

PRESSURE RELIEVING DESIGN**JGS 210-120-1-40E**

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1. SCOPE

- (1) This standard practice provides the recommendations and the guidelines to calculate the relieving rates that result from various causes of overpressure in order to design the pressure relieving system in refineries, petrochemical plants and similar plants.
- (2) This standard practice shall be applied with the regulations of pressure relieving facilities in the country where the facilities will be installed. The requirements of the national and local regulations shall take precedence over any other requirements indicated in this practice.
- (3) Specific instructions given in the Project Specifications take precedence over the requirements given in this standard practice.

2. WORK PROCEDURE**2.1 Input to the Design****2.1.1 Source of Process Conditions**

The data to be used for the calculation of the pressure relieving load should be clarified on the following points:

- (1) Source of data

The data will be obtained from, but not limited to, the following documents:

- Process Flow Diagram (PFD)
- Basic Engineering Design Data (BEDD)
- Piping & Instrument Diagram (P&ID)
- Equipment data sheets
- Piping material specification
- Safety relief valve summary
- Rupture disk summary

- (2) Related documents to be used as a part of the input data.
- (3) Related documents to be checked or revised based on the calculation results.

2.1.2 Required Data for Calculation

The following is a summary of data to be used for the calculation of pressure relieving load :

- (1) General data

- Item No. and service of protected equipment
- Tag number of pressure relief devices
- Service for identification
- Code and standard to be applied, if specified

- (2) Relieving data

- Normal operating pressure and temperature
- Design pressure
- Physical properties at relieving conditions :
Latent heat of vaporization, Enthalpies for vapor and liquid, Molecular weight of vapor
- Cause of failure

- (3) Construction data

- Destination of discharge

2.2 Output from the Calculation

Safety relief valve summary or rupture disc summary as a product of basic design should include, but not limited to, the following ;

(1) General data

- Item No. and service of protected equipment
- Tag number of pressure relief devices
- Service for identification
- Code and standard to be applied, if specified
- Normal operating pressure and temperature
- Set pressure or specified bursting pressure

(2) Relieving load data

- Cause of failure
- Fluid name for identification
- Required relieving capacity
- Relieving temperature, inlet/outlet
- Physical properties at relieving conditions
 - Liquid service : Specific gravity, Viscosity
 - Vapor service : Molecular weight, Viscosity, Specific heat ratio (k), Compressibility factor (Z)
 - Two-phase flow : all data for liquid and vapor
- Back pressure, maximum and constant for controlling case, if available.
- Accumulation of Relieving pressure

(3) Construction data

- Destination of discharge

2.3 Work Steps

The preparation of safety relief valve summary should be conducted as follows ;

- (1) Evaluation of causes of failure
- (2) Establishing calculation basis such as fire area, fire elevation, relative effects of causes and so on.
- (3) Relieving load calculation
- (4) Complete safety relief valve or rupture disc summary

2.4 Computer Programs

Computer program is not available. (BEST can be used near future)

3. DESIGN

3.1 General

3.1.1 Basic Concept

- (1) In sizing the pressure relief valve, the typical contingencies which should be examined are as follows.
 - (a) External fire
 - (b) Closed outlets on vessels
 - (c) Inadvertent valve opening such as gas break through
 - (d) Check-valve malfunction
 - (e) Utility failure : Electricity, Cooling water, Instrument air, Steam, Fuel gas, Fuel oil, Inert gas, and so on.
 - (f) Equipment failure : Fans, Compressor, Pump, Blower, and so on
 - (g) Abnormal process condition : For example, runaway reaction, and so on
 - (h) Thermal expansion
 - (i) Tube rupture of heat exchanger
 - (j) Transient pressure surges
- (2) The probability of two unrelated contingencies, double-failure, does not need to be considered ¹.
- (3) Fail-safe devices and automatic start-up equipment should not replace pressure relieving devices as protection for individual process equipment. However, when a relieving system is designed for multiple contingencies, the continued operation of these devices may be considered if overpressure is attributed to a different contingency ².
- (4) If one of the two energy sources fails, partial credit may be given for the other power source that continues to function ³.
- (5) Fans on air-cooled exchangers or cooling towers occasionally become inoperative because of a loss of power or a mechanical breakdown. On air-cooled exchangers and cooling towers, independent operation of the louvers can be maintained by convection and radiation in still air at ambient conditions ⁴.
Because of natural convection effects, credit for a partial condensing capacity of 20 - 30% of normal duty is often used unless the effects at relieving conditions are determined to be significantly different ⁵.
- (6) A commonly accepted time range for the operator response is between 10 and 30 minutes, depending on the complexity of the plant ⁶. It should be assumed that the operational staff are well trained and , therefore, it will not be necessary to consider complex miss-operation.
- (7) Unless the condition of flow through the control valves changes, credit may be taken for the normal capacity of these valves, corrected to relieving conditions, provided that the downstream system is capable of handling any increased flow ⁷.
To evaluate relieving requirements for any reason, it should be assumed that all automatic control valves remain in the position required for normal process flow.
- (8) Where limit stops are installed on valves including control valves, the wide-open capacity, rather than the capacity at the stop setting, should be used for relieving calculation ⁸.
- (9) In shell-and-tube heat exchange equipment, heat input should be calculated on the basis of clean, rather than foul, conditions ⁹ if no other specific instruction given.
Reboilers and vaporizers are designed for specified heat inputs. But additional heat input above the normal design can occur, when these heat exchangers are new or have been recently cleaned.

¹ API RP521 3.2

² API RP521 2.2

³ API RP521 2.3.6

⁴ API RP521 2.3.8

⁵ API RP521 3.6.4

⁶ API RP521 3.4

⁷ API RP521 3.10.2

⁸ API RP521 3.11

⁹ API RP521 3.11

3.1.2 Relieving Load Calculation

- (1) A relieving load due to a particular contingency should generally be calculated based on the heat and material balance under failure condition. In a failure condition, operating pressures, temperatures, flow rates, and heat duties will change to new conditions where complete heat and material balance can not be calculated. Therefore, hypothetical *material accumulation* should be introduced to account for any discrepancies in heat and material balance. The relieving load calculation is basically as follows (derivation is shown on the Technical Report [1]) :

$$W = \frac{1}{\lambda} \left[\sum_i (H_i - H_L) W_i + \sum_j \Delta Q_j \right] \quad (1)$$

Where :

	Metric	SI	British
W = relieving load	(kg/h)	(kg/s)	(lb/h)
W _i = flow rate into(+)/from(-) system	(kcal/h)	(kW)	(Btu/h)
H _i = enthalpy of fluid	(kcal/kg)	(kJ/kg)	(Btu/lb)
λ = latent heat of vaporization = H _V - H _L	(kcal/kg)	(kJ/kg)	(Btu/lb)
H _V = enthalpy of relieving vapor	(kcal/kg)	(kJ/kg)	(Btu/lb)
H _L = enthalpy of liquid in equilibrium with relieving vapor	(kcal/kg)	(kJ/kg)	(Btu/lb)
ΔQ _j = heat duty into(+)/from(-) system	(kcal/h)	(kW)	(Btu/h)

Refer to Appendix-1, A1.3 "Examples of Relieving Load Calculation".

- (2) The physical properties should be used at the relieving pressure and the corresponding equilibrium temperature in calculating the relieving load.
- For the distillation tower, since the material accumulation should be evaluated at the tray where liquid re-vaporization takes a place, the physical properties should be taken at a tray two or three below the top tray.
- (3) In special case such as external fire where no feed and product flow exist, a relieving rate can be calculated based on net heat absorbed and latent heat of vaporization at the relieving condition as follows ;

$$W = \frac{1}{\lambda} \sum_j \Delta Q_j \quad (2)$$

- (4) During pressure relieving, the changes in vapor rates and molecular weights at various time intervals should be investigated to determine the peak relieving rate and the composition of the vapor ¹⁰.

3.1.3 Emergency Shutdown System

- (1) To minimize the flaring load under a general emergency such as electric power failure or cooling water failure, an emergency shutdown system (ESD system) should be adopted and immediately cut the plant feed and the heat input to distillation towers which will be a cause of relieving.
- (2) It is standard practice for designing a flare system to assume that the trip functions on individual equipment for relieving will not be correctly activated by the ESD system.
- However, for redundant ESD system such as two-out-of-three system, assume that the trip functions can be activated correctly.

¹⁰ API RP521 3.3

3.2 External Fire

- (1) When a fire occurs, it will be assumed that all fluid flow to the equipment in the fire risk area has been stopped and that the equipment contain a normal liquid inventory.
Also in assessing the effects of a fire, it shall be assumed that the air tubing to all pneumatic control valves will be destroyed so the valves will act as they would on air failure.
- (2) Fire area :
All vessels and exchangers within a 20 meter fire circle shall be considered to contribute to the calculated relief quantity. The vapor quantities generated in each exposed vessel and exchanger shall be calculated separately ¹¹.
- (3) Duration of fire :
The design period during which the equipment is exposed to a fire shall be 20 to 60 minutes ¹².
- (4) Installation of pressure relief valve for fire contingency :
Fire pressure relief valves shall be installed if all of the following circumstances apply :
(a) If the equipment is located in an area where a sizable fire may occur.
(b) If the equipment under consideration can be blocked in while the unit remains in operation.
(c) If the equipment is not adequately protected with a pressure relief valve for operational emergencies.
(d) If the wetted area of equipment below the fire elevation can not be ignored.
- (5) Vessels not requiring protection against fire contingency :
If the equipment is basically constructed with pipe, a pressure relief valve is not required for protection against fire exposure. This is on the basis that piping is not provided with protection against overpressure from fire contingency. If overpressure can result from contingencies other than fire, however, pressure relief valve is required.

3.2.1 Heat Absorption

- (1) API basis
Heat absorption shall be calculated as follows ¹³:

$$Q = q_0 \cdot F \cdot A^{0.82} \quad (3)$$

Where :

	Metric	SI	British
Q = total heat absorbed	(kcal/h)	(kW)	(Btu/h)
F = environmental factor, see 3.2.2	(-)	(-)	(-)
A = wetted surface, see 3.2.3	(m ²)	(m ²)	(ft ²)
q ₀ =	37,130	43.2	21,000

- (2) The conservative value of q₀ = 34,500 in British units which will oversize the safety relief valve, is provided in API RP521 Appendix A formula A-3. This value should, however, be used only when physical properties for the fluid are not available ¹⁴.

¹¹ JGC standard. API RP521 3.19.2.2 and 5.2.2 recommend the fire area of 230 - 460 m².

¹² API RP521 3.15.2.2

¹³ API RP521 A.5.1

¹⁴ API RP521 3.3

(3) HPGCL (High Pressure Gas Control Law - Japan) basis Heat absorption formula shall be classified as follows.

$$Q = q_0 \cdot A^{0.82} \text{ (without insulation)}$$

$$= q_1 \cdot \frac{\lambda \{ (650 - t) A^{0.82} + H \}}{\delta L} \text{ (with insulation)}$$

Where:

	Metric	SI
Q = total heat absorbed	(kcal/h)	(kW)
A = wetted surface, see 3.2.3	(m ²)	(m ²)
q ₀ =	61,000	71.0
q ₁ =	2.61	0.003
L = latent heat of fluid at relieving pressure	(kcal/kg)	(kW/kg)
t = relieving temperature at relieving pressure	(°C)	(°C)
H = correction factor due to sunshine heat source	(H ₁) or other (H ₂)	
H ₁ = (65 - t) × 0.5A		
H = H ₁ + H ₂		
δ = thickness of insulation	(m)	(m)
λ = thermal conductivity of insulation	(kcal/m·hr°C)	(W/hr·°K)

The calculation method of heat absorption are requested in each Codes and Standards. Refer to the following documents in detail.

NFPA 30	Flammable and Combustible Liquids Code
NFPA 59	Standard for the Storage and Handling of LP Gases at Utility Gas Plants
NFPA 59A	Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)

3.2.2 Environment Factor

(1) Environment factors, F, shall be taken as follows :

Table-2 Environment factor [API RP521 a.5 and A.8.3.1]

Type of equipment	U (kcal/m ² ·h.°C)	Factor F API RP521	Factor F NFPA 30
Bare vessel	-	1.0	1.0
Insulated vessel, see item (3) for insulation materials and thermal conductivity.	20 10 5 3.3 2.5 2.0 1.25	0.3 0.15 0.075 0.05 0.0376 0.03 0.026	0.3 (Note-1)
Water-application facilities on bare vessel	-	1.0	0.3
Water-application facilities on insulated vessel	-	1.0	0.15
Depressuring and emptying facilities	-	1.0	-
Underground storage	-	0.0	0.3 (Note-2)
Earth-covered storage above grade	-	0.03	-

(Note-1) Applicable for k < 6 kcal/m·h.°C at mean temperature of 537.8°C

(Note-2) Indicated in NFPA 59 Para. 3-4.1

(2) The overall heat transfer coefficient, U , should be calculated as follows ¹⁵ ;

$$U = \frac{k}{t} \quad (4)$$

Where :

U = overall heat transfer coefficient (kcal/m².h.°C)

k = thermal conductivity of insulation material at mean temperature between 904°C and internal temperature. (kcal/m.h.°C)

t = insulation thickness (m)

(3) Fire proofing effect of insulation system :

(a) Credit can be taken for external insulation to reduce the heat absorption, satisfying the following requirements :

- The insulating material should be fixed by stainless steel bands and covered with galvanized or stainless steel jacket, to resist dislodgment by fire hose streams ¹⁶.
- The insulating material being used can withstand a temperature of 650°C for one(1) hour ¹⁷.
- Thermal conductivity of the insulation material should be evaluated as the value at the mean temperature between 904°C and relieving temperature ¹⁸.

(b) The insulating materials which satisfy the above requirements are as follows :

- Calcium silicate
- Perlite

(c) For full liquid service which do not require insulation from process requirement, a fire proof insulation should be considered so that fire relief load can be drastically reduced.

3.2.3 Wetted Surface

(1) To determine vaporization rate, the surface area wetted by a vessel's internal liquid and is up to 7.5m (25 feet) above grade , denoted as "fire elevation", needs to be considered. The term "grade" usually refers to ground level, but may be at any level at which a sizable fire could be sustained ¹⁹.

NOTE : The fire elevation shall not be applied to the Project in Japan, since no limitation is requested in the Japanese Codes and Standards.

(2) Effects of fire on the wetted surface of equipment

Table-3.2.3 Wetted surface [API RP521 3.19.2.3 and A.5.1]

Class of Vessel	Portion of Liquid Inventory	Remarks
Columns	Normal liquid level of the column bottom and the draw-off tray capacity, plus normal tray liquid holdup; total wetted surface up to the fire elevation.	Level in reboiler is to be included if the reboiler is an integral part of the column.

¹⁵ API RP521 3.15.2.4

¹⁶ API RP521 3.15.2.3

¹⁷ Established based on API RP521 3.15.2.2

¹⁸ API RP521 3.15.2.4 and A.8.3.1

¹⁹ API RP521 A.4

(1) Bottom section A_B

A skirt is covered with concrete.

(a) $L_1 + L_2 \leq 7.5$ (m) or HPGCL basis

$$A = \left(L_1 + \frac{D}{4} + 0.15D \right) \pi D \text{ (m}^2\text{)}$$

(b) $L_1 + L_2 > 7.5$ (m)

$$A = \left(7.5 - L_2 + \frac{D}{4} + 0.15D \right) \pi D \text{ (m}^2\text{)}$$

(2) Tray section A_t

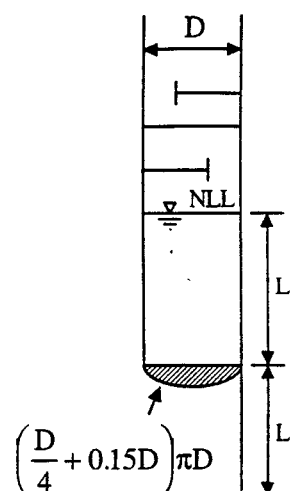
$$A_t = hw \times \pi D \times N$$

Where:

hw = weir height

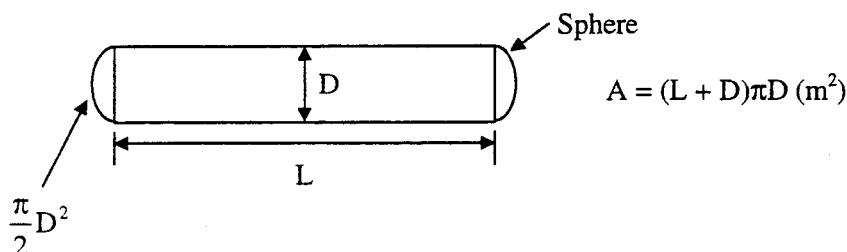
If not specified, 0.05 m is assumed as standard value.

= bed height (for packing)



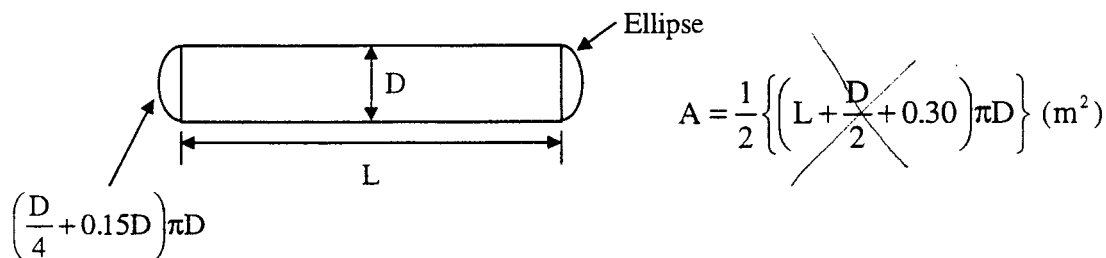
Liquid fill vessel

All surface up to the fire elevation



Surge drum

N.L.L of all surface up to the fire elevation

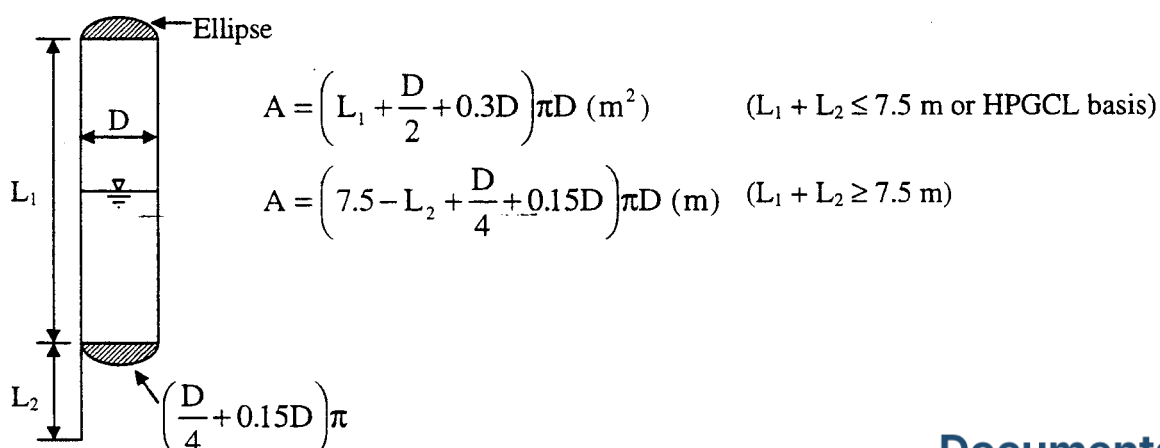


NOTE: All surface area should be considered in HPGCL basis.

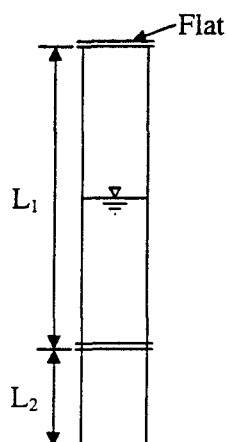
Knock out drum

All surface p to the fire elevation

(a)



(b)



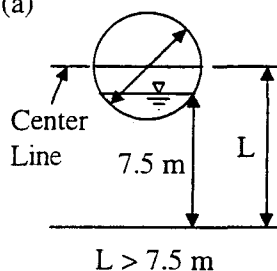
$$A = \left(L_1 + \frac{D}{2} \right) \pi D \text{ (m}^2\text{)} \quad (L_1 + L_2 \leq 7.5 \text{ m or HPGCL basis})$$

$$A = \left(7.5 - L_2 + \frac{D}{4} \right) \pi D \text{ (m)} \quad (L_1 + L_2 \geq 7.5 \text{ m})$$

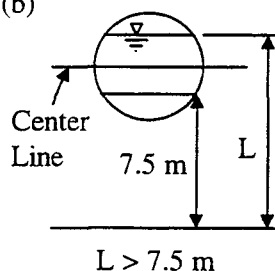
Spherer

All surface up to the fire elevation

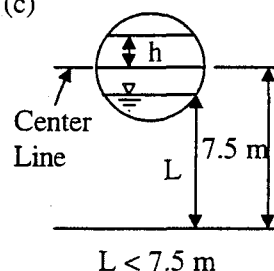
(a)

 $L > 7.5 \text{ m}$

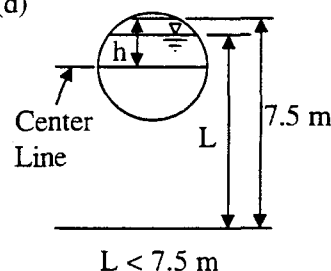
(b)

 $L > 7.5 \text{ m}$

(c)

 $L < 7.5 \text{ m}$

(d)

 $L < 7.5 \text{ m}$

$$\text{a, b} \quad A = \frac{\pi}{2} D^2 \text{ (m}^2\text{)}$$

$$\text{c, d} \quad A = \frac{\pi}{2} (D + h) D \text{ (m}^2\text{)}$$

Air-cooled exchangers

Since fins on the outer surface can not withstand under fire exposure, as a basic concept, outer surface area should be evaluated on bare tube basis ²⁰.

The other concept is that the continuity of vaporization at the wetted surface, i.e. continuity of wetted surface, is necessary to increase the internal pressure; this is evaluated as a inventory of liquid that will be possibly vaporized. The total vapor input into air-cooled exchanger under relieving conditions will be a reasonable minimum for condensing services ²¹.

Although the following instructions, (a) to (e), are offered as a guide, the individual circumstances involved in each situation should be considered to determine the wetted surface for air-cooled exchanger.

(a) Condensing without subcooling

The wetted surface area is equal to 0.3 times the bare tube area (based on the bottom 30 percent of the circumference being wetted by the condensate layer).

(b) Condensing with subcooling

The condensing section should be treated as in Item 1; for the subcooling section, the wetted surface area is equal to the bare tube area.

(c) Gas cooling

The surface area is equal to the bare tube area.

²⁰ API RP521 3.15.4.1

²¹ API RP521 3.15.4.2

(d) Liquid cooling service ²²

The wetted surface area is equal to the bare tube area.

(e) No height limit on fire exposure should apply ²³.(f) Water spray will not be effective because the reliability of effective water application depends on so many variable factors ²⁴.

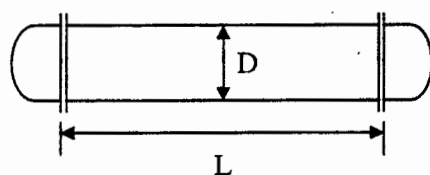
In the wetted-surface cases, the area term, A, would be taken to an exponent of 1.0 instead of 0.82 as is done for vessels; the environmental factor for insulation, F, would be taken as 1.0.

Table-4 Wetted surface

Heat exchanger	All surface up to the fire elevation
----------------	--------------------------------------

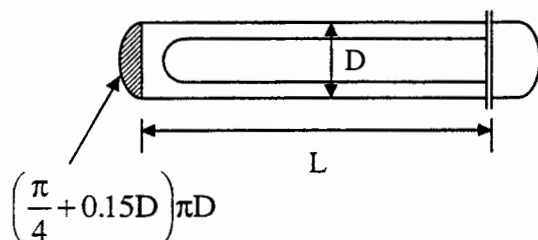
Shell side

(a) Fixed type



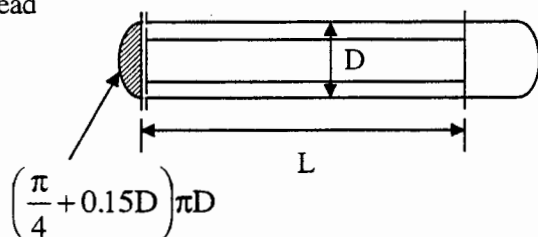
$$A = \pi DL \text{ (m}^2\text{)}$$

(b) U-tube



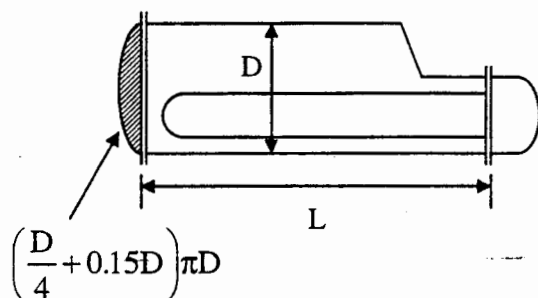
$$A = \left(L + \frac{D}{4} + 0.15D \right) \pi D \text{ (m}^2\text{)}$$

(c) Floating head



$$A = \left(L + \frac{D}{4} + 0.15D \right) \pi D \text{ (m}^2\text{)}$$

(d) Kettle type



$$A = \left(L + \frac{D}{4} + 0.15D \right) \pi D \text{ (m}^2\text{)}$$

²² API RP521 3.15.4.3

²³ API RP521 3.15.4.4

²⁴ API RP521 3.15.4.5