SEAL CLASS	Sealing Requirements	Applicable Static Pressure Construction Class
A	All Transverse joints, longitudinal seams, and duct wall penetrations	4" wg and up (1000 Pa)
B	All Transverse joints and longitudinal seams only	3" wg (750 Pa)
C	Transverse joints only	2" wg (500 Pa)
In addition to the above, any variable air volume system duct of 1" (250 Pa) and ½" wg (125 Pa) construction class that is upstream of the VAV boxes shall meet Seal Class C.		

Table 1-1 Standard Duct Sealing Requirements

d. That where distinctions are made between seams and joints, a seam is defined as joining of two longitudinally (in the direction of airflow) oriented edges of duct surface material occurring between two joints. Helical (spiral) lock seams are exempt from sealant requirements. All other duct wall connections are deemed to be joints. Joints include but are not limited to girth joints, branch and subbranch intersections, so-called duct collar tap-ins, fitting subsections, louver and air terminal connections to ducts, access door and access panel frames and jambs, and duct, plenum, and casing abutments to building structures

e. Unless otherwise specified by the designer, that sealing requirements do not contain provisions to:

1. resist chemical attack;
2. be dielectrically isolated;
3. be waterproof, weatherproof, or ultraviolet ray resistant;
4. withstand temperatures higher than 120°F (48°C) or lower than 40°F (4.4°C);
5. contain atomic radiation or serve in other safety-related construction;
6. be electrically grounded;
7. maintain leakage integrity at pressures in excess of their duct classification;
8. be underground below the water table;
9. be submerged in liquid;
10. withstand continuous vibration visible to the naked eye;
11. be totally leakfree within an encapsulating vapor barrier; and
12. create closure in portions of the building structure used as ducts, such as ceiling plenums, shafts, or pressurized compartments;

f. The requirements to seal apply to both positive and negative pressure modes of operation

g. Externally insulated ducts located outside of buildings shall be sealed before being insulated, as though they were inside. If air leak sites in ducts located outside of buildings are exposed to weather, they shall receive exterior duct sealant. An exterior duct sealant is defined as a sealant that is marketed specifically as forming a positive air- and watertight seal, bonding well to the metal involved, remaining flexible with metal movement, and having a service temperature range of –30°F (–34°C) to 175°F (79°C). If exposed to direct sunlight, it shall also be ultraviolet ray- and ozone-resistant or shall, after curing, be painted with a compatible coating that provides such resistance. The term sealant is not limited to adhesives or mastics but includes tapes and combinations of open-weave fabric or absorbent strips and mastics.

B.1 SAMPLE LEAKAGE ANALYSIS

Since the system size and the impracticality of attempting to reach unrealistically low levels of leakage are such prominent considerations, *the evaluation of leakage by the percentage method* should *be a secondary consideration.* However, it is recognized that a percent of fan cfm or a percent of flow in a section of a system that passes through unconditioned space (considered as a heat loss or a heat gain) can be a useful parameter in energy conservation analysis. Leakage as a percent of flow entering one selected section of duct is not an adequate appraisal of the system performance. Five percent of the system flow is quite a different criteria than allowing 5% in each 100 ft of a 500 ft continuous run of duct. It should also be remembered that actual leakage will tend to be less than that appraised for the maximum pressure, because the average pressure under operating conditions will be less.

Leakage as a percent of flow has been related to leakage class and pressure in Appendix A. As Appendix A is studied, the significance of seal classes A, B, and C as applicable to duct pressure classes (*see* Table 4-1) must be understood. An example of the application of leakage classes to a duct system is provided to aid a realistic approach to the use of seal class, leakage class and percentage method analysis. While other parameters such as cubic contents (of duct interior) or lineal feet of joint might be used for leakage evaluation they are less practical and should not be used unless the square footage analysis has already been made.

B.2 SYSTEM LEAKAGE CLASSIFICATION ANALYSIS

SYSTEM DATA

Leakage Evaluation for Supply Duct in Figure 8-1, page 8-4 of the SMACNA *HVAC Duct Design Manual*

8000 cfm fan
½" wg duct construction class
320 l.f. of duct
2,074 ft² duct

3.9 cfm/s.f. is average distribution

(*i.e.*, $\frac{8000 \text{ cfm}}{2074 \text{ s.f.}} = 3.857$)

6.3 ft² duct per l.f. of duct

B.3 LEAKAGE ANALYSIS

a. *Unsealed duct* at ½" static pressure. At ½" s.p. on Class 48 curve in Figure 4-1, 30 cfm/100 s.f. is read.

$$\frac{30}{100} \times 2074 \text{ ft}^2 = 622 \text{ cfm}$$

622 cfm is 7.8% of 8000 cfm fan capacity.

Alternative Calculation (as in Appendix A)

$$\frac{8000 \text{ cfm}}{2074 \text{ ft}^2} = 3.9 \text{ to 1 ratio}$$

Allowable leakage factor $30 \times \frac{1}{3.9} = 7.7\%$

NOTE: The difference (7.7 vs. 7.8) occurs because 3.9 is rounded from 3.857.

b. Unsealed duct (½" s.p. class) operating at 0.3" s.p. If the system actually operates with 0.3" average static pressure and is unsealed, 22 cfm/100 s.f. leakage is read from the Class 48 curve on Figure 4-1 at 0.3" pressure. This is 456 cfm or 5.7%.

c. Leakage Class 24 Requirement, (½" Static Pressure)

From Figure 4-1, 16 cfm/100 s.f. is read.

$$\frac{16}{100} \times 2074 \times 322 \text{ cfm,}$$

which is 4.1% of fan cfm.

Alternative method: $16 \times \frac{1}{3.9} = 4.1$

d. Leakage Class 12 Requirement, (½" Static Pressure)

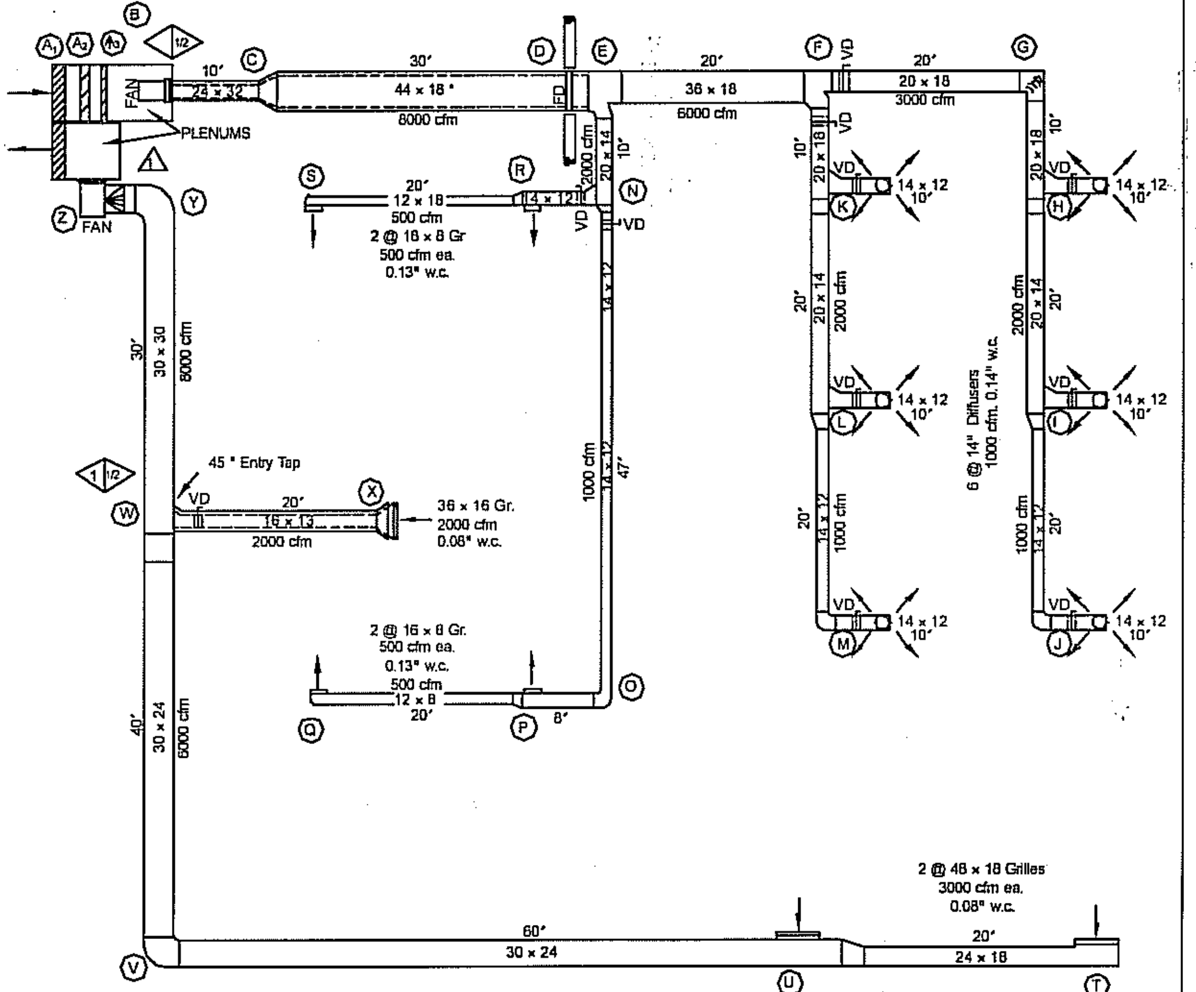
From Figure 4-1, 7.5/100 x 2074 = 156 cfm or 1.94%

e. Allowable leakage of 5%

If 5% is allowed (*i.e.*, 400 cfm) this is $\frac{400}{2074}$ or 19.3 cfm/100 s.f. allowable;

Leakage class if $C_L = \frac{F}{P^{0.65}} = \frac{19.3}{0.64} = 30$

The plan on page 8-5 of the duct design manual shows an access door, two volume dampers and a flexible connection (vibration isolation type); leakage allowance for these is prorated to duct surface.



* indicates duct liner used; sizes are interior dimensions.

FIGURE B-1 DUCT SYSTEM EXAMPLE

1.5 DUCT SEALING COMMENTARY

Ducts must be sufficiently airtight to ensure economical and quiet performance of the system. It must be recognized that airtightness in ducts cannot, and need not, be absolute (as it must be in a water piping system). Codes normally require that ducts be reasonably airtight. Concerns for energy conservation, humidity control, space temperature control, room air movement, ventilation, maintenance, etc., necessitate regulating leakage by prescriptive measures in construction standards. Leakage is largely a function of static pressure and the amount of leakage in a system is significantly related to system size. Adequate airtightness can normally be ensured by a) selecting a static pressure construction class suitable for the operating condition, and b) sealing the ductwork properly.

The designer is responsible for determining the pressure class or classes required for duct construction and for evaluating the amount of sealing necessary to achieve system performance objectives. It is recommended that all duct constructed for the 1" (250 Pa) and ½" (125 Pa) pressure class meet Seal Class C. However, because designers sometimes deem leakage in unsealed ducts not to have adverse effects, the sealing of all ducts in the 1" (250 Pa) and ½" (125 Pa) pressure class is not required by this construction manual. Designers occasionally exempt the following from sealing requirements: small systems, residential occupancies, ducts located directly in the zones they serve, ducts that have short runs from volume control boxes to diffusers, certain return air ceiling plenum applications, etc. When Seal Class C is to apply to all 1" (250 Pa) and ½" (125 Pa) pressure class duct, the designer must require this in the project specification. The designer should review *the HVAC Air Duct Leak*age *Test Manual* for estimated and practical leakage allowances.

Seven pressure classes exist (½"wg [125 Pa], 1" [250 Pa], 2" [500 Pa], 3" [750 Pa], 4" [1000 Pa], 6" [1500 Pa] and 10" [2500 Pa]). If the designer does not designate pressure class for duct construction on the contract drawings, the basis of compliance with the SMACNA HVAC *Duct Construction Standards* is as follows: 2"wg [500 Pa] wg for all ducts between the supply fan and variable volume control boxes and 1"wg [250 Pa] for all other ducts of any application.

Some sealants can adversely affect the release function of breakaway connections to fire dampers; consult the damper manufacturer for installation restrictions.

1.5.1 Leakage Tests

There is no need to verify leakage control by field testing when adequate methods of assembly and sealing are used. Leakage tests are an added expense in system installation. It is not recommended that duct systems constructed to 3" (750 Pa) wg class or lower be tested because this is generally not cost effective. For duct systems constructed to 4" (1000 Pa) wg class and higher, the designer must determine if any justification for testing exists. If it does, the contract documents must clearly designate the portions of the system(s) to be tested and the appropriate test methods. ASHRAE energy conservation standards series 90 text on leakage control generally requires tests only for pressures in excess of 3" (750 Pa).

The *HVAC Air Duct Leakage Test Manual* provides practical and detailed procedures for conducting leakage tests.

Apparent differences of about ten percent between fan delivery and sum of airflow measurements at terminals do not necessarily mean poor sealing and excess leakage. Potential accuracy of flow measurements should be evaluated.

Otherwise, open access doors, unmade connections, missing end caps, or other oversights contribute to such discrepancies. When air terminals are at great distances from fans (over 500 feet [152m]), more effective sealing is probably required to avoid diminished system performance.

Schools, shopping centers, airports, and other buildings may use exposed ductwork. Selecting sealing systems for such ducts may involve more attention to the final appearance of the duct system than with ducts in concealed spaces.

Certain types of paint may form reliable seals, particularly for small cracks and holes. Further research and confirmation is needed in this area.

Longstanding industry acceptance of so-called low pressure duct systems without sealants may have left some contractors (and designers) with little or no experience with sealing. The contractor should carefully select construction details consistent with sealing requirements, the direction of the air pressure, and familiar sealing methods. The cost of restoring systems not receiving the required sealing or not being properly sealed can greatly exceed the modest cost of a proper application. Contractors using slip and drive connection systems must control connector length and notch depth on rectangular duct ends to facilitate sealing.

Failure to do so will compromise seal effectiveness. Round duct joints are normally easier to seal than other types. However, with proper attention to joint selection, workmanship, and sealant application, almost any joint can achieve low leakage. The mere presence of sealant at a connection, however, does not ensure low leakage. Applying sealant in a spiral lockseam can result in poor seam closure and less satisfactory control. No single sealant is the best for all applications. Selecting the most appropriate sealant depends primarily on the basic joint design and on application conditions such as joint position, clearances, direction of air pressure in service, etc.

The listing of certain duct products by recognized test laboratories may be based on the use of a particular joint sealing product. Such a component listing only reflects laboratory test performance and does not necessarily mean that the closure method can routinely be successful for the contractor or that it will withstand in-service operation of the system on a long-term basis.

1.5.2 Liquids

Many manufacturers produce liquid sealants specifically for ducts. They have the consistency of heavy syrup and can be applied either by brush or with a cartridge gun or powered pump. Liquid sealants normally contain 30 to 60 percent volatile solvents; therefore, they shrink considerably when drying. They are recommended for slip-type joints where the sealant fills a small space between the overlapping pieces of metal. Where metal clearances exceed 1⁄16 inch (1.6 mm), several applications may be necessary to fill the voids caused by shrinkage or runout of the sealant. These sealants are normally brushed on to round slip joints and pumped into rectangular slip joints.

1.5.3 Mastics

Heavy mastic sealants are more suitable as fillets, in grooves, or between flanges. Mastics must have excellent adhesion and elasticity. Although not marketed specifically for ductwork, high quality curtain wall sealants have been used for this application. Oilbase caulking and glazing compounds should not be used.

1.5.4 Gaskets

Durable materials such as soft elastomer butyl or extruded forms of sealants should be used in flanged joints. For ease of application, gaskets should have adhesive backing or otherwise be tacky enough to adhere to the metal during joint assembly. The choice of open cell or closed cell rubber gaskets depends on the amount and frequency of compression and on the elastic memory.

1.5.5 Tapes

Nothing in this standard is intended to unconditionally prohibit the use of pressure sensitive tapes. Several such closures are listed as components of systems complying with UL Standard 181 tests. There are no industry recognized performance standards that set forth peel adhesion, shear adhesion, tensile strength, temperature limits, accelerated aging, etc., which are quality control characteristics specifically correlated with metal duct construction service. However, the SMACNA *Fibrous Glass Duct Construction Standards* illustrate the closure of a fibrous duct to metal duct with a tape system. The variety of advertised products is very broad. Some test results for tapes are published in the product directories of the Pressure Sensitive Tape Council located in Chicago, IL.

The shelf life of tapes may be difficult to identify. It may be only six months or one year. Although initial adhesion may appear satisfactory, the aging characteristics of these tapes in service is questionable. They tend to lose adhesion progressively at edges or from exposures to air pressure, flexure, the drying effects at the holes or cracks being sealed, etc. The tape's adhesive may be chemically incompatible with the substrate, as is apparently the case with certain nonmetal flexible ducts. Application over uncured sealant may have failures related to the release of volatile solvents. Sea air may have different effects on rubber, acrylic, silicone-based (or other) adhesives.

Tapes of a gum-like consistency with one or two removable waxed liners have become popular for some applications. They are generally known as the peel and seal variety and have been used between flanges and on the exterior of ducts. Such tapes are typically of thicknesses several times that of tapes traditionally known as the pressure sensitive type. Some may have mesh reinforcement. Others may have metal or nonmetal backing on one surface.

1.5.6 Heat Applied Materials

Hot melt and thermally activated sealants are less widely known but are used for ductwork. The hot melt type is normally a shop application. Thermally activated types use heat to either shrink-fit closures or to expand compounds within joint systems.

1.5.7 Mastic and Embedded Fabric

There are several combinations of woven fabrics (fibrous glass mesh, gauze, canvas, etc.) and sealing compounds (including lagging adhesive) that appear better suited for creating and maintaining effective seals than sealant alone. Glass fabric and Mastic (GFM) used for fibrous glass duct appears to adhere well to galvanized steel.

1.5.8 Surface Preparation

Surfaces to receive sealant should be clean, meaning free from oil, dust, dirt, rust, moisture, ice crystals, and other substances that inhibit or prevent bonding. Solvent cleaning is an additional expense. Surface primers are now available, but their additional cost may not result in measurable long-term benefits.

1.5.9 Sealant Strength

No sealant system is recognized as a substitute for mechanical attachments. Structural grade adhesive systems are being developed to replace spot welded and soldered connections of metals. They have lap shear strengths of 1000 to 5000 psi (6895 to 34475 kPa) or more. SMACNA is not able to comprehensively define their characteristics at this time; however, authorities are encouraged to monitor their development progress and consider their use.

1.5.10 Shelf Life

The shelf life of all sealant products may be one year or less; often it is only six months. The installer is cautioned to verify that the shelf life has not been exceeded.

1.5.11 Safety Considerations

Sealant systems may be flammable in the wet, partially cured, or cured state.

USE LIQUIDS AND MASTICS IN WELL VENTILATED AREAS AND OBSERVE PRINTED PRECAUTIONS OF MANUFACTURERS.

The contractor should carefully consider the effects of loss of seal and fire potential when welding on or near sealed connections. NFPA Standard 90A requires adhesives to have a flame spread rating not over 25 and a smoke developed rating not over 50.

Reprinted from pages 1.8 – 1.12 SMACNA HVAC Duct Construction Standards — 2nd Ed., 1995

SECTION 2

RESPONSIBILITIES

2.1 The duct system designer should:

a. Match the fan to the system pressure losses.

b. Designate the pressure class or classes for construction of each duct system, as appropriate and cost effective, and clearly identify these *in the contract document.*

c. Evaluate the leakage potential for ducts conforming to SMACNA or other standards and supplement the requirements therein with deletions and additions as may be prudent and economical, giving due attention to the location of the ducts, the type of service, the equipment, dampers and accessories in the system, the tolerances on air balance and the performance objectives. He must account for leakage in equipment such as fans, coils, volume regulating boxes, etc., independently of duct leakage.

d. Prudently specify the amount and manner of leakage testing (if testing is deemed justified) and clearly indicate the acceptance criteria.

e. Reconcile all significant inconsistencies between his performance specifications and his prescription specifications before releasing contract documents for construction.

f. Avoid ambiguity created by references to non-specific editions of SMACNA or other documents he has specified.

g. Have his contract documents reflect a clear scope of work known by him to conform to applicable codes and regulations, including those addressing energy conservation.

h. Require adequate submittals and recordkeeping to insure that work in progress conforms to the contract documents in a timely manner.

2.2 The ductwork installer should:

a. Comply with the contract documents.

b. Provide all required preconstruction and after-installation submittals.

c. Report discovery of conflicts and ambiguities, etc., in a timely manner.

d. Schedule any required leakage tests in a timely manner, with appropriate notice to authorities.

e. Seal duct where and as specified.

f. Examine the leakage criteria, the specified duct construction classes, and the testing and balancing specifications for consistency!

g. Select duct construction options and sealing methods that are appropriate and compatible, giving due consideration to the size of the system.

h. Control workmanship.

i. Acquire increased understanding of the nature and amount of leakage and of the methods and costs of sealing and leak testing, especially the amount of preparation time inherent in demonstrating a successful test.

j. Demonstrate that following prescriptive measures for construction precludes the need for leak testing.

SECTION 3

GENERAL PROCEDURES

3.1 Conventional leak testing is based on positive pressure mode analysis. It involves inserting temporary plugs (plates, sheets, balloons, bags, etc.) in openings in a section of duct and connecting a blower and a flowmeter to the specimen in such a manner that pressurizing the specimen will cause all air escaping from the specimen to pass through the flowmeter.

3.2 Select a test pressure not in excess of the pressure class rating of the duct.

3.3 Calculate the allowable or allocated leakage using leakage factors related to the duct surface area.

3.4 Select a limited section of duct for which the estimated leakage will not exceed the capacity of the test apparatus.

3.5 Connect the blower and flowmeter to the duct section and provide temporary seals at all open ends of the ductwork.

3.6 To prevent overpressurizing of the ducts, start the blower with the variable inlet damper closed. Controlling pressure carefully, pressurize the duct section to the required level.

3.7 Read the flowmeter and compare the leakage in cfm per square foot with the allowable rate determined in step 3.3. If it meets the allowable rate proceed to step 3.8. If it does not meet the allowable rate follow steps 3.7a through 3.7c.

a. Inspect the pressurized duct (and all connections between the flowmeter and the duct) for all sensible leaks. A smoke bomb test may be used to identify actual leak sources. If necessary apply a soap solution to locate small leaks.

b. Depressurize; repair all audible and other significant leaks. If the first pressurization failed to develop the required test pressure level and significant leak sites were not discovered, consider the following alternatives: Divide the specimen being tested into smaller segments or use larger test apparatus.

c. Allow repaired seals to cure and retest until the leakage rate is acceptable.

3.8 Complete test reports and, if required, obtain witness's signature.

3.9 Remove temporary blanks and seals.

3.10 Precautions

a. Verify that an adequate and matched electric power source is available for the test apparatus.

b. Determine that the capacity of the test apparatus is suitable for the amount of duct to be tested.

c. Consider acquiring experience with leakage rates in the type of construction used before formally conducting field tests. This is especially advisable if the contractor has little experience with testing, is attempting to meet allowable rates much lower than normal, is including equipment in the test or is dealing with unfamiliar duct construction.

d. Isolate equipment (fans, in-line flanged coils, volume regulating boxes, etc.) from tested ductwork. The system designer should have independently accounted for leakage in equipment.

e. Anticipate difficulty with any test of ductwork that has no prescription for sealing yet is required to meet an allowable leakage level.

f. Do not overpressurize ducts. Provide pressure control or pressure relief if test apparatus behavior is unfamiliar; *e.g.*, start test apparatus with flow restricted and gradually build up pressure.

g. Do not test uncured seals.

h. Prepare carefully when testing in cold weather. Low temperature influences the effectiveness of sealants and gaskets.

i. Instruct installers to use special care when assembling ducts that will be relatively inaccessible for repair.

j. Conduct required tests before external insulation is applied and before ducts are concealed by building enclosures.

k. Do not overlook leakage potential at access doors.

l. Do not leave test apparatus unattended.

m. Avoid panic by informing occupants and bystanders when you will conduct smoke tests.

n. Avoid excessive blanking, consistent with industry practice, by testing prior to installation of collars for room air terminals.

o. Take testing seriously; work sequence, work duration and costs can be significantly affected.

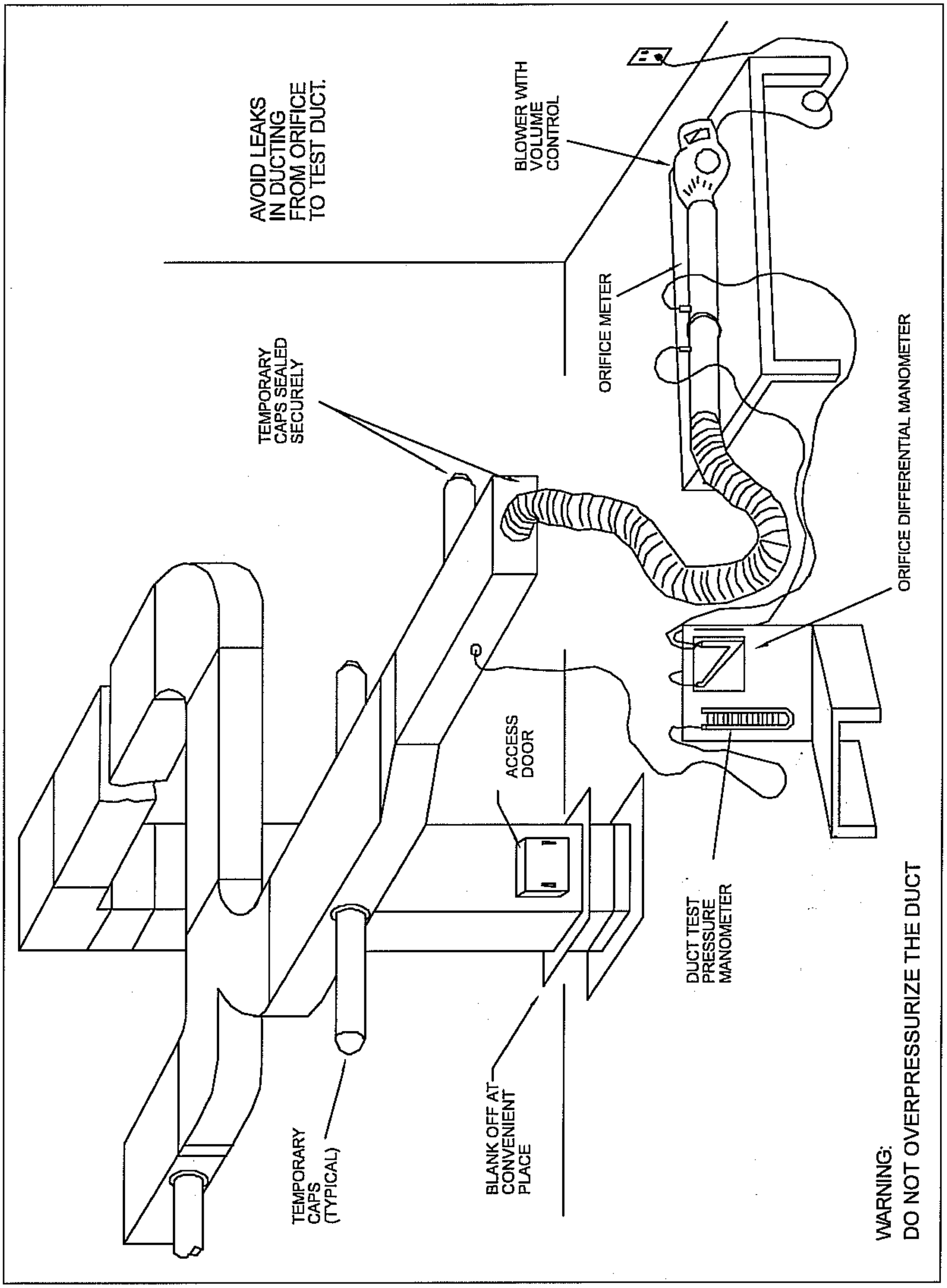


FIGURE 3-1 ILLUSTRATION OF TESTING