ISSN No. 2231-0045 VOL.II* ISSUE-IV*MAY-2014
Periodic Research

Design and Manufacturing of Condensers and Evaporators for Chiller Plant for Industrial Application

Abstract

This paper presents the design of condenser and evaporator for a refrigeration cycle. Factors considered such as choice of refrigerant, pressure-temperature ratio, efficiency, size, as well as many other criteria were considered and analyzed. The result of this analysis is the design of condenser and evaporator for water chiller cycle, based on a double pipe heat exchanger, that is environmentally friendly, mechanically sound, cost efficient, and small in size.

Keyword Design of condenser for plant, Design of evaporator for plant, Manufacturing procedure for condenser and evaporator (Shell and Tube Type),Testing and commissioning of Chiller Plant.

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Introduction

Condensers and evaporators are basically heat exchangers in which the refrigerant undergoes a phase change. Next to compressors, proper design and selection of condensers and evaporators is very important for satisfactory performance of any refrigeration system. Since both condensers and evaporators are essentially heat exchangers, they have many things in common as far as the design of these components is concerned. However, differences exists as far as the heat transfer phenomena is concerned. In condensers the refrigerant vapour condenses by rejecting heat to an external fluid, which acts as a heat sink. Normally, the external fluid does not undergo any phase change, except in some special cases such as in cascade condensers, where the external fluid (another refrigerant) evaporates. In evaporators, the liquid refrigerant evaporates by extracting heat from an external fluid (low temperature heat source). The external fluid may not undergo phase change, for example if the system is used for sensibly cooling water, air or some other fluid. There are many refrigeration and air conditioning applications, where the external fluid also undergoes phase change. For example, in a typical summer air conditioning system, the moist air is dehumidified by condensing water vapour and then, removing the condensed liquid water. In many low temperature refrigeration applications freezing or frosting of evaporators takes place.These aspects have to be considered while designing condensers and evaporators. In the respective project the condenser and the evaporator used are shell and tube type water cooled condenser and plain copper tube evaporator immersed in water bath.

Condensors

As already mentioned, condenser is an important component of any refrigeration system. In a typical refrigerant condenser, the refrigerant enters the condenser in a superheated state. It is first de-superheated and then condensed by rejecting heat to an external medium. The refrigerant may leave the condenser as a saturated or a sub-cooled liquid, depending upon the temperature of the external medium and design of the condenser. Figure shows the variation of refrigeration cycle on T-s diagram. In the figure, the heat rejection process is represented by 2-3’-3-4. The temperature profile of the external fluid, which is assumed to undergo only sensible heat transfer, is shown by dashed line. It can be seen that process 2-3’ is a de-superheating process, during which the refrigerant is cooled sensibly from a temperature T2 to the saturation temperature corresponding condensing pressure, T3'. Process 3'-3 is the condensation process during which the temperature of the refrigerant remains constant as it undergoes a phase change process. In actual refrigeration systems with a finite pressure drop in the condenser or in a system using a zeotropic refrigerant mixture, the temperature of the refrigerant changes during the condensation process also. However, at present for simplicity, it is assumed that the refrigerant used is a pure refrigerant (or an azeotropic mixture) and the condenser pressure remains constant during the condensation process. Process 3-4 is a sensible, sub cooling process, during which the refrigerant temperature drops from T 3to T4 .

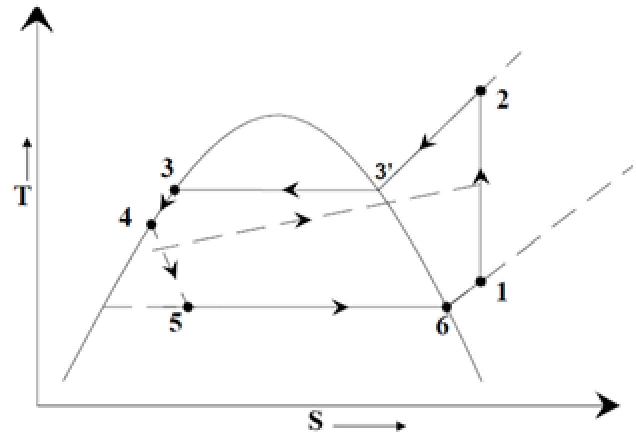


Fig.1 Refrigeration Cycle On T-S Digram

Classification of Condensors

Based on the external fluid, condensers can be classified as:

a) Air cooled condensers
b) Water cooled condensers, and
c) Evaporative condensers

In the respective system the condenser used is water cooled condenser. In water cooled condensers water is the external fluid. Depending upon the construction, water cooled condensers can be further classified into:

1. Double pipe or tube-in-tube type
2. Shell-and-coil type
3. Shell-and-tube type

The condenser used is shell and tube type water cooled condenser.

Shell and Tube Type Condenser

This is the most common type of condenser used in systems from 2 TR upto thousands of TR capacity. In these condensers the refrigerant flows through the shell while water flows through the tubes in single to four passes. The condensed refrigerant collects at the bottom of the shell. The coldest water contacts the liquid refrigerant so that some subcooling can also be obtained. The liquid refrigerant is drained from the bottom to the receiver. There might be a vent connecting the receiver to the condenser for smooth drainage of liquid refrigerant. The shell also acts as a receiver. Further the refrigerant also rejects heat to the surroundings from the shell. The most common type is horizontal shell type. A schematic diagram of horizontal shell-and-tube type condenser is shown in Fig.2 Vertical shell-and-tube type condensers are usually used with ammonia in large capacity systems so that cleaning of the tubes is possible from top while the plant is running.

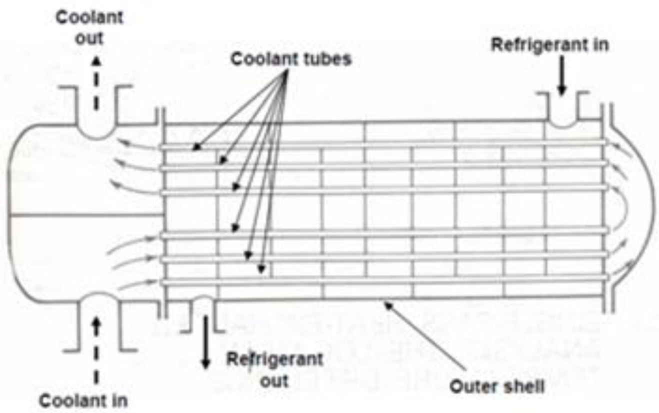


Fig.2 Vertical shell-and-tube type condenser

Design Of Condenser For System:

Condenser Design :

Refrigerant R22
Evaporating temperature – 3℃
Condensing temperature – 45℃
Inlet temperature of water – 30℃
Outlet temperature of water – 35℃
No. of passes – 2
No. of tubes– 42
I.D. of copper tube -14mm
O.D. Of copper tube- 16mm

Heat rejection ratio =1.27

Heat rejected to condenser

Q = (14.5+2.86) × 3.157 × 1.27
=77.54 KW

Condensing coefficient :-

hcond = 0.725 gρ2k3hfgμΔtND14

the density and latent heat of vaporization hfg at 45℃

ρ= 10.90203
= 1.109 kg/l
= 1109 kg/m3

hfg = 160900 j/kg (refrigeration and air conditioning by stoecker table A6)

K= 0.0779 W/mK

μ = 0.000180 pa-s

The average no. of vertical tubes in a vertical row N is

N = 2+3+4+3+4+3+4+3+4+3+4+3+213
=3.23

Assuming Δt= 50k

hcond = 0.725
9.81×11092×0.07793×1609000.00018×5×3.23×0.016
14
= 1528W/m2k

Conductivity of copper is 390 W/mK and resistance of tube is

xA0KAm = (0.016-0.014)/2390 × 16(14+16)/2

= 0.000002735 m2k/w

Fouling factor

1hf= 0.000176 m2k/w

Water side coefficient:

The flow rate of water

= 77.544.19 × (35-30)

= 3.7 kg/s

Volume flow rate is

= 3.71000

= 3.7 × 10-3 m3/sec

Velocity of water through tubes

V = 3.7×10-321 ×π4 ×0.0142

= 1.14 m/s

Properties of water at 32℃

ρ=1000 kg/m3

μ = 0.000773pa-s

Cp = 4190 J/kg.k

K= 0.617 w/mk

Water side heat transfer coefficient:-

hw = (VDρμ)0.8×(cmk)0.4×ckD

= (1.14×0.014×10000.000773)0.8×0.617×0.023

0.014 × (4190×0.0007730.617)0.4

hw =5548.69 W/m2K

Overall heat transfer coefficient:-

1U0 = 11528+0.000002735+0.0160.014 × 0.000176 × 0.0160.014 × 15548.69

1U0 = 0.001064

U0=939.58 w/m2k

Logarithmic mean temperature difference:-

LMTD = 45-30-45-35ln45-3045-35

= 12.33 ℃

Outside Tube surface area:-

A0= 77.54 ×103939.58 ×12.33

= 6.69 m2

=74.21 ft2

Length of tubes

L = 6.6942×0.016×π

= 3.168m

= 10.55 ft

For individual condensor ,

Shell diameter Ds=203.2mm (8")

No. of tubes NT=42

Outer tube diameter do=16mm

Inner tube diameter di=14mm

Length L=1.584m

Material History Overview

The introduction of the first stainless steel welded tubing began in the U.S. with "ordinary" grades such as UNS S30403 or UNS S31603, which provided good service records in fresh water. S31603 was used for a short period in seawater applications but proved to be susceptible to localized pitting and crevice corrosion in concentrated chloride environments.

The titanium development in Europe and Japan in 1970 offered a timely solution. Demonstrating outstanding resistance to general and localized attack in high chloride environments, it has pro-vided nearly forty years of trouble-free seawater service for the power generation and process industries. In the late 70's, due to the titanium market crisis, highly alloyed stainless steels, also called super stainless steels, were developed to offer a lower-cost alternative solution. These new alloys included UNS S31254 and UNS N08367 super austenitic alloys and UNS S44735 and UNS S44660 super-ferritic alloys. However, the use of these alloys has been quite limited mainly to the use of titanium retubing programs in Europe and USA.

Since the year 2000, material prices for Nickel and Molybdenum have been unstable and fluctuating. As a result, the duplex and lean duplex stainless steels including UNS S31803, UNS S32003, UNS S32304 and UNS S32101 have been developed as a cost-effective alternative to traditional standard austenitic stainless steel alloys for use in mild cooling water service. Recently, super-duplex alloys have also been developed in strip form offering additional material options for brackish and seawater service.

Today, titanium and stainless steel welded tubing represent the vast majority of the condenser tubing market. The pallet of corrosion-resistant alloys covers a large spectrum of applications in terms of corrosion resistance and corrosion constraints. The material selection criteria for condenser tubing is mainly based on the choice of the most suitable alloy according to the cooling water quality.

Manufracturing Process

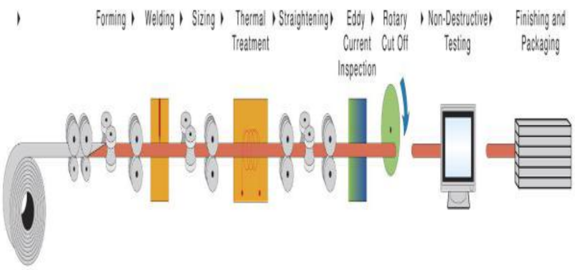


Fig.3Valtimet TitaniumAnd Stainles Steel Welded Tubing Process

Steps Involved In Manufracturing Process

Figure describes Valtimet titanium and stainless steel welded tubing manufacturing process. Tube mill strip is uncoiled and fed through a multiple stand forming mill which shapes the strip into L. de Kerret 6 a tube. The tube is autogenous welded in an inert atmosphere with a non-consumable tungsten electrode (T.I.G. welding) or with the laser technology. Dimensional properties are achieved when the as-welded tube passes through a final, multi-stage sizing mill. Mechanical and thermal stresses are relieved by in-line induction heating under inert atmosphere (bright annealing). Following that, the tube is straightened, 100% Eddy Current (EC) tested, line marked, then automatically cut. Finished tube ends are deburred. The product is subsequently dimensionally inspected, tested through NDT controls (pneumatic testing, EC inspection and Ultrasonic Testing) and pack-aged to customer specification.

Weld Gas Smoother

Considering a seam-welded tube cross section, the weld is obviously never 100% invisible.

There are some inherent characteristics to the welding process, which lead to a geometrical difference from the base material (laminated strip). This is specially the case with TIG welding: Tungsten Inert Gas process is an autogenous welding, resulting in a wide weld bead (up to several times the wall thickness). During solidification, the weld bead is pulled down by gravity, even more considering the pressure applied on the tube sides, by the welding rolls. If no care is taken, the weld bead will collapse down. Such a phenomenon will result in a shape irregularity, harmful to the mechanical resistance (especially fatigue), to the corrosion resistance (crevice corrosion) if it forms a confinement zone, and harmful to the tube controllability (especially for Ultrasonic control). To avoid this phenomenon, VALTIMET has developed a process, named Weld Gas Smoother. As indicated by its name, a gas flow under pressure is injected into the tube, during welding, to hold up the weld bead. This gas is, of course, inert, to avoid any oxidation of the ID surface; Argon is used for that purpose. In addition, a special care is taken, to use the right parameters: weld rolls pressure and positioning, sufficient gas flow... to insure the control of weld dimensions and geometry. Figure 3 shows the principle of the Weld Gas Smoother process.

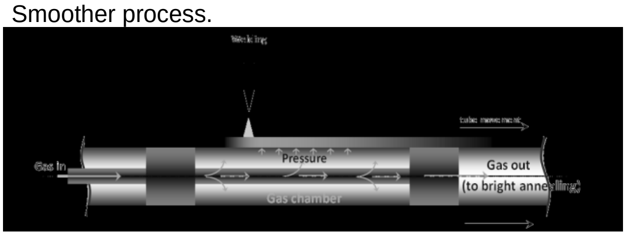
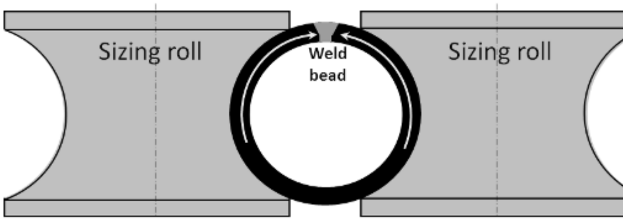


Fig.4 Weld Gas Smoother Process Principle

Roll Sink Anneal

For Austenitic Stainless Steel tubes manufacturing, ASTM A249 and A688 require a cold work operation on the welded tubes before annealing; this cold work operation can be carried out on the entire section of the tube (weld parent metal), or only on the weld . Today, several technologies exist to satisfy this requirement (bead rolling, bead hammering, roll sinking, redrawing…) Valtimet has chosen to use another technology: the Roll Sink Anneal process. This technique provides a cold work operation during sizing (Roll Sink), followed by a bright annealing.The sizing is operated by 4 horizontal and 4 vertical roll sets, as shown on figure 4. Passing through those rolls, the tube diameter is reduced, so as to reach the final tube diameter. Diameter reduction goes up to *12%* reduction, depending on the material grade and on the wall thickness.



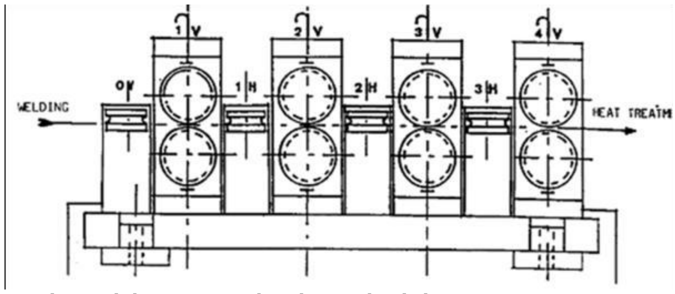


Fig.5 Sizing OD Reduction Principle

The weld bead material being softer than the base material, most of the cold work is supported by the weld. This is easily visible on figure 5, representing a TIG welded S31603 tube: with a 10% OD reduction sizing, the dimensional reduction of the weld zone is up to 16%.

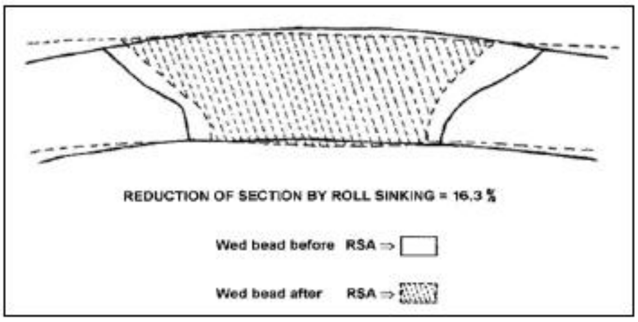


Fig.6 Weld Bead Profile Before After Sizing

Figure 5shows the evolution of micro-hardness in Weld and Base metal, throughout the manufacturing process, on a TIG welded S30403 tube, which supported an OD reduction of 10%. It clearly demonstrates that sizing takes the weld bead hardness at the same level than the base material.

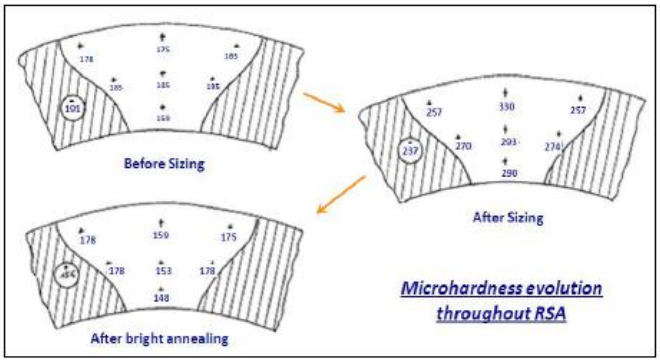


Fig.7 ***Micro-hardness evolution TIG welded S31603***

The second step is an in-line annealing treatment, which main purpose is to relax the residual strains from forming and sizing. The most visible result is a homogenization of mechanical proper-ties, as shown on figure 6 (Hardness values after bright annealing). For austenitic stainless steel tubes, annealing leads to a re-crystallization of the weld material, and dissolution of ferrite, as shown on Figure 7. Here, annealing has lowered the ferrite rate down to 0.02%.

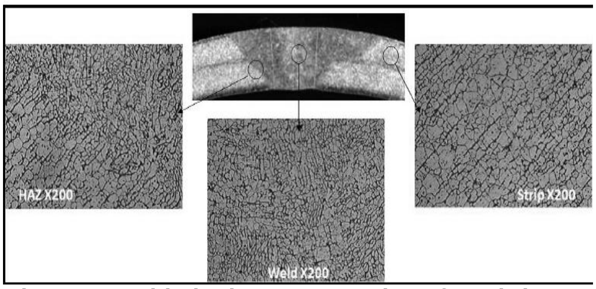


Fig.8 ***TIG welded tube cross section after nitric acid etching (S30403)***

VALTIMET has developed a Bright Annealing process, which ensures no oxidation, neither on external tube surface, nor on internal surface, thanks to an inert atmosphere protecting the tube during Heat treatment (induction with an encircling coil) and cooling (carbon sleeves cooled by water flow).The utility of a bright annealing compared to annealing + pickling will be detailed in a next chapter. The main proof of RSA efficiency and reliability would be its references. As a matter of facts, RSA process has been already qualified by more than 30 companies in the world. Today, more than 200.000 km of tubes have been manufactured by Valtimet with RSA process; more than 400 power stations in the world, fossil or nuclear, are equipped with condenser and feed water heater tubes cold worked by RSA.

Influence of cold work technology on weld corrosion resistance

The strengths and drawbacks of each cold work technology is very well known now, excepted may be the influence on the corrosion resistance of the weld. The present work8 will compare a tube cold worked with RSA process and a tube cold worked with bead rolling, with ASTM G48 method A test in order to evaluate the pitting corrosion susceptibility of both welds. The investigated tubes were manufactured at CST Hyderabad plant by CST VALINOX, on the same line, and with the same operating conditions. Their final dimensions were 31.75 mm OD, 0.80 mm wall thickness. The tubes were manufactured in 304L and TIG welded. In both cases, after cold work, an in line annealing at 1050°C was performed.

Table No. 1

Table : Nominal chemical composition of tested AISI 304L TIG welded tubes (weight fractions)

	C	Cr	Ni	Mn	Si	P	N	S	Fe
304L	0.030 max	18.2	10.1	2.00 max	0.75 max	0.045 max	0.10 max	0.030 max	Bal.

Above figure shows micrographs of both Bead Rolled tube weld and Roll Sinked tube weld. The micro-graphic examinations show no evident differences between the two tube samples .The microstruc-tures are very similar as well as the ferrite content (1.25% for the bead rolled weld and 1.30% for the non bead rolled weld).

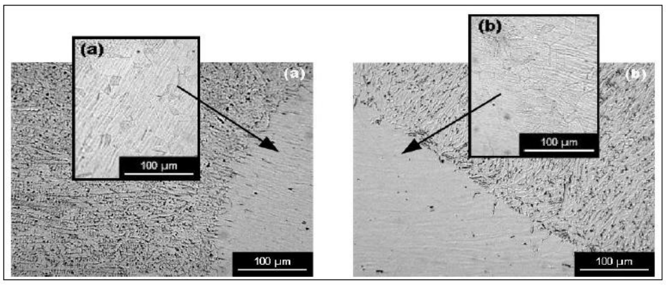


Fig.9 ***Micrographs and dendrite/austenite interface of the (a) bead rolled and (b) roll-sinked welds.***

Based on the chemical composition, the critical pitting temperature of UNS 30403 stainless steel is estimated to be 10°C (Table 2). However, welding is known to induce microstructural modifications and is thus expected to modify the corrosion susceptibility of the welded product. For that reason, the critical pitting temperature of the tubes was investigated starting to temperatures below 10°C. According to the ASTM G48 Method A standard (Ferric Chloride Pitting Test), samples were immersed into a ferric chloride solution (PH ≈ 1) during 24 hours. The temperature of the ferric chloride test solution was controlled via a thermostated water bath at 5°C (heater chiller). This tests allows the determination of the Critical Pitting Temperature (CPT), which is defined as the temperature at which pits of at least 25 µm depth are developed on the metal (ASTM G48 standard).

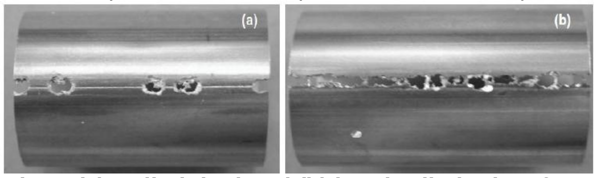


Fig.10*(a) Roll-sinked and (b) bead rolled tube after 24 hrs at 5°C in the ferric chloride solution*

After 24 hours immersion in the ferric test solution at 5°C, both tubes exhibited strong pitting corrosion features. Figure 9 shows that :

- Pitting corrosion is localized along the weld with extent of the attack leading to holes.
- The rolled tube was significantly more attacked than the non-rolled one.

Influence of Bright Annealing on corrosion resistance

Investigations were carried out on UNS S44735 in order to assess the impact on the corrosion resistance of the different heat treatment processes which can be used during the welded tubing manufacturing. A conventional ASTM G48 test has been performed on three different states ac-cording to heat treatment processes:

- "As received": UNS S44735 strip without any additional heat treatment than the one performed during the strip production.
- "900-Air": strip which has been heat treated at 900°C under air (open air annealed) and pickled to remove the residual oxidation due to the oxidizing environment during the heat treatment process

ISSN No. 2231-0045

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(representative of tubes which are open air annealed and pickled)

- "900-H2": welded tube which has been heat treated at 900°C under hydrogen protective atmosphere (representative of tubes which are bright annealed with Valtimet process)

Influence of weld technology on corrosion resistance

TIG and Laser weld description

For welded condenser tubing manufacture, two welding technologies are available: La-ser and TIG. Both are autogenous welds (without added filler metal), but, as the two micrographics on figure 11, the result is completely different. The biggest advantage of Laser welding is actually the welding speed, especially for heavy wall stainless steel tubes. Indeed, as shown on figure 13, the higher the wall thickness, the faster is Laser welding compared to TIG welding.

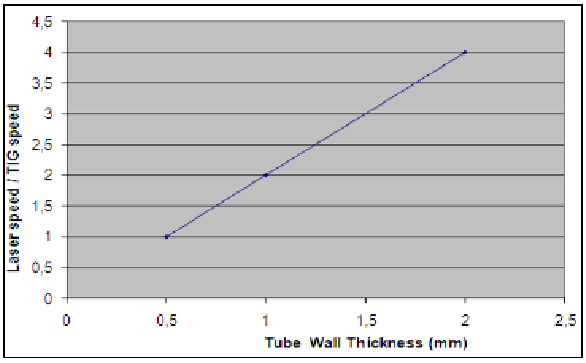

Fig.11TIG and LASER Welding Comparison

Compared pitting corrosion susceptibility for super austenitic welded tubes.

This study10 aims at evaluating the resistance of a super austenitic stainless steel welded tube to pitting corrosion, and more specifically to compare the influence of welding process on the pitting susceptibility. The alloy studied is UNS N08367, and its chemical composition is presented in Ta-ble 5. Since it is highly alloyed, UNS N08367 has a PREN of 44.3.

Table1:

Chemical composition of AL-6XN Laser and TIG welded tubes.

Chemical composition of tested UNS N08367 tubes, in %									
C	Mn	P	S	Si	Cr	Ni	Mo	N	Cu
0.022	0.71	0.023	0.0003	0.38	20.5	24	6.2	0.21	0.44

The evaluation of tube Critical Pitting Temperature is conducted using tests following ASTM G48 E (24 hours exposure). During this experiment, if minimum pitting attack is observed, the next test is performed at a temperature 5°C lower than the previous one. If less than minimum pitting attack is observed, the next test is conducted 10°C higher. The procedure is repeated using a new tube and a fresh solution. For each steel at each temperature, test is repeated twice.The first test campaign investigating pitting corrosion of UNS N08367 Laser and TIG welded, gave respectively 80°C and 50°C as CPT values. Tested at their respective CPT, UNS N08367 Laser tubes showed pits on both the base metal and the weld while UNS N08367 TIG tubes developed holes and pits on the weld only. The second test campaign gave similar results.

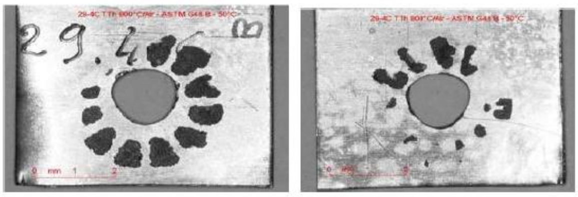

Fig.12 ASTMG48 Method B-900

The next figure shows the aspect of Laser and TIG welded tubes at their CPT and 5°C below. At 80°C, Laser welded presents holes and pits on both the base metal and the weld. At 50°C, TIG welded shows holes and pits on the weld; the base metal is not affected because the temperature is not high enough.The sequence of increasing resistance to pitting corrosion is the following:

UNS N08367 TIG (50°C - weld) < UNS N08367 Laser (80°C - base metal) For UNS N08367 tubes, laser welding process provides better pitting corrosion resistance than TIG welding process. Indeed, the laser welded tubes resist until the base metal limit (80°C). Contrary to the TIG welded tubes, the laser weld is not the weak point of the tube. A similar experiment10 has been performed on 1.4565 TIG and Laser welded tube, showing the same tendency. For super-austenitic tubes, Laser welding is then more appropriate than TIG welding.

Evaporator

Introduction

In the evaporation process, concentration of a product is accomplished by boiling out a solvent, generally water. The recovered end product should have an optimum solids content consistent with desired product quality and operating economics. It is a unit operation that is used extensively in processing foods, chemicals, pharmaceuticals, fruit juices, dairy products, paper and pulp, and both malt and grain beverages. Also it is a unit operation which, with the possible exception of distillation, is the most energy intensive. While the design criteria for evaporators are the same regardless of the industry involved, two questions always exist: is this equipment best suited for the duty, and is the equipment arranged for the most efficient and economical use? As a result, many types of evaporators and many variations in processing techniques have been developed to take into account different product characteristics and operating parameters.

Types of Evaporators

1. Batch pan	5. Rising/falling film tubular
2.Natural circulation	6. Forced circulation
3.Rising film tubular	4.Falling film tubular
7.Wiped film	8.Plate equivalents of tubular evaporators

Design of Evaporator For System:

Evaporator Design

Given-

Mass flow rate of water for evaporator - 17300 kg/hr.

R22 inlet temperature - 3℃

Temperature Reduction-13 ℃ to 8 ℃

Energy balance equation is given by,
Q = mw cpw (Twi – Two)
Q = 1730×4.187×(286-281)3600
Q = 100.6 KW
= 100.63.517
Q = 28.6 TR ≈ 29 TR
Q = 102 KW
Q = mc×cpc (Tco– Tci)
102 = 1.31×29×1.18× (Tco– 3)
Tco = 5.28 ℃

Logarithmic mean temperature difference(LMTD), ∆Tm

∆Tm=Twi – Two-(Tco– Tci)lnTwi – Two(Tco– Tci)
= 13 – 3-(8-5.28)ln13-3(8-5.28)
∆Tm=5.6℃

Inner diameter of tube (di)=17.3mm
Outer diameter of tube(do)=19mm
………(from table 8.1 pg no 289 from ref.[18] BWG Gauge 17, od of tubing 34", Heat exchanger selection, rating & thermal design-KAKAC)----------[18]

Properties of tube side fluid(R22) at 3℃ (276K).

Cp= 1.18 × 103 J/kgK
K= 0.099 W/m2K
Pr= 2.766
ρ= 1272kg/m3
μ= 2.314× 10-4 N-sec/m2

Properties of shell side fluid(water) at avg. temperature 283K.

Cp= 4.184 × 103 J/kgK
K= 0.583 W/m2K
Pr= 8.61
ρ= 1000 kg/m3
μ= 10.149× 10-4 N-sec/m2

First estimate the no. of tubes(14.5TR)

NT = mcp×Um×Ac
= 1.31×14.51272×2×π4(0.0173)2
= 31.76
≈ 32 tubes (as per table no. 8.3 , page no.294 ,Heat exchanger design by kakac) -------------[18]

Tube shell layout (Tube counts)
34" O.D tubes on 1″ Square pitch 6-pass 36 tubes taken..
Hence,
NT = 36
The flow area through the tubes is,
AT=π4di2×NT
= π4(0.0173)2×36
= 0.0085 m2

Inner shell diameter

Ds2= (NT)CL(PR)2(do)20.785×(CTP)
Where,
CL = tube layout constant
CL = 0.87 for 300 & 600
CTP = tube count calculation constant….(Page no. 303)
CTP = 0.5 …. for 6 tube passes
Ds = { [36× 0.87× (0.0254/0.0190)2×(0.019)2]/(0.785×0.5) }1/2
= 0.226m
= 226mm
≈ 254 mm ≈ (10 inch)

Baffle spacing

B = (1/5) × (Shell I.D.)
= (1/5) × (0.254)
= 0.05m

Kern Method

<u>Cross flow area at the shell diameter</u>
As= (Ds-NTC.do)B
Where,
NTC = DsPT = shell diameterSquare tube pitch
= 10
As = (0.254-10×0.019) ×0.05
= 0.0032 m2

Equivalent diameter

De = 4(PT2-πd024)πdo
= 4[(0.0254)2-π4(0.019)2π×0.019
= 0.0242m

Reynold's no. can be calculated as
Re=mAsDeμ
= 4.87×0.02420.0032×10.149×10-4
= 36228.6
Assuming constant properties, the heat transfer coefficient can be estimated from
ho= 0.36KDeRe0.55Pr1/3
= 0.36×0.5830.0242(36228.6)0.55(8.61)13
= 5723.96 w/m2 k
Tube side heat transfer coefficient:-
Re=ρUmdtμ
= 1272×2×0.01732.314×10-4
= 190195.33

By using petukhov-kirillov correlation

Nub=(f2)RePr1.07+12.7(f2)12[(Pr)12-1]
f = (1.58 ln Re- 3.28)-2
= (1.58 ln 190195.33 – 3.28)-2
= 0.0039
Nub= 0.00392×190195.33×2.7661.07+12.7×(0.00392)1/2[(2.766)12-1]
= 717.81
hi=Nub×kdi
= 717.81 x (0.099/0.0173)
= 4107.69 w/m2 k
The overall heat transfer coefficient for clean surface is
1Uc=1ho+1hi×dodi+roln(rori)k
= 15723.96+14107.69×0.0190.0173+[0.0192 × ln0.01920.017322]400
Uc=2250.74 w/m2 k
And for fouled surface
1Uf=1Uc+Re
= (1/ 2250.74)+ 0.0001
Uf = 1837.22 w/m2 k
Now,
Q = Uf Af∆Tm = Uc Ac∆Tm
Af=1021837.22×5.6
= 9.91 m2
≈ 106.71 ft2
Ac= 1022250.74×5.6
= 8.09 m2

<u>Length of heat exchanger</u>

L= AfNTπdo
= 9.9136×π×0.019

ISSN No. 2231-0045 VOL.II* ISSUE-IV*MAY-2014
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L = 4.61 m
≈15.12 ft
L= 5m (which is round up)

For individual evaporator

Shell diameter Ds=254mm
No. of tubes NT=36
Length L=2.5m
Outer tube diameter do=19mm
Inner tube diameter di=17.3mm
Square tube pitch PT=0.0254m
Baffle spacing B = 0.05m

Compressor Selection

Condensing Tempreture 45℃
Evaporating Tempreture 3℃
Condensing Pressure= 1609.6 Pascal
h1=406.44 kj/kg
h2=440kj/kg
h3=h4=251.016
R.E=h1-h4
=406.44 - 251.016
=155.424
Flow rate of refrigerant = 102 155.424
= 0.6kg/sec
Power required for compressor
= (0.6) × (h2-h1)
=(0.6) × (440-406.44)
= 20.12 KW
For single compressor 10.06 KW (2.86TR)

Material history

It is usual for plain, round tube to be used in the construction of shell and tube, shell coil and coil type heat exchangers. Depending upon the service conditions, the following copper alloys are most widely used for these tube applications:

- C106 Phosphorus deoxidised non-arsenical copper
- CZ110 Aluminium brass
- CZ111 Admiralty brass
- CZ126 Special 70/30 arsenical brass
- CN102 90/10 Copper-nickel-iron
- CN107 70/30 Copper-nickel
- CA102 7 % Aluminium bronze

It must be emphasized that copper and copper alloys are not recommended for service in contact with ammonia but are entirely suitable for use with most other primary refrigerants.

Manufracturing details

Bimetal tubes

In primary heat exchangers handling ammonia, plain steel tubes are frequently used. However,in some applications it is necessary to employ bimetal tubes, having steel in contact with the primary refrigerant and a copper alloy exposed to the other fluid. One such application is in marine refrigeration condensers where materials resistant to sea water corrosion are essential.

Extended surface tubes

In heat transfer involving a liquid or an evaporating or condensing refrigerant and air or other gas, there is considerable advantage in providing some form of finning of the tubes. The extended surface provided by the fins is always in contact with the air or gas. A similar, but usually somewhat lesser advantage may be obtained in the case of heat exchange between an evaporating or condensing refrigerant and a low viscosity liquid such as water. In this case the extended surface is in contact with the refrigerant.

Ribbon tubes

A type of extended surface tube used particularly in the construction of larger air-cooled or aircooling heat exchangers has a metal ribbon wound edgewise on to the tube in the form of a helix. Since heat must be conducted efficiently along the ribbon in a radial direction, a material of high thermal conductivity is desirable. For this reason, and because of its comparatively low cost, commercially pure aluminium is the most frequently used material. In some environments,for example in shipboard applications, aluminium is not sufficiently corrosion resistant and a copper ribbon is then used. In all cases a good thermal contact must exist between the ribbon and the tube on which it is wound. For operation at metal temperatures below 100°C the Lshaped fin is most commonly used with aluminium ribbon, whereas above this temperature, the ribbon is peened into the groove. Although these methods are also employed with copper ribbon, it is more usual for the ribbon to be wound edgewise on to the tube and the joint made by soldering or brazing.

Integrally finned tubes

Instead of winding a separate ribbon on to a bare tube, a form of finned tube is available in which helical fins are extruded from the tube itself by a rolling process. Tubes with fin dimensions comparable to ribbon tubes are made by this process in both aluminium and copper. For refrigerant-to-liquid heat exchange applications, tubes with much lower fins, resembling a threaded tube, are produced by the same process in a variety of materials including copper alloys and stainless steel. All the extended surface tubes described above can be made in bimetal form with a dissimilar metal liner

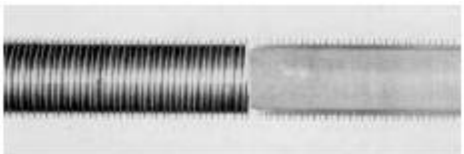

Fig.13 Integrally Finned Tubes

Wire wound tubes

A tube construction adopted for some refrigeration heat exchangers makes use of extended surface in the form of rectangular loops of wire helically wound and soldered on to the tube. Copper wire is employed to give high conductivity and thereby maximise the efficiency of this form of extended surface.

Internally finned tubes

Heat exchangers used particularly as water chillers have fins within the tube bore as an alternative to the low finned construction. These fins are made from copper foil strip, obliquely corrugated and then twisted into a spiral form. After fitting inside the tube, contact between fin and tube wall is obtained by inserting a small tube into the core formed within the twisted strip which is subsequently expanded hydraulically. An alternative form of internal fin consists of a star-shaped aluminium section twisted along its length and mechanically bonded to the copper tube to give good heat transfer across the interface.

Fig.14 Internal Finned Tubes

Fin and tube construction

Round tube forms

Probably the most widely used type of heat exchanger in the refrigeration industry is made from a stack of regularly spaced aluminium fins pierced with a pattern of holes sized to receive the round tubes. The copper tubes are inserted through the holes and expanded either mechanically, by passing a stepped plug through the bore, or by the application of hydraulic pressure. A complete heat exchanger, used either as an aircooled condenser or an evaporator, can be constructed by linking individual tubes together by copper U-bends brazed to the tubes.

Flat tube forms

Flat sided tubes are employed in place of round tubes for some applications. In this case the joints between the tubes and fins are brazed. Where both tubes and fins are of steel, brazing with copper can be carried out in a controlled-atmosphere furnace. A further use of flat sided tubes is in the tube - and - centre type where the tubes are interleaved with corrugated foil fins, the whole assembly being brazed together. This form of construction is confined almost entirely to vehicle air conditioning systems and is normally made from aluminium.

Testing and Commissioning Report:

Observation Results

- While working on the project we have conducted nitrogen test and kept the system under observation for two days. After two days we have came across observation that gas was leaked from the pipe joints.

Corrective action:- To avoid the leakage from the elbow joint we have replaced it by continous pipe of larger thickness than previous. And again we have fill the nitrogen in the system

Result: - we have observed that no leakage had been found.

- The system was implemented at the plant location successfully with all required connections(cooling tower , processing unit).

Conclusion

While concluding this part , we feel quite contended in having completed the project assignment well on time. We had enormous particle experience on the manufacture scheduled of the working project model .We are therefore happy to state that the inculation of mechanical aptitude proved to be very useful purpose . We are as such overt whelming elated in the arriving at the targeted mission.

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