences through lectures, workshops, product presentations, publications and expositions.
- Rendition of career guidance and financial assistance to students of the said sciences.
- Encouragement of scientific research.

Activities

Knowledge Dissemination: ISHRAE conducts conferences, seminars, exhibitions, workshops, panel discussions and product presentations throughout the country with both national and international participants to discuss, promote and display the state-of-the-art technologies, systems, products and services.

Books and Publications: ISHRAE publications help its members and the industry to keep up with technical developments, latest trends and sunrise technologies. ISHRAE publishes Standards, books on fundamentals of various topics, HVAC&R Handbooks and the extremely popular and informative ISHRAE Journal. The latest publication is on Insulation

Exhibitions cum Conferences: ISHRAE organises ACREX India, the largest international exposition in South Asia on the Air Conditioning, Refrigeration, Ventilation and Building Services industry. Held annually, ACREX showcases the latest technologies and innovations, and provides a platform for buyer-seller meets for technical and commercial personnel in the HVAC&R field. To serve the interests of the Refrigeration and Cold-chain sector, ISHRAE organises REFCOLD annually. ISHRAE is a member and active supporter of the National Centre for Cold-chain Development (NCCD).

Education: ISHRAE is actively engaged in Education and Training, and offers several courses for technical professionals, some with post-examination certification. This helps to bring trained manpower into the HVACR industry.

Research: ISHRAE promotes research in the field of HVAC&R technologies. It offers financial support to graduate and post-graduate students to carry out innovative R&D work in technology, systems and processes. ISHRAE partners with the industry, academia and the government to carry out scientific research at Institutes of Excellence associated with ISHRAE.

Standards: ISHRAE works in the national interest with various government ministries and departments; for example, in the development of Standards and drafting of the National Building Code for the Bureau of Indian Standards, working on Energy Conservation Building Code with the Bureau of Energy Efficiency, and with the Ozone Cell of the Ministry of Environment, Forest and Climate Change on refrigerant gases. ISHRAE has also developed a pioneering Standard on Indoor Environmental Quality.

Student Activities: ISHRAE student chapters in more than 150 engineering colleges encourage students to opt for careers in the HVAC&R industry with industry exposure including factory visits. The K-12 initiative of ISHRAE reaches out to young school children to make them aware of subjects like energy conservation and environmental concerns through drawing competitions, poster designs, quizzes and more, with emphasis on STEM education to inculcate scientific fervour and help them to grow up as responsible citizens.

Global Reach: ISHRAE works in close co-operation with other similar societies and organisations, both at national and international levels, for the promotion and development of concepts like health and safety, sustainability, Green buildings, energy efficiency and environmental responsibility, often interacting with UN bodies like UNDP and UNEP.

ISHRAE is indeed looked upon as a repository of technical knowledge in the HVAC&R and Building Services Industry globally by peer organizations and the Government.