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STAINLESS STEEL IN PROCESS WASTE SYSTEMS

A request was submitted by a reader suggesting we post an article on the subject of process waste systems. And more specifically on the use and application of stainless steel (SS) in such systems. And I have to agree with the reader, that this is indeed a worthwhile topic.

The reader goes on to state that, “The condition of stainless steel pipe specifications in this world is atrocious!” And again, I have to agree with the reader, but perhaps I would word it a little differently.

In discussing this issue of using SS in waste system piping I will break it down into what I see as three distinct issues.

The first being that of poorly manufactured SS material being dumped onto the world market. The second being that of specifying the proper SS. And the third being that of proper fabrication.

Each of these factors play a role in building a waste system that cannot stand up to the chemistry of the fluid being handled. In knowing this we will now touch on the first issue.

FIRST ISSUE

Guarding Against Non-Compliant SS

Trading or doing business on the world market is no different than living and surviving in a jungle. In order to survive in a jungle you need to assume, if you don’t already know, that there are predators just waiting for you to make a wrong move, to make a mistake. And the first mistake you make will most likely be the last one you make.

While making a mistake in the business world may not cost you your life it can inflict damage on your business. The extent of which is dependent upon the size of your loss in comparison to the size of your business.

In combating predators in business, as in the jungle, you need to be proactive when buying SS product. And there are multiple ways in which this can be done.

There are suppliers that have inspectors in place (boots on the ground) to regionally perform quality audits of companies they represent or companies whose product they supply.

Such quality audits help the supplier/distributor determine the ongoing quality and traceability of the product being manufactured. And the first thing your potential supplier should be asking is, “Does the manufacturer have a QMS (Quality Management System) in place. And does the supplier’s auditors verify that the manufacturers are indeed following that protocol.

So if you are a vessel fabricator, skid fabricator, or pipe fabricator you should be doing

due diligence in selecting your suppliers of SS sheet, pipe, tube, fittings, and any other component you may need in your work.

Preventing the receipt of non-compliant SS at the source will help mitigate the onset of serious headaches once such product hits your loading docks only to discover that it doesn't pass receipt verification. And receipt verification should be a part of a user's protocol as a fabricator — a thorough receipt verification procedure.

SECOND ISSUE

Specifying the Proper SS for a Waste System

In a hypothetical scenario the SS material you ordered is received, it meets the specified material specification, is properly fabricated, and finally installed. But after being in service for just a brief amount of time it's discovered that the material was not compatible with the cocktail of waste chemicals and has developed leaks.

Specifying the proper material for a waste system is crucial. Assessing the compatibility of a piping material for a cocktail of chemicals can be something of a guessing game. That is, unless coupon testing is performed on the combination of waste streams expected.

Specifying a piping material for a process waste system is not as straight forward as specifying material for a specific fluid service. The only way to select a material that is compatible with a specific waste fluid solution is to test the expected chemical variations of the waste stream fluids with presupposed material coupons. The material candidates leave us with the usual suspects, as far as SS is concerned.

The usual suspects will include the austenitic stainless steels 304, 316, and 317. And why, you may ask, are these materials considered the usual suspects? Simply put, these materials lie in the sweet spot of having well documented corrosion resistance against a broad range of chemicals in addition to their strength of material while remaining cost effective. Having those three attributes makes these stainless steels

very attractive when being used in an application such as a process waste system

There are certainly other stainless steels to consider as well, for use in chemical applications. Stainless steels with a higher percentage of alloying chemistry and increased allowable stress. And what comes with that are increased cost and a possible availability issue. With that said, let's take a look at the attributes of each of the three named SS materials.

Type 304: This material performs well as an architectural metal and also in food processing. It does not do well at elevated temperatures with fluids consisting of high levels of acids or chlorides. It has good corrosion resistance against organic chemicals, dyestuffs, and inorganic chemicals.

Type 304L: This low carbon variant of Type 304, in addition to its above described attributes, has good corrosion resistance against nitric and sulfuric acid in low concentrations at moderate temperatures.

Type 316: This material contains slightly more nickel than Type 304 and in addition contains 2 – 3% molybdenum, which is not part of the chemistry of Type 304. This added moly improves the material's corrosion and chloride pitting resistance beyond that of Type 304 while retaining its strength at elevated temperatures. It also works well with sulfuric, hydrochloric, acetic, and formic acids, to a point.

Type 316L: The lower carbon (the L suffix) version of Type 316 retains all of the attributes of Type 316 SS with the added benefit of minimizing the effects of carbide precipitation that could otherwise occur during welding. Making this an excellent application for a welded system.

Type 317: This material, with its higher content of chromium, molybdenum and nickel, has even better corrosion resistance characteristics and strength than does Type 316 or 316L. These added benefits do come at a price though.

And to reiterate, in selecting a stainless steel material, or any material for a process waste piping system it is best to perform corrosion testing with concocted chemical solutions that best represent the chemical cocktails that are expected to be carried in the waste stream.

Selecting the harshest of the chemicals alone, as the test medium for the test coupons, may not be sufficient. There may be an interaction between the chemicals that could cause some unforeseen detrimental effect on the piping material.

THIRD ISSUE

Proper Fabrication of the Pipe

Leading into the topic of fabrication I would, first of all, like to explain what makes stainless steel stainless. In my book on bioprocess piping and equipment design I state that, “The phenomenon that makes stainless steel stainless is the natural inclination for the material’s surface to self-passivate in an oxygen-enriched environment as a result of the chromium metal, as a percentage, contained in the material’s chemistry composition.”

In mentioning that this microscopic passive chromium rich oxide protective layer is the means by which the base ferritic metal of the pipe is protected from corrosive fluids, the implication is that should the protective passive layer be depleted or eroded in some fashion, the material’s corrosion resistance would be gone. Which is exactly what would happen.

The extraordinary thing that happens, if the passive layer should be depleted in some way in an oxygen rich environment, is that it will self-passivate. And will retain its corrosion resistance in doing so. There is however, a caveat to that, which goes to the fabrication process itself.

When welding SS there are limitations with regard to the heat tint of the inside surface of the pipe within the heat affected zone (HAZ) of a weld. The darker the heat tint the more diminished the corrosion resistance of the inside surface of the pipe.

In a February 1999 Nickel Development Institute article by Arthur H. Tuthill and Richard E. (Dick) Avery, both with the Nickel Institute, they write,

“When heat tint scale forms, chromium diffuses outward from the base metal in the heated zone. The zone extends as far as elevated temperatures allow chromium diffusion to occur. The diffusion of chromium into the scale leaves a thin chromium-reduced layer just beneath the heat tint scale. This thin layer is lower in chromium, and is the primary constituent that gives SS its good corrosion resistance. Corrosion that would not occur elsewhere can initiate in the HAZ unless the heat tint scale and the thin chromium-depleted layer just beneath are removed.”

In other words, if heat or discoloration goes beyond what is considered acceptable by the ASME BPE Standard, Part MJ, and is left as-is, it is very likely that pitting corrosion will initiate within the HAZ of any such occurrence. And while there is ample opportunity to mitigate the onset of corrosion at such locations by removing the chromium depleted layer with a rotating fiber brush, pickling, or electropolishing, in all likelihood it will go unnoticed.

In most cases engineers, contractors, or inspectors unfamiliar with this anomaly will perform their weld OD visual and their x-ray examinations without concern for ID discoloration.

IN SUMMARY

The failing of process waste piping systems constructed of SS pipe and components can often be attributed to one or all of the issues described above. It is up to the engineer and fabricator to:

- Make certain the source of the raw material is in compliance.
- Make certain the Type of SS is compatible with your specific process waste solutions.
- Examine weld ID for discoloration.■

ASME B31.3 and BPE MEETINGS

The ASME B31.3 Process Piping Committee meets two times each year and the BPE Committee meets three time each year. This year their Meetings, which are open to the public, will be held as follows:

B31.3 Process Piping Committee Meetings

Spring 2020

April 06 2020 08:30 AM - April 08 2020 05:00 PM, Monday - Wednesday

Venue & Location:

Royal Sonesta New Orleans
<https://www.reservationcounter.com/hotels/show/6123778/royal-sonesta-new-orleans-new-orleans-la/>
300 Bourbon Street
New Orleans LA, United States

Fall 2020

September 14, 2020 08:30 AM – September 16, 2020 05:00 PM, Monday - Wednesday

Venue & Location:

Hilton Long Beach
<https://www3.hilton.com/>
701 W. Ocean Blvd
Long Beach, California, USA

Bioprocessing Equipment (BPE) Committee Meetings

Winter 2020

January (Dates TBD)

Venue & Location:

Caribe' Hilton
<https://www.caribehilton.com/>
1 San Geronimo Street
San Juan, Puerto Rico 00901

Spring 2020

May 18, 2020 08:00 AM to May 21, 202 12:00 PM, Monday – Thursday

Venue & Location

Royal Sonesta New Orleans
<https://www.reservationcounter.com/hotels/show/6123778/royal-sonesta-new-orleans-new-orleans-la/>
300 Bourbon Street
New Orleans LA, United States

Fall 2020

September 21, 2020 08:00 AM to September 24, 202 12:00 PM, Monday – Thursday

Venue & Location

Hotel Bonaventure Montreal
<http://hotelbonaventure.com>
900 Rue de la Gauchetiere Quest
Montreal, Saskatchewan, CAN

STEAM SYSTEM DESIGN – THE BASICS

INTRODUCTION

Steam is the oldest and arguably the most widely used form of manufactured energy in industry. Yet in many plants and engineering offices it is still not understood to the degree it should be. And once the steam distribution and condensate collection piping systems are installed, they become largely ignored. Boiler operation and maintenance become the main focus, and rightly so. But not paying attention to the steam distribution and condensation collection systems will be at the detriment of operations, and possibly worse.

Steam is used in such a wide spread manner in most chemical processing facilities that it's taken for granted until something fails or inefficiencies become noticeably affecting. A good example of that is the care and maintenance of strainers that are installed upstream of steam traps. These strainers prevent the trap from plugging up from various deposits of pipe scale and residue from chemical treatment and boiler upsets. Knowing this, one would logically conclude that if scale and residue are anticipated then it would stand to reason that they would get trapped in the strainer, which is the intent. This should then require periodic blow

-downs and/or cleaning of the strainer.

It is surprising the number of times a system's failure or reduction in efficiency can be attributed to something as simple as the impacted build-up of scale and chemical residue in strainers; something that could have been averted with a little planned preventative maintenance. In conjunction with that is the periodic testing of the steam traps. All too often steam systems are installed and forgotten. Until, as I mentioned earlier, a system breaks down or gradually becomes more and more inefficient.

Inefficiency translates into additional operating costs. In older plants the savings potential is enormous, not only from a fiscal standpoint, but also from an environmental standpoint.

A good way to find out how current a plant is with its steam system maintenance is to find out if there is a steam distribution list, a location plan, or any documentation accounting for all of the steam traps throughout the plant. If any of these documents do exist, when was the last time they were checked or updated? And, are these documents actually used as a preventative maintenance tool?

In a surprising number of plants the answer is that there is no formal record, of any kind, for steam traps. If this is true in your plant then this is an indication that the potential for cost savings is a likely possibility.

This article will provide the designer with basic, but essential information regarding steam system design. And the first thing we're going to touch on is the definition of the terminology used when discussing steam.

DEFINITIONS

Working with steam requires an understanding of some of the basics in heat transfer. Keep in mind, this is not an in depth study into the physics of heat transfer, but more of a primer with regard to the design of steam systems and steam applications. In discussing

steam there are some common terminologies used, which need to be explained before we start. Following are definitions of terminology used when discussing steam and condensate fluid service:

Absolute Pressure: The theoretical pressureless state of a perfect vacuum is "absolute zero". Absolute pressure is, therefore, the pressure above absolute zero. At sea level, for instance, the pressure exerted by the atmosphere is 14.7 PSI absolute. Absolute pressure, when measured as pounds per square inch, is indicated as "PSIA". It is also commonly measured in millimeters of mercury, or "mm Hg".

Gauge Pressure: The internal pressure, as indicated on a gauge, of a sealed system, such as a tank or piping system. Gauge pressure measures the pressure above atmospheric pressure where zero pounds gauge equals approximately 14.7 PSIA at sea level. Below zero pounds gauge a vacuum exists which is often expressed in either inches of mercury (Hg) or inches of water (H₂O). Gauge pressure indication is shown as PSIG.

Enthalpy: The total energy, due to both pressure and temperature, of a fluid or vapor at any given time or condition. The basic unit of measurement for all types of energy is the British Thermal Unit (BTU).

Specific Enthalpy: This is the enthalpy of a unit mass (1 pound), generally expressed in BTU/lb.

Specific Heat Capacity: The measure of the ability of a substance to absorb heat. It is the amount of energy (BTU's) required to raise 1 pound of water 1°F. Thus specific heat capacity is expressed in BTU/lb/°F. The specific heat capacity of water is 1 BTU/lb/°F. This means that an increase in enthalpy of 1 BTU will raise the temperature of 1 pound of water by 1°F.

Heat: A form of energy and as such is part of the enthalpy of a liquid or gas.

Heat Transfer: The flow of enthalpy from

Heat Transfer (cont.): matter at a high temperature to matter at a lower temperature when brought into contact.

Heat of the Liquid (Enthalpy of Saturated Water): Expressed in BTU's, this is the amount of heat required to raise the temperature of 1 pound of water from 32°F to the boiling point at a given pressure/temperature correlation; also referred to as Sensible Heat.

Example

Assuming that 50°F water is available as feedwater to a boiler at atmospheric pressure. The water will begin to boil at 212°F. 1 BTU will be required to raise each pound of water 1°F. Therefore, for each pound of water in the boiler, the increase in enthalpy required to raise the temperature from 50°F to 212°F is:

$$(212 - 50) \times 1 = 162 \text{ BTU/lb}$$

If the boiler holds 22,000 pounds mass the increase in enthalpy to bring the total mass of water to its boiling point is therefore:

$$162 \text{ BTU/lb} \times 22,000 \text{ lb} \text{ or } 3,564,000 \text{ BTU.}$$

It must be remembered, this figure is not the sensible heat, but merely the increase in sensible heat required to raise the temperature from 50°F to 212°F. The datum point of steam tables is water at 32°F, which is assumed to have a heat content of zero for our purposes. (The absolute heat content clearly would be considerable, if measured from absolute zero at minus 459°F). The total sensible heat of water at 212°F is therefore:

$$(212 - 32) \times 1 = 180 \text{ BTU/lb.}$$

DEFINITIONS CONTINUED

Latent Heat of Evaporation (Enthalpy of Evaporation): Expressed in BTU's, this is the amount of heat required to change 1 pound of boiling water to 1 pound of steam. This same amount of heat is released when a pound of steam is condensed back to a pound of water. The quantity of latent heat will vary with the pressure and/or temperature of a closed system.

Total Heat of Steam (Enthalpy of Saturated Steam): The sum of the Heat of the Liquid and Latent Heat of Evaporation, also expressed in BTU's.

Flash Steam: When hot condensate, under pressure, is released to a lower pressure, a percentage of that liquid is re-evaporated into flash steam. Depending on various economics, this can certainly be a viable source of low pressure steam.

STEAM 101

Steam is the gas phase of water. It is created when heat energy is added to the water until at some corresponding point of pressure and temperature the water can no longer remain as a liquid. This is called the "Saturation" point and any additional heat energy added to the water at this point will cause some of the water to boil off as steam. This action is referred to as evaporation. The energy in the evaporated state is referred to as the "Latent Heat of Evaporation".

The amount of energy required for evaporation, at lower pressures, is significantly higher than the amount of energy needed to bring the water to the saturation point. The condensing process of steam takes place when the steam is allowed to give up its latent heat content and condense back to a liquid state.

The latent heat content of the steam is the energy that is given up so readily for heat transfer. In fact the steam is so willing to give up this heat energy that we have to take various measures, sometimes costly, just to contain it long enough to get it to where we need to use it. Some of these measures include insulation to contain the heat, steam traps and separators to keep condensate from accumulating in the distribution piping, and proper line sizing to reduce friction loss. These measures will be covered in more detail later.

Steam can exist in either a saturated condition or in a superheated condition. The temperature of saturated steam is in constant correlation with its pressure. If you know what the temperature

of saturated steam is you then know what the pressure is. Inversely, if you know what the pressure is you then know what the temperature is.

To illustrate; if we were to take a container with a volume of 26.8 cubic feet and pour in 1 pound of water at the temperature of melting ice, 32°F, in all practicality the heat content, or enthalpy, would be zero. By adding heat to the water, while under atmospheric pressure, until it reached 212°F the heat content of that water at 212°F will then be 180.2 BTU's. By adding additional heat, or enthalpy, to the water it will begin to change state and evaporate into steam. The heat content of this latent heat of evaporation is 970.6 BTU's. At atmospheric conditions these numbers will always be constant. Water at its saturation point will contain 180.2 BTU/lb and any steam that is formed will contain 970.6 BTU/lb.

By sealing our container, and continuing to heat the water until it has been completely evaporated, that 1 pound of water, with a volume of .016 cubic feet, has been transformed into 1 pound of steam with a volume of 26.8 cubic feet. That is an increase in volume of 1675 times. This mass volume is indeed one of the considerations when designing for steam distribution.

At atmospheric pressure we now know that the constants are: 212°F at saturation point, heat content of the liquid is 180.2 BTU/lb, heat content of the steam is 970.6 BTU/lb and the specific volume of the steam is 26.8 cubic feet.

We will now remove the seal on our container and install a vertical piston. The only thing holding down the piston initially is atmospheric pressure at 14.7 P.S.I.A. or zero P.S.I.G. Consequently the container still has a volume of 26.8 cubic feet and the steam is still at atmospheric pressure.

By adding a 10 P.S.I. weight on top of the piston, two things happen: The steam condenses back to water and the volume in the container is reduced. However, the heat of the liquid will still remain at 180.2 BTU's. With 10 P.S.I. of compression on the hot water in the container it

will take more energy to release the molecules into steam. At 10 PSIG the saturation, or boiling point of water is 239.4°F, at which point the heat of the liquid will be 207.9 BTU/lb. By adding an additional 27.7 BTU to the water we can bring it to its saturation point of 239.4°F. If we continue to add heat the water will begin to boil off to steam. If we boil off the entire pound of water under the 10 P.S.I.G. pressure the latent heat of the steam will then be 952.9 BTU's and occupy 16.5 cubic ft.

Therefore, under 10 PSIG pressure, the constants are: 239.4°F saturation point, heat content of the liquid is 207.9 BTU/lb, heat content of the steam is 952.9 BTU/lb and specific volume of the steam is 16.5 cubic feet.

Superheated steam, on the other hand, does not have a pressure/temperature correlation. While saturated steam and water exist at the same pressure and temperature, if heat transfer continues into the steam after saturation and evaporation has been accomplished, the steam temperature will continue to rise. Once the temperature has exceeded that of saturated steam at its coincidental pressure it becomes superheated.

This superheat condition can be manufactured to achieve a certain amount of superheat for use in mechanical work such as steam turbines or for transmission over long distances (this will be discussed later). It can also be the unneeded result at pressure reducing stations and other cases where there is a turndown of steam pressure to affect temperature control or pressure control, the amount of superheat depends on the turndown ratio.

In order to put into action what we have discussed to this point we will require steam generation in the form of boilers. The boilers will be fired by coal, gas or oil, determined purely on the economics of the site location. As was mentioned earlier, the sensible heat of water at 32°F is taken as zero. The specific heat capacity of water is 1.0 BTU/lb/°F. Therefore raising the

In order to put into action what we have discussed to this point we will require steam generation in the form of boilers. The boilers will be fired by coal, gas or oil, determined purely on the economics of the site location. As was mentioned earlier, the sensible heat of water at 32°F is taken as zero. The specific heat capacity of water is 1.0 BTU/lb/°F. Therefore raising the temperature of 1 pound of water from 32°F to 212°F will require a sensible heat of:

$$(212 - 32) \times 1 = 180 \text{ BTU}$$

If 2000 pounds of water in the boiler is heated to 212°F, the total sensible heat will be:

$$2000 \times 180 = 360,000 \text{ BTU}$$

But, if the water in the boiler was already at 70°F, the enthalpy required to bring the mass to saturation would be:

$$(212 - 70) \times 1 \times 2000 = 284,000 \text{ BTU}$$

It must be remembered that the total heat of the liquid is still 360,000 BTU. But, since the water, at 70°F, already had some heat content, we only had to make up the difference to get it to saturation. And that difference is 284,000 BTU.

As we did with the 1 pound container, we will close off the boiler and continue adding heat, allowing the water to evaporate to steam. As the volume of steam increases the pressure inside the boiler will continue to increase until the supply of heat to the water is stopped or the pressure inside the boiler released.

Since we want to generate steam at a specific pressure/temperature, say 300 PSIG, we need to continue adding heat and water to the boiler and releasing the steam that is formed at a controlled 300 PSIG. In referring to the steam tables (which will be discussed a bit later) we can see that at 300 PSIG the temperature is 422°F, sensible heat is 399.08 BTU/lb, latent heat is 804.7 BTU/lb and specific volume of the steam is 1.45 cubic ft/lb.

Taking into account peak winter demands as well as the lighter summer requirements for a

moderate size plant we can average out those demands and assume a use rate (for our purpose here) of 20,000 lb/hr of 300 PSIG saturated steam. The average demand for this plant, in terms of energy requirements, would therefore be:

$$20,000 \text{ lb/hr} \times 399.08 \text{ BTU/lb} = 7,981,600 \text{ BTU/hr}$$

If all of the services and equipment requiring steam had the same steam pressure requirements of 300 PSIG, and operated year-round it would make life a little simpler. But life and plant operation are never simple. When determining what pressure steam should be generated at, economics, efficiency, equipment design limits, production demands, and other criteria will help make that determination. Seasonal requirements, for those facilities that see seasonal temperature fluctuations, will dictate the overall required peak production rate. ■

Next in Our Steam Series

Next month we will discuss the sizing of a steam distribution system. We will touch on what the basis is for sizing a steam piping distribution system and how to determine what steam pressure needs to be generated at the boilers.

ASME A13.1 – Scheme for the Identification of Piping Systems

ASME A13.1 – Scheme for the Identification of Piping Systems was originally affirmed in 1928. It was then reaffirmed in 1945, revised in 1956, 1975, 1981, reaffirmed in 1985 and 1993, revised in 1996, reaffirmed in 2002, revised in 2007, reaffirmed in 2013, and revised in 2017.

Having gone through a series of revisions and reaffirmations over the past 91 years it is once again time to review the document's reaffirmation or revision.

For those of you not familiar with this ASME standard, the following is indicative of ASME's ongoing efforts in advancing workplace safety.

In the Introduction of A13.1 it states the following:

“In order to promote greater safety, lessen the changes of error, confusion, or inaction, especially in times of emergency, a uniform system for the identification of piping contents has been established to warn personnel when the piping contents are inherently hazardous. Therefore, while this Standard has been prepared to specify the identification of the contents of piping systems on the basis of legends, it also suggests the use of color as a supplementary means of identifying the type of hazard of the material contained in the system.”

This standard therefore provides the means and methods by which the owners of a chemical processing facility can add a final layer of safety to their workplace. By adding markers to the pipelines and equipment maintenance and operations personnel as well as first responders to an accident can readily see what hazardous constituents they are dealing with.

By having pipelines and equipment labeled with color coded markers it makes it much easier to separate hazardous fluids from non-hazardous fluids. In an emergency situation the few seconds to recognize fluid services can make all the difference in the world as to whether or not you return home from work that day.

ASME A13.1 provides guidance that helps comply with OSHA (Occupational Safety and Health Administration), in which A13.1 is referenced under 29 1910.261(a)(3),

subparagraph (ii) as follows:

“1910.261(a)(3) General incorporation of standards. Establishments subject to this section shall comply with the following standards of the American National Standards Institute, which are incorporated by reference as specified in §1910.6:

1910.261(a)(3)(ii) Scheme for the Identification of Piping Systems, A13.1—1956.”

And while the date of the referenced standard has not been updated for quite some time, the inference still remains clear.

Even with the clearly stated requirement by OSHA to mark the content of pipelines and equipment notwithstanding, it just makes good practical sense to do it.

In many cases over the years chemical processing facilities have created their own color coding scheme, placement requirements, and chemical legends. What ASME has done is to standardize the process. This helps the emergency responders to recognize the meaning of these color coded labels no matter what facility they have to enter.

And when referring chemical processing facilities it includes: the conversion of raw materials and intermediates into chemicals and petrochemicals, fats and oils, paints and coatings, food and beverages, the refining of petroleum, the production of pharmaceuticals and other such processes.■

QUESTION OR COMMENTS

If you would like us to address a specific topic or simply answer a question, related or unrelated to the content of this Newsletter, please contact us at: staff@wmhuittco.com. In the subject line of the email please enter “Newsletter Question/Comment.”

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