ENGINEERING AND MATERIAL STANDARD

FOR

AIR COOLED HEAT EXCHANGER

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0. INTRODUCTION

This Standard Specification gives the amendments and supplements to API Standard 661, Second Edition January 1978 and reconfirmed 1987.

"Air-Cooled Heat Exchangers for General Refinery Services"

It is intended that API Standard together with this standard shall be used for air-cooled heat exchanger equipment for use in oil refineries, chemical plants, gas plants and, where applicable, in exploration and production and new ventures.

For ease of reference, the clause or section numbering of API Standard 661 has been used throughout this Standard. Clauses in API Standard 661 not mentioned remain unaltered.

For the purpose of this Standard, the following definitions shall hold:

Sub. (Substitution): The API Standard clause is deleted and replaced by a new clause.

Del . (Deletion): The API Standard clause is deleted without any replacement.

Add. (Addition): A new clause with a new number is added.

Mod. (Modification): Part of the API Standard clause is modified, and/or a new description and/or condition is added to that clause.

SECTION 1 : GENERAL

1.1 Scope

1.1.1 This Standard covers the minimum requirements for mechanical design, materials, fabrication, inspection, testing, and preparation for shipment of air-cooled heat exchangers for general refinery services. (Mod.)

1.1.3 Requirements concerning civil engineering, electricity and instrumentations are not included in this Standard. (Add.)

1.2 General

1.2.4 Where for reasons of control, an air-cooled heat exchanger has to be provided with automatic variable-pitch fans, as in the case of overhead condensers, it shall not share its fans with air cooled heat exchangers on other duties, for example product run-down coolers. (Add.)

1.2.5 For refinery applications, horizontal heat exchangers of either type are preferred, so that several air cooled heat exchangers can be grouped into one bank. (Add.)

1.3 Referenced Publications

In preparation of this supplementary standard, in addition to the referenced codes and standards mentioned in API 661, the following standards and publications have also been referred to or considered: (Add.)

API (AMERICAN PETROLEUM INSTITUTE)

673	"Special-Purpose Centrifugal Fans for General Refinery Services"
613	"Special-Purpose Gear Units for Refinery Services"
671	"Special-Purpose Couplings for Refinery Services"
614	"Lubrication, Shaft-Sealing and Control Oil Systems for Special-Purpose Applications"

ANSI (AMERICAN NATIONAL STANDARDS INSTITUTE)

A 12.1	"Safety Requirements for Floor and Wall Openings, Railings and Toaboards"
A 14.3	"Safety Requirements for Fixed Ladders"
B 16.1	"Cast Iron Pipe Flanges and Flanged Fittings 25, 125, 250 and 800"
B 31.3	"Chemical Plants and Petroleum Refinery Piping"

TEMA (TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION)

AGMA (AMERICAN GEAR MANUFACTURER ASSOCIATION)

421.06	"Practice for High Speed Helical and Herringbone Gear Units"

EEMUA (ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION)

Publication No. 135	"Heat Exchanger Tubes"

BSI (BRITISH STANDARD INSTITUTION)

BS 5500	"Unfired Fusion Welded Pressure Vessels"
BS 4395 Parts 1 & 2	"High Strength Friction Grip Bolts Associated Nuts and Washers for Structural Engineering"
BS 4604 Parts 1, 2 & 3	"Specification for the Use of High Strength Friction Grip Bolts in Structural Steel Work Metric Series"

ERNEST E. LUDWIG

"Applied Process Design for Chemical and Petrochemical Plants"

NIOC (NATIONAL IRANIAN OIL COMPANY)

Engineering Standard

SP-45-11	"Spec. for Air-Cooled Heat Exchanger"

IPS (IRANIAN PETROLEUM STANDARDS)

G-ME-220	"Shell and Tube Heat Exchangers"
M-PM-320	"Lubrication Shaft Sealing and Control Oil Systems for Special Purpose"
M-EL-132	"Materials and Equipment Standard for Three Phase Induction Motors"
E-SF-900	"Noise and Vibration Control"
E-TP-100	"Engineering Standard for Paints"

1.4 Conflicting Requirements

1.4.1 For requirement of the design and construction of a particular air cooled heat exchanger the following priorities shall be considered:

- The information given in the specification sheets and drawings.
- The purchase order.
- This Standard. (Sub.)

1.5 Units

This Standard is based on International System of Units (SI) except where otherwise is specified. (Add.)

SECTION 2 : PROPOSALS

2.2.12 The proposal shall include a characteristic performance curve for fans, and for louvers (when provided). (Add.)

SECTION 3 : DOCUMENTATION

3.1 All documentation shall be in English unless otherwise specified. However, descriptions on drawings and similar documents may be in other languages providing English translations are also given.

The Vendor shall furnish all drawings, design details, operation and maintenance manuals and other information necessary for the design assessment, erection, operation and maintenance of the installation. The design details shall include stress calculations of header box and tube bundle covering all combinations of flow, temperatures and pressure for the specified operating conditions. All information, especially the manuals for operation and maintenance, shall be explicit and not open to misinterpretation, and shall apply specifically to the installation supplied.

Use shall be made of the data/requisition sheets for the exchange of information between the Company and Vendor. Units of measurement shall be as shown on the data/requisition sheets. (Add.)

3.1.1 The following statement to be added to No. 10 of this Sub-subclause:

- Loading diagrams and all information necessary for the design of the supporting structure. (Mod.)

The following numbers to be added:

14. Nameplate and its position. (Add.)

15. The manufacturer shall provide the detailed drawings and information required by Clauses 3.1.3 and 3.1.4 of API standard 661, as amended by this standard, when submitting outline drawings for approval. (Add.)

3.1.3 The following statement to be added to this Sub-subclause:

- Drawings shall show methods of fixing tubes to tubesheets, position of joints and details of joint preparation details of the precise arrangements for lubrication shall also be included. (Mod.)

3.1.4 Delete "if specified" from this Sub-sub clause. (Mod.)

3.1.5

a) Header details including metal thicknesses, internal header dimensions, pass partitions, stiffeners and tube layout, shall be provided. If the entire header thickness is increased to provide necessary reinforcement for nozzles, the thickness for reinforcement shall be noted on the header drawing.

b) Fabrication drawings shall show weld details and reference applicable welding procedures. The drawing shall also include impact test requirements, showing (as applicable):

1) Component
2) Thickness for impact purpose
3) Material specification
4) Critical Exposure Temperature
5) Appropriate charpy impact requirements (average/minimum values).

c) Vendor's proposal for spare parts shall include proposed method of protection from corrosion during shipment and subsequent storage. (Sub.)

3.2 The following documents shall be submitted after the contract has been awarded, and well in advance of estimated date of shipment:

a) List of all spare parts including a list of initial spare parts necessary for start-up and first year of operation with detailed prices and time of delivery.

b) List of all tools necessary for operation, maintenance, inspection and cleaning insofar as not normally found in a refinery workshop.

c) Six copies of the operation and maintenance manuals. (Add.)

SECTION 4 : GUARANTEE

4.1.2 The manufacturer shall guarantee that the air-cooled heat exchanger shall meet the required design conditions of the specific application. (Sub.)

4.1.6 The air-cooled heat exchanger supplied shall be free of defects in materials and workmanship. Any materials, or equipment which fail under normal operating conditions due to defects in material or workmanship if the defect is observed and/or such failure occurs within one year from the date such material or equipment is put to use, or eighteen (18) months from the date of shipment, shall be replaced or repaired by the supplier in the shortest possible time, free of charge, inclusive of dismantling reassembling at site and all trasportation costs. (Sub.)

4.1.7 The Vendor shall guarantee interchangeability of equal mechanical parts. (Add.)

SECTION 5 : DESIGN

5.1 Tube Bundle Design

5.1.1 General requirements

5.1.1.1 Each tube bundle shall be rigid and self-contained so that it can be handled as one complete assembly. The width of the tube bundle shall be chosen with due regard to transport and handling aspects, and shall not, in general, exceed 3 meters. Tube-to-tube sheet joints shall preferably be rolled and shall also be strong enough to contain the stresses caused by differential thermal expansion in the case of plugged or fouled tubes. (Sub.)

5.1.1.5 The following statement to be added to this clause:

Tubes shall be adequately supported either by tube support boxes or proprietary collar zinc supports. Collar zinc supports shall not be used in combination with austenitic stainless steel tubes, in that case Aluminum supports shall be used. (Mod.)

5.1.1.11 Wind and seismic forces shall be considered in the design of a tube bundle as required in the data sheet. (Add.)

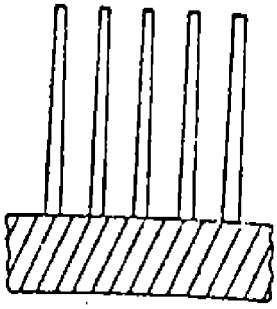
5.1.2 Tube bundle design temperature

5.1.2.1 The temperature used in design shall be based on the actual metal temperature expected under operating conditions for the part considered at the designated coincident pressure. (Sub.)

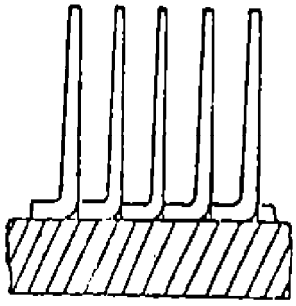
5.1.2.3 Fin selection shall be based on the max. specified operating temperature (fin design temp.) (see Fig. 1 in this Standard). (Mod.)

5.1.3 Tube bundle design pressure

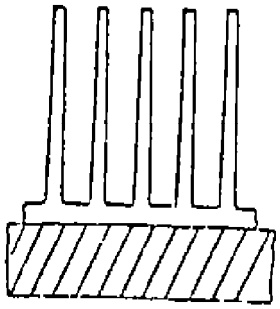
5.1.3.2 The design pressure (i.e., the pressure to be used in the equations for the purposes of calculation) shall be not less than:



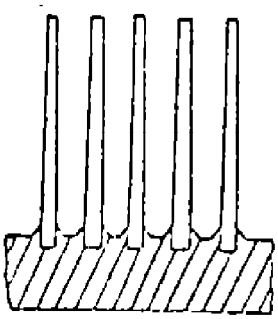
Edge Wound
(Design Temp = 120°C max.)
(rarely used)



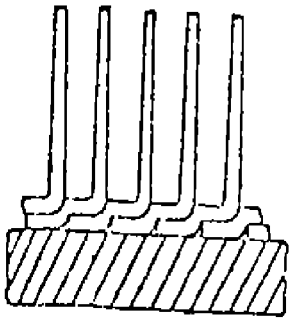
Footed Tension
(Design Temp = 150°C max.)



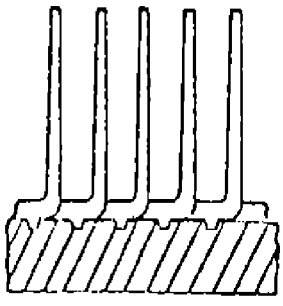
Extruded
(Design Temp = 260°C max.)



Embedded
(Design Temp = 400°C max.)



Double Footed Tension
(Design Temp = 150°C max.)



Footed Grooved Tension
(Design Temp = 260°C max.)

TYPES OF FINNED TUBES USED IN AIR COOLED HEAT EXCHANGERS (Add.)

Fig. 1

a) The pressure which will exist in the tube bundle when the pressure relieving device starts to relieve, or the set pressure of the pressure relieving device, whichever is higher;

b) the maximum pressure which can be attained in service where this pressure is not limited by a relieving device. (Sub.)

5.1.4 Corrosion allowance

5.1.4.2 Corrosion allowances for carbon steel, and for low-alloy steel pressure parts, shall be 3 mm for oil processing applications and 1.5 mm for chemical processing applications, unless otherwise specified. Alloy parts are not required to have corrosion allowance. (Mod.)

5.1.5 General requirements for headers

5.1.5.4 Headers with multiple nozzle or an increased header cross-sectional area may be required. At least one inlet nozzle is required per meter of bundle width. (Mod.)

5.1.5.5 The minimum tube sheet thickness shall be in accordance with TEMA R and nominal thickness of header components shall conform as a minimum to the following:

	CARBON OR LOW ALLOY STEEL mm	HIGH-ALLOY STEEL, OTHER MATERIALS mm
Tube Sheet	20	16
Lug Sheet	20	16
Bottom, And End Plates	12	10
Removable Cover Plate	15	25

The thickness for any carbon or low-alloy steel component up to 3 mm corrosion allowance. The thickness for any component of high-alloy steel or another material does not provide corrosion allowance. (Mod.)

5.1.5.7 In multi-pass headers, split headers shall be used where the temperature differential across the bundle is sufficient to cause wrapage of the header tube sheets or bowing of tubes. This would normally occur when the temperature differential between inlet and outlet exceeds 110°C. (Add.)

5.1.5.8 Header pass arrangements and location of nozzles for bank arrangement shall be designed to mini- mize piping runs and thermal stresses. (Add.)

5.1.6 Headers-removable-cover-plate and removable-bonnet-type

5.1.6.3 Bolted joints shall be designed with confined gaskets in accordance with Fig. 4 (A) or (B). (Mod.)

5.1.6.5 Either jackscrews or 5 mm minimum clearance shall be provided at the cover periphery to facilitate dismantling. Lifting lugs or eye bolts shall be provided for all cover plates. (Mod.)

5.1.6.7 Stud bolts and through bolts shall be used. (Mod.)

5.1.6.12 Cover plate bolting smaller than 16 mm (5/8 inch) shall not be used. (Add.)

5.1.6.13 Unless otherwise specified, the headers shall be of the cover-plate-type designed for working pressures up to 30 bar. For hydrogen service and for working pressures above 30 bar, plug-type headers shall be applied. For very high pressures, manifold type headers may be used with return bends. (Add.)

5.1.7 Headers-plug-type

5.1.7.1 Plugged holes shall be provided opposite the ends of each tube for access. Plug type headers shall have easy accessibility for:

a) Cleaning;
b) re-rolling to tighten tube joint, and;
c) plugging tube in case of singular tube leaks;
d) inspection. (Mod.)

5.1.9 Gaskets

5.1.9.2 The selection of gaskets for cover plate header flanges depends on the temperature, pressure, and corrosive conditions of the fluids to be sealed.

For air-cooled heat exchangers made of steel,and provided that hydrocarbon streams are free from hydrogen, gaskets shall be selected as per following Table. (For hydrogen service, the plug-type header design only shall be allowed.)

GASKETS DIMENSIONS

TEMPERATURE °C	PRESSURE bar	GASKET TYPE	MINIMUM GASKET WIDTH mm	GASKET THICKNESS mm
Max. 240	Max. 20.5	Oil or acid resistant	9	1.5
> 240-Max. 450	Max. 30	Corrugated metal Jaketed soft iron	12	3

For certain chemical services, Gaskets of the Type, e.g., solid metal or spiral-wound may be required. (Sub.)

5.1.9.4 Gaskets shall have a continuous periphery with no radial leak paths. This shall not exclude gaskets made continuous by welding or other methods which produce a homogeneous bond. (Mod.)

5.1.10 Nozzles and other connections

5.1.10.1 Nozzles DN 40 (1½ inch) and larger shall be flanged. The use of sizes 2½, 3½ and 5 in. is not permitted. (Mod.)

5.1.10.2 Flange rating and type of facing will be specified. Flange dimensions and facing shall be in accordance with ANSI B16.5. The finish of the nozzle flange facing shall conform to the appropriate piping class. (For flange face finish and gaskets see Appendix N.) (Mod.)

5.1.10.4 Flanged carbon steel connections shall be of one of the following types:

1) Integrally forged steel with welding-neck-type flange.
2) Seamless pipe or, for sizes DN 400 (16 in.) and larger, pipe rolled from steel plate and longitudinally double butt-welded, to which a welding-neck flange or slip-on flange is attached.

Welding neck flange shall be used for swaged nozzle for low-temperature applications, for the containment of lethal substances or liquefied gases, and in hydrogen service. The minimum permissible thickness of flanged carbon steel nozzles and connections shall be:

For size DN 40 (1½ in.) and DN 50 (2 in.) schedule 160
For size DN 75 (3 in.) and DN 100 (4 in.) schedule 80
For size DN 150 (6 in.) and DN 200 (8 in.) schedule 40
For size DN 250 (10 in.) and larger schedule 30

(Sub.)

5.1.10.7 All pipe tap connections shall be a minimum of 41, 500 kPa (6000 psi) standard coupling or equivalent. Each connection shall be fitted with a round head bar stock plug conforming to ANSI B16.11 of the same material as the connection.

Alternate plug materials may be used when galling is anticipated, except cast iron plugs shall not be used. (Mod.)

5.1.10.8 All flanged nozzles of DN 100 (4 in.) or larger shall be provided with one connection of DN 25 (1 in) minimum, for a thermometer. For smaller sizes connection shall be on header adjacent to the nozzle. (Sub.)

5.1.10.9 All flanged nozzles of DN 50 (2 in.) or larger shall be provided with one connection of DN 20 (¾ in) minimum, for a pressure gage. If the nozzle is less than DN 50 the connection shall be on the header adjacent to the nozzle. (Sub.)

5.1.10.11 Multi-Purpose service connections when specified shall be flanged. These may be used for flushing/washing out, steaming out and chemical cleaning. (Sub.)

5.1.10.15 Vent and drain connections, of DN 20 (¾ in) minimum, shall be provided at high and low points on each header or header nozzle unless larger size is specified. Connections serving as vents and drains shall not extend into the header beyond the inside surface. (Mod.)

5.1.10.18 Screwed or socket weld connection for hydrogen service shall not be used. All flanged nozzles shall be directly welded to the header. (Add.)

5.1.10.19 Telltale holes, on reinforcing pads shall be threaded ¼ in. NPT in accordance with ANSI B2.1. Reinforcing pads are not allowed in hydrogen service. (Add.)

5.1.12 Tubes

5.1.12.1 The minimum acceptable tube diameter is 25.4 mm (1 in.) OD. (Mod.)

5.1.12.2 Most common tube length for IPS project is prefered to be 9144 mm (30 ft) although standard bundles are available in lengths of 2438.4 mm (8 ft), 3048 mm (10 ft), 4572 mm (15 ft), 6096 mm (20 ft), 7315.2 mm (24 ft) 10363.2 mm (34 ft), and 12192 mm (40 ft). (Sub.)

5.1.12.3 The preferred and minimum wall thickness for tubes of 25.40 mm and 38.10 mm OD are shown below:

O.D mm	WALL THICKNESS		TUBE MATERIAL
	PREFERED	MINIMUM	
25.40	2.1	1.6	All alloys
25.40	3.3	2.7	Carbon steel only
38.10	3.3	2.7	Carbon steel only

(Sub.)

5.1.12.5 Tubes shall be finned tube or bare tube as specified. (Mod.)

5.1.12.6 The total unfinned length of a finned tube between tube sheets after assembly shall be 50 mm. (Mod.)

5.1.12.7 Fins may be of same or different material than tube wall. Aluminum fins are most popular for average installation.

The fins may be extruded on the host tube, embedded, wrapped into spiral grooves cut into the host tube, or just wrapped on the host tube (see Fig. 1 of this Standard). For aluminum fins maximum design temperatures are listed below:

1) Tubes of mechanically embedded fin type shall not be used for design temperatures exceeding 400°C (750°F).

2) Tubes of extruded fin type shall not be used for design temperatures exceeding 260°C (500°F).

3) Tubes of footed tension wound fin type shall not be used for design temperatures exceeding 150°C (300°F).

4) Tubes of overlapped footed tension wound fin type shall not be used for design temperatures exceeding 150°C (300°F).

5) Tubes of spiral groove footed fin type shall not be used for design temperatures exceeding 260°C (500°F). The groove shall be per sub-item 1 above for mechanically embedded fins. The fin foot shall be extruded into the groove to a minimum depth of one-half the fin thickness ±0.05 mm (±0.002 in).

6) Tubes of tension wound fin type shall not be used for design temperatures exceeding 120°C (250°F). Tubes of tension wound fin type are prohibited in steam condensing services. (Mod.)

5.1.12.8 Minimum stock thickness for L-shaped and embedded fins shall be 0.35 mm for up to a fin height of 6.35 mm (0.25 in.) and 0.40 mm for fin heights above 6.35 mm. For extruded fins these thicknesses shall apply at the root of the fin. (Mod.)

5.1.12.9 Stainless steel and non-ferrous tubes shall be seamless. Carbon steel tubes shall be seamless. If electric resistance welded type is used prior approval of the Company shall be obtained. For high pressure and high temperature the use of seamless tube is mandatory. (Add.)

5.1.12.10 Carbon steel, ferritic alloy, and austenitic alloy steel tubes shall meet the requirements of ASTM A-450 "General Requirements for Carbon, Ferritic and Austenitic Alloy Steel Tubes". (Add.)

5.1.12.11 All tubes shall have no circumferential weld seam. (Add.)

5.1.12.12 Fin ends of tension wound fins shall be secured by rivet, screw, or staple fasteners. (Add.)

5.1.12.13 The maximum allowable number of fins is 400 per meter of the tube length. In order to prevent fouling, fin surfaces shall be smooth. (Add.)

5.2 Air Side Design

5.2.1 General requirements

5.2.1.6 The driver and fan assemblies shall be so located as to have easy access to all components. (Add.)

5.2.1.7 Fouling on the outside of finned surface is usually rather small, but must be recognized. Values of 0.020 to 0.030 kj/h.m². °C usually satisfy most fin side conditions.

5.2.2 Noise control [1)]

5.2.2.7 The noise level is usually limited to 75 decibels maximum at 15.24 meters (50 ft) from the fan, and the blade tip speed is limited: to 3352.8-3657.6 meter per minute (11,000-12,000 feet per minute). This may run higher for unit below 121.92 cm (48 in) dia. (Add.)

5.2.3 Fans and fan hubes

5.2.3.5 The rated speed of the fan shall not exceed 1200 revolutions per minute unless otherwise approved by the Company.

5.2.3.11 Fans equipped for pneumatically actuated, automatically controlled pitch adjustment of blades shall comply with the followings:

1) The actuators shall be diaphragm or piston type, and be suitable for an air supply pressure of 7 bar.g normal and 2.5 bar.g minimum. Make and type shall be approved.

2) Each actuator shall have an integral positioner mechanism and mechanical maximum and minimum stops. These stops shall be adjustable over the full range without dismantling the mechanism. The positioner shall be designed to operate on 0.2 to 1 bar pneumatic control signal. Each change in the control signal shall result in a corresponding change in the fan blade pitch. The operating range of the positioner shall be adjusted so that the maximum pitch obtained is equal to the selected design blade angle setting. Maximum and minimum blade pitch limit stops shall be set by the fan manufacturer. Unless otherwise specified by the Company, the minimum blade pitch limit will result in essentially zero air flow with hot bundles. Exposed actuator shafts shall be protected with canvas gaiters. The stroking time, from minimum to maximum pitch or reverse, shall be 10 seconds maximum with the fan rotating. Hysteresis shall not exceed 1% of full stroke.

3) In the case of air failure, blades shall move to a maximum pitch and be locked in position.

4) Actuators and positioners shall be easily accessible for maintenance and adjustment. For induced drought, actuators and positioners may be installed above the fans provided ease of access is maintained and outlet air temperatures do not exceed 100°C. For forced drought, actuators and positioners shall be installed under the drive mechanism. Typical arrangements for forced drought, induced drought, direct drive, and A-belt in-direct drive are shown respectively, in Appendices H and K of this Standard.

5) The rotating parts of actuators shall be protected by a wire mesh screen with a removable panel allowing actuator adjustment. (Mod.)

1) For more information refer to the following standards:

IPS-E-SF-900	**"Noise & Vibration Control"**
ISO 1999	**"Assessment of Occupational Noise Exposure for Hearing Conservation Purposes"**
EEMUA	**"Guide to The Use of Noise Procedure Specification Publication No. 141"**
BS 4142	**"Method of Rating Industrial Noise Affecting Mixed Residential and Industrial Areas"**
BS 5330	**"Method of Test for Estimating Hearing Handicap Due To Noise Exposure"**

5.2.3.14 The equipment, including auxiliaries, covered by this standard shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation. It is recognized that this is a design criterion.(Add.)

5.2.3.15 Fans shall be designed and constructed to operate satisfactorily at all specified operating conditions, maximum continuous speed, and to the trip speed setting of the driver, if applicable. (Add.)

5.2.3.16 Induced draft fans shall be mechanically designed for operation at least at 37.7°C (100°F) above maximum specified fan inlet air temperature. (Add.)

5.2.3.17 Fan, components, and accessories shall be designed to withstand all loads and stresses during rapid load changes, such as across-the-line starting of motor drivers, failure of damper operator and sudden opening of dampers. (Add.)

5.2.3.18 All equipment shall be designed to permit rapid and economical maintenance. (Add.)

5.2.4 Fan shafts and bearings

5.2.4.6 Shafts shall be one piece, heat treated, forged steel, suitably ground. Shafts 15 centimeters (6 in.) in diameter and smaller may be machined from hot rolled steel. Shaft diameter shall be stepped on both sides of impeller fit area to facilitate impeller removal. (Add.)

5.2.4.7 Ball type thrust bearings shall be dual single row, 40 degree, light preload, angular contact type (7000 series), installed back-to-back. (Add.)

5.2.4.8 Fan wheels preferably shall have a nonoverloading horsepower characteristic and shall be designed for highest possible efficiency. (Add.)

5.2.4.9 Impellers shall have solid hubs, be keyed to the shaft, and be secured with a thermal shrink fit. Cast iron, nodular iron, and hollow hubs are not acceptable. (Add.)

5.2.4.10 Shaft seals shall be replaceable from the outside of the inlet boxes without disturbing the shaft or bearings. (Add.)

5.2.4.11 Bearing housing mounting surfaces shall be machined in a flat continuous plan parallel to the bearing bore. (Add.)

5.2.4.12 Bearing housings shall be drilled with pilot holes for use in final doweling. (Add.)

5.2.5 Lubrication facilities

5.2.5.1 All linkage, shaft fittings, and bearings preferably shall be permanently lubricated. Components requiring periodic lubrication shall be furnished with lubrication fittings which are accessible while the fan is in operation. (Add.)

5.2.6 Fan guards

5.2.6.9 Where the fan guards are specified for induced-draft with top mounted drivers, the guard shall be provided with a hinged door to enable replacement of V-belts without removal of the entire guard. (Add.)

5.2.6.10 The guard shall be constructed to be rigid enough to withstand a 91 kilogram (200 pound) static load with a deflection of not more than 0.0005 times the unsupported length of the guard. (Add.)

5.2.6.11 The guard shall contain anti swirl baffles, as required, to minimize the effects of windage and air swirl. (Add.)

5.2.7 Drivers-general requirements

5.2.7.1 The type of driver will be specified by the purchaser. (Mod.)

5.2.8 Electric motor drivers

5.2.8.7 Electrical Induction Motors shall conform to IPS-M-EL-132 "Material and Equipment Standard for Three Phase Induction Motors". (Add.)

5.2.11 Belt drives

5.2.11.1 Whether timing belt, V-belt or power band drive is required will be specified on the data sheets. Poly V-belts shall be used instead of V-Belts. (Sub.)

5.2.11.11 The maximum parallel misalignment of motor and fan shaft shall not exceed 0.1 mm total indicator reading (TIR). (Add.)

5.2.12 Gear drives

5.2.12.3 Gear units shall be in accordance with AGMA 421.06 and shall be of the spiral, single-reduction-type with outboard bearing and have an AGMA service factor of not less than 2.0 based on the power of the drive. The gears shall be SAE 4620 or equivalent, hardened, lapped and match-marked. (Sub.)

5.3 Structural Design

5.3.1 General requirements

5.3.1.1 Structural steel design, fabrication, and erection shall be in accordance with American Institute of Steel Construction (AISC) Standard Specifications for structural steel buildings or approved equivalent. (Mod.)

5.3.1.2 High-strength friction grip bolts in accordance with BS 4395: Parts 1 & 2 and BS 4604: Parts 1, 2 & 3 may be used for all site connections. (Mod.)

5.3.1.8 Manufacturer shall be responsible for meeting the vibration requirement of field assembled units. (Add.)

5.3.1.9 Structural supports for suspended drivers:

a) Shall be assembled using through-bolts;
b) shall not be attached to the bundle side frames. (Add.)

5.3.3 Plenums

5.3.3.2 Each fan shall have its own plenum chamber effectively sealed off from adjacent chambers. Where an automatic variable-pitch fan is installed, its plenum chamber shall serve one unit only. (Sub.)

5.3.3.6 Bottom of fan ring shall be a minimum of 2 meters above grade. (Add.)

5.3.4 Access facilities

5.3.4.1 Platforms shall be provided to serve inlet and return headers if the elevation of the bottom of the header above grade is greater than 3 meters (10 ft).

The need for additional platforms will be determined from the final arrangement and layout of the unit. The layout and sizing of platforms to serve driver and fan assemblies shall permit access to all components. Space shall be provided for placement of drivers, transmissions, and fan components. (Sub.)

5.3.4.3

a) Floor plate shall have raised pattern and a minimum thickness of 6 mm (¼ in.);

b) floor plate drainage shall be provide by one 13 mm (½ in.) diameter hole for approximately every 1.5 m² (15 sq ft.) hols shall be located at low spots and drilled after erection. (Mod.)

5.3.4.4 The need for the ladders will be determined from the final arrangement and layout of the unit. (Sub.)

5.3.4.5 Ladders, guard railings, toe plates, safety cages and similar items shall be constructed of steel per ANSI A 12.1 and A 14.3.

1) Safety cages shall be provided for ladders with a height of over 3 meters (10 feet).

2) Chains with safety hooks or safety gates shall be provided across ladder opening on the platforms.

3) Ladders shall be provided for side-step access to platforms. (Mod.)

SECTION 6 : MATERIALS

6.1 General Requirements

6.1.1.1 All materials of equivalent to ASTM Standard Specification may be used upon approval of purchaser. (Add.)

6.1.4 Fin material shall be aluminum in accordance with ASTM B 209 alloy 1060 unless otherwise specified. (Mod.)

6.1.8 Fan blades shall be of aluminum alloy or glass-fiber reinforced plastic and in case of induced draft fan arrangement shall be able to withstand a temperature of minimum 110°C. (Mod.)

6.1.16 Damper or variable guide vane operating mechanisms, linkages, and other external part subject to rotary or sliding motions shall be of corrosion resistant materials suitable for the site environment.

Internal operating parts subject to rotary or sliding motion shall be stainless steel or other equally corrosion resistant material. Minor parts associated with such mechanism (bolts, nuts, springs, washer, gaskets, and keys) shall have equal corrosion resistnace. (Sub.)

6.1.24 Proposals to use materials having a specified maximum tensile strength greater than 620 MPa (90,000 psi) at room temperature shall be approved by the Company. (Add.)

SECTION 7 : FABRICATION

7.1 Welding

7.1.1 General

7.1.1.3 All header welds subject to pressure, shall be full penetration and full-fusion. All header welds, other than connection to header welds, shall be double welded joints, except that when one side of a weld on a pressure part is not accessible, single-welded joints are acceptable provided full penetration is obtained. Typical weld details are shown in Appendix N of this Standard. No welding shall be carried out after postweld heat treatment. (Mod.)

7.1.3.1 Removable-cover-plate-type header flanges for through bolting shall be installed with full penetration welding. (Sub.)

7.2 Postweld Heat Treatment (PWHT)

7.2.1 Postweld heat treatment of headers constructed of P-1 materials used for sour water (hydrogen sulfide and water) service shall be performed. The exemption provided for in ASME Code Section VIII, Table UCS-56 Note (1), allowing PWHT at lower temperature for longer periods of time, is not permitted. (Mod.)

7.3 Tube-to-Tube Sheet Joints

7.3.2 Tube hole grooving

7.3.2.1 Tube hole grooving shall be in accordance with TEMA R. (Sub.)

7.3.3 Expanded tube-to-tube sheet joints

7.3.3.3 The ends of tubes shall extend at least 1.5 mm and not more than 5 mm beyond the tube sheet unless otherwise specified. (Mod.)

7.3.4 Welded tube-to-tube sheet joints

7.3.4.1 Tube-to-tube sheet joints shall be welded only if specified on the data/requisition sheets. When welded joints are specified, bonding with silver is not permitted. (Mod.)

7.3.4.4 Welding procedure and testing techniques for either sealwelded or strength-welded tube-to-tube sheet joints shall be submitted for approval before work is started. (Mod.)

7.3.4.5 Expanded tubes shall be seal-welded to the headers for hydrogen service over 6900 kPa (1000 psig) or over 540°C (1000°F) unless specified otherwise. (Add.)

SECTION 8 : INSPECTION, EXAMINATION, AND TEST

8.1 General

8.1.6

1) In general, the scope of inspection and testing and/or verification of records at the manufacturer's shop shall be as shown in Appendix G.

2) The manufacturer's inspection record for radiographic, magnetic particle and liquid penetrant examination shall be as shown in Appendix F.

8.3 Pressure Test

8.3.1 Tube bundle shall be hydrostatically tested in accordance with the requirements of the ASME Code.

The hydrostatic test pressure shall be as specified on the Air Cooler Specification sheet and shall be not less than 1½ times the design pressure corrected for temperature except for cast iron parts where other ASME Code requirements govern. (Mod.)

8.3.4 Water used for hydrostatic testing of units in which austenitic stainless steel material will be exposed to the test fluid shall be potable water having less than 100 parts per million (100 milligrams per kilogram) chlorides. After hydrostatic testing, these units shall be drained immediately. (Mod.)

8.3.5 Paint or other coating shall not be applied over welds prior to the final hydrostatic test.

Surfaces in contact with the fluid and also flange facings shall be thoroughly cleaned before the apparatus is closed for the pressure test. (Mod.)

8.3.7 When liquid cannot be tolerated as a test medium, then by agreement between the company and manufacturer, the tube bundle shall be given a pneumatic test in accordance with the code requirements. (Add.)

8.3.8 All hydrostatic tests shall be made in the presence of an inspector and with his approval. Units shall not be previously tested by the manufacturer. (Add.)

8.3.9 Reinforcing pads shall be pneumatically tested at a pressure of 1 barg. The telltale holes in the reinforcing pads shall be left open after testing. (Add.)

SECTION 9 : PREPARATION FOR SHIPMENT

9.1.2 All surfaces to be painted shall be dry and free from burrs, weld spatter, flux, dirt, grease, oil, rust, loose mills-cale and other matter before any paint is applied. (Mod.)

9.1.3 All exposed machined contact surfaces shall be coated with a removable rust preventive and protected against mechanical damage by suitable covers. (Mod.)

9.1.4 All surfaces requiring painting shall be painted in accordance with paint standard IPS-E-TP-100. (Mod.)

9.1.5 All flanged auxiliary piping connections shall be provided with metal closure of 5 mm minimum thickness, with rubber gaskets, and at least four full diameter bolts. (Mod.)

9.1.10 All threaded openings shall be suitably plugged. (Add.)

9.1.11 The exchanger and any spare parts are to be suitably protected to prevent damage during shipment. (Add.)

9.1.12 Exchangers and parts separately packages shall be clearly identified by painting the purchase order number and the item number in two different locations on the outside of the containers. (Add.)

APPENDICES

APPENDIX B (Mod.)
AIR-COOLED HEAT EXCHANGER CHECKLIST

(by API 661 Second Edition, January 1978 Reconfirmed 1987)

This checklist shows the standard requirements of IPS as purchaser, which items are indicated by bullet (o) in API Std. 661.

REFERENCE PARAGRAPH	ITEM	DECISION
1.2.3	Applicable local rules and regulations	To be specified
2.1.2	Number of copies of outlined drawings, approved drawings and final records required	To be specified
2.2.8	Noise data sheet required	Yes
3.1.4	Proposed welding procedures and qualifications required for approval	Yes
3.1.5	Additional engineering information required	To be specified
3.2.1	Additional final records required	No, in general
5.1.5.1	Analysis of alternative operations for excessive tube stress required	No, in general
5.1.6.7	Cover plate bolting type	Through bolt
5.1.10.4(4)	Cast or fabricated transitions allowed	To be specified
5.1.11.4	Maximum allowable moments and forces for floating headers	To be specified
5.2.1.1	Special environmental factors affecting air-side design	To be specified
5.2.1.5	Alternative design temperature for mechanical components located above tube bundle	To be specified
5.2.3.11(2)	Positioner required on fan blade actuator	To be specified
5.2.3.11(3)	Special blade pitch limit stop setting	To be specified
5.2.7.1	Driver supplier	Vendor
5.2.8.3	Alternative motor service factor	As API Std

(to be continued)

APPENDIX B - (continued)

REFERENCE PARAGRAPH	ITEM	DECISION
5.2.15.4	Alternative louver blade design load	As API Std.
5.2.15.11	Alternative motive air design pressure	As API Std.
5.3.1.5	Shop test for vibration check required	Vendor's option
5.3.1.7	Tube bundles removable without removing platforms	Yes
5.3.2(1)	Dead loads	To be specified
5.3.2.(2)	Live load	As API Std.
5.3.2(4)	Thermal forces	As API Std.
5.3.2(6)	Alternative wind load	To be specified
5.3.2(7)	Alternative earthquake design	To be specified
5.3.2(8)	Special loading combinations	As API Std.
5.3.4.1	Access platforms required	Yes
	Number and location	To be specified
5.3.4.3	Grating or expanded metal floor plates acceptable	Yes
	Number and location	To be specified
5.3.4.4	Number and location of ladders	Ladders shall be provided at both ends of the bank
6.1.9	Alternative galvanizing requirements for tube bundle components	As API Std.
6.1.10	Additional structural steel galvanizing requirements	The plenum fan deck shall be galvanized (not including tube bundles and its frames)
7.1.3.1	Cover-plate and bonnet header flange welding	Full Penetration
7.3.1.2	Reduced tube hole diameter and undertolerance required	No
7.4.2	Special finish for gasket contact surfaces	None
8.2.3	Full radiography required	No

(to be continued)

APPENDIX B - (continued)

REFERENCE PARAGRAPH	ITEM	DECISION
8.3.6	Special test other than hydrostatic	Yes
	Detail	pneumatic test in accordance with the code requirements
8.4	Shop run-in required	No, in general
9.1.9	Special preparation for export shipment	Detail to be specified individual cases
10.1	Section 10 supplemental requirements when apply	No, in general

*** Vendor shall be responsible for meeting the vibration requirement (Max. 150 μ peak-to-peak) for field assembled unit.**

APPENDIX C (Mod.)
TYPICAL PROCESS AND PHYSICAL PROPERTY DATA SHEET SI UNITS

Revision	No.	Date	By

Manufacturer

Sheet No. _____
Proposal No. _____
Contract No. _____
Date _____

1	Customer					Item No.			
2	Plant Location					Purch. Inq. No.			
3	Service					Purch. Ord. No.			
4	Heat Exchanged/Unit		W			Number of Components			
5			Code (1)						
6	Fluid Name		LVG						
7	Total Fluid Entering	kg/s	111						
8	Temperature, In/Out	°C	111	/					
9	Temperature, Dew Point/Bubble Point	°C	111	/					
10	Component Name		111						
11	Component Phase Entering		111						
12	Liquid Entering	kg/s	110						
13	Gas Entering	kg/s	011						
14	Fluid Condensed	kg/s	010						
15	Molecular Weight		211						
16	Critical Temperature	°C	011						
17	Critical Pressure	kPa	011						
18									
19	Physical Properties at Reference Temp. 1, °C		LVG						
20	Density, Liquid	kg/m^3	110						
21	Viscosity, Liquid	mPa.s	110						
22	Viscosity, Gas	mPa.s	011						
23	(Enthalpy)(Specific Heat Capacity), Liquid (3)		110						
24	(Enthalpy)(Specific Heat Capacity), Gas (3)		021						
25	Latent Heat	kJ/kg	010						
26	Thermal Conductivity, Liquid	W/(m.°C)	110						
27	Thermal Conductivity, Gas	W/(m.°C)	021						
28	Surface Tension	dyn/cm	010						
29	Vapor Pressure	kPa	010						
30	Equilibrium (or Van Laar) Constant		010						
31									
32	Physical Properties at Reference Temp. 2, °C		LVG						
33	Density, Liquid	kg/m^3	110						
34	Viscosity, Liquid	mPa.s	110						
35	Viscosity, Gas	mPa.s	011						
36	(Enthalpy)(Specific Heat Capacity), Liquid (3)		111						
37	(Enthalpy)(Specific Heat Capacity), Gas (3)		021						
38	Latent Heat	kJ/kg	010						
39	Thermal Conductivity, Liquid	W/(m.°C)	110						
40	Thermal Conductivity, Gas	W/(m.°C)	021						
41	Surface Tension	N/m	010						
42	Vapor Pressure	kPa	010						
43	Equilibrium (or Van Laar) Constant		010						
44									
45	Profile Information for Condensing Fluid								
46	Mole Fraction Vapor								
47	Equil. Temp/@ Press. _____ kPa)	°C							
48	Enthalpy, Liquid	kJ/kg							
49	Enthalpy, Vapor (@ Press.)	kJ/kg							
50	Vapor Average Mole Weight								
51									

52 NOTES: 1. Code: 0 – Not Needed, 1 – Needed for Any Method, 2 – Required for Multicomponents
53 L – Sensible Liquid, V – Condensing Vapor, G – Sensible Gas
54 2. If More Than 6 Components are Supplied, Use an Extra Sheet
55 3. Units: Enthalpy – kJ/kg Specific Heat Capacity – kJ/kg °C

APPENDIX F (Add.)
EXAMPLE "A" MANUFACTURER'S INSPECTION RECORD

MANUFACTURER'S INSPECTION RECORD
FOR RADIOGRAPHIC EXAMINATION

PURCHASER _____ ITEM No. _____
(JOB CODE No.) ( )

USER _____ EQUIPMENT _____

PROJECT _____ APPLICABLE CODE OR SPEC. _____

P.O. No. _____

MANUFACTURER _____

Radiation source	X - Ray : ☐ X - Ray (up to 400 KVP) ☐ Linear accelerator ☐ Other r - Ray : ☐ Iridium ☐ Cobalt ☐ Other
Source size	
Voltage and amperage	
Distance (source to film)	
Film type	
Screen type	
IQI (penetramater designation)	
Radiographic technique	☐ Single wall ☐ Double wall
Location examined, weld No., thickness, film No. or film mark	☐ See attached detail record
Judgement	☐ See attached detail record

Date : _____

Sign : _____
Inspector

APPENDIX F (Add.)

EXAMPLE "B" MANUFACTURER'S INSPECTION RECORD

MANUFACTURER'S INSPECTION RECORD
FOR MAGNETIC PARTICLE EXAMINATION

PURCHASER _____ ITEM No. _____
(JOB CODE No.) ( )

USER _____ EQUIPMENT _____

PROJECT _____ APPLICABLE CODE OR SPEC. _____

P.O. No. _____

MANUFACTURER _____

Stage of Examination	☐ Prepared Edge ☐ As Welded	☐ After P.W.H.T ☐ After Hydro Test	☐ Other		
Surface Preparation	☐ Grinding	☐ Machining	☐ As Welded	☐ Other	
Instrument	Type				
Mag. Method	☐ Yoke	☐ Prod	☐ Other		
Calibration					
Prod. Space	mm				
Current	☐ AC	☐ DC	A	AT	
Test Temperature					
Particle	☐ Dry	☐ Wet	☐ Black	☐ Brown	☐ Fluorescent
Location examined	☐ See attached detail record				
Result	☐ See attached detail record				

Date : _____

Sign : _____
Inspector

APPENDIX F (Add.)

EXAMPLE "C" MANUFACTURER'S INSPECTION RECORD

MANUFACTURER'S INSPECTION RECORD
FOR LIQUID PENETRANT EXAMINATION

PURCHASER _____ ITEM No. _____
(JOB CODE No.) ( )

USER _____ EQUIPMENT _____

PROJECT _____ APPLICABLE CODE OR SPEC. _____

P.O. No. _____ MANUFACTURER _____

Stage of Examination	☐ Prepared Edge ☐ As Welded	☐ After P.W.H.T ☐ After Hydro Test	☐ Other	
Surface Preparation	☐ Grinding	☐ Machining	☐ As Welded	☐ Other
Penetrant	Type	☐ Color Contrast	☐ Fluorescent	
	Application	☐ Brushing	☐ Spraying	
	Temperature	℃	Penetrant Time	min.
Removal	☐ Water Washable Penetrants ☐ Post Emulsifying Penetrants ☐ Solvent Removal Penetrants		Developing	☐ Dry Developer ☐ Wet Developer
Location Examined	☐ See attached detail record			
Result	☐ See attached detail record			

Date : _____

Sign : _____
Inspector

APPENDIX G (Add.)
SCOPE OF INSPECTION AND TESTING

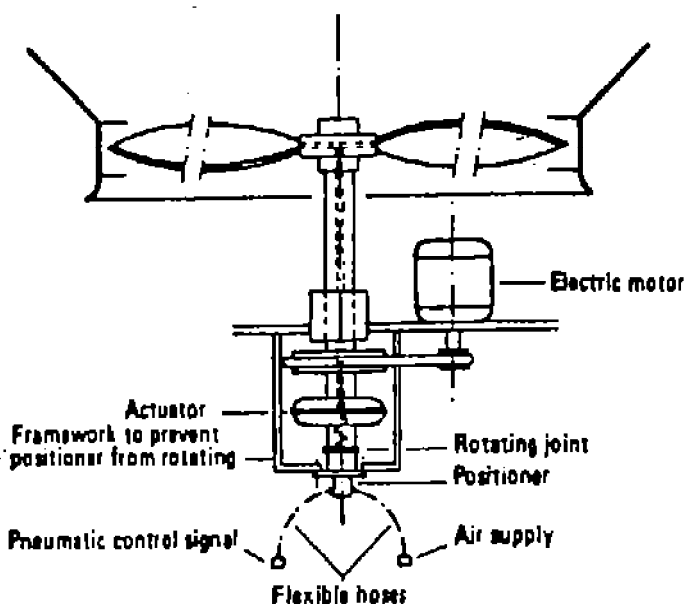
INSPECTION AND TESTING ITEMS	DIVISION OF WORK		REMARKS
	P.A.I.	M.F.R	
A. Tube Bundle Inspection			
1. Welding Qualification			
1.1 Confirmation of Procedure Qualification Record	R	S	
1.2 Welding Procedure Qualification Test	R	Tr & S	Before Fabrication
1.3 Welding Performance Qualification Test	R	Tr & S	
1.4 Verification of Qualification Welder's Test	R	S	
2. Material Inspection Verification of Material Certificate or Mill Test Report	R	Tr & S	
3. Inspection of wedling edge Preparation			
3.1 Magnetic Particle or liquid penetrant Examination	R R	Tr & S	Back Gouged Portion
3.2 Fit-up Inspection	R	Tr	
4. Welding Inspection			
4.1 Visual Inspection for Weldment	W	T	
4.2 Raidographic Examination	W/R	Tr & S	Verifying the Films
4.3 Magnetic Particle Examination	W/R	Tr & S	
4.4 Magnetic Particle Examination for Root Weld	R	Tr & S	
4.5 Liquid Penetrant Examination	W/R	Tr & S	
4.6 Liquid Penetrant Examination for Root Weld	R	Tr & S	
4.7 Hardness Test	W/R	Tr & S	
4.8 Confirmation of Heat Treatment	R	Tr & S	
5. Inspection for Completed Tube Bundle			
5.1 Dimensional Inspection	W/R	Tr & S	
5.2 Visual Inspection	W	T	
5.3 Confirmation of Tube Expanding	R	Tr & S	
5.4 Confirmation of Material Identification Marks	W/R	Tr & S	AS Built Sketch or Material List Showing Locations and Heat Number of Material
B. Air-Side Component Inspection			
1. Fan and Dirver Assembly Inspection			
1.1 Dimensional Inspection	R	Tr & S	
1.2 Visual Inspection	—	T	
2. Confirmation of Certificate or Test Report for Driver	R	Tr & S	
3. Balance Test for Fan Blades and Hubs	R	Tr & S	
C. Structural Steel Inspection			
1. Steel Memeber Inspection			
1.1 Dimensional Inspection	R	Tr & S	
1.2 Visual Inspection	—	T	
D. Accessories Inspection			
Confirmation of Quantities and Items of the Accessories	R	Tr & S	

Abbreviations:

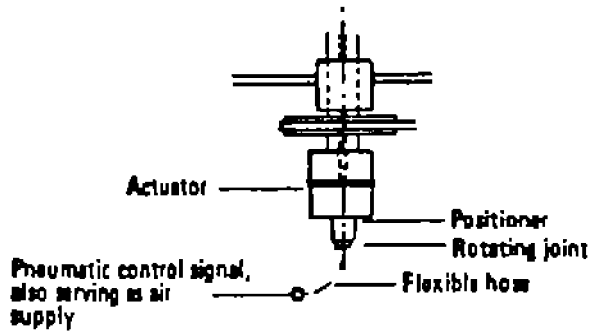
P.A.I.	Purchaser's Authorized Inspector
M.F.R	The Manufacturer
R	Verify by reviewing the manufacturer's inspection/test record
W	Witness inspection/testing
Tr	Manufacturer's own inspection/testing with the record to be prepared
T	Manufacturer's own inspection/testing
S	Submission of manufacturer's inspection/testing record

APPENDIX H (Add.)

TYPICAL INSTALLATION OF ACTUATORS FOR DIRECT - DRIVEN VARIABLE - PITCH FANS



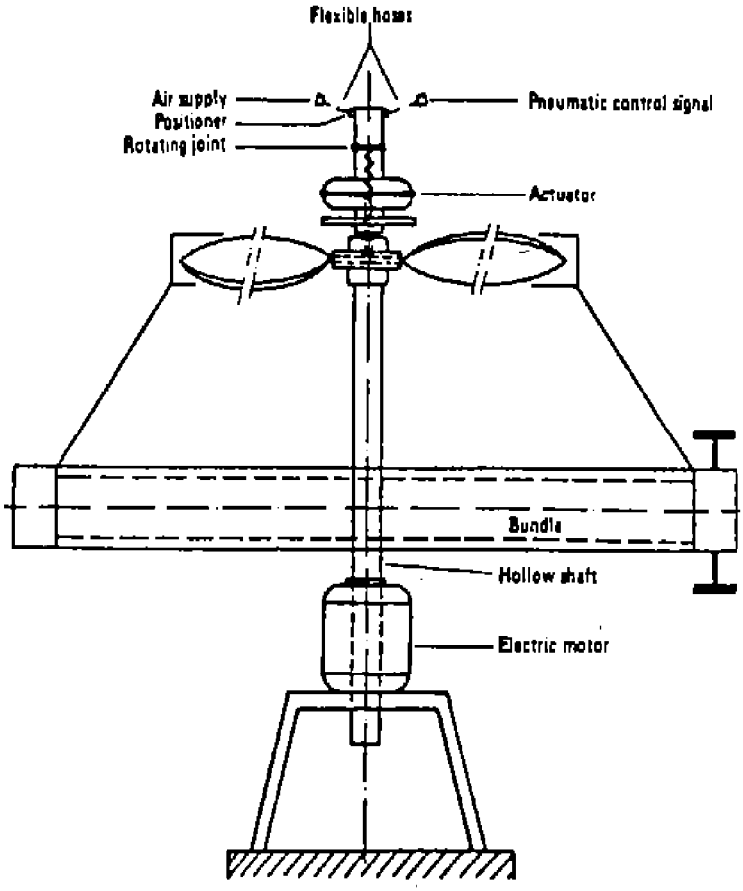
ACTUATOR WITH TWO PNEUMATIC CONNECTIONS



ACTUATOR WITH ONE PNEUMATIC CONNECTION

(to be continued)

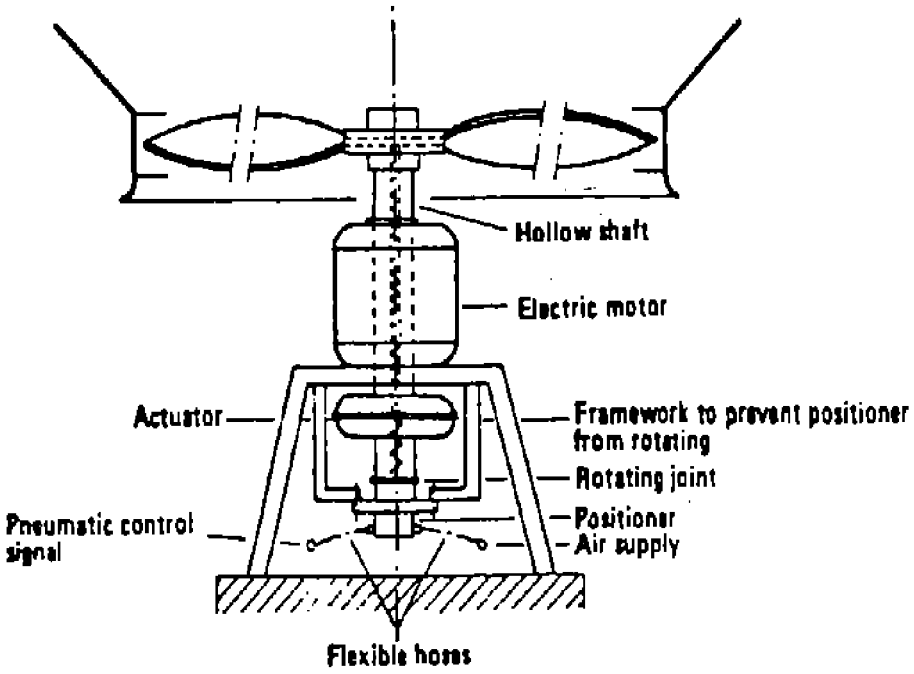
APPENDIX H (continued)



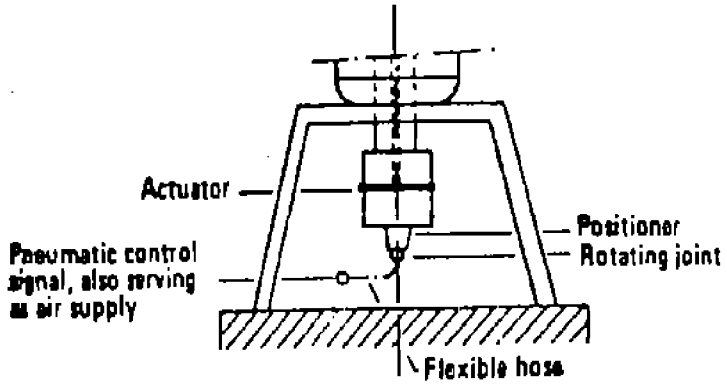
ACTUATOR WITH TWO PNEUMATIC CONNECTIONS

APPENDIX K (Add.)

TYPICAL INSTALLATION OF ACTUATORS FOR INDIRECT - DRIVEN VARIABLE - PITCH FANS

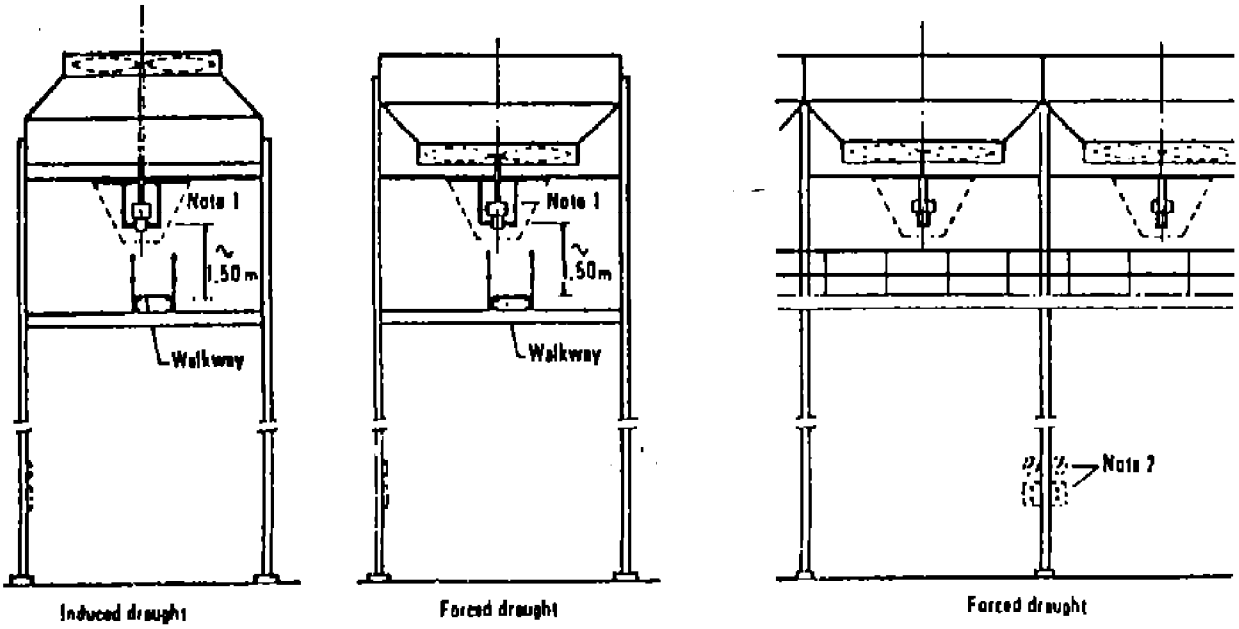


ACTUATOR WITH TWO PNEUMATIC CONNECTIONS



ACTUATOR WITH ONE PNEUMATIC CONNECTION

APPENDIX L (Add.)
TYPICAL MOUNTING OF ACTUATORS FOR VARIABLE - PITCH FANS

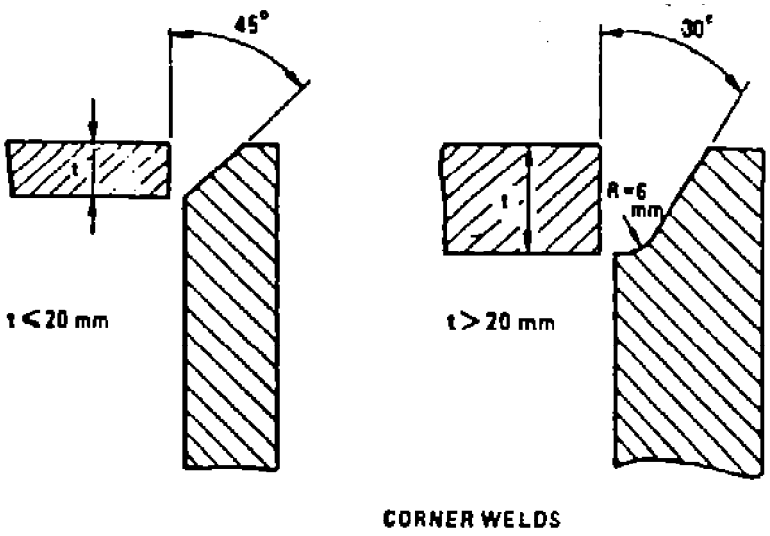


Notes:

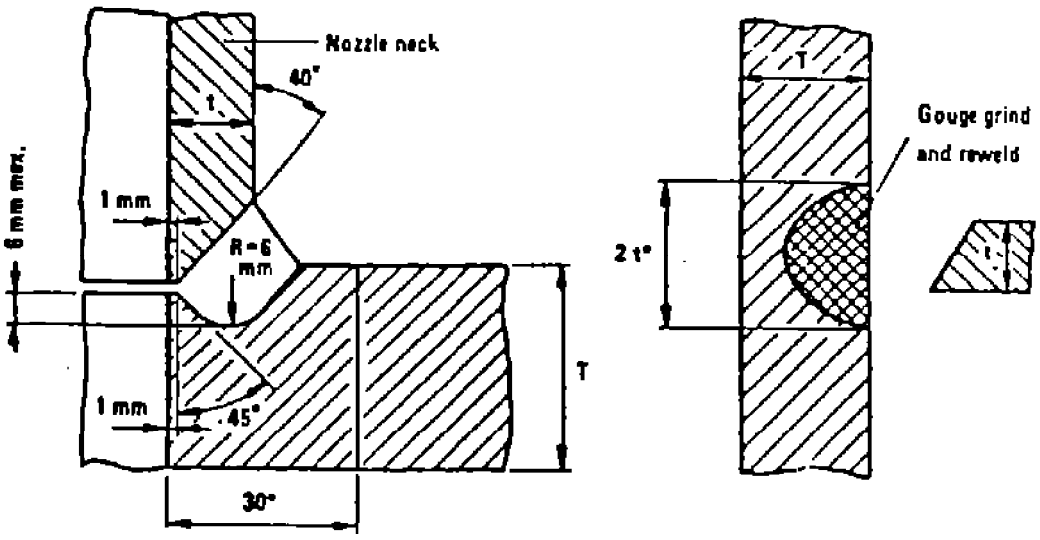
1) For details of actuator installation, see App. H and K.

2) Location of pneumatic receiving indicator and motor starting equipment.

APPENDIX M (Add.)
TYPICAL WELDING DETAILS



CORNER WELDS



SET-ON NOZZLE

PARTITION PLATE

To be used only if set-in nozzles cannot be used.
For T > mm and t > 15 mm.

For T < 35 mm and t > 15 mm, if plate quality is sensitive to lamellar tearing.

For T > 35 mm, steels with specified through thickness properties, Z 35 shall be used.

*** To be ultrasonically tested before welding.**

APPENDIX N (Add.)
FLANGE FACE FINISH AND GASKETS (ANSI B 46.1)

TYPE OF GASKETS	FLANGE SIZE	Ra VALUE
CAF (Compressed Asbestos Fiber)	12 in. and under	12.5 μm
CAF	Over 12 in.	25 μm
Spiral Wound	All	3.2-6.3 μm
Jacketed (Envelope Type)	All	1.6-3.2 μm
Solid Metallic	All	1.6 μm