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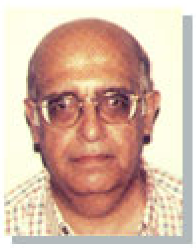
DUCTING
The Next Frontier



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Ultimately, any system can only be as good as its weakest link.

Yet it is common to see in India today HVAC installations with world-class centrifugal, screw and reciprocating packaged chillers, double-skin AHUs and modern building automation systems coupled with poorly fabricated air duct distribution systems. Of course, it is only with the economy opening up in this decade that such advanced equipment and technologies have made their appearance in India and it takes time for components of any new system to find a balance.

Unfortunately, the reality of the weak link will not go away. If the end-user is to receive the benefits of present day HVAC technologies, we will have to stop relegating ductwork to the hidden spaces where it has long resided - out of sight and out of mind. The predominant practice in India is that of fabricating ducts at site using basic hand tools such as snips, mallets and channel sections functioning dually as anvils and straight edges. This has two consequences. First the fabrication process is naturally slow and is frequently the leading cause of delays at HVAC project sites. Second dependent as this practice is on the rudimentary tools used and individual skills of the sheet-metal workers, there is little scope for maintaining uniform quality of the ducted systems. Occasionally hand operated folders and electrical lock forming machines are brought to job sites-but these address only a narrow aspect of duct quality.

So why do we continue to rely predominantly on this practice of site fabrication in India especially when automated factories for sheet-metal ducting are now an established norm the world over? The answer appears to be rooted in the perception that this is the only economical way of fabricating ducts in this country.

Photo 1 Typical layout of sheet metal profile manufacturing facility for rectangular ducting

The commonly held belief is that labour in India is plentiful and cheap, actual site conditions keep changing relative to plans ,and, if fabricated anywhere other than at site, additional expenses of transportation, duties and taxes would be incurred. But when the current practice of fabricating ductwork doesn't adequately satisfy the fundamental requirements of quality, reliability or speed of fabrication, it's clearly time to re-examine our economic assumptions and ways of doing things.

To begin with, one must keep in perspective that the total ducting cost is generally not much more than 10% of a typical AC project cost (somewhat greater for ventilation projects). The scope for controlling the overall project cost through ducting is therefore quite limited. It gets even more so as we focus selectively on isolated elements of ductwork cost such as fabrication labour without looking at the total economic picture.

For instance, we consistently tend to underestimate the high cost project sites. This is quite an oversight as raw material accounts for some 70% of overall ducting costs land is typically 3-4 times the unit labour cost for duct fabrication. Further, with site fabrication one also has to contend with poor storage conditions, difficulties of finding skilled manpower, absenteeism, temperamental job supervisers - all of which causes expensive delays in job completion and even more expensive call-backs. And yet the best-of-class technology and practices employed the world over for the fabrication and installation of sheet-metal and ducting is available in India as well and can readily be the norm.

To achieve this, four areas need to be addressed:

Duct Construction Norms

A review of existing industry standards is an obvious starting point.

Here, the Bureau of Indian Standards (BIS) specifications IS 655 governing metal air ducts is clearly out of date. Barring two very minor amendments in 1985 and 1991 these standards essentially remain as they were first drafted in 1963. By contrast, and DW 142/144 (UK) the corresponding international standards, have undergone several fundamental changes in the same period reflecting developments in both the demands of functional performance and sheet-metal fabrication technology.

One essential difference between IS 655 and the major international standards is in the manner they explicitly recognize the performance characteristics to be met. For instance we know that duct strength, deflection and leakage are more functions of pressure than velocity while noise, vibration and friction loss are more related to air velocity. Consequently, whereas duct design is primarily influenced by air velocity in order to meet the required flow requirements and to control parameters such as frictional losses, duct construction standards should be based primarily on static pressure considerations.

Hence, comparing the BIS and SMACNA standards with reference to the two key performance requirements:

- *Structural Rigidity:* In 18-655, sheet-metal gauge is given only as a function of cross-sectional duct dimensions with no reference to reassure classification. Consequently, for a given duct size, the same gauge of material is prescribed regardless of whether the ducting is for a low pressure 1/2" w.g. Static pressure application or for a 6" high pressure one. Under SMACNA however, in addition of sheet metal gauge is also a function of pressure class, spacing between joints, reinforcements and type of joints. Further, SMACNA explicitly recognises that the shorter the section length, its inherent stiffness and rigidity will be greater and therefore a lower thickness of sheet metal is adequate In fact the tendency of SMACNA is to prescribe the least thickness of sheet-metal possible as an unduly heavier gauge will increase both the self weight of the assembly leading to greater deflection and leakage as well as resulting in greater noise and vibration.

- *Leakage:* Except for mentioning that system should be "checked for air-tightness"' BIS is otherwise silent on the subject. It does not even specify the duct construction method to be followed to minimise air leakage.

Under SMACNA a leakage limit of 5% is deemed acceptable for most applications (less than this also achievable by greater use of sealants). Of course it is not practical to have every duct system tested for leakage and SMACNA explicitly recognises this. Having tested a range of duct systems of varying sizes and pressure classes, SMACNA confirms that by following their recommended construction standards for fabrication and assembly, leakage will be kept within limits.

Interestingly, while both leakage and structural rigidity characteristics inevitably deteriorate with an increase in the number of longitudinal seams or joints neither BIS nor SMACNA specify a limit on the number of such joints in a duct assembly.

In India, sheets of 2500 mm x 900 mm (or 1000 mm) are typically used with seams along the long lengths(**Fig.1**). With this method of construction, the number of seams will clearly increase with the cross-sectional dimensions of the duct section. Further, most seams will be in the side faces of the duct section and of the "Acme" lock type (**Fig.2**) which is relatively poor from both leakage and strength considerations. However, as the predominant form of fabrication in the West is with coils rather than sheets, seams are typically located on the *edges* (**Fig.3**) and commonly of the "Pittsburgh" or "Snap" lock type (**Fig.4 & 5**) both of which provide for lower leakage and higher reinforced structural strengths.

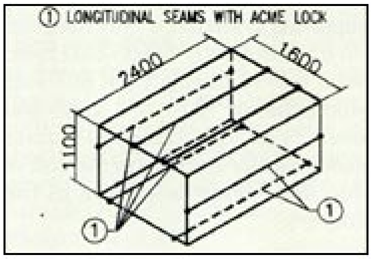

Fig 1
Typ. Duct (1600 x 1100 x 2400 mm lg)
fabricated from 2.4 m x 1.0 m sheet

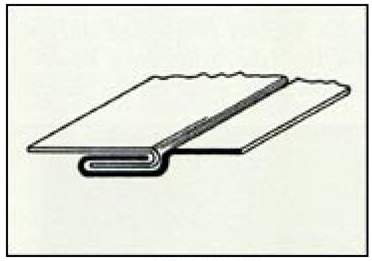

Fig 2
Acme lock

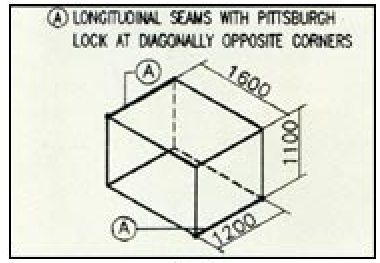

Fig 3
Typ. duct (1600 x 1100 x 1200 mm lg)
fabricated frow 1.2 m wide coils

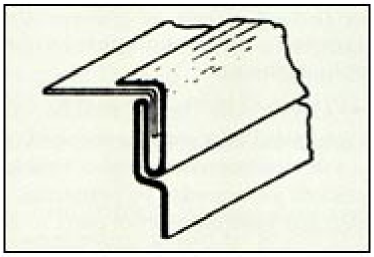

Fig 4: Pittsburg lock

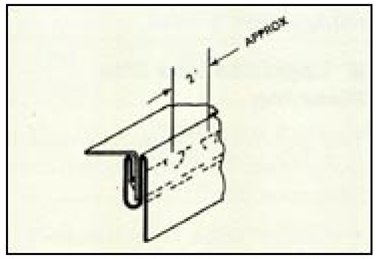

Fig 5: Button Punch Snap lock

Selection of Suitable Raw Material

Raw material selection plays a vital row with three characteristics being particularly important for duct quality and economy.

- *Lock Forming Quality (LFQ)* - i.e. the ability of the metal not to crack when folded, particularly relevant for GI material as the zinc coating will peel off at cracks or if folding is not uniform.
- *Zinc Coating* : Above a threshold thickness of zinc coating, the uniformity of coating and adherence to substrate is more important than the amount of coating. Indeed extra heavy coatings may in fact be detrimental to long-term performance as the zinc may tend to flake.

  BIS specifies 275 gsm (gsm/sq.m) zinc coating which appears to be over-specified. SMACNA uniformly recommends a G-60 grade (180 gsm) suitable for most applications using GI ducting. Coatings heavier than necessary (e.g. 350 gsm) have also led to a secondary problem - that of availability. Steel mills will generally produce these only against custom orders involving large quantities and long lead times.
- *Raw Material in Coil form as opposed to Sheets :* The use of coils is vastly preferred to sheets from considerations of both quality and economy. As discussed earlier, the use of sheets (typically 2400 mm x 900 mm or 1000mm wide) will inevitably lead to an increase in the number of longitudinal seams as duct sizes get

larger. By contrast, when coils are used in a "wrap-around" style (i.e. the length of the section equals the width of the coils), the longitudinal seams can be restricted to one (at corner) in the case of fully boxed sections or two (at diagonally opposite corners) in case of L-sections.

There is also considerably less wastage when the raw material is in coil form as opposed to fixed length sheets.

While raw material selection appears to be independent of the issue of whether the ducting should be factory - or hand-fabricated, it in fact has considerable bearing. Factory-made ducting will tend to use more uniform quality of material due to their bulk purchasing power. In any event, with GI coils sourced directly from the mills, available in coil weights of 4-5 MT or greater, these can only be handled at the factory rather than at job-site, for all practical purposes.

Sheet Metal Fabrication Technology

There is the perception in some quarters that the use of roll-forming equipment alone renders ductwork as machine-made. Roll-forming equipment such as a Pittsburgh lock-former are speciality equipment performing just one of the several manufacturing finishes required (in this case, end-finishing for longitudinal edge joints). Several other finishing equipment are typically required in today's sheet-metal shop - folders and flanging equipment for transverse connectors, edge-formers for contoured profiles and cleat-making equipment to name but a few. It is the collective use of such equipment which determines the extent to which ductwork is truly "machine-made".

In addition to the range of finishing machines a modern sheet-metal shop also has two other features - namely coil-handling capabilities (as discussed earlier) and computerization. Indeed the use of CAD/CAM and general computerization in today's sheet-metal fabrication shop has actually become a functional necessity. See **photo 1**.

- Contrary to popular conceptions, speed of fabrication is most affected by the time taken for measurement of the customized sections (finished dimensions, location of folds and notches, development of contoured profiles, etc) rather than by the actual cutting and folding operations. Computer-aided measurements, an integral part of CAM, thus plays a vital role in minimizing job delays to an extent which is just not achievable with non-computerised factory fabrication, leave alone hand-fabrication.
- A key determinant of duct quality the dimensional accuracy of each section of a duct assembly - also ensured by computer-aided manufacturing.

- Given the large number of customized duct sections required on a job, computerisation also enables smooth job execution by permitting a detailed identification of parts to be fabricated, handled and installed through bills of materials, packing lists, labels, duct quantities/weights/surface area summaries required for billing, etc.

Logistics and Site Planning

Two arguments commonly used in favour of site-fabrication over factory-fabrication are:

- Transportation costs involved in delivering ducts to job sites.
- Changes in site conditions relative to original plans which make it easier plans which make it easier to fabricate ducts based on actual site measurements.

In actual practice, deliveries to sites over vast distances are eminently workable and even economical if ducts are provided in L-sections (in the case of rectangular ducting). Here, most of the sizing / folding / edge-preparation operations are done at the factory except for minimal assembly and actual installation at job site. See **Photo 2**

Photo 2
Truck loading of L-sections

Also since raw material has to be supplied to the job sites in any event, the increase in transportation cost y supplying L-section is only marginal on a full truck - or tempo-load basis. As a rule of thumb, even half-load shipments of 500 - 600 sq.m. and over can be shipped quite economically (relative to the cost of ducting) almost anywhere in the country.

With reference to the second issue, while duct sizes are more definitively known when based on final site measurements, this aspect is nevertheless quit manageable even with factory-fabricated ducting. Factory fabrication does, however, impose a discipline on the planning process and there is ultimately no substitute planning. Even so, it is typical to find about 5% of the ductwork being done on a "suit-to-site" basis and in this, the situation in India is no different from elsewhere in the world. The important point is that factory fabrication is a proven, workable approach in the Indian context.

The Next Step

The process of change will have to begin with developing a new set of uniform specifications including changes to BIS. To this end we have outlined below the key elements of specifications which have their genesis in SMACNA and might be considered for inclusion in the relevant standards.

It's time to cross the next frontier.

Proposed Additions and changes to Specifications

Rather than re-invent the wheel, the sheet-metal industries of some countries have adopted a major international standard specification such as SMACNA in toto or with minor modifications. There is certainly merit in the Indian industry choosing to adopt the same approach - indeed even the UK standard of DW 142 /144 has its genesis in SMACNA.

While we will have to accept the fact that change in trade practice will not be sudden, we will have to ensure that our ductwork standards are set appropriate to the performance levels we wish to achieve. The objective after all is to have improved ducting - not merely accommodate the capabilities of the lowest common denominator.

We therefore list here the more important elements which we believe should be included in any set of specifications covering rectangular ductwork fabrication. These are drawn largely from SMACNA.

Raw Material

1. Coil stock preferred
2. Material should be of the minimum gauge necessary to resist both reflection caused by internal pressure and vibration due to turbulent air flow. For any given pressure class, alternative material gauges are permissible depending on the spacing between transverse joints/reinforcements. These shall conform to tables 1-3 to 1-9 of SMACNA 1995 Second Edition
3. GI material in particular must be of Lock Forming Quality (LFQ) conforming to the standards of ASTM A653 and A924 or conforming to grade D of IS 1079:1988 or IS

513: 1986 as specified in IS 277:1992.

4. Zinc coating should be of 180 gms./sq.m.
5. Yield strength for steel sheet and reinforcement should be 30,000 PSI (207 MPa).

(Note: where no pressure classes are specified by the designer, the 1" W.G. (250 Pa) pressure class is the basis of compliance regardless of velocity in the duct. However, all variable volume duct upstream of VAV boxes should have a 2" W.G. (500 Pa) basis of compliance when the pressure class is not defined).

Longitudinal Joints (Seams)

6. Longitudinal joints shall be preferably restricted to two diagonally opposite edges.
7. These should be machine-formed of any of the following types:
   a. Pittsburgh lock type.
   b. Button Punch Snap lock type.
8. Joints and seams should be able to withstand 1.5 times maximum operating pressure without deformation or failure.

Table 1 Standard Duct Sealing Requirements

Seal Class	Sealing Requirements	Applicable Static Pressure Construction Class
A	All transverse joints, longitudinal seams and duct wall penetrations	4" (1000 Pa) w.g. and upwards
B	All transverse joints and longitudinal seams only	3" (750 Pa) w.g.
C	Transverse joints only	2" (500 Pa) w.g.

In addition to the above, any variable air volume system duct of 1" (250 Pa) and ½" (125 Pa) w.g. construction class that is upstream of the VAV boxes shall be Seal Class C.
All Acme joints should be sealed.

Transverse Joints

9. Transverse joint must be able to withstand 1.5 times the maximum operating pressure without deformation or failure.

10. Where a transverse joint acts as a reinforcing member its maximum allowable deflection will be 0.25" (6.25 mm) for ducts upto 48" (1220 mm) width (W), and W/200 for greater widths.
11. For the spacing of transverse joints and type of reinforcement refer 'SMACNA' tables for rectangular ducting covering pressure class from 12" (125 Pa) W.G. to 10" (2500 Pa) W.G.

Crossbreaking or Beading

Crossbreaking or beading are effective ways in dealing with commercial tolerances on out-of-flatness, natural sag from dead weight and with the flexure reversals that may result when duct pressure is inadequate to stretch the sheet taut. Beading is preferred to crossbreaking (**Fig.6 &7**) applicable to 20g (1.00 mm0 or less and 3" W.G. (750 Pa) pressure or less. Ducts for 4" W.G. (1000 Pa) or more do not require beads or cross-breaks.

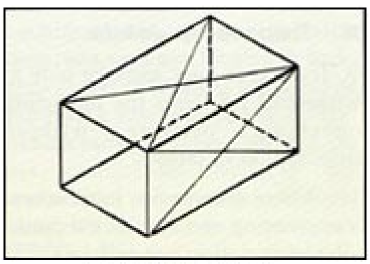
Fig 6: Cross breaking

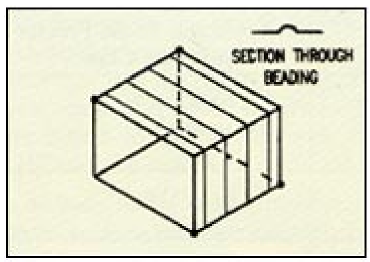

Fig 7: Beading

Leakage and Sealing ducts

Leakage is largely a function of static pressure and amount of leakage in a system is significantly related to system size. Economical and quiet performance of the ducting system can be ensured by making ducts reasonably airtight which can be achieved by a) selecting a static pressure construction class suitable for the operating condition, and b) properly scaling the duct work.

Transverse joints should be sealed with gaskets, and for ease of application, gaskets should preferably be self adhesive.

Heavy mastic sealants are more suitable as fillets in grooves of longitudinal seams. Mastics having excellent adhesion and elasticity are preferred.