



**STANDARDS and TYPICAL SPECIFICATIONS**  
**for**  
**TRAY TYPE DEAERATORS**

**NINTH EDITION**

## **Heat Exchange Institute, Inc.**

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#### **Deaerator Tech Sheets**

Tech Sheet #121: Vacuum Relief

Tech Sheet #120: Steam Pressure Control Valves

Tech Sheet #119: Safety and Relief Valves

Tech Sheet #118: Level Control

Tech Sheet #114: Deaerator Accessories

Tech Sheet #112: Technical Discussion  
on Pressure Vessel Post Weld Heat Treatment

Tech Sheet #111: Radiographic Testing (RT)  
Deaerator Vessels

Tech Sheet 109: Corrosion Allowance  
in Deaerator Design

Tech Sheet 108: Magnetic Particle Testing  
in New Deaerators

Tech Sheet 105: Deaerator Troubleshooting Guide

# **HEAT EXCHANGE INSTITUTE, INC.**

## **STANDARDS and TYPICAL SPECIFICATIONS for TRAY TYPE DEAERATORS**

*NINTH EDITION*

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## FOREWORD

The Deaerator Section of the Heat Exchange Institute has developed the Ninth edition of this standard. The material in this standard has been selected to incorporate the safest available design criteria, as well as the highest levels of deaerator performance.

This standard contains practical information on the design, construction, and operation of tray type deaerators. It is intended to serve as a guide for individuals who design, specify, purchase, and use tray type deaerators. This standard has been renamed from its original edition and the content revised to reflect the Institute's position that the tray type deaerator is the superior design type with regard to corrosion resistance and turn down performance.

This standard reflects the collective knowledge and experience of the Deaerator Technical Committee, and is reviewed and discussed during regularly scheduled meetings. This process insures that the standard will be regularly updated to reflect the changes in technology, codes, and member experience.

This standard continues to be influenced by the work of other organizations, such as American National Standards Institute (ANSI), American Society of Mechanical Engineers (ASME), American Society for Testing Materials (ASTM), NACE International, The Corrosion Society, and the Technical Association of the Pulp and Paper Industry. Special consideration and credit is given to NACE and TAPPI, for their extensive research on deaerator pressure vessel cracking. Particular attention and credit is given to NACE standard RPO 590-90. Adherence to this standard is strongly recommended.

Comments and suggestions for the improvement of this standard are always welcome and should be directed in writing to the Deaerator Section at the Institute's address.



## 1.0 SCOPE AND PURPOSE

### 1.1 Scope

The Ninth Edition of the HEI Standards and Typical Specifications for Tray Type Deaerators is intended to apply only to tray type designs that use steam as a means to heat incoming water and drive the deaeration process. This process heats the incoming water, condenses the steam, and liberates noncondensable gases from the incoming water.

The HEI realizes that there are other deaerator designs in the marketplace including spray type deaerators. This standard is written for tray type deaerators.

### 1.2 Purpose

The Ninth Edition of the Standard has been developed by the Deaerator Section of the Heat Exchange Institute. This Standard provides

practical information on nomenclature, design considerations, testing, and performance of the tray type deaerator. Use of the Standard will ensure a minimum of misunderstanding between manufacturer and purchaser and will assist in the proper selection of equipment best suited to the requirements of the application.

The equipment covered by this standard should also conform to the appropriate part, and most current edition, of the ASME Boiler and Pressure Vessel Code. Typically, ASME Section VIII, Division 1 is applicable, although other sections and divisions can be utilized. While this HEI standard is intended to apply to all tray type deaerators, some specialized types may require additional specifications. This HEI specification will be required as a minimum standard for ASME Section I, HRSG (Heat Recovery Steam Generator) Integral Deaerators.

## 2.0 DEFINITIONS

### 2.1 Deaerator

A deaerator is defined as a thermo-mechanical device for removal of dissolved gasses, primarily oxygen and carbon dioxide, from water. For the purposes of this standard, we will consider only pressurized and vacuum types which deaerate by contacting water with steam and elevating the temperature. Vacuum degassifiers remove dissolved gasses by reducing the pressure over the liquid without heating and will not be considered in this standard. Also, in cases where the storage section is a separate vessel, the term deaerator is used to describe what might better be called the deaerator vessel or deaerator section.

### 2.2 Tray Deaerator

This is a common industry term for a type of deaerator also known as a spray-tray deaerator. Inlet water is sprayed into a steam atmosphere and falls onto a bank of trays through which the steam passes. Steam flow may be co-current, cross-current, or counter-current to the water flow.

### 2.3 Spray Deaerator

This is the common industry term for a unit which might more properly be called a spray-

practical information on nomenclature, design water is sprayed into a steam atmosphere and falls onto a collector pan from which it flows into the scrubber/atomizer where it is mixed with incoming steam.

### 2.4 Storage Section

The storage section is an area in or below a deaerator which contains a specified volume of deaerated water. This may be contained in the lower portion of an integral unit or may be a separate tank located below the deaerator tank. See Section 7.5.

### 2.5 Pressure Vessel

A pressure vessel is "a metal container, generally cylindrical or spheroid, capable of withstanding various loadings."<sup>1</sup>

### 2.6 Vent Condenser

The vent condenser is typically an internal direct contact area in a deaerator where steam is cooled by the incoming water and caused to condense. Shell and tube heat exchangers may be used as external vent condensers, where specified by the customer on vacuum units.

<sup>1</sup> Pressure Vessel Handbook, Eugene F. Megyesy, 10th Edition, 1995, page 489.

**2.7 Vent**

A vent is an opening in the deaerator through which the noncondensable gasses and some steam are released. This release is normally to the atmosphere, although it is possible to vent to a vacuum for special applications.

**2.8 Design Pressure and Temperature**

The pressure and temperature for which the pressure vessel is mechanically designed. The maximum allowable working pressure (MAWP) shall be equal to the design pressure, unless otherwise specified. The minimum design metal temperature (MDMT) shall be -20°F, unless otherwise specified.

**2.9 Operating Pressure and Temperature**

The operating pressure is the pressure inside the deaerator when operating. This pressure is important as it determines what the temperature of the deaerator effluent will be. The deaerator effluent temperature will be within 2°F of the saturated temperature at the operating pressure.

**2.10 Corrosion Allowance**

An additional thickness of steel added to the pressure vessel in addition to that required to meet the structural requirements for pressure vessel design normally expressed in inches.

**2.11 Rated Capacity**

The total quantity of deaerator effluent including condensed inlet steam, water inlet, high pressure returns, and all other inlet flows normally expressed in pounds per hour.

**2.12 High Pressure Returns**

Flows which enter the deaerator or storage tank from higher pressure sources or sources such as high pressure feedwater heaters.

**2.13 Low Pressure Returns**

Flows which enter the deaerator at elevated, but less than saturation, temperatures.

**2.14 Makeup**

Undeaerated flow which enters the deaerator and is saturated with dissolved noncondensable gasses at the temperature specified.

**2.15 Sentinel Partial Relief Valve**

A warning device that indicates pressure exceeding normal operating conditions by exhausting steam.

**2.16 Safety Relief Valve**

A device that protects the vessel against pressurization above the design pressure.

**2.17 Downcomer Flow**

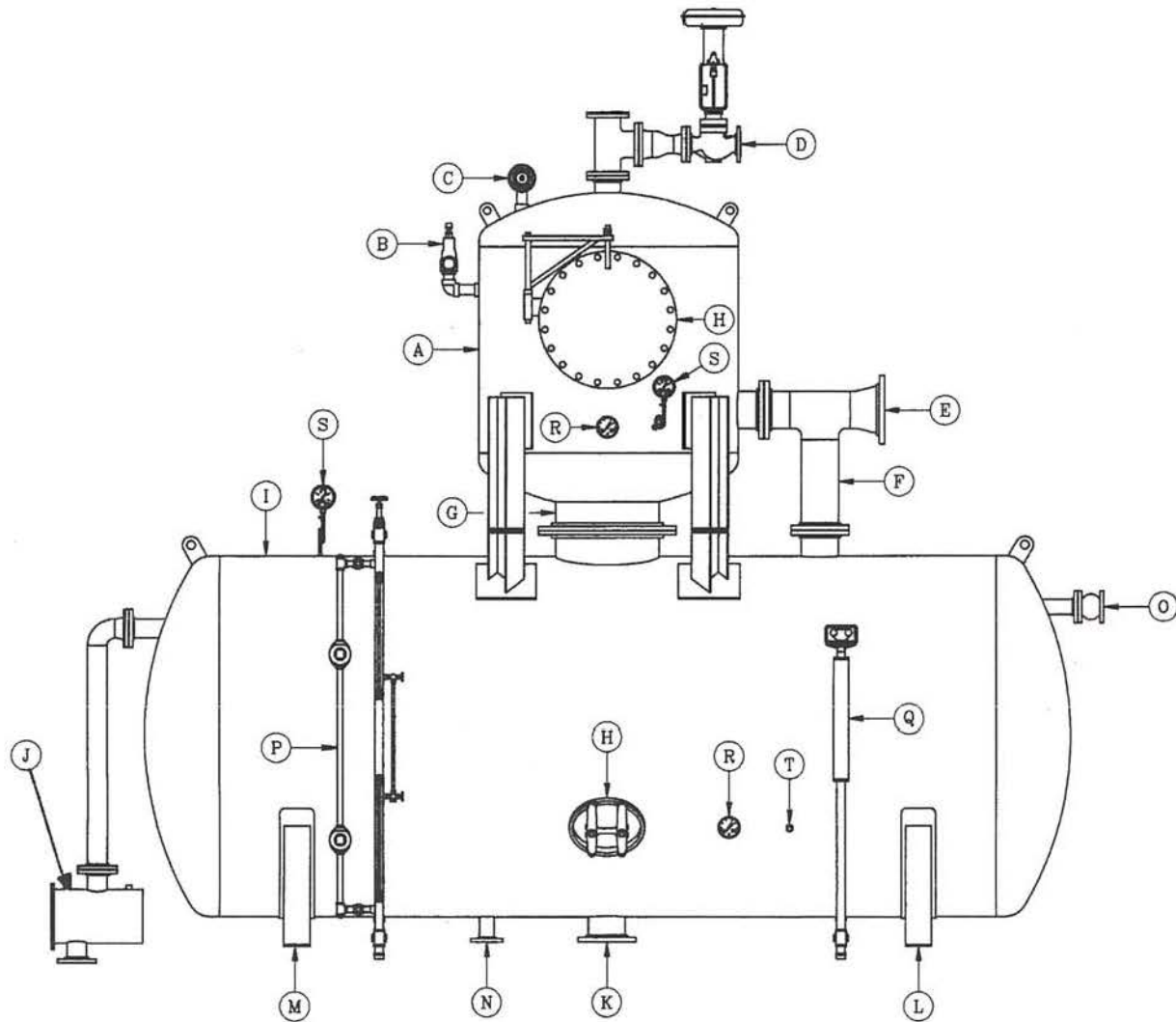
Deaerated outlet flow to the storage section.

**2.18 Equalizer**

A method of maintaining equal pressure between the deaerator and storage section.

### 3.0 TYPICAL VESSEL CONNECTIONS, ACCESSORIES, AND ORIENTATION

Please see Figure 1 for typical deaerator connections and accessories and Figure 2 for vessel orientations. The sketch itself is merely illustrative for the purpose of indicating names of parts.

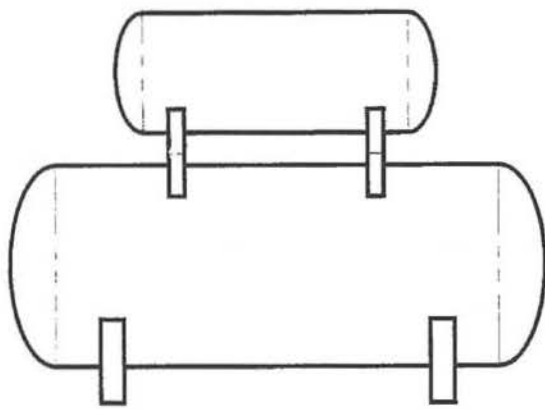


- |                      |                                   |
|----------------------|-----------------------------------|
| A. Deaerator Section | K. Outlet                         |
| B. Relief Valve      | L. Fixed Support Saddle           |
| C. Vent              | M. Sliding Support Saddle         |
| D. Water Inlet       | N. Drain                          |
| E. Steam Inlet       | O. Vacuum Breaker                 |
| F. Equalizer         | P. Level Gauge/Level Alarm Column |
| G. Downcomer         | Q. Level Controller               |
| H. Access Manway     | R. Thermometer                    |
| I. Storage Section   | S. Pressure Gauge                 |
| J. Overflow Control  | T. Sampling Connection            |

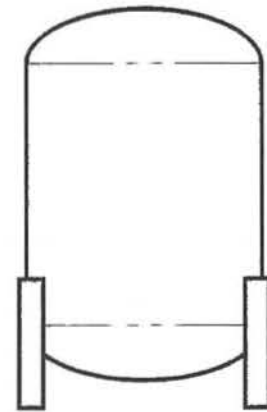
### TYPICAL CONNECTIONS AND ACCESSORIES

Fig. No. 1

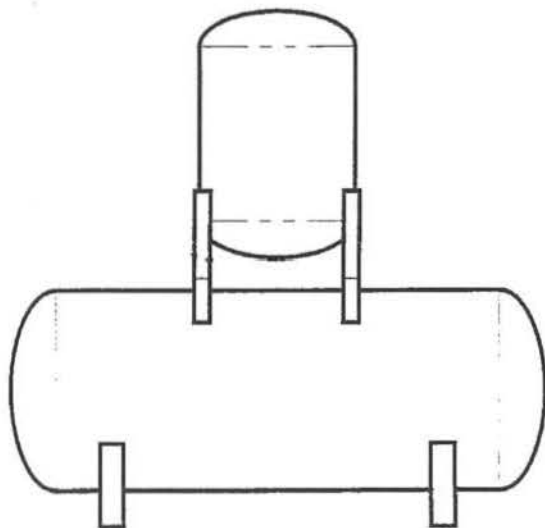
#### 4.0 ILLUSTRATIONS OF TYPICAL TRAY DEAERATOR ORIENTATIONS



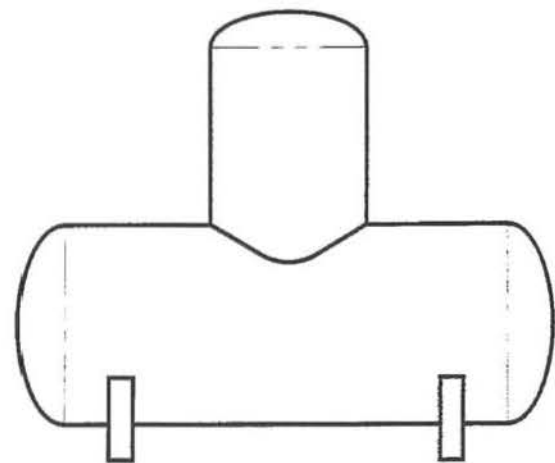
HORIZONTAL DEAERATOR ON  
HORIZONTAL STORAGE TANK



VERTICAL DEAERATOR WITH  
INTEGRAL STORAGE TANK



VERTICAL DEAERATOR ON  
HORIZONTAL STORAGE TANK



TANK CAR DEAERATOR ON  
HORIZONTAL STORAGE TANK

#### TYPICAL ORIENTATIONS

Fig. No. 2

## 5.0 STANDARDS OF CONSTRUCTION

### 5.1 Code Requirements

A deaerator shall be constructed and stamped in accordance with the applicable portion of the ASME Code, normally Section VIII, Division 1, and/or the appropriate state and local requirements for pressure vessel construction.

### 5.2 Design Requirements

The ASME Code may not be adequate for minimum deaerator pressure vessel design for all applications. Many of these units operate at conditions which require more stringent design standards. Deaerator design shall therefore incorporate the following, in addition to the ASME Code:

**5.2.1** A corrosion allowance of 1/8" (3 mm) is to be included in the deaerator head and shell. A minimum corrosion allowance of 1/16" (1.5 mm) is to be included on nozzles, internal nozzle reinforcing pads, nozzle necks, and manway covers. The corrosion allowance for stainless steel nozzles shall be zero.

**5.2.2** The vessels shall be post weld heat treated (PWHT). Unless otherwise specified, PWHT shall be performed after all required NDE. Treatment shall be in accordance with the ASME Code.

As noted herein, the HEI requires post weld heat treatment for deaerators. In most cases deaerators will receive 1-stage post weld heat treatment (PWHT) with welded stainless steel components in place. If stainless steel components are subjected to PWHT, they should be composed of "L" grade (low carbon) to minimize sensitization and intergranular corrosion. (See also Section 6.0, Table 3.)

In certain cases 2-stage PWHT is specified to allow for additional NDE, or to avoid heat treating stainless steel components. When 2-stage PWHT is required, stainless steel internals are installed after PWHT of carbon steel materials. Typically, one head and the vessel shell are welded together, nozzles are installed, carbon steel attachments are welded in place, and the assembly is subjected to PWHT. Stainless steel components are then installed and the closing head seam receives a local PWHT.

Unless otherwise specified, and when allowed by ASME code, weld repairs may be performed on a pressure component after PWHT but before final hydrotest, without additional PWHT. This may include repairs to base metal or weld metal, or the addition of an attachment weld, at the discretion of the inspector and the client's representative.

Welding to a pressure component after final

hydrotest falls outside the scope of ASME code, and is within the scope of a post-construction code such as NBIC. PWHT of post-construction welds is normally performed as per the original code of construction. In some cases, alternatives to PWHT may be used if allowed by the post-construction code. Alternatives may employ preheat and welding techniques that minimize residual stresses.

**5.2.3** The internal nozzle to vessel welds shall be examined by using wet fluorescent magnetic particle testing; dye penetrant testing shall be used where magnetic particle testing is not applicable.

**5.2.4** Internal and external weld seams must be sufficiently smooth to produce satisfactory NDE results. The transition between the base metal and weld metal need not have a radius.

**5.2.5** Longitudinal and circumferential head and shell weld seams are to be radiographed per ASME Section VIII, Division 1 in order to obtain a 1.0 joint efficiency.

### 5.3 Pressure/Vacuum Design

The vessels shall be designed for the pressure and temperature as specified by user/engineer. Internal design pressure shall be a minimum of 30 psig. Design temperature shall be a minimum 400 degrees F. The vessels shall be designed for full vacuum or shall be provided with a vacuum relief device.

### 5.4 Pump Suction Design

The pump suction outlet nozzle shall extend a minimum of 3" into the storage section and shall be provided with a vortex breaker.

### 5.5 Nozzle Loads

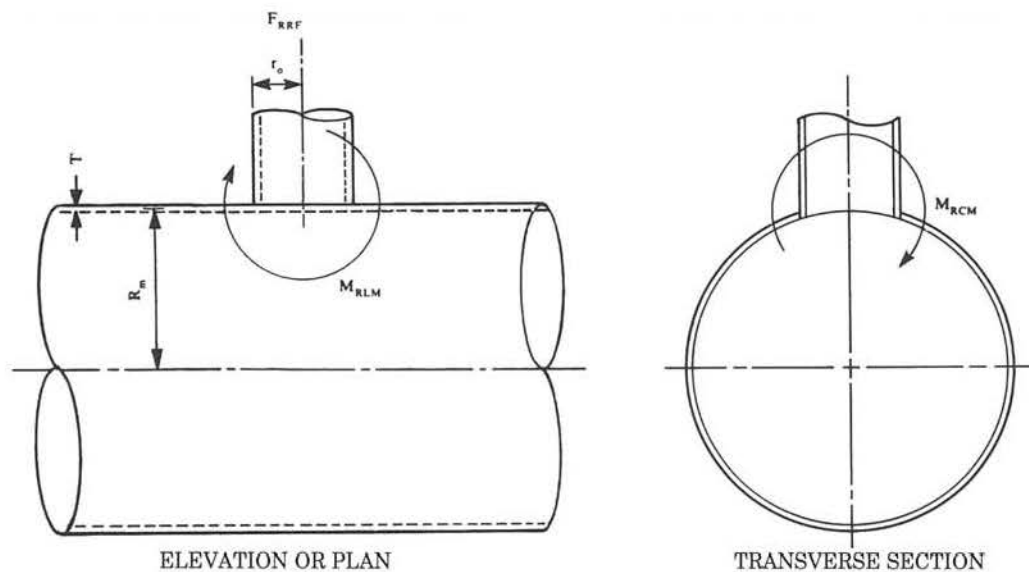
The determination of acceptable nozzle loads is a complex problem involving the interaction of external forces and moments applied at the vessel wall. These loads are functions of the mechanical and thermal piping design. Frequently, the piping designer has a need to know the allowable loads at the nozzle in order to determine the piping configuration and generate the actual loads. The following procedure permits estimating nozzle loads for cylindrical shells. The procedure is based in part on the design data included in Welding Research Council Bulletin 107.<sup>2</sup> The allowable loads have been linearized to show the interaction between the maximum permitted external radial load and the maximum permitted applied moment

vector. Once the maximum forces and moments are determined, a diagram similar to Figure 4.1 should be plotted to ensure that the maximum combined loads are not exceeded.

The procedure represents a simplification of the method of WRC 107 and users of the procedure included in this standard are cautioned that more exact analysis is required to verify the adequacy of final designs. The stresses considered in developing the procedure have been defined as secondary stresses with stress limits established according to the definition. Although

the effect of internal pressure has been included in the combined stresses, the effect of pressure on nozzle thrust has not been included and requires combination with other radial loads.

Loads exceeding those calculated by this method usually require additional reinforcement. The user is cautioned that the higher allowable loads obtained through design modification may require strengthening other parts such as supports, supporting structure and floors. It should be understood by the user that the deaerators are not intended to serve as anchor points for the piping.



### PROCEDURE FOR CALCULATING NOZZLE EXTERNAL FORCES AND MOMENTS IN CYLINDRICAL VESSELS

Figure No. 3

#### 5.5.1 Nomenclature

|          |                                                                               |
|----------|-------------------------------------------------------------------------------|
| $P$      | = Design Pressure, pounds per square inch                                     |
| $r_o$    | = Nozzle Outside Radius, inches                                               |
| $R_m$    | = Mean Radius of Shell, inches                                                |
| $T$      | = Shell Thickness, inches                                                     |
| $S_y$    | = Yield Strength of Material at Design Temperature, pounds per square inch    |
| $\sigma$ | = Stress Due to Design Pressure, pounds per square inch                       |
| $S_a$    | = ASME Section VIII, Division 1 Code Allowable Stress, pounds per square inch |
| $\beta$  | = Dimensionless Numbers                                                       |
| $\gamma$ | = Dimensionless Numbers                                                       |

|           |                                                          |
|-----------|----------------------------------------------------------|
| $\alpha$  | = Dimensionless Numbers                                  |
| $\Sigma$  | = Dimensionless Numbers                                  |
| $\Delta$  | = Dimensionless Numbers                                  |
| $F_{RRF}$ | = Maximum Resultant Radial Force, pounds*                |
| $M_{RCM}$ | = Maximum Resultant Circumferential Moment, inch-pounds* |
| $M_{RLM}$ | = Maximum Resultant Longitudinal Moment, inch-pounds*    |
| $F_{RF}$  | = Maximum Resultant Force, pounds*                       |
| $M_{RM}$  | = Maximum Resultant Moment, inch-pounds*                 |

\*Use absolute values.

Note: All thicknesses and dimensions are in the corroded condition.

### 5.5.2 External Forces and Moments

To calculate the maximum force and moment, first evaluate  $\beta$  and  $\gamma$ . Then determine  $\alpha$ ,  $\Sigma$  and  $\Delta$  from Figures 5, 6 and 7 for the specified  $\beta$  and  $\gamma$ , substitute into the equations below and calculate  $F_{RRF}$ ,  $M_{RCM}$  and  $M_{RLM}$ .

$$\beta = 0.875 \left( \frac{r_o}{R_m} \right) \quad \gamma = \frac{R_m}{T}$$

Determine  $\alpha$ ,  $\Sigma$  and  $\Delta$  from Figures 5, 6 and 7.  
Calculate Pressure Stress ( $\sigma$ ).

$$\sigma = \frac{P}{T} \left( R_m - \frac{T}{2} \right)$$

$$F_{RRF} = \frac{R_m^2}{\alpha} (S_y - \sigma)$$

$$M_{RCM} = \frac{R_m^2 r_o}{\Sigma} (S_y - \sigma)$$

$$M_{RLM} = \frac{R_m^2 r_o}{\Delta} (S_y - \sigma)$$

Plot the value of  $F_{RRF}$  as  $F_{RF}$  and the smaller of  $M_{RCM}$  and  $M_{RLM}$  as  $M_{RM}$ . The allowable nozzle loads are bounded by the area  $F_{RF}$ , 0,  $M_{RM}$ .

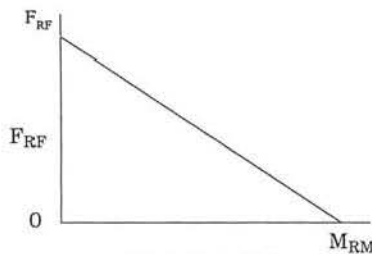


Fig. No. 4.1

### 5.5.3 Sample Problem

Determine Resultant Force and Moment for a vessel made from SA-516-70 with a design temperature of 650°F.

$$\begin{aligned} R_m &= 37.5 \text{ in} & S_y &= 28,200 \text{ psi @ } 650^\circ\text{F} \\ r_o &= 15 \text{ in} & S_a &= 18,800 \text{ psi @ } 650^\circ\text{F} \\ T &= 0.75 \text{ in} \\ P &= 150 \text{ psig} \end{aligned}$$

$$\beta = 0.875 \left( \frac{r_o}{R_m} \right) = 0.875 \left( \frac{15}{37.5} \right) = 0.35$$

$$\gamma = \left( \frac{R_m}{T} \right) = \frac{37.5}{0.75} = 50$$

From Figure 5,  $\alpha = 440$

From Figure 6,  $\Sigma = 1,085$

From Figure 7,  $\Delta = 330$

Calculate Pressure Stress

$$\sigma = \frac{P}{T} \left( R_m - \frac{T}{2} \right) = \frac{(150)}{0.75} \left( 37.5 - \frac{0.75}{2} \right) =$$

$$7,425 \text{ psi} < S_a = 18,800 \text{ psi}$$

Use  $\sigma = 7,425$  psi in the equations for calculating  $F_{RRF}$ ,  $M_{RLM}$  and  $M_{RCM}$ .

Calculate Allowable Forces and Moments

$$F_{RRF} = \frac{R_m^2}{\alpha} (S_y - \sigma) =$$

$$\frac{(37.5)^2}{440} (28,200 - 7,425) = 66,397 \text{ lbf}$$

$$M_{RCM} = \frac{R_m^2 r_o}{\Sigma} (S_y - \sigma) =$$

$$\frac{(37.5)^2 (15)}{1,085} (28,200 - 7,425) = 403,892 \text{ in-lbf}$$

$$M_{RLM} = \frac{R_m^2 r_o}{\Delta} (S_y - \sigma) =$$

$$\frac{(37.5)^2 (15)}{330} (28,200 - 7,425) =$$

$$1,327,947 \text{ in-lbf}$$

Plot the value of  $F_{RRF}$  as  $F_{RF}$  and the smaller of  $M_{RCM}$  and  $M_{RLM}$  as  $M_{RM}$ . The allowable nozzle loads are bounded by the area of  $F_{RF}$ , 0,  $M_{RM}$ .

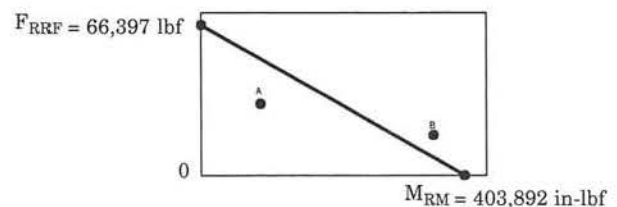
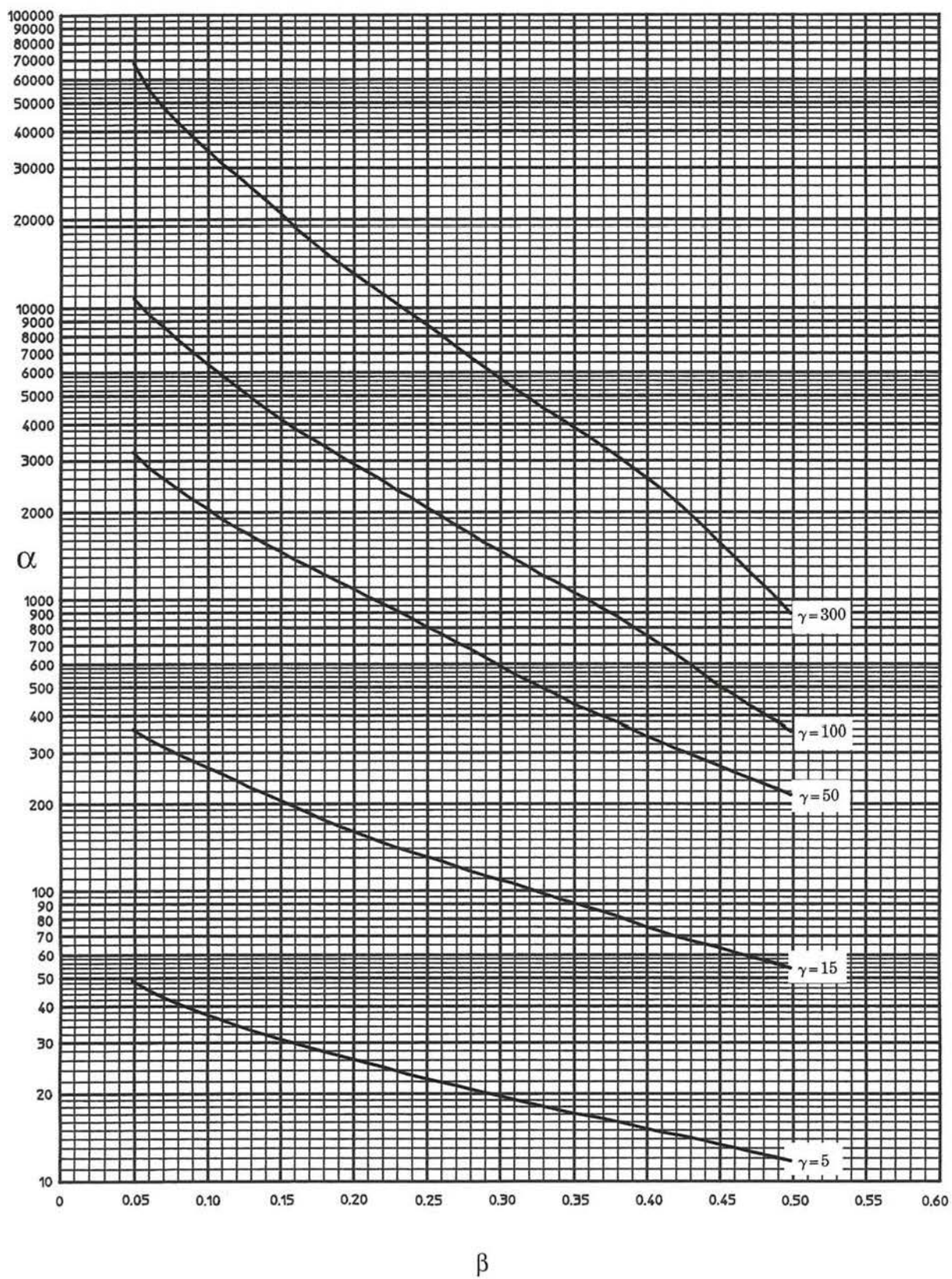


Fig. No. 4.2

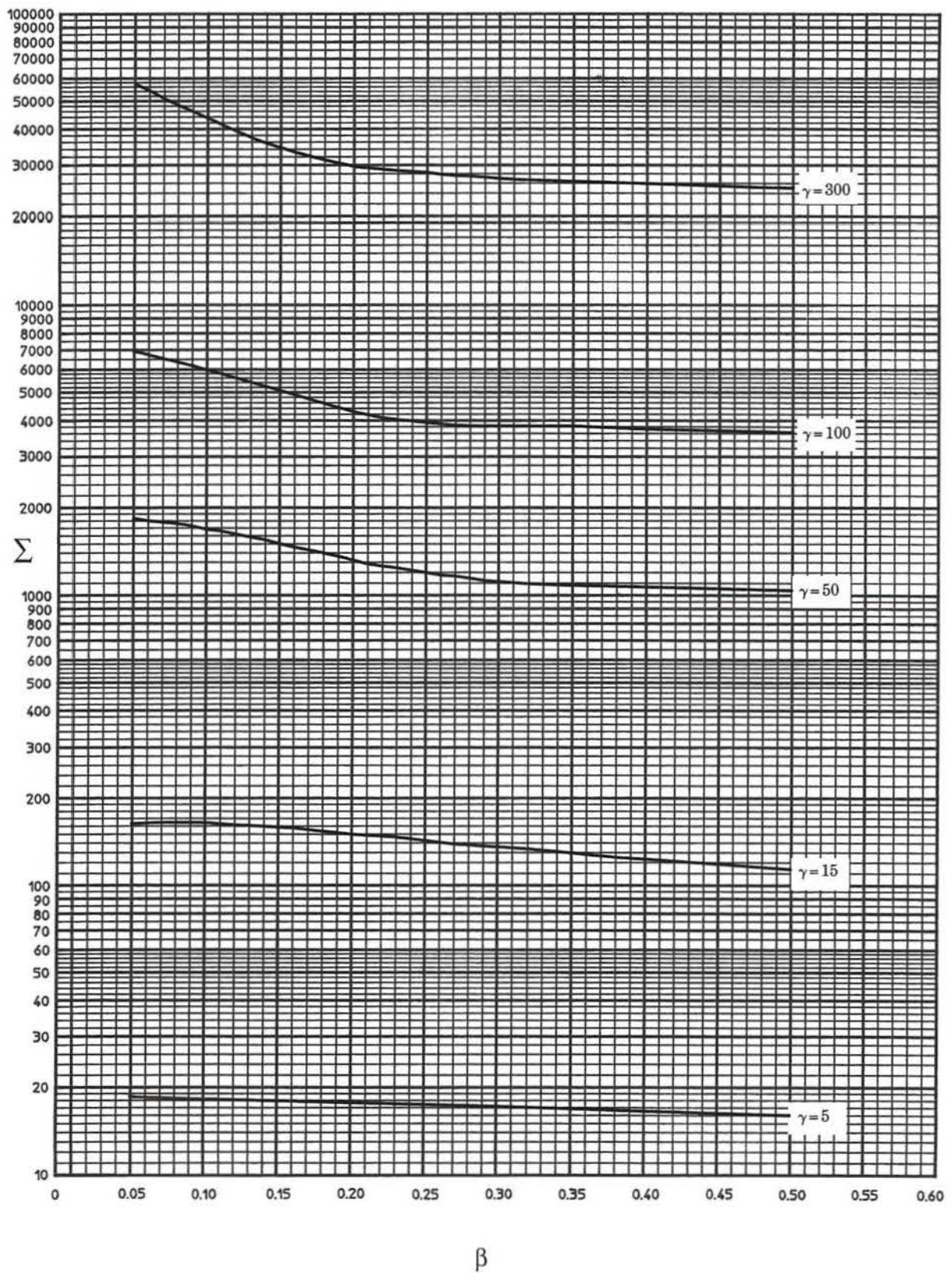
Therefore, a nozzle reaction of  $F = 35,000$  lbf. and  $M = 100,000$  in-lbf would be allowable (point A) but a nozzle reaction of  $F = 20,000$  lbf and  $M = 350,000^*$  in-lbf would not be allowable (point B).

\*Note: Use absolute values in the graph.



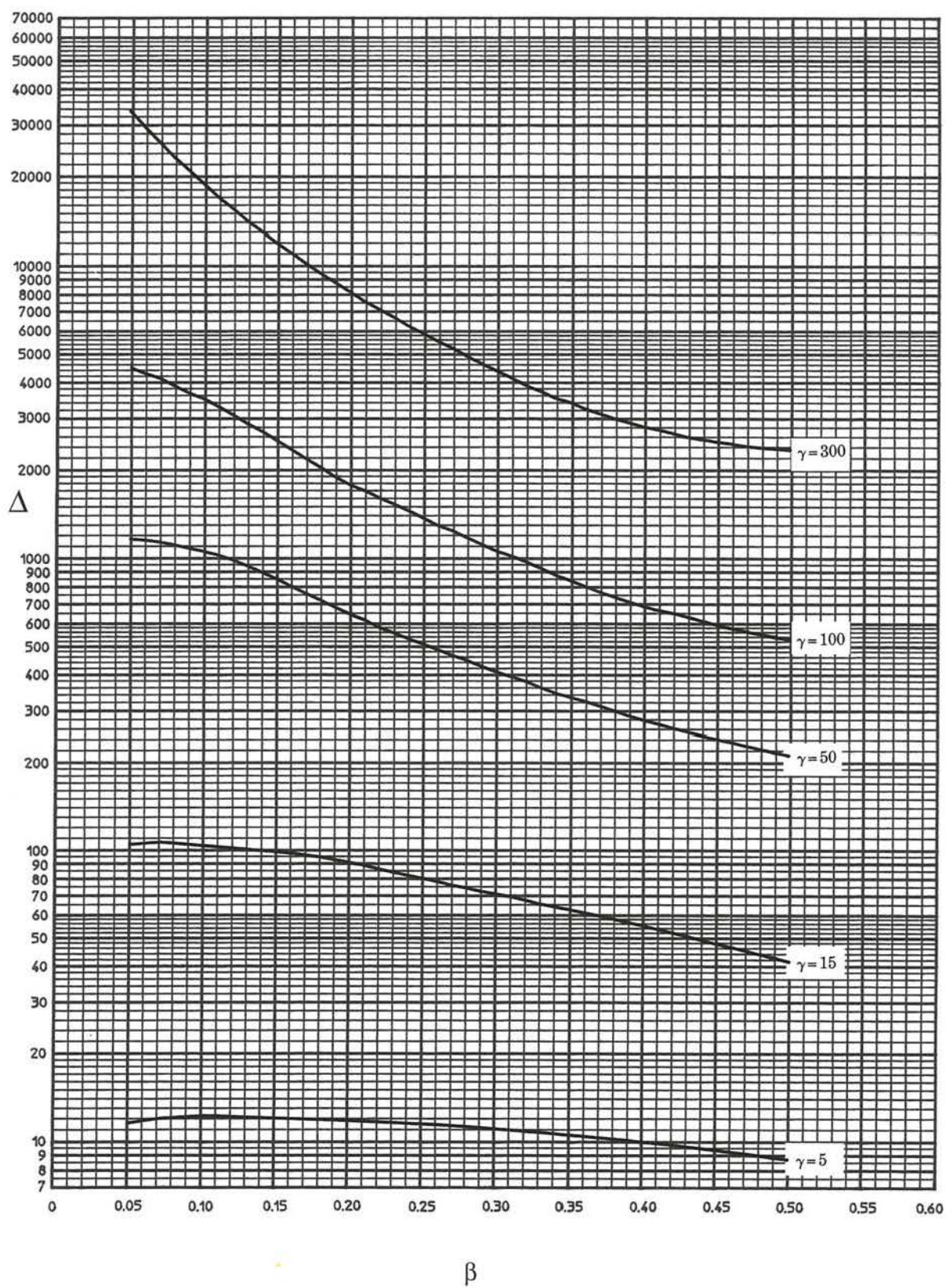
## ALLOWABLE NOZZLE LOADS

Fig. No. 5



### ALLOWABLE NOZZLE LOADS

Fig. No. 6



### ALLOWABLE NOZZLE LOADS

Fig. No. 7

## 5.6 Nozzle Sizes

The deaerator shall be provided with a minimum of steam inlet, water inlet, pump suction, overflow, drain, vent, relief valve, sample, pressure gauge, and thermometer connections. Suitable openings shall be provided for inspection and removal of parts.

The following velocity ranges should be used for nozzle sizing:

| Connection                | Velocity    |
|---------------------------|-------------|
| Water Inlet               | 6-8 fps     |
| Steam Inlet (> 0 psig)    | 125-175 fps |
| Pump Suction (≤ 4 in)     | 3 fps       |
| Pump Suction (> 4 in)     | 3-5 fps     |
| Overflow –                |             |
| 749,000                   | 3-5 fps     |
| 750,000 – 1,999,999       | 10 fps      |
| Above 2 million           | 12 fps      |
| Inlet High Pressure Drain | 10-14 fps   |
| Downcomer                 | 2 fps max.  |

For large capacity units, the overflow connection size is considered a function of individual plant design. This table serves only as a guideline to be used when no specific information is provided.

Manways - Elliptical manway size shall be a minimum 12" x 16" on the storage vessel and a minimum of 18" diameter hinged or davited manway on the deaerator section.

## 5.7 Accessories

Selection and sizes should be based on maximum operating conditions specified. Accessories shall be provided when specifically requested by the purchaser.

### 5.7.1 Relief Valves

One or more relief valves shall be provided to either protect the pressure vessel against over-pressurization or act as sentinel relief. This can occur upon a failure of the steam pressure reducing valve, single or multiple trap discharges entering the deaerator, or other conditions. It is the responsibility of the purchaser to evaluate all possible conditions and determine the worst case scenario for sizing the relief valve. If sentinel relief is selected by the customer for the deaerator, safety relief must be provided elsewhere in the system.

It is the Institute's minimum recommendation that the relief valve(s) be capable of passing the fail open capacity of the steam pressure reducing valve with the relief pressure set at the vessel design pressure. If high pressure trap discharges

or heater drains are present, additional relieving capacity may be required to protect the vessel. These valve(s) may be supplied by the deaerator manufacturer or the purchaser; however, all sizing criteria is to be determined by the purchaser and/or engineer. Table 1 indicates the minimum suggested sentinel relief valve size based on the rated capacity of the deaerator.

**TABLE 1**  
**Minimum Sentinel Relief Valve Size**

| Rated Capacity<br>Lbs./Hr | Relief Valve<br>Size - Inches |
|---------------------------|-------------------------------|
| 0 - 19,999                | 1.5                           |
| 20,000 - 44,999           | 2                             |
| 45,000 - 99,999           | 2.5                           |
| 100,000 - 199,999         | 3                             |
| 200,000 - 599,999         | 4                             |
| 600,000 - 1,199,999       | 6 (Quantity = 1)              |
| 1,200,000 and over        | 6 (Quantity = 2)              |

### 5.7.2 Vacuum Breaker

If vessel is not designed for full vacuum, vacuum breaker(s) shall be provided with minimum suggested sizes as shown in Table 2

**TABLE 2**  
**Vacuum Breaker Selection**

| Rated Capacity<br>Lbs./Hr | Vacuum Breaker<br>Size - Inches |
|---------------------------|---------------------------------|
| 0 - 19,999                | 1                               |
| 20,000 - 44,999           | 1.5                             |
| 45,000 - 99,999           | 2                               |
| 100,000 - 199,999         | 2.5                             |
| 200,000 - 599,999         | 3                               |
| 600,000 - 899,999         | 4                               |
| 900,000 - 1,199,000       | 6 (Quantity = 1)                |
| 1,200,000 and over        | 6 (Quantity = 2)                |

### 5.7.3 Water Inlet Regulating Valves and Controls

It may be desirable to control the water flow from one or more sources. The valve size depends on the required flow rate, temperature, and valve inlet and outlet pressures. External control equipment shall be complete with equalizing lines and shutoff valves to connect to the storage space.

#### **5.7.4 Overflow Control**

This control is a device to protect against high water level in the storage area.

#### **5.7.5 Level Gauges**

At a minimum, level gauges shall be provided to cover from 10% to 90% of storage tank diameter.

#### **5.7.6 Thermometers**

Thermometers, properly located, give a visual indication of deaerator performance. Probable locations are the steam space of the deaerator, and under the water level in the storage area.

#### **5.7.7 Level Switches**

Switches may be desirable for warning of high or low water levels and for boiler feedpump cutoff. Audible or visible alarms may be specified if desired.

#### **5.7.8 Pressure Gauge**

A pressure gauge shall be provided for the steam space. Range shall cover the design pressure of the unit.

#### **5.7.9 Vent Valve(s)**

Properly sized vent valve(s) or vent orifice(s) shall be installed.

#### **5.8 Other Design Considerations**

In many plants today, it is necessary to save energy in every way possible. One of the ways this is done is to heat the inlet water to the deaerator, usually using a shell and tube heat exchanger. It should be recognized that this practice may be detrimental to proper deaerator operation and may also shorten deaerator life, often by many years. Preheating the cold makeup water to the deaerator reduces steam demand in the deaerator, but more importantly, if the inlet water is saturated or nearly saturated with noncondensable gasses, preheating it may cause liberation of these gasses, resulting in free air, which the deaerator may not be able to remove. This should be taken into consideration in the original design concept of the plant and in subsequent modifications.

Optimum deaerator performance is achieved at steady state operation. Events such as turbine trips, deaerator pressure loss, cold water inlet surges, etc. will degrade performance and potentially damage the deaerator.

It must be recognized that frequent cooldown and reheat of a deaerator can cause cracking

and premature corrosion. It is recommended that deaerators which are operated intermittently be maintained in a hot, standby mode. At the very least, the purchaser/engineer should consider an auxiliary means of warming the stored water prior to start-up, such as a sparger pipe, electric heaters, or other method.

Mixing high temperature and low temperature flows within the deaerator can cause thermal stresses, potentially damaging to the deaerator internals. Makeup and low pressure condensate shall be mixed at least 10 pipe diameters prior to introduction into the deaerator to eliminate possible damage to the internals. Makeup and low pressure condensate, including all flows lower than the outlet deaerator temperature shall be mixed in a tee in the external piping to the deaerator.

## 6.0 MATERIALS OF CONSTRUCTION

### 6.1 General

The materials used for pressure parts and for external supports, where applicable, shall be in accordance with the ASME Code, as necessitated by the Design Specifications.

Some materials which are permitted for use in Section VIII deaerators may not be permitted by the ASME Code for use in the construction of Section I deaerators. Furthermore, the required tests and inspections differ depending on the applicable section of the ASME Code.

All materials in contact with undeaerated or partially deaerated water shall be a minimum of 1/8" thick stainless steel, including the inlet nozzle, waterbox, waterbox lining, vent condenser, valve plate, vent, and spray valves. Tray enclosures shall be a minimum of 1/8" thick stainless steel. Trays shall be a minimum of 20 gauge stainless steel.

All materials, including heads and shells, in contact with steam which has previously been in contact with undeaerated water or partially deaerated water shall be stainless steel, stainless steel lined, or stainless steel clad.

It would be impractical to list all the materials that may be used in Code constructed units; however, some of the more commonly used materials and the parts for which they are used are given in Table 3. It is recommended that the materials in Table 3 be utilized as minimum requirements for materials of construction. It is recommended that SA-515 not be utilized.

### 6.2 Gaskets

The choice of suitable gasket material depends upon the condition of service and, unless otherwise specified by the Purchaser, will be in accordance with the standards of the deaerator manufacturer.

### 6.3 Makeup Inlet Nozzle

The makeup inlet nozzle for deaerators shall be stainless steel, or stainless steel lined.

### 6.4 Water Inlet Distribution

The water inlet chamber shall be fully enclosed by stainless steel so as to prohibit all undeaerated water from coming in contact with any carbon steel.

### 6.5 Vent Condenser Area

The valve plate and vent condenser area is where noncondensable gasses and steam collect. This area shall be constructed of stainless steel so as to prohibit noncondensibles and steam which

have been in contact with undeaerated or partially deaerated water from coming in contact with any carbon steel.

### 6.6 Tray Enclosure

The tray enclosure contains the trays that remove the final traces of noncondensable gasses and shall be stainless steel.

### 6.7 Trays

Trays shall be stainless steel and shall be stamped or riveted. Welding shall not be utilized for tray construction.

### 6.8 Corrosion Allowance & Minimum Thicknesses

The vessel head and shells shall be fabricated in accordance with the ASME Code with 1/8" corrosion allowance<sup>3</sup>. Nozzles, reinforcing pads, nozzle necks, and manway covers shall include a minimum of 1/16" corrosion allowance. A corrosion allowance is not required for stainless steel components.

See Table 3 for additional minimum thicknesses of materials.

**TABLE 3**  
**Minimum Thickness and Material**

| Deaerator Component          | Minimum Thickness and Material                    |
|------------------------------|---------------------------------------------------|
| Waterbox                     | 1/4" 300 Series S.S.                              |
| Inlet Header Pipe            | Schedule 10S<br>300 Series S.S.                   |
| Tray Enclosure               | 1/8" 300 Series S.S.                              |
| Vent Hood & Vent Condenser   | 1/8" 300 Series S.S.                              |
| Trays                        | 20 Gauge 430 S.S.                                 |
| Baffle Plates                | 1/4" 300 Series S.S.                              |
| Drip Shields/Vortex Breakers | 1/4" C.S.                                         |
| Head and Shell               | 3/16" + corrosion allowance for C.S. or 1/4" S.S. |
| Tray Enclosure & Vent Hood   |                                                   |
| Stiffeners & Supports        | 1/4" C.S.                                         |
| Spray Valves                 | 300 Series S.S.                                   |

Note 1: The thickness of corrosion resisting linings and cladding shall not be included in the above minimum thicknesses for heads and shell material.

Note 2: L Grade S.S. is required in case of one stage post weld heat treatment of a deaerator.

<sup>3</sup> 3 mm is substantially equivalent to 1/8" and 1.5 mm is substantially equivalent to 1/16" for projects using SI Units.

## 7.0 DEAERATOR PERFORMANCE

### 7.1 Operating Conditions

In order for the deaerator manufacturer to properly design the unit, the buyer must make available all known operating conditions and circumstances (heat/mass balances), including especially, start-up, minimum flow, maximum flow, and others. Simply providing a design condition may not provide sufficient information to adequately design the unit.

### 7.2 Thermal Capacity

The deaerator shall be guaranteed to heat the influent water to within 2°F of the saturation temperature of the steam in the deaerator at the operating pressure. Note that the potential exists for temperature indicators to give readings higher than saturation temperatures if superheat is present in the steam. Saturation temperature must be verified using the operating pressure of the unit.

The user shall provide the minimum inlet water temperature, percentage of makeup and operating pressure at each design condition. (Refer to Deaerator Specification Sheet attached).

### 7.3 Performance Guarantee

Tray deaerators are capable of and shall operate from 10% to 100% of design point and achieve .005ml/l (7PPB) outlet dissolved oxygen content. Oxygen/carbon dioxide removal guarantees are based on the following assumptions unless more specific data is provided by the customer.

**TABLE 4**  
**Incoming Flow Assumptions**

| Flow       | Oxygen Inlet                                      | Carbon Dioxide Inlet |
|------------|---------------------------------------------------|----------------------|
| Makeup     | saturated at inlet temp. at atmospheric condition | < 10 PPM             |
| Condensate | < 50 PPB                                          | < 50 PPB             |
| HP returns | < 7 PPB                                           | None                 |
| Steam      | None                                              | None                 |

The deaerator shall remove all carbon dioxide from loads of 10% to 100% when tested by the APHA method.

### 7.4 Testing

When operated properly, deaerators can and do produce water with very low levels of dissolved noncondensable gasses. In order to determine what noncondensable gas level the deaerator is producing, it is imperative that the analysis be conducted very carefully. Atmospheric gasses that enter a water sample can lead to a completely erroneous reading. The analyst must be diligent in preventing gasses from entering the sample. Gasses can be introduced into pressurized piping systems through leaking pump seals and other mechanical means.

Testing should be in accordance with a suitable colorimetric test. "On-line" testing shall not be an acceptable method of verifying.

Testing shall be performed at the storage vessel as close to the pump suction as possible, and below the water level. The sample point should never be downstream of the boiler feed pump.

BFP recirculations must be turned off or directed elsewhere prior to the performance test.

The test shall be performed at the deaerator storage section with less than 5 feet of SS tubing and a SS sample cooler with one isolation valve on the inlet and outlet. All excess fittings shall be removed.

Oxygen scavenger shall be turned off prior to the test.

The unit shall be running at a minimum of three days and at a constant load for three hours (see footnote in Section 8.0).

Testing shall be performed in accordance with the instrument manufacturer's guidelines. Run sample for 2 hours prior to test.

The test must be completed within 10 seconds of drawing the sample from the storage tank.

Additional tests shall be taken (approximately five or six). The lowest reading shall be determined as the oxygen level, as false low readings are not possible. High readings are assumed to be in error as a false high reading is possible due to a poor test. Do not average readings.

If the results of the colorimetric test are not acceptable, the customer shall conduct testing in accordance with ASME PTC 12.3. Carbon dioxide test shall be run per the APHA method.

### 7.5 Storage Capacity

For deaerators with separate storage and deaerating vessels, it is recommended that a ten minute storage to overflow be supplied as a minimum unless otherwise specified. Storage of 5 to 7 minutes for central station utility units may be adequate. The overflow level shall not be closer to the top of the vessel than 85% of the tank diameter.

For a single tank deaerator with integral storage, the storage capacity shall be 10 minutes to overflow as determined by the manufacturer's design criteria.

The storage capacity shall be calculated using the density of water at the effluent temperature.

Refer to Table 5 for approximate storage requirements for different rated capacities.

**TABLE 5**  
**Storage Tank Requirements**

| <b>Flow<br/>PPH</b> | <b>Lbs</b> | <b>Cu Ft</b> | <b>Gallons</b> |
|---------------------|------------|--------------|----------------|
| 10,000              | 1,667      | 28           | 208            |
| 20,000              | 3,334      | 56           | 416            |
| 30,000              | 5,000      | 83           | 623            |
| 40,000              | 6,667      | 111          | 831            |
| 50,000              | 8,334      | 139          | 1,039          |
| 60,000              | 10,000     | 167          | 1,247          |
| 75,000              | 12,500     | 208          | 1,558          |
| 100,000             | 16,667     | 278          | 2,078          |
| 150,000             | 25,000     | 417          | 3,117          |
| 200,000             | 33,334     | 556          | 4,156          |
| 250,000             | 41,667     | 694          | 5,195          |
| 300,000             | 50,000     | 833          | 6,233          |
| 400,000             | 66,667     | 1,111        | 8,311          |
| 500,000             | 83,334     | 1,389        | 10,389         |
| 600,000             | 100,000    | 1,667        | 12,467         |
| 700,000             | 116,667    | 1,944        | 14,545         |
| 800,000             | 133,334    | 2,222        | 16,622         |
| 900,000             | 150,000    | 2,500        | 18,700         |
| 1,000,000           | 166,667    | 2,778        | 20,778         |

Above table is based on a water density of 60 lb/ft<sup>3</sup>, and 10 minutes of storage.

## 8.0 GUIDE TO TROUBLESHOOTING DEAERATORS

| Symptom                            | Possible Causes                                                                                                                                                                                                                                                                                                                                                                                                                                     | Comments or Possible Solutions                                                                                                                                                                                                                                                                                                                                    |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 8.1 High O <sub>2</sub>            | <ul style="list-style-type: none"> <li>- Air in-leakage</li> <li>- Insufficient stabilization period*</li> <li>- Trays not installed properly and in place</li> <li>- Not steady state conditions*</li> <li>- O<sub>2</sub> inlet not in accordance with specified design conditions</li> <li>- Spray valves not installed correctly</li> <li>- Water inlet temperature too low</li> <li>- Improper venting</li> <li>- Incorrect testing</li> </ul> | <ul style="list-style-type: none"> <li>- See test procedures in section 7.4</li> <li>- Loose fittings</li> <li>- Shut scavenger off</li> <li>- Remove chemical interferences</li> <li>- Verify design conditions</li> </ul>                                                                                                                                       |
| 8.2 Excessive Pressure Fluctuation | <ul style="list-style-type: none"> <li>- Steam PRV improperly sized or calibrated</li> <li>- Improperly sized downcomer and equalizer</li> <li>- Inlet steam pressure too high or too low</li> <li>- Improper pilot installation</li> <li>- Excessive inlet temperature variation</li> <li>- Heater flooding</li> </ul>                                                                                                                             | <ul style="list-style-type: none"> <li>- Check size and calibration</li> <li>- Keep within design range</li> <li>- Check all valve and control settings</li> </ul>                                                                                                                                                                                                |
| 8.3 Low Outlet Temperature         | <ul style="list-style-type: none"> <li>- Incorrect thermometer reading</li> <li>- Insufficient steam flow</li> <li>- Incorrect steam/water ratio</li> <li>- Spray valves or internals malfunctioning</li> <li>- Heater flooding</li> <li>- Inlet flows piped incorrectly</li> </ul>                                                                                                                                                                 | <ul style="list-style-type: none"> <li>- Check calibration</li> <li>- Check steam supply</li> <li>- Check for restrictions</li> <li>- Check pipe and valve sizing</li> <li>- Check heat and mass balances</li> <li>- Check spray valves, trays, etc.</li> <li>- Check all valve and control settings</li> <li>- Check all inlet flows and temperatures</li> </ul> |
| 8.4 Water Hammer                   | <ul style="list-style-type: none"> <li>- Inlet flows mixing just prior to deaerator inlet</li> <li>- Improper pipe design</li> <li>- High inlet velocities</li> </ul>                                                                                                                                                                                                                                                                               | <ul style="list-style-type: none"> <li>- Mix flows farther upstream of deaerator</li> <li>- Check and/or redesign</li> <li>- Keep within HEI</li> </ul>                                                                                                                                                                                                           |

\*Often, high oxygen measurements can be traced to inadequate test procedures. In order to conduct a proper test, it is important that there be a sufficient stabilization period and steady state conditions. The proper length of a stabilization period is extremely dependent on system-specific conditions, particularly the size of the system. Therefore, while three days of boiler operation are typically required to reach steady state, no definitive guidelines can be given. As a general rule, if there is a downward trend in oxygen content measurements, steady state condition has not yet been attained.

\*\*Shading is provided for the ease of reading only.

## GUIDE TO TROUBLESHOOTING DEAERATORS (con't.)

| Symptom                                      | Possible Causes                                                                                                                                                                                    | Comments or Possible Solutions                                                                                                                                                |
|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 8.5 High CO <sub>2</sub>                     | <ul style="list-style-type: none"> <li>- High CO<sub>2</sub> at inlet</li> <li>- High pH</li> <li>- Improper venting</li> </ul>                                                                    | <ul style="list-style-type: none"> <li>- Verify CO<sub>2</sub> design condition</li> <li>- Lower pH</li> <li>- Review vent system</li> </ul>                                  |
| 8.6 Tray Upsets                              | <ul style="list-style-type: none"> <li>- Tray hold down not secure</li> <li>- Turbine trip</li> <li>- Flashing</li> </ul>                                                                          | <ul style="list-style-type: none"> <li>- Install correctly</li> <li>- Gradual increase/decrease of controlled flows</li> </ul>                                                |
| 8.7 Unexpected Storage Tank Level Excursions | <ul style="list-style-type: none"> <li>- Malfunctioning level control system</li> <li>- Malfunctioning overflow or improper boiler feed pump operation</li> <li>- Pressure fluctuations</li> </ul> | <ul style="list-style-type: none"> <li>- Check setting and system operation</li> <li>- Check overflow level and boiler feed pump operation</li> <li>- Refer to 8.2</li> </ul> |
| 8.8 Water Out of Vent                        | <ul style="list-style-type: none"> <li>- Cracked vent welds</li> <li>- Improper vent piping</li> <li>- Water carryover</li> </ul>                                                                  | <ul style="list-style-type: none"> <li>- Repair or redesign</li> <li>- Should be as short and as vertical as possible</li> <li>- Reset vent flow</li> </ul>                   |
| 8.9 Iron Oxide in Deaerator                  | <ul style="list-style-type: none"> <li>- Condensate or system corrosion</li> <li>- Frequent shutdowns</li> <li>- High O<sub>2</sub></li> </ul>                                                     | <ul style="list-style-type: none"> <li>- Keep positive pressure on deaerator</li> <li>- See 8.1</li> </ul>                                                                    |

\*\*Shading is provided for the ease of reading only.

## APPENDIX A GENERAL CONVERSION FACTORS

\*Indicates preferred SI system units

| To convert from                                      | To                                                           | Multiply by |
|------------------------------------------------------|--------------------------------------------------------------|-------------|
| acres                                                | square feet (ft <sup>2</sup> )                               | 43 560      |
|                                                      | *square meters (m <sup>2</sup> )                             | 4 046.9     |
|                                                      | *hectares (ha)                                               | 0.404 69    |
| acre-feet                                            | cubic feet (ft <sup>3</sup> )                                | 43 560      |
|                                                      | gallons (U.S.)                                               | 325 851     |
|                                                      | *cubic meters (m <sup>3</sup> )                              | 1 233.5     |
| atmospheres (standard)                               | bars (bar)                                                   | 1.013 25    |
|                                                      | centimeters of mercury (cmHg) at 32°F (0°C)                  | 76.0        |
|                                                      | feet of water (ftH <sub>2</sub> O) at 68°F (20°C)            | 33.96       |
|                                                      | inches of mercury at 32°F (0°C)                              | 29.921      |
|                                                      | kilograms-force per square centimeter (kgf/cm <sup>2</sup> ) | 1.033 2     |
|                                                      | kilograms-force per square meter (kgf/m <sup>2</sup> )       | 10 332      |
|                                                      | *kilopascals (kPa)                                           | 101.325     |
|                                                      | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)    | 14.696      |
|                                                      | tons-force (short) per square foot (tonf/ft <sup>2</sup> )   | 1.058 1     |
|                                                      | torr (torr) (= mmHg at 0°C)                                  | 760         |
| barrels (U.S. liquid)                                | gallons (U.S.)                                               | 31.5        |
| barrels (oil)                                        | cubic meters (m <sup>3</sup> )                               | 0.119 24    |
|                                                      | gallons of oil (U.S.)                                        | 42          |
|                                                      | cubic meters (m <sup>3</sup> )                               | 0.158 99    |
| bars                                                 | atmospheres (atm) (standard)                                 | 0.986 92    |
|                                                      | feet of water (ftH <sub>2</sub> O at 68°F) (20°C)            | 33.52       |
|                                                      | inches of mercury (inHg) at 0°C                              | 29.53       |
|                                                      | kilograms-force per square centimeter (kgf/cm <sup>2</sup> ) | 1.019 7     |
|                                                      | kilograms-force per square meter (kgf/m <sup>2</sup> )       | 10 197      |
|                                                      | *kilopascals (kPa)                                           | 100         |
|                                                      | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)    | 14.504      |
|                                                      | torr (torr) (= mmHg at 0°C)                                  | 750.06      |
| boiler horsepower                                    | British thermal units per hour (Btu/h) (see note)            | 33 479      |
|                                                      | *kilowatts (kW)                                              | 9.809 5     |
|                                                      | pounds of water evaporated per hour at 212°F (100°C)         | 34.5        |
| British thermal units<br>(Btu) (see note)            | calories (cal)                                               | 252.0       |
|                                                      | foot-pounds (ftlb)                                           | 778.2       |
|                                                      | horsepower hours (hp·h)                                      | 0.000 393   |
|                                                      | *joules (J)                                                  | 1 055       |
|                                                      | kilowatt-hours (kW·h)                                        | 0.000 293   |
|                                                      | kilo-calories (kcal)                                         | 0.252       |
|                                                      | kilogram-force-meters (kgf·m)                                | 107.6       |
| British thermal units (Btu)<br>per second (see note) | *watts (W)                                                   | 1 055       |
| British thermal units (Btu)<br>per minute (see note) | horsepower (hp)                                              | 0.023 58    |
| British thermal units (Btu)<br>per hour (see note)   | *watts (W)                                                   | 17.58       |
|                                                      | *watts (W)                                                   | 0.293 1     |
| calories                                             | British thermal units (Btu)                                  | 0.003 968 3 |
|                                                      | foot-pounds (ft·lb)                                          | 3.088       |
|                                                      | *joules (J)                                                  | 4.186 8     |
|                                                      | kilogram-meters (kg·m)                                       | 0.426 5     |
|                                                      | watt hours (W·h)                                             | 0.001 163   |
| *centimeters (cm)                                    | inches (in)                                                  | 0.393 7     |
| centimeters of mercury<br>(cmHg at 0°C)              | atmospheres (standard) (atm)                                 | 0.013 158   |
|                                                      | bars                                                         | 0.013 33    |
|                                                      | feet of water (ftH <sub>2</sub> O) at 68°F                   | 0.446 8     |
|                                                      | inches of water (inH <sub>2</sub> O) at 68°F                 | 5.362       |
|                                                      | kilograms-force per square centimeter (kgf/cm <sup>2</sup> ) | 0.013 595   |
|                                                      | *kilopascals (kPa)                                           | 1.333 2     |
|                                                      | pounds-force per square inch (lbf/in <sup>2</sup> )(psi)     | 0.193 37    |
|                                                      | pounds-force per square foot (lbf/ft <sup>2</sup> )          | 27.85       |
|                                                      | torr (= mmHg at 0°C)                                         | 10          |

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## APPENDIX A (continued) GENERAL CONVERSION FACTORS

\*Indicates preferred SI system units

| To convert from                                 | To                                                          | Multiply by     |
|-------------------------------------------------|-------------------------------------------------------------|-----------------|
| centimeters per second (cm/s)                   | feet per second (ft/s)                                      | 0.032 81        |
|                                                 | feet per minute (ft/min)                                    | 1.968 5         |
|                                                 | miles per hour (mph)                                        | 0.022 37        |
|                                                 | kilometers per hour (km/h)                                  | 0.036 00        |
|                                                 | meters per minute (m/min)                                   | 0.600 00        |
| circumference                                   | radians (rad)                                               | 6.283           |
| circular mils                                   | square inches (in <sup>2</sup> )                            | 0.000 000 785 4 |
| cubic centimeters (cm <sup>3</sup> )            | cubic inches (in <sup>3</sup> )                             | 0.061 02        |
|                                                 | cubic feet (ft <sup>3</sup> )                               | 0.000 035 315   |
|                                                 | cubic yards (yd <sup>3</sup> )                              | 0.000 001 308   |
|                                                 | gallons (U.S.) (U.S. gal)                                   | 0.000 264 2     |
|                                                 | gallons (Imperial) (imp gal)                                | 0.000 22        |
|                                                 | *liters (L)                                                 | 0.001           |
| cubic feet (ft <sup>3</sup> )                   | cubic centimeters (cm <sup>3</sup> )                        | 28 317          |
|                                                 | *cubic meters (m <sup>3</sup> )                             | 0.028 317       |
|                                                 | cubic inches (in <sup>3</sup> )                             | 1 728           |
|                                                 | cubic yards (yd <sup>3</sup> )                              | 0.037 04        |
|                                                 | gallons — U.S. (U.S. gal)                                   | 7.480 5         |
|                                                 | gallons — Imperial (imp gal)                                | 6.229           |
|                                                 | *liters (L)                                                 | 28.32           |
| cubic feet per minute<br>(ft <sup>3</sup> /min) | cubic centimeters per second (cm <sup>3</sup> /s)           | 471.9           |
|                                                 | *cubic meters per second (m <sup>3</sup> /s)                | 0.000 471 9     |
|                                                 | cubic meters per hour (m <sup>3</sup> /h)                   | 1.699           |
|                                                 | liters per second (L/s)                                     | 0.471 9         |
|                                                 | gallons — U.S. per second (U.S. gps)                        | 0.124 7         |
|                                                 | pounds of water per minute (lbH <sub>2</sub> O/min) at 68°F | 62.32           |
| cubic feet per second<br>(ft <sup>3</sup> /s)   | *cubic meters per second (m <sup>3</sup> /s)                | 0.028 317       |
|                                                 | cubic meters per minute (m <sup>3</sup> /min)               | 1.699           |
|                                                 | cubic meters per hour (m <sup>3</sup> /h)                   | 101.9           |
|                                                 | gallons — U.S. per minute (U.S. gal/min)                    | 448.8           |
|                                                 | gallons — U.S. per 24 hours (U.S. gpd)                      | 646 315         |
|                                                 | liters per second (L/s)                                     | 28.32           |
| cubic inches (in <sup>3</sup> )                 | cubic centimeters (cm <sup>3</sup> )                        | 16.387          |
|                                                 | cubic feet (ft <sup>3</sup> )                               | 0.000 578 7     |
|                                                 | *cubic meters (m <sup>3</sup> )                             | 0.000 016 387   |
|                                                 | cubic yards (yd <sup>3</sup> )                              | 0.000 021 43    |
|                                                 | gallons — U.S. (U.S. gal)                                   | 0.004 329       |
|                                                 | gallons — Imperial (imp gal)                                | 0.003 605       |
|                                                 | *liters (L)                                                 | 0.016 387       |
| *cubic meters (m <sup>3</sup> )                 | cubic inches (in <sup>3</sup> )                             | 61 024          |
|                                                 | cubic feet (ft <sup>3</sup> )                               | 35.315          |
|                                                 | cubic yards (yd <sup>3</sup> )                              | 1.308 0         |
|                                                 | gallons — U.S. (U.S. gal)                                   | 264.17          |
|                                                 | gallons — Imperial (imp gal)                                | 219.97          |
|                                                 | liters (L)                                                  | 1 000           |
| *cubic meters per hour<br>(m <sup>3</sup> /h)   | cubic meters per minute (m <sup>3</sup> /min)               | 0.016 667       |
|                                                 | *cubic meters per second (m <sup>3</sup> /s)                | 0.000 277 78    |
|                                                 | gallons U.S. per minute (U.S. g/min)                        | 4.403 3         |
|                                                 | liters per second (L/s)                                     | 0.277 78        |
| cubic meters per second<br>(m <sup>3</sup> /s)  | cubic meters per hour (m <sup>3</sup> /h)                   | 3 600           |
|                                                 | gallons U.S. per minute (U.S. gpm)                          | 15 850          |
| cubic yards (yd <sup>3</sup> )                  | cubic centimeters (cm <sup>3</sup> )                        | 764 550         |
|                                                 | cubic feet (ft <sup>3</sup> )                               | 27              |
|                                                 | cubic inches (in <sup>3</sup> )                             | 46 656          |
|                                                 | *cubic meters (m <sup>3</sup> )                             | 0.764 55        |
|                                                 | gallons — Imperial (imp gal)                                | 168.17          |
|                                                 | gallons — U.S. (U.S. gal)                                   | 201.97          |
| degrees angular                                 | liters (L)                                                  | 764.55          |
|                                                 | grade (gon)                                                 | 1.111           |
| degrees per second (angular)                    | radians (rad)                                               | 0.017 453       |
|                                                 | radians per second (rad/s)                                  | 0.017 453       |
|                                                 | revolutions per minute (r/min)                              | 0.166 67        |
|                                                 | revolutions per second (r/s)                                | 0.002 777 8     |

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## APPENDIX A (continued) GENERAL CONVERSION FACTORS

\*Indicates preferred SI system units

| To convert from                              | To                                                           | Multiply by     |
|----------------------------------------------|--------------------------------------------------------------|-----------------|
| drams-avoir                                  | grains (gr)                                                  | 27.344          |
|                                              | *grams (g)                                                   | 1.771 8         |
|                                              | ounces (oz)                                                  | 0.062 5         |
| dynes                                        | *newtons (N)                                                 | 0.000 01        |
| ergs                                         | *joules (J)                                                  | 0.000 000 1     |
| fathoms                                      | feet (ft)                                                    | 6               |
|                                              | *meters (m)                                                  | 1.828 8         |
| feet (ft)                                    | centimeters (cm)                                             | 30.480          |
|                                              | inches (in)                                                  | 12              |
|                                              | *meters (m)                                                  | 0.304 80        |
|                                              | yards (yd)                                                   | 0.333 3         |
| feet of water (ftH <sub>2</sub> O) at 68°F   | atmosphere (standard) (atm)                                  | 0.029 45        |
|                                              | bars (bar)                                                   | 0.029 84        |
|                                              | inches of mercury at 0°C (inHg)                              | 0.881 1         |
|                                              | kilograms-force per square centimeter (kgf/cm <sup>2</sup> ) | 0.030 42        |
|                                              | *kilopascals (kPa)                                           | 2.984           |
|                                              | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)    | 0.432 8         |
|                                              | pounds-force per square foot (lbf/ft <sup>2</sup> )          | 62.32           |
| feet per minute (ft/min)                     | centimeters per second (cm/s)                                | 0.508 0         |
|                                              | kilometers per hour (km/h)                                   | 0.018 29        |
|                                              | meters per minute (m/min)                                    | 0.304 80        |
|                                              | *meters per second (m/s)                                     | 0.005 08        |
|                                              | miles per hour (mph)                                         | 0.011 36        |
| feet per second (ft/s)                       | centimeters per second (cm/s)                                | 30.480          |
|                                              | kilometers per hour (km/h)                                   | 1.097           |
|                                              | meters per minute (m/min)                                    | 18.29           |
|                                              | *meters per second (m/s)                                     | 0.304 80        |
|                                              | miles per hour (mph)                                         | 0.681 8         |
| feet per second squared (ft/s <sup>2</sup> ) | centimeters per second squared (cm/s <sup>2</sup> )          | 30.480          |
|                                              | *meters per second squared (m/s <sup>2</sup> )               | 0.304 80        |
| foot-pounds-force (ft·lbf)                   | British thermal units (Btu) (see note)                       | 0.001 285       |
|                                              | calories                                                     | 0.323 8         |
|                                              | horsepower hours (hp·h)                                      | 0.000 000 505 0 |
|                                              | *joules (J)                                                  | 1.355 8         |
|                                              | kilocalories (kcal)                                          | 0.000 323 8     |
|                                              | kilogram-force meters (kgf·m)                                | 0.138 25        |
|                                              | kilowatt hours (kW·h)                                        | 0.000 000 376 6 |
| foot candle                                  | *lumen per square meter (lux)                                | 10.764          |
| gallons (U.S.) (gal)                         | cubic centimeters (cm <sup>3</sup> )                         | 3.785.4         |
|                                              | *cubic meters (m <sup>3</sup> )                              | 0.003 785 4     |
|                                              | cubic inches (in <sup>3</sup> )                              | 231             |
|                                              | cubic feet (ft <sup>3</sup> )                                | 0.133 68        |
|                                              | cubic yards (yd <sup>3</sup> )                               | 0.004 951 5     |
|                                              | pints—liquid (pt)                                            | 8               |
|                                              | quarts—liquid (qt)                                           | 4               |
|                                              | gallons—Imperial (imp gal)                                   | 0.832 7         |
|                                              | *liters (L)                                                  | 3.785 4         |
|                                              | pounds of water at 60°F                                      | 8.338           |
| gallons (Imperial)                           | cubic centimeters (cm <sup>3</sup> )                         | 4 546.1         |
|                                              | *cubic meters (m <sup>3</sup> )                              | 0.004 546 1     |
|                                              | cubic feet (ft <sup>3</sup> )                                | 0.160 54        |
|                                              | cubic yards (yd <sup>3</sup> )                               | 0.005 946       |
|                                              | gallons U.S. (U.S. gal)                                      | 1.200 94        |
|                                              | *liters (L)                                                  | 4.546 1         |
|                                              | pounds of water at 62°F                                      | 10.000          |
| gallons (U.S.) per minute<br>(U.S. gpm)      | *cubic meters per second (m <sup>3</sup> /s)                 | 0.000 063 090   |
|                                              | *cubic meters per minute (m <sup>3</sup> /min)               | 0.003 785 4     |
|                                              | *cubic meters per hour (m <sup>3</sup> /h)                   | 0.227 1         |
|                                              | cubic feet per second (ft <sup>3</sup> /s)                   | 0.002 228       |
|                                              | cubic feet per hour (ft <sup>3</sup> /h)                     | 8.021           |
|                                              | *liters per second (L/s)                                     | 0.063 09        |

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## APPENDIX A (continued) GENERAL CONVERSION FACTORS

\*Indicates preferred SI system units

| To convert from                                    | To                                                           | Multiply by |
|----------------------------------------------------|--------------------------------------------------------------|-------------|
| grains (gr)                                        | *grams (g)                                                   | 0.064 8     |
|                                                    | ounces-avoir (oz)                                            | 0.002 285 7 |
| grains per gallon (U.S.)<br>(gr/U.S. gal)          | grams per cubic meter (g/m <sup>3</sup> )                    | 17.118      |
|                                                    | *kilograms per cubic meter (kg/m <sup>3</sup> )              | 0.017 118   |
|                                                    | parts per million by weight in water (ppm)                   | 17.118      |
|                                                    | pounds per million gallons                                   | 142.9       |
| grains per gallon (Imperial)                       | grams per cubic meter (g/m <sup>3</sup> )                    | 14.25       |
|                                                    | *kilograms per cubic meter (kg/m <sup>3</sup> )              | 0.014 25    |
|                                                    | parts per million by weight in water (ppm)                   | 14.25       |
| grams (g)                                          | grains (gr)                                                  | 15.432      |
|                                                    | ounces-avoir (oz)                                            | 0.035 274   |
|                                                    | pounds-avoir (lb)                                            | 0.002 204 6 |
| grams-force (gf)                                   | *newtons (N)                                                 | 0.009 806 6 |
| grams-force per centimeter<br>(gf/cm)              | *newtons per meter (N/m)                                     | 98.07       |
|                                                    | pounds-force per inch (lbf/in)                               | 0.005 600   |
| grams per cubic centimeter<br>(g/cm <sup>3</sup> ) | *kilograms per cubic meter (kg/m <sup>3</sup> )              | 0.001       |
|                                                    | pounds per cubic inch (lb/in <sup>3</sup> )                  | 0.036 13    |
|                                                    | pounds per cubic foot (lb/ft <sup>3</sup> )                  | 62.427      |
| *grams per liter (g/L)                             | grains per U.S. gallon (gr/U.S. gal)                         | 58.417      |
|                                                    | parts per million (ppm) by mass weight in water              | 1 000       |
|                                                    | pounds per cubic foot (lb/ft <sup>3</sup> )                  | 0.062 242 7 |
|                                                    | pounds per 1000 U.S. gallons                                 | 8.354 4     |
| hectares (ha)                                      | acres                                                        | 2.471 0     |
|                                                    | square feet (ft <sup>2</sup> )                               | 107 639     |
|                                                    | *square meters (m <sup>2</sup> )                             | 10 000      |
| horsepower (hp)                                    | British thermal units per minute (see note) (Btu/min)        | 42.43       |
|                                                    | foot-pounds force per minute (ft·lbf/min)                    | 33 000      |
|                                                    | foot-pounds force per minute (ft·lbf/s)                      | 550         |
|                                                    | kilocalories per minute (kcal/min)                           | 10.69       |
|                                                    | *kilowatts (kW)                                              | 0.745 7     |
|                                                    | horsepower-metric                                            | 1.013 9     |
|                                                    | *watts (W)                                                   | 745.7       |
| horsepower-boiler                                  | British thermal units per hour (see note) (Btu/h)            | 33 479      |
|                                                    | kilowatts (kW)                                               | 9.809 5     |
|                                                    | pounds of water evaporated per hour at 212°F                 | 34.5        |
| horsepower hours (hp·h)                            | British thermal units (Btu)                                  | 2 545       |
|                                                    | foot-pounds-force (ft·lbf)                                   | 1 980 000   |
|                                                    | *joules (J)                                                  | 2 684 500   |
|                                                    | kilocalories (kcal)                                          | 641.5       |
|                                                    | kilogram-force-meters (kgf·m)                                | 273 200     |
|                                                    | *kilowatt-hours (kW·h)                                       | 0.745 7     |
| inches (in)                                        | centimeters (cm)                                             | 2.540       |
|                                                    | *meters (m)                                                  | 0.025 40    |
|                                                    | *millimeters (mm)                                            | 25.40       |
| inches of mercury (inHg)<br>at 0°C                 | atmospheres (standard) (atm)                                 | 0.033 42    |
|                                                    | bars (bar)                                                   | 0.033 864   |
|                                                    | feet of water (ftH <sub>2</sub> O) at 68°F                   | 1.135       |
|                                                    | inches of water (inH <sub>2</sub> O) at 68°F                 | 13.62       |
|                                                    | kilograms-force per square centimeter (kgf/cm <sup>2</sup> ) | 0.034 532   |
|                                                    | kilograms-force per square meter (kgf/m <sup>2</sup> )       | 345.32      |
|                                                    | *kilopascals (kPa)                                           | 3.386 4     |
|                                                    | millimeters of mercury (mmHg)                                | 25.40       |
|                                                    | pounds-force per square foot (lbf/ft <sup>2</sup> )          | 70.73       |
|                                                    | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)    | 0.491 2     |
| inches of water (inH <sub>2</sub> O)<br>at 68°F    | atmosphere (standard) (atm)                                  | 0.002 454   |
|                                                    | bars (bar)                                                   | 0.002 487   |
|                                                    | inches of mercury (inHg) at 0°C                              | 0.073 42    |
|                                                    | kilograms-force per square centimeter (kgf/cm <sup>2</sup> ) | 0.002 535   |
|                                                    | *kilopascals (kPa)                                           | 0.248 7     |
|                                                    | ounces-force per square inch (ozf/in <sup>2</sup> )          | 0.577 0     |
|                                                    | pounds-force per square foot (lbf/ft <sup>2</sup> )          | 5.193       |
|                                                    | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)    | 0.036 06    |

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## APPENDIX A (continued) GENERAL CONVERSION FACTORS

\*Indicates preferred SI system units

| To convert from                                              | To                                                             | Multiply by  |
|--------------------------------------------------------------|----------------------------------------------------------------|--------------|
| *joules (J)                                                  | British thermal units (see note)                               | 0.000 948 4  |
|                                                              | calories (cal) (thermochemical)                                | 0.239 0      |
|                                                              | foot-pounds-force (ft·lbf)                                     | 0.737 56     |
|                                                              | watt-hours (W·h)                                               | 0.000 277 78 |
| *kilograms (kg)                                              | pounds (lb)                                                    | 2.204 6      |
|                                                              | tons (ton) short                                               | 0.001 102 3  |
| kilograms-force (kgf)                                        | *newtons (N)                                                   | 9.806 6      |
|                                                              | pounds-force (lbf)                                             | 2.204 6      |
| kilograms-force per meter (kgf/m)                            | *newtons per meter (N/m)                                       | 9.806 6      |
|                                                              | pounds-force per foot (lbf/ft)                                 | 0.672 1      |
| kilograms-force per square centimeter (kgf/cm <sup>2</sup> ) | atmospheres (standard) (atm)                                   | 0.967 8      |
|                                                              | bars (bar)                                                     | 0.980 66     |
|                                                              | feet of water (ftH <sub>2</sub> O) at 68°F                     | 32.87        |
|                                                              | inches of mercury (inHg) at 0°C                                | 28.96        |
|                                                              | *kilopascals (kPa)                                             | 98.066       |
|                                                              | pounds-force per square foot (lbf/ft <sup>2</sup> )            | 2 048        |
|                                                              | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)      | 14.223       |
| kilograms-force per square millimeter (kgf/mm <sup>2</sup> ) | kilograms-force per square meter (kgf/m <sup>2</sup> )         | 1 000 000    |
|                                                              | *megapascals (Mpa)                                             | 9.806 6      |
| *kilometers (km)                                             | feet (ft)                                                      | 3 280.8      |
|                                                              | miles (mi)                                                     | 0.621 37     |
| kilometers per hour (km/h)                                   | centimeters per second (cm/s)                                  | 27.778       |
|                                                              | feet per second (ft/s)                                         | 0.911 3      |
|                                                              | feet per minute (ft/min)                                       | 54.68        |
|                                                              | international knots (kn)                                       | 0.539 96     |
|                                                              | meters per minute (m/min)                                      | 16.667       |
|                                                              | *meters per second (m/s)                                       | 0.277 78     |
|                                                              | miles per hour (mph)                                           | 0.621 4      |
| kilometers per hour per second (km/h·s)                      | centimeters per second squared (cm/s <sup>2</sup> )            | 27.778       |
|                                                              | feet per second squared (ft/s <sup>2</sup> )                   | 0.911 3      |
|                                                              | *meters per second squared (m/s <sup>2</sup> )                 | 0.277 78     |
| kilometers per second (km/s)                                 | miles per minutes (mi/min)                                     | 37.28        |
| *kilopascals (kPa)                                           | dynes per square centimeter (dy/cm <sup>2</sup> )              | 10 000       |
|                                                              | feet of water (ftH <sub>2</sub> O) at 68°F                     | 0.335 1      |
|                                                              | inches of mercury (inHg) at 32°F                               | 0.295 3      |
|                                                              | inches of water (inH <sub>2</sub> O) at 68°F                   | 4.021        |
|                                                              | kilograms-force per square centimeter (kgf/cm <sup>2</sup> )   | 0.010 197    |
|                                                              | pascals (Pa) (or newtons per square meter) (N/m <sup>2</sup> ) | 1 000        |
|                                                              | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)      | 0 145 0      |
| kiloponds                                                    | *newtons (N)                                                   | 9.807        |
|                                                              | kilograms-force (kgf)                                          | 1            |
|                                                              | pounds-force (lbf)                                             | 2.204 6      |
|                                                              | poundals                                                       | 70.932       |
|                                                              | kips                                                           | 0.002 205    |
| kips (1000 lbf)                                              | *newton (N)                                                    | 4.448        |
|                                                              | kilogram-force (kgf)                                           | 453.6        |
|                                                              | pounds-force (lbf)                                             | 1 000        |
|                                                              | poundal                                                        | 32 174       |
|                                                              | kilopond                                                       | 453.6        |
| kips per square inch (ksi)                                   | *kilopascals                                                   | 6 894.8      |
|                                                              | kilograms-force per square centimeter (kgf/cm <sup>2</sup> )   | 70.307       |
|                                                              | bars (bar)                                                     | 68.94        |
|                                                              | pounds per square inch (psi)                                   | 1 000        |
| *kilowatts (kW)                                              | British thermal units per minute (Btu/min)                     | 56.92        |
|                                                              | foot-pounds-force per minute (ft·lbf/min)                      | 44.254       |
|                                                              | foot-pounds-force per second (ft·lbf/s)                        | 737.6        |
|                                                              | horsepower (hp)                                                | 1.341 0      |
|                                                              | kilocalories per minute (kcal/min)                             | 14.34        |

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## APPENDIX A (continued) GENERAL CONVERSION FACTORS

\*Indicates preferred SI system units

| To convert from                 | To                                                           | Multiply by |
|---------------------------------|--------------------------------------------------------------|-------------|
| kilowatt hours (kW·h)           | British thermal units (Btu) (see note)                       | 3 413       |
|                                 | foot-pounds-force (ft·lbf)                                   | 2 655 000   |
|                                 | horsepower hours (hp·h)                                      | 1.341 0     |
|                                 | *joules (J)                                                  | 3.600 000   |
|                                 | kilocalories (kcal)                                          | 860         |
|                                 | kilogram-force meters (kgf·m)                                | 367 100     |
| knots (international)           | *meters per second (m/s)                                     | 0.514 4     |
|                                 | miles per hour (mph)                                         | 1.151 6     |
| *liters (L)                     | cubic centimeters (cm <sup>3</sup> )                         | 1 000       |
|                                 | cubic feet (ft <sup>3</sup> )                                | 0.035 315   |
|                                 | cubic inches (in <sup>3</sup> )                              | 61.024      |
|                                 | cubic meters (m <sup>3</sup> )                               | 0.001       |
|                                 | cubic yards (yd <sup>3</sup> )                               | 0.001 308   |
|                                 | gallons U.S. (U.S. gal)                                      | 0.264 18    |
|                                 | gallons Imperial (imp gal)                                   | 0.220 0     |
| *liters per minute (L/min)      | cubic feet per second (ft <sup>3</sup> /s)                   | 0.000 588 5 |
|                                 | *liters per second (L/s)                                     | 0.016 67    |
|                                 | gallons (U.S.) per second (U.S. gal/s)                       | 0.004 403   |
|                                 | gallons (U.S.) per minute (U.S. gal/min)                     | 0.264 18    |
|                                 | gallons (Imperial) per min (imp gal/min)                     | 0.003 666   |
| *liters per second (L/s)        | cubic meters per second (m <sup>3</sup> /s)                  | 0.001       |
|                                 | cubic meters per minute (m <sup>3</sup> /min)                | 0.06        |
|                                 | cubic meters per hour (m <sup>3</sup> /h)                    | 3.600       |
|                                 | *liters per minute (L/min)                                   | 60          |
|                                 | gallons (U.S.) per minute (U.S. gal/min)                     | 15.85       |
|                                 | gallons (Imperial) per minute (imp gal)                      | 13.20       |
| *megapascals (MPa)              | kilograms-force per square millimeter (kgf/mm <sup>2</sup> ) | 0.101 97    |
|                                 | kilograms-force per square centimeter (kgf/cm <sup>2</sup> ) | 10.197      |
|                                 | *kilopascals (kPa)                                           | 1 000       |
|                                 | *pascals (Pa)                                                | 1 000 000   |
|                                 | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)    | 145.0       |
| *meters (m)                     | feet (ft)                                                    | 3.280 8     |
|                                 | inches (in)                                                  | 39.370      |
|                                 | yards (yd)                                                   | 1.093 6     |
| *meters per minute (m/min)      | centimeters per second (cm/s)                                | 1.666 7     |
|                                 | feet per minute (ft/min)                                     | 3.280 8     |
|                                 | feet per second (ft/s)                                       | 0.054 68    |
|                                 | kilometers per hour (km/h)                                   | 0.060 0     |
|                                 | miles per hour (mph)                                         | 0.037 28    |
| *meters per second (m/s)        | feet per minute (ft/min)                                     | 196.8       |
|                                 | feet per second (ft/s)                                       | 3.281       |
|                                 | kilometers per hour (km/h)                                   | 3.600       |
|                                 | kilometers per minute (km/min)                               | 0.060 0     |
|                                 | miles per hour (mph)                                         | 2.237       |
|                                 | miles per minute (mi/min)                                    | 0.037 28    |
| *micrometers (formerly microns) | *meters (m)                                                  | 0.000 001   |
| mills (0.001 inches)            | *millimeters (mm)                                            | 0.025 4     |
| miles                           | feet (ft)                                                    | 5 280       |
|                                 | *kilometers (km)                                             | 1.609 3     |
|                                 | *meters (m)                                                  | 1 609.3     |
|                                 | yards (yd)                                                   | 1 760       |
| miles per hour (mph)            | centimeters per second (cm/s)                                | 44.70       |
|                                 | feet per minute (ft/min)                                     | 88          |
|                                 | feet per second (ft/s)                                       | 1.466 7     |
|                                 | international knots (kn)                                     | 0.869 0     |
|                                 | *kilometers per hour (km/h)                                  | 1.609 3     |
|                                 | *meters per minute (m/min)                                   | 26.82       |
| milligrams per liter (mg/L)     | parts per million (ppm)                                      | 1.0         |
| *millimeters (mm)               | inches (in)                                                  | 0.039 370   |

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## APPENDIX A (continued) GENERAL CONVERSION FACTORS

\*Indicates preferred SI system units

| To convert from                                        | To                                                           | Multiply by   |
|--------------------------------------------------------|--------------------------------------------------------------|---------------|
| millimeters of mercury at 0°C<br>(mmHg)                | bars (bar)                                                   | 0.001 333 2   |
|                                                        | feet of water at 68°F                                        | 0.004 680     |
|                                                        | inches of mercury (inHg)                                     | 0.039 37      |
|                                                        | inches of water (68°F)                                       | 0.536 16      |
|                                                        | kilograms per square centimeter (kg/cm <sup>2</sup> )        | 0.001 359 5   |
|                                                        | *pascals (Pa)                                                | 133.32        |
|                                                        | pounds per square inch (psi)                                 | 0.019 336 8   |
| minutes, angular (')                                   | radians (rad)                                                | 0.000 290 9   |
| *newtons (N)                                           | dynes (dyn)                                                  | 100 000       |
|                                                        | kilograms-force (kgf)                                        | 0.101 97      |
|                                                        | poundals                                                     | 7.233 0       |
|                                                        | pounds-force (lbf)                                           | 0.224 8       |
| ounces-avoir (oz)                                      | drams—avoir (dr)                                             | 16            |
|                                                        | grains (gr)                                                  | 437.5         |
|                                                        | *grams (g)                                                   | 28.349 5      |
|                                                        | *kilograms (kg)                                              | 0.028 350     |
|                                                        | pounds-avoir (lb)                                            | 0.062 50      |
|                                                        | tons (ton) long                                              | 0.000 027 90  |
|                                                        | *tonnes (t) metric ton                                       | 0.000 028 350 |
| ounces-U.S. fluid                                      | cubic inches (in <sup>3</sup> )                              | 1.804 6       |
|                                                        | *liters (L)                                                  | 0.029 57      |
| ounces-force per square inch<br>(ozf/in <sup>2</sup> ) | grams-force per square centimeter (gf/cm <sup>2</sup> )      | 4.395         |
|                                                        | *pascals (Pa)                                                | 43.1          |
|                                                        | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)    | 0.062 50      |
|                                                        | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)    | 0.062 50      |
| parts per million by mass (ppm)                        | grains per U.S. gallon at 60°F (gr/U.S. gal)                 | 0.058 3       |
|                                                        | grains per Imperial gallon at 62°F (gr/imp gal)              | 0.070 0       |
|                                                        | grams per cubic meter (g/m <sup>3</sup> ) at 15°C            | 0.999 1       |
|                                                        | *milligrams per liter (mg/L)                                 | 1.0           |
|                                                        | pounds per million U.S. gallons at 60°F                      | 8.328         |
| *pascals (Pa)                                          | bars (bar)                                                   | 0.000 01      |
|                                                        | dynes per square centimeters (dyn/cm <sup>2</sup> )          | 10.0          |
|                                                        | grams-force per square centimeter (gf/cm <sup>2</sup> )      | 0.010 197     |
|                                                        | kilograms-force per square centimeter (kg/cm <sup>2</sup> )  | 0.000 010 197 |
|                                                        | kilograms-force per square meter (kg/m <sup>2</sup> )        | 0.101 97      |
|                                                        | *kilopascals (kPa)                                           | 0.001         |
|                                                        | *newtons per square meter (N/m <sup>2</sup> )                | 1.0           |
|                                                        | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)    | 0.000 145 0   |
| poise                                                  | centipoises (CP)                                             | 100           |
|                                                        | *pascal second (Pa·s)                                        | 0.100 0       |
|                                                        | pound-force-seconds per square foot (lbf·s/ft <sup>2</sup> ) | 0.002 088 6   |
|                                                        | pounds per foot second (lb/ft·s)                             | 0.067 21      |
| poundals                                               | *newtons (N) (joules per meter)                              | 0.138 26      |
| pounds-force (lbf)                                     | kilograms-force (kgf)                                        | 0.453 59      |
|                                                        | *newtons (N)                                                 | 4.448 2       |
| pounds-avoir (lb)                                      | drams-avoir (dr)                                             | 256           |
|                                                        | grains (gr)                                                  | 7 000         |
|                                                        | *grams (g)                                                   | 453.59        |
|                                                        | *kilograms (kg)                                              | 0.453 59      |
|                                                        | ounces-avoir (oz)                                            | 16            |
|                                                        | *tonnes-metric tons (t)                                      | 0.000 453 59  |
|                                                        | tons — long                                                  | 0.000 446 43  |
|                                                        | tons — short                                                 | 0.000 5       |
| pounds per foot (lb/ft)                                | *kilograms per meter (kg/m)                                  | 1.488 2       |
| pounds per square foot (lb/ft <sup>2</sup> )           | *kilograms per square meter (kg/m <sup>2</sup> )             | 4.882 4       |
| pounds-mass of water at 60°F                           | cubic centimeters (cm <sup>3</sup> )                         | 454.00        |
|                                                        | cubic feet (ft <sup>3</sup> )                                | 0.016 03      |
|                                                        | cubic inches (in <sup>3</sup> )                              | 27.70         |
|                                                        | gallons (U.S.) (U.S. gal)                                    | 0.119 93      |
|                                                        | liters (L)                                                   | 0.453 98      |

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## APPENDIX A (continued)

### GENERAL CONVERSION FACTORS

\*Indicates preferred SI system units

| To convert from                                                 | To                                                                                      | Multiply by   |
|-----------------------------------------------------------------|-----------------------------------------------------------------------------------------|---------------|
| pounds of water per minute at 60°F                              | cubic centimeters per second (cm <sup>3</sup> /s)                                       | 7.566 7       |
|                                                                 | cubic feet per second (ft <sup>3</sup> /s) (cfs)                                        | 0.000 267 5   |
|                                                                 | *cubic meters per minute (m <sup>3</sup> /min)                                          | 0.000 453 98  |
|                                                                 | *kilograms per second (kg/s)                                                            | 0.007 559 9   |
| pounds per cubic foot (lb/ft <sup>3</sup> )                     | grams per cubic centimeter (g/cm <sup>3</sup> )                                         | 0.016 018     |
|                                                                 | *kilograms per cubic meter (kg/m <sup>3</sup> )                                         | 16.018        |
|                                                                 | pounds per cubic inch (lb/in <sup>3</sup> )                                             | 0.000 578 7   |
| pounds per cubic inch (lb/in <sup>3</sup> )                     | grams per cubic centimeter (g/cm <sup>3</sup> )                                         | 27.68         |
|                                                                 | *kilograms per cubic meter (kg/m <sup>3</sup> )                                         | 27 680        |
|                                                                 | pounds per cubic foot (lb/ft <sup>3</sup> )                                             | 1 728         |
| pounds-force per foot (lbf/ft)                                  | grams-force per centimeter (gf/cm)                                                      | 14.882        |
|                                                                 | kilograms-force per meter (kgf/m)                                                       | 1.488 2       |
|                                                                 | *newtons per meter (N/m)                                                                | 14.594        |
| pounds-force per square foot (lbf/ft <sup>2</sup> )             | feet of water (ftH <sub>2</sub> O) at 68°F                                              | 0.016 05      |
|                                                                 | kilograms-force per square centimeter (Kgf/cm <sup>2</sup> )                            | 0.000 488 2   |
|                                                                 | *kilopascals (kPa)                                                                      | 0.004 788 0   |
|                                                                 | *pascals (Pa)                                                                           | 47.880        |
|                                                                 | pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)                               | 0.006 944 4   |
| pounds-force per square inch (lbf/in <sup>2</sup> ) (psi)       | atmospheres (standard) (atm)                                                            | 0.068 05      |
|                                                                 | feet of water (ftH <sub>2</sub> O) at 68°F                                              | 2.311         |
|                                                                 | inches of water (inH <sub>2</sub> O) at 68°F                                            | 27.73         |
|                                                                 | inches of mercury (inHg) at 0°C                                                         | 2.036         |
|                                                                 | kilograms-force per square centimeter (kgf/cm <sup>2</sup> )                            | 0.070 31      |
|                                                                 | *kilopascals (kPa)                                                                      | 6.894 8       |
| quarts—dry (qt dry)                                             | cubic centimeters (cm <sup>3</sup> )                                                    | 1 101.2       |
|                                                                 | cubic inches (in <sup>3</sup> )                                                         | 67.20         |
|                                                                 | *cubic meters (m <sup>3</sup> )                                                         | 0.001 101 2   |
| quarts—liquid (qt liquid)                                       | cubic centimeters (cm <sup>3</sup> )                                                    | 946.35        |
|                                                                 | cubic inches (in <sup>3</sup> )                                                         | 57.75         |
|                                                                 | *liters (L)                                                                             | 0.946 35      |
| radians (rad)                                                   | degrees (°) angular                                                                     | 57.296        |
| radians per second (rad/s)                                      | degrees per second (°/s) angular                                                        | 57.296        |
|                                                                 | revolutions per minute (r/min)                                                          | 9.549         |
| revolutions per minute (r/min)                                  | degrees per second                                                                      | 6             |
|                                                                 | radians per second (rad/s)                                                              | 0.014 72      |
| square centimeters (cm <sup>2</sup> )                           | square inches (in <sup>2</sup> )                                                        | 0.155 0       |
| square feet (ft <sup>2</sup> )                                  | acres                                                                                   | 0.000 022 956 |
|                                                                 | *square meters (m <sup>2</sup> )                                                        | 0.092 903     |
| square inches (in <sup>2</sup> )                                | square centimeters (cm <sup>2</sup> )                                                   | 6.451 6       |
| square kilometers (km <sup>2</sup> )                            | acres                                                                                   | 247.10        |
|                                                                 | square miles                                                                            | 0.386 10      |
| *square meters (m <sup>2</sup> )                                | acres                                                                                   | 0.000 247 10  |
|                                                                 | square feet (ft <sup>2</sup> )                                                          | 10.764        |
| square miles                                                    | acres                                                                                   | 640           |
|                                                                 | square kilometers (km <sup>2</sup> )                                                    | 2.590         |
| square yards (yd <sup>2</sup> )                                 | acres                                                                                   | 0.000 206 61  |
|                                                                 | *square meters (m <sup>2</sup> )                                                        | 0.836 13      |
| standard cubic feet per minute (scfm) (at 14 696 psia and 60°F) | cubic meters per hour (m <sup>3</sup> /h) at standard conditions (15°C and 101.325 kPa) | 1.695 7       |
|                                                                 | liters per second (L/s) at standard conditions (15°C and 101.325 kPa)                   | 0.471 03      |
| stokes                                                          | square feet per second (ft <sup>2</sup> /s)                                             | 0.001 076     |
|                                                                 | *square meters per second (m <sup>2</sup> /s)                                           | 0.000 1       |

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## APPENDIX A (continued) GENERAL CONVERSION FACTORS

\*Indicates preferred SI system units

| To convert from                                                                  | To                                                                      | Multiply by |
|----------------------------------------------------------------------------------|-------------------------------------------------------------------------|-------------|
| temperature degrees—<br>Fahrenheit (°F)                                          | *degrees Celsius (°C); $^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32)$ |             |
| *degrees Celsius (°C)                                                            | degrees Fahrenheit (°F); $^{\circ}\text{F} = 9/5^{\circ}\text{C} + 32$  |             |
| degrees Fahrenheit (°F)                                                          | *kelvin (K) $\text{K} = 5/9 (^{\circ}\text{F} + 459.67)$                |             |
| *degrees Celsius (°C)                                                            | *kelvin (K) $\text{K} = ^{\circ}\text{C} + 273.15$                      |             |
| degrees Rankine (°R)                                                             | *kelvin (K) $\text{K} = ^{\circ}\text{R}/1.8$                           |             |
| degrees Fahrenheit (°F)                                                          | degrees Rankine (°R); $^{\circ}\text{R} = ^{\circ}\text{F} + 459.67$    |             |
| for temperature conversion tables; i.e. °F to °C and vice versa refer to page 27 |                                                                         |             |
| tons — long                                                                      | *kilograms (kg)                                                         | 1 016.0     |
|                                                                                  | metric tons (t)                                                         | 1.016 0     |
|                                                                                  | pounds-avoir (lb)                                                       | 2 240       |
|                                                                                  | tons — short                                                            | 1.120       |
| *tonnes-metric ton                                                               | *kilograms (kg)                                                         | 1 000       |
|                                                                                  | pounds (lb)                                                             | 2 204.6     |
| tons — short                                                                     | *kilograms (kg)                                                         | 907.18      |
|                                                                                  | pounds-avoir (lb)                                                       | 2 000       |
|                                                                                  | tons — long                                                             | 0.892 86    |
|                                                                                  | tonnes (metric ton) (t)                                                 | 0.907 2     |
| tons (short) of water per<br>24 hours (at 60°F)                                  | cubic feet per hour (ft <sup>3</sup> /h)                                | 1.338       |
|                                                                                  | cubic meters per hour (m <sup>3</sup> /h)                               | 0.037 89    |
|                                                                                  | gallons (U.S.) (U.S. gal/min)                                           | 0.166 8     |
|                                                                                  | pounds of water per hour (lbH <sub>2</sub> O/h) at 60°F                 | 83.333      |
| tons of refrigeration                                                            | British thermal units (Btu) (see note) per hour                         | 12 000      |
|                                                                                  | British thermal units (Btu) (see note) per 24 hours                     | 288 000     |
| *watts (W)                                                                       | British thermal units (Btu) per minute (Btu/min)                        | 0.056 91    |
|                                                                                  | foot-pounds-force per second (ft·lbf/s)                                 | 0.737 56    |
|                                                                                  | foot-pounds-force per minute (ft·lbf/min)                               | 44.254      |
|                                                                                  | horsepower (hp)                                                         | 0.001 341 0 |
|                                                                                  | joules per second (J/s)                                                 | 1.0         |
|                                                                                  | kilocalories per minute (kcal/min)                                      | 0.014 340   |
| watt-hours (W·h)                                                                 | British thermal units (Btu)                                             | 3.413       |
|                                                                                  | foot-pounds-force (ft·lbf)                                              | 2 655       |
|                                                                                  | horsepower hours (hp·h)                                                 | 0.001 341 0 |
|                                                                                  | *joules (J)                                                             | 3 600       |
|                                                                                  | kilocalories (kcal)                                                     | 0.860 4     |
|                                                                                  | kilograms-force-meters (kgf·m)                                          | 367.10      |
| yards (yd)                                                                       | *meters (m)                                                             | 0.914 40    |

**NOTE:** British Thermal Units (Btu)—since there are several definitions of the Btu, the values of applicable and/or equivalent factors may vary slightly depending on the definition used. In the accompanying tables of conversion factors, the first three or four significant figures given, in most cases, are common to most definitions of the Btu; if greater accuracy is required for certain calculations then reference to the appropriate handbooks and standards should be made.

# APPENDIX A (continued)

## DEGREES FAHRENHEIT TO DEGREES CELSIUS CONVERSION TABLE

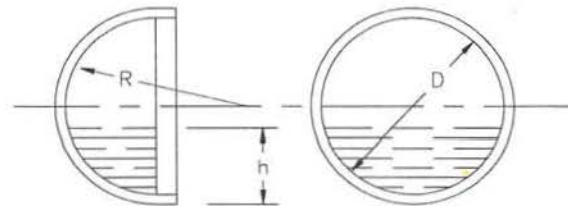
| Degrees<br>Fahrenheit Celsius |       | Degrees<br>Fahrenheit Celsius |       | Degrees<br>Fahrenheit Celsius |       | Degrees<br>Fahrenheit Celsius |        | Degrees<br>Fahrenheit Celsius |        | Degrees<br>Fahrenheit Celsius |        |
|-------------------------------|-------|-------------------------------|-------|-------------------------------|-------|-------------------------------|--------|-------------------------------|--------|-------------------------------|--------|
| 40                            | 4.44  | 94                            | 34.44 | 148                           | 64.44 | 202                           | 94.44  | 256                           | 124.44 | 310                           | 154.44 |
| 41                            | 5.00  | 95                            | 35.00 | 149                           | 65.00 | 203                           | 95.00  | 257                           | 125.00 | 311                           | 155.00 |
| 42                            | 5.56  | 96                            | 35.56 | 150                           | 65.56 | 204                           | 95.56  | 258                           | 125.56 | 312                           | 155.56 |
| 43                            | 6.11  | 97                            | 36.11 | 151                           | 66.11 | 205                           | 96.11  | 259                           | 126.11 | 313                           | 156.11 |
| 44                            | 6.67  | 98                            | 36.67 | 152                           | 66.67 | 206                           | 96.67  | 260                           | 126.67 | 314                           | 156.67 |
| 45                            | 7.22  | 99                            | 37.22 | 153                           | 67.22 | 207                           | 97.22  | 261                           | 127.22 | 315                           | 157.22 |
| 46                            | 7.78  | 100                           | 37.78 | 154                           | 67.78 | 208                           | 97.78  | 262                           | 127.78 | 316                           | 157.78 |
| 47                            | 8.33  | 101                           | 38.33 | 155                           | 68.33 | 209                           | 98.33  | 263                           | 128.33 | 317                           | 158.33 |
| 48                            | 8.89  | 102                           | 38.89 | 156                           | 68.89 | 210                           | 98.89  | 264                           | 128.89 | 318                           | 158.89 |
| 49                            | 9.44  | 103                           | 39.44 | 157                           | 69.44 | 211                           | 99.44  | 265                           | 129.44 | 319                           | 159.44 |
| 50                            | 10.00 | 104                           | 40.00 | 158                           | 70.00 | 212                           | 100.00 | 266                           | 130.00 | 320                           | 160.00 |
| 51                            | 10.56 | 105                           | 40.56 | 159                           | 70.56 | 213                           | 100.56 | 267                           | 130.56 | 321                           | 160.56 |
| 52                            | 11.11 | 106                           | 41.11 | 160                           | 71.11 | 214                           | 101.11 | 268                           | 131.11 | 322                           | 161.11 |
| 53                            | 11.67 | 107                           | 41.67 | 161                           | 71.67 | 215                           | 101.67 | 269                           | 131.67 | 323                           | 161.67 |
| 54                            | 12.22 | 108                           | 42.22 | 162                           | 72.22 | 216                           | 102.22 | 270                           | 132.22 | 324                           | 162.22 |
| 55                            | 12.78 | 109                           | 42.78 | 163                           | 72.78 | 217                           | 102.78 | 271                           | 132.78 | 325                           | 162.78 |
| 56                            | 13.33 | 110                           | 43.33 | 164                           | 73.33 | 218                           | 103.33 | 272                           | 133.33 | 326                           | 163.33 |
| 57                            | 13.89 | 111                           | 43.89 | 165                           | 73.89 | 219                           | 103.89 | 273                           | 133.89 | 327                           | 163.89 |
| 58                            | 14.44 | 112                           | 44.44 | 166                           | 74.44 | 220                           | 104.44 | 274                           | 134.44 | 328                           | 164.44 |
| 59                            | 15.00 | 113                           | 45.00 | 167                           | 75.00 | 221                           | 105.00 | 275                           | 135.00 | 329                           | 165.00 |
| 60                            | 15.56 | 114                           | 45.56 | 168                           | 75.56 | 222                           | 105.56 | 276                           | 135.56 | 330                           | 165.56 |
| 61                            | 16.11 | 115                           | 46.11 | 169                           | 76.11 | 223                           | 106.11 | 277                           | 136.11 | 331                           | 166.11 |
| 62                            | 16.67 | 116                           | 46.67 | 170                           | 76.67 | 224                           | 106.67 | 278                           | 136.67 | 332                           | 166.67 |
| 63                            | 17.22 | 117                           | 47.22 | 171                           | 77.22 | 225                           | 107.22 | 279                           | 137.22 | 333                           | 167.22 |
| 64                            | 17.78 | 118                           | 47.78 | 172                           | 77.78 | 226                           | 107.78 | 280                           | 137.78 | 334                           | 167.78 |
| 65                            | 18.33 | 119                           | 48.33 | 173                           | 78.33 | 227                           | 108.33 | 281                           | 138.33 | 335                           | 168.33 |
| 66                            | 18.89 | 120                           | 48.89 | 174                           | 78.89 | 228                           | 108.89 | 282                           | 138.89 | 336                           | 168.89 |
| 67                            | 19.44 | 121                           | 49.44 | 175                           | 79.44 | 229                           | 109.44 | 283                           | 139.44 | 337                           | 169.44 |
| 68                            | 20.00 | 122                           | 50.00 | 176                           | 80.00 | 230                           | 110.00 | 284                           | 140.00 | 338                           | 170.00 |
| 69                            | 20.56 | 123                           | 50.56 | 177                           | 80.56 | 231                           | 110.56 | 285                           | 140.56 | 339                           | 170.56 |
| 70                            | 21.11 | 124                           | 51.11 | 178                           | 81.11 | 232                           | 111.11 | 286                           | 141.11 | 340                           | 171.11 |
| 71                            | 21.67 | 125                           | 51.67 | 179                           | 81.67 | 233                           | 111.67 | 287                           | 141.67 | 341                           | 171.67 |
| 72                            | 22.22 | 126                           | 52.22 | 180                           | 82.22 | 234                           | 112.22 | 288                           | 142.22 | 342                           | 172.22 |
| 73                            | 22.78 | 127                           | 52.78 | 181                           | 82.78 | 235                           | 112.78 | 289                           | 142.78 | 343                           | 172.78 |
| 74                            | 23.33 | 128                           | 53.33 | 182                           | 83.33 | 236                           | 113.33 | 290                           | 143.33 | 344                           | 173.33 |
| 75                            | 23.89 | 129                           | 53.89 | 183                           | 83.89 | 237                           | 113.89 | 291                           | 143.89 | 345                           | 173.89 |
| 76                            | 24.44 | 130                           | 54.44 | 184                           | 84.44 | 238                           | 114.44 | 292                           | 144.44 | 346                           | 174.44 |
| 77                            | 25.00 | 131                           | 55.00 | 185                           | 85.00 | 239                           | 115.00 | 293                           | 145.00 | 347                           | 175.00 |
| 78                            | 25.56 | 132                           | 55.56 | 186                           | 85.56 | 240                           | 115.56 | 294                           | 145.56 | 348                           | 175.56 |
| 79                            | 26.11 | 133                           | 56.11 | 187                           | 86.11 | 241                           | 116.11 | 295                           | 146.11 | 349                           | 176.11 |
| 80                            | 26.67 | 134                           | 56.67 | 188                           | 86.67 | 242                           | 116.67 | 296                           | 146.67 | 350                           | 176.67 |
| 81                            | 27.22 | 135                           | 57.22 | 189                           | 87.22 | 243                           | 117.22 | 297                           | 147.22 | 351                           | 177.22 |
| 82                            | 27.78 | 136                           | 57.78 | 190                           | 87.78 | 244                           | 117.78 | 298                           | 147.78 | 352                           | 177.78 |
| 83                            | 28.33 | 137                           | 58.33 | 191                           | 88.33 | 245                           | 118.33 | 299                           | 148.33 | 353                           | 178.33 |
| 84                            | 28.89 | 138                           | 58.89 | 192                           | 88.89 | 246                           | 118.89 | 300                           | 148.89 | 354                           | 178.89 |
| 85                            | 29.44 | 139                           | 59.44 | 193                           | 89.44 | 247                           | 119.44 | 301                           | 149.44 | 355                           | 179.44 |
| 86                            | 30.00 | 140                           | 60.00 | 194                           | 90.00 | 248                           | 120.00 | 302                           | 150.00 | 356                           | 180.00 |
| 87                            | 30.56 | 141                           | 60.56 | 195                           | 90.56 | 249                           | 120.56 | 303                           | 150.56 | 357                           | 180.56 |
| 88                            | 31.11 | 142                           | 61.11 | 196                           | 91.11 | 250                           | 121.11 | 304                           | 151.11 | 358                           | 181.11 |
| 89                            | 31.67 | 143                           | 61.67 | 197                           | 91.67 | 251                           | 121.67 | 305                           | 151.67 | 359                           | 181.67 |
| 90                            | 32.22 | 144                           | 62.22 | 198                           | 92.22 | 252                           | 122.22 | 306                           | 152.22 | 360                           | 182.22 |
| 91                            | 32.78 | 145                           | 62.78 | 199                           | 92.78 | 253                           | 122.78 | 307                           | 152.78 | 361                           | 182.78 |
| 92                            | 33.33 | 146                           | 63.33 | 200                           | 93.33 | 254                           | 123.33 | 308                           | 153.33 | 362                           | 183.33 |
| 93                            | 33.89 | 147                           | 63.89 | 201                           | 93.89 | 255                           | 123.89 | 309                           | 153.89 | 363                           | 183.89 |

## APPENDIX B

### SEMI-ELLIPTICAL HEAD CAPACITIES WHEN FILLED TO VARIOUS DEPTHS

CONTENTS IN U.S. GALLONS. THIS TABLE IS ONLY APPROXIMATE,  
BUT CLOSE ENOUGH FOR PRACTICAL USE.

|        |        | HEAD DIAMETER (IN)<br>FULL HEAD CAPACITIES |        |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
|--------|--------|--------------------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|------|------|------|------|-----|-----|-----|
|        |        | 144                                        | 132    | 120   | 114   | 108   | 102   | 96    | 90    | 84    | 78    | 72    | 66    | 60    | 54   | 48   | 42   | 36   | 30   | 24  | 18  | 12  |
| h (in) |        | 1692.0                                     | 1303.0 | 979.2 | 839.5 | 713.8 | 601.3 | 501.3 | 413.1 | 335.9 | 268.9 | 211.5 | 162.9 | 122.4 | 89.2 | 62.7 | 42.0 | 26.4 | 15.3 | 7.6 | 3.3 | 1.0 |
| 141    | 1690.0 |                                            |        |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 138    | 1683.0 |                                            |        |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 135    | 1673.0 |                                            |        |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 132    | 1659.0 |                                            |        |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 129    | 1641.0 | 1301.0                                     |        |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 126    | 1619.0 | 1295.0                                     |        |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 123    | 1595.0 | 1285.2                                     |        |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 120    | 1567.0 | 1272.6                                     |        |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 117    | 1536.0 | 1256.1                                     | 977.4  |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 114    | 1502.0 | 1236.3                                     | 972.1  |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 111    | 1460.0 | 1213.6                                     | 963.5  | 837.8 |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 108    | 1428.0 | 1189.2                                     | 951.8  | 832.8 |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 105    | 1387.0 | 1161.2                                     | 937.1  | 824.7 | 712.2 |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 102    | 1344.0 | 1130.7                                     | 919.7  | 813.6 | 707.5 |       |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 99     | 1300.0 | 1099.4                                     | 899.7  | 799.8 | 699.8 | 599.8 |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 96     | 1253.0 | 1064.7                                     | 877.4  | 783.4 | 689.4 | 595.4 |       |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 93     | 1206.0 | 1028.1                                     | 852.8  | 764.6 | 676.3 | 588.1 | 499.8 |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 90     | 1157.0 | 989.8                                      | 826.2  | 743.6 | 661.0 | 578.3 | 495.7 |       |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 87     | 1107.0 | 951.8                                      | 797.6  | 720.6 | 643.4 | 566.2 | 488.8 | 411.7 |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 84     | 1056.0 | 910.8                                      | 767.7  | 694.9 | 623.1 | 551.8 | 479.6 | 407.8 |       |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 81     | 1004.0 | 868.6                                      | 735.2  | 669.2 | 602.3 | 535.4 | 468.5 | 401.5 | 334.6 |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 78     | 952.0  | 825.5                                      | 703.3  | 641.3 | 579.2 | 517.1 | 454.8 | 393.0 | 331.0 |       |       |       |       |       |      |      |      |      |      |     |     |     |
| 75     | 899.0  | 783.6                                      | 669.4  | 612.0 | 554.6 | 494.3 | 439.9 | 382.5 | 325.1 | 267.7 |       |       |       |       |      |      |      |      |      |     |     |     |
| 72     | 846.0  | 739.2                                      | 634.5  | 581.7 | 526.8 | 475.9 | 423.0 | 370.1 | 317.3 | 264.5 |       |       |       |       |      |      |      |      |      |     |     |     |
| 69     | 793.0  | 694.5                                      | 596.3  | 550.4 | 501.8 | 453.3 | 404.7 | 356.1 | 307.6 | 259.0 | 210.4 |       |       |       |      |      |      |      |      |     |     |     |
| 66     | 740.0  | 651.5                                      | 562.6  | 518.4 | 473.9 | 429.5 | 385.1 | 340.6 | 296.2 | 251.8 | 207.4 |       |       |       |      |      |      |      |      |     |     |     |
| 63     | 688.0  | 608.5                                      | 526.3  | 485.8 | 445.3 | 404.8 | 364.4 | 323.9 | 283.4 | 244.9 | 202.4 | 161.9 |       |       |      |      |      |      |      |     |     |     |
| 60     | 636.0  | 563.8                                      | 489.6  | 452.9 | 416.2 | 379.4 | 342.7 | 306.0 | 269.3 | 232.6 | 195.6 | 159.1 |       |       |      |      |      |      |      |     |     |     |
| 57     | 585.0  | 519.4                                      | 452.9  | 419.8 | 386.6 | 353.5 | 320.4 | 287.2 | 254.1 | 220.6 | 187.8 | 154.7 | 121.5 |       |      |      |      |      |      |     |     |     |
| 54     | 535.0  | 477.5                                      | 416.6  | 386.7 | 356.9 | 327.2 | 297.4 | 267.7 | 237.9 | 208.2 | 178.5 | 148.7 | 119.0 |       |      |      |      |      |      |     |     |     |
| 51     | 486.0  | 434.4                                      | 382.9  | 353.7 | 327.2 | 300.7 | 274.1 | 247.5 | 221.1 | 194.5 | 168.0 | 141.1 | 115.0 | 88.4  |      |      |      |      |      |     |     |     |
| 48     | 439.0  | 392.2                                      | 344.7  | 321.1 | 297.7 | 273.6 | 250.7 | 227.2 | 203.7 | 181.2 | 156.7 | 135.0 | 109.7 | 86.1  |      |      |      |      |      |     |     |     |
| 45     | 392.0  | 351.2                                      | 309.8  | 289.1 | 268.5 | 247.9 | 227.2 | 206.5 | 185.9 | 165.2 | 144.5 | 123.9 | 103.3 | 82.6  | 62.0 |      |      |      |      |     |     |     |
| 42     | 348.0  | 313.2                                      | 275.9  | 257.8 | 239.9 | 221.9 | 203.9 | 185.9 | 167.9 | 149.9 | 132.0 | 114.0 | 96.0  | 77.9  | 60.0 |      |      |      |      |     |     |     |
| 39     | 305.0  | 274.9                                      | 244.0  | 227.5 | 212.0 | 196.5 | 180.9 | 165.6 | 150.0 | 134.5 | 118.9 | 103.4 | 87.9  | 72.4  | 56.9 | 41.4 |      |      |      |     |     |     |
| 36     | 264.0  | 238.3                                      | 211.5  | 198.2 | 187.0 | 171.8 | 158.6 | 145.4 | 132.9 | 119.0 | 105.7 | 92.6  | 79.3  | 67.0  | 52.9 | 39.7 |      |      |      |     |     |     |
| 33     | 232.0  | 203.6                                      | 181.6  | 170.3 | 159.2 | 148.0 | 136.9 | 125.9 | 114.8 | 103.7 | 92.6  | 81.5  | 70.4  | 59.2  | 48.1 | 37.0 | 25.9 |      |      |     |     |     |
| 30     | 190.0  | 172.3                                      | 153.0  | 144.6 | 134.6 | 125.4 | 116.2 | 107.1 | 98.0  | 87.7  | 79.5  | 70.4  | 61.2  | 51.9  | 42.8 | 33.7 | 24.5 |      |      |     |     |     |
| 27     | 156.0  | 141.8                                      | 126.4  | 118.9 | 111.5 | 107.0 | 96.6  | 89.2  | 81.8  | 74.4  | 67.0  | 59.4  | 52.0  | 44.5  | 37.2 | 29.7 | 22.3 | 14.8 |      |     |     |     |
| 24     | 125.0  | 113.8                                      | 101.8  | 95.9  | 90.7  | 84.2  | 78.3  | 72.5  | 66.6  | 60.7  | 54.8  | 48.9  | 43.1  | 37.3  | 31.3 | 25.5 | 19.6 | 13.7 |      |     |     |     |
| 21     | 97.0   | 89.4                                       | 79.5   | 74.9  | 70.4  | 65.9  | 61.4  | 57.0  | 52.5  | 48.3  | 43.5  | 39.0  | 34.5  | 30.0  | 25.5 | 21.0 | 16.5 | 12.0 | 7.3  |     |     |     |
| 18     | 73.0   | 66.7                                       | 59.5   | 56.1  | 52.8  | 49.5  | 46.5  | 43.0  | 39.7  | 36.3  | 33.0  | 27.9  | 26.4  | 22.2  | 19.8 | 16.5 | 13.2 | 9.9  | 6.4  |     |     |     |
| 15     | 51.0   | 46.9                                       | 42.1   | 39.7  | 37.5  | 35.1  | 32.8  | 30.6  | 28.3  | 24.0  | 23.7  | 21.8  | 19.1  | 16.9  | 14.5 | 12.2 | 10.0 | 7.7  | 5.2  | 3.1 |     |     |
| 12     | 33.0   | 30.4                                       | 27.4   | 25.9  | 24.4  | 23.0  | 21.7  | 20.1  | 18.6  | 17.1  | 15.9  | 14.2  | 12.7  | 11.4  | 9.8  | 8.3  | 6.9  | 5.4  | 3.8  | 2.4 |     |     |
| 9      | 19.0   | 17.8                                       | 15.7   | 14.8  | 14.0  | 13.2  | 12.5  | 11.6  | 10.8  | 9.9   | 9.1   | 8.2   | 7.4   | 6.7   | 5.8  | 4.9  | 4.1  | 3.3  | 2.4  | 1.7 | 0.8 |     |
| 6      | 9.0    | 8.0                                        | 7.1    | 6.7   | 6.3   | 5.9   | 5.6   | 5.3   | 4.9   | 4.4   | 4.1   | 3.8   | 3.4   | 3.1   | 2.7  | 2.3  | 2.0  | 1.6  | 1.2  | 0.9 | 0.5 |     |
| 3      | 2.0    | 2.0                                        | 1.8    | 1.7   | 1.6   | 1.5   | 1.5   | 1.4   | 1.3   | 1.2   | 1.1   | 1.0   | 0.9   | 0.8   | 0.7  | 0.6  | 0.5  | 0.5  | 0.3  | 0.2 | 0.3 |     |

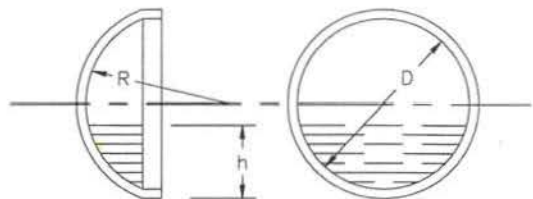


## APPENDIX B (continued)

### HEAD CAPACITIES DISHED (RAD. = DIAM.), WHEN FILLED TO VARIOUS DEPTHS (ONE HEAD ONLY)

CONTENTS IN U.S. GALLONS. THIS TABLE IS ONLY APPROXIMATE,  
BUT CLOSE ENOUGH FOR PRACTICAL USE.

|       | HEAD DIAMETER (IN)<br>FULL HEAD CAPACITIES |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
|-------|--------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|------|------|------|------|------|-----|-----|-----|-----|
|       | 144                                        | 132   | 120   | 114   | 108   | 102   | 96    | 90    | 84    | 78    | 72    | 66   | 60   | 54   | 48   | 42   | 36   | 30  | 24  | 18  | 12  |
| h(in) | 1048.0                                     | 807.3 | 611.0 | 527.0 | 414.0 | 380.0 | 308.0 | 251.0 | 203.0 | 162.0 | 128.0 | 98.9 | 73.4 | 53.4 | 37.5 | 26.3 | 15.7 | 9.1 | 4.6 | 1.9 | 0.5 |
| 141   | 1045.3                                     |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 138   | 1042.7                                     |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 135   | 1036.2                                     |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 132   | 1027.4                                     |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 129   | 1016.2                                     | 805.5 |       |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 126   | 1003.0                                     | 802.4 |       |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 123   | 987.6                                      | 796.6 |       |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 120   | 970.4                                      | 788.5 |       |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 117   | 952.3                                      | 778.4 | 609.5 |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 114   | 930.5                                      | 766.4 | 607.3 |       |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 111   | 908.1                                      | 752.5 | 602.2 | 525.6 |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 108   | 884.2                                      | 736.9 | 596.3 | 523.4 |       |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 105   | 859.0                                      | 719.8 | 588.4 | 518.6 | 412.8 |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 102   | 832.5                                      | 701.2 | 579.2 | 512.8 | 410.5 |       |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 99    | 804.9                                      | 681.2 | 568.8 | 505.4 | 406.5 | 378.9 |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 96    | 774.3                                      | 659.9 | 555.4 | 497.0 | 400.7 | 376.6 |       |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 93    | 746.6                                      | 637.5 | 541.6 | 487.0 | 394.1 | 372.8 | 307.1 |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 90    | 716.4                                      | 614.1 | 525.5 | 474.3 | 386.0 | 367.5 | 304.9 |       |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 87    | 685.4                                      | 589.8 | 509.7 | 461.2 | 375.8 | 361.0 | 301.2 | 250.2 |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 84    | 653.8                                      | 564.7 | 490.0 | 451.1 | 364.7 | 353.0 | 296.6 | 248.0 |       |       |       |      |      |      |      |      |      |     |     |     |     |
| 81    | 622.6                                      | 538.6 | 471.8 | 430.6 | 351.9 | 343.5 | 290.8 | 245.0 | 202.2 |       |       |      |      |      |      |      |      |     |     |     |     |
| 78    | 589.2                                      | 512.5 | 449.8 | 412.8 | 339.0 | 332.9 | 283.7 | 240.5 | 200.2 |       |       |      |      |      |      |      |      |     |     |     |     |
| 75    | 556.7                                      | 485.7 | 429.0 | 394.1 | 323.0 | 321.1 | 275.1 | 235.2 | 197.5 | 161.2 |       |      |      |      |      |      |      |     |     |     |     |
| 72    | 524.0                                      | 458.6 | 405.5 | 375.2 | 307.7 | 308.2 | 264.9 | 228.2 | 193.3 | 159.6 |       |      |      |      |      |      |      |     |     |     |     |
| 69    | 491.3                                      | 431.2 | 381.7 | 354.9 | 289.9 | 294.2 | 254.8 | 220.4 | 188.4 | 157.0 | 127.4 |      |      |      |      |      |      |     |     |     |     |
| 66    | 458.8                                      | 403.7 | 359.4 | 332.9 | 274.0 | 278.8 | 242.8 | 211.1 | 181.2 | 153.3 | 125.8 |      |      |      |      |      |      |     |     |     |     |
| 63    | 425.4                                      | 376.1 | 335.0 | 312.8 | 253.0 | 262.8 | 231.1 | 201.3 | 174.6 | 148.5 | 123.3 | 98.3 |      |      |      |      |      |     |     |     |     |
| 60    | 394.2                                      | 348.7 | 305.5 | 290.0 | 235.0 | 245.2 | 216.4 | 190.7 | 166.6 | 142.7 | 119.9 | 96.9 |      |      |      |      |      |     |     |     |     |
| 57    | 362.6                                      | 321.6 | 276.0 | 263.5 | 216.0 | 228.9 | 201.8 | 179.5 | 157.5 | 136.2 | 115.3 | 94.6 | 73.0 |      |      |      |      |     |     |     |     |
| 54    | 331.6                                      | 294.8 | 251.6 | 237.0 | 192.0 | 210.8 | 187.0 | 166.6 | 147.5 | 129.1 | 110.1 | 91.5 | 71.6 |      |      |      |      |     |     |     |     |
| 51    | 301.4                                      | 268.7 | 229.3 | 214.2 | 198.0 | 190.0 | 177.9 | 153.9 | 136.8 | 120.2 | 104.1 | 87.4 | 69.6 | 53.0 |      |      |      |     |     |     |     |
| 48    | 273.7                                      | 242.6 | 205.5 | 194.1 | 179.0 | 169.2 | 154.0 | 141.0 | 125.8 | 111.5 | 97.2  | 82.7 | 66.7 | 51.9 |      |      |      |     |     |     |     |
| 45    | 243.1                                      | 217.5 | 182.0 | 172.1 | 161.0 | 151.1 | 130.1 | 125.5 | 113.0 | 101.7 | 89.7  | 77.2 | 63.1 | 50.0 | 37.1 |      |      |     |     |     |     |
| 42    | 215.5                                      | 193.2 | 161.2 | 151.8 | 140.0 | 134.8 | 121.0 | 110.0 | 101.5 | 92.3  | 81.8  | 70.9 | 58.9 | 47.5 | 36.1 |      |      |     |     |     |     |
| 39    | 189.0                                      | 169.8 | 139.2 | 132.9 | 124.1 | 117.2 | 106.2 | 97.1  | 88.0  | 81.0  | 74.6  | 64.1 | 54.0 | 44.3 | 34.5 | 26.0 |      |     |     |     |     |
| 36    | 163.8                                      | 147.4 | 121.0 | 114.2 | 106.3 | 101.2 | 91.6  | 84.4  | 77.2  | 69.7  | 64.0  | 57.5 | 48.8 | 40.7 | 32.3 | 25.1 |      |     |     |     |     |
| 33    | 139.9                                      | 126.1 | 101.3 | 96.4  | 91.0  | 85.8  | 76.9  | 71.5  | 66.2  | 60.3  | 53.4  | 49.4 | 43.2 | 36.3 | 29.6 | 23.6 | 15.4 |     |     |     |     |
| 30    | 117.5                                      | 106.1 | 85.5  | 75.9  | 75.0  | 71.8  | 65.2  | 60.3  | 55.5  | 50.5  | 46.2  | 41.4 | 36.7 | 32.0 | 26.3 | 21.6 | 14.7 |     |     |     |     |
| 27    | 95.7                                       | 87.5  | 69.4  | 65.8  | 62.1  | 58.9  | 53.2  | 49.7  | 45.5  | 41.8  | 38.3  | 34.8 | 30.2 | 26.7 | 22.8 | 19.2 | 13.5 | 8.9 |     |     |     |
| 24    | 77.6                                       | 70.4  | 55.6  | 52.7  | 49.3  | 47.1  | 43.1  | 39.9  | 36.4  | 32.9  | 30.8  | 28.0 | 24.6 | 21.4 | 18.7 | 16.3 | 12.0 | 8.3 |     |     |     |
| 21    | 60.4                                       | 54.8  | 42.2  | 40.0  | 38.2  | 36.5  | 32.9  | 30.6  | 28.4  | 25.8  | 23.9  | 21.7 | 19.4 | 17.1 | 14.7 | 13.2 | 10.1 | 7.3 | 4.4 |     |     |
| 18    | 45.0                                       | 40.9  | 31.8  | 30.0  | 28.0  | 27.0  | 24.3  | 22.8  | 21.8  | 19.3  | 17.9  | 16.2 | 14.5 | 12.7 | 11.2 | 10.0 | 7.9  | 6.0 | 3.9 |     |     |
| 15    | 31.8                                       | 28.9  | 22.6  | 21.6  | 19.9  | 19.0  | 17.2  | 15.8  | 14.6  | 13.5  | 12.7  | 11.5 | 10.3 | 9.1  | 8.0  | 7.1  | 5.7  | 4.6 | 3.2 | 1.8 |     |
| 12    | 20.6                                       | 18.8  | 14.7  | 14.2  | 13.3  | 12.5  | 11.4  | 10.5  | 9.8   | 8.8   | 8.1   | 7.4  | 6.7  | 5.9  | 5.3  | 4.7  | 3.7  | 3.1 | 2.3 | 1.4 |     |
| 9     | 11.8                                       | 10.7  | 8.9   | 8.4   | 7.5   | 7.2   | 6.8   | 6.0   | 5.5   | 5.0   | 4.7   | 4.4  | 3.8  | 3.4  | 3.0  | 2.7  | 2.2  | 1.8 | 1.4 | 0.9 | 0.5 |
| 6     | 5.3                                        | 4.9   | 3.7   | 3.6   | 3.5   | 3.4   | 3.1   | 3.0   | 2.8   | 2.4   | 2.2   | 2.0  | 1.8  | 1.6  | 1.4  | 1.2  | 1.0  | 0.8 | 0.7 | 0.4 | 0.3 |
| 3     | 2.8                                        | 1.9   | 1.5   | 1.4   | 1.2   | 1.1   | 0.9   | 0.9   | 0.8   | 0.8   | 0.6   | 0.6  | 0.4  | 0.4  | 0.4  | 0.3  | 0.3  | 0.2 | 0.2 | 0.1 | 0.1 |

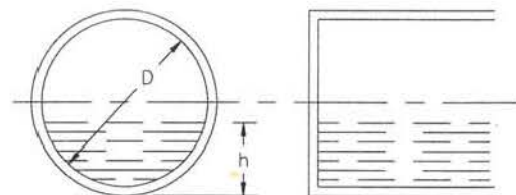


## APPENDIX B (continued)

### TANK CAPACITIES HORIZONTAL, CYLINDRICAL, FLAT ENDS, WHEN FILLED TO VARIOUS DEPTHS

CONTENTS IN U.S. GALLONS. THIS TABLE IS ONLY APPROXIMATE,  
BUT CLOSE ENOUGH FOR PRACTICAL USE.

|        |       | TANK DIAMETER (IN)   |       |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
|--------|-------|----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|------|------|------|------|
|        |       | FULL TANK CAPACITIES |       |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| h (in) | 144   | 132                  | 120   | 114   | 108   | 102   | 96    | 90    | 84    | 78    | 72    | 66    | 60    | 54    | 48   | 42   | 36   | 30   | 24   |
| h (in) | 846.0 | 710.9                | 587.5 | 530.3 | 476.1 | 424.5 | 376.0 | 330.5 | 287.9 | 248.2 | 211.5 | 177.7 | 146.9 | 119.0 | 94.0 | 72.0 | 52.9 | 36.7 | 23.5 |
| 141    | 841.7 |                      |       |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 138    | 833.8 |                      |       |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 135    | 823.7 |                      |       |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 132    | 812.5 |                      |       |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 129    | 801.4 | 706.7                |       |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 126    | 785.0 | 699.5                |       |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 123    | 769.5 | 689.5                |       |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 120    | 753.1 | 678.7                |       |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 117    | 735.8 | 666.1                | 583.6 |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 114    | 718.6 | 652.9                | 576.6 |       |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 111    | 699.9 | 638.1                | 567.5 | 526.5 |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 108    | 680.6 | 622.5                | 557.0 | 519.5 |       |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 105    | 660.8 | 606.1                | 545.2 | 510.8 | 472.4 |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 102    | 640.4 | 589.7                | 532.3 | 500.5 | 465.7 |       |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 99     | 619.6 | 571.9                | 518.5 | 489.0 | 457.2 | 420.9 |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 96     | 599.5 | 553.6                | 503.9 | 476.5 | 447.2 | 414.4 |       |       |       |       |       |       |       |       |      |      |      |      |      |
| 93     | 578.0 | 535.7                | 488.6 | 463.2 | 436.1 | 406.1 | 372.5 |       |       |       |       |       |       |       |      |      |      |      |      |
| 90     | 556.2 | 516.5                | 472.6 | 449.0 | 424.0 | 396.5 | 366.2 |       |       |       |       |       |       |       |      |      |      |      |      |
| 87     | 534.2 | 496.9                | 456.2 | 434.2 | 411.0 | 385.5 | 358.2 | 327.1 |       |       |       |       |       |       |      |      |      |      |      |
| 84     | 512.0 | 477.0                | 439.3 | 418.8 | 397.4 | 374.0 | 348.9 | 321.0 |       |       |       |       |       |       |      |      |      |      |      |
| 81     | 489.6 | 457.7                | 422.0 | 402.9 | 383.1 | 361.5 | 338.5 | 313.3 | 284.6 |       |       |       |       |       |      |      |      |      |      |
| 78     | 468.2 | 437.4                | 404.3 | 386.6 | 368.2 | 348.3 | 327.2 | 304.3 | 278.8 |       |       |       |       |       |      |      |      |      |      |
| 75     | 445.6 | 416.8                | 386.3 | 369.9 | 352.9 | 334.6 | 315.2 | 294.3 | 271.3 | 245.1 |       |       |       |       |      |      |      |      |      |
| 72     | 423.0 | 396.1                | 368.1 | 352.9 | 337.2 | 320.3 | 302.5 | 283.4 | 262.7 | 239.5 |       |       |       |       |      |      |      |      |      |
| 69     | 400.4 | 376.3                | 349.7 | 335.7 | 321.2 | 305.6 | 289.3 | 271.9 | 253.1 | 232.3 | 208.5 |       |       |       |      |      |      |      |      |
| 66     | 377.8 | 355.5                | 331.1 | 318.2 | 304.9 | 290.6 | 275.6 | 259.7 | 242.7 | 224.0 | 203.1 |       |       |       |      |      |      |      |      |
| 63     | 356.4 | 334.6                | 312.5 | 300.6 | 288.4 | 275.3 | 261.6 | 247.1 | 231.6 | 214.8 | 196.3 | 174.8 |       |       |      |      |      |      |      |
| 60     | 334.0 | 314.8                | 293.8 | 282.9 | 271.7 | 259.7 | 247.2 | 234.1 | 220.0 | 204.9 | 188.4 | 169.7 |       |       |      |      |      |      |      |
| 57     | 311.8 | 294.1                | 275.1 | 265.1 | 255.0 | 244.0 | 232.6 | 220.7 | 208.0 | 194.4 | 179.6 | 163.2 | 144.1 |       |      |      |      |      |      |
| 54     | 289.8 | 273.5                | 256.4 | 247.4 | 238.1 | 228.1 | 217.9 | 207.0 | 195.6 | 183.4 | 170.2 | 155.7 | 139.3 |       |      |      |      |      |      |
| 51     | 268.0 | 253.2                | 237.9 | 229.7 | 221.1 | 212.3 | 203.0 | 193.2 | 182.9 | 172.0 | 160.2 | 147.4 | 133.1 | 116.4 |      |      |      |      |      |
| 48     | 246.5 | 233.9                | 219.5 | 212.1 | 204.4 | 196.4 | 188.0 | 179.3 | 170.1 | 160.3 | 149.8 | 138.5 | 126.0 | 111.8 |      |      |      |      |      |
| 45     | 226.4 | 214.0                | 201.2 | 194.6 | 187.7 | 180.5 | 173.1 | 165.2 | 157.0 | 148.3 | 139.1 | 129.1 | 118.2 | 105.9 | 91.6 |      |      |      |      |
| 42     | 205.6 | 194.4                | 183.3 | 177.3 | 171.2 | 164.8 | 158.2 | 151.2 | 144.0 | 136.3 | 128.1 | 119.3 | 109.8 | 99.3  | 87.2 |      |      |      |      |
| 39     | 185.3 | 175.2                | 165.6 | 160.3 | 154.9 | 149.3 | 143.4 | 137.3 | 130.9 | 124.1 | 117.0 | 109.3 | 101.1 | 92.0  | 81.8 | 69.7 |      |      |      |
| 36     | 165.4 | 157.3                | 148.3 | 143.6 | 138.9 | 133.9 | 128.8 | 123.5 | 117.9 | 112.0 | 105.8 | 99.1  | 92.0  | 84.3  | 75.6 | 65.7 |      |      |      |
| 33     | 146.1 | 139.0                | 131.3 | 127.3 | 123.2 | 118.9 | 114.4 | 109.8 | 105.0 | 99.9  | 94.5  | 88.9  | 82.8  | 76.2  | 68.9 | 60.7 | 50.8 |      |      |
| 30     | 127.4 | 121.2                | 115.0 | 111.4 | 107.9 | 104.2 | 100.4 | 96.4  | 92.3  | 88.0  | 83.4  | 78.6  | 73.5  | 67.9  | 61.8 | 55.0 | 47.1 |      |      |
| 27     | 110.2 | 104.9                | 99.0  | 96.1  | 93.0  | 89.9  | 86.7  | 83.4  | 79.9  | 76.3  | 72.5  | 68.4  | 64.1  | 59.5  | 54.5 | 48.9 | 42.5 | 34.8 |      |
| 24     | 93.0  | 88.4                 | 83.7  | 81.2  | 78.7  | 76.2  | 73.5  | 70.8  | 67.9  | 64.9  | 61.7  | 58.4  | 54.9  | 51.1  | 47.0 | 42.5 | 37.5 | 31.5 |      |
| 21     | 76.5  | 72.8                 | 69.1  | 67.1  | 65.1  | 63.0  | 60.8  | 58.6  | 56.3  | 53.9  | 51.3  | 48.7  | 45.8  | 42.8  | 39.5 | 36.0 | 32.0 | 27.5 | 21.8 |
| 18     | 61.0  | 58.0                 | 55.3  | 53.7  | 52.1  | 50.5  | 48.8  | 47.1  | 45.2  | 43.3  | 41.4  | 39.3  | 37.1  | 34.7  | 32.2 | 29.5 | 26.4 | 23.0 | 18.9 |
| 15     | 44.6  | 44.8                 | 42.4  | 41.2  | 40.0  | 39.0  | 37.5  | 36.2  | 34.9  | 33.4  | 31.9  | 30.4  | 28.7  | 27.0  | 25.1 | 23.1 | 20.9 | 18.4 | 15.5 |
| 12     | 33.5  | 32.2                 | 30.6  | 29.8  | 28.9  | 28.0  | 27.1  | 26.2  | 25.2  | 24.2  | 23.2  | 22.1  | 20.9  | 19.7  | 18.4 | 17.0 | 15.4 | 13.7 | 11.8 |
| 9      | 22.3  | 21.4                 | 20.0  | 19.5  | 18.9  | 18.4  | 17.8  | 17.2  | 16.6  | 15.9  | 15.3  | 14.6  | 13.8  | 13.0  | 12.2 | 11.3 | 10.3 | 9.3  | 8.1  |
| 6      | 12.2  | 11.4                 | 11.0  | 10.7  | 10.4  | 10.1  | 9.8   | 9.5   | 9.1   | 8.8   | 8.4   | 8.0   | 7.6   | 7.2   | 6.8  | 6.3  | 5.8  | 5.2  | 4.6  |
| 3      | 4.3   | 4.2                  | 3.9   | 3.8   | 3.7   | 3.6   | 3.5   | 3.4   | 3.3   | 3.2   | 3.0   | 2.9   | 2.8   | 2.6   | 2.5  | 2.3  | 2.1  | 1.9  | 1.7  |



## APPENDIX C

### PROPERTIES OF SATURATED STEAM AT PRESSURES LESS THAN THAT OF THE ATMOSPHERE

| Vacuum<br>Inches Hg.<br>Referred to<br>30"<br>Barometer<br>(Mercury at<br>58.4°F.) | Absolute<br>Pressure in<br>Inches<br>Mercury at<br>32°F | Temp.<br>Degrees<br>Fahrenheit | Specific<br>Volume<br>Cu. Ft.<br>per Pound | Heat of the<br>Liquid | Total Heat<br>of Steam | Absolute<br>Pressure in<br>Lbs. per<br>Sq. Inch |
|------------------------------------------------------------------------------------|---------------------------------------------------------|--------------------------------|--------------------------------------------|-----------------------|------------------------|-------------------------------------------------|
| 29.5                                                                               | 0.498                                                   | 58.77                          | 1259.0                                     | 26.85                 | 1085.3                 | 0.244                                           |
| 29.0                                                                               | 0.997                                                   | 79.07                          | 657.0                                      | 47.11                 | 1094.3                 | 0.488                                           |
| 28.5                                                                               | 1.495                                                   | 91.70                          | 446.2                                      | 59.70                 | 1100.0                 | 0.732                                           |
| 28.0                                                                               | 1.994                                                   | 101.15                         | 339.6                                      | 69.12                 | 1104.1                 | 0.977                                           |
| 27.5                                                                               | 2.493                                                   | 108.70                         | 275.2                                      | 76.64                 | 1107.4                 | 1.221                                           |
| 27.0                                                                               | 2.991                                                   | 115.06                         | 231.9                                      | 82.98                 | 1110.2                 | 1.465                                           |
| 26.5                                                                               | 3.490                                                   | 120.55                         | 200.2                                      | 88.46                 | 1112.6                 | 1.710                                           |
| 26.0                                                                               | 3.989                                                   | 125.38                         | 176.7                                      | 93.28                 | 1114.7                 | 1.954                                           |
| 25.5                                                                               | 4.487                                                   | 129.75                         | 158.1                                      | 97.64                 | 1116.5                 | 2.198                                           |
| 25.0                                                                               | 4.98                                                    | 133.77                         | 143.0                                      | 101.65                | 1118.3                 | 2.44                                            |
| 24.0                                                                               | 5.98                                                    | 140.64                         | 129.0                                      | 108.51                | 1121.3                 | 2.93                                            |
| 23.0                                                                               | 6.98                                                    | 146.78                         | 104.5                                      | 114.64                | 1123.9                 | 3.42                                            |
| 22.0                                                                               | 7.97                                                    | 152.16                         | 92.3                                       | 120.02                | 1126.2                 | 3.90                                            |
| 21.0                                                                               | 8.97                                                    | 157.00                         | 82.6                                       | 124.86                | 1128.2                 | 4.39                                            |
| 20.0                                                                               | 9.97                                                    | 161.42                         | 74.8                                       | 129.28                | 1130.1                 | 4.88                                            |
| 19.0                                                                               | 10.97                                                   | 165.42                         | 68.5                                       | 133.28                | 1131.8                 | 5.37                                            |
| 18.0                                                                               | 11.96                                                   | 169.14                         | 63.1                                       | 137.00                | 1133.4                 | 5.86                                            |
| 17.0                                                                               | 12.96                                                   | 172.63                         | 58.6                                       | 140.50                | 1134.8                 | 6.35                                            |
| 16.0                                                                               | 13.96                                                   | 175.93                         | 54.6                                       | 143.80                | 1136.1                 | 6.84                                            |
| 15.0                                                                               | 14.95                                                   | 179.03                         | 51.17                                      | 146.91                | 1137.4                 | 7.32                                            |
| 14.0                                                                               | 15.95                                                   | 181.92                         | 49.03                                      | 149.80                | 1138.6                 | 7.81                                            |
| 13.0                                                                               | 16.95                                                   | 184.68                         | 45.55                                      | 152.57                | 1139.7                 | 8.30                                            |
| 12.0                                                                               | 17.95                                                   | 187.31                         | 43.18                                      | 155.21                | 1140.7                 | 8.79                                            |
| 11.0                                                                               | 18.94                                                   | 189.83                         | 41.05                                      | 157.73                | 1141.7                 | 9.28                                            |
| 10.0                                                                               | 19.94                                                   | 192.23                         | 39.13                                      | 160.14                | 1142.3                 | 9.77                                            |
| 9.0                                                                                | 20.94                                                   | 194.52                         | 37.40                                      | 162.44                | 1143.6                 | 10.26                                           |
| 8.0                                                                                | 21.94                                                   | 196.73                         | 35.79                                      | 164.68                | 1144.5                 | 10.75                                           |
| 7.0                                                                                | 22.93                                                   | 198.87                         | 34.33                                      | 166.81                | 1145.4                 | 11.23                                           |
| 6.0                                                                                | 23.93                                                   | 200.94                         | 33.00                                      | 168.88                | 1146.3                 | 11.72                                           |
| 5.0                                                                                | 24.93                                                   | 202.92                         | 31.76                                      | 170.89                | 1147.0                 | 12.21                                           |
| 4.0                                                                                | 25.92                                                   | 204.85                         | 30.62                                      | 172.81                | 1147.6                 | 12.70                                           |
| 3.0                                                                                | 26.92                                                   | 206.71                         | 29.55                                      | 174.68                | 1148.4                 | 13.19                                           |
| 2.0                                                                                | 27.92                                                   | 208.52                         | 28.57                                      | 176.50                | 1149.1                 | 13.68                                           |
| 1.0                                                                                | 28.92                                                   | 210.28                         | 27.66                                      | 178.27                | 1149.7                 | 14.17                                           |
| 0.0                                                                                | 29.92                                                   | 212.00                         | 26.79                                      | 180.00                | 1150.4                 | 14.67                                           |

# APPENDIX C (continued)

## PROPERTIES OF SATURATED STEAM

| Vacuum,<br>Inches of<br>Mercury          | Absolute<br>Pressure<br>Lbs. per<br>Sq. In. | Tempera-<br>ture,<br>Fahren-<br>heit | Total Heat Above<br>32 °F             |                                       | Latent<br>Heat,<br>$L=H-h$<br>Heat-<br>Units | Volume,<br>Cu. Ft. in<br>1 Lb. of<br>Steam | Weight of<br>1 Cu. Ft.<br>Steam,<br>Lb. | Entropy<br>of the<br>Water | Entropy<br>of<br>Evapor-<br>ation |
|------------------------------------------|---------------------------------------------|--------------------------------------|---------------------------------------|---------------------------------------|----------------------------------------------|--------------------------------------------|-----------------------------------------|----------------------------|-----------------------------------|
|                                          |                                             |                                      | In the<br>Water $h$<br>Heat-<br>Units | In the<br>Steam<br>$H$ Heat-<br>Units |                                              |                                            |                                         |                            |                                   |
| 29.74                                    | 0.0886                                      | 32                                   | 0.00                                  | 1073.4                                | 1073.4                                       | 3294                                       | 0.000304                                | 0.0000                     | 2.1832                            |
| 29.67                                    | 0.1217                                      | 40                                   | 8.05                                  | 1076.9                                | 1068.9                                       | 2438                                       | 0.000410                                | 0.0162                     | 2.1394                            |
| 29.56                                    | 0.1780                                      | 50                                   | 18.08                                 | 1081.4                                | 1063.3                                       | 1702                                       | 0.000587                                | 0.0361                     | 2.0865                            |
| 29.40                                    | 0.2562                                      | 60                                   | 28.08                                 | 1085.9                                | 1057.8                                       | 1208                                       | 0.000828                                | 0.0555                     | 2.0358                            |
| 29.18                                    | 0.3626                                      | 70                                   | 38.06                                 | 1090.3                                | 1052.3                                       | 871                                        | 0.001148                                | 0.0745                     | 1.9868                            |
| 29.89                                    | 0.505                                       | 80                                   | 48.03                                 | 1094.8                                | 1046.7                                       | 636.8                                      | 0.001570                                | 0.0932                     | 1.9398                            |
| 28.50                                    | 0.696                                       | 90                                   | 58.00                                 | 1099.2                                | 1041.2                                       | 469.3                                      | 0.002131                                | 0.1114                     | 1.8944                            |
| 28.00                                    | 0.946                                       | 100                                  | 67.97                                 | 1103.6                                | 1035.6                                       | 350.8                                      | 0.002851                                | 0.1295                     | 1.8505                            |
| 27.88                                    | 1                                           | 101.83                               | 69.8                                  | 1104.4                                | 1034.6                                       | 333.0                                      | 0.00300                                 | 0.1327                     | 1.8427                            |
| 25.85                                    | 2                                           | 126.15                               | 94.0                                  | 1115.0                                | 1021.0                                       | 173.5                                      | 0.00576                                 | 0.1749                     | 1.7431                            |
| 23.81                                    | 3                                           | 141.52                               | 109.4                                 | 1121.6                                | 1012.3                                       | 118.5                                      | 0.00845                                 | 0.2008                     | 1.6840                            |
| 21.78                                    | 4                                           | 153.01                               | 120.9                                 | 1126.5                                | 1005.7                                       | 90.5                                       | 0.01107                                 | 0.2198                     | 1.6416                            |
| 19.74                                    | 5                                           | 162.28                               | 130.1                                 | 1130.5                                | 1000.3                                       | 73.33                                      | 0.01364                                 | 0.2348                     | 1.6084                            |
| 17.70                                    | 6                                           | 170.06                               | 137.9                                 | 1133.7                                | 995.8                                        | 61.89                                      | 0.01616                                 | 0.2471                     | 1.5814                            |
| 15.67                                    | 7                                           | 176.85                               | 144.7                                 | 1136.5                                | 991.8                                        | 53.56                                      | 0.01867                                 | 0.2579                     | 1.5582                            |
| 13.63                                    | 8                                           | 182.86                               | 150.8                                 | 1139.0                                | 988.2                                        | 47.27                                      | 0.02115                                 | 0.2673                     | 1.5380                            |
| 11.60                                    | 9                                           | 188.27                               | 156.2                                 | 1141.1                                | 985.0                                        | 42.36                                      | 0.02361                                 | 0.2756                     | 1.5202                            |
| 9.56                                     | 10                                          | 193.22                               | 161.1                                 | 1143.1                                | 982.0                                        | 38.38                                      | 0.02606                                 | 0.2832                     | 1.5042                            |
| 7.52                                     | 11                                          | 197.75                               | 165.7                                 | 1144.9                                | 979.2                                        | 35.10                                      | 0.02849                                 | 0.2902                     | 1.4895                            |
| 5.49                                     | 12                                          | 201.96                               | 169.9                                 | 1146.5                                | 976.6                                        | 32.36                                      | 0.03090                                 | 0.2967                     | 1.4760                            |
| 3.45                                     | 13                                          | 205.87                               | 173.8                                 | 1148.0                                | 974.2                                        | 30.03                                      | 0.03330                                 | 0.3025                     | 1.4639                            |
| 1.42                                     | 14                                          | 209.55                               | 177.5                                 | 1149.4                                | 971.9                                        | 28.02                                      | 0.03569                                 | 0.3081                     | 1.4523                            |
| Gauge<br>Pressure<br>Lbs. per<br>Sq. In. | Absolute<br>Pressure                        | Tempera-<br>ture                     | $h$                                   | $H$                                   | Latent<br>Heat                               | Volume                                     | Weight of<br>1 Cu. Ft.<br>Steam         | Entropy<br>of the<br>Water | Entropy<br>of<br>Evapor-<br>ation |
| 0                                        | 14.70                                       | 212                                  | 180.0                                 | 1150.4                                | 970.4                                        | 26.79                                      | 0.03732                                 | 0.3118                     | 1.4447                            |
| 0.3                                      | 15                                          | 213.0                                | 181.0                                 | 1150.7                                | 969.7                                        | 26.27                                      | 0.03806                                 | 0.3133                     | 1.4416                            |
| 1.3                                      | 16                                          | 216.3                                | 184.4                                 | 1152.0                                | 967.6                                        | 24.79                                      | 0.04042                                 | 0.3183                     | 1.4311                            |
| 2.3                                      | 17                                          | 219.4                                | 187.5                                 | 1153.1                                | 965.6                                        | 23.38                                      | 0.04277                                 | 0.3229                     | 1.4215                            |
| 3.3                                      | 18                                          | 222.4                                | 190.5                                 | 1154.2                                | 963.7                                        | 22.16                                      | 0.04512                                 | 0.3273                     | 1.4127                            |
| 4.3                                      | 19                                          | 225.2                                | 193.4                                 | 1155.2                                | 961.8                                        | 21.07                                      | 0.04746                                 | 0.3315                     | 1.4045                            |
| 5.3                                      | 20                                          | 228.0                                | 196.1                                 | 1156.2                                | 960.0                                        | 20.08                                      | 0.04980                                 | 0.3355                     | 1.3965                            |
| 6.3                                      | 21                                          | 230.6                                | 198.8                                 | 1157.1                                | 958.3                                        | 19.18                                      | 0.05213                                 | 0.3393                     | 1.3887                            |
| 7.3                                      | 22                                          | 233.1                                | 201.3                                 | 1158.0                                | 956.7                                        | 18.37                                      | 0.05445                                 | 0.3430                     | 1.3811                            |
| 8.3                                      | 23                                          | 235.5                                | 203.8                                 | 1158.8                                | 955.1                                        | 17.62                                      | 0.05676                                 | 0.3465                     | 1.3739                            |
| 9.3                                      | 24                                          | 237.8                                | 206.1                                 | 1159.6                                | 953.5                                        | 16.93                                      | 0.05907                                 | 0.3499                     | 1.3670                            |
| 10.3                                     | 25                                          | 240.1                                | 208.4                                 | 1160.4                                | 952.0                                        | 16.30                                      | 0.0614                                  | 0.3532                     | 1.3604                            |
| 11.3                                     | 26                                          | 242.2                                | 210.6                                 | 1161.2                                | 950.6                                        | 15.72                                      | 0.0636                                  | 0.3564                     | 1.3542                            |
| 12.3                                     | 27                                          | 244.4                                | 212.7                                 | 1161.9                                | 949.2                                        | 15.18                                      | 0.0659                                  | 0.3594                     | 1.3483                            |
| 13.3                                     | 28                                          | 246.4                                | 214.8                                 | 1162.6                                | 947.8                                        | 14.67                                      | 0.0682                                  | 0.3623                     | 1.3425                            |
| 14.3                                     | 29                                          | 248.4                                | 216.8                                 | 1163.2                                | 946.4                                        | 14.19                                      | 0.0705                                  | 0.3652                     | 1.3367                            |
| 15.3                                     | 30                                          | 250.3                                | 218.8                                 | 1163.9                                | 945.1                                        | 13.74                                      | 0.0728                                  | 0.3680                     | 1.3311                            |
| 16.3                                     | 31                                          | 252.2                                | 220.7                                 | 1164.5                                | 943.8                                        | 13.32                                      | 0.0751                                  | 0.3707                     | 1.3257                            |
| 17.3                                     | 32                                          | 254.1                                | 222.6                                 | 1165.1                                | 942.5                                        | 12.93                                      | 0.0773                                  | 0.3733                     | 1.3205                            |
| 18.3                                     | 33                                          | 255.8                                | 224.4                                 | 1165.7                                | 941.3                                        | 12.57                                      | 0.0795                                  | 0.3759                     | 1.3155                            |
| 19.3                                     | 34                                          | 257.6                                | 226.2                                 | 1166.3                                | 940.1                                        | 12.22                                      | 0.0818                                  | 0.3784                     | 1.3107                            |
| 20.3                                     | 35                                          | 259.3                                | 227.9                                 | 1166.8                                | 938.9                                        | 11.89                                      | 0.0841                                  | 0.3808                     | 1.3060                            |

**APPENDIX C (continued)**  
**PROPERTIES OF SATURATED STEAM**

| Gauge Pressure<br>Lbs. per<br>Sq. In. | Absolute Pressure | Temperature | $h$   | $H$    | Latent Heat | Volume | Weight of<br>1 Cu. Ft.<br>Steam | Entropy<br>of the<br>Water | Entropy<br>of<br>Evaporation |
|---------------------------------------|-------------------|-------------|-------|--------|-------------|--------|---------------------------------|----------------------------|------------------------------|
| 21.3                                  | 36                | 261.0       | 229.6 | 1167.3 | 937.7       | 11.58  | 0.0863                          | 0.3832                     | 1.3014                       |
| 22.3                                  | 37                | 262.6       | 231.3 | 1167.8 | 936.6       | 11.29  | 0.0886                          | 0.3855                     | 1.2969                       |
| 23.3                                  | 38                | 264.2       | 232.9 | 1168.4 | 935.5       | 11.01  | 0.0908                          | 0.3877                     | 1.2925                       |
| 24.3                                  | 39                | 265.8       | 234.5 | 1168.9 | 934.4       | 10.74  | 0.0931                          | 0.3899                     | 1.2882                       |
| 25.3                                  | 40                | 267.3       | 236.1 | 1169.4 | 933.3       | 10.49  | 0.0953                          | 0.3920                     | 1.2841                       |
| 26.3                                  | 41                | 268.7       | 237.6 | 1169.8 | 932.2       | 10.25  | 0.0976                          | 0.3941                     | 1.2800                       |
| 27.3                                  | 42                | 270.2       | 239.1 | 1170.3 | 931.2       | 10.02  | 0.0998                          | 0.3962                     | 1.2759                       |
| 28.3                                  | 43                | 271.7       | 240.5 | 1170.7 | 930.2       | 9.80   | 0.1020                          | 0.3982                     | 1.2720                       |
| 29.3                                  | 44                | 273.1       | 242.0 | 1171.2 | 929.2       | 9.59   | 0.1043                          | 0.4002                     | 1.2681                       |
| 30.3                                  | 45                | 274.5       | 243.4 | 1171.6 | 928.2       | 9.39   | 0.1065                          | 0.4021                     | 1.2644                       |
| 31.3                                  | 46                | 275.8       | 244.8 | 1172.0 | 927.2       | 9.20   | 0.1087                          | 0.4040                     | 1.2607                       |
| 32.3                                  | 47                | 277.2       | 246.1 | 1172.4 | 926.3       | 9.02   | 0.1109                          | 0.4059                     | 1.2571                       |
| 33.3                                  | 48                | 278.5       | 247.5 | 1172.8 | 925.3       | 8.84   | 0.1131                          | 0.4077                     | 1.2536                       |
| 34.3                                  | 49                | 279.8       | 248.8 | 1173.2 | 924.4       | 8.67   | 0.1153                          | 0.4095                     | 1.2502                       |
| 35.3                                  | 50                | 281.0       | 250.1 | 1173.6 | 923.5       | 8.51   | 0.1175                          | 0.4113                     | 1.2468                       |
| 36.3                                  | 51                | 282.3       | 251.4 | 1174.0 | 922.6       | 8.35   | 0.1197                          | 0.4130                     | 1.2432                       |
| 37.3                                  | 52                | 283.5       | 252.6 | 1174.3 | 921.7       | 8.20   | 0.1219                          | 0.4147                     | 1.2405                       |
| 38.3                                  | 53                | 284.7       | 253.9 | 1174.7 | 920.8       | 8.05   | 0.1241                          | 0.4164                     | 1.2370                       |
| 39.3                                  | 54                | 285.9       | 255.1 | 1175.0 | 919.9       | 7.91   | 0.1263                          | 0.4180                     | 1.2339                       |
| 40.3                                  | 55                | 287.1       | 256.3 | 1175.4 | 919.0       | 7.78   | 0.1285                          | 0.4106                     | 1.2309                       |
| 41.3                                  | 56                | 288.2       | 257.5 | 1175.7 | 918.2       | 7.65   | 0.1307                          | 0.4212                     | 1.2278                       |
| 42.3                                  | 57                | 289.4       | 258.7 | 1176.0 | 917.4       | 7.52   | 0.1329                          | 0.4227                     | 1.2248                       |
| 43.3                                  | 58                | 290.5       | 259.8 | 1176.4 | 916.5       | 7.40   | 0.1350                          | 0.4242                     | 1.2218                       |
| 44.3                                  | 59                | 291.6       | 261.0 | 1176.7 | 915.7       | 7.28   | 0.1372                          | 0.4257                     | 1.2189                       |
| 45.3                                  | 60                | 292.7       | 262.1 | 1177.0 | 914.9       | 7.17   | 0.1394                          | 0.4272                     | 1.2160                       |
| 46.3                                  | 61                | 293.8       | 263.2 | 1177.3 | 914.1       | 7.06   | 0.1416                          | 0.4287                     | 1.2132                       |
| 47.3                                  | 62                | 294.9       | 264.3 | 1177.6 | 913.3       | 6.95   | 0.1438                          | 0.4302                     | 1.2104                       |
| 48.3                                  | 63                | 295.9       | 265.4 | 1177.9 | 912.5       | 6.85   | 0.1460                          | 0.4316                     | 1.2077                       |
| 49.3                                  | 64                | 297.0       | 266.4 | 1178.2 | 911.8       | 6.75   | 0.1482                          | 0.4330                     | 1.2050                       |
| 50.3                                  | 65                | 298.0       | 267.5 | 1178.5 | 911.0       | 6.65   | 0.1503                          | 0.4344                     | 1.2024                       |
| 51.3                                  | 66                | 299.0       | 268.5 | 1178.8 | 910.2       | 6.56   | 0.1525                          | 0.4358                     | 1.1998                       |
| 52.3                                  | 67                | 300.0       | 269.6 | 1179.0 | 909.5       | 6.47   | 0.1547                          | 0.4371                     | 1.1972                       |
| 53.3                                  | 68                | 301.0       | 270.6 | 1179.3 | 908.7       | 6.38   | 0.1569                          | 0.4385                     | 1.1946                       |
| 54.3                                  | 69                | 302.0       | 271.6 | 1179.6 | 908.0       | 6.29   | 0.1590                          | 0.4398                     | 1.1921                       |
| 55.3                                  | 70                | 302.9       | 272.6 | 1179.8 | 907.2       | 6.20   | 0.1621                          | 0.4411                     | 1.1896                       |
| 56.3                                  | 71                | 303.9       | 273.6 | 1180.1 | 906.5       | 6.12   | 0.1634                          | 0.4424                     | 1.1872                       |
| 57.3                                  | 72                | 304.8       | 274.5 | 1180.4 | 905.8       | 6.04   | 0.1656                          | 0.4437                     | 1.1848                       |
| 58.3                                  | 73                | 305.8       | 275.5 | 1180.6 | 905.1       | 5.96   | 0.1678                          | 0.4449                     | 1.1825                       |
| 59.3                                  | 74                | 306.7       | 276.5 | 1180.9 | 904.4       | 5.89   | 0.1699                          | 0.4462                     | 1.1801                       |
| 60.3                                  | 75                | 307.6       | 277.4 | 1181.1 | 903.7       | 5.81   | 0.1721                          | 0.4474                     | 1.1778                       |
| 61.3                                  | 76                | 308.5       | 278.3 | 1181.4 | 903.0       | 5.74   | 0.1743                          | 0.4487                     | 1.1755                       |
| 62.3                                  | 77                | 309.4       | 279.3 | 1181.6 | 902.3       | 5.67   | 0.1764                          | 0.4499                     | 1.1730                       |
| 63.3                                  | 78                | 310.3       | 280.2 | 1181.8 | 901.7       | 5.60   | 0.1786                          | 0.4511                     | 1.1712                       |
| 64.3                                  | 79                | 311.2       | 281.1 | 1182.1 | 901.0       | 5.54   | 0.1808                          | 0.4523                     | 1.1687                       |
| 65.3                                  | 80                | 312.0       | 282.0 | 1182.3 | 900.3       | 5.47   | 0.1829                          | 0.4535                     | 1.1665                       |
| 66.3                                  | 81                | 312.9       | 282.9 | 1182.5 | 899.7       | 5.41   | 0.1851                          | 0.4546                     | 1.1644                       |
| 67.3                                  | 82                | 313.8       | 283.8 | 1182.8 | 899.0       | 5.34   | 0.1873                          | 0.4557                     | 1.1623                       |
| 68.3                                  | 83                | 314.6       | 284.6 | 1183.0 | 898.4       | 5.28   | 0.1894                          | 0.4568                     | 1.1602                       |

**APPENDIX C (continued)**  
**PROPERTIES OF SATURATED STEAM**

| Gauge Pressure<br>Lbs. per<br>Sq. In. | Absolute Pressure | Temperature | $h$   | $H$    | Latent Heat | Volume | Weight of<br>1 Cu. Ft.<br>Steam | Entropy<br>of the<br>Water | Entropy<br>of<br>Evapor-<br>ation |
|---------------------------------------|-------------------|-------------|-------|--------|-------------|--------|---------------------------------|----------------------------|-----------------------------------|
| 69.3                                  | 84                | 315.4       | 285.5 | 1183.2 | 897.7       | 5.22   | 0.1915                          | 0.4579                     | 1.1581                            |
| 70.3                                  | 85                | 316.3       | 286.3 | 1183.4 | 897.1       | 5.16   | 0.1937                          | 0.4590                     | 1.1561                            |
| 71.3                                  | 86                | 317.1       | 287.2 | 1183.6 | 896.4       | 5.10   | 0.1959                          | 0.4601                     | 1.1540                            |
| 72.3                                  | 87                | 317.9       | 288.0 | 1183.8 | 895.8       | 5.05   | 0.1980                          | 0.4612                     | 1.1520                            |
| 73.3                                  | 88                | 318.7       | 288.9 | 1184.0 | 895.2       | 5.00   | 0.2001                          | 0.4623                     | 1.1500                            |
| 74.3                                  | 89                | 319.5       | 289.7 | 1184.2 | 894.6       | 4.94   | 0.2023                          | 0.4633                     | 1.1481                            |
| 75.3                                  | 90                | 320.3       | 290.5 | 1184.4 | 893.9       | 4.89   | 0.2044                          | 0.4644                     | 1.1461                            |
| 76.3                                  | 91                | 321.1       | 291.3 | 1184.6 | 893.3       | 4.84   | 0.2065                          | 0.4654                     | 1.1442                            |
| 77.3                                  | 92                | 321.8       | 292.1 | 1184.8 | 892.7       | 4.79   | 0.2087                          | 0.4664                     | 1.1423                            |
| 78.3                                  | 93                | 322.6       | 292.9 | 1185.0 | 892.1       | 4.74   | 0.2109                          | 0.4674                     | 1.1404                            |
| 79.3                                  | 94                | 323.4       | 293.7 | 1185.2 | 891.5       | 4.69   | 0.2130                          | 0.4684                     | 1.1385                            |
| 80.3                                  | 95                | 324.1       | 294.5 | 1185.4 | 890.9       | 4.65   | 0.2151                          | 0.4694                     | 1.1367                            |
| 81.3                                  | 96                | 324.9       | 295.3 | 1185.6 | 890.3       | 4.60   | 0.2172                          | 0.4704                     | 1.1348                            |
| 82.3                                  | 97                | 325.6       | 296.1 | 1185.8 | 889.7       | 4.56   | 0.2193                          | 0.4714                     | 1.1330                            |
| 83.3                                  | 98                | 326.4       | 296.8 | 1186.0 | 889.2       | 4.51   | 0.2215                          | 0.4724                     | 1.1312                            |
| 84.3                                  | 99                | 327.1       | 297.6 | 1186.2 | 888.6       | 4.47   | 0.2237                          | 0.4733                     | 1.1295                            |
| 85.3                                  | 100               | 327.8       | 298.3 | 1186.3 | 888.0       | 4.429  | 0.2258                          | 0.4743                     | 1.1277                            |
| 87.3                                  | 102               | 329.3       | 299.8 | 1186.7 | 886.9       | 4.347  | 0.2300                          | 0.4762                     | 1.1242                            |
| 89.3                                  | 104               | 330.7       | 301.3 | 1187.0 | 885.8       | 4.268  | 0.2343                          | 0.4780                     | 1.1208                            |
| 91.3                                  | 106               | 332.0       | 302.7 | 1187.4 | 884.7       | 4.192  | 0.2336                          | 0.4798                     | 1.1174                            |
| 93.3                                  | 108               | 333.4       | 304.1 | 1187.7 | 883.6       | 4.118  | 0.2429                          | 0.4816                     | 1.1141                            |
| 95.3                                  | 110               | 334.8       | 305.5 | 1188.0 | 882.5       | 4.047  | 0.2472                          | 0.4834                     | 1.1108                            |
| 97.3                                  | 112               | 336.1       | 306.9 | 1188.4 | 881.4       | 3.978  | 0.2514                          | 0.4852                     | 1.1076                            |
| 99.3                                  | 114               | 337.4       | 308.3 | 1188.7 | 880.4       | 3.912  | 0.2556                          | 0.4869                     | 1.1045                            |
| 101.3                                 | 116               | 338.7       | 309.6 | 1189.0 | 879.3       | 3.848  | 0.2599                          | 0.4886                     | 1.1014                            |
| 103.3                                 | 118               | 340.0       | 311.0 | 1189.3 | 878.3       | 3.786  | 0.2641                          | 0.4903                     | 1.0984                            |
| 105.3                                 | 120               | 341.3       | 312.3 | 1189.6 | 877.2       | 3.726  | 0.2683                          | 0.4919                     | 1.0954                            |
| 107.3                                 | 122               | 342.5       | 313.6 | 1189.8 | 876.2       | 3.668  | 0.2726                          | 0.4935                     | 1.0924                            |
| 109.3                                 | 124               | 343.8       | 314.9 | 1190.1 | 875.2       | 3.611  | 0.2769                          | 0.4951                     | 1.0895                            |
| 111.3                                 | 126               | 345.0       | 316.2 | 1190.4 | 874.2       | 3.556  | 0.2812                          | 0.4967                     | 1.0865                            |
| 113.3                                 | 128               | 346.2       | 317.4 | 1190.7 | 873.3       | 3.504  | 0.2854                          | 0.4982                     | 1.0837                            |
| 115.3                                 | 130               | 347.4       | 318.6 | 1191.0 | 872.3       | 3.452  | 0.2897                          | 0.4998                     | 1.0809                            |
| 117.3                                 | 132               | 348.5       | 319.9 | 1191.2 | 871.3       | 3.402  | 0.2939                          | 0.5013                     | 1.0782                            |
| 119.3                                 | 134               | 349.7       | 321.1 | 1191.5 | 870.4       | 3.354  | 0.2981                          | 0.5028                     | 1.0755                            |
| 121.3                                 | 136               | 350.8       | 322.3 | 1191.7 | 869.4       | 3.308  | 0.3023                          | 0.5043                     | 1.0728                            |
| 123.3                                 | 138               | 352.0       | 323.4 | 1192.0 | 868.5       | 3.263  | 0.3065                          | 0.5057                     | 1.0702                            |
| 125.3                                 | 140               | 353.1       | 324.6 | 1192.2 | 867.6       | 3.219  | 0.3107                          | 0.5072                     | 1.0675                            |
| 127.3                                 | 142               | 354.2       | 325.8 | 1192.5 | 866.7       | 3.175  | 0.3150                          | 0.5086                     | 1.0649                            |
| 129.3                                 | 144               | 355.3       | 326.9 | 1192.7 | 865.8       | 3.133  | 0.3192                          | 0.5100                     | 1.0624                            |
| 131.3                                 | 146               | 356.3       | 328.0 | 1192.9 | 864.9       | 3.092  | 0.3234                          | 0.5114                     | 1.0599                            |
| 133.3                                 | 148               | 357.4       | 329.1 | 1193.2 | 864.0       | 3.052  | 0.3276                          | 0.5128                     | 1.0574                            |
| 135.3                                 | 150               | 358.5       | 330.2 | 1193.4 | 863.2       | 3.012  | 0.3320                          | 0.5142                     | 1.0550                            |
| 137.3                                 | 152               | 359.5       | 331.4 | 1193.6 | 862.3       | 2.974  | 0.3362                          | 0.5155                     | 1.0525                            |
| 139.3                                 | 154               | 360.5       | 332.4 | 1193.8 | 861.4       | 2.938  | 0.3404                          | 0.5169                     | 1.0501                            |
| 141.3                                 | 156               | 361.6       | 333.5 | 1194.1 | 860.6       | 2.902  | 0.3446                          | 0.5182                     | 1.0477                            |
| 143.3                                 | 158               | 362.6       | 334.6 | 1194.3 | 859.7       | 2.868  | 0.3488                          | 0.5195                     | 1.0454                            |
| 145.3                                 | 160               | 363.6       | 335.6 | 1194.5 | 858.8       | 2.834  | 0.3529                          | 0.5208                     | 1.0431                            |
| 147.3                                 | 162               | 364.6       | 336.7 | 1194.7 | 858.0       | 2.801  | 0.3570                          | 0.5220                     | 1.0409                            |

**APPENDIX C (continued)**  
**PROPERTIES OF SATURATED STEAM**

| Gauge Pressure<br>Lbs. per<br>Sq. In. | Absolute Pressure | Temperature | $h$   | $H$    | Latent Heat | Volume | Weight of<br>1 Cu. Ft.<br>Steam | Entropy<br>of the<br>Water | Entropy<br>of<br>Evapor-<br>ation |
|---------------------------------------|-------------------|-------------|-------|--------|-------------|--------|---------------------------------|----------------------------|-----------------------------------|
| 149.3                                 | 164               | 365.6       | 337.7 | 1194.9 | 857.2       | 2.769  | 0.3612                          | 0.5233                     | 1.0387                            |
| 151.3                                 | 166               | 366.5       | 338.7 | 1195.1 | 856.4       | 2.737  | 0.3654                          | 0.5245                     | 1.0365                            |
| 153.3                                 | 168               | 367.5       | 339.7 | 1195.3 | 855.5       | 2.706  | 0.3696                          | 0.5257                     | 1.0343                            |
| 155.3                                 | 170               | 368.5       | 340.7 | 1195.4 | 854.7       | 2.675  | 0.3738                          | 0.5269                     | 1.0321                            |
| 157.3                                 | 172               | 369.4       | 341.7 | 1195.6 | 853.9       | 2.645  | 0.3780                          | 0.5281                     | 1.0300                            |
| 159.3                                 | 174               | 370.4       | 342.7 | 1195.8 | 853.1       | 2.616  | 0.3822                          | 0.5293                     | 1.0278                            |
| 161.3                                 | 176               | 371.3       | 343.7 | 1196.0 | 852.3       | 2.588  | 0.3864                          | 0.5305                     | 1.0257                            |
| 163.3                                 | 178               | 372.2       | 344.7 | 1196.2 | 851.5       | 2.560  | 0.3906                          | 0.5317                     | 1.0235                            |
| 165.3                                 | 180               | 373.1       | 345.6 | 1196.4 | 850.8       | 2.533  | 0.3948                          | 0.5328                     | 1.0215                            |
| 167.3                                 | 182               | 374.0       | 346.6 | 1196.6 | 850.0       | 2.507  | 0.3989                          | 0.5339                     | 1.0195                            |
| 169.3                                 | 184               | 374.9       | 347.6 | 1196.8 | 849.2       | 2.481  | 0.4031                          | 0.5351                     | 1.0174                            |
| 171.3                                 | 186               | 375.8       | 348.5 | 1196.9 | 848.4       | 2.455  | 0.4073                          | 0.5362                     | 1.0154                            |
| 173.3                                 | 188               | 376.7       | 349.4 | 1197.1 | 847.7       | 2.430  | 0.4115                          | 0.5373                     | 1.0134                            |
| 175.3                                 | 190               | 377.6       | 350.4 | 1197.3 | 846.9       | 2.406  | 0.4157                          | 0.5384                     | 1.0114                            |
| 177.3                                 | 192               | 378.5       | 351.3 | 1197.4 | 846.1       | 2.381  | 0.4199                          | 0.5395                     | 1.0095                            |
| 179.3                                 | 194               | 379.3       | 352.2 | 1197.6 | 845.4       | 2.358  | 0.4241                          | 0.5405                     | 1.0076                            |
| 181.3                                 | 196               | 380.2       | 353.1 | 1197.8 | 844.7       | 2.335  | 0.4283                          | 0.5416                     | 1.0056                            |
| 183.3                                 | 198               | 381.0       | 354.0 | 1197.9 | 843.9       | 2.312  | 0.4325                          | 0.5426                     | 1.0038                            |
| 185.3                                 | 200               | 381.9       | 354.9 | 1198.1 | 843.2       | 2.290  | 0.437                           | 0.5437                     | 1.0019                            |
| 190.3                                 | 205               | 384.0       | 357.1 | 1198.5 | 841.4       | 2.237  | 0.447                           | 0.5463                     | 0.9973                            |
| 195.3                                 | 210               | 386.0       | 359.2 | 1198.8 | 839.6       | 2.187  | 0.457                           | 0.5488                     | 0.9928                            |
| 200.3                                 | 215               | 388.0       | 361.4 | 1199.2 | 837.9       | 2.138  | 0.468                           | 0.5513                     | 0.9885                            |
| 205.3                                 | 220               | 389.9       | 363.4 | 1199.6 | 836.2       | 2.091  | 0.478                           | 0.5538                     | 0.9841                            |
| 210.3                                 | 225               | 391.9       | 365.5 | 1199.9 | 834.4       | 2.046  | 0.489                           | 0.5562                     | 0.9799                            |
| 215.3                                 | 230               | 393.8       | 367.5 | 1200.2 | 832.8       | 2.004  | 0.499                           | 0.5586                     | 0.9758                            |
| 220.3                                 | 235               | 395.6       | 369.4 | 1200.6 | 831.1       | 1.964  | 0.509                           | 0.5610                     | 0.9717                            |
| 225.3                                 | 240               | 397.4       | 371.4 | 1200.9 | 829.5       | 1.924  | 0.520                           | 0.5633                     | 0.9676                            |
| 230.3                                 | 245               | 399.3       | 373.3 | 1201.2 | 827.9       | 1.887  | 0.530                           | 0.5655                     | 0.9638                            |
| 235.3                                 | 250               | 401.1       | 375.2 | 1201.5 | 826.3       | 1.850  | 0.541                           | 0.5676                     | 0.9600                            |
| 245.3                                 | 260               | 404.5       | 378.9 | 1202.1 | 823.1       | 1.782  | 0.561                           | 0.5719                     | 0.9525                            |
| 255.3                                 | 270               | 407.9       | 382.5 | 1202.6 | 820.1       | 1.718  | 0.582                           | 0.5760                     | 0.9454                            |
| 265.3                                 | 280               | 411.2       | 385.0 | 1203.1 | 817.1       | 1.658  | 0.603                           | 0.5800                     | 0.9385                            |
| 275.3                                 | 290               | 414.4       | 389.4 | 1203.6 | 814.2       | 1.602  | 0.624                           | 0.5840                     | 0.9316                            |
| 285.3                                 | 300               | 417.5       | 392.7 | 1204.1 | 811.3       | 1.551  | 0.645                           | 0.5878                     | 0.9251                            |
| 295.3                                 | 310               | 420.5       | 395.9 | 1204.5 | 808.5       | 1.502  | 0.666                           | 0.5915                     | 0.9187                            |
| 305.3                                 | 320               | 423.4       | 399.1 | 1204.9 | 805.8       | 1.456  | 0.687                           | 0.5951                     | 0.9125                            |
| 315.3                                 | 330               | 426.3       | 402.2 | 1205.3 | 803.1       | 1.413  | 0.708                           | 0.5986                     | 0.9065                            |
| 325.3                                 | 340               | 429.1       | 405.3 | 1205.7 | 800.4       | 1.372  | 0.729                           | 0.6020                     | 0.9006                            |
| 335.3                                 | 350               | 431.9       | 408.2 | 1206.1 | 797.8       | 1.334  | 0.750                           | 0.6053                     | 0.8949                            |
| 345.3                                 | 360               | 434.6       | 411.2 | 1206.4 | 795.3       | 1.298  | 0.770                           | 0.6085                     | 0.8894                            |
| 355.3                                 | 370               | 437.2       | 414.0 | 1206.8 | 792.8       | 1.264  | 0.791                           | 0.6116                     | 0.8840                            |
| 365.3                                 | 380               | 439.8       | 416.8 | 1207.1 | 790.3       | 1.231  | 0.812                           | 0.6147                     | 0.8788                            |
| 375.3                                 | 390               | 442.3       | 419.5 | 1207.4 | 787.9       | 1.200  | 0.833                           | 0.6178                     | 0.8737                            |
| 385.3                                 | 400               | 444.8       | 422   | 1208   | 786         | 1.17   | 0.86                            | 0.621                      | 0.868                             |
| 435.3                                 | 450               | 456.5       | 435   | 1209   | 774         | 1.04   | 0.96                            | 0.635                      | 0.844                             |
| 485.3                                 | 500               | 467.3       | 448   | 1210   | 762         | 0.93   | 1.08                            | 0.648                      | 0.822                             |
| 535.3                                 | 550               | 477.3       | 459   | 1210   | 751         | 0.83   | 1.20                            | 0.659                      | 0.801                             |
| 585.3                                 | 600               | 486.6       | 469   | 1210   | 741         | 0.76   | 1.32                            | 0.670                      | 0.783                             |

## APPENDIX D

### FRICTION & VELOCITY CHART FOR SCHEDULE 40 STEEL PIPE

| U. S.<br>Gallons<br>per<br>Minute | 1 in. (1.049" I. D.) |                | 1 1/4 in. (1.3880" I. D.) |                | 1 1/2 in. (1.610" I. D.) |                | U. S.<br>Gallons<br>per<br>Minute |
|-----------------------------------|----------------------|----------------|---------------------------|----------------|--------------------------|----------------|-----------------------------------|
|                                   | V                    | h <sub>f</sub> | V                         | h <sub>f</sub> | V                        | h <sub>f</sub> |                                   |
| 4                                 | 1.48                 | 1.29           |                           |                |                          |                | 4                                 |
| 5                                 | 1.86                 | 1.93           |                           |                |                          |                | 5                                 |
| 6                                 | 2.23                 | 2.68           | 1.29                      | 0.70           |                          |                | 6                                 |
| 7                                 | 2.60                 | 3.56           | 1.50                      | 0.93           |                          |                | 7                                 |
| 8                                 | 2.97                 | 4.54           | 1.72                      | 1.18           | 1.26                     | 0.56           | 8                                 |
| 9                                 | 3.34                 | 5.65           | 1.93                      | 1.46           | 1.42                     | 0.69           | 9                                 |
| 10                                | 3.71                 | 6.86           | 2.15                      | 1.77           | 1.58                     | 0.83           | 10                                |
| 12                                | 4.45                 | 9.62           | 2.57                      | 2.48           | 1.89                     | 1.16           | 12                                |
| 14                                | 5.20                 | 12.8           | 3.00                      | 3.28           | 2.21                     | 1.53           | 14                                |
| 16                                | 5.94                 | 16.5           | 3.43                      | 4.20           | 2.52                     | 1.96           | 16                                |
| 18                                | 6.68                 | 20.6           | 3.86                      | 5.22           | 2.84                     | 2.42           | 18                                |
| 20                                | 7.42                 | 25.1           | 4.29                      | 6.34           | 3.15                     | 2.94           | 20                                |
| 25                                | 9.29                 | 37.4           | 5.37                      | 9.66           | 3.94                     | 4.50           | 25                                |
| 30                                | 11.1                 | 54.6           | 6.44                      | 13.6           | 4.73                     | 6.26           | 30                                |
| 35                                | 13.0                 | 73.3           | 7.52                      | 18.5           | 5.52                     | 8.38           | 35                                |
| 40                                | 14.8                 | 95.0           | 8.58                      | 23.5           | 6.30                     | 10.8           | 40                                |
| 45                                | 16.7                 | 119            | 9.66                      | 29.5           | 7.10                     | 13.5           | 45                                |
| 50                                | 18.6                 | 146            | 10.7                      | 36.0           | 7.88                     | 16.4           | 50                                |
| 60                                | 22.3                 | 209            | 12.9                      | 51.0           | 9.46                     | 23.2           | 60                                |
| 70                                | 26.0                 | 283            | 15.0                      | 68.8           | 11.0                     | 31.3           | 70                                |
| 80                                |                      |                | 17.2                      | 89.2           | 12.6                     | 40.5           | 80                                |
| 90                                |                      |                | 19.3                      | 112            | 14.2                     | 51.0           | 90                                |
| 100                               |                      |                | 21.5                      | 138            | 15.8                     | 62.2           | 100                               |
| 120                               |                      |                | 25.7                      | 197            | 18.9                     | 88.3           | 120                               |
| 140                               |                      |                |                           |                | 22.1                     | 119            | 140                               |

\*V = Velocity in ft./sec.

\*\*h<sub>f</sub> = Friction head loss in ft./100ft.

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# APPENDIX D (continued)

## FRICITION & VELOCITY CHART FOR SCHEDULE 40 STEEL PIPE

| U. S.<br>Gallons<br>per<br>Minute | 2 in. (2.067" I. D.) |                | 2½ in. (2.469" I. D.) |                | 3 in. (3.068" I. D.) |                | U. S.<br>Gallons<br>per<br>Minute |
|-----------------------------------|----------------------|----------------|-----------------------|----------------|----------------------|----------------|-----------------------------------|
|                                   | V                    | h <sub>f</sub> | V                     | h <sub>f</sub> | V                    | h <sub>f</sub> |                                   |
| 30                                | 2.87                 | 1.82           | 2.01                  | 0.75           |                      |                | 30                                |
| 35                                | 3.35                 | 2.42           | 2.35                  | 1.00           |                      |                | 35                                |
| 40                                | 3.82                 | 3.10           | 2.68                  | 1.28           |                      |                | 40                                |
| 50                                | 4.78                 | 4.67           | 3.35                  | 1.94           | 2.17                 | .66            | 50                                |
| 60                                | 5.74                 | 6.59           | 4.02                  | 2.72           | 2.60                 | 0.92           | 60                                |
| 80                                | 7.65                 | 11.4           | 5.36                  | 4.66           | 3.47                 | 1.57           | 80                                |
| 100                               | 9.56                 | 17.4           | 6.70                  | 7.11           | 4.34                 | 2.39           | 100                               |
| 120                               | 11.5                 | 24.7           | 8.04                  | 10.0           | 5.21                 | 3.37           | 120                               |
| 140                               | 13.4                 | 33.2           | 9.38                  | 13.5           | 6.08                 | 4.51           | 140                               |
| 160                               | 15.3                 | 43.0           | 10.7                  | 17.4           | 6.94                 | 5.81           | 160                               |
| 180                               | 17.2                 | 54.1           | 12.1                  | 21.9           | 7.81                 | 7.28           | 180                               |
| 200                               | 19.1                 | 66.3           | 13.4                  | 26.7           | 8.68                 | 8.90           | 200                               |
| 220                               | 21.0                 | 80.0           | 14.7                  | 32.2           | 9.55                 | 10.7           | 220                               |
| 240                               | 22.9                 | 95.0           | 16.1                  | 38.1           | 10.4                 | 12.6           | 240                               |
| 260                               | 24.9                 | 111            | 17.4                  | 44.5           | 11.3                 | 14.7           | 260                               |
| 280                               | 26.8                 | 128            | 18.8                  | 51.3           | 12.2                 | 16.9           | 280                               |
| 300                               | 28.7                 | 146            | 20.1                  | 58.5           | 13.0                 | 19.2           | 300                               |
| 350                               |                      |                | 23.5                  | 79.2           | 15.2                 | 26.3           | 350                               |
| 400                               |                      |                | 26.8                  | 103            | 17.4                 | 33.9           | 400                               |
| 500                               |                      |                | 33.5                  | 160            | 21.7                 | 52.5           | 500                               |
| 600                               |                      |                |                       |                | 26.0                 | 74.8           | 600                               |
| 700                               |                      |                |                       |                | 30.4                 | 101            | 700                               |
| 800                               |                      |                |                       |                | 34.7                 | 131            | 800                               |
| 1000                              |                      |                |                       |                |                      |                | 1000                              |

\*V = Velocity in ft./sec.

\*\*h<sub>f</sub> = Friction head loss in ft./100ft.

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# APPENDIX D (continued)

## FRICTION & VELOCITY CHART FOR SCHEDULE 40 STEEL PIPE

| U. S.<br>Gallons<br>per<br>Minute | 4 in. (4.026" I. D.) |                | 5 in. (5.047" I. D.) |                | 6 in. (6.065" I. D.) |                | 8 in. (7.981" I. D.) |                | Gallons<br>per<br>Minute |
|-----------------------------------|----------------------|----------------|----------------------|----------------|----------------------|----------------|----------------------|----------------|--------------------------|
|                                   | V                    | h <sub>f</sub> | V                    | h <sub>f</sub> | V                    | h <sub>f</sub> | V                    | h <sub>f</sub> |                          |
| 140                               | 3.53                 | 1.16           | 2.25                 | 0.38           |                      |                |                      |                | 140                      |
| 160                               | 4.03                 | 1.49           | 2.57                 | 0.49           |                      |                |                      |                | 160                      |
| 180                               | 4.54                 | 1.86           | 2.89                 | 0.61           |                      |                |                      |                | 180                      |
| 200                               | 5.04                 | 2.27           | 3.21                 | 0.74           | 2.22                 | 0.3            |                      |                | 200                      |
| 240                               | 6.05                 | 3.21           | 3.85                 | 1.03           | 2.66                 | 0.42           |                      |                | 240                      |
| 280                               | 7.06                 | 4.3            | 4.49                 | 1.38           | 3.11                 | 0.56           |                      |                | 280                      |
| 320                               | 8.06                 | 5.51           | 5.13                 | 1.78           | 3.55                 | 0.72           |                      |                | 320                      |
| 360                               | 9.07                 | 6.92           | 5.77                 | 2.22           | 4                    | 0.9            |                      |                | 360                      |
| 400                               | 10.1                 | 8.47           | 6.41                 | 2.72           | 4.44                 | 1.09           | 2.57                 | 0.28           | 400                      |
| 450                               | 11.3                 | 10.5           | 7.23                 | 3.42           | 5                    | 1.37           | 2.89                 | 0.35           | 450                      |
| 500                               | 12.6                 | 13             | 8.02                 | 4.16           | 5.55                 | 1.66           | 3.21                 | 0.42           | 500                      |
| 600                               | 15.1                 | 18.6           | 9.62                 | 5.88           | 6.66                 | 2.34           | 3.85                 | 0.6            | 600                      |
| 700                               | 17.6                 | 25             | 11.2                 | 7.93           | 7.77                 | 3.13           | 4.49                 | 0.8            | 700                      |
| 800                               | 20.2                 | 32.4           | 12.8                 | 10.2           | 8.88                 | 4.03           | 5.13                 | 1.02           | 800                      |
| 900                               | 22.7                 | 40.8           | 14.4                 | 12.9           | 9.99                 | 5.05           | 5.77                 | 1.27           | 900                      |
| 1000                              | 25.2                 | 50.2           | 16                   | 15.8           | 11.1                 | 6.17           | 6.41                 | 1.56           | 1000                     |
| 1200                              | 30.2                 | 72             | 19.2                 | 22.5           | 13.3                 | 8.76           | 7.7                  | 2.2            | 1200                     |
| 1400                              | 35.3                 | 97.6           | 22.5                 | 30.4           | 15.5                 | 11.8           | 8.98                 | 2.95           | 1400                     |
| 1600                              |                      |                | 25.7                 | 39.5           | 17.8                 | 15.4           | 10.3                 | 3.82           | 1600                     |
| 1800                              |                      |                | 28.8                 | 49.7           | 20                   | 19.4           | 11.5                 | 4.79           | 1800                     |
| 2000                              |                      |                | 32.1                 | 61             | 22.2                 | 23.8           | 12.8                 | 5.86           | 2000                     |
| 2400                              |                      |                |                      |                | 26.6                 | 34.2           | 15.4                 | 8.31           | 2400                     |
| 2800                              |                      |                |                      |                | 31.1                 | 46.1           | 18                   | 11.2           | 2800                     |
| 3200                              |                      |                |                      |                | 35.5                 | 59.9           | 20.5                 | 14.5           | 3200                     |
| 3600                              |                      |                |                      |                |                      |                | 23.1                 | 18.4           | 3600                     |
| 4000                              |                      |                |                      |                |                      |                | 25.7                 | 22.6           | 4000                     |

\*V = Velocity in ft./sec.

\*\*h<sub>f</sub> = Friction head loss in ft./100ft.

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# APPENDIX D (continued)

## FRICTION & VELOCITY CHART FOR SCHEDULE 40 STEEL PIPE

| U. S.<br>Gallons<br>per<br>Minute | 10 in. (10.020" I. D.) |                | 12 in. (11.938" I. D.) |                | 14 in. (13.124" I. D.) |                | 16 in. (15.000" I. D.) |                | Gallons<br>per<br>Minute |
|-----------------------------------|------------------------|----------------|------------------------|----------------|------------------------|----------------|------------------------|----------------|--------------------------|
|                                   | V                      | h <sub>f</sub> | V                      | h <sub>f</sub> | V                      | h <sub>f</sub> | V                      | h <sub>f</sub> |                          |
| 800                               | 3.25                   | 0.328          |                        |                |                        |                |                        |                | 800                      |
| 900                               | 3.66                   | 0.410          | 2.58                   | 0.173          |                        |                |                        |                | 900                      |
| 1000                              | 4.07                   | 0.500          | 2.87                   | 0.210          | 2.37                   | 0.131          |                        |                | 1000                     |
| 1200                              | 4.88                   | 0.703          | 3.44                   | 0.296          | 2.85                   | 0.185          |                        |                | 1200                     |
| 1400                              | 5.70                   | 0.940          | 4.01                   | 0.395          | 3.32                   | 0.247          |                        |                | 1400                     |
| 1600                              | 6.51                   | 1.21           | 4.59                   | 0.509          | 3.79                   | 0.317          | 2.90                   | 0.163          | 1600                     |
| 1800                              | 7.32                   | 1.52           | 5.16                   | 0.636          | 4.27                   | 0.395          | 3.27                   | 0.203          | 1800                     |
| 2000                              | 8.14                   | 1.86           | 5.73                   | 0.776          | 4.74                   | 0.483          | 3.63                   | 0.248          | 2000                     |
| 2500                              | 10.2                   | 2.86           | 7.17                   | 1.19           | 5.93                   | 0.738          | 4.54                   | 0.377          | 2500                     |
| 3000                              | 12.2                   | 4.06           | 8.60                   | 1.68           | 7.11                   | 1.04           | 5.45                   | 0.535          | 3000                     |
| 3500                              | 14.2                   | 5.46           | 10.0                   | 2.25           | 8.30                   | 1.40           | 6.35                   | 0.718          | 3500                     |
| 4000                              | 16.3                   | 7.07           | 11.5                   | 2.92           | 9.48                   | 1.81           | 7.26                   | 0.921          | 4000                     |
| 4500                              | 18.3                   | 8.88           | 12.9                   | 3.65           | 10.7                   | 2.27           | 8.17                   | 1.15           | 4500                     |
| 5000                              | 20.3                   | 10.9           | 14.3                   | 4.47           | 11.9                   | 2.78           | 9.08                   | 1.41           | 5000                     |
| 6000                              | 24.4                   | 15.6           | 17.2                   | 6.39           | 14.2                   | 3.95           | 10.9                   | 2.01           | 6000                     |
| 7000                              | 28.5                   | 21.1           | 20.1                   | 8.63           | 16.6                   | 5.32           | 12.7                   | 2.69           | 7000                     |
| 8000                              | 32.5                   | 27.5           | 22.9                   | 11.2           | 19.0                   | 6.90           | 14.5                   | 3.49           | 8000                     |
| 9000                              | 36.6                   | 34.6           | 25.8                   | 14.1           | 21.3                   | 8.7            | 16.3                   | 4.38           | 9000                     |
| 10,000                            |                        |                | 28.7                   | 17.4           | 23.7                   | 10.7           | 18.2                   | 5.38           | 10,000                   |
| 12,000                            |                        |                | 34.4                   | 24.8           | 28.5                   | 15.2           | 21.8                   | 7.69           | 12,000                   |
| 14,000                            |                        |                | 40.1                   | 33.5           | 33.2                   | 20.7           | 25.4                   | 10.4           | 14,000                   |
| 16,000                            |                        |                |                        |                | 37.9                   | 26.8           | 29.0                   | 13.5           | 16,000                   |
| 18,000                            |                        |                |                        |                | 42.7                   | 33.9           | 32.7                   | 17.2           | 18,000                   |
| 20,000                            |                        |                |                        |                |                        |                | 36.3                   | 21.2           | 20,000                   |

\*V = Velocity in ft./sec.

\*\*h<sub>f</sub> = Friction head loss in ft./100ft.

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# APPENDIX E

## PIPE DATA

| Nominal<br>Pipe<br>Size<br><br>Inches | Outside<br>Diameter<br><br>Inches | Identification       |               |                                     | Wall<br>Thickness<br>(t)<br><br>Inches | Inside<br>Diameter<br>(d)<br><br>Inches | Transverse<br>Internal Area<br>(A)<br><br>Square<br>Feet | Weight<br>Pipe<br>Pounds<br>per<br>foot | Weight<br>Water<br>Pounds<br>per foot<br>of pipe |
|---------------------------------------|-----------------------------------|----------------------|---------------|-------------------------------------|----------------------------------------|-----------------------------------------|----------------------------------------------------------|-----------------------------------------|--------------------------------------------------|
|                                       |                                   | Steel                |               | Stainless<br>Steel<br>Sched.<br>No. |                                        |                                         |                                                          |                                         |                                                  |
|                                       |                                   | Iron<br>Pipe<br>Size | Sched.<br>No. |                                     |                                        |                                         |                                                          |                                         |                                                  |
| 1/8                                   | 0.405                             | --                   | --            | 10S                                 | 0.049                                  | 0.307                                   | 0.00051                                                  | 0.19                                    | 0.032                                            |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.068                                  | 0.269                                   | 0.00040                                                  | 0.24                                    | 0.025                                            |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.095                                  | 0.215                                   | 0.00025                                                  | 0.31                                    | 0.016                                            |
| 1/4                                   | 0.540                             | --                   | --            | 10S                                 | 0.065                                  | 0.410                                   | 0.00091                                                  | 0.33                                    | 0.057                                            |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.088                                  | 0.364                                   | 0.00072                                                  | 0.42                                    | 0.045                                            |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.119                                  | 0.302                                   | 0.00050                                                  | 0.54                                    | 0.031                                            |
| 3/8                                   | 0.675                             | --                   | --            | 10S                                 | 0.065                                  | 0.545                                   | 0.00162                                                  | 0.42                                    | 0.101                                            |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.091                                  | 0.493                                   | 0.00133                                                  | 0.57                                    | 0.083                                            |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.126                                  | 0.423                                   | 0.00098                                                  | 0.74                                    | 0.061                                            |
| 1/2                                   | 0.840                             | --                   | --            | 5S                                  | 0.065                                  | 0.710                                   | 0.00275                                                  | 0.54                                    | 0.172                                            |
|                                       |                                   | --                   | --            | 10S                                 | 0.083                                  | 0.674                                   | 0.00248                                                  | 0.67                                    | 0.155                                            |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.109                                  | 0.622                                   | 0.00211                                                  | 0.85                                    | 0.132                                            |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.147                                  | 0.546                                   | 0.00163                                                  | 1.09                                    | 0.102                                            |
|                                       |                                   | --                   | 160           | --                                  | 0.187                                  | 0.466                                   | 0.00118                                                  | 1.31                                    | 0.074                                            |
|                                       |                                   | XXS                  | --            | --                                  | 0.294                                  | 0.252                                   | 0.00035                                                  | 1.71                                    | 0.022                                            |
| 3/4                                   | 1.050                             | --                   | --            | 5S                                  | 0.065                                  | 0.920                                   | 0.00462                                                  | 0.69                                    | 0.288                                            |
|                                       |                                   | --                   | --            | 10S                                 | 0.083                                  | 0.884                                   | 0.00426                                                  | 0.86                                    | 0.266                                            |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.113                                  | 0.824                                   | 0.00371                                                  | 1.13                                    | 0.231                                            |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.154                                  | 0.742                                   | 0.00300                                                  | 1.47                                    | 0.188                                            |
|                                       |                                   | --                   | 160           | --                                  | 0.219                                  | 0.612                                   | 0.00206                                                  | 1.94                                    | 0.128                                            |
|                                       |                                   | XXS                  | --            | --                                  | 0.308                                  | 0.434                                   | 0.00103                                                  | 2.44                                    | 0.064                                            |
| 1                                     | 1.315                             | --                   | --            | 5S                                  | 0.065                                  | 1.185                                   | 0.00766                                                  | 0.87                                    | 0.478                                            |
|                                       |                                   | --                   | --            | 10S                                 | 0.109                                  | 1.097                                   | 0.00656                                                  | 1.40                                    | 0.409                                            |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.133                                  | 1.049                                   | 0.00600                                                  | 1.68                                    | 0.375                                            |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.179                                  | 0.957                                   | 0.00499                                                  | 2.17                                    | 0.312                                            |
|                                       |                                   | --                   | 160           | --                                  | 0.250                                  | 0.815                                   | 0.00362                                                  | 2.84                                    | 0.230                                            |
|                                       |                                   | XXS                  | --            | --                                  | 0.358                                  | 0.599                                   | 0.00196                                                  | 3.66                                    | 0.122                                            |
| 1¼                                    | 1.660                             | --                   | --            | 5S                                  | 0.065                                  | 1.530                                   | 0.01277                                                  | 1.11                                    | 0.797                                            |
|                                       |                                   | --                   | --            | 10S                                 | 0.109                                  | 1.442                                   | 0.01134                                                  | 1.81                                    | 0.708                                            |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.140                                  | 1.380                                   | 0.01040                                                  | 2.27                                    | 0.649                                            |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.191                                  | 1.278                                   | 0.00891                                                  | 3.00                                    | 0.555                                            |
|                                       |                                   | --                   | 160           | --                                  | 0.250                                  | 1.160                                   | 0.00734                                                  | 3.76                                    | 0.458                                            |
|                                       |                                   | XXS                  | --            | --                                  | 0.382                                  | 0.896                                   | 0.00438                                                  | 5.21                                    | 0.273                                            |
| 1½                                    | 1.900                             | --                   | --            | 5S                                  | 0.065                                  | 1.770                                   | 0.01709                                                  | 1.28                                    | 1.066                                            |
|                                       |                                   | --                   | --            | 10S                                 | 0.109                                  | 1.682                                   | 0.01543                                                  | 2.09                                    | 0.963                                            |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.145                                  | 1.610                                   | 0.01414                                                  | 2.72                                    | 0.882                                            |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.200                                  | 1.500                                   | 0.01225                                                  | 3.63                                    | 0.765                                            |
|                                       |                                   | --                   | 160           | --                                  | 0.281                                  | 1.338                                   | 0.00976                                                  | 4.86                                    | 0.608                                            |
|                                       |                                   | XXS                  | --            | --                                  | 0.400                                  | 1.100                                   | 0.00660                                                  | 6.41                                    | 0.42                                             |
| 2                                     | 2.375                             | --                   | --            | 5S                                  | 0.065                                  | 2.245                                   | 0.02749                                                  | 1.61                                    | 1.72                                             |
|                                       |                                   | --                   | --            | 10S                                 | 0.109                                  | 2.157                                   | 0.02538                                                  | 2.64                                    | 1.58                                             |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.154                                  | 2.067                                   | 0.02330                                                  | 3.65                                    | 1.45                                             |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.218                                  | 1.939                                   | 0.02050                                                  | 5.02                                    | 1.28                                             |
|                                       |                                   | --                   | 160           | --                                  | 0.344                                  | 1.687                                   | 0.01556                                                  | 7.46                                    | 0.97                                             |
|                                       |                                   | XXS                  | --            | --                                  | 0.436                                  | 1.503                                   | 0.01232                                                  | 9.03                                    | 0.77                                             |
| 2 ½                                   | 2.875                             | --                   | --            | 5S                                  | 0.083                                  | 2.709                                   | 0.04002                                                  | 2.48                                    | 2.50                                             |
|                                       |                                   | --                   | --            | 10S                                 | 0.120                                  | 2.635                                   | 0.03787                                                  | 3.53                                    | 2.36                                             |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.203                                  | 2.469                                   | 0.03322                                                  | 5.79                                    | 2.07                                             |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.276                                  | 2.323                                   | 0.02942                                                  | 7.66                                    | 1.87                                             |
|                                       |                                   | --                   | 160           | --                                  | 0.375                                  | 2.125                                   | 0.02463                                                  | 10.01                                   | 1.54                                             |
|                                       |                                   | XXS                  | --            | --                                  | 0.552                                  | 1.771                                   | 0.01710                                                  | 13.69                                   | 1.07                                             |
| 3                                     | 3.500                             | --                   | --            | 5S                                  | 0.083                                  | 3.334                                   | 0.06063                                                  | 3.03                                    | 3.78                                             |
|                                       |                                   | --                   | --            | 10S                                 | 0.120                                  | 3.260                                   | 0.05796                                                  | 4.33                                    | 3.62                                             |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.216                                  | 3.068                                   | 0.05130                                                  | 7.58                                    | 3.20                                             |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.300                                  | 2.900                                   | 0.04587                                                  | 10.25                                   | 2.86                                             |
|                                       |                                   | --                   | 160           | --                                  | 0.438                                  | 2.624                                   | 0.03755                                                  | 14.32                                   | 2.35                                             |
|                                       |                                   | XXS                  | --            | --                                  | 0.600                                  | 2.300                                   | 0.02885                                                  | 18.58                                   | 1.80                                             |

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# APPENDIX E (continued)

## PIPE DATA

| Nominal<br>Pipe<br>Size<br><br>Inches | Outside<br>Diameter<br><br>Inches | Identification       |               |                                     | Wall<br>Thickness<br>(t)<br><br>Inches | Inside<br>Diameter<br>(d)<br><br>Inches | Transverse<br>Internal Area<br>(A)<br><br>Square<br>Feet | Weight<br>Pipe<br>Pounds<br>per<br>foot | Weight<br>Water<br>Pounds<br>per foot<br>of pipe |       |       |
|---------------------------------------|-----------------------------------|----------------------|---------------|-------------------------------------|----------------------------------------|-----------------------------------------|----------------------------------------------------------|-----------------------------------------|--------------------------------------------------|-------|-------|
|                                       |                                   | Steel                |               | Stainless<br>Steel<br>Sched.<br>No. |                                        |                                         |                                                          |                                         |                                                  |       |       |
|                                       |                                   | Iron<br>Pipe<br>Size | Sched.<br>No. |                                     |                                        |                                         |                                                          |                                         |                                                  |       |       |
| 3 1/2                                 | 4.000                             | --                   | --            | 5S                                  | 0.083                                  | 3.834                                   | 0.08017                                                  | 3.48                                    | 5.00                                             |       |       |
|                                       |                                   | --                   | --            | 10S                                 | 0.120                                  | 3.760                                   | 0.07711                                                  | 4.97                                    | 4.81                                             |       |       |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.226                                  | 3.548                                   | 0.06870                                                  | 9.11                                    | 4.29                                             |       |       |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.318                                  | 3.364                                   | 0.06170                                                  | 12.50                                   | 3.84                                             |       |       |
| 4                                     | 4.500                             | --                   | --            | 5S                                  | 0.083                                  | 4.334                                   | 0.10245                                                  | 3.92                                    | 6.39                                             |       |       |
|                                       |                                   | --                   | --            | 10S                                 | 0.120                                  | 4.260                                   | 0.09898                                                  | 5.61                                    | 6.18                                             |       |       |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.237                                  | 4.026                                   | 0.08840                                                  | 10.79                                   | 5.50                                             |       |       |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.337                                  | 3.826                                   | 0.07986                                                  | 14.98                                   | 4.98                                             |       |       |
|                                       |                                   | --                   | 120           | --                                  | 0.438                                  | 3.624                                   | 0.0716                                                   | 19.00                                   | 4.47                                             |       |       |
|                                       |                                   | --                   | 160           | --                                  | 0.531                                  | 3.438                                   | 0.0645                                                   | 22.51                                   | 4.02                                             |       |       |
|                                       |                                   | XXS                  | --            | --                                  | 0.674                                  | 3.152                                   | 0.0542                                                   | 27.54                                   | 3.38                                             |       |       |
| 5                                     | 5.563                             | --                   | --            | 5S                                  | 0.109                                  | 5.345                                   | 0.1558                                                   | 6.36                                    | 9.72                                             |       |       |
|                                       |                                   | --                   | --            | 10S                                 | 0.134                                  | 5.295                                   | 0.1529                                                   | 7.77                                    | 9.54                                             |       |       |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.258                                  | 5.047                                   | 0.1390                                                   | 14.62                                   | 8.67                                             |       |       |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.375                                  | 4.813                                   | 0.1263                                                   | 20.78                                   | 7.88                                             |       |       |
|                                       |                                   | --                   | 120           | --                                  | 0.500                                  | 4.563                                   | 0.1136                                                   | 27.04                                   | 7.09                                             |       |       |
|                                       |                                   | --                   | 160           | --                                  | 0.625                                  | 4.313                                   | 0.1015                                                   | 32.96                                   | 6.33                                             |       |       |
| 6                                     | 6.625                             | XXS                  | --            | --                                  | 0.750                                  | 4.063                                   | 0.0901                                                   | 38.55                                   | 5.61                                             |       |       |
|                                       |                                   | --                   | --            | 5S                                  | 0.109                                  | 6.407                                   | 0.2239                                                   | 7.60                                    | 13.97                                            |       |       |
|                                       |                                   | --                   | --            | 10S                                 | 0.134                                  | 6.357                                   | 0.2204                                                   | 9.29                                    | 13.75                                            |       |       |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.280                                  | 6.065                                   | 0.2006                                                   | 18.97                                   | 12.51                                            |       |       |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.432                                  | 5.761                                   | 0.1810                                                   | 28.57                                   | 11.29                                            |       |       |
|                                       |                                   | --                   | 120           | --                                  | 0.562                                  | 5.501                                   | 0.1650                                                   | 36.39                                   | 10.30                                            |       |       |
|                                       |                                   | --                   | 160           | --                                  | 0.719                                  | 5.187                                   | 0.1469                                                   | 45.35                                   | 9.16                                             |       |       |
| 8                                     | 8.625                             | XXS                  | --            | --                                  | 0.864                                  | 4.897                                   | 0.1308                                                   | 53.16                                   | 8.16                                             |       |       |
|                                       |                                   | --                   | --            | 5S                                  | 0.109                                  | 8.407                                   | 0.3855                                                   | 9.93                                    | 24.06                                            |       |       |
|                                       |                                   | --                   | --            | 10S                                 | 0.148                                  | 8.329                                   | 0.3784                                                   | 13.40                                   | 23.61                                            |       |       |
|                                       |                                   | --                   | 20            | --                                  | 0.250                                  | 8.125                                   | 0.3601                                                   | 22.36                                   | 22.47                                            |       |       |
|                                       |                                   | --                   | 30            | --                                  | 0.277                                  | 8.071                                   | 0.3553                                                   | 24.70                                   | 22.17                                            |       |       |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.322                                  | 7.981                                   | 0.3474                                                   | 28.55                                   | 21.70                                            |       |       |
|                                       |                                   | --                   | 60            | --                                  | 0.406                                  | 7.813                                   | 0.3329                                                   | 35.64                                   | 20.77                                            |       |       |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.500                                  | 7.625                                   | 0.3171                                                   | 43.39                                   | 19.78                                            |       |       |
|                                       |                                   | --                   | 100           | --                                  | 0.594                                  | 7.437                                   | 0.3018                                                   | 50.95                                   | 18.83                                            |       |       |
|                                       |                                   | --                   | 120           | --                                  | 0.719                                  | 7.187                                   | 0.2819                                                   | 60.71                                   | 17.59                                            |       |       |
|                                       |                                   | --                   | 140           | --                                  | 0.812                                  | 7.001                                   | 0.2673                                                   | 67.76                                   | 16.68                                            |       |       |
|                                       |                                   | XXS                  | --            | --                                  | 0.875                                  | 6.875                                   | 0.2578                                                   | 72.42                                   | 16.10                                            |       |       |
|                                       |                                   | --                   | 160           | --                                  | 0.906                                  | 6.813                                   | 0.2532                                                   | 74.69                                   | 15.80                                            |       |       |
|                                       |                                   | 10                   | 10.750        | --                                  | --                                     | 5S                                      | 0.134                                                    | 10.482                                  | 0.5992                                           | 15.19 | 37.39 |
| --                                    | --                                |                      |               | 10S                                 | 0.165                                  | 10.420                                  | 0.5922                                                   | 18.65                                   | 36.95                                            |       |       |
| --                                    | 20                                |                      |               | --                                  | 0.250                                  | 10.250                                  | 0.5731                                                   | 28.04                                   | 35.76                                            |       |       |
| --                                    | 30                                |                      |               | --                                  | 0.307                                  | 10.136                                  | 0.5603                                                   | 34.24                                   | 34.96                                            |       |       |
| STD                                   | 40                                |                      |               | 40S                                 | 0.365                                  | 10.020                                  | 0.5475                                                   | 40.48                                   | 34.20                                            |       |       |
| XS                                    | 60                                |                      |               | 80S                                 | 0.500                                  | 9.750                                   | 0.5185                                                   | 54.74                                   | 32.35                                            |       |       |
| --                                    | 80                                |                      |               | --                                  | 0.594                                  | 9.562                                   | 0.4989                                                   | 64.43                                   | 31.13                                            |       |       |
| --                                    | 100                               |                      |               | --                                  | 0.719                                  | 9.312                                   | 0.4732                                                   | 77.03                                   | 29.53                                            |       |       |
| --                                    | 120                               |                      |               | --                                  | 0.844                                  | 9.062                                   | 0.4481                                                   | 89.29                                   | 27.96                                            |       |       |
| XXS                                   | 140                               |                      |               | --                                  | 1.000                                  | 8.750                                   | 0.4176                                                   | 104.13                                  | 26.06                                            |       |       |
| --                                    | 160                               |                      |               | --                                  | 1.125                                  | 8.500                                   | 0.3941                                                   | 115.64                                  | 24.59                                            |       |       |
| 12                                    | 12.75                             |                      |               | --                                  | --                                     | 5S                                      | 0.156                                                    | 12.438                                  | 0.8438                                           | 20.98 | 52.65 |
|                                       |                                   |                      |               | --                                  | --                                     | 10S                                     | 0.180                                                    | 12.390                                  | 0.8373                                           | 24.17 | 52.25 |
|                                       |                                   |                      |               | --                                  | 20                                     | --                                      | 0.250                                                    | 12.250                                  | 0.8185                                           | 33.38 | 51.07 |
|                                       |                                   | --                   | 30            | --                                  | 0.330                                  | 12.090                                  | 0.7972                                                   | 43.77                                   | 49.74                                            |       |       |
|                                       |                                   | STD                  | 40            | 40S                                 | 0.375                                  | 12.000                                  | 0.7854                                                   | 49.56                                   | 49.00                                            |       |       |
|                                       |                                   | --                   | 60            | --                                  | 0.406                                  | 11.938                                  | 0.7773                                                   | 53.52                                   | 48.50                                            |       |       |
|                                       |                                   | XS                   | 80            | 80S                                 | 0.500                                  | 11.750                                  | 0.7528                                                   | 65.42                                   | 46.92                                            |       |       |
|                                       |                                   | --                   | 100           | --                                  | 0.562                                  | 11.626                                  | 0.7372                                                   | 73.15                                   | 46.00                                            |       |       |
|                                       |                                   | --                   | 120           | --                                  | 0.688                                  | 11.374                                  | 0.7058                                                   | 88.63                                   | 44.04                                            |       |       |
|                                       |                                   | --                   | 140           | --                                  | 0.844                                  | 11.062                                  | 0.6677                                                   | 107.32                                  | 41.66                                            |       |       |
|                                       |                                   | XXS                  | 160           | --                                  | 1.000                                  | 10.750                                  | 0.6303                                                   | 125.49                                  | 39.33                                            |       |       |
|                                       |                                   | --                   | --            | --                                  | 1.125                                  | 10.500                                  | 0.6013                                                   | 139.67                                  | 37.52                                            |       |       |
|                                       |                                   | --                   | --            | --                                  | 1.312                                  | 10.126                                  | 0.5592                                                   | 160.27                                  | 34.89                                            |       |       |
|                                       |                                   | --                   | --            | --                                  | --                                     | --                                      | --                                                       | --                                      | --                                               |       |       |
|                                       |                                   | --                   | --            | --                                  | --                                     | --                                      | --                                                       | --                                      | --                                               |       |       |

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# APPENDIX E (continued)

## PIPE DATA

| Nominal<br>Pipe<br>Size<br><br>Inches | Outside<br>Diameter<br><br>Inches | Identification       |               |                                     | Wall<br>Thickness<br>(t)<br><br>Inches | Inside<br>Diameter<br>(d)<br><br>Inches | Transverse<br>Internal Area<br>(A)<br><br>Square<br>Feet | Weight<br>Pipe<br>Pounds<br>per<br>foot | Weight<br>Water<br>Pounds<br>per foot<br>of pipe |
|---------------------------------------|-----------------------------------|----------------------|---------------|-------------------------------------|----------------------------------------|-----------------------------------------|----------------------------------------------------------|-----------------------------------------|--------------------------------------------------|
|                                       |                                   | Steel                |               | Stainless<br>Steel<br>Sched.<br>No. |                                        |                                         |                                                          |                                         |                                                  |
|                                       |                                   | Iron<br>Pipe<br>Size | Sched.<br>No. |                                     |                                        |                                         |                                                          |                                         |                                                  |
| 14                                    | 14.00                             | --                   | --            | 5S                                  | 0.156                                  | 13.688                                  | 1.0219                                                   | 23.07                                   | 63.77                                            |
|                                       |                                   | --                   | --            | 10S                                 | 0.188                                  | 13.624                                  | 1.0124                                                   | 27.73                                   | 63.17                                            |
|                                       |                                   | --                   | 10            | --                                  | 0.250                                  | 13.500                                  | 0.9940                                                   | 36.71                                   | 62.03                                            |
|                                       |                                   | --                   | 20            | --                                  | 0.312                                  | 13.376                                  | 0.9758                                                   | 45.61                                   | 60.89                                            |
|                                       |                                   | STD                  | 30            | --                                  | 0.375                                  | 13.250                                  | 0.9575                                                   | 54.57                                   | 59.75                                            |
|                                       |                                   | --                   | 40            | --                                  | 0.438                                  | 13.124                                  | 0.9394                                                   | 63.44                                   | 58.64                                            |
|                                       |                                   | XS                   | --            | --                                  | 0.500                                  | 13.000                                  | 0.9217                                                   | 72.09                                   | 57.46                                            |
|                                       |                                   | --                   | 60            | --                                  | 0.594                                  | 12.812                                  | 0.8956                                                   | 85.05                                   | 55.86                                            |
|                                       |                                   | --                   | 80            | --                                  | 0.750                                  | 12.500                                  | 0.8522                                                   | 106.13                                  | 53.18                                            |
|                                       |                                   | --                   | 100           | --                                  | 0.938                                  | 12.124                                  | 0.8020                                                   | 130.85                                  | 50.04                                            |
|                                       |                                   | --                   | 120           | --                                  | 1.094                                  | 11.812                                  | 0.7612                                                   | 150.79                                  | 47.45                                            |
|                                       |                                   | --                   | 140           | --                                  | 1.250                                  | 11.500                                  | 0.7213                                                   | 170.28                                  | 45.01                                            |
| --                                    | 160                               | --                   | 1.406         | 11.188                              | 0.6827                                 | 189.11                                  | 42.60                                                    |                                         |                                                  |
| 16                                    | 16.00                             | --                   | --            | 5S                                  | 0.165                                  | 15.670                                  | 1.3393                                                   | 27.90                                   | 83.57                                            |
|                                       |                                   | --                   | --            | 10S                                 | 0.188                                  | 15.624                                  | 1.3314                                                   | 31.75                                   | 83.08                                            |
|                                       |                                   | --                   | 10            | --                                  | 0.250                                  | 15.500                                  | 1.3103                                                   | 42.05                                   | 81.74                                            |
|                                       |                                   | --                   | 20            | --                                  | 0.312                                  | 15.376                                  | 1.2895                                                   | 52.27                                   | 80.50                                            |
|                                       |                                   | STD                  | 30            | --                                  | 0.375                                  | 15.250                                  | 1.2684                                                   | 62.58                                   | 79.12                                            |
|                                       |                                   | XS                   | 40            | --                                  | 0.500                                  | 15.000                                  | 1.2272                                                   | 82.77                                   | 76.58                                            |
|                                       |                                   | --                   | 60            | --                                  | 0.656                                  | 14.688                                  | 1.1766                                                   | 107.50                                  | 73.42                                            |
|                                       |                                   | --                   | 80            | --                                  | 0.844                                  | 14.312                                  | 1.1175                                                   | 136.61                                  | 69.73                                            |
|                                       |                                   | --                   | 100           | --                                  | 1.031                                  | 13.938                                  | 1.0596                                                   | 164.82                                  | 66.12                                            |
|                                       |                                   | --                   | 120           | --                                  | 1.219                                  | 13.562                                  | 1.0035                                                   | 192.43                                  | 62.62                                            |
|                                       |                                   | --                   | 140           | --                                  | 1.438                                  | 13.124                                  | 0.9394                                                   | 223.64                                  | 58.64                                            |
|                                       |                                   | --                   | 160           | --                                  | 1.594                                  | 12.812                                  | 0.8956                                                   | 245.25                                  | 55.83                                            |
| 18                                    | 18.00                             | --                   | --            | 5S                                  | 0.165                                  | 17.670                                  | 1.7029                                                   | 31.43                                   | 106.26                                           |
|                                       |                                   | --                   | --            | 10S                                 | 0.188                                  | 17.624                                  | 1.6941                                                   | 35.76                                   | 105.71                                           |
|                                       |                                   | --                   | 10            | --                                  | 0.250                                  | 17.500                                  | 1.6703                                                   | 47.39                                   | 104.21                                           |
|                                       |                                   | --                   | 20            | --                                  | 0.312                                  | 17.376                                  | 1.6467                                                   | 58.94                                   | 102.77                                           |
|                                       |                                   | STD                  | --            | --                                  | 0.375                                  | 17.250                                  | 1.6230                                                   | 70.59                                   | 101.18                                           |
|                                       |                                   | --                   | 30            | --                                  | 0.438                                  | 17.124                                  | 1.5990                                                   | 82.15                                   | 99.84                                            |
|                                       |                                   | XS                   | --            | --                                  | 0.500                                  | 17.000                                  | 1.5763                                                   | 93.45                                   | 98.27                                            |
|                                       |                                   | --                   | 40            | --                                  | 0.562                                  | 16.876                                  | 1.5533                                                   | 104.67                                  | 96.93                                            |
|                                       |                                   | --                   | 60            | --                                  | 0.750                                  | 16.500                                  | 1.4849                                                   | 138.17                                  | 92.57                                            |
|                                       |                                   | --                   | 80            | --                                  | 0.938                                  | 16.124                                  | 1.4183                                                   | 170.92                                  | 88.50                                            |
|                                       |                                   | --                   | 100           | --                                  | 1.156                                  | 15.688                                  | 1.3423                                                   | 207.96                                  | 83.76                                            |
|                                       |                                   | --                   | 120           | --                                  | 1.375                                  | 15.250                                  | 1.2684                                                   | 244.14                                  | 79.07                                            |
| --                                    | 140                               | --                   | 1.562         | 14.876                              | 1.2070                                 | 274.22                                  | 75.32                                                    |                                         |                                                  |
| --                                    | 160                               | --                   | 1.781         | 14.438                              | 1.1369                                 | 308.50                                  | 70.88                                                    |                                         |                                                  |
| 20                                    | 20.00                             | --                   | --            | 5S                                  | 0.188                                  | 19.624                                  | 2.1004                                                   | 39.78                                   | 131.06                                           |
|                                       |                                   | --                   | --            | 10S                                 | 0.218                                  | 19.564                                  | 2.0876                                                   | 46.06                                   | 130.27                                           |
|                                       |                                   | --                   | 10            | --                                  | 0.250                                  | 19.500                                  | 2.0740                                                   | 52.73                                   | 129.42                                           |
|                                       |                                   | STD                  | 20            | --                                  | 0.375                                  | 19.250                                  | 2.0142                                                   | 78.60                                   | 125.67                                           |
|                                       |                                   | XS                   | 30            | --                                  | 0.500                                  | 19.000                                  | 1.9690                                                   | 104.13                                  | 122.87                                           |
|                                       |                                   | --                   | 40            | --                                  | 0.594                                  | 18.812                                  | 1.9305                                                   | 123.11                                  | 120.46                                           |
|                                       |                                   | --                   | 60            | --                                  | 0.812                                  | 18.376                                  | 1.8417                                                   | 166.40                                  | 114.92                                           |
|                                       |                                   | --                   | 80            | --                                  | 1.031                                  | 17.938                                  | 1.7550                                                   | 208.87                                  | 109.51                                           |
|                                       |                                   | --                   | 100           | --                                  | 1.281                                  | 17.438                                  | 1.6585                                                   | 256.10                                  | 103.39                                           |
|                                       |                                   | --                   | 120           | --                                  | 1.500                                  | 17.000                                  | 1.5762                                                   | 296.37                                  | 98.35                                            |
|                                       |                                   | --                   | 140           | --                                  | 1.750                                  | 16.500                                  | 1.4849                                                   | 341.09                                  | 92.66                                            |
|                                       |                                   | --                   | 160           | --                                  | 1.969                                  | 16.062                                  | 1.4074                                                   | 379.17                                  | 87.74                                            |
| 22                                    | 22.00                             | --                   | --            | 5S                                  | 0.188                                  | 21.624                                  | 2.5503                                                   | 43.80                                   | 159.14                                           |
|                                       |                                   | --                   | --            | 10S                                 | 0.218                                  | 21.564                                  | 2.5362                                                   | 50.71                                   | 158.26                                           |
|                                       |                                   | --                   | 10            | --                                  | 0.250                                  | 21.500                                  | 2.5212                                                   | 58.07                                   | 157.32                                           |
|                                       |                                   | STD                  | 20            | --                                  | 0.375                                  | 21.250                                  | 2.4629                                                   | 86.61                                   | 153.68                                           |
|                                       |                                   | XS                   | 30            | --                                  | 0.500                                  | 21.000                                  | 2.4053                                                   | 114.81                                  | 150.09                                           |
|                                       |                                   | --                   | 60            | --                                  | 0.875                                  | 20.250                                  | 2.2365                                                   | 197.41                                  | 139.56                                           |
|                                       |                                   | --                   | 80            | --                                  | 1.125                                  | 19.75                                   | 2.1275                                                   | 250.81                                  | 132.76                                           |
|                                       |                                   | --                   | 100           | --                                  | 1.375                                  | 19.25                                   | 2.0211                                                   | 302.88                                  | 126.12                                           |
|                                       |                                   | --                   | 120           | --                                  | 1.625                                  | 18.75                                   | 1.9175                                                   | 353.61                                  | 119.65                                           |
|                                       |                                   | --                   | 140           | --                                  | 1.875                                  | 18.25                                   | 1.8166                                                   | 403.00                                  | 113.36                                           |
|                                       |                                   | --                   | 160           | --                                  | 2.125                                  | 17.75                                   | 1.7184                                                   | 451.06                                  | 107.23                                           |

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# APPENDIX E (continued)

## PIPE DATA

| Nominal<br>Pipe<br>Size<br><br>Inches | Outside<br>Diameter<br><br>Inches | Identification       |               |                                     | Wall<br>Thickness<br>(t)<br><br>Inches | Inside<br>Diameter<br>(d)<br><br>Inches | Transverse<br>Internal Area<br>(A)<br>Square<br>Feet | Weight<br>Pipe<br>Pounds<br>per<br>foot | Weight<br>Water<br>Pounds<br>per foot<br>of pipe |
|---------------------------------------|-----------------------------------|----------------------|---------------|-------------------------------------|----------------------------------------|-----------------------------------------|------------------------------------------------------|-----------------------------------------|--------------------------------------------------|
|                                       |                                   | Steel                |               | Stainless<br>Steel<br>Sched.<br>No. |                                        |                                         |                                                      |                                         |                                                  |
|                                       |                                   | Iron<br>Pipe<br>Size | Sched.<br>No. |                                     |                                        |                                         |                                                      |                                         |                                                  |
|                                       |                                   | --                   | --            | 5S                                  | 0.218                                  | 23.564                                  | 3.0285                                               | 55.37                                   | 188.98                                           |
|                                       |                                   | --                   | 10            | 10S                                 | 0.250                                  | 23.500                                  | 3.0121                                               | 63.41                                   | 187.95                                           |
| 24                                    | 24.00                             | STD                  | 20            | --                                  | 0.375                                  | 23.250                                  | 2.9483                                               | 94.62                                   | 183.95                                           |
|                                       |                                   | XS                   | --            | --                                  | 0.500                                  | 23.000                                  | 2.8853                                               | 125.49                                  | 179.87                                           |
|                                       |                                   | --                   | 30            | --                                  | 0.562                                  | 22.876                                  | 2.8542                                               | 140.68                                  | 178.09                                           |
|                                       |                                   | --                   | 40            | --                                  | 0.688                                  | 22.624                                  | 2.7921                                               | 171.29                                  | 174.23                                           |
|                                       |                                   | --                   | 60            | --                                  | 0.969                                  | 22.062                                  | 2.6552                                               | 238.35                                  | 165.52                                           |
|                                       |                                   | --                   | 80            | --                                  | 1.219                                  | 21.562                                  | 2.5362                                               | 296.58                                  | 158.26                                           |
|                                       |                                   | --                   | 100           | --                                  | 1.531                                  | 20.938                                  | 2.3911                                               | 367.39                                  | 149.06                                           |
|                                       |                                   | --                   | 120           | --                                  | 1.812                                  | 20.376                                  | 2.2645                                               | 429.39                                  | 141.17                                           |
|                                       |                                   | --                   | 140           | --                                  | 2.062                                  | 19.876                                  | 2.1547                                               | 483.12                                  | 134.45                                           |
|                                       |                                   | --                   | 160           | --                                  | 2.344                                  | 19.312                                  | 2.0346                                               | 542.13                                  | 126.84                                           |
| 26                                    | 26.00                             | --                   | 10            | --                                  | 0.312                                  | 25.376                                  | 3.5122                                               | 85.60                                   | 219.16                                           |
|                                       |                                   | STD                  | --            | --                                  | 0.375                                  | 25.250                                  | 3.4774                                               | 102.63                                  | 216.99                                           |
|                                       |                                   | XS                   | 20            | --                                  | 0.500                                  | 25.000                                  | 3.4088                                               | 136.17                                  | 212.71                                           |
| 28                                    | 28.00                             | --                   | 10            | --                                  | 0.312                                  | 25.376                                  | 4.0876                                               | 92.26                                   | 255.07                                           |
|                                       |                                   | STD                  | --            | --                                  | 0.375                                  | 27.250                                  | 4.0501                                               | 110.64                                  | 252.73                                           |
|                                       |                                   | XS                   | 20            | --                                  | 0.500                                  | 27.000                                  | 3.9761                                               | 146.85                                  | 248.11                                           |
|                                       |                                   | --                   | 30            | --                                  | 0.625                                  | 26.750                                  | 3.9028                                               | 182.73                                  | 243.53                                           |
| 30                                    | 30.00                             | --                   | --            | 5S                                  | 0.250                                  | 29.500                                  | 4.7465                                               | 79.43                                   | 296.18                                           |
|                                       |                                   | --                   | 10            | 10S                                 | 0.312                                  | 29.376                                  | 4.7067                                               | 98.93                                   | 293.70                                           |
|                                       |                                   | STD                  | --            | --                                  | 0.375                                  | 29.250                                  | 4.6664                                               | 118.65                                  | 291.18                                           |
|                                       |                                   | XS                   | 20            | --                                  | 0.500                                  | 29.000                                  | 4.5869                                               | 157.53                                  | 286.22                                           |
|                                       |                                   | --                   | 30            | --                                  | 0.625                                  | 28.750                                  | 4.5082                                               | 196.08                                  | 281.31                                           |
| 32                                    | 32.00                             | --                   | 10            | --                                  | 0.312                                  | 31.376                                  | 5.3694                                               | 105.59                                  | 335.05                                           |
|                                       |                                   | STD                  | --            | --                                  | 0.375                                  | 31.250                                  | 5.3263                                               | 126.66                                  | 332.36                                           |
|                                       |                                   | XS                   | 20            | --                                  | 0.500                                  | 31.000                                  | 5.2414                                               | 168.21                                  | 327.06                                           |
|                                       |                                   | --                   | 30            | --                                  | 0.625                                  | 30.750                                  | 5.1572                                               | 209.43                                  | 321.81                                           |
|                                       |                                   | --                   | 40            | --                                  | 0.688                                  | 30.624                                  | 5.1151                                               | 230.08                                  | 319.18                                           |
| 34                                    | 34.00                             | --                   | 10            | --                                  | 0.344                                  | 33.312                                  | 6.0524                                               | 123.65                                  | 377.67                                           |
|                                       |                                   | STD                  | --            | --                                  | 0.375                                  | 33.250                                  | 6.0299                                               | 134.67                                  | 376.27                                           |
|                                       |                                   | XS                   | 20            | --                                  | 0.500                                  | 33.000                                  | 5.9396                                               | 178.89                                  | 370.63                                           |
|                                       |                                   | --                   | 30            | --                                  | 0.625                                  | 32.750                                  | 5.8499                                               | 222.78                                  | 365.03                                           |
|                                       |                                   | --                   | 40            | --                                  | 0.688                                  | 32.624                                  | 5.8050                                               | 244.07                                  | 362.23                                           |
| 36                                    | 36.00                             | --                   | 10            | --                                  | 0.312                                  | 35.376                                  | 6.8257                                               | 118.92                                  | 425.92                                           |
|                                       |                                   | STD                  | --            | --                                  | 0.375                                  | 35.250                                  | 6.7771                                               | 142.68                                  | 422.89                                           |
|                                       |                                   | XS                   | 20            | --                                  | 0.500                                  | 35.000                                  | 6.6813                                               | 189.57                                  | 416.91                                           |
|                                       |                                   | --                   | 30            | --                                  | 0.625                                  | 34.750                                  | 6.5862                                               | 236.13                                  | 417.22                                           |
|                                       |                                   | --                   | 40            | --                                  | 0.750                                  | 34.500                                  | 6.4918                                               | 282.35                                  | 405.09                                           |

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## APPENDIX F

Heat Exchange Institute, Inc.  
Standards and Typical Specifications for Tray Type Deaerators 9th Edition

### DEAERATOR SPECIFICATION SHEET

|     |                                              |                                           |                                            |
|-----|----------------------------------------------|-------------------------------------------|--------------------------------------------|
| 1.  | CUSTOMER                                     | DATE                                      |                                            |
| 2.  | ADDRESS                                      | CUSTOMER NO.                              |                                            |
| 3.  | PLANT LOCATION                               | PROPOSAL NO.                              |                                            |
| 4.  | SERVICE OF UNIT                              | JOB NO.                                   |                                            |
| 5.  | TYPE Spray Tray/Spray Scrubber               | ITEM NO.                                  |                                            |
| 6.  | NO. UNITS                                    |                                           |                                            |
| 7.  |                                              | 7a. HEATER<br>ORIENTATION<br>(HOR) (VERT) | 7b. STORAGE<br>ORIENTATION<br>(HOR) (VERT) |
| 8.  | <b>PERFORMANCE</b>                           |                                           |                                            |
| 9.  |                                              | RECOMMENDED                               | DESIGN POINT                               |
| 10. | FLOWS                                        | —                                         | AVG. FLOW                                  |
| 11. | MAKE-UP                                      | —                                         | #HR °F.                                    |
| 12. | LP CONDENSATE                                | —                                         | #HR °F.                                    |
| 13. | HP CONDENSATE                                | —                                         | #HR °F.                                    |
| 14. | STEAM                                        | —                                         | #HR °F.                                    |
| 15. | OTHER                                        | —                                         | #HR °F.                                    |
| 16. | TOTAL OUTLET                                 | —                                         | #HR °F.                                    |
| 17. | BFP RECIRCULATION                            | —                                         | #HR °F.                                    |
| 18. | OPERATING PRESSURE/TEMP                      | —                                         | PSIG °F.                                   |
| 19. | OTHER SPECIAL CONDITIONS                     | —                                         |                                            |
| 20. |                                              |                                           |                                            |
| 21. |                                              |                                           |                                            |
| 22. | VENT RATE (% OF STEAM INLET)                 | 0.5%                                      | #HR                                        |
| 23. | EFFLUENT PPB O <sub>2</sub> /CO <sub>2</sub> | 7 / 0                                     | PPB PPB                                    |
| 24. | STORAGE TANK CAPACITY AT OVERFLOW (MIN)      | —                                         |                                            |
| 25. |                                              |                                           |                                            |
| 26. | <b>CONSTRUCTION</b>                          |                                           |                                            |
| 27. |                                              | HEATER                                    | STORAGE                                    |
| 28. | DESIGN PRESSURE                              | —                                         | PSIG                                       |
| 29. | VACUUM                                       | —                                         | PSIG                                       |
| 30. | TEST PRESSURE                                | —                                         | PSIG                                       |
| 31. | DESIGN TEMPERATURE                           | —                                         | °F.                                        |
| 32. | SHELL THICKNESS                              | —                                         | IN.                                        |
| 33. | HEAD THICKNESS                               | —                                         | IN.                                        |
| 34. | TYPE HEADS F&D/2:1                           | —                                         |                                            |
| 35. | CORROSION ALLOWANCE (IN.)                    | 1/8 IN.                                   | IN.                                        |
| 36. | VACUUM RINGS                                 | —                                         |                                            |
| 37. | WEIGHT: EMPTY/OPERATING/FLOODED              | —                                         | / /                                        |
| 38. | RADIOGRAPHY: HEAD/SHELL                      | 1.0 JE.                                   | /                                          |
| 39. | MAGNETIC PARTICLE INSPECTION                 | INCL.                                     |                                            |
| 40. | LIQUID DYE PENETRANT                         | INCL.                                     |                                            |
| 41. | STRESS RELIEF: (1 STAGE/2 STAGE)             | INCL.                                     |                                            |
| 42. | ASME CODE SECTION (8 OR 1)                   | —                                         |                                            |
| 43. | SURFACE PREP: INT/EXT                        | —                                         | /                                          |
| 44. | INSULATION CLIPS                             | —                                         |                                            |
| 45. | <b>MATERIALS</b>                             |                                           |                                            |
| 46. |                                              | HEATER                                    | STORAGE                                    |
| 47. | SHELL                                        | SA516-70                                  |                                            |
| 48. | WATERBOX                                     | 1/4" S.S. min, L grade                    |                                            |
| 49. | INLET WATERPIPE                              | S.S. 10s<br>S.S., L grade                 |                                            |
| 50. | TRAYS                                        | 20 g S.S.                                 |                                            |
| 51. | SPRAY VALVES                                 | S.S.                                      |                                            |
| 52. | TRAY ENCLOSURE                               | 1/8" S.S. min, L grade                    |                                            |
| 53. | VENT CONDENSER                               | 1/8" S.S. min, L grade                    |                                            |
| 54. | <b>ACCESSORIES</b>                           |                                           |                                            |
| 55. |                                              |                                           |                                            |
| 56. |                                              |                                           |                                            |
| 57. |                                              |                                           |                                            |
| 58. |                                              |                                           |                                            |
| 59. |                                              |                                           |                                            |





## **Heat Exchange Institute, Inc.**

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#### **Deaerator Tech Sheets**

Tech Sheet #121: Vacuum Relief

Tech Sheet #120: Steam Pressure Control Valves

Tech Sheet #119: Safety and Relief Valves

Tech Sheet #118: Level Control

Tech Sheet #114: Deaerator Accessories

Tech Sheet #112: Technical Discussion  
on Pressure Vessel Post Weld Heat Treatment

Tech Sheet #111: Radiographic Testing (RT)  
Deaerator Vessels

Tech Sheet 109: Corrosion Allowance  
in Deaerator Design

Tech Sheet 108: Magnetic Particle Testing  
in New Deaerators

Tech Sheet 105: Deaerator Troubleshooting Guide

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