CHAPTER 7

MECHANICAL SYSTEM STRUCTURES

7-1. General

Design of support features for mechanical systems such as heating, ventilating, and air-conditioning (HVAC) systems (including items such as foundations, support frames, braces, and other items) will be in accordance with current practice, sound engineering principles, and manufacturer's recommendations as appropriate. The minimum safety factor for stability against overturning and for resistance against sliding will be as set forth in paragraph 1-6. For design of structures associated with power plants, see applicable portions of TM *5-811-6*. Design of mechanical support systems for seismic restraint is covered in TM 5-809-10/NAVFAC P-355/AFM 88-3, Chapter 13.

7-2. Equipment supports and enclosures

a. Static. Design of supports and enclosures for static equipment will consider the maximum weight and eccentricity of the equipment as well as the required clearance for access to and maintenance of the equipment. Lateral supports and bracing will be provided as necessary to maintain the stability of the equipment under lateral loading, particularly seismic.

b. Rotating or vibrating. Design of supports and enclosures for vibrating or rotating machinery will consider the need for isolation pads, isolation joints, and damping devices either alone or in combination. Care will be taken to assure that the natural frequency of supports is sufficiently offset from the operating frequency of the equipment so that there is no danger of objectionable or damaging resonant vibration. Whenever practical, supports for rotating or vibrating equipment will be physically isolated from the adjacent structure to prevent the transmission of vibration into occupied areas. NAVFAC DM-7.3 and Design of Structures and Foundations for Vibrating Machines by Arya, O'Neill, and Pincus are among the references which will be consulted for further guidance on structural design for vibrating equipment.

7-3. Utility tunnels

Utility tunnels will be provided for mechanical systems where a number of systems follow the same general alignment. Design of utility tunnels and similar underground structures will be in accordance with ASTM C 857 and ASTM C 858 unless more stringent requirements are imposed by the agency having jurisdiction.

7-4. Pipe supports

Pipe supports will be designed to resist the various forces to which the piping system will be subjected. As a minimum, all pipe supports will be designed to carry the weight of the piping system plus water to account for hydrostatic testing. Other forces including those due to wind, snow, seismic activity, thermal expansion and contraction, thrust, impact, etc., will be considered as appropriate for the details of the system and materials being used. For systems conveying materials at temperatures other than ambient, consideration will be given to the effect of thermal expansion and contraction on the support system. Where possible, the flexibility of the support structure will be considered to avoid the need for slide bearings or similar construction. In any case, appropriate allowance will be made for movement and restraint to conform with the assumptions made in the pipe system flexibility analysis. In regions of potential seismic activity, particular attention will be given to assure that sufficient lateral support is provided.

7-5. Gas and air conveyances

Gas and air conveyances, particularly for hot gases, will be designed to meet fire protection requirements including National Fire Protection Association (NFPA) 211. Design of supports for HVAC systems will comply with TM 5-8 10-1.

a. Large-scale ductwork. Large-scale ductwork refers to ductwork typically associated with major supply air and hot gas conveyances, e.g., between the various components of large industrial or power generation boiler plants. Large-scale ductwork may be of either circular or rectangular cross section and is usually constructed of steel. Structural design of large-scale ductwork will be in accordance with the following Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) publications: Accepted Industry Practice for Industrial Duct Construction, Rectangular Industrial Duct Construction Standards, and Round Industrial Duct Construction Standards. Design considerations will include forces exerted on the duct system such as those due to gas pressure, dead and live loads, wind loads, snow loads, seismic loads, and loads due to thermal expansion and contraction. In addition, the design will consider the effects of elevated temperature which can reduce the yield point and other mechanical properties of steel. The layout of duct systems will include a sufficient, but minimum number of expansion joints, adequate provisions for movement, and appropriate restraint at supports. For duct with large, circular cross sections, structural design may be based on methods described in the Structural Engineering

Handbook by Gaylord & Gaylord for circular steel stacks. Components will be proportioned so that resonance due to vortex shedding at low wind velocities is avoided. For duct of rectangular cross section, structural design will be in accordance with the AISI Design of Plate Structures, Design of Welded Structures by Blodgett, and applicable portions of the American Institute of Steel Construction (AISC) Specification for Structural Steel Buildings Allowable Stress Design and Plastic Design that relates to plate girders. Design will include a determination of plate thickness required to resist flexural loading, the size and spacing of stiffeners, the size and location of internal bracing, and additional plate thickness and features which may be required if the duct is designed as a spanning box girder.

b. Stacks. In addition to maximum loadings, stacks will be designed to resist the effects of vortex shedding or fluttering caused by steady wind. Stack designs will consider pressure differential stresses caused by virtue of the stack's conveying a gas of different specific gravity than atmospheric conditions and to temperature differential stresses caused by an uneven temperature distribution within the stack. See also ASCE Design and Construction of Steel Chimney Liners.

(1) Reinforced concrete stacks. Reinforced concrete stacks will be designed in accordance with ACI 307.

(2) Aluminum stacks. If constructed of aluminum, design of stacks will follow similar design guidance and general references given for design of steel stacks.

(3) Steel stacks.

(a) Design of steel stacks will be in accordance with the AISC Specification for Structural Steel Buildings Allowable Stress Design and Plastic Design; Structural Engineering Handbook by Gaylord & Gaylord; SMACNA Guide for Steel Stack Design and Construction; and ASME STS-1. Allowable stresses will be in accordance with table 7-1. The allowable stress is for a design condition of dead load combined with either seismic or wind loads.

Table 7-1. Steel stack allowable stresses*

The basic formula for allowable longitudinal compressive stress is: $F = XY$

where:

$$X = \begin{cases} 0.0625Et/R & \text{for } 0 \ t/R \ 8F_p/E \\ 0.5[F_y - k_s(F_y - F_p)] & \text{for } 8F_p/E \ t/R \ 20F_y/E \\ 0.5F_y & \text{for } t/R \ 20F_y/E \end{cases}$$

$$k_s = [(F_y - 0.05Et/R)/(F_y - 0.4F_p)]2$$

$$Y = \begin{cases} 1 & \text{for } L/r \ 60 \text{ and } F_y \ 50 \text{ ksi} \\ 21{,}600/[18{,}000 + (L/r)2] & \text{for } L/r \ 60 \text{ and } F_y \ 50 \text{ ksi} \end{cases}$$

and:

F_y = yield strength at mean shell temperature, ksi.
F_p = proportional limit at mean shell temperature, ksi; may be taken as 0.7Fy.
E = modulus of elasticity at mean shell temperature, ksi.
t = shell plate thickness, in., at the section under consideration.
R = radius of shell, in.
L = length of stack between points of lateral support.
For a self-supporting stack, L should be taken as the effective length, i.e., $L = 2 \times$ stack height,in.
r = radius of gyration = 0.707R for circular stack, in.

* Obtained from Structural Engineering Handbook, Second Edition, Gaylord & Gaylord, McGraw Hill Book Company, 1979. Reproduced with permission of McGraw-Hill, Inc.

(b) Shell thickness will be at least 1/4 inch for lined stacks and 5/16 inch for unlined stacks. The computed shell thickness will be increased by 1/16th inch to allow for possible corrosion. The net section area (gross area minus bolt hole areas) will be used to determine actual stresses. Allowable stresses for parts other than the shell plate will be in accordance with AISC Specification for Structural Steel Buildings Allowable Stress Design and Plastic Design.