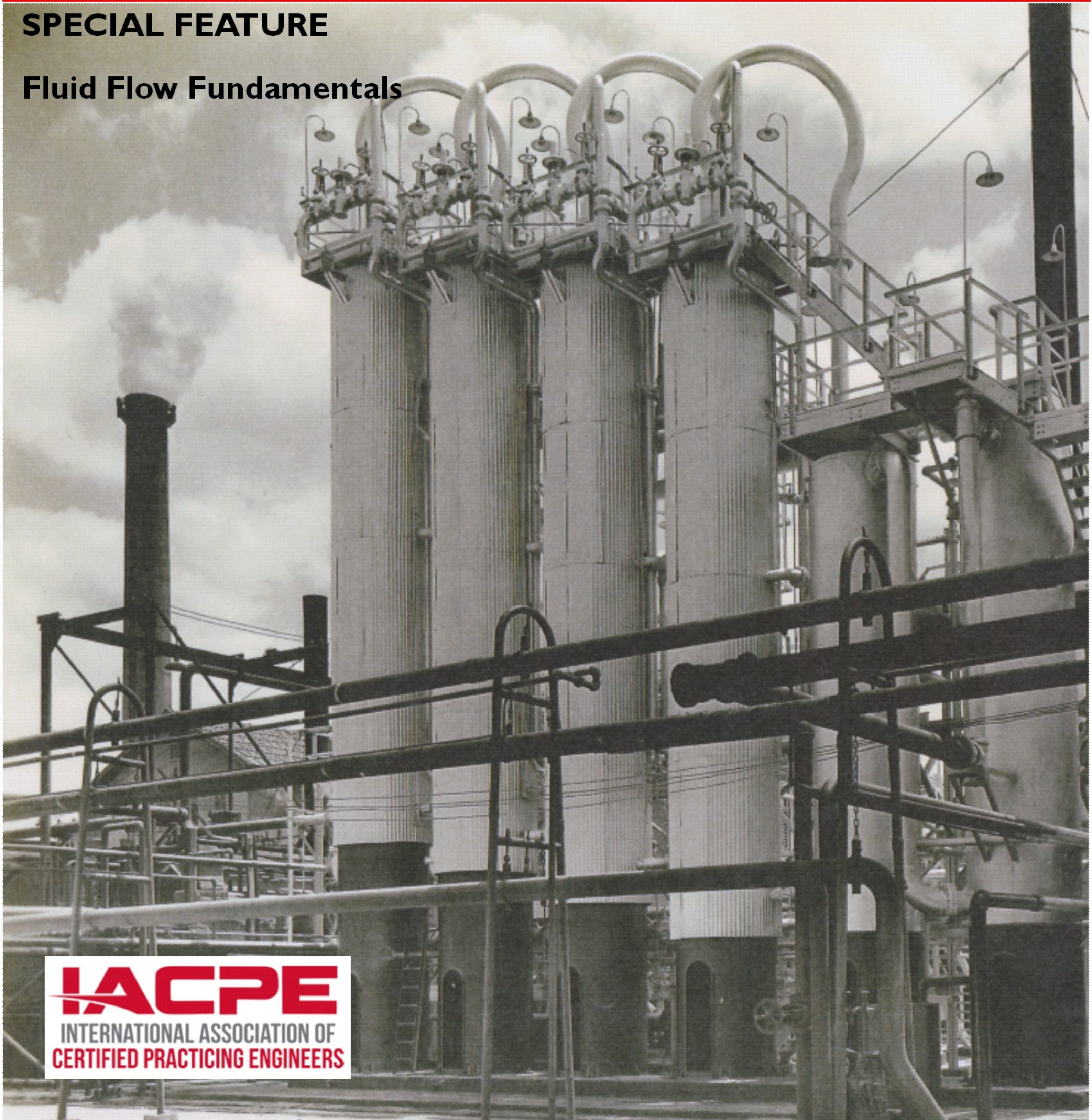
ENGINEERING PRACTICE

VOLUME 2 NUMBER 6 JULY 2016

SPECIAL FEATURE

Fluid Flow Fundamentals



IACPE
INTERNATIONAL ASSOCIATION OF CERTIFIED PRACTICING ENGINEERS

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ABOUT

International Association of Certified Practicing Engineers provides a standard of professional competence and ethics. Identifies and recognizes those individuals that have meet the standard. And requires our members to participate in continuing education programs for personal and professional development.

In additional to insuring a professional level of competency and ethics the IACPE focuses on three major areas of development for our members: Personal, Professional, and Networking.

HISTORY

The International Association of Certified Practicing Engineers concept was formulated by the many young professionals and students we meet during our careers working in the field, running training courses, and lecturing at universities.

During question and answer sessions we found the single most common question was: What else can I do to further my career?

We found, depending on the persons avail able time and finances, and very often dependent on the country in which the person was from, the options to further ones career were not equal.

Many times we found the options available to our students in developing countries were too costly and or provided too little of value in an expanding global business environment.

The reality is that most of our founders come from countries that require rigorous academic standards at four year universities in order to achieve an engineering degree. Then, after obtaining this degree, they complete even stricter government and state examinations to obtain their professional licenses in order to join professional organizations. They have been afforded the opportunity to continue their personal and professional development with many affordable schools, programs, and professional organizations. The IACPE did not see those same opportunities for everyone in every country.

So we set out to design and build an association dedicated to supporting those engineers in developing in emerging economies.

The IACPE took input from industry leaders, academic professors, and students from Indonesia, Malaysia, and the Philippines. The goal was to build an organization that would validate a candidates engineering fundamentals, prove their individuals skills, and enhance their networking ability. We wanted to do this in a way that was cost effective, time conscience, and utilized the latest technologies.

MISSION

Based on engineering first principles and practical real world applications our curriculum has been vetted by academic and industry professionals. Through rigorous study and examination, candidates are able to prove their knowledge and experience. This body of certified professionals engineers will become a network of industry professionals leading continuous improvement and education with improved ethics.

VISION

To become a globally recognized association for certification of professional engineers.

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KNOWLEDGE. CERTIFICATION. NETWORKING

LETTER FROM THE PRESIDENT

KARL KOLMETZ

Dear Friends,
I hope you are doing great. There are many people that attempt to predict the future. Science Fiction writers have been amazingly accurate. Financial analysts have not been as successful. How are you going to predict your future?

One way to predict your future is to create it.
One of the best methods to create your future comes from entrepreneurs: those people who have created two or more successful businesses. In the face of an unknown, unpredictable future, these entrepreneurs act specifically, they:

- Figure out what they want in their life
- Take a small step toward making it reality this year
- Pause to think about what they learned from taking that step.
- Build that learning into their next step

In other words, the best way to create the future is to: Act. Learn. Build. Repeat.

Figure out what you want in your life.
Make a long term plan to be happy, healthy, have a good family and be financially stable. If you cannot make a good 20 year plan; make a five-year plan. You will need to readjust your five-year plan as you get older and your situation changes.

Take a small step toward making it reality this year - Act.
Make plans for this year to accomplish your five-year goals. Accomplish this year's goals.

Pause to think about what you learned from taking that step - Learn.
Learn the lessons from the one-year plan – sometimes this can be a hard lesson, but be honest to yourself.

Build that learning into your next step - Build.
Take the hard honest lessons and adjust your one and five-year goals If that means adjusting from the initial path, so be it.

Repeat.
Repeat the process yearly.

We believe that the best way to assure your future, is to create it even in this uncertain changing world. There are many ways to assure your future. Most people state the same items when asked: work hard, be honest, gain knowledge, certify your knowledge and build a network.

We also believe that IACPE is a great way to create your future.

All the best in your career and life,
Karl

INDUSTRY NEWS

CB&I awarded license and engineering design for alkylation technology in Indonesia

CB&I has been awarded the license and engineering design of a grassroots alkylation unit by PT Pertamina (Persero). The unit will use CB&I's advanced sulfuric acid alkylation technology and Haldor Topsoe's WSA (Wet gas Sulfuric Acid) technology as part of the upgrade of Pertamina's Refinery Unit V in Balikpapan, East Kalimantan, Indonesia.

Amec Foster Wheeler wins Indonesian refinery upgrade contract

Amec Foster Wheeler has been awarded an engineering and project management services contract by PT Pertamina (Persero) and Saudi Aramco for the upgrade and expansion of the 348 Mbpd Cilacap Refinery in Central Java.

The upgrade and expansion project is intended to increase the capacity of the refinery to 370 Mbpd, maximize production of cleaner gasoline and diesel, produce higher quality base oils for the domestic market, and expand aromatics and polypropylene production to more than 600 Mtpy and 160 Mtpy, respectively.

Indonesia's Pertamina to appoint Shell to process Iraq crude

Indonesia's Pertamina has selected Shell to process one million barrels per month of crude from Iraq at a Singapore refinery, a senior official at the state owned company said on Wednesday.

"We've selected Shell because they are the most competitive," said Daniel Purba, the senior vice president of Pertamina's Integrated Supply Chain unit.

Thailand's PTT delays building of Vietnam petrochemical complex

Thailand's largest energy company PTT Plc has postponed plans to build a $20 B refinery and petrochemical complex in Vietnam, it said on Tuesday, citing uncertainty in global oil markets.

PTT has studied the possibility of investing in central Vietnam for more than four years and had aimed to start construction this year in partnership with Saudi Aramco, the world's biggest oil producer.

Petron Malaysia says no supply disruption from Port Dickson fire

Petron Malaysia reported a fire broke out at its Port Dickson oil refinery on Friday 24th June, but there were no injuries or supply disruptions. The fire started at 21:00 local time (13:00 GMT) and was put out two hours later.

Petron Malaysia said it was assessing the damage and investigating the cause of the fire at the refinery, which has a capacity of 88,000 bbpd.

Axiall and Lotte Chemical break ground on its grassroots ethane cracker

LACC LLC, the joint-venture company formed by Axiall Corp. and Lotte Chemical Corp., held a groundbreaking ceremony at its Calcasieu Parish, La. construction site.

This follows a December 2015 announcement that the boards of Lotte and Axiall reached final investment decisions to construct an ethane cracker facility adjacent to Axiall's existing Lake Charles complex. In addition to constructing the ethane cracker that is expected to produce 1 MMtpy of ethylene, Lotte Chemical will also construct an adjacent plant to produce 700 Mtpy of ethylene glycol.

Schneider Electric implements SimSci Spiral Suite at SK Innovation site

SK Innovation, South Korea's largest refining and petrochemicals company, has successfully implemented Schneider Electric's SimSci Spiral Suite software solution for unified supply chain optimization, planning and crude knowledge management.

The suite's unified enterprise supply chain solution has successfully been implemented to replace the installed legacy system. SK Innovation's assay specialists, process engineers and planners from multiple sites can now collaborate to optimize plans, manage business and ultimately increase performance across their enterprise.

NEWS

Career Guidelines Seminar at W.R Supratman University in Surabaya, Indonesia

In July 2016 the IACPE held a seminar titled *Career Guidelines* conduct by IACPE's President Karl Kolmetz, CPE at W.R Supratman University in Surabaya, Indonesia. There were over 150 students, along with the president, lectures and alumni attending the seminar.

PHENMA 2016

In July IACPE sponsored the 2016 International Conference on Physics and Mechanics of New Materials and their Applications hosted by Universitas 17 Agustus 1945 in Surabaya, Indonesia. IACPE sent *Guidelines for Reducing Corrosion under Insulation and it's Safety Consequences* authors IACPE President Karl Kolmetz, M.Salem Abdul Ajes and Reni Mutiara Sari. PHENMA 2016 held at the Hotel ELMI.

Fluid Flow Fundamentals

INTRODUCTION

Understanding the fundamentals of fluid flow is critical when designing equipment. Most equipment has internal fluid flows, including pumps, compressors, control valves, relief valves, distillation columns, reactors, and pipelines. The equipment may have vapor, liquids and sometime both vapor and liquids.

The understanding of how gasses and liquids flow in equipment is the foundation of equipment design. The principles of single phase fluid flow are not complex, but neither are they simple due to the interdependence of pressure drop and friction. The principles of two phase flow are complex and well as the principles of hydraulic surge.

One of the best ways to understand single phase fluid flow fundamentals is to study the principles of pipe sizing. Piping accounts for as much as one-third of the total plant cost. Pumping energy cost is directly related to the design of the piping and hydraulic systems.

Fluid Physical Properties

Liquid Density

The density of a liquid is the weight of a unit volume at the temperature during measurement, and is may be expressed in lb/ft^3. For example, the density of water is: ρ_{60w} = 62.37 lb/ft^3 at 60°F.

For a hydrocarbon sometimes the API Gravity is utilized

$$S(60F/60F) = \frac{141.5}{131.5 + \deg.API}$$

Pressure has no practical effect on liquid density. However, increasing temperatures will cause liquids to expand. Process flowrates may be given at a basic 60°F temperature, coupled with an expansion factor at points where the temperature changes in a pipe system.

This expansionfactor is:

$E = \rho_{60}/\rho$,

where ρ is the density at flowing temperature. Hence, the volume flowrate, Q in gpm, at temperature will be:$Q = Q_{60}E$ where Q_{60} is volumeflowrate at 60°F.Piping-design calculations should be made at flowing temperatures. In addition, alternative conditions (for example, at a cold startup) should also be investigated.

Specific Volume

Specific volume, $\tilde{V}$; is the reciprocal of density $\tilde{V}$, $=1/\rho$, ft^3/lb.Specific gravity at standard temperature relates thedensity of any liquid at 60°F to that of water at 60°F:

$$S_{60} = \rho_{60l} / \rho_{60_w}$$

A relation more often used gives the specific gravity of the liquid at flowing temperature, S, from:

$$S_{60} = \rho_{60w}$$

where ρ is the density of liquid at fl.owing temperature. If $S>1$,the liquid is heavier than water at 60°F; and if $S<1$, the liquid is lighter than water.

Vapor and Gas Density

A convenient equation for calculating vapor or gas densities is derived from the well-known gas law:

$$PV = RTz,$$

where:

$P$is absolute pressure, lb/ft^2; $\tilde{V}$ is specific volume, ft^3/lb; T is temperature, °R; R is the universal gas constant, (ft)(lb)/(lb)(°R); and z is a correction factor accounting for the nonideal behavior of a gas (usually, $z = 1$).

Since $R = 1{,}544/M$, *where*$M$is the molecular weight; $P = 144P'$, *where* $P'$is the absolute pressure, psia; and $\tilde{V} = 1/\rho$, ft^3/lb, the gas law can be rewritten as:

$$\frac{1}{\tilde{V}} = \rho = \frac{P}{RTz} = \frac{144P'}{1{,}544T/M}$$

From equation above, we can now find an expression. for gas density, ρ, as:

$$\rho = \frac{MP'}{10.72Tz}, \text{lb/ft}^3$$

As the equation above shows, gas densities depend on pressure and temperature; Hence, for purposes of

calculation, a pipe line is separated into segments over which the pressure and temperature are essentially constant. By using this procedure, calculations for pipe size and pressure drop can be made for each segment overof the length of the pipeline.

Specific volume is the reciprocal of density, $\tilde{V} = 1/\rho$, ft^3/lb. At high temperatures and pressures, gases do not follow closely the ideal gas law, and $z \neq 1$. The numerical value of z can be obtained by calculating reduced pressure and reduced temperature dependence.

Specific gravity of a vapor or gas, S_{60g}, relates the density of the gas at 60"F and 1atm (14.7 psia), ρ_{60g}, to the density of air, ρ_{60a}, under the same .conditions:

$$S_{60g} = \frac{\rho_{60g}}{\rho_{60a}} = \frac{M_g}{M_a}$$

The equation above also shows that specific gravity of a gas can be obtained by dividing the molecular weight of the gas, M_g, by the molecular weight of air, M_a.

$$Sg = \rho_g / \rho_{60a}$$

For determining the specific gravity of a gas, S_g, at the flowing temperature and pressure, the relation is where ρ_g is the density of the gas at flowing temperature and pressure.

The density of air, ρ_{60a}, is 0.0764 lb/ft^3 and the molecular weight, M_a, is 28.97. Densities and specific gravities of vapors and gases are listed in many industry handbooks.

Liquid-Vapor Mixtures Density

If a liquid-vapor mixture occupies 1ft^3 of volume, the weight of vapor, W_v, in the mixture, divided by the volume it occupies, V_v, gives its density: $\rho_v = W_v / V_v$. Similarly, for the liquid part : $\rho_l = W_l / V_l$. The mixture density will be : The mixture density will be : $P_{l+v} = W_{l+v} / V_{l+v}$. Since $V_{l+v} = V_l + V_v$ the mixture density becomes:

$$\rho_{l+v} = \frac{W_{l+v}}{(W_l/\rho_l)+(W_v/\rho_v)}, lb/ft^3$$

In equation above, W can represent the weight of fluid, weight flow rate, or percentage of each component in the mixture.

Even a small amount (about 1%) of vaporization greatly reduces liquid density. Hence, in designing flow systems, we must be aware that :

1. With a very small amount of vaporization, the decreased density significantly reduces the static head back pressure in a vertical pipe.
2. With a constant weight and a small amount of vaporization, the volume of flow greatly increases. In turn, this increases pipe resistance significantly. Such a condition is common in condensate lines.

Fluid In Motion

Velocity

A fluid moving in a pipeline has a parabolicvelocity-distribution profile. The average velocity is calculated at a given cross-section and steady flowrate: v= q/A, ft/s, where q is volume flowrate inft^3/s,and A is cross-sectional area of the pipe in $ft.^2$.

Mean Velocity

Mean velocity is the average velocity in flow across the given cross section as determined by the continuity equation for steady state flow. It normally express as ratio of the volumetric flow rate (Q) to sectional area (A) of the pipe.

which,

V = mean velocity, ft/s (m/s)
Q = volumetric flow rate, ft^3/s (m^3/s)
A = radius-sectional area, ft^2 (m^2)

For liquid-flow calculations:

$$\text{Mean Velocity, } V = \frac{Q}{A}$$

For vapor – flow or gas – flow calculations

$$v = 0{,}408(Q/d^2)$$

Where n is velocity, ft/s;Q is volume flowrate, gpm.; W is weight flowrate, lb/h; d is internal diameter of pipe, in; and p is gas density at flowing temperature and pressure, $lb/ft.^3$

The relationship between volume flowrate (Q, gpm and weight flowrate (W, lb/h) is:

$$v = 0{,}0509W/(d_2\rho)$$

Since specific gravity,S, is ρ/ρ_{60w} we find that W = 500QS. In the case of water close to 60°F, W = 500Q, lb/h, with ρ_{60w} = 62.37 lb/ft^3.

The initial pipe diameter can be estimated by choosinga reasonable velocity for a specific type of pipeline. Thus, for liquid lines:

$$(Q\rho/7.48)60 = W = 8Q\rho$$
$$Q = 0.125(W/\rho)$$

$$d^2 = 0.408(Q/v) \text{ in.}^2$$

And for vapor lines and gas lines :

$$d^2 = 0.509W/(v\rho) \text{ in.}^2$$

Viscosity

Viscosity is the measure of how easily the liquid or gas flows. It is a measure of the internal resistance of fluids. With increasing temperatures, liquid viscosity decreases and gas viscosity increases.

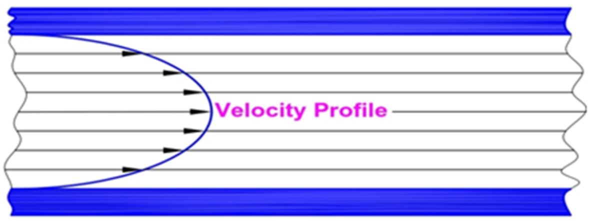
For measuring viscosity, many English and metric units have been developed. In this series, centipoise, cp, willbe used. Elaborate instruments are required for measuring absolute viscosity such as cp. Kinematic viscosity is simple to measure. The relation between kinematic and absolute is:

$$v = \mu / S$$

Where v is viscosity in centistokes; μ is viscosity in cp; and S is specific grafity. Note that 1 Stoke has dimensions of cm^2/s.The viscosity of water at 68°F is 1 cp. If data are not available, the following viscosities can be used: μ = 1 cp for liquids similar to water, 0.1 cp for liquid – vapor mixtures, and 0.01 cp for gases or vapors.

Reynolds Number and Friction Factors.

Experiment and observations made in glass pipes have shown that several types of flow exist in a fluid stream; these depend on the velocity of the stream. Such flows can be observed by injecting fine colored streams into the main body of the liquid. At low velocities, the colored streams retain their sharpness, and flow is laminar.

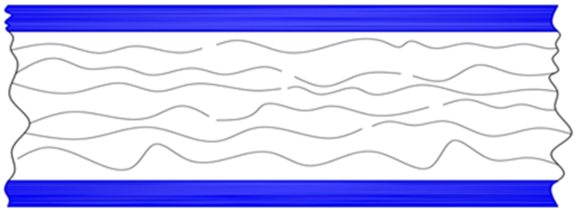


Viscous Flow

$N_{Re} \leq 2{,}000$

$f = 64/N_{Re}$

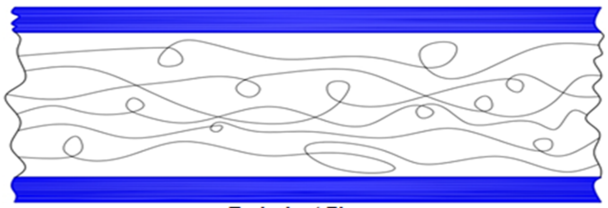
As fluid velocity increases, the fine streams begin to break up, and glow is now in a transition or critical zone.



Transition Flow

N_{Re}= 2,000 to 4000

f = 0.04 to 0.052 for steel pipes



Turbulent Flow

$N_{Re} > 4{,}000$

For estimating the type of flow in a pipeline, the Reynolds number, N_{Re}, is used. The Reynolds number is a dimensionless combination of pipe diameter, velocity, density and viscosity.

$$N_{\mathrm{Re}} = Dv\rho / \mu_e$$

, where μ_e is the absolute viscosity in $lb_m/(ft\text{-}s)(ft^2)$

Practical formulas for calculating N_{Re} are :

$$N_{\mathrm{Re}} = 50.6(Q/d)(\rho/\mu) = 6.31W/d\mu$$

Where Q is volume flow, gpm; W is weight flow, lb/h; d is internal diameter of pipe, in.; ρ is density, lb/ft^3 and μ is viscosity, cp.

Resistance to fluid motion depends on the type of flow in the pipeline and on the roughness of the pipe wall.

Relative roughness is ε / D where ε is the absolute roughness (i.e., the depth of the unevenness of the internal pipe wall), and D is the internal diameter of the pipe. Both ε and D should be measured with the same dimensional unit.

In the laminar zone, where N_{Re}<2,000, the friction factor depends on the Reynolds number only. Hence, $f = 64 / N_{\mathrm{Re}}$. In the critical zone, where 2,000 $\leqslant N_{Re} \leqslant$ 4,000, the friction factor is unpredictable.

If the N_{Re} ranges from 4,000, the flow is in the transitional turbulent zone. Here the friction factor varies with the Reynolds number. The zone to the right of the dashed line is totally turbulent, and the friction factor remains constant with increasing Reynolds number.

Because glass and plastic materials have smooth pipe walls, the friction factors for them are independent of relative roughness or pipe diameter.For steel pipes, the border line between transitional and total turbulence can be estimated. This is done by multiplying the nominal pipe size (in) by 10^6 to get the borderline N_{Re}. Friction factors in the totally turbulent zone are listed in the table below.

Friction factors obtained directly from tables and diagrams are used in calculations where the pipe material is new, and where the fluids (for example, light hydrocarbons) do not deteriorate the pipe wall. For fluids that corrode the pipe wall, form deposits, or cause scaling or erosion, the friction factor should be increased by a safety factor can be 1.25 to 1.5, depending on the size and the expected life of the installation

Friction factors for Total Turbulence (In new commercial steel pipes)

The dimensional properties of pipe are published by manufacturers. For steel pipes, these are based on the

Nominal Pipe Size Ln	Friction Factor *f*	Nominal Pipe Size Ln	Friction Factor *f*
1 ½	0.0205	10	0.0136
2	0.0195	12	0.0132
3	0.0178	14	0.0125
4	0.0165	16	0.0122
5	0.016	18	0.012
6	0.0152	20	0.0118
8	0.0142	24	0.0116

recommendations of the American National Standards Institute.

The tables below give practical velocities for liquid lines, and vapor lines.

Typical Liquid Velocities in steel Pipelines

Nominal Pipe Sizes, In	2 or less	3 to 10	10 to 20
Lioquid and Line	**Velocity Ft/S**	**Velocity Ft/S**	**Velocity Ft/S**
Water			
Pump suction	1 to 2	2 to 4	3 to 6
Pump discharge (long)	2 to 3	3 to 5	4 to 7
Discharge (short)	4 to 9	5 to 12	8 to 14
Boiler feed	4 to 9	5 to 12	8 to 14
Drains	3 to 4	3 to 5	---
Sloped sewer	---	3 to 5	4 to 7
Hydrocarbon liquids			
(Normal viscosities)			
Pump suction	1.5 to 2.5	2 to 4	3 to 6
Discharge header (long)	2.5 to 3.5	3 to 5	4 to 7
Discharge leads (short)	4 to 9	5 to 12	---
Drains	3 to 4	3 to 5	---
Viscous oils	---	1.5 to 3	2.5 to 5
Pump suction			
Medium viscosity	---	1.5 to 3	2.5 to 5
Tar and fuel oils	---	0.4 to 0.75	0.5 to 1
Discharge (short)	---	3 to 5	4 to 6
Drains	1	1.5 to 3	---

Typical Velocities in gas Vapor Lines

Nominal Pipe Size Ln	Saturated Steam or Saturated Vapor	Superheated Steam Superheated Vapor, or Gas	
	Low Pressure	Medium Pressure	High Pressure
	Velocity, Ft/s	Velocity, Ft/s	Velocity Ft/s
2 or less	45 to 10	40 to 80	30 to 60
3 to 4	50 to 110	45 to 90	35 to 70
6	60 to 120	50 to 120	45 to 90
8 to 10	65 to 125	80 to 160	65 to 125
12 to 14	70 to 130	100 to 190	80 to 145
16 to 18	75 to 135	110 to 210	90 to 160
20	80 to 140	120 to 220	100 to 170

Note: Within the above velocities and line-size ranges, (a) large lines can have higher velocities than smaller ones, and (b) short lines, and leads from headers, can have higher velocities lhan long lines and headers.

Equipment Lines	Velocity,Ft/s
Reboiler,downcomer 9liquid)	3 to 7
Reboiler, riser (liquid and vapor)............	35 to 45
Overhead condenser..............................	25 to 100
Two-phase flow......................................	35 to 75
Compressor, suction..	75 to 200
Compressor, discharge...	100 to 250
Inlet, steam turbine................................	120 to 320
Inlet, gas turbine....................................	150 to 350

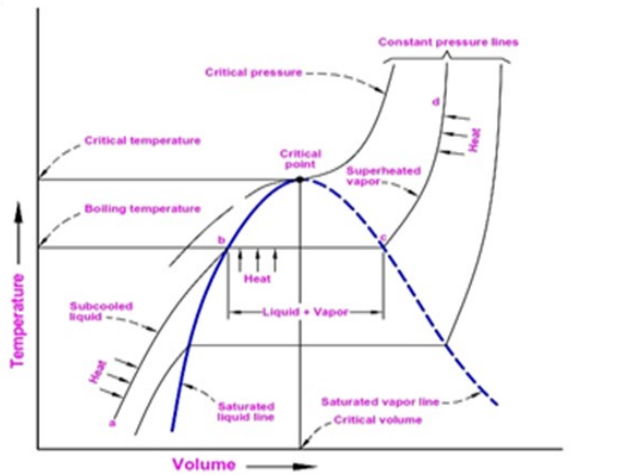
To prevent corrosion or erosion of the internal pipe wall, some chemicals should not exceed the maximum velocities listed in the table below. Only a few examples are listed in this table.

Maximum Velocities To Prevent Erosion Or Corrosion of Pipe Wall

Liquid in carbon-steel pipe	Maximum Velocity Ft/S
Phenolic water	**3**
Concentrated sulfuric acid	4
Cooling-tower water	12
Salt water	6
Calcium chloride brine	8
Caustic soda C>5% by volume	4
Aqueous amine (mono or diethanol amine	10
Wet phenolic water	60
Liquid in plastic or rubber-lined pipe	10

Thermodynamic Properties

In routine calculations for pipng and component sizing, thermodynamics is rarely involved. However, it is useful to recognize when physical changes takes place in the flowing fluid. For example, if a liquid flows near its boiling point, even a little vaporization (usually due to pressure reduction) can increase piping and component resistances.



Phase equilibria between liquid and vapor for a material under going heating or cooling in a closed system

In order to understand the meanings of the terms subcooled and saturated as applied to a liquid, and the terms saturated and superheated as applied to a vapor, we will use the temperature – volume relations that are shown.

When a liquid is heated a t constant pressure, its temperature increases and its volume expands. (See line segment from a to b) On reaching the boiling temperauture , the liquid becomes saturated. The liquid below the boiling point is called subcooled. More heat will gradually vaporize the liquid while its pressure and temperature remain constant but its volume increases (Line b to c).

During this stage; both liquid and vapor phases are present. After sufficient heat absorption, all of the liquid vaporizes (Point c). At this point, the vapor is saturated. Further heating (Line c-d) will cause both the temperature and the volume of vapor to increase. Vapor above the saturation temperature is superheated.

At a higher constant pressure, the boiling temperature will be higher, and less heat will be required to vaporizethe liquid. At the critical point, the densities of liquid and vapor become identical. Just below the critical temperature, the substance is considered liquid, just above it is considered vapor.

The quantity of heat needed to vaporize a unit weight of saturated liquid at constant pressure (Line b-c) is called the latent heat (usually expressed in Btu/1b).

Flashing Liquid

When a liquid is flowing near its saturation point (also called the equilibrium point or boiling point) in a pipeline, decreased pressure will cause vaporization. The greater the pressure difference, the greater the vaporization. When flashing occurs,pipe resistance cannot be calculated as for liquid flow. We will now have a two-phase flow problem. The quantity of vaporized liquid can be estimated by using the data of the thermodynamicproperties of the liquid.

Specific Heat

The quantity of heat aborsed by a unit weight of substance while its temeperature is raised 1° is termed the specific heat. Customary units are in Btu/(lb)(°F).

Specific heat can be measured at constant volume, c_v, and at constant pressure, c_p. At constant pressure, $c_p \approx \Delta h/\Delta t$, where Δh is the number of Btu absorbed by 1 lb of substance over a temperature span of Δt°F.

At adiabatic gas flow (no heat exchange betwee the gas and its environment), the ideal-gas law becomes $P\tilde{V}^k = RT$, where $k = c_p/c_v$. For various gases,therange of ***k*** is from 1.2 to 1.4,with few exceptions. In isothermal (constant temperature) flow, $k = 1$. Thequantity ***k*** is called the specific heat ratio or adiabaticexponent. Data for c_p, c_v and k are available in engineering hand books.

Bernoulli's Equation

Bernoulli's equation is useful in the calculation of the fluid flow. It follows the first law of Thermodynamics and it calculates the energy balance in steady state and incompressible flow. The formula for the friction term in pipe line is expressed as :

$$\Delta\left(\frac{P}{\rho} + z + \frac{V^2}{2g}\right) = h_L$$

which,

- P = pressure drop in pipe, lbf/in^2(Pa – For the SI unit remember to divide the pressure head with the acceleration of gravity.)
- z = elevation of pipe, ft (m)
- g = acceleration of gravity, ft/s^2 (m/s^2) – 32.2ft/s^2
- h_L = Head loss, ft (m)

Dancy's Formula

Dancy's formula of the friction in pipe line is expressed as

$$h_L = f\,\frac{L}{D}\cdot\frac{V^2}{2g}$$

which,

- f = friction factor, dimensionless
- L = length of pipe, ft (m)

Dancy's friction factor, f is determined experimentally. Normally friction factor for the laminar flow conditions (Re <2100) is simple calculated with just function of the Reynolds number only, which can be expressed as

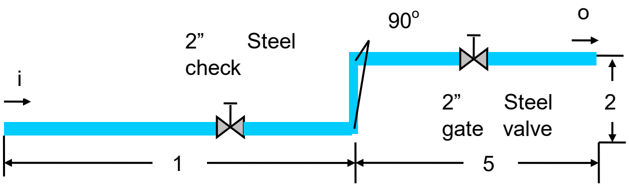
$$f = \frac{64}{R_e}$$

In the transition zone which with the Reynolds number of approximately 2100 to 4000. In this zone, the flow is either laminar or turbulent depending upon several factors. In this zone the friction factor is indeterminate and has lower limits based on laminar flow and upper limits based on turbulent flow conditions.

For the turbulent flow with the Reynolds number > 4000, the friction factor is not only factor of the function of Reynolds number it is function of the pipe wall as well. The piping roughness will affect the friction loss as well.

Example: In-Compressible flow with Water (from Kolmetz Handbook of Process Equipment Design – Fluid Flow Chapter - a free complete chapter down load from the web)

Water at 80F with weight density 62.22 lb/ft^3 , viscosity 0.85 cp is flowing through 2" carbon steel Schedule 40 pipe with internal diameter 2.067 in at flow rate of 100 gallons per minute in the system as per below;



Find the velocity in ft/s and the pressure drop from the inlet through outlet in lb/in^2 and pressure drop in psig/100ft.

Solution:

Water flows in circular pipe then the d in the all formulas take it as internal diameter.

Part 1:

Velocity can be determined with equation

$$V = \frac{Q}{A} = \frac{0.408Q_1}{d^2}$$

$$= \frac{0.408x100}{2.067^2}$$

V = **9.55 ft/s**

Part 2:

Determine the Reynolds number

$$Re = \frac{50.6\, Q_1 \rho}{d\mu}$$

$$= \frac{50.6x100x62.22}{2.067x0.85}$$

= 1.8x10^5 > 2100; turbulence flow

Because of the turbulence flow and the imperial friction factor is used for calculation

$$f = \frac{1}{(2Log[(\frac{7}{Re})^{0.9} + (\frac{3.24\varepsilon}{d})])^2}$$

take , ε as 0.00018 in

$$f = 0.021$$

Valve and fitting resistance coefficient K determination

$$K = f_t \frac{L_{eq}}{D}$$

f_t for the 2" pipe from is f_t = 0.019

K = 8(0.019) = 0.152 ....gate valve

Gate valve the	L_{eq}/D = 8;	K = 8f_t
Check valve the	L_{eq}/D = 100;	K = 100 f_t
2X 90° Elbow the	L_{eq}/D = 30 ;	K = 30 f_t

K = 100(0.019) = 1.900 ....check valve
K = 30 (0.019) = 0.570 .... 90° elbow

And for the pipe

K = f L/D

$$= \frac{(0.021)(150+50+20)\,(12)}{2.067}$$

$= 26.82$ Total of the resistance coefficient of the system,

K = 0.152+1.9+ (2x0.570) +26.82 = 30.01

Pressure of the system = Pressure drop in horizontal line + Pressure drop in elevation

$$= \frac{30.01(9.55)^2}{2x144x32.2}x62.22 + \frac{20x62.22}{144}$$

$$= (18.36 + 8.64) lb / in^2$$

$$= 27.00 lb / in^2$$

Pressure drop in

$$psi/100\,ft = \frac{(0.021)(100)(9.55)^2(12)(62.22)}{2(144)(32.2)(2.067)}$$

$$= 7.46\, psi/100\,ft$$

Exit velocity

$$V_{ex} = \left[\frac{2\times\left(g\times\Delta p_{tot} + 0.5\times\rho\times V^2\right)}{\rho}\right]^{0.5} = \left[\frac{2\times\left(32.174\times27 + 0.5\times62.22\times9.55^2\right)}{62.22}\right]^{0.5} = 10.93\,ft/s$$

Summary
The paper is a review of fluid flow fundamentals which are essential to understand before designing equipment. This review has included physical properties, thermodynamic properties and dimensionless units. It has given some typical industry standards for velocity in pipe sizing.

References

1. Keenan,J.H., Keyes, F. G, Hill, P. G. and Moore, J. G., "Steam Tables," Wiley, New York, 1969.
2. Gallant, R. W., "Physical Properties of Hydrocarbons," Vol.1 and Vol. 2, Gulf Publishing Co., Houston, 1968 and 1971.
3. Perry, R. H. and Chilton, C. H., "Chemical Engineers' Handbook,"5th ed., McGraw-Hill, New York, 1973.
4. "Flow of Fluids,"Crane TechnicalPaper No. 410,Chicago, IL 60632
5. Kern, Robert, "Useful Properties of Fluids" Chemical Engineering, Dec 23, 1974
6. Kolmetz Handbook of Process Equipment Design, 1st Edition, 2015

THE ENGINEER OF TOMORROW

WISDOM AND JUDGESMENT VERSES COMPILING AND HOLDING

I think of how much the engineering profession has changed since I entered the workforce in the 1980s. I walked into a production plant my first day ready to put all my years of school to use. I had even thought about a set of ideas to implement my first few weeks on the job. I had been hired as a production manager for a small facility that manufactured polyurethane material in the U.S. I managed a staff of 12, including one supervisor. In retrospect, that was not a good entry-level job for me or, I would argue, most engineers. There are so many things you need to know about managing people that you do not have when you come out of an engineering curriculum. (However, this is all fodder for a future article, let me get back to the point of this one.)

I walked through the door full of ideas, and quickly found that I was going to need information from others. During my interviews with various plant managers, I had gleaned some of the problems the plant was having making product that was on-spec (i.e., passing the specification standards set up by the customers). I started with the assumption that we could do better. I still start with that assumption when facing problems today. But I realized that to improve the process, I needed to know more about how we were currently running the process.

This was in the days just before initiatives like statistical quality control had taken firm hold throughout industry – especially in smaller companies. But I knew intuitively that controlling the process and eliminating variability were keys to producing a more consistent product. However, the more I asked for information on the current process, the more people seemed to resist providing it. That was not true in all cases, some people from the laboratory, production floor, and engineering department were eager to help and appreciated my effort to improve the process which, I explained, would improve the outcome. However, more people seemed to resist.

So what caused people to withhold information from me? I think there were at least two things, maybe more, that I was witnessing. In some cases, people who had been involved with a decision did not feel completely comfortable with it, and did not want someone else to revisit it. That was especially true for some young fresh out of school know-it-all like me.

The other reason I think people withheld information, and the real point of this article, is that a lot of people at that plant felt their job security depended on them being the only person to know something. They had mounds of folders in their offices, often locked up in cabinets, and only they knew where the information was kept. I would often hear comments like,

"Oh, (*fill in the blank with a name*) knows about that. You have to go see him." This situation fed a culture of one person having compiled and held onto information such that, that individual really was invaluable to the organization. And maybe that was good for that individual, but it was not good for the organization. An organization cannot be so person-based that if that person leaves or does not perform well, the organization suffers.

engineers of today live in exciting times. Information is more readily accessible than ever in history. Considering the field of safety where I have been for much of my career, I remember safety managers in the past walking into a meeting with a folder full of information on accidents that happened at other similar facilities. He, or she, had that folder, they knew where the accidents had happened, and they were the single-point "go to" person on accidents.

Today, most any engineer with access to the internet can find gobs of information on accidents, provided the information is in the public domain. Therefore, it could be argued that today, having information is not nearly as important as knowing what to do with the information. Today's engineer, and tomorrow's engineer, are – and will be - judged less by what they know, and more by the reasoning skills and decision making they apply using information: What I call wisdom and judgement verses compiling and holding. It is not enough to simply know that an accident happened in a similar plant and having a hard copy of the report. You absolutely have to be aware that something happened, but that information is more readily available than ever. It is important to understand the breadth of inputs and breakdowns that led to that that accident, what cultural issues at the plant may have either caused or enabled those breakdowns, deficits in their management systems, and how all that applies to different operations.

Oftentimes, I have seen people look at an accident and focus on differences between the plant where the accident happened and their own plant to provide a sense of relief that the same thing cannot happen where they are. Instead, engineers should strive to determine the similarities between the conditions where an accident occurred and conditions in their own plant. This rationale applies not just to safety, but environmental initiatives, process improvement, product enhancement, and even areas such as public relations.

Exercising wisdom to know what to do about a problem counts for much more than knowing a problem may exist. It is basically a given today that engineers will know something went wrong (or consequently – know that some companies have best practices and consistently do things right). What is not a given, and can set a young engineer apart from the rest, is to exercise good judgement in determining a course of action to apply that knowledge to a different – though similar – situation.

In summary, we may never completely get away from the temptation of some to acquire and hoard information. I still run into that with some people today. However, this approach gets less and less successful over time. Today and tomorrow's engineers are expected to know information, what will set them apart is the wisdom they demonstrate in applying that information to different problem sets. The ability to find information, which often valued in the past, has given way to the ability to wisely use information. Tomorrow's engineer will strive to constantly develop and enhance the necessary skills to use wisdom and good judgement where the amount of information that exists outweighs the solutions available.

Stephen J. Wallace is a Certified Safety Professional and Professional Engineer, registered in multiple states in the US. In his career, he has led award-winning environment, safety, and health programs in the public and private sectors. He was a lead investigator into the causes of chemical accidents for the US Government for several years. He has published numerous articles in engineering and safety journals, and has provided consulting services and taught courses throughout the US and internationally. He is an honorary Industrial Advisor to the IACPE Board.

Process, Air & Water

A Process Challenge in NASA Spacesuits

July 2016

Antoine Technical Consulting LLC | (832) 356-3903

Antoine Technical Consulting LLC joined forces with Adelante Sciences Corporation to shed some light on the issue of water intrusion into the helmets of astronauts that has been plaguing NASA over the past three years. The latest occurrence was as recent as January 2016, indicating that this potentially life-threatening issue still remains unresolved. Antoine Technical Consulting LLC and Adelante Sciences Corporation worked on this issue in hopes of providing an outside perspective that could lead to a solution. Please note that the work described in this article was done as a matter of interest using publicly available information and does not represent paid work done by any of these business entities for NASA.

NASA has had a nagging issue of water intrusion into the helmets of astronauts' spacesuits over the past three years. By far the most concerning case was the incident with Luca Parmitano, a European Space Agency (ESA) astronaut from Italy, on July 16, 2013. This incident could have resulted in loss of life as Luca's helmet filled with about 1.5 L of water over a 45-minute period during his spacewalk on the International Space Station (ISS). Luca's mouth and ears were submerged, his vision was impaired and he had difficulty communicating with ground control and other support in orbit in the ISS

The spacesuit underwent a major parts overhaul and it seemed that the water intrusion problem had been fixed. However, these water intrusion incidences have recurred, although with reduced severity. The reduced severity is in great part due to the difference in the response behavior of the astronauts, on-orbit and ground control support. NASA personnel are now quick to terminate a spacewalk if a water intrusion event occurs

Many systems require water for various needs such as fire suppression/sprinkler system, thermal management, and drinking water to name a few. In this study, we see that a process requiring water can extend to something as individual as the liquid cooling ventilation garment that an astronaut wears for thermal management during spacewalks. Regardless of the end-use of the water, addition of biocides is a necessary step to prevent bio fouling, for health safety preventing the transmission of waterborne diseases such as Legionnaires disease and to inhibit microbiological induced corrosion.

From the NASA Mishap Investigation Report, it was found that what caused the water intrusion event was a buildup of moisture in the ventilation loop, a piping network which carries humidified breathing gas to the astronaut – principally oxygen – and metabolic waste gases and moisture away from the astronaut for elimination. This buildup was due to blockage of the separator part of the complex, highly integrated fan/pump/separator component. There was a buildup of silica on the pitot separator that came from the offline water scrubbing protocol that is periodically used to rid the thermal water of particulate contaminants, corrosion products, and biological contaminants. The pitot separator separates moisture from the ventilation gas.

Fig. 2. *The liquid cooling ventilation garment (LCVG) is for thermal regulation of the astronaut during spacewalks. It is worn underneath the bulky pressurized garment.*

What is particularly interesting about this study is that it led us to explore the possibility that the addition of iodine biocide to the water system could have led to stress corrosion cracking in metal alloys in water-contact equipment. NASA uses iodine as the biocide agent in the liquid cooling ventilation garment (LCVG) that astronauts wear for thermal management. Iodine is known to cause stress corrosion cracking in zircaloy, used as cladding for fuel rods in water reactors in the nuclear industry. Some aluminum alloys and titanium-aluminum alloys have been shown to exhibit stress corrosion cracking in a mixture of iodine and methanol.

Stress corrosion cracking (SCC) is the growth of cracks from sites of corrosion in an alloy or metal that is subjected to a sustained tensile stress. This phenomenon can lead to unexpected sudden failure of normally ductile metals in a corrosive environment, especially at elevated temperature. Stress corrosion cracking (SCC) is highly chemical specific, i.e., a metal or alloy may undergo SCC only when exposed to a small number of chemical environments.

NASA's current metal selection protocol is outlined in a publicly available specification, MSFC-STD-3029, Revision A, titled, "Guidelines for the Selection of Metallic Materials for Resistance in Sodium Chloride Environments". This document discusses testing protocols and provides tables of approved aerospace metals that qualitatively define their corrosion resistance in sodium chloride environments. All titanium alloys are cleared for use without further investigation. To answer the question about the possibility of stress corrosion cracking, it is important to know: 1) the identity of the corrosion products; 2) what process equipment are in contact with the water in the spacesuit; 3) their materials of construction; and4) whether those materials are subject to corrosion in the presence of iodinated water.

The thermal water in the spacesuit can be in contact with several component parts, however, publicly available information attributes the failure of NASA spacesuits to the fan/pump/separator. This component circulates the gas in the ventilation loop; pumps the water in thermal loop and separates the moisture from the waste ventilation gas. The water scrubbing protocol mentioned earlier, was introduced to preserve water quality by removing corrosion products in the water that was causing the fan/pump/separator to malfunction. It should be noted that the presence of the corrosion products in the thermal water followed the propagation of the fan/pump/separator component in NASA spacesuits. We have not been able to locate information within the public domain that explicitly calls out the materials of construction of the fan/pump/separator to which failure of several spacesuits have been attributed. It is known, however, that the corrosion products are due to rotor growth from internal corrosion of the permanent magnet (typically a NdFeB alloy) potting within the rotor. As corrosion would not occur in a moisture-free environment, the presence of corrosion products suggests that the exclusion of moisture in supposedly dry areas, like inside the rotor shaft, still remains a challenge.

Summarizing, we have not explicitly found that iodinated water would accelerate corrosion in the thermal water loop. NASA has done extensive materials compatibility tests in iodine environments for time periods as long as one year and so materials currently in use have been selected with care. It may be that for the extended period of use of the spacesuits, ~ 6 years, the materials may be reaching the end of their useful lives. We suggest that a migration to an ionic silver-based biocide may be beneficial. There is precedent as the Russian Space Agency uses an ionic silver biocide in cosmonaut suits. NASA is already looking at replacing the iodine biocide with ionic silver in drinking water due to the non-related but important logistics of removing the biocide prior to astronaut consumption. It may well be, however, that a move to ionic silver is serendipitous to the reduction of corrosion products in the thermal cooling water.

Antoine Technical Consulting LLC offers solutions to help clients improve their primary and auxiliary processes using chemical process simulation to perform process engineering and design, energy assessments, troubleshooting and scale-up.

For your service inquiry, please contact:
Antoine Technical Consulting LLC
P.O. Box 57862, Webster, TX 77598
832-356-3903
Keisha@antoinetech.com
www.antoinetech.com

Thank you for reading the *Process, Air & Water*. In this issue we see that water quality is an issue that can affect mechanical equipment even in small parts used on NASA spacesuits. References were obtained by performing searches at NASA Technical Reports Server: http://ntrs.nasa.gov/search.jsp.

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