INTERNSHIP AT ISOTHERM, INC.

A Record of Study

by

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Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF ENGINEERING

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ABSTRACT

This record of study involves the intern's experience at Isotherm, Inc. in fulfillment of the requirements for the Doctor of Engineering program at Texas A & M University. A profile of Isotherm and its capabilities were presented. The intern was involved in the design, fabrication and installation of a novel shell and tube type chiller (evaporator) called the SX chiller. This new chiller was put into operation on a test stand in Norway and a fishing trawler in Ecuador.

The European Pressure Equipment Directive (PED) certification was discussed in detail and the in-depth involvement of the intern in the equipment certification process which included intense level of correspondence with the Det Norske Veritas (DNV) officials and the resolution of various serious issues thereof. The intern was successful in certifying Isotherm as an approved manufacturer according to the standards of DNV.

In addition to the SX chiller design, PED and DNV certifications to fulfill the requirements of technical skills development, the intern also gained managerial skills development at Isotherm, Inc. The experiences of Engineering Manager and the Sales & Applications Manager were discussed too. Based on the intern's experience during this tenure he was able to provide recommendations on Isotherm's future business direction.

DEDICATION

I dedicate this record of study to my wife, children, parents, siblings and in-laws. I would not have succeeded without their unconditional love and support. I also want to dedicate this record of study to the late Dr. Arthur Bergles, without whom my family would not have had the opportunities for a better life in the United States.

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I am very grateful to my committee chair, Dr. Michael Pate, for his help and guidance throughout my Doctor of Engineering program. I will never forget the support that he provided.

I also would like to thank the committee members, Dr. Donald Smith, Dr. N.K. Anand, and Dr. Richard Lester for their support and for serving on my advisory committee. I am also thankful to Dr. Haji-Sheikh for serving as the internship supervisor.

Also, I would like to thank Mr. Daniel Cabrera Garay for his guidance, especially in reference to the SX chiller.

I express my sincere gratitude to my father, Dr. Zahid Ayub, who served as the engineering supervisor during my internship at Isotherm. I am also grateful to him for providing me the valuable guidance throughout the program. My father's hard work and unwavering perseverance has truly helped the lives of my family. I also want to thank the late Dr. Arthur Bergles, who acted as a mentor to my father and the rest of my family.

I express my appreciation to my brother Nader for his support and to my sister Shereen for her help and feedback.

I appreciate and love my parents-in-law, sister-in-law and the rest of my wife's extended family for their prayers and belief in me.

Furthermore, I express my deep love and gratitude to my mother Shahnaz for her unconditional love and belief in me, since my birth, as the many sacrifices she directly made provided a better future for my siblings and me.

Finally, I want to show my sincerest, deepest gratitude and love to my wife, Rida, who always believed in and encouraged me, even during the hard times. Without the inspiration from her, I believe that this record of study would not have been accomplished. I am blessed to have two beautiful children, who have also inspired me.

NOMENCLATURE

AI	Authorized Inspector
API	American Petroleum Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
BPVCC	Boiler and Pressure Vessel Code Committee
BV	Bureau Veritas
D. Eng	Doctor of Engineering
DNV	Det Norske Veritas
DX	Direct Expansion
ESR	Essential Safety Requirement
EU	European Union
FT.	Feet
GPM	Gallons per minute
GWP	Global Warming Potential
IIAR	International Institute of Ammonia Refrigeration
IN.	Inches
ITP	Inspection & Test Plan
KG	Kilograms
KW	Kilowatts

LBS	Pounds
M^3/HR	Cubic Meters per hour
MTR	Material Test Report
NB	Notified Body
NBIC	National Board of Boiler and Pressure Vessel Inspectors
NDE	Non Destructive Examination
NPS	Nominal Pipe Size
OD	Outside Diameter
ODP	Ozone Depletion Potential
P&ID	Piping and Instrumentation Diagram
PED	Pressure Equipment Directive
PMA	Particular Material Appraisal
PQR	Procedure Qualification Record
QC	Quality Control
RFQ	Request for Quotation
RSW	Refrigerated Sea Water
SX	Shell Side DX
TEMA	Tubular Exchanger Manufacturers Association
API	American Petroleum Institute
TR	Tonnage of Refrigeration
WPQ	Welder/Welding Operator Performance Qualification
WPS	Welding Procedure Specification

WPT	Weld Production Test

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CHAPTER I

INTRODUCTION

The need for natural refrigerants has been a major topic of discussion because of Global Warming Potential (GWP) and Ozone Depletion Potential (ODP). Scientists and governmental agencies worldwide have been addressing their concerns regarding these two important issues and have been actively pursuing to device policies to reduce the environmental effects of ever increasing industrial activities. Per Ciconkov and Ayub (2009), one measure is the implementation of Montreal Protocol on January 1, 1989, which requires various synthetic refrigerants, such as R-11 and R-12, be outlawed due to higher ODP levels. In addition to the Montreal Protocol, Ciconkov and Ayub (2009) also specified that the Kyoto Protocol was enforced on February 16, 2005, which stipulated the use of those refrigerants that have a significant effect on the global warming. Thus, the most commonly used refrigerants, such as R-22, R-134a are slowly being phased out. Since January 1, 2010, Europe has imposed stringent rules regarding the use of high GWP refrigerants (Ayub et. al, 2013). Recently, President Obama issued an executive order to adopt practices that would reduce any activities involving greenhouse gas emissions (Taylor, 2015). Although alternative halocarbons, such as R-404a, R-507a, and various others are still being used as refrigerants, Taylor (2015) had mentioned that they will soon be phased out because of their higher GWP values. Currently the most attractive natural refrigerant with ODP and GWP equal to zero is ammonia (Ayub et. al., 2013). Ayub et. al. (2013) also mentioned that ammonia is readily available at an insignificant cost and has a relatively higher latent heat capability as compared to synthetic refrigerants, which qualifies it to be at the top of the list. The only drawback that Ayub et. al. (2013) had identified about ammonia is its toxicity; however, this aspect can be overcome by innovative system designs that result in minimal charge. Low-charge ammonia systems are being actively explored for industrial refrigeration markets. The intern had the opportunity to design a unique evaporator suited for small or large ammonia refrigeration system. This goal was achieved at Isotherm, Incorporated.

Profile of Isotherm

Isotherm, Inc. is a custom manufacturer of heat exchangers, pressure vessels, and skid based systems. It was founded in 1999 by Dr. Zahid Ayub, P.E., current president and owner. Isotherm has a shop capacity of around 32,000 sq. ft. (Fig, 1.1). The company is known for ammonia enhanced heat transfer systems. As mentioned previously, ammonia is a natural refrigerant that is extensively used due to key features such as, low cost, zero ODP and GWP. Historically, ammonia enhanced heat transfer was not extensively studied as compared to halocarbons. Isotherm's push for ammonia enhanced heat transfer for the design of its equipment, and the industry's interest in utilizing ammonia for its applications gave Isotherm the advantage in the market. With Isotherm's background in advanced concepts in the subject of enhanced heat transfer with ammonia, the company flourished in this aspect of their business by selling equipment to contractors. Marine refrigeration is another major industry that Isotherm sells its equipment because of its extensive experience and clear advantage over competitors. The company has also been active in other related industries such as food and beverage, cold storage warehousing, pharmaceutical and chemical processing.

Fig 1.1: Aerial view of Isotherm, Inc. in Arlington, Texas

Contractors in industrial refrigeration are moving towards ammonia instead of Freons (halocarbon), such as R-22, due to the reasons mentioned above. But while it is getting common to use ammonia in marine and industrial refrigeration, Freons are still being used in the industries until their phase out. Isotherm also has the background in designing equipment for such systems. The company is also involved in hydrocarbon based refrigeration systems. Propane, a hydrocarbon, is another natural refrigerant that is commonly used in the oil and gas industry, such as amine gas sweetening. Therefore, Isotherm is not limited to any specific refrigeration area utilizing its equipment.

Isotherm has the capability to design, fabricate, and certify its equipment per the ASME Section VIII, Division, Boiler & Pressure Vessel Code (2013 Edition). Not only ASME is used for the design code, Isotherm can design and fabricate units per the

Pressure Equipment Directive 97/23/EC (PED), a European Union standard, and Det Norske Veritas (DNV), a Norwegian standard that has been extensively used for offshore and onshore applications in the oil and gas industries and for refrigeration systems on fishing vessels. Other codes and standards, such as API 660 (7th Edition, 2003), Tubular Exchanger Manufacturers Association (9th Edition, 2007), Canadian Registration (CRN), Australian Standard 1210, and various others are also handled by the company. However, since the majority of equipment is designed and certified to ASME Section VIII, Division 1 Pressure Vessel Code, it is important to understand this particular code and its relevance to Isotherm's equipment.

ASME Section VIII, Div. 1 Pressure Vessel Code

ASME Section VIII seminar (2007) gave the following as the reason for the creation of the ASME Code:

> In 1905, an explosion occurred at a shoe factory in Brockton, Massachusetts, resulting in 58 fatalities and 117 injuries. The explosion was a result of an inadequate design and fabrication of a steam boiler. However, this was one of many explosions that were common occurrences between the 1800s to the early 1900s. This explosion was the last of many boiler explosions that occurred during at least a ten year time frame and prompted the Massachusetts government to enact the first steam boiler construction rules in the United States. Thereafter, several states adopted similar regulations for steam boiler construction; though, each state adopted different rules. This prompted the

American Society of Mechanical Engineers (ASME) to compile and unify a set of rules for pressure vessel design. To achieve this Boiler and Pressure Vessel Code Committee (BPVCC) was created to ensure that a uniform code would be adopted for all states, known as the ASME Section VIII, Division 1 Code. While the BPVCC had the responsibility to create a set of rules for pressure vessel design, the National Board of Boiler and Pressure Vessel Inspectors (NBIC) was created to ensure that the rules by ASME were enforced and that the ASME authorized inspector (AI) were qualified by NBIC (2013a). Currently, these two committees still play a vital role in the pressure equipment certification. This code not only serves the requirements of pressure vessel code for United States and Canada, but it has been adopted by several countries around the world as a reputable standard.

The ASME Code (2013c) requires that the manufacturer holds an ASME certificate of authorization to prove that it can produce and ship ASME certified pressure equipment. Besides holding a certificate, the ASME Code (2013c) requires the fabricator to have the following capabilities:

1. Knowledge of ASME Section VIII, Division 1
2. Adequate shop with qualified personnel, such as welders
3. Signed contract with the ASME Authorized Inspection Agency
4. Quality Control System approved by the Authorized ASME inspector
5. Joint Review every three years with ASME and the Authorized Inspection Agency

The Code also requires that the manufacturer undergoes the following minimum steps in producing pressure equipment:

1. Design
2. Procurement of Raw Materials
3. Fabrication
4. Non-Destructive Testing
5. Heat Treatment
6. Pressure Testing (ASME, 2013c)

For the design of pressure equipment, the client would provide Isotherm the design pressure, the minimum and maximum design temperatures, the preferred choice of material and the size. The Engineering Department would perform calculations, such as the required thicknesses of various components such as the shell, the end cap, and the nozzles. After completing the design, the ASME approved materials are procured, with the Material Test reports that indicate that the mechanical and chemical tests of the raw material have met the ASME requirements per Section II. Upon receipt of the ASME materials, the production proceeds with fabrication of the Code equipment. However, it is important that the manufacturer have the necessary qualified procedures and personnel prior to production. Thus, another ASME Code that supplements the ASME Section VIII, Division 1 and provides information on qualifications for welding procedure specifications (WPS) and the welding personnel for the construction of pressure vessels, is known as the ASME Section IX (2013 Edition).

As defined in the ASME Section IX (2013d), a “Welding Procedure Specification (WPS) is a written document that provides direction to the welder or welding operator for making production welds in accordance with Code requirements.” Furthermore, Section IX (2013d) further states that the manufacturer, such as Isotherm, bears responsibility for the control of production welding based on the approved WPS. An example can be found in Figure A.1 of Appendix A. The WPS is approved if the test coupon used for the WPS complies with the minimum requirements for the intended application (ASME, 2013d). Therefore, a Procedure Qualification Record (PQR) is created as a record of the welding data used to weld a test coupon, as per Section IX (2013).

The required variables are listed in the PQR, and it is obligatory for the manufacturer to prove that those variables meet the minimum requirements of ASME Section VIII Division I (2013c), ASME Section II (2013a) and ASME Section IX (2013d). Variables include, but not limited to, the thickness of the base metal qualified and the welding wire and its properties (ASME, 2013d). Therefore, the successful qualification of the PQR is used to prove that the WPS used for fabrication of the heat exchangers and pressure vessels comply with ASME Section VIII and IX requirements. An example of the PQR can be found in Figures A.2 and A.3 of Appendix A.

Each welder in the fabrication shop has to prove that they are able to perform the welding in accordance with the approved WPS. Therefore, Section IX requires that the manufacturer complete and certify a Welder/Welding Operator Performance Qualification (WPQ) record for each welder (2013d); Fig. A.4 of Appendix A is one example. The manufacturer is also obligated by Section IX that each welder or operator to perform a test coupon, using the WPS, and that the results from the testing of the coupon prove that the welder/s have met the ASME Code (2013d).

With approved WPS's and with each welder having its approved WPQ, fabrication of ASME certified equipment can proceed. Isotherm maintains the required documentation accordingly. It is important that the designers in the Engineering Department lists the approved WPS's, with approval from the Engineering Manager, on the drawings so that each welder knows the applicable WPS for each project and that the production manager decides on which qualified welder can fabricate the ASME approved heat exchangers and pressure vessels. Having mentioned the fabrication with the required welding documentation and personnel qualifications, ASME Section VIII, Div. 1 (2013c) lists the requirements for non-destructive examination, such as radiography (method of using X-ray for inspection of welding), ultrasonic testing, liquid penetrant, and magnetic particle testing. The non-destructive testing (NDT) rules are covered in ASME Section V (2013b). The required procedures are set in place prior to conducting the tests in the manufacturing shop. Since Isotherm only has an approved procedure for liquid penetrant testing, it is only limited to this type of test. Not only the procedure must be approved by ASME, it also requires qualified personnel conducting the tests, which Isotherm has the documentation necessary to carry out the procedure (2013b). For all other NDT requirements, the company subcontracts qualified sub-contractors.

After the non-destructive testing, if the fabricated equipment is to be heat treated it is out sourced to a code approved sub-contractor (ASME 2013c). The majority of Isotherm's equipment does not require heat treatment, thus further discussion is not necessary. Pressure testing of the equipment is also necessary to detect any defects in the material and fabrication. There are two types of tests allowed by ASME: hydrostatic testing and pneumatic testing (2013c). Isotherm has the capability to perform both; however, it mostly performs pneumatic testing since most of the equipment is used for refrigeration application traces of water are undesirable. According to the rules of ASME Section VIII, the pressure test must be witnessed by the ASME authorized inspector (AI) and after successful test witnesses the affixing of the nameplate on the equipment (2013c). After all the necessary steps in design, materials, fabrication, and testing are complete, the ASME Code also necessitates the manufacturer to complete a special form, also known as the data report that provides complete information on materials, operating pressure and temperature and test data as shown in Fig. A.5 of Appendix A. (2013c)

A discussion about the history of ASME and its role for pressure vessels was mentioned, along with the steps to achieve ASME certification of the equipment, which were design, materials, fabrication, non-destructive examination, heat treatment, and pressure testing. With Isotherm being an authorized ASME shop, it is qualified to sell equipment with ASME certification to its clients that require pressure vessels for their refrigeration packages. One of the components of the refrigeration package is the chiller. As previously mentioned, the intern had worked at Isotherm for an internship, as outlined in the Doctor of Engineering program at Texas A & M, and was primarily involved in the development of a new and unique type of chiller (patent applied for) that is expected to make a major impact in the refrigeration industry. The implementation of the ASME certification to this chiller was necessary prior to having the chiller marketed in the U.S. and other parts of the world. It is important to note that the chiller is not limited to ASME certification only since there are other standards that are required in certain areas of the world, such as the Pressure Equipment Directive (PED) of the European Union, and Det Norske Veritas (DNV), which is commonly used in Norwegian fishing vessels and off shore oil drilling platforms.

Final Internship Objectives

As mentioned above, the intern had the opportunity to work at Isotherm and was involved in the design of the new patent pending ammonia chiller during the internship. As required in the Doctor of Engineering program of Texas A & M, the intern was expected to develop both the technical and managerial skills during the internship. Several months after starting the internship, the intern narrowed the Final Internship Objectives as follows:

Technical

1. Enhance technical skills necessary for the design of the new type of chiller
2. Develop knowledge of certification of Isotherm's equipment to meet the requirements of the Pressure Equipment Directive (PED)

3. Develop the skills necessary to certify Isotherm's spray chillers and condensers to meet the DNV Rules for Ships, Pt. 4 Ch. 7: Pressure Vessels

Managerial

1. Acquire the skills as an Engineering Manager at Isotherm, Incorporated.
2. Gain more knowledge necessary for future ownership of Isotherm, Incorporated.

As per the requirements of the Doctor of Engineering degree, this Record of Study is to show that the above mentioned objectives show that the intern gained technical and managerial skills during his internship at Isotherm, Incorporated. While all the above five objectives were important to fulfill, the primary focus in this internship was to develop a new chiller.

CHAPTER II

NEW CHILLER DESIGN

Isotherm's heat exchangers and pressure vessels are utilized in the refrigeration systems that operates under a classical reverse Rankine cycle (Fig. 2.1) consisting of the evaporator (also called chiller), separator (also known as accumulator), compressor, condenser, receiver and the throttling expansion valve. The major focus of the internship is the chiller design. In a chiller, the process fluid is being cooled while the refrigerant is undergoing phase change from liquid to vapor by the heat transferred from the process fluid to the refrigerant. There are three types of chillers that Isotherm, Inc. has traditionally manufactured: Flooded, Direct Expansion (DX) and Spray.

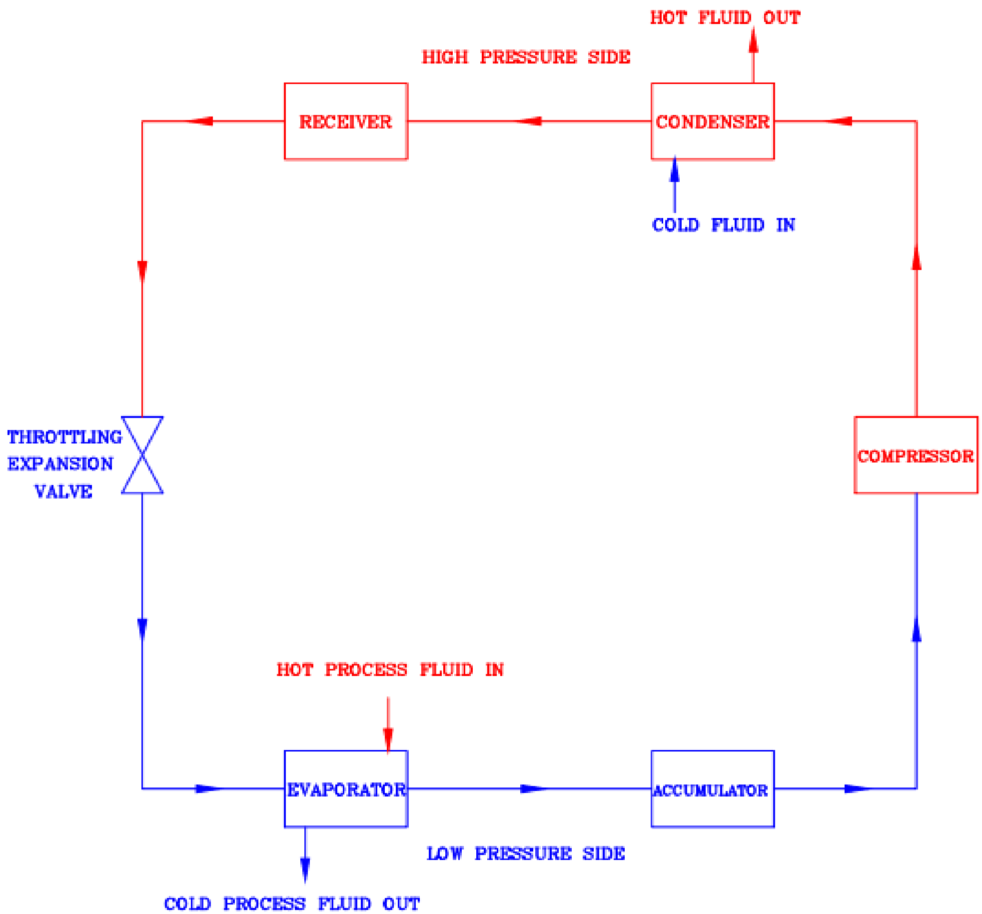


Fig. 2.1: Typical Reverse Rankine Cycle Refrigeration System

Flooded Chiller

A flooded chiller as shown in Figs. 2.2 and 2.3 is where the two-phase refrigerant is in the shell while the process fluid is cooled in the tubes. A horizontal separator vessel is mounted on top of the chiller for liquid-vapor separation. The shell-side of the flooded chiller is 80-90% occupied by a pool of refrigerant so that when the refrigerant is undergoing two-phase flow, vapor flows upward towards the separator vessel. The vapor contains droplets of liquid, thus the separator vessel is designed to ensure that the liquid droplets are not carried over to the compressor. The flooded chiller does not require a pump for refrigerant flow, but a large amount of refrigerant is required in the shell for proper operation, hence increasing the refrigerant cost and increasing the safety hazard in the event of a leak, especially if the refrigerant is either toxic or flammable or both. Large refrigerant inventory also increases the risk of freezing the process side in case of malfunction due to the "thermal inertia" effect.

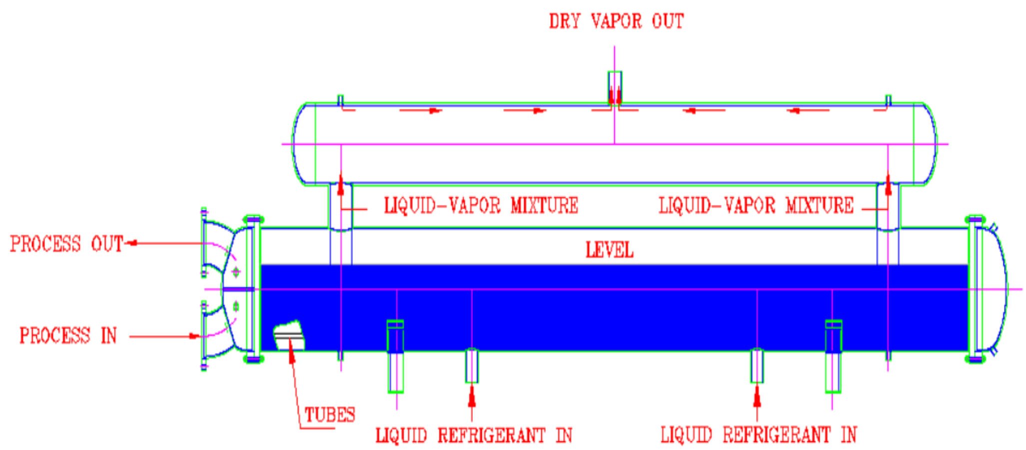


Fig. 2.2: A typical Flooded Evaporator design

Fig. 2.3: Fabricated Flooded Evaporator

Direct Expansion (DX) Chiller

In a DX chiller (Figs 2.4 and 2.5), refrigerant flow is maintained inside the tubes while the process liquid is cooled within the shell. It is important to keep a consistent distribution of the liquid-vapor refrigerant mixture; otherwise, the lack of proper distribution could result in early liquid separation with vapor occupying the upper portion of the tubes, thus larger void fraction. Since vapor has a lower heat transfer coefficient than the liquid, a uniform mixture is necessary for the refrigerant flow inside the tubes. There is no such thing as an ideal mixture; consequently, it is difficult to estimate the magnitude of liquid-vapor mixture that actually occurs within the tubes. The goal of a better design is to strive for the least amount of mal-distribution.

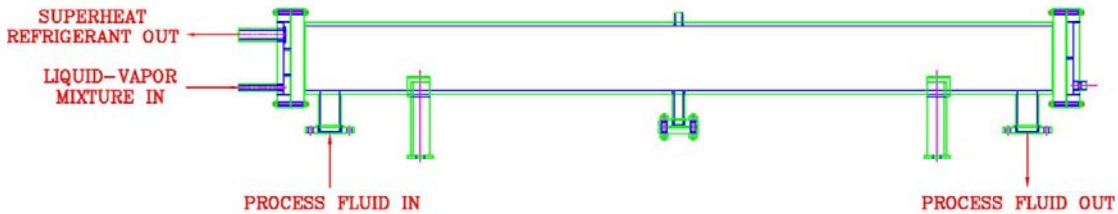


Fig. 2.4: A typical DX Evaporator design

Fig. 2.5: Fabricated DX Evaporator

Spray Chiller

In the spray chiller design as shown in Fig. 2.6, thin-film evaporation is involved, resulting in a relatively higher heat transfer coefficient than that obtained in pool boiling found in flooded evaporators. As compared to the flooded chillers, it requires a lower operating refrigerant charge. However, the shell needs extra space to accommodate a spray header, whose role is to hold the spray nozzles for spraying the refrigerant. To maintain a positive refrigerant flow in the spray loop, a pump is required. If the pump malfunctions, the spray chiller will either have to shut down or in case of an extra pump has to be switched over to the standby pump. In the food processing industry, two pumps are always required for this reason. Figure 2.7 shows a typical fabricated spray evaporator ready to be installed at a site.

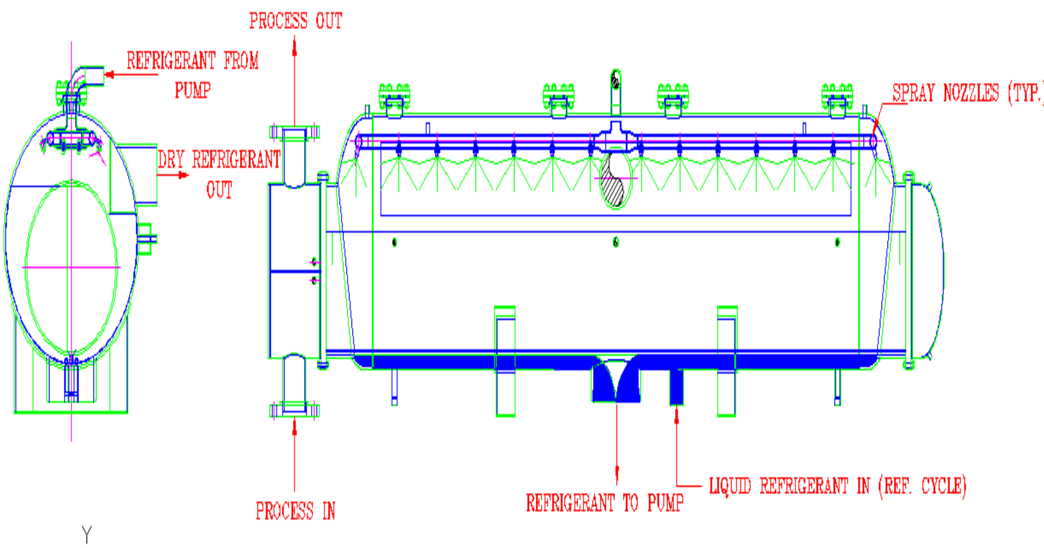


Fig. 2.6: A typical Spray Chiller design

Fig. 2.7: Fabricated Spray Chiller

New Shell Side DX Chiller (SX)

Isotherm has embarked on a new special DX technology that combines the concepts of spray chiller and DX chiller. This new design is referred to as the SX (Shell side DX) Chiller. The key driving features in initiating the concept of SX chiller design were:

1. Compact design
2. Low refrigerant charge
3. Higher efficiency
4. Ease of maintenance
5. Reduced cost

Under the supervision of the owner the intern was given the task to work out the most optimized new SX chiller. First, the compactness was emphasized. Next, the low charge, as is the case with Spray and DX chillers, is considered. As previously mentioned, the spray chiller utilizes thin film evaporation, which results in a higher heat transfer coefficient than that with flooded chiller. This feature was also considered in the SX chiller design. Consideration of all the above features resulted in a unique design as shown in Fig. 2.8. The following paragraphs describe this new technology taken verbatim from the US Patent (Ayub and Ayub, 2012):

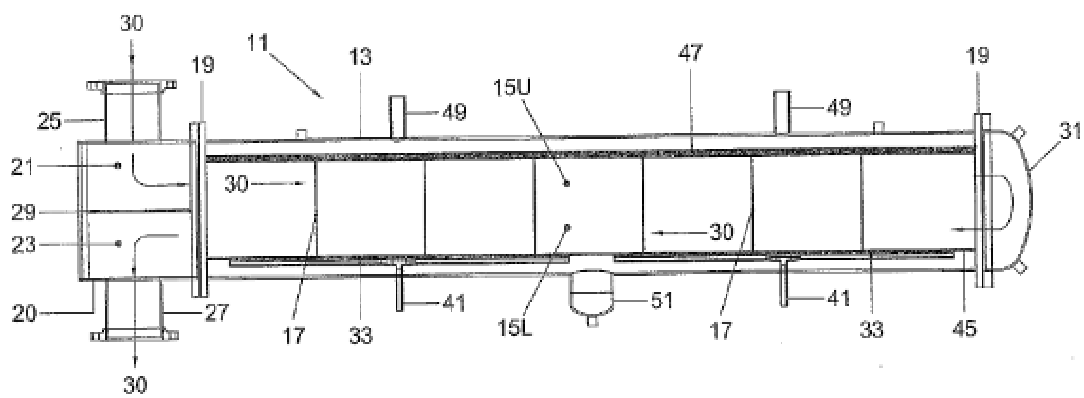


Fig. 2.8: SX Chiller design

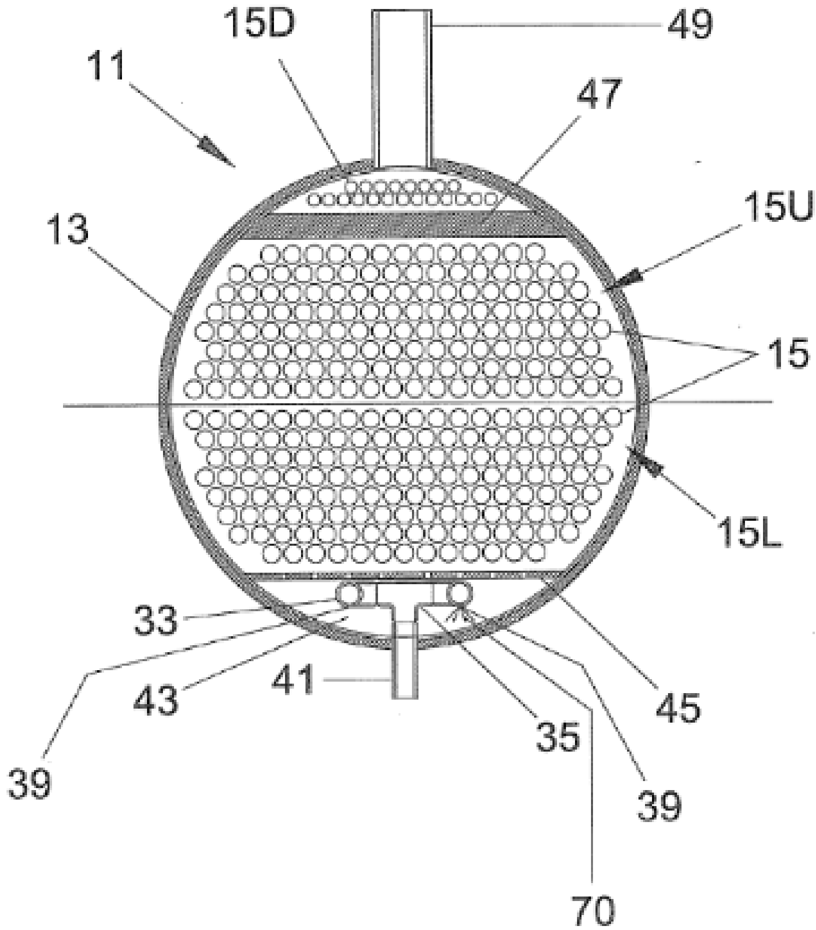


Fig. 2.9: Bundle view of SX Chiller without end heads

As shown in Fig. 2.8 the process fluid goes through the tube side of the SX Chiller via the top nozzle (25), which flows through a body of tubes. The body of tubes is shown in Fig. 2.9 as a side view of the SX chiller without the tube-side heads, as shown as 20 in Fig. 2.8. The process fluid cools before leaving at the bottom nozzle, shown as 27 of Fig. 2.8. The process fluid is cooled by the transfer of heat from the process fluid to refrigerant, which in turn evaporates into superheated vapor. On the other hand, the refrigerant enters through the bottom side of the shell, through the shell-side nozzle(s), shown as 41. The shell-side nozzle(s) are connected to the refrigerant spray header(s) (35 of Fig. 2.9) located on the bottom inside diameter of the shell-side. The spray headers act as a source of refrigerant distribution on the tubes, which is important for efficient heat transfer. The spray header has small orifices (39 of Fig. 2.9) that are sized for the spray mechanism, depending on the flow rate of the refrigerant. The refrigerant goes through several circuits of vaporization so that it leaves from the refrigerant outlets (49 of Fig. 2.9) as superheated vapor to the accumulator or directly to the compressor. This is important because the compressor cannot have any traces of liquid entering the suction side of the compressor due to incompressibility of liquid; otherwise, the compressor malfunctions. The small orifices in the header directs the refrigerant liquid-vapor mixture to the lower part of the shell where oil is separated and refrigerant hits a perforated plate (45 of Fig. 2.9), which is welded slightly above the refrigerant header. This creates a slight back pressure, resulting in even distribution along the length of the bundle. The evenly distributed two-phase refrigerant then moves upward through the bundle due to the positive lift caused by the compressor suction. This upward flow of two phase mixture creates a thin film of liquid refrigerant that evaporates at the expense of cooling the process fluid in the tubes. This concept makes it different than pool boiling in flooded chillers that require large refrigerant pool to sustain the chilling process. To ensure that there are no traces of liquid after flowing through the outside of the body of tubes, a separating device in the form of a specially calculated and designed demister pad (47 of Fig. 2.9) is placed above the main body of the tubes so that the mixture will coalesce the liquid back down to the shell where it is evaporated while vapor continues to flow towards the refrigerant outlet. To ensure that the vapor is superheated, an extra body of tubes above the demister pad is placed, known as superheat tubes, as shown as 15D of Fig. 2.9. This is critical since the refrigerant expansion valve, located at the entrance to the shell, modulates via a controller under a pre-set superheat level at the outlet. Lastly, an oil sump is added to the bottom of the chiller for oil drainage purposes (shown as 51 of Fig. 2.8) since oil is carried over with the refrigerant from the compressor. It is very important to have good drainage, especially for ammonia applications because oil and ammonia are immiscible.

The new chiller design has many advantages over contemporary chillers. First, the charge is significantly less than the flooded chiller. This is really important since ammonia is toxic, and the ammonia released into the atmosphere should be minimal. Another benefit is that the new chiller eliminates the need for a pump, unlike the spray chiller because one of the issues with the pump is that it would require spare sealing and that operator is required to maintain the pump concurrently, thus driving potential repair and spare part costs high. Also, a backup pump is needed in the event of the malfunction of the main pump in order to avoid shutting down the refrigeration system. Although the spray chiller requires less charge than the flooded and DX chillers, the new chiller requires even less of a refrigerant charge than the spray chiller. Moreover, the new chiller offers a more compact design for the same refrigeration conditions as compared to all three conventional chillers. Other benefits include simple controls since the refrigerant level controller is not required, less oil due to minimal carryover from the compressor, and easy cleaning of the process tube side. After designing this new technology, the intern received some purchase orders for the new chillers.

Design and Results for SX Chiller in Norway

One project that the intern was involved with was for a test stand in Norway. The design parameters are shown in Table 2.1.

Table 2.1 – Norway test SX Chiller design parameters

Parameter	Value	Unit
Capacity	250 (71)	kW (TR)
Seawater Flow rate	180 (793)	m^3/hr (gpm)
Seawater Inlet Temperature	0.17 (32.3)	°C (°F)
Seawater Outlet Temperature	-1.0 (30.2)	°C (°F)
NH_3 Suction Temperature	-5.0 (23.0)	°C (°F)

Based on the above data, the intern and the engineering supervisor designed a SX chiller as shown in Fig. 2.10 while Fig. 2.11 shows the chiller mounted on the test stand skid at the client's site. The final design characteristics are shown in Table 2.2.

Table 2.2 – Norway test SX Chiller size		
Parameter	Value	Unit
Outside Diameter	356 (14)	mm (in.)
Tube Length	3048 (10)	mm (ft.)
Overall Length	3353 (11)	mm (ft.)

Fig. 2.10: Fabricated SX Chiller for Norwegian Test Stand

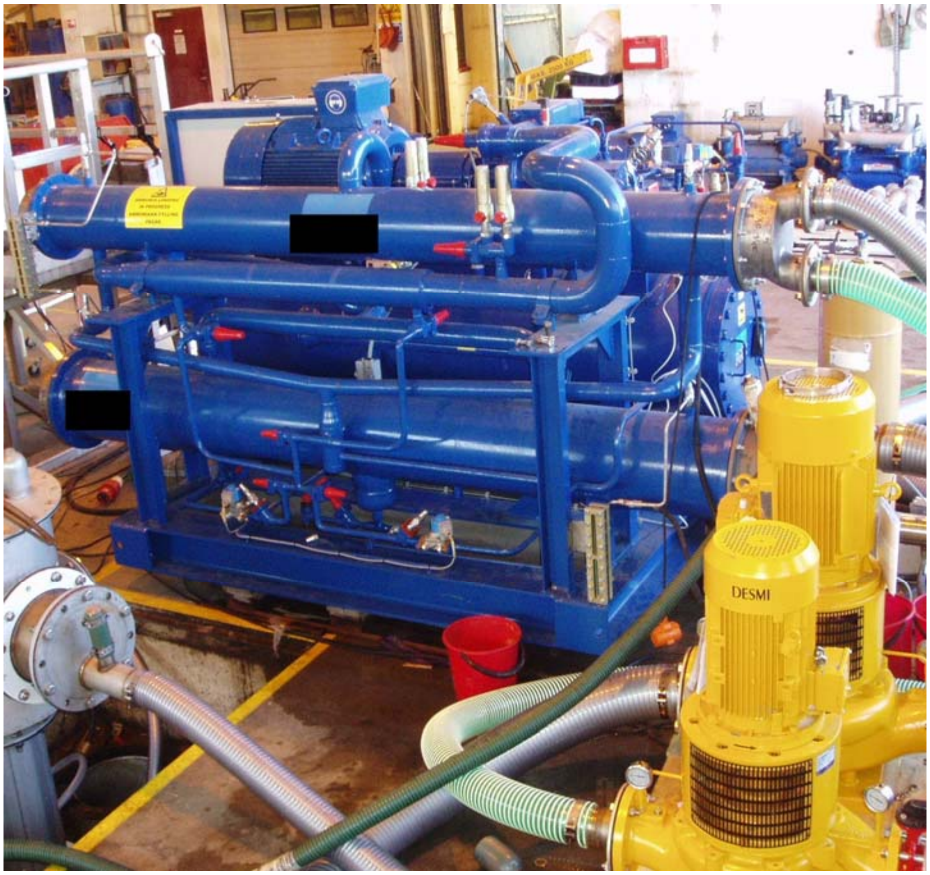


Fig. 2.11: SX Chiller on Test Stand Skid in Norway

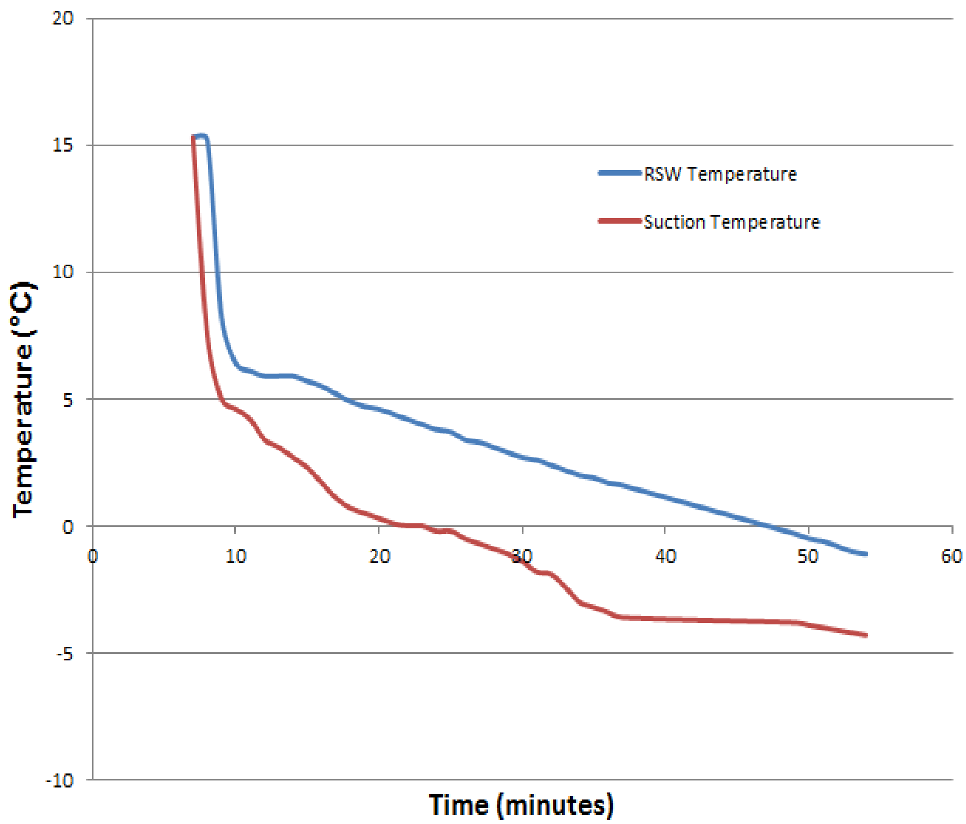


Fig. 2.12: Field data of SX Chiller for Norwegian Test Stand

Figure 2.12 shows a snap shot of data indicating the measured refrigerated sea water (RSW) outlet temperature and suction temperature versus the pull down time from several test runs conducted during a 2-3 month period. An average data from several test runs is shown in Table 2.3.

Table 2.3 – Norway test results for the SX Chiller		
Parameter	Value	Unit
Seawater Outlet Temperature	-1.1 (30.0)	°C (°F)
NH_3 Suction Temperature	-4.3 (23.0)	°C (°F)

The results showed that at the design suction temperature the sea water outlet temperatures were in agreement with the required design conditions. Detailed data showing pull down time versus temperature can be found in Fig. B.1 of Appendix B. The refrigerant charge was approximately 35 kilograms (77 lbs.) which translates to 0.14 kg/kW. According to the current industry standards this is considered to be extremely low. A typical comparative analysis for various other types of chillers was performed as shown in Table 2.4. This shows that the charge required for the same capacity as the Spray, Flooded and Plate and frame is 4, 8 and 10 times more than the SX chiller, respectively. This is considered to be a major breakthrough in the heat exchanger business.

Table 2.4 – Comparison of refrigerant charges of each chiller		
Type	Charge	Unit
Shell & Tube SX Chiller	35 (77)	kg (lbs.)
Shell & Tube Spray Chiller	140 (308)	kg (lbs.)
Shell & Tube Flooded Chiller	280 (616)	kg (lbs.)
Plate & Frame Flooded Chiller (with Surge Drum)	350 (770)	kg (lbs.)

Effect of COP of SX Evaporator vs. Flooded Evaporator

The effect of this higher efficiency of SX evaporator can be directly observed on the system theoretical overall coefficient of performance (COP). To show this, a comparison was run with a flooded evaporator with exactly similar geometric parameters and similar operating conditions on the sea water side. Assuming same condensing temperature (95°F), it was evaluated that for the flooded evaporator to achieve the same capacity the saturated suction temperature had to be 18.2°F versus 23.0°F for the SX evaporator which therefore resulted in a 10% enhancement in COP for the system. This is primarily due to higher specific volume of ammonia at lower suction temperature in the flooded system that results in higher compressor brake horse power requirement.

Design and Results for SX Chiller in Ecuador

Another project was for a sea water refrigeration system onboard a fishing trawler in Ecuador. The design parameters are shown in Table 2.5.

Table 2.5 – Ecuador SX Chiller design parameters

Parameter	Value	Unit
Capacity	250 (71)	kW (TR)
Seawater Flow rate	136 (600)	m^3/hr (gpm)
Seawater Inlet Temperature	2.2 (36.0)	°C (°F)
Seawater Outlet Temperature	1.1 (34.0)	°C (°F)
NH_3 Suction Temperature	-5.0 (23.0)	°C (°F)

The intern and the engineering supervisor designed an SX chiller based on the above data. The final size turned out to be the same as that for Norway test stand. In this case four chillers were fabricated as the requirement was two chillers per fishing vessel; one for starboard side and another for port side as shown in Fig. 2.13. The refrigerant charge for this chiller was similar to that in the Norwegian test stand unit. The field results turned out to be very promising as shown in Table 2.6. Fig. 2.14 shows the temperature versus pull down time, while Fig. B.2 of Appendix B consists of the table with time and temperature recorded. Based on these two successful installations, the SX chiller proved that it could play a significant role in the industrial refrigeration market especially where low charge systems are either a requirement through regulation or clients' preference.

Table 2.6 – Ecuador SX Chiller field data		
Parameter	Value	Unit
Seawater Starboard Outlet Temp	0.0 (32.0)	°C (°F)
Seawater Portside Outlet Temp	0.0 (32.0)	°C (°F)
NH_3 Suction Temp	-5.3 (22.5)	°C (°F)

Fig. 2.13: One of the two installed SX chillers on a trawler in Ecuador

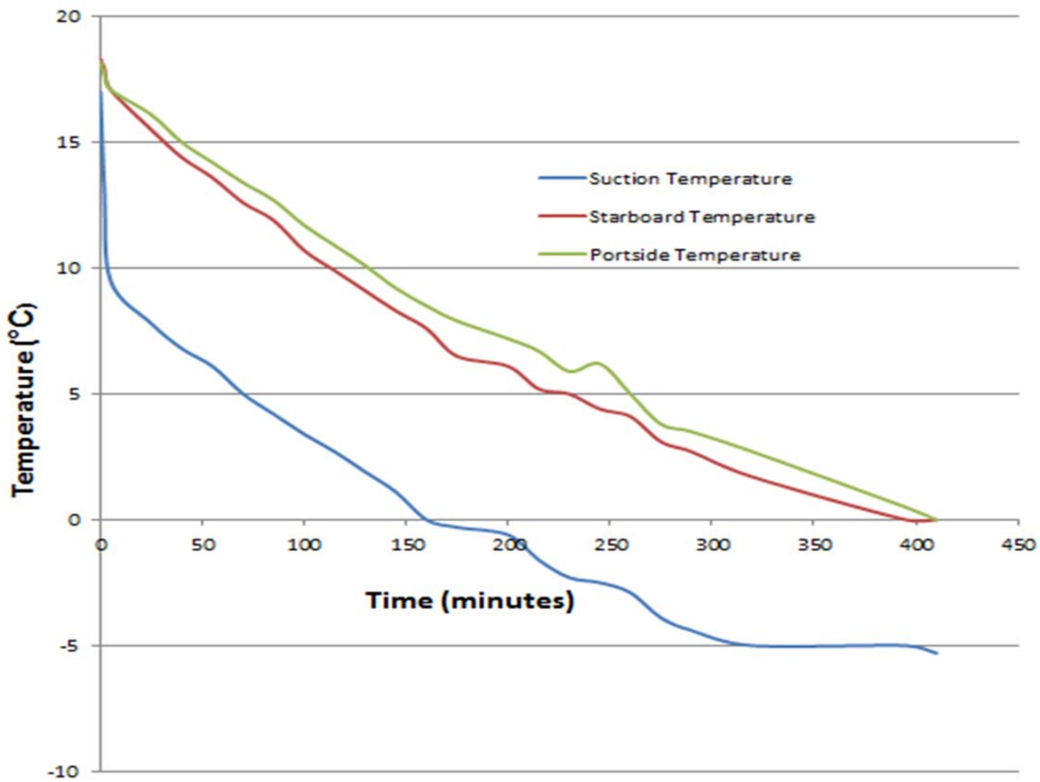


Fig. 2.14: Field data of SX Chiller for Ecuador fishing vessel

Commissioning Process

To date, over eighty SX chillers of various capacities, ranging from 45 to 500 TR have been built and installed worldwide. The commissioning and start-up of early chillers had been a vast learning experience for the entire Isotherm team, including the intern, especially the piping and control aspects. Different types of control valves by various manufacturers were tested. In the end, the electronic pulse valve, AKVA manufactured by Danfoss, resulted in a good match for the efficient performance of SX chiller. A typical AKVA valve is shown in Fig. 2.15. It was also established that chillers over 50 TR required two AKVA valves installed in a master/slave configuration.

Figure 2.16 shows a simple Process and Instrumentation Diagram (P&ID) for a dual valves configuration. A client in Chile and Norway had used this concept on all the chillers supplied to them and had no problem in achieving capacity. Fig. 2.17 shows the proper dual valves installation. On the other hand, a client in Peru did not follow the instructions and used a single AKVA valve configuration as shown in Fig. 2.18 irrespective of the capacity. After checking their control system, Isotherm instructed them to revert to the proper valve configuration. During the trouble shooting process, the intern and Isotherm engineers also found serious piping issues. Almost all the liquid feed lines were undersized, which resulted in flashing of liquid at the valve inlet. This is a highly undesirable phenomenon and is strictly warned against by the valve manufacturer. The valves were also not located at the correct location in relation to the chiller inlet nozzles.

Another recent case was an SX chiller sold to a contractor at a wine plant in California. Although it was mentioned by the contractor and its client that the SX chiller was operating well, the field data have yet to be provided. Fig. 2.19 shows the SX chiller installed at the wine plant.

Fig. 2.15: Danfoss AKVA Valve

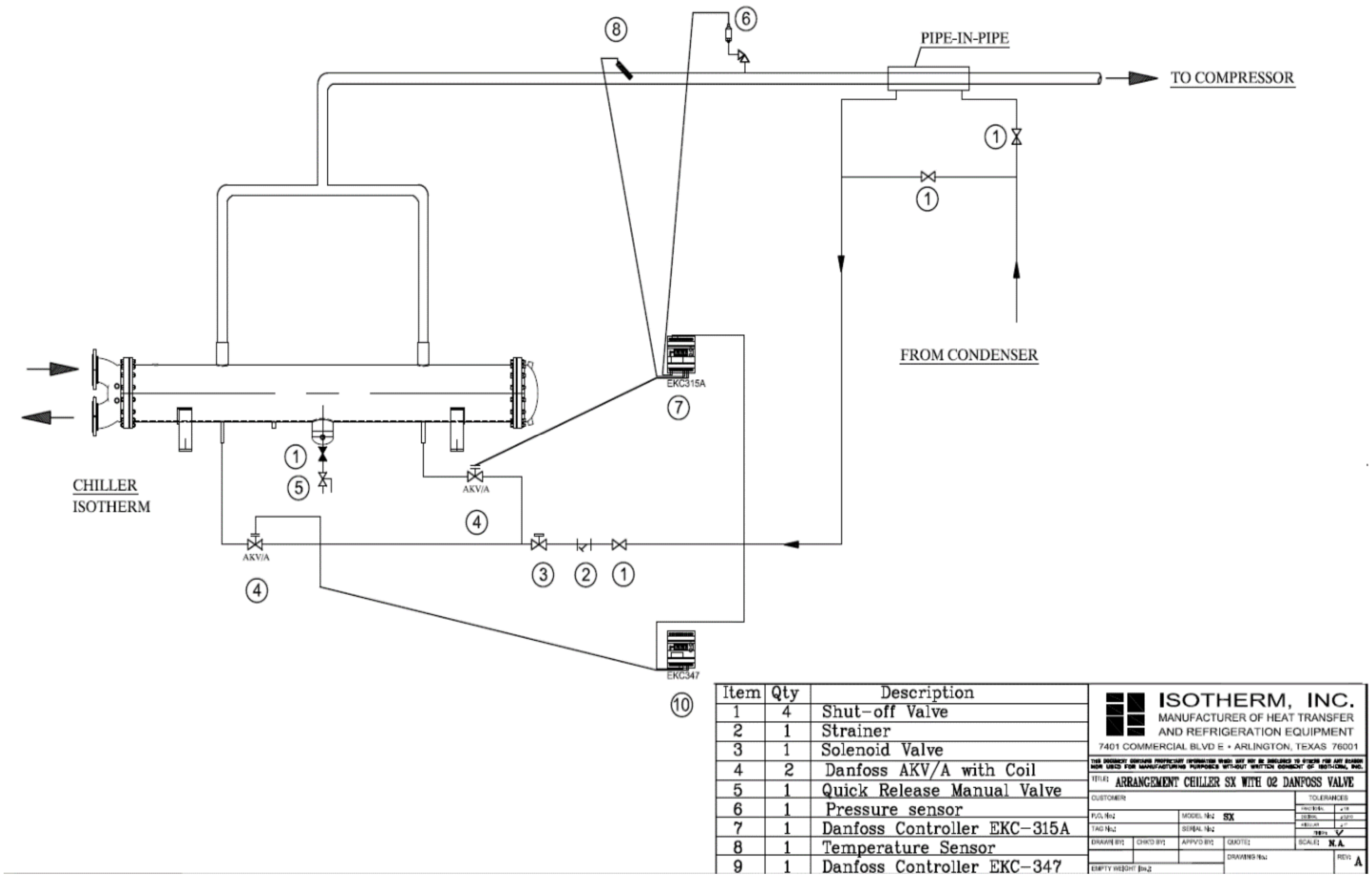
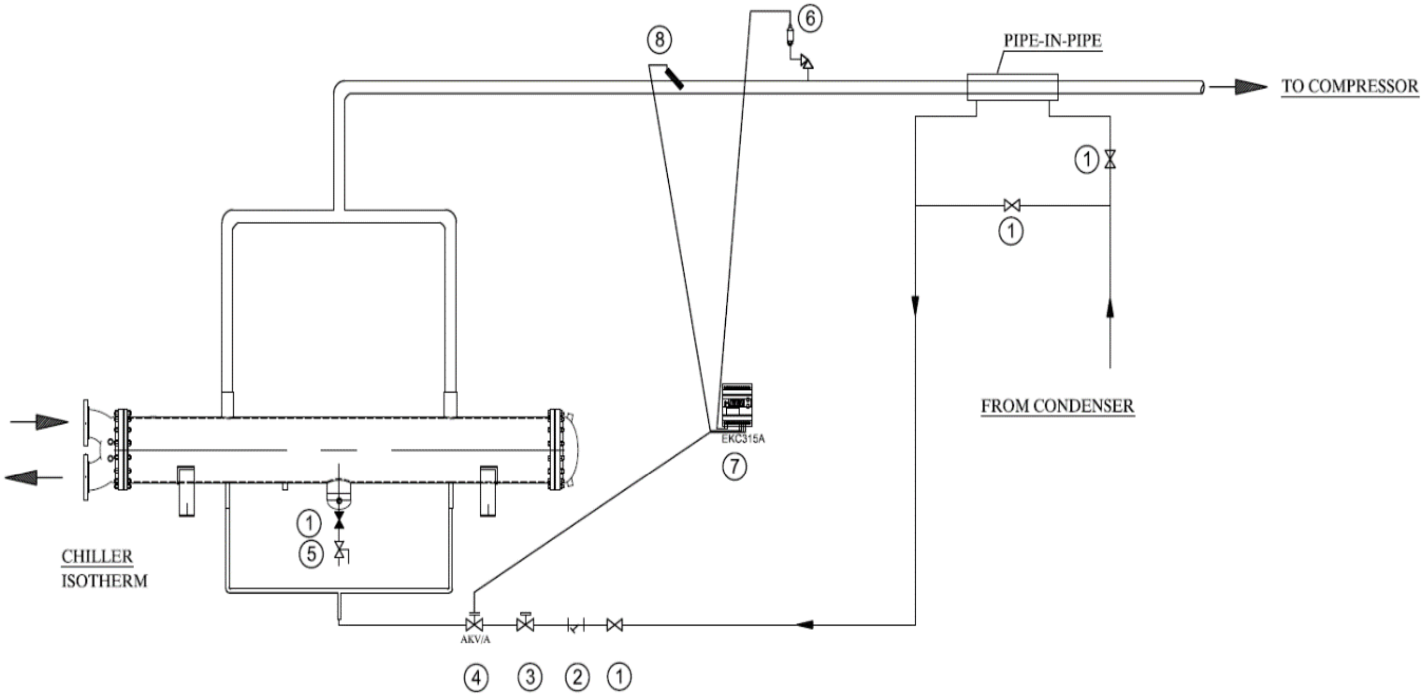


Fig. 2.16: P&ID for dual valves Master/Slave AKVA configuration

Fig. 2.17: Correct dual valves AKVA installation on an SX Chiller in a Master/Slave configuration



Item	Qty	Description
1	4	Shut-off Valve
2	1	Strainer
3	1	Solenoid Valve
4	1	Danfoss AKV/A with Coil
5	1	Quick Release Manual Valve
6	1	Pressure sensor
7	1	Danfoss Controller EKC-315A
8	1	Temperature Sensor

ISOTHERM, INC.
MANUFACTURER OF HEAT TRANSFER AND REFRIGERATION EQUIPMENT
7401 COMMERCIAL BLVD E • ARLINGTON, TEXAS 76001
TITLE: ARRANGEMENT CHILLER SX WITH 01 DANFOSS VALVE
MODEL No: SX
SCALE: N.A
REV: A

Fig. 2.18: P&ID for a single valve AKVA configuration

Fig 2.19: SX Chiller installed at California Wine Plant

Conclusion

As mentioned previously, the SX chiller was designed and patented to offer a compact design with lower refrigerant charge, easier maintenance, and lower risk of maldistribution than the DX and spray chillers. The two projects in Norway and Ecuador showed promising results, provided that correct piping and controls are implemented. In the Norwegian test stand project, only ASME certification of the chiller was required. But for the same Norwegian client, equipment shipped to them would require certifications other than ASME. Therefore, the intern had to familiarize himself with the requirements of European certification criterion in order to continue selling to European clients.

CHAPTER III

PRESSURE EQUIPMENT DIRECTIVE (PED) CERTIFICATION

At the start of the internship, the intern was given a project consisting of two heat exchangers, a 30 inch Outside Diameter (OD) spray chiller and a 14 inch OD condenser, for a fish processing plant in Norway. These two pieces of equipment required European certification, referred to as Pressure Equipment Directive (PED) certification. Why is PED certification of pressure equipment necessary in the European Union (EU)?

As was the case of each state in the U.S. prior to the adoption of the ASME Code, each member state of the EU had its own regulations, or harmonized standards, for pressure equipment safety, thus complicating free trade among the member states (Bureau Veritas 2009). The Bureau Veritas (BV) seminar stated that the European Parliament adopted the PED to synthesize the harmonized standards of each member state into a new set of standards, known as Essential Safety Requirements (ESRs) to facilitate free trade within the EU member countries (2009). They further mentioned that the manufacturer of the pressure equipment must prove to the EU authorities that the heat exchangers and pressure vessels meet the ESRs (2009). Despite the PED certification requirement for pressure equipment in the EU, they also highlighted that PED does not address the design calculations for the pressure vessels, thus it allows the manufacturer to use any PED approved code, such as ASME VIII Division 1. However, the ASME design is not considered as a harmonized standard to the EU since the PED design addresses additional requirements that ASME does not, such as, but not limited to, the hazardous analysis of the fluids within the pressure vessels and providing operating instructions of the pressure equipment (Bureau Veritas 2009). Moreover, Bureau Veritas had addressed the differences between ASME and PED requirements of pressure vessel certification (2009). They mentioned that the ASME code allows any authorized manufacturer to use its ASME approved quality control manual as a guide for fabrication, whereas the PED requires third party inspection and approval of the design, fabrication, and pressure test for each pressure vessel.

Another difference highlighted is that each standard has different allowable stresses for the pressure bearing materials. PED has additional requirements for third party inspection and approval of the manufacturer’s welding procedures, qualifications of each welder, and non-destructive testing, whereas ASME allows the manufacturer to declare conformance of the welding and non-destructive testing in accordance with ASME requirements.

Lastly, the ASME and PED codes have differences in the pressure testing procedures. The hydrostatic test pressure per ASME is the design pressure multiplied by a factor of 1.3, whereas PED’s hydrostatic test pressure is the design pressure multiplied by a factor of 1.43. Therefore, due to the differences of fabrication, testing, and hazard analysis and operating instructions, the pressure equipment designed per ASME must be met with additional requirements that satisfy PED.

As mentioned above, it is obligatory for the manufacturer to fulfill the ESRs, such as the classification of fluids (toxicity, hazard, etc.), material restrictions added with ASME certified materials, and pressure testing based on EU standards. The manufacturer must prove that the ESRs are met by submitting the technical data book to the PED Notified Body (NB), as stipulated by the European Parliament (1997). Three departments within the manufacturer, i.e., Engineering, Procurement, and Fabrication, must prove to the NB that the ESRs have been met (European Parliament, 1997). The Engineering department is required to submit the following to the PED Notified Body:

1. The signed application for certification of the equipment
2. Technical Documentation for CE marking of Pressure Equipment
3. Fabrication Drawings and Design Calculations
4. Allowable stress comparison of the materials per ASME requirements with PED requirements.
5. Pressure test calculations based on PED requirements (Bureau Veritas 1997)

The documentation from the above list can be found in Appendix C.

The application is a document addressing the overview of the equipment and the level of assessment by the NB for conformance to PED requirements. The Technical Documentation for CE Marking of Pressure Equipment is the document that addresses the information required to prove that the equipment is in compliance with the PED requirements. Examples include, but not limited to:

1. Description of the equipment and design calculations and conditions
2. Fabrication Drawings
3. Fluid hazard categories
4. Amount of conformance assessment required by the authorized third party inspection agency

5. List of solutions to address the ESRs (Bureau Veritas 2009)
6. List of particular material appraisals (PMAs)
7. PED approved welding procedures and welder qualifications
8. PED approved NDE personnel (Bureau Veritas 2009)

After completing the signed application and the Technical Documentation for CE marking, the complete fabrication drawings and design calculations were also prepared. The allowable stresses calculations and the PED pressure test calculations were also submitted with the first three documents. After the intern submitted the above information, the PED inspector submitted the documentation to the NB in order to process this project as a new job in their system. The intern released the job for fabrication to the procurement department for ordering the materials. Before the materials could be ordered by Procurement, the intern was required to complete the Particular Material Appraisals (PMAs), as shown in Fig. C.11 of Appendix C, which lists the ASME approved material and whether the materials' mechanical and chemical compositions fulfilled the ESRs, as listed in the Technical Documentation for CE marking (Bureau Veritas 2009). Not only were PMAs required, but the Material Test Reports (MTRs) were also necessary with the European Parliament expecting the manufacturer to prove that the MTRs meet European standards and that the material manufacturer is approved by the European body, which is shown in their Quality Assessment certificate (i.e. ISO 9001) (1997). The MTR must show that the material was produced while the manufacturer's quality control procedures were approved by the NB.

Once complying with the above requirements, the Procurement department ordered the materials and upon arrival, production of the equipment is started. The PED inspector is required to be present at the shop for the weld startup. Therefore, the intern, the QC manager, and production were responsible for scheduling the PED inspector's visit to the shop. The PED inspector verified if the welding by the qualified personnel is done per the PED approved welding procedures. A document, known as the welder suitability checklist, outlines the qualifications of the welders and the procedures involved (Bureau Veritas 2009). Figure C.12 of Appendix C shows an example of this document. The PED inspector had to complete the inspection checklist to show as proof of his witness of the welding and documentation verification. After that, the production continued and was completed so that the NDE and the hydrostatic testing were to be done. While the PED inspector was not required to witness the NDE provided it was done by the PED approved operators, the hydrostatic test had to be witnessed and verified in the Inspection checklist, as shown in Fig C.13 of Appendix C (Bureau Veritas 2009)

After completion of the hydrostatic test, the European Parliament requires the CE Nameplate, as shown in Fig. 3.1, to be mounted on the equipment in the PED inspector's presence, which shows the equipment has been stamped to PED certification (1997).

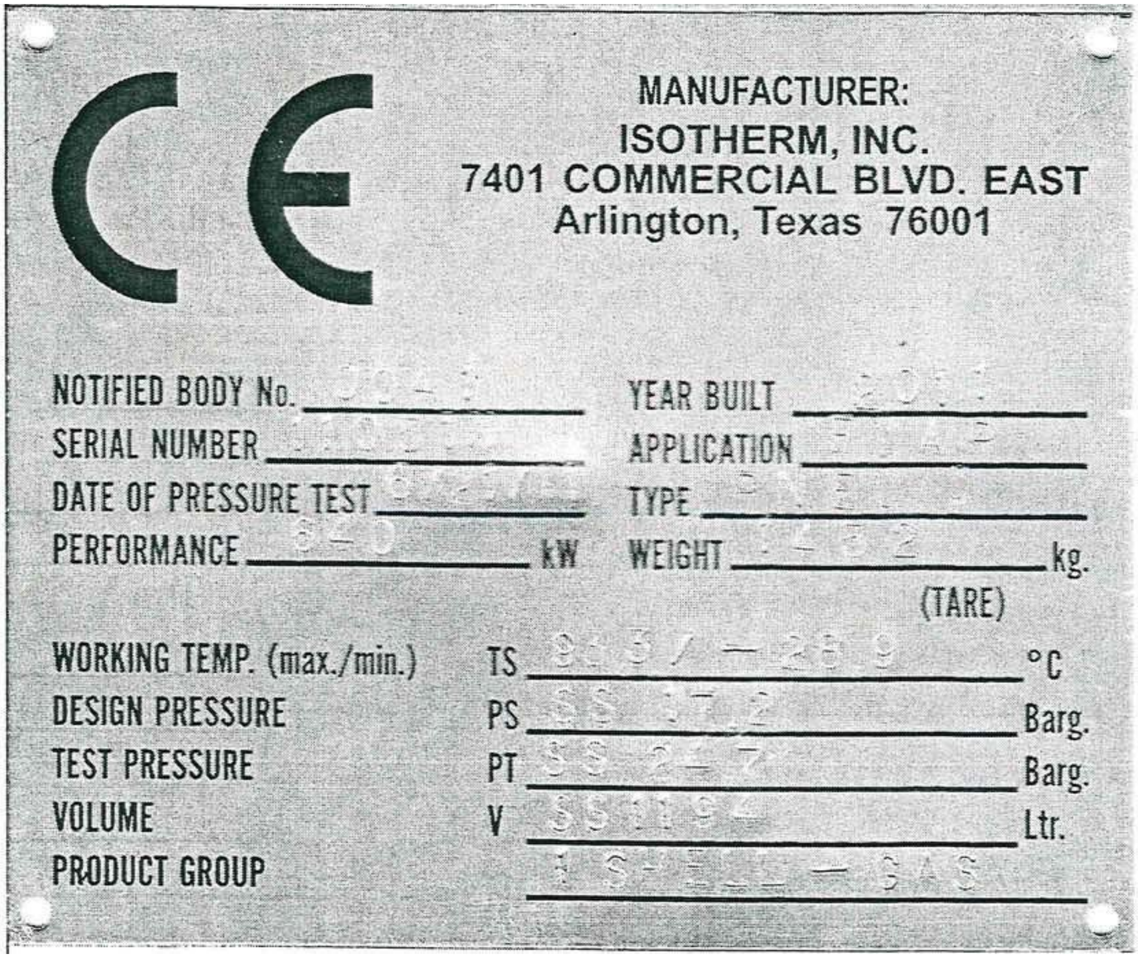


Fig. 3.1: CE Nameplate

After the PED inspector completed the witness points, the equipment was successfully completed and shipped to the client. The intern had to complete the Declaration of Conformity as part of the requirements by the PED inspector and the client, as shown in Fig. C.14 of Appendix C (Bureau Veritas 2009). This document confirms the description of the equipment, as outlined in the Technical Documentation for CE Marking, and it has the statement of verification that the equipment is in compliance with the PED. The intern was required to sign and date it. After completing the Declaration of Conformity, the PED inspector required the QC data book consisting of the technical documentation that backs the Technical Documentation for CE Marking. Not only the documentation mentioned previously was compiled, but additional documents were required for the data book, as shown in Fig. 3.2.

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Pressure Equipment Directive

Technical File

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Fig. 3.2: List for PED QC Data book

When the data book is completed and submitted to the PED inspector, it is checked and submitted to the NB for a final check and if approved, then the NB issues a Certificate of Conformance. The intern successfully received the documents from the NB for the spray chiller and condenser, as shown in Figs C.15 and C.16 of Appendix C. Based on the experience of the above project, the intern further got involved in other projects that successfully got PED certification, including the SX chillers that were sold to the same client. But while the same client required PED certification of Isotherm equipment, the majority of that client's equipment required DNV certification; therefore, the intern had the opportunity to get involved in the DNV certification of Isotherm's products.

CHAPTER IV

DET NORSKE VERITAS (DNV) CERTIFICATION

The next objective in the record of study is related to the certification of Isotherm heat exchangers and pressure vessels according to DNV classification. What is DNV and why is it important for Isotherm? Originally DNV started as an insurance organization that established rules for Norwegian ships in the mid-eighteen hundreds (Det Norske Veritas 2015). During that time, fishing was the main source of income for Norway, thus Norwegian ships were flourishing throughout the country (Heritage, n.d.) However, it was important for the country to set forth safety regulations for ships that operated in Norwegian waters, i.e., part of the North Sea (Det Norske Veritas 2015). After the industrial boom and two world wars, oil and gas were discovered in the North Sea, resulting in DNV's preparation of safety standards in the marine area, which eventually turned into a major third party insurance agency for both marine and oil applications (Det Norske Veritas, 2015)

Way Forward

Isotherm has a major client in Norway, who purchases heat exchangers and installs them on packages that are sold to the owners of the fishing ships around the world. Isotherm's Quality Control (QC) Manager was leaving the company within two weeks at the time the intern arrived. The outgoing QC Manager informed the intern that DNV only required the witness of the Weld Production Test (WPT) coupon of the heat exchanger. This WPT coupon would ensure that the welders were meeting the requirements of the DNV approved WPS's. Besides the WPT coupon, the DNV surveyor's witness of the pressure testing of the equipment is also an essential requirement. Additionally, DNV informed the outgoing QC Manager that as long as the heat exchangers are designed and fabricated to ASME Section VIII, Division 1, and that if the company provides a conformity letter, similar to that of the Declaration of Conformity as required by PED rules as shown in Fig D.1 of Appendix D, then DNV will approve the heat exchangers and issue a Product Certificate. The Product Certificate is important since Isotherm's client needs this certificate for their marine refrigeration package to show the DNV surveyors at the site that all the components of the package comply with DNV rules.

The intern was informed by one engineer from the DNV office in Houston that DNV requires that materials, such as pipes, flanges, fittings, plates, must be from DNV approved mills (2015). Most of the materials received from the mills were not approved by DNV, thus more correspondences from DNV were required in regards to dealing with non-DNV approved materials. After several discussions, the intern understood that the materials must undergo traceability, which requires a surveyor to attend the facility in which a piece of material from the one ordered by Isotherm shall be stamped by the surveyor to prove that the material at the suppliers match with the MTR. The surveyor then writes a report confirming the traceability. After the stamping of the material, DNV expects the material sample must undergo chemical and mechanical tests (such as yield stress, tensile stress, Charpy impact tests) from a DNV approved testing laboratory

(2015). If the tests meet DNV Rules, the material with the specific heat number, as shown in the MTR, will be DNV approved and can be used for fabricating any DNV certified equipment. Based on the above requirements for DNV approved materials, the intern had to ensure that all these materials are acceptable for DNV. Because most of the correspondences with DNV have been conducted by email and only based on the availability of the DNV contacts, the intern realized the necessity to meet the DNV contacts in the Houston office. Both the intern and the new QC manager took a trip to Houston to clarify the procedures of certification with the DNV contacts. Based on the meeting, the following was concluded:

1. Design per ASME Section VIII, Division 1
2. Procurement of materials shall be from DNV approved mills. If material is from non-DNV approved mills, it must undergo traceability and testing in the presence of the DNV surveyor
3. Weld Production coupon test shall be done at Isotherm in the presence of the DNV surveyor
4. After fabrication, the DNV surveyor shall witness the pressure test of the equipment in which Isotherm can use the ASME requirements for pneumatic test (dry nitrogen test) since DNV Rules only covers hydrostatic (water) testing

The intern, with the help and coordination of the new QC Manager, conducted the first three steps for a project that required full DNV approval. The job reference is designated as Job 10074.

During the pressure test phase, the DNV surveyor was informed that the raw plate materials used for fabrication did not meet DNV Rules for Ships, despite the materials being ordered from DNV approved mills. The surveyor suggested that each plate required an additional DNV approved certificate, which is referred to as an NV certificate (Det Norske Veritas 2015). This NV certificate is to prove that the plate material undergoing the production process was witnessed and approved by the DNV surveyor. This was the first time that the issue of a NV certificate for plate materials was addressed to Isotherm, at a time when the vessels in question were already built. Since no further information about the NV certificate was provided by DNV and the delivery of equipment was near, both the intern and the QC manager took the risk of proceeding with the shipment of the equipment because the requirements as mentioned above were the only ones that the intern and Isotherm were aware at the time.

After the shipment of Job 10074, it was informed by the Norwegian client that two shipped projects, Jobs 10045 and 10046, did not have the DNV certificates and that Isotherm must inform DNV Houston about the status of these certificates. The intern had to push DNV Houston about the status and was informed by DNV Houston that no design approval was conducted by DNV. As mentioned previously, DNV had informed Isotherm that as long as the equipment is designed and built to ASME Section VIII, Division 1, along with procurement of materials from DNV approved mills, weld production coupon testing and pressure testing in presence of the DNV surveyor, then it would meet DNV requirements, provided that a letter of conformity mentioning the above is submitted to DNV Houston. A new requirement was first addressed to

Isotherm, thus compelled the intern to start the procedure by submitting the drawings and calculations for Jobs 10045 and 10046. The DNV surveyor who reviewed the project required that the intern submit a QC data book of the shipped projects. After several discussions with the intern having to show that some of the DNV rules were complied, it was concluded that the projects can proceed forward, provided that the verification by the DNV Quality Assessment team was done at the site. After several months of intense deliberations, the DNV approved Jobs 10045 and 10046. However, Job 10074, as mentioned above, was already completed and shipped before new correspondences about non-compliance of DNV were addressed. The intern had to convince all of the personnel in DNV Houston and in the main headquarters in Oslo about the miscommunication in the beginning and that 10074, along with 10045 and 10046, would be the last projects that would be designed to only ASME Section VIII, Division 1. After many months of discussions, Job 10074 was finally approved by the DNV Quality Assessment team, thus the DNV certificate was also issued.

Based on the above experiences the intern was compelled to return back to Houston to discuss with the DNV office about a new job (referred as Job 10080) so that in the future, no new surprises are presented during the production phase. The intern created an Inspection & Test Plan (ITP) to present to DNV Houston (see Fig. D.2 of Appendix D) based on Isotherm's procedures of design, procurement, fabrication, and testing and with the previous correspondences and project experiences with DNV. After the meeting, it was agreed that the following shall be done prior to issuing a DNV Product Certificate for Isotherm equipment:

1. Submission of fabrication drawings to DNV Houston
2. Calculations to be per DNV Rules for Ships, Pt. 4 Ch. 7, not ASME Section VIII, Division 1; however, ASME can be used if specific designs are not covered in DNV Rules
3. Material procured shall be from DNV approved mills with the appropriate certificates. If no certificate, then the DNV surveyors shall be present for the stamping of the material coupon
4. Material coupon shall be tested mechanically and chemically in the presence of the DNV surveyor at a DNV approved laboratory
5. WPT coupon shall be made in the presence of DNV surveyor at Isotherm factory
6. Radiography shall be done and reviewed by DNV surveyor
7. Magnetic particle testing of completed equipment and hydrostatic testing shall be done in presence of DNV surveyor
8. DNV surveyor shall stamp on the nameplate the reference number which will be on the DNV Product certificate
9. Isotherm shall compile the QC data book including all the above listed and submit to the DNV surveyor

The draft of the meeting can be found in Figs D.3 – D.5 of Appendix D. As mentioned above, DNV requires that the calculations of the heat exchangers shall be per DNV Rules instead of ASME Section VIII, Division 1. Therefore, the intern had to create the calculations per DNV Rules, which is found in Figs D.6 – D.8 of Appendix D.

Following the above procedures, the intern applied the steps necessary for Job 10080. After careful assessment and coordination with the Production and Quality Control and DNV, the project successfully met DNV Rules and a product certificate was issued, as shown in Fig. D.9 of Appendix D. This was a major achievement for the company and the intern was highly lauded by the management.

Result

Based on the previous experience of non-compliance for Jobs 10045, 10046, and 10074, along with the compliance of Job 10080, the intern was able to achieve an understanding of DNV certification of Isotherm equipment for future projects. In fact, the Norwegian client issued a purchase order in 2012 for the patented SX chiller that was to be certified by DNV for the first time and successfully received the product certificate for that SX chiller, as shown in Figure D.10 of Appendix D. After the experiences of working with DNV to get the product certificates of Isotherm equipment, the intern successfully got Isotherm to be a DNV approved manufacturer, as shown in Figure D.11 of Appendix D. The intern was able to get Isotherm to offer DNV equipment which proved to be useful since another client in the Northwest U.S. asked for DNV approved equipment which the intern successfully completed. This entire exercise also proved useful since it will now pave way for opening business opportunities with other organization such as the U.S. Coast Guard or US flag fishing vessels that need to be built per DNV rules (Bernton, 2015)

This chapter and the previous two proved that the intern was able to get involved in the technical aspect of the internship, such as the design of the patented SX chiller, the PED and DNV certifications of Isotherm equipment. While the intern had the opportunity to gain technical knowledge from the internship as required by the Doctor of Engineering program, the intern also had the opportunity to achieve management experience at Isotherm to fulfill the managerial requirement of the Doctor of Engineering program. This aspect will be discussed in the next chapters.

CHAPTER V

ENGINEERING MANAGER

The intern took the responsibility of Engineering Manager at Isotherm, Inc. as part of the first step of gaining managerial experience. As outlined in Isotherm's quality control manual, the Engineering Manager is responsible for the following:

1. Initiating engineering folders for new jobs that include information such as job number, serial number and the National Board number
2. Assigning the jobs to the mechanical designers for producing fabrication drawings
3. Approving all drawings, design calculations, and material specifications in accordance with ASME Section VIII, Division 1 and other applicable codes and standards
4. Coordinating with clients regarding approval of drawings
5. Reviewing fabrication drawings and material requisitions prior to releasing the jobs for fabrication.

When the intern came to Isotherm, three mechanical designers were part of the engineering team. After receiving new jobs from the sales department, the intern would review the correspondences between the Sales department and the clients. If anything beyond the standard practices of Isotherm were noticed, the intern as an Engineering Manager would list the extra requirements in the sales and engineering folders. Upon the receipt of new jobs, the intern assigned a job number, serial number, and a national board number for each job followed by assigning each mechanical designer the responsibility of creating top level (general arrangement) drawings as shown in Fig. 5.1 below.

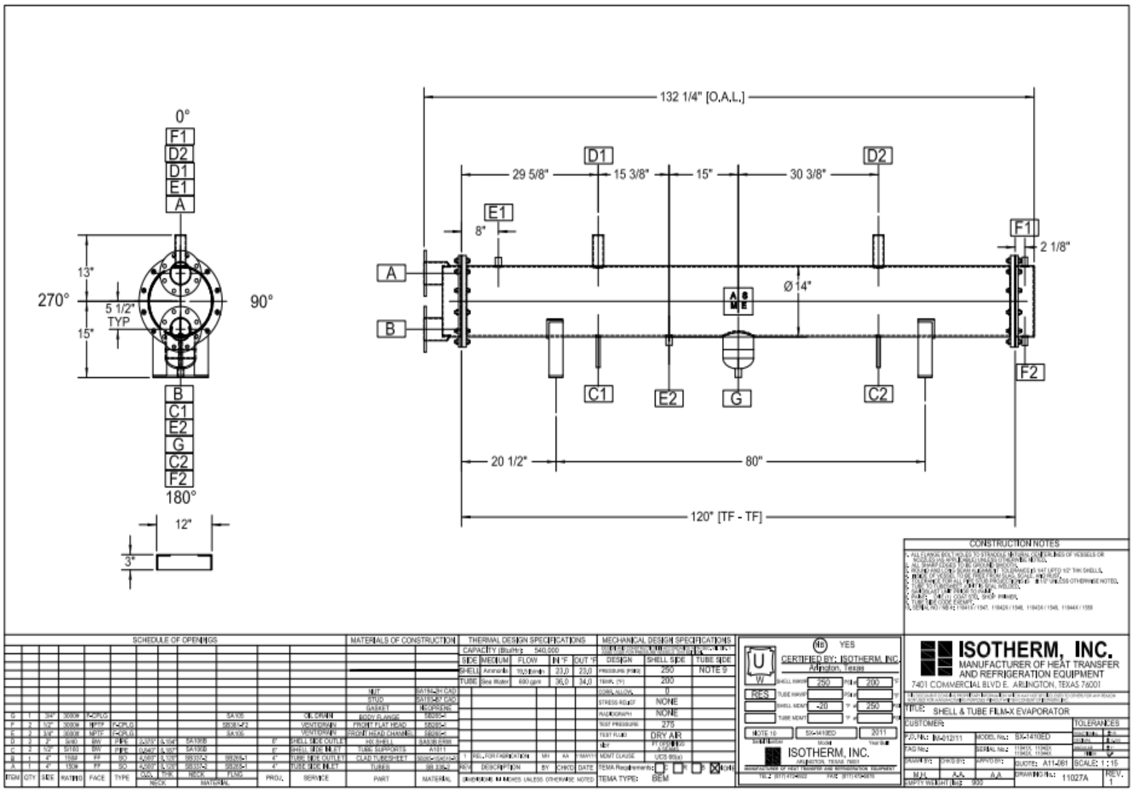
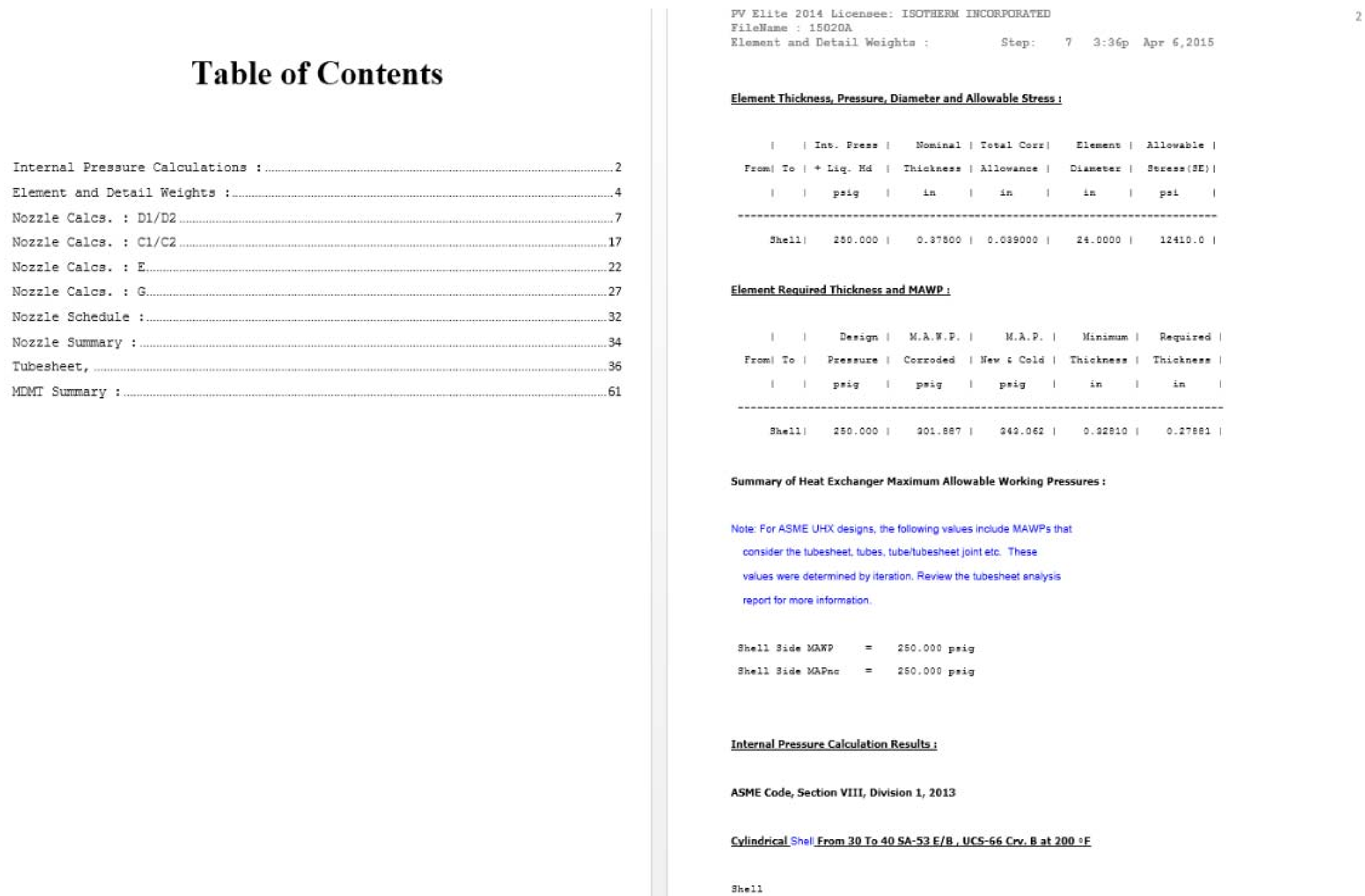


Fig. 5.1: Top Level Drawing

The intern had to submit the top level drawing for approval to the client and contact the client frequently for either full approval or any requested changes from the client. If the client requested changes, the intern was responsible for immediately communicating with the responsible mechanical designer regarding the revisions of the drawing. After the client fully approved the drawing, the intern required the mechanical designer to generate detailed fabrication drawings. Upon completion of the fabrication drawings, the intern reviewed and approved the drawings. The intern then instructed the mechanical designers to release the jobs for fabrication. As required by Isotherm's QC Manual, the fabrication drawings were to be filed in the fabrication folder and stamped as "Shop Dwgs". Another set of drawings were to be stamped as "Office Dwgs", and were to be kept in the engineering folder, along with the design calculations, which were performed in the software called PV Elite or Compress by the intern as shown in Fig. 5.2.

A green folder was to be kept in the engineering folder, which serves as a fabrication traveler. This traveler consisted of the final inspection checklist, inspection checklist for the QC manager and the ASME authorized inspector (AI), a top level drawing (letter size) that serves as a weld map, the NDE (Liquid Penetrant) examination record, and the nameplate drawing; see Figs E.1 – E.5 of Appendix E. The last document required is the material requisition list. A typical sample is shown in Fig. 5.3.



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PV Elite 2014 Licensee: ISOTHERM INCORPORATED
FileName : 15020A
Element and Detail Weights : Step: 7 3:36p Apr 6,2015

2

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd psig	Nominal Thickness in	Total Corr Allowance in	Element Diameter in	Allowable Stress(SE) psi
Shell		250.000	0.37500	0.039000	24.0000	12410.0

Element Required Thickness and MAWP :

From	To	Design Pressure psig	M.A.W.P. Corroded psig	M.A.P. New & Cold psig	Minimum Thickness in	Required Thickness in
Shell		250.000	301.887	343.062	0.32810	0.27881

Summary of Heat Exchanger Maximum Allowable Working Pressures :

Note: For ASME UHX designs, the following values include MAWPs that consider the tubesheet, tubes, tube/tubesheet joint etc. These values were determined by iteration. Review the tubesheet analysis report for more information.

Shell Side MAWP = 250.000 psig
Shell Side MAPnc = 250.000 psig

Internal Pressure Calculation Results :

ASME Code, Section VIII, Division 1, 2013

Cylindrical Shell From 30 To 40 SA-53 E/B , UCS-66 Crv. B at 200 °F

Shell

Fig. 5.2: Sample page of the ASME Design Calculations in PV Elite

MATERIALREQUISITION/TABULATION

CUST:
QUOTE: A12-236
DELIVERY: **02/22/13**
DATE: **01/17/13**

JOB #: 12095A
MODEL #: ZE-806D
SERIAL #: 12212X
QTY: 1

SHELL ASSEMBLY

QTY.	MATERIAL DESCRIPTION	MATERIAL	VENDOR	ISO P.O.	ITEM	IDENTIFICATION	PRICE	ORD.DATE	SCH. DEL.	REMARKS
1	8" x S/20 x 69 3/4" LG	SA53B-ERW								
2	ANGLE: 3" x 7" x 1/4" THK x 9" LG	SA36								
1	STD ASME NO BRKT, 2" STAND-OFF	SA36								
1	1" x S/80 x 7" LG	SA106B								
1	3/4" x S/80 x 7" LG	SA106B								
2	3/4" x 3000#, NPTF F-CPLG	SA105								

TUBESHEET & BUNDLE ASSEMBLY

QTY	MATERIAL DESCRIPTION	MATERIAL	VENDOR	ISO P.O.	ITEM	IDENTIFICATION	PRICE	DATE	SCH. DEL.	REMARKS
2	PL: 13 1/2" OD x 1" THK	SA516-70								SEE DRAWING
42	Ø3/4" x 16 ga x 72" LG	SA214-ERW								
4	PL: 7 7/8" OD x 1/8" THK	A1011								
3	TIE ROD: Ø1/2" x 57 1/4" LG	SA36								
1	TIE ROD: Ø1/2" x 43 1/4" LG	SA36								

HEAD ASSEMBLIES

QTY	MATERIAL DESCRIPTION	MATERIAL	VENDOR	ISO P.O.	ITEM	IDENTIFICATION	PRICE	DATE	SCH. DEL.	REMARKS
2	8", 150# ASME RFSO FLANGE	SA105								
1	8" x S/20 x 7 7/8" LG	SA53B-ERW								
1	PL: 7 7/8" OD x 3/8" THK	SA516-70								
1	PL: 7 7/8" W x 1/4" THK x 7 5/8" LG	SA36								
1	8" x STD WT, WELD CAP	SA234-WPB								
2	3" x S/40 x 7" LG	SA106B								
2	3/4" x 3000#, NPTF F-CPLG	SA105								

MISCELLANEOUS

QTY	MATERIAL DESCRIPTION	MATERIAL	VENDOR	ISO P.O.	ITEM	IDENTIFICATION	PRICE	DATE	SCH. DEL.	REMARKS
1	STD ASME NAMEPLATE	SA240-304								SEE DRAWING
2	STD 8" BACKING RING	SA109								
1	FRT GSKT: 10 5/8" OD x 8 3/4" ID x 1/8" THK	G-2900								
1	RR GSKT: 10 5/8" OD x 8 3/4" ID x 1/8" THK	G-2900								
16	STUDS: Ø3/4" x 4 1/4" LG	SA193-B7								
32	NUTS: Ø3/4", H-HEX	SA194-2H								

Fig. 5.3: Material Requisition Form

The intern was responsible to check if the material requisition consisted of the correct materials as listed in the fabrication drawings. Completion of the above tasks entailed completion of engineering work for the said job; however, the intern was at all times responsible for providing any clarifications to the production regarding the fabrication drawings. Near the completion of the equipment, the intern was responsible for creating the data report, which serves as a certificate of the ASME equipment with the description and tests that have been conducted. The intern and the QC manager had to ensure that the AI signs off the data reports prior to the required submission to the National Board. The signed data reports are necessary for the clients at the field when providing the required documentation to their clients or site authorities; see Fig. E.6 of Appendix E. These skills were applied for the creation of approval and fabrication drawings for the SX chiller.

As shown in Fig. 5.1, the designer made the top level drawing of the SX chiller in AutoCAD, which was done by the designer and approved by the intern (initialed as A.A.) and the intern was responsible to verify if the chiller met the operational requirements, such as distribution pipe design and the location of the refrigerant inlets and outlets based on the client's thermal design requirements. While the intern had the above responsibilities of assigning jobs, along with approving, releasing, and creating the required paperwork for each job, he also had the opportunity to manage the engineering department, for example tracking the progress of each mechanical designer (Fig. E.7 of Appendix E shows the Engineering Time Sheet). He was also responsible for providing training to any new designers and checking the drawings for accuracy and compliance with ASME and Isotherm's standard practices. The intern had the opportunity to keep track of the performance of each designer. During the year, the intern had the opportunity to discuss with each designer their progress and steps needed for improvement. The intern also interacted with the Production Department if any changes had been incorporated by the client during the production phase.

The intern also got involved in employees' conduct issues. One experience involved a designer who made frequent mistakes that resulted in the issuance of a warning letter by the intern to the employee. Another case was with a different designer who, despite being skilled in the Auto-CAD software, had not been cooperative in regards to the intern's requirements for work and had made issues regarding company policy, in spite of his signed acknowledgment of the policy. As a result, the intern had to release him for misconduct. The fired employee filed for unemployment so the intern had the opportunity to discuss at length his case with the Texas Workforce Commission regarding the termination of the said employee. A well-presented case with all the written evidences resulted in a judgment in favor of the company. Another experience involved an employee who left the company to take up a job with a competitor. The reason for his leaving was his feeling of not being rewarded for his skills, despite his unwillingness to discuss with the intern during his tenure. This was a learning experience from a human aspect point of view and thus compelled the intern to be more careful in dealing with employees, both professionally and emotionally. The intern hired a new design engineer who had diverse management skills. From the get go, the new design engineer and the intern agreed to setting up a skilled engineering team with ample experience in pressure equipment design.

Based on the above experiences, the intern was able to manage technical matters and also develop a grasp on human management skills. The intern’s position as an Engineering Manager lasted for about three years until he moved on to the Sales and Applications Manager position, which is one more stepping stone to becoming an effective owner of the company.

CHAPTER VI

FUTURE OWNERSHIP

The last objective is acquiring the responsibilities for future ownership, which involves the responsibilities of sales and applications. After completing the stint as Engineering Manager, the intern had the opportunity to change to Sales and Applications Manager. This experience was necessary for future ownership since the current ownership had been involved in this area since the start-up. The following responsibilities as Sales and Applications Manager are listed below:

1. Receive RFQ’s from clients and offer Isotherm’s products based on clients’ requirements
2. Follow up on RFQ’s
3. Attend trade shows
4. Travel to existing and potential clients
5. Keep track of the financial matters

With the first responsibility of receiving RFQ’s, the intern received the quotation requests from the clients for pressure vessels and heat exchangers. The intern performed the calculations and the pricing, based on the proprietary software, and generated the quotation to the clients. One example was the case of a shell and tube flooded chiller for a cheese plant in New York. The client requirements are shown in Table 6.1.

Table 6.1 – New York Cheese Plant design parameters		
Parameter	Value	Unit
Flow Rate	68 (300)	M3/h (gpm)
Capacity	176 (50)	kW (TR)
Brine Inlet Temperature	-2.2 (28)	°C (°F)
Brine Outlet Temperature	-4.4 (24)	°C (°F)
NH_3 Suction Temperature	-6.7 (20)	°C °F

The intern successfully closed the contract for a 22” shell diameter by 12 ft. tube length chiller (with 12” NPS integral accumulator on top), as shown in Fig. 6.1.

Fig. 6.1: Flooded Evaporator for Cheese Plant

Another example is a vertical recirculation pressure vessel for a food plant in Illinois. This vessel’s function is to separate liquid from a liquid/vapor stream and circulate liquid refrigerant through the evaporator coils in the cold rooms. This is also commonly known as a pump recirculator vessel since the pump is required to facilitate the recirculation effect. However, the client required that Isotherm provide the complete vessel package instead of a bare vessel. The intern coordinated with the client and received the following information as shown in Table 6.2:

Table 6.2 – Illinois Food Plant vessel design parameters		
Parameters	Values	Unit
Capacity	120 (34)	kW (TR)
Recirculation Ratio	3 : 1	
Suction Temperature	-10 (14)	°C (°F)
Flow Rate	1.6 (7)	m3/h (gpm)
Type of Pumps, Quantity	Nikkiso, 2	

Using this information provided by the client, the intern calculated and offered a recirculator package comprising a 20”shell x 8 ft. overall height. The entire package also included all the necessary piping, valves, pumps, and various other components. The control panel was not included since the client intended to use its own PLC based control at the site. Fig. 6.2 shows the completed package upon shipping. Per confirmation from the client, the package is operating well.

Fig. 6.2: Completed Recirculation Package

There were several other quotations that the intern worked on for clients, where some were awarded to the intern and some were not, but to keep the list less exhaustive, the above two examples proved the intern's involvement in the application side of the business, which is one of the requirements for future ownership. The intern had another responsibility that was to aggressively follow-up on quotations still in progress. The intern experienced cases where the follow-ups resulted in purchase orders. One example was a quotation for a heat exchanger for a brine under-floor warming application in North Carolina where the intern was awarded the purchase order due to frequent reminders to the client. There were cases where purchase orders were not awarded to the intern. The reasons include, but not limited to, the project being cancelled by the end user, the intern's offered price and/or delivery did not satisfy the clients' requirements, or the client's lack of confidence in taking a risk in dealing with the intern. Figure F.1 of Appendix F shows a quotation status template that the intern developed to keep track of the status of the quotes. Despite the success and failures, the intern still worked on the quotations for different clients and assessed what problems had occurred that resulted in losing the project.

It was also important for the intern to interact with the clients to understand their expectations of the equipment for their refrigeration packages. This resulted in the intern attending various trade shows, such as Institute of Industrial Ammonia Refrigeration (IIAR). Various clients from U.S., Canada, and the rest of the world attend this show. The intern attended the show as an exhibitor representing Isotherm, Inc. Various questions were asked by the clients at the show, such as delivery times for high pressure receivers, Isotherm's experience in ammonia and carbon dioxide applications, and other related questions. The intern had the opportunity to discuss with clients about the advantages of SX chiller and how it could help meet their needs, such as lower charge, high efficiency, simple controls and easy oil management compared to other types of chillers as discussed in Chapter II. This resulted in various clients consequently asking for quotations on SX chillers. In fact, a client in California placed an order for cooling wine that resulted in two SX chillers being designed, fabricated and shipped to the client, as shown in Fig. 2.18. Both chillers are operating at full capacity and the end user is extremely happy, but the operational data had yet to be provided. The intern visited the site in October 2015 and met the contractor and the end user. While the intern met current clients at trade shows and offices, he also met new clients and visited their offices. After visiting the clients, the intern completed a sales visit report, as shown in Fig. 6.3 to keep track of the discussions between the intern and the client. These visits at trade shows or at clients' offices proved useful for the company since they opened new opportunities for Isotherm in regards to more business.

ISOTHERM, INC.
ENHANCED HEAT TRANSFER

Visit Report

Visit by	
Visit Date	
Client	
Client Personnel Met	
Agenda	
Discussion	
Action Plan	
Miscellaneous	

Fig. 6.3: Sales Visit Report

One such case was a client from Canada who despite attending the IIAR trade shows in the past had not heard of Isotherm, Inc. The client discussed their issues with Isotherm's competitors, in terms of delivery, thus the intern had the opportunity to meet the client in Canada several months later. This opened the doors for new business, especially in oil and gas projects, as the intern was pushing to move Isotherm into that area. After several discussions, the intern worked on a quotation consisting of several pressure vessels and heat exchangers worth over $1,500,000. The intern successfully received the purchase order from the Canadian client and the equipment was shipped several months later.

During the course of the internship, the intern also had the opportunity to explore marketing strategies and to review the financials of Isotherm in order to prepare him for eventual ownership. This required the intern to review the balance sheets, the pending invoices of clients, and the invoices from suppliers. The intern also had the opportunity to call clients about past due invoices. Besides client invoices, the intern coordinated with accounting about past due invoices with the suppliers and to confirm whether payments had been made. Based on understanding the company books, the intern had the opportunity to keep track of the clients' payment track history. One case was a client based in the Eastern part of the U.S., who was delinquent on payments, despite the original terms of payment as Net 30. Another client had not done business in the past and had failed to provide credit references, thus compelling the intern to offer 50% down payment and remaining balance before shipment. The intern also had the opportunity to track the amount of sales booked each month. Monthly sales figures gave the intern an idea as to how to strategize and increase the booking volume. For example, if sales were low for the current month, the intern reviewed and decided as to how many clients he had to visit and discuss about new opportunities.

With the experience of generating quotations, attending trade shows, meeting new and current clients, and tracking the financials of Isotherm, the intern had acquired the knowledge necessary for future ownership.

CHAPTER VII

CONCLUSION

During the course of this record of study, the intern had the opportunity to work at Isotherm, Inc. to fulfill the internship requirement for the Doctor of Engineering program at the Texas A & M University. The main technical portion of the internship that the intern took part in was the design of the SX chiller. Under the direction of Isotherm, Inc.'s engineering supervisor, the SX chiller was designed so that it would work at a reduced refrigerant charge and at the same time be economical compared to what is currently available in the market. With two successful operations in Norway and Ecuador, the SX chiller proved to be the next generation solution to greatly sought-after low charge systems.

Besides the SX chiller, the intern accomplished in getting Isotherm's equipment certified according to the PED and DNV classifications. Not only they are helpful for continuing business with the existing valuable client in Norway, Isotherm can penetrate further into the European markets that require pressure vessel equipment with these certifications. With the above mentioned experiences, the required technical skills development was fulfilled.

In addition to working on technical skills, the intern also worked on developing the managerial skills as required by the program. Specifically, the intern earned the position of Engineering Manager for three years in which he managed a group of designers and engineers and was responsible for reviewing and approving the engineering design of various types of equipment.

After the experience gained as Engineering Manager, the intern was assigned to a position of Sales and Applications Manager, which consisted of sales management and marketing opportunities, to start the path for future ownership.

Recommendations

Since Isotherm is a small private company, resources are limited. For example, the intern was the only person who frequently followed up on projects with clients, whereas the previous protocol had been that the project would be awarded only if the quotation had generated the client's interest. Consequently, opportunities for more business are impeded due to the limited amount of sales personnel; hence, this area could definitely improve by hiring new employees to the sales department.

Furthermore, within most contracting companies, there are certain individuals who knew Dr. Zahid Ayub for many years, thus business generation is dependent on those individuals. For example, one project engineer working at a contracting company in the Eastern U.S. knew Dr. Ayub since they always met at the ASHRAE conference annually, whereas the rest of the project engineers within that same contracting company did not know Dr. Ayub nor about Isotherm's capabilities. For this reason, relationship building and marketing of Isotherm's products and services are important for new business opportunities. In fact, the case of the new Canadian client, who had no relationship with Isotherm in the past, is one example of how important it was to build new relationships for future opportunities. Moreover, the engineering supervisor and the intern were the only employees familiar with sales and applications, which can be a weakness since timely offers to clients are critical; therefore, more employees within the Sales and Applications department should be considered.

The SX chillers were sold for marine refrigeration applications, as were the cases for the Norway test stand and the Ecuador fishing boats. It is important to penetrate other markets, especially in food and beverage industries. In the food and beverage plants, the most common chiller is a plate and frame-type chiller due to more compact design compared to shell and tube-type heat exchangers; however, the SX chiller can be a viable alternative to plate and frame as it offers less refrigerant charge, as indicated in Table 2.4. This aspect is critical because low refrigerant charge is an important factor for food and beverage industries. Based on feedback from clients who were offered the SX chillers for their applications, the food and beverage industry was not ready to adopt the new SX chiller in lieu of the plate and frame chiller due to their concern regarding limited operational history. Thus, upon availability of operational data for the SX wine chiller the apprehensions of adopting the SX chiller in the food and beverage industries can potentially be alleviated.

While working as the Engineering Manager, the intern observed that most of the designers were not engineers. This limited the performance of engineering, particularly in relation to ASME calculations. As a result, projects could not be completed and released for fabrication without the intern’s review and approval. While reviewing and approving the drawings and calculations, intern was also dealing with the clients with regards to the approval of drawings. In addition, the intern was also dealing with clarifying the questions and comments that the production personnel had in regards to the fabrication drawings. Subsequently, a design engineer was hired in order to assist in the ASME calculations and drawing reviews; however, the engineer lacked the initiative and was not up to the task. Consequently, the intern continued to review and approve the engineering documentation.

It should be noted that a number of additional improvements not mentioned above could in fact have been discussed, so the ones focused on are just examples. To summarize, as a potential owner of Isotherm, Inc., this internship had an eye-opening experience that will pave the way to recognizing areas of company's strengths and weaknesses and therefore, establishing key long-term goals for Isotherm, Inc.

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APPENDIX A

ASME SECTION VIII DIV. 1 DOCUMENTATION

QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATION (WPS)
(See QW-201.1, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name: Isotherm Inc. By: Warren Patterson

Welding Procedure Specification No.: 30 Date: 3/19/13 Supporting PQR No.(s): 30A & 30B

Revision No.: 1 Date: 10/6/14

Welding Process(es): SAW Type (s): Machine
(Automatic, Manual, Machine or Semi-Automatic)

JOINTS (QW-402)

Joint Design: See Note Below
Root Spacing: 1/8 +/- 1/16"
Backing (Yes): x (No):
Backing Material (Type): Weld Metal
(refer to both backing and retainers)

☒ Metal ☐ Nonfusing Metal
☐ Nonmetalic ☐ Other

Details

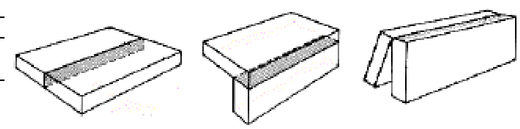

FIG A (BUTT JOINT) FIG B (CORNER JOINT) FIG C (EDGE JOINT)

Sketches, Production Drawings, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of weld groove may be specified.

[At the option of the manufacturer, sketches may be attached to illustrate joint design, weld layers and bead sequence (e.g., for notch toughness procedures, for multiple process procedures etc.)]

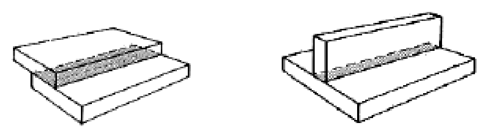

FIG D (LAP JOINT) FIG E (TEE JOINT)

☐ Other (Describe)

☒ Figure A ☒ Figure B ☒ Figure C ☒ Figure D ☒ Figure E

***BASE METALS (QW-403)**

P-No. 1 Group No. 1 & 2 to P-No. 1 Group No. 1 & 2

OR

Specification type/grade or UNS number
to Specification type/grade or UNS number

OR

Chem. Analysis and Mech. Prop.
to Chem. Analysis and Mech. Prop.

Thickness Range:
Base Metal: Groove *0.188"-1.5" Fillet Unlimited
Other * If Impact Tested 0.625" - 1.5"

Maximum Pass Thickness <=1/2 inch (13 mm) (Yes) ☒ (No) ☐

***FILLER METALS (QW-404)**

Spec. No. (SFA)	5.17			
AWS No. (Class)	EM12K			
F-No.	6			
A-No.				
Size of Filler Metals	3/32"			
Filler Metal Product Form	Solid			
Supplemental Filler Metal	None			
Weld Metal Thickness Range:				
Groove	0-1.5"			
Fillet	Unlimited			
Electrode-Flux (Class)	F7A6			
Flux Trade Name	Lincolnweld 882*			
Consumable Insert	N/A			
Other	No Alloy Elements			
*Neutral Flux				

*Each base metal-filler metal combination should be recorded individually.

Fig A.1: Example of Weld Procedure Specification (WPS)

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORDS (PQR)
(See QW-200.2, Section IX, ASME Boiler and Pressure Vessel Code)
Record Actual Conditions Used to Weld Test Coupon

Company Name: Isotherm, Inc.
Procedure Qualification Record No. 30A Date 3/19/13
WPS No. 30
Welding Process (es) SAW
Types (Manual, Automatic, Semi-Automatic) Machine

JOINTS (QW-402)

Groove Design of Test Coupon (sketch, figure or reference)

(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal and process used.)

BASE METALS (QW-403)

Material Specification: SA516
Type or Grade or UNS Number: 65/70
P No. 1 Group No.1/2 to P No. 1 Group No1/2
Thickness of Test Coupon: 3/4"
Diameter of Test Coupon: N/A
Maximum Pass Thickness: 1/4"
Other: Ht# E3A070

POST WELD HEAT TREATMENT (QW-407)

Temperature: N/A
Time:
Other:

GAS (QW-408)

	Percent Composition Gas (es)	(Mixture)	Flow Rate
Shielding	N/A		
Trailing	N/A		
Backing	N/A		
Other			

FILLER METALS (QW-404)

Layer (combination welds)	1	2	3
SFA Specification	5.17		
AWS Classification	EM12K		
Filler Metal F No.	6		
Weld Metal Analysis A No.			
Size of Filler Metal	3/32"		
Filer Metal Product Form	Solid		
Supplemental Filler Metal	None		
Electrode Flux Classification	F7A6		
Flux Type	Neutral		
Flux Trade Name	Lincolnweld 882		
Weld Metal Thickness	3/4"		

Other: No Alloy Elements
Recrushed slag not used.

ELECTRICAL CHARACTERISTICS (QW-409)

Current: DC
Polarity: EP
Amps: 475-575 Volts: 27-30
Tungsten Electrode Size: N/A
Transfer Mode for GMAW (FCAW): N/A
Other: Heat input per pass: 56,117 J/in

POSITION (QW-405)

Position of Groove: 1G
Weld Progression (Uphill, Downhill): N/A
Other:

TECHNIQUE (QW-410)

Travel Speed: 15-25 ipm
String or Weave Bead: String
Oscillation: None
Multipass or Singles Pass (per side): Multiple
Single or Multiple Electrodes: Single
Other:

PREHEAT (QW-406)

Preheat Temperature: 60ºF
Interpass Temperature: 400ºF Max
Other:

Fig A.2: Example of Procedure Qualification Record (PQR) Page 1

QW-483 (Back)

PQR No. 30A

Tensile Test (QW-150)

Specimen Number	Width	Thickness	Area	Ultimate Total Load	Ultimate Unit Stress (psi or MPa)	Type of Failure & Location
1	.752"	.713"	.5362"	42,301	78,900	WM
2	.753"	.703"	.5294"	42,275	79,900	WM

Guided Bend Tests (QW-160)

Type and Figure No.	Result
QW 462.2 Side Bend	Passed
QW 462.2 Side Bend	Passed
QW 462.2 Side bend	Passed
QW 462.2 Side Bend	Passed
QW 462.2 Side Bend	Passed
QW 462.2 Side Bend	Passed

Toughness Tests (QW-170)

Specimen Number	Notch Location	Specimen Size	Test Temperature	Impact Values			Drop Weight Break
				Ft-lb or J	% Shear	Mils (in.) or mm	(Yes/No)
1	CVN HAZ	10mmX10mm	-60F	73			No
2	CVN HAZ	"'	-60F	121			No
3	CVN HAZ	"	-60F	90			No
1	CVN WELD	10mm X 10mm	-60F	82			No
2	CVN WELD	"	-60F	76			No
3	CVN WELD	"	-60F	79			No
		"					

Comments ____________________

Fillet Weld Test (QW-180)

Result- Satisfactory: Yes ________ No ________ Penetration into Parent Metal: Yes ________ No ________

Macro - Results ____________________

Other Tests

Type of Test Impact

Deposit Analysis

Other Visual Examination (QW-194) Satisfactory, Vickers Hardness

Welders Name __________ Clock No. N/A Stamp No. K

Tests Conducted by __________ Laboratory Test Number 13040020,13040021,13040212,13040373

We certify that statements made in this record are correct and that the test welds were prepared, welded, and tested in accordance with the Requirements of Section IX of the ASME Boiler and Pressure Vessel Code

Manufacturer or Contractor Isotherm Inc.

Date 04/02/13 Certified By __________

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the code.)

Fig A.3: Example of Procedure Qualification Record (PQR) Page 2

QW-484A – SUGGESTED FORMAT A FOR WELDER PERFORMANCE QUALIFICATIONS (WPQ)
(SEE QW-301, SECTION IX, ASME BOILER AND PRESSURE VESSEL CODE)

Welders Name ______ Identification No. STAMP K

Test Description

Identification of WPS followed 30 ☒ Test Coupon ☐ Production weld

Specification and type/grade or UNS number of base metal(s) SA 516 GRADE 65/70 Thickness: 3/4 "

Testing Conditions and Qualification Limits

Welding Variables (QW-350)	Actual values	Range qualified
Welding process (es)	SAW	SAW
Type (i.e., manual, semi-auto) used	Semi-Automatic	Semi Auto/Automatic
Backing (metal, weld metal, double-welded, etc.)	with backing	with backing
☒ Plate ☐ Pipe (enter diameter, if pipe or tube)	3/4"	2 7/8"OD and >
Base metal P- or S-Number to P-or S-Number	P1 to P1	P1-P11, P34, P41-P49 .
Filler metal or electrode specification(s) (SFA) (info only)	SAW SFA 5.23	
Filler metal or electrode classification(s) (info only)	SAW EM12K	
Filler metal F-Number(s)	SAW F6 Root and Cover	F6 w backing
Consumable insert (GTAW or PAW)	N/A	N/A
Filler type (solid/metal or flux cored/powder (GTAW or PAW)	N/A	N/A
Deposit thickness for each process		
Process 1: SAW 3 layers minimum ☒ Yes ☐ No	1"	Maximum to be welded
Process 2: ______ 3 layers minimum ☐ Yes ☐ No	"	
Position qualified (2G, 6G, 3F, etc.)	1G	F
Vertical progression (uphill or downhill)	Flat	Flat
Type of fuel gas (OFW)	N/A	N/A
Inert gas backing (GTAW, PAW, GMAW)	N/A	
Transfer mode (spray/globular or pulse to short circuit –GMAW)	N/A	N/A
GTAW current type/polarity (AC, DCEP, DCEN)	N/A	N/A

RESULTS

Visual Examination of Completed Weld (QW-302.4) Satisfactory

☐ Transverse root/face bend tests[QW-462.3 (a)]; ☐ Longitudinal root/face bend tests[QW-462.3 (b)]; ☒ Side bend tests (QW-462.2)
☐ Pipe bend specimen, corrosion-resistant overlay [QW-462.5(c)]; ☐ Plate bend specimen, corrosion-resistant overlay [QW-462.5 (d)];
☐ Macro test for fusion [QW-462.5 (b)]; ☐ Macro test for fusion [QW-462.5 (e)];

Type	Result	Type	Result	Type	Result
Side	Satisfactory	-----	-----	-----	-----
Side	Satisfactory	-----	-----	-----	-----

Alternative radiographic examination results (QW-191) ----------

Fillet weld -- Fracture test (QW-180) N/A Length and percent of defects N/A
Plate [QW-462.4(b)] ☐ Pipe [QW-462.4(c) ☐

Macro examination (QW-184) N/A Fillet size (in.): N/A X N/A Concavity/convexity (in.): N/A

Other tests N/A

Film or specimens evaluated by N/A Company Isotherm Inc.

Mechanical testing by: ______ Laboratory Test Number 13040020,13040021, 13040212

Welding supervised by ______

We certify that the statements in this record are correct and that the test coupons were prepared welded and tested in accordance with the requirements of Section IX of the ASME Code.

Organization: Isotherm Inc.

Date: 4/8/2013 By:

Fig A.4: Example of Welder Performance Qualification (WPQ)

FORM U-1A MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS

(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1

1. Manufactured and certified by **Isotherm, Inc., 7401 Commercial Blvd. East, Arlington, Texas, 76001** (Name and address of manufacturer)

2. Manufactured for (Name and address of purchaser)

3. Location of Installation **Not Known** (Name and address)

4. Type **Vertical** (Horizontal or vertical, tank) 13163V (Manufacturer's serial number) - (CRN) **13070A, Rev 1** (Drawing number) 1986 (National Board number) **2013** (Year built)

5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to ASME Rules, Section VIII, Division 1 **2010** (year) to **2011** [Addenda, if applicable (Date)]

\- (Code Case numbers) - (Special Service per UG-120(d))

6. Shell: **SA516-70** (Material spec. number, grade) **0.500"** (Nominal thickness) **0 in** (Corr. allow.) **4' 5.000" (OD)** (Inner diameter) **9' 4.250"** [Length (overall)]

7. Seams: **Sngl Butt, Type 1** [Long. (welded, dbl., sngl., lap, butt)] **None** R.T.(Spot or Full) **70%** Eff.(%) - (H.T. temp) - Time (hr) **Sngl Butt, Type 1** [Girth. (welded, dbl., sngl., lap, butt)] **None** [R.T. (spot or full)] **70%** Eff.(%) **1** No. of Courses

8. Heads: (a) Material **SA516-70** (Spec. no., grade) (b) Material **SA516-70** (Spec. no., grade)

	Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)	Top	0.460"	0	N/A	N/A	2:1	N/A	N/A	N/A	Concave
(b)	Bottom	0.460"	0	N/A	N/A	2:1	N/A	N/A	N/A	Concave

If removable, bolts used (describe other fastenings) **N/A** (Material spec. number, grade, size, number)

9. MAWP **85/250** (Internal) **N/A** (External) at max. temp. **200 °F** (Internal) **N/A** (External)

Min. design metal temp. **-50/20** at **85/250** . Hydro, pneu., or comb. test pressure **PNEU. at 275 psi**

Proof test -

10. Nozzles, inspection and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diameter or Size	Type	Material		Nozzle Thickness		Reinforcement Material	Attachment Details		Location (Insp. Open.)
				Nozzle	Flange	Nom.	Corr.		Nozzle	Flange	
Inlet	1	12"	WE	SA53B-ERW		0.375"	0	Inherent	Welded		
Outlet	1	14"	WE	SA53B-ERW		0.375"	0	Inherent	Welded		
Pump Suction	2	5"	WE	SA106B		0.258"	0	Inherent	Welded		
Liquid Make-up	1	1 1/2"	WE	SA106B		0.200"	0	Inherent	Welded		
Level Column	2	1 1/4"	WE	SA106B		0.191"	0	Inherent	Welded		

Additional Nozzles - See Attached U-4...

11. Supports: Skirt **No** (Yes or no) Lugs - (Number) Legs **4** (Number) Other **N/A** (Describe) Attached **Welded to Item 6** (Where and how)

12. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors, have been furnished for the following items of the report:

N/A (Name of part, item number, Manufacturer's name and identifying stamp)

Model: VPR-5412 for non-corrosive, non-lethal service. Pressure relief devices by others. No inspection openings per UG 46(a). UG 22(a) only considered in design.

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. "U" Certificate of Authorization No. **31095** expires **June 17, 2014**

Date **11/22/2013** Co. name Isotherm, Inc. (Manufacturer) Signed (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by Isotherm, Inc at 7401 Commercial Blvd. East, Arlington, Texas, 76001 I, the undersigned, holding a valid commission issued by The National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province TEXAS and employed by OneCIS Insurance Company, of Lynn, MA have inspected the component described in this Manufacturer's Data Report on December 8, 2013 and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 12/08/2013 Signed (Authorized Inspector) Commissions 9441A (National Board (incl. endorsements), State, Province and number)

1864024 exec v6.2.66 *Form and version: U1A-17*

Figure A.5: ASME Data Report

APPENDIX B

SX CHILLER DOCUMENTATION

Per Clock	Time (min)	RSW Temp Out	Suction Temp
10:37:33	7	15.3	15.3
10:38:33	8	15.2	7.5
10:39:33	9	8.2	5
10:40:33	10	6.4	4.6
10:41:33	11	6.1	4.2
10:42:33	12	5.9	3.4
10:43:33	13	5.9	3.1
10:44:33	14	5.9	2.7
10:45:33	15	5.7	2.3
10:46:33	16	5.5	1.7
10:47:33	17	5.2	1.1
10:48:33	18	4.9	0.7
10:49:33	19	4.7	0.5
10:50:33	20	4.6	0.3
10:51:33	21	4.4	0.1
10:52:33	22	4.2	0
10:53:33	23	4	0
10:54:33	24	3.8	-0.2
10:55:33	25	3.7	-0.2
10:56:33	26	3.4	-0.5
10:57:33	27	3.3	-0.7
10:58:33	28	3.1	-0.9
10:59:33	29	2.9	-1.1
11:00:33	30	2.7	-1.4
11:01:33	31	2.6	-1.8
11:02:33	32	2.4	-1.9
11:03:33	33	2.2	-2.4
11:04:33	34	2	-3
11:05:33	35	1.9	-3.2
11:06:33	36	1.7	-3.4
11:07:33	37	1.6	-3.6
11:19:33	49	-0.3	-3.8
11:20:33	50	-0.5	-3.9
11:21:33	51	-0.6	-4
11:22:33	52	-0.8	-4.1
11:23:33	53	-1	-4.2
11:24:33	54	-1.1	-4.3

Fig B.1: Field Data for Norwegian SX Chiller

Per clock	Time (min	Suction T	Star T	Port T
10:50	0	17	18.3	18.2
10:52	2	13	17.9	17.7
10:55	5	9.5	17.1	17.1
11:15	25	7.8	15.5	16.1
11:30	40	6.8	14.4	15
11:45	55	6.1	13.6	14.2
12:00	70	5	12.6	13.4
12:15	85	4.2	11.9	12.7
12:30	100	3.4	10.7	11.7
12:45	115	2.7	9.9	10.9
13:00	130	1.9	9.1	10.1
13:15	145	1.1	8.3	9.2
13:30	160	0	7.6	8.5
13:45	175	-0.3	6.5	7.9
14:00	200	-0.6	6.1	7.2
14:15	215	-1.6	5.2	6.7
14:30	230	-2.3	5	5.9
14:45	245	-2.5	4.4	6.2
15:00	260	-2.9	4.1	5
15:15	275	-3.9	3.1	3.8
15:30	290	-4.4	2.7	3.5
16:00	320	-5	1.7	2.7
17:15	395	-5	0	0.5
17:30	410	-5.3	0	0

Fig B.2: Field Data for Ecuador SX Chiller

APPENDIX C

PED DOCUMENTATION

Application To: Bureau Veritas UK Limited for Certification in accordance with UK Legislation implementing Relevant European Directives

Applicant details:

Applicant Name:	**Isotherm, Inc.**
Applicant Address:	**7401 Commercial Blvd., East Arlington, TX 76001**
Responsible Person:	**Adnan Ayub**

We hereby request that Bureau Veritas UK Limited carry out the Conformity Assessment procedure and certification of the below mentioned equipment.

Description of Equipment:

Shell & Tube Spray Evaporator - Drawing # 11034A – Serial # 11051X

Applicable Regulations

Machinery	Lifts	Pressure Equipment	Transportable PV
☐	☐	☒	☐

Service Required:

Initial/Re-Assessment	☒	Modification	☐	Existing BV Ref No.	

Review Technical File and issue Certificate of Adequacy	☐	Carry out EC type examination and issue EC type examination certificate (Module B)	☐
Carry out Design Examination and issue EC Design Examination Certificate (Module B1)	☐	Carry out monitoring of final assessment (Module A1)	☐
Carry out Conformity to Type with random checking (Module C1)	☐	Carry out Final Inspection of equipment: Product Verification (Module F)	☐
Carry out Unit Verification (Module G)	☒	Carry out additional design examination and special surveillance of final assessment as per Module H1	☐
Review the Quality Management System and perform required surveillance Full Quality Assurance — Module H (H1) Production Quality Assurance — Module D (D1) Product Quality Assurance — Module E (E1)			☐ ☐ ☐
(Complete only if approval of QMS is requested). We are in possession of quality system certification issued by an Accredited Certification Body Current Certification is: Name of Certification Body: Date of expiry of Certification			

We hereby declare we have not lodged the same application with any other Notified Body

Signed: [signature] Date: 04/21/2011

Bureau Veritas UK Limited. "Parklands", Wilmslow Road, Didsbury, Manchester M20 2RE

IND 1620 rev 2

Fig. C.1: PED Application to Notified Body

Manufacturer

Technical Documentation for CE Marking of Pressure Equipment

Pressure Equipment: Shell and Tube Evaporator Technical File No. 11034A Rev No. 0

General Description of Pressure Equipment							
Shell and Tube Spray Evaporator Ø762 mm x 3658 mm long, for a refrigeration system. Pressure relief device will be installed by user at no more than 110% of stamped MAWP.							
Operating conditions							
	MAP	17.2 bar	MAT	93.3°C	Min T	-28.9°C	
Contents:	Fluid Group		1 (Gas)				

Drawings and Diagrams		
Document No.	Rev No.	Description
11034A	1	Top Level Drawing
11034A1	1	Shell Assembly
11034A2	1	Tube Sheet Layout & Machining Details
11034A3	1	Bundle Assembly
11034A4	1	Spray Header Assembly

Calculations/Test Results			
Document No.	Rev No	Source	Description
11034A_asme	1	PV Elite 2011	ASME Code Section VIII, Division 1

Description for Understanding of Drawings

Potential Hazards Due to Pressure	
	Potential Loading: Excessive nozzle load, over pressurization
	Possible Failure Modes: Pressure/temperature exceeded
	Operating Conditions: Opening while under pressure, failure due to damage
	Foreseeable Misuse: Human error
	Other Relevant Directives: None

Page No 1 of 5 Form TDE Rev No. 7

Fig. C.2: Page 1 of Technical Documentation for CE Marking

Manufacturer

Technical Documentation for CE Marking of Pressure Equipment

Pressure Equipment: Shell and Tube Evaporator Technical File No. 11034A Rev No. 0

Responsible Person		
Who is Responsible for:	Hazard Analysis	Engineering
	Design for adequate strength	Engineering
	Operational Design	Engineering
	Safety Design	Engineering
	Material Selection	Engineering/Purchasing Department
	Manufacture & Testing	Quality Control Department
Responsible Person is:	Adnan Ayub	

Hazard Category			
Determine hazard category	Fluid Group – Dangerous 1, Others 2?	1	
	Nature of Fluid Gas/Liquid?	Gas	
	Fired/heated, steam, s/heated water?	Gas	
	Pressure Bar?	17.2 bar (max)	
	Volume/DN?	1194 L	
	Table No.	1	
Hazard category		4	

Conformity Assessment Module				
Cat	Conventional Inspection		Quality Assurance	
	Single prod	Series prod	Single prod	Series prod
I	A	A*		
II	A1	A1*	D1 or E1	D1 or E1
III	B1+F	B+C1	B1+D or H*	B+E or H*
IV	G	B+F	H1	B+D
Conformity Assessment Module			G	
Global Conformity of Assembly			N/A	
Application to Notified Body			Yes	

- One off production of vessels and equipment in Category III, referred to in Article 3 § 1.2 (fired or otherwise heated pressure equipment) manufactured under module H, the Notified Body performs the final assessment. (Ref. Article 10 § 1.6)

Harmonized standards used in full or part		
Standard No.	Issue	Applicable to
None		

Page No 2 of 5 Form TDE Rev No. 7

Fig. C.3: Page 2 of Technical Documentation for CE Marking

Manufacturer

Technical Documentation for CE Marking of Pressure Equipment

Pressure Equipment: Shell and Tube Evaporator   Technical File No. 11034A   Rev No. 0

Design (Solutions adopted)				
	ESR		Applicable?	Solution*
Scantling Design	2.2	Design for adequate strength	Yes	Per ASME VIII Div 1 Calculations
	2.6	Corrosion and Chemical attack	No	
	2.7	Wear	No	
	7.1	Within Max membrane stress	No	
	7.2	Joint Efficiencies	Yes	Per ASME VIII Div 1 Requirements
	7.4	Hydro-test pressure	No	Pneumatic Testing
	7.5	Material Characteristics	Yes	Per ASME Sec. II Part D Requirements
Operational Design	2.3	Safe handling and operation	Yes	IOM Manual
	2.4	Means of examination	Yes	Refer to drawings
	2.5	Draining and Venting	Yes	Couplings provided for vent/drain
	2.9	Filling and discharge	Yes	See Drawing 11034A
	3.4	Operating Instruction	Yes	IOM Manual
Safety Design	2.10	Protection against exceeding allowable limits	Yes	Provided by end user
	2.11/7.5	Pressure not exceeds 1.1 PS	Yes	Safety Valve By End User
	2.12	External fire	No	
Manufacturing	3.1	Manufacturing Procedures	Yes	ASME VIII, Div. 1
	3.1.1/2	In-process inspections	Yes	Inspection Checklist
	3.1.4	Heat Treatment	No	
	3.1.5	Material Traceability	Yes	Per ASME VIII Div 1 Requirements
	3.2.1	Internal/External Examination	Yes	Per ASME VIII Div 1 Requirements
	3.2.2	Proof Test	No	
	3.3	Marking & Labelling	Yes	Article 15 Annex 6
Fired Equipment	5	Specific requirements for fired equipment	No	
Piping	6	Specific requirements for piping	No	
Approval by Notified Body			0041	

- Provide reference numbers and use additional sheets where applicable

Hazard Analysis Reconciliation		
Hazard identified	Solution adopted	Residual
Overpressure	Safety Valves by end user	None

Page No 3 of 5   Form TDE Rev No. 7

Fig. C.4: Page 3 of Technical Documentation for CE Marking

Manufacturer

Technical Documentation for CE Marking of Pressure Equipment

Pressure Equipment: Shell and Tube Evaporator Technical File No. 11034A Rev No. 0

Materials

	ESR		Applicable?	Solution*
Materials	4.1 a	Appropriate properties	Yes	In accordance with ASME Section II
	4.1.b	Sufficiently chemically resistant	Yes	In accordance with ASME Section VIII
	4.1.c	Not significantly affected by ageing	Yes	In accordance with ASME Section VIII
	4.1 d	Suitable for intended processing	Yes	In accordance with ASME Section VIII
	4.1 e	Compatible with adjacent materials	Yes	In accordance with ASME Section VIII

ESR 4.2 & 4.3

Material	Source			Certification			
	Harm Std	EAM	PMA Ref No.	3.1	C of C	QA Approval	3.2
SA516-70N	None		sa516-70n-1	x			
SA106B	None		sa106b-1	x			
SA106B	None		sa106b-2	x			
SA105	None		sa105-1	x			
SA105	None		sa105-2	x			
SA234-WPB	None		sa234-wpb-1	x			
PMAs Approved by Notified Body			0041				

Joining

Approvals	Procedures	Tested to: EN 288/ ISO 15614	WPS 21, 26
	Personnel	Tested to: EN 287 ISO 9606	Welder Stamp K, J, Y, P, L
	Properties as base material	Impacts? Weld HAZ	None
PQR & WPS approved by NB (Cats II, III & IV)			Yes, NoBo 0041

NDE

Personnel NDE Approvals for Cats III & IV)	RT	RTPO Approved	None
	UT		None
	MT		Yes, Subcontractor approved by RTPO BINDT
	PT		None

Page No 4 of 5 Form TDE Rev No. 7

Fig. C.5: Page 4 of Technical Documentation for CE Marking

Manufacturer

Technical Documentation for CE Marking of Pressure Equipment

Pressure Equipment: Shell and Tube Evaporator Technical File No. 11034A Rev No. 0

Administration		
	EC Design/Type Certificate from NoBo (B, B1 & H1)	NA
	Certificate of Conformity from NoBo (F& G)	Module G
	D of Cs of incorporated parts	None
	D of C of pressure equipment or Assembly	Yes
	CE Marking	Yes

Comments
Serial Number 11051X

Signed: Date: 04/21/2011

Position: Engineering Manager

Page No 5 of 5 Form TDE Rev No. 7

Fig. C.6: Page 5 of Technical Documentation for CE Marking

Table of Contents

Approved by:
ADNAN AYUB
ENGINEERING MANAGER
6/21/2011

PV Elite 2011 SP1 Licensee: ISOTHERM INCORPORATED
FileName : 11034a
Internal Pressure Calculations : Step: 5 4:44p Apr 27,2011

2

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd (psig)	Nominal Thickness (in)	Total Corr Allowance (in)	Element Diameter (in)	Allowable Stress(SE) (psi)
Frt Channe		250.000	0.37500	...	20.0000	14535.0
Frt HD		250.000	0.37500	...	30.0000	17000.0
Hx Shell		250.000	0.37500	...	30.0000	14000.0
Rr HD		250.000	0.37500	...	30.0000	17000.0
Rr Shell S		250.000	0.37500	...	20.0000	14535.0

Element Required Thickness and MAWP :

From	To	Design Pressure (psig)	M.A.W.P. Corroded (psig)	M.A.P. New & Cold (psig)	Minimum Thickness (in)	Required Thickness (in)
Frt Channe		250.000	No Calc	No Calc	0.32800	0.17082
Frt HD		250.000	No Calc	No Calc	0.34000	0.21771
Hx Shell		250.000	No Calc	No Calc	0.37500	0.26596
Rr HD		250.000	No Calc	No Calc	0.34000	0.21771
Rr Shell S		250.000	No Calc	No Calc	0.32800	0.17082

Summary of Heat Exchanger Maximum Allowable Working Pressures :

Note: For ASME UHX designs, the following values include MAWPs that consider the tubesheet, tubes, tube/tubesheet joint etc. These values were determined by iteration. Review the tubesheet analysis report for more information,

Fig C.7: Engineering Calculations approved by Intern

PED Comparison of Stress Values per EC 97/23, Annex I, Paragraph 7.1

ASME Code of Construction: Section VIII Division 1

Vessel/Equipment Manufacturer: Isotherm Inc.

Vessel or Equipment ID: Shell & Tube Refrigerant Condenser

Maximum Design Temperature: 300 F

Job No.: 11034B

Date: 4/24/2011

Notified Body No.: 0041

For Ferritic Steels w/o exceptions 7.1.2 1st indent

Material Description	Material Specification	ASME Section II, Part D S_{allow} at Room Temp (<100 deg. F) (psi)	Ultimate Strength @ < 100 F From ASME Sect. II, Part D, Table 1A(Current Ed. & Add.) (ksi)($R_{m/20}$)
HX SHELL, NOZZLES	SA106B	17100	60000
TUBESHEET BASE MAT'L	SA516-70	20000	70000

For Austenitic Steels per Annex I, 7.1.2, 2nd indent, sub 1st indent
(Elong. > 30%)

Material Description	Material Specification	ASME Section II, Part D S_{allow} at Room Temp (<100 deg. F) (psi)	Ultimate Strength @ < 100 F From ASME Sect. II, Part D, Table 1A(Current Ed. & Add.) (psi)($R_{m/20}$)

Fig. C.8: PED Material Stress Analysis Page 1

S_{allow} @ Max Design Temp. From ASME Sect. II, Part D, Table 1A(Current Ed. & Add.) (ksi)	PED 5/12 of Ultimate Strength @ Room Temp.(ksi) ($R_{m/20}$)	Yield Stress @ Max. Design Temp(ksi) ($R_{e/t}$) (*) (psi)	2/3 of Yield Strength (Sy) or ($R_{e/t}$) at MAT(psi)	Stress Allow. (2) to be used in Calculations (psi)	
17100	25000	31500	21000	**17,100**	
20000	29167	34200	22800	**20,000**	
	0		0	**0**	
	0		0	**0**	
	0		0	**0**	
	0		0	**0**	
	0		0	**0**	**(1)**

(See Conclusion Note)

(1)- If used as Cplg, no calc. required for info only.

S_{allow} @ Max Design Temp. From ASME Sect. II, Part D, Table 1A(Current Ed. & Add.) (psi)	Column Not Used	Yield Stress @ Max. Design Temp(ksi) ($R_{e/t}$) (*) (psi)	2/3 of Yield Strength ($R_{e/t}$) at MAT(psi)	Stress Allow. (2) to be used in Calculations(psi)
			0	**0**
			0	**0**
			0	**0**
			0	**0**
			0	**0**
			0	**0**

Fig. C.9: PED Material Stress Analysis Page 2

Hydrostatic Testing Analysis per EC 97/23, Annex I, Paragraph

Vessel/Equipment Manufacturer: Isotherm Inc.

Vessel or Equipment ID: Shell & Tube Refrigerant Condenser
Maximum Design Temperature: 300 F
Job No.: 11034B

Date: 4/24/2011

Notified Body No.: 0041

Material Specification	S_{room}	$S_{des.temp}$	MAP	ASME Multiplier (per Sect. VIII)	ASME Multiplier (per B31.3)	PED Multiplier (Using Stress Multiplier)	PED Std. Multiplier	ASME Hydro Pressure(B31.3) (w Multiplier)	PED Hydro(1.25 (w/ Stress Mult.)	PED Hydro Std. 1.43x	ASME Sect. I & B31.1/3 Hydro(x1.5) (No Multiplier)	ASME Hydro(x1.3) (Sect. VIII)	ASME VIII Hydro(1.3 x Stress Multi.)
SA516-70	20000	20000	250	1.3	1.5	1.25	1.43	375	313	358	375	325	325
SA106B	17100	17100	250	1.3	1.5	1.25	1.43	375	313	358	375	325	325
				1.3	1.5	1.25	1.43	#DIV/0!	#DIV/0!	0	0	0	#DIV/0!
				1.3	1.5	1.25	1.43	#DIV/0!	#DIV/0!	0	0	0	#DIV/0!

Hydro Pressure, from the table is based on the max of any one material per the category of the hydro basis, meaning the multiplier whether it is ASME or on of the two PED methods. Then that is compared to the other two methods and the worse case prevails.

Conclusion:

Fig. C.10: PED Hydrostatic Analysis

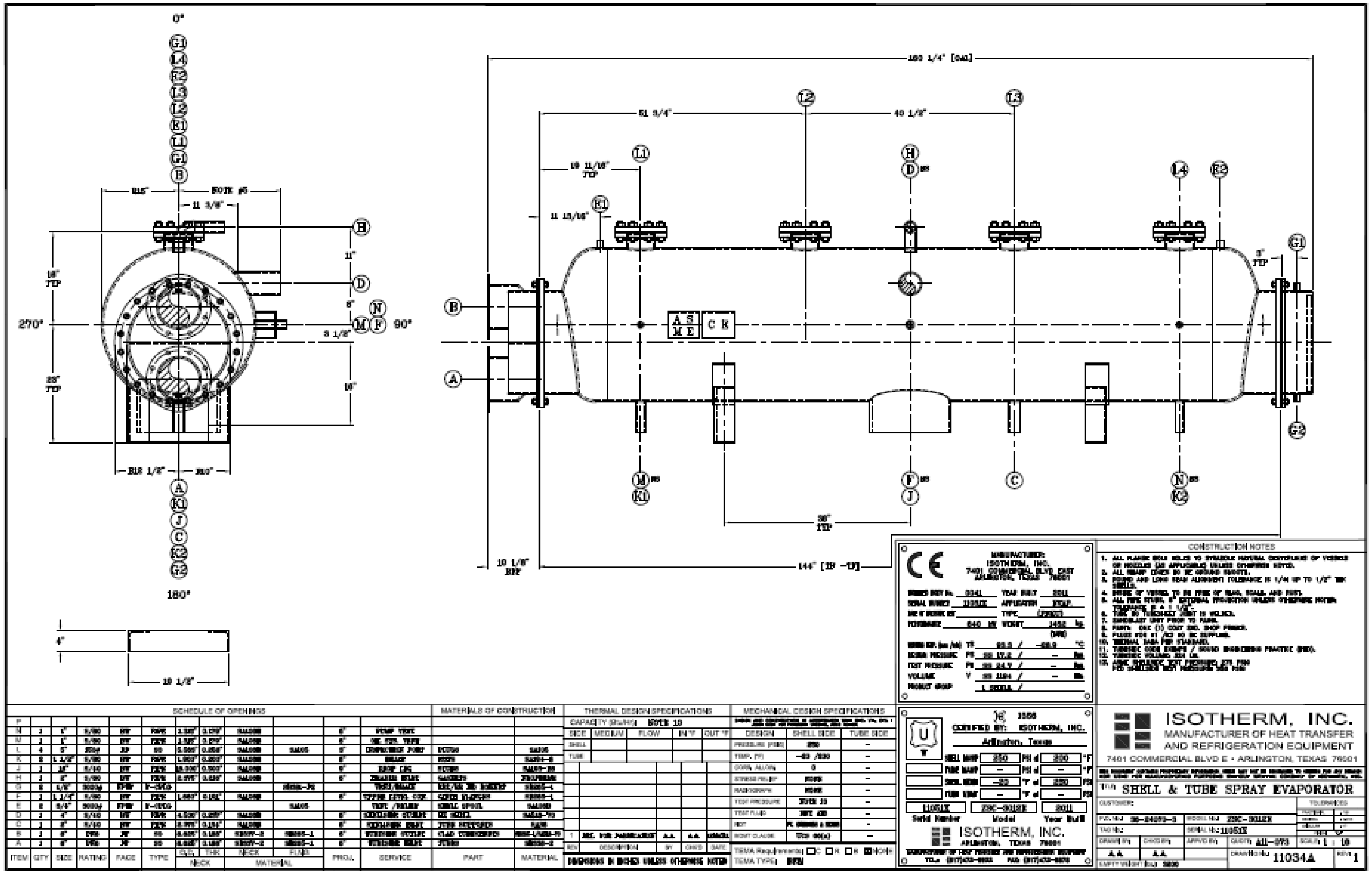

Fig. C.11: Fabrication drawing of Spray Chiller

Particular Material Appraisal

Pressure Equipment Manufacturer:		
Isotherm Inc.		
PMA Ref. No.	**Rev.**	**Material Group:**
sa234 wpb-1	0	Per ASME Section IX P No. 1 Group 1
Material specification including date:	**Grade:**	**Delivery condition:**
ASME SA234 2004 Ed. Or later	WPB	Seamless fittings
Application:		
Main Pressure bearing parts of pressure equipment		

Applicable Design Code:	Dimension range:
ASME Section VIII Div. 1	All NPS from 1/2" - 12" (Schedules 40 & 80)
Maximum allowable temperature:	**Minimum allowable temperature:**
650 °F	-20 °F

Compliance with Essential Safety Requirements for materials (in finished pressure equipment)

Property	Requirement	Details of Compliance
Appropriate properties (Annex I - 4.1(a)) (Assured by material manufacturer)	Proof strength/Yield strength (at appropriate temperature) UTS Creep data	The Minimum stress allowable to be used is either specified in ASME Section II Part D or Stress allowable per PED Annex 1, par. 7.1.2 indent 1.
Sufficiently ductile (Annex I - 4.1(a)) (Annex I - 7.5)	In steel; min 14%	Min. Longitudinal : 22% Min. Transverse: 14%
Sufficiently tough (Annex I - 4.1(a), Annex I - 7.5)	e.g. in steel; 27J at 20 °C or lowest operating temperature.	Material shall fulfill PED impacts or in lieu of impact testing, material shall satisfy UCS 66 Curve B (w/ MDMT of -20 deg F) of ASME Section VIII Division 1 and the below chemical restrictions
Not significantly affected by ageing	Appropriate selection. Suitable composition (e.g. for non alloy steel Al/N ≥ 2)	Not subject to significant aging at intended operating temperatures.
Test programme	Not applicable	
Results of test programme	Not applicable	

The named material specification may be used for the construction of pressure equipment intended for use within the stated limits and subject to the following restrictions:

Restrictions:

Carbon	*0.23% max*
Sulphur	*0.025% max*
Phosphorus	*0.035% max*
Manganese	*0.60% min*

Signed: (Manufacturer) Date 03/10/11

Approved: Bureau Veritas UK Limited Notified Body No. 0041 (Cats III & IV only) Date 03/10/11

BUREAU VERITAS UK LIMITED

Fig. C.12: PED approved Particular Material Appraisal (PMA)

	Welding Procedure Suitability Checklist	Page: 1 of 1
Client: Isotherm Inc.	Ref. Nos: 671/BSN/11, 672/BSN/11	
Manufacturer: Isotherm Inc.	Code: ASME Section IX	
Procedure: As indicated below	Special Requirements: EN 15614-1	

Suitability of proposed Joining Procedures

	Specification numbers					
WPS	21	21	26			
Qualified by PQR No.	21A	21B, 21C	26A			
Welding Qualification Standard	Section IX	Section IX	Section IX			
Process	GMAWS/ GMAW	GMAWS/ GMAW	SAW			
Metal transfer	Spray/S.C.	Spray	N/A			
Electrical Details	DCEP	DCEP	DCEP			
Mechanisation	Yes	Yes	No			
Material Grouping	P1 Gr.1&2	P1 Gr.1&2	P1 Gr.1&2			
Consumable	ER70S-3/6	ER70S-3	EM12K			
Joint type	Single Vee	Single Vee	Single Vee			
Thickness	¾"	1.5"	1.5"			
Diameter	No	No	No			
Heat input	61,714 J/in	73,143 J/in	82,759 J/in.			
Heat treatment	No	yes/no	No			
Tests required by hEN	Yes	Yes	Yes			
Impact testing	Yes	Yes	Yes			
Approved by NB/RTPO	Yes	Yes	Yes			
Application Std.	ASME IX	ASME IX	ASME IX			
	15614-1	15614-1	15614-1			
Suitable	Yes	Yes	Yes			
Qualified	Yes	Yes	Yes			

Suitability of welding personnel

	Welding Personnel Suitability/Approval					
WPS	21	21	26			
Initials/No	J	P.L	J			
Welding Qualification Standard	Section IX	Section IX	Section IX			
Process	GMAW	GMAW	SAW			
Metal transfer mode	Spray/S.C.	Spray	N/A			
Mechanisation	None	None	None			
Material Grouping/F #	6	6	6			
Joint type/backing	with & w.o.	with	With			
Thickness	See WPS	See WPS	See WPS			
Diameter	No	No	No			
Position	1G/2G	1G/2G	1G			
Current/Polarity	DCEP	DCEP	DCEP			
Gas	Ar/Co2/O2	Ar/O2	N/A			
Validity	8/09-8/11; 9/10-9/12	9/10-9/12; 9/10-9/12; 9/10-9/12	9/10-9/12			
Qualified	Yes	Yes	Yes			

APPROVAL STATUS	Approved		

N.B. For each WPS used on the pressure equipment the Inspector should check the boxes to indicate that the parameter is within the scope of approval of the PQR. Actual values are not required

Comments:

Name:

Signed: Date:

IND 1675-6a rev 2

Fig. C.13: Welding Procedure Suitability Checklist

	Inspection Checklist	Page: 1 of 1

Manufacturer: ISOTHERM, Inc.	Ref. No.: 671/BSN/11
Pressure Equipment: Shell & Tube Spray Evaporator	Man Ref. : 11034A
Volume: Shellside=1,194 Ltrs. | DN:	Tare Wt. 1,452 Kgs.
Item/Serial No.: 11051X	Cat: IV CA Module: G
Date(s) of inspection: June 9 & 21,2011	

Module A1, Review of Technical Documentation	For Module C1 - Module B Certificate Number	For Module F - Module B or B1 Certificate No.	Module G - Approval of technical documentation Ref
Not Applicable	Not applicable	Not applicable	CE-0041-PED-G-ISM-003-11-USA

Inspection Activity		Detail
Statement that the same application has not been lodged with any other notified body;		Satisfactory
Visual internal and external examination.		Satisfactory
Dimensions geometry and tolerances.		Satisfactory
Conformance to drawings and technical documentation		Drg No. 11034A rev.1
Source of material ; PMA, EAM, Harm Std		PMA
Conformance to material specification and restrictions, if any		Satisfactory
Traceability on receipt and throughout manufacture		Heat Numbers Marked on Materials.
Material manufactures certification (Scope/EU Comp Body)		Satisfactory
Materials: source, type of certificate, Manufacturer's affirmation		Satisfactory
Items for assembly have CE marking		Not applicable
Joining procedures suitable for application		WPS #'s 21 and 26.
Joining procedure specifications qualified by appropriate PQR & approved by Competent Body for Cat II, III & IV.		Satisfactory; Qualified by NoBo 0041
Joining personnel qualifications are appropriate and valid.		Welder I.D. : "J"
Heat treatment records.		Not Applicable
NDE – Personnel Qualifications. (RTPO for Cats III & IV)		Satisfactory
NDE – required extent and acceptance		Satisfactory MT only.
Destructive testing		Test Report No. Not Applicable
Manufacturer performed required inspection and tests		QP No. 11034A Satisfactory
Witness of pressure test	Date: June 21, 2011	P = 24.7 bar, Duration : 60 mins
		P = bar, Duration mins
Calibration and suitability of pressure gauge(s).		Expiry: 05/10/2012 Range: 0 ~ 68.94 bar No. CP70465
Proof test or burst-test (experimental method).		Not Applicable
Safety accessories, suitability and conformance.		Not supplied
Marking		Satisfactory
Comprehensive Instructions		Satisfactory
Other tests to demonstrate conformance with ESRs		Not Applicable

Recommended interval to next inspection visit, (Modules' A1, C1 & H1)	Not applicable

Comments:

BUREAU VERITAS U.K. LIMITED
Notified Body No. 0041

Name: Date: June 21, 2011

Signed: Assessment Engineer

IND 1671-1 rev 3 draft

Fig. C.14: PED Inspection Checklist

ISOTHERM, INC.

7401 Commercial Blvd. E. • P.O. Box 172379 • Arlington, Texas 76003 • Ph: (817) 472-9922 • Fax: (817) 472-5878

Declaration of Conformity

Manufacturer:

Isotherm, Inc.
7401 Commercial Blvd. East
Arlington, Texas 76001

We herby declare that the pressure equipment specified below has been designed, manufactured and tests in accordance with the requirements of the Pressure Equipment Regulations 2002 [European Directive 97/23/EC]

Description of Pressure Equipment:

Shell & Tube Spray Evaporator Ø762 mm x 3658 mm long

Drawing: 11034A Rev. 1
Model: ZSC-3012E
Serial Number: 11051X

Conformity Assessment Procedure Followed:

EC Unit Verification, Category IV, Module G (Shellside Only). Tubeside is SEP.

The Notified Body has issued the following EC certificates:

EC Certificate of Conformity: CE-0041-PED-G-ISM-003-11-USA

Notified Body:

The Notified Body that carried out the inspections: 0041

Bureau Veritas UK Limited
Parklands
Wimslow Road
Didsbury
Manchester M20 2RE
United Kingdom

Harmonized Standards Applied:
None

Other Technical Standards and Specifications Used:

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 (2010 Edition)

Other Community Directives Applied:
None

Signed: [signature] Date: 6/21/2011
Engineering Manager

Manufacturer of Heat Transfer & Refrigeration Equipment
e-mail: info@iso-therm.com • www.iso-therm.com

Fig. C.15: Declaration of Conformity

Bureau Veritas UK Limited **Notified Body 0041**

BUREAU VERITAS

CERTIFICATE OF CONFORMITY

Module G - Pressure Equipment Directive 97/23/EC

N° CE-0041-PED-G-ISM-003-11-USA

We hereby certify that the design, manufacture and testing of the below pressure equipment complies with the applicable Essential Safety Requirements of the Pressure Equipment Regulations 1999 (EC pressure Equipment Directive 97/23/EC).

Manufacturer (name):	**Isotherm, Inc.**
Address:	**7401 Commercial Blvd. E.** **Arlington, Texas 76001** **UNITED STATES OF AMERICA**

EQUIPMENT

Item :	**Model # ZSC-3012E**
Description :	**Shell & Tube Spray Evaporator.**

TESTS CARRIED OUT

Final tests:	**Reviewed Client PED Application, Drawings, Calculations, PMA's, Permanent Joining WPS's & WPQ's; RTPO NDE Personnel Qualifications & MT Tests Reports; Hydrostatic Pressure Gauge Calibration Status; Witnessed Hydrostatic Pressure Test; conducted an Interior and Exterior Visual Examination; Witnessed CE Nameplate Attachment.**
Remarks -List of enclosures:	**Drawing # 11034A Rev.1 ; Tubeside = SEP**

INFORMATION

Trading name of the manufacturer:	**Isotherm, Inc.**
Trading name of the authorized representative:	**NA**
Marking :	**CE 0041** (*BVIL notified body number*)
Nature and location of the affixing of the marking of the equipment:	**CE Nameplate welded to bracket on Shell.**
Year of manufacture :	**2011**
Serial number :	**11051X**

Essential maximum/minimum allowable limits :

- *Maximum allowable pressure:*	**17.2 Bar**
- *Minimum/maximum allowable temperature:*	**-28.9 deg. C / 93.3 deg. C**

BVIL 1686 rev 01 1/2 Annexe G Contract No : 05009-005167.03 / 671/BSN/11 http://www.bureauveritas.com/ped

Fig. C.16: Certificate of Conformity for Spray Chiller

Bureau Veritas UK Limited

Notified Body 0041

BUREAU VERITAS

CERTIFICATE OF CONFORMITY

Module G - Pressure Equipment Directive 97/23/EC

N° CE-0041-PED-G-ISM-004-11-USA

We hereby certify that the design, manufacture and testing of the below pressure equipment complies with the applicable Essential Safety Requirements of the Pressure Equipment Regulations 1999 (EC pressure Equipment Directive 97/23/EC).

Manufacturer (name):	**Isotherm, Inc.**
Address:	**7401 Commercial Blvd. E. Arlington, Texas 76001 UNITED STATES OF AMERICA**

EQUIPMENT

Item :	**Model # ZC-1410D**
Description :	**Shell & Tube Refrigerant Condenser.**

TESTS CARRIED OUT

Final tests:	**Reviewed Client PED Application, Drawings, Calculations; PMA's; Permanent Joining WPS & WPQ's; RTPO NDE personnel Qualifications & MT Test Report; Hydrostatic Pressure Gauge Calibration Status; Witnessed Hydrostatic Pressure Test; Conducted an Interior & Exterior Visual Examination; Witnessed CE Nameplate Attachment.**
Remarks -List of enclosures:	**Drawing # 11034B Rev.1; Tubeside = SEP.**

INFORMATION

Trading name of the manufacturer:	**Isotherm, Inc.**
Trading name of the authorized representative:	**NA**
Marking :	**CE 0041** (*BVIL notified body number*)
Nature and location of the affixing of the marking of the equipment:	**Ce Nameplate welded to bracket on shell.**
Year of manufacture :	**2011**
Serial number :	**11028X**

Essential maximum/minimum allowable limits :

- *Maximum allowable pressure:*	**17.2 Bar**
- *Minimum/maximum allowable temperature:*	**-28.9 deg. C / 149 deg. C.**

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1/2 Annexe G

Contract No : 05009-005167.03 / 672/BSN/11
http://www.bureauveritas.com/ped

Fig. C.17: Certificate of Conformity for Condenser

APPENDIX D

DNV DOCUMENTATION

ISOTHERM, INC.

7401 Commercial Blvd. E. • P.O. Box 172379 • Arlington, Texas 76003 • Ph: (817)472-9922 • Fax: (817)472-5878

November 16, 2005

DNV
Houston, Texas

Ref: **Shell and Tube Condensers for RSW Application**

We are an ASME Code Shop carrying "U" and "UM" stamps. All our exchangers and pressure vessels are designed, fabricated and tested according to the Rules of ASME Section VIII, Div. 1. We have an inspection agreement with Authorized Inspection Agency, IB&M RE, Inc. Our ASME certificate numbers are as follows:

U: 31,095 expires June 17, 2008
UM: 31,096 expires June 17, 2006

We designed, fabricated and tested two shell and tube ammonia condensers for a customer in Norway who will install them in a fishing vessel. The condenser will not be part of propulsion loop. They will be integral part of the refrigeration system on board. They have asked us for DNV approval and per my phone discussion with you today our understanding is that the following information about the equipment suffices this requirement.

Condenser Model: ZC-1612D (16" dia x 12' tube length)
Material of construction: All carbon steel except for clad titanium tube sheets and titanium tubes.
Design Working Pressure Shellside/Tubeside: 250 / 150 psig
Design Working Temperature Shellside/Tubeside: -20 / 200 °F
Test pressure Shellside/Tubeside: 275/165 psig
Test Medium: Dry Air
MDMT Clause: UCS 66(a), UNF 65, UHA 51 (d) (1) (a)
Serial Nos.: 05124X and 05125X
National Board Nos: 637 and 638
Documentation: ASME U1 forms

Thank you for your help. If there is anything else required of us please let us know since we are to ship these two units to Norway on November 18, 2005. We will appreciate acknowledgement to this memo so we can file it in the job file.

Regards

Zahid Ayub, Ph.D., P.E.
President
Isotherm, Inc.
Arlington, Texas 76001

Fig D.1: DNV Old Conformity Letter

Inspection and Test Plan

Job No: 10080A Doc. No: 10080A Rev: 1 1/1

Customer Tag#:

Equipment Description: Spray Chiller Date: 7/27/11

Item	Activity	Inspection/ Test	Procedure	Acceptance Criterion	Verifying Document	Isotherm	AI*	DNV	Remarks
1	**Documentation**								
a	Design/Calcs/Dwgs	Design/verify		ASME/DNV	DVR or TAC Cert.	M		R	
b	ITP	DNV Approval		DNV Approval	ITP	M		R	
c	WPS/PQR	DNV Approval	10, 21, 23, 24, 25	ASME Section IX	ITP Sign-off	M	R	R	WPS/PQR already approved
2	**Mat. Purchasing**								
a	Order Materials	Verify	QCM	ASME/DNV	Purchase order	M			
b	Witness & Hard stamp	Visual		DNV	Survey Report	M		W	Sample to be hard-stamped
c	Witness Testing	Visual		DNV	Survey Report	M		W	Sample to be tested
3	**Mat. Receiving**								
a	Inspection	Verify	QCM	Comply/PO	Dwg	M			
b	Identification	Verify	QCM	Comply/PO	MTR	M			
c	Certs.	Review	QCM	Comply/PO	MTR, Survey Rep.	M	R	R	
4	**Fabrication**								
a	Weld seam of shell	Visual	WPS	ASME	Survey Report	M	R	W	
b	Stencil openings	Verify dims		Dwgs	ITP Sign-off	M			
c	Tack nozzles	Visual	WPS	ASME	ITP Sign-off	M			
d	Weld nozzles	Visual	WPS	ASME	ITP Sign-off	M	R		
e	Tack Hd-Shell	Visual	WPS	ASME	ITP Sign-off	M			
f	Weld Hd-Shell	Visual	WPS	ASME	ITP Sign-off	M			
g	NDE (Radiography)	Visual	3rd Party	ASME Section V	NDE Report	M			
h	*WPT Coupon	Visual	WPS	ASME	Survey Report	M		W	* To be stamped by DNV
i	WPT Testing	Visual	3rd Party	DNV	Survey Report	M		W	
j	Drill tubesheet/suppts	Visual	Design	ASME	ITP Sign-off	M			
k	Attach tubes-tbst	Visual	Design	ASME	ITP Sign-off	M			
l	Weld Legs	Visual	WPS	ASME	ITP Sign-off	M			
m	Ck Dims	Re-ck		Dwgs/DNV	As Blt dwgs	M		R	
n	Visual inspection	Visual	WPS	Dwgs/DNV	ITP Sign-off	M		W	
5	**Testing**								
a	NDT (Mag Part.)	Defect Ck	3rd Party	ASME Section V	NDT Report			R	
b	Pressure test	Leak ck		ASME, DNV	Survey Report	M	W	*W	*DNV Test Pres. = 1.3 x MAWP
c	Final insp.	Vessel Cmplt		Complete	ITP Sign-off	M			
d	Stamp nameplate			ASME/DNV	Photo copy	M	R	W	NV Stamp
e	Attach nameplate	Check			ITP Sign-off	M	R		
f	Data report	Complete		ASME, NB	MDR	M	R		
g	Data Book	Complete		DNV	Data Book	M		R	
h	Product Certificate	Complete		DNV	Product Cert.	M			

M = manufacturer inspector; R = review of inspection report
SW (spot) = random or interim inspection by DNV
W = Witness (hold point)

* OneCIS Ins. Company - *A Bureau Veritas Company*
DNV: Det Norsk Veritas

Note: NDT and other pertinent requirements per spec. will be administered accordingly

Fig D.2: Inspection & Test Plan for Job 10080

DNV

Document No.: ANMUS467/PPXXXX/skel /2011-7-27-A

PRE-PRODUCTION MEETING REPORT

DNV Project No.:	**PPXXXX**	**Manufacturer:**	**Isotherm, Inc.**
Vessel / Rig I.D. (Name):	MS Kings Bay /	**Location:**	Arlington, Texas USA
NB PM-F (DNV):	*TBA*	**NB Yard / Location:**	Norway
NPS System Ref.:	*TBA*	**Purchase Order Ref.:**	*TBA*
NPS Component Ref.:	*TBA*	**Tentative Delivery Date:**	31 December, 2011

Equipment Description:	**Qty. 2:** Spray Chillers, each with a capacity of min. 1300 kW at -5 C., with a LMTD of 4.5 C., Seawater flow 9000 m3/h. **Qty. 2:** Seawater Condensers, each with a capacity of min. 1760 kW at 30 C. in condensing and 20 C. seawater inlet temperature, seawater flow 333 m3/h.
Equipment Identification:	**Model No. – ZSC 4214E, Serial No.'s - 10164X & 10165X** **Model No. – ZC 1614D, Serial No.'s – 10166X & 10167X**
Pre-Production Meeting Date:	27 July, 2011
DNV CMC Project Manager:	e-mail:
Customer / Manufacturer Contact:	**Adnan Ayub:** adnan@iso-therm.com **(Q.A. Manager):** Warren Patterson e-mail: warren@iso-therm.com
Manufacturers Quality Plan / Inspection & Test Plan:	(Chiller) – Job No. 10080A, dated 2011-7-27 (Condenser) – Job No. 10080B, dated 2011-7-27

APPROVAL BASIS DOCUMENTS

DNV Standard / Rule	Revision	Normative Code / Standard	Revision
DNV Rules for Ships, Pt. 4, Ch. 7	July 2011	ASME Section VIII, Division 1 (reference)	2010 Ed.
DNV Rules for Ships, Pt. 2, Ch. 2	July 2011	ASME Section IX	2010 Ed.
DNV Rules for Ships, Pt. 2, Ch. 3	July 2011	ASME Section II, Parts A & B (reference)	2010 Ed.

NOTE : DNV Rules for Ships Pt. 4, Ch. 7 is the Design Code for these Chillers and Condensers

SUB-CONTRACTORS

Name	Location	Equipment / Component	Separate Pre-Production Meeting Required?
	Texas USA	**NDT (Radiography and Magnetic Particle)**	No
	Texas USA	**Mechanical, Chemistry and Impact Testing**	No

Page 1 of 3

Fig D.3: DNV Pre-Production Meeting Report Page 1

DNV

Document No.: ANMUS467/PPXXXX/skel /2011-7-27-A

(Continued)

CMC SURVEY AND PLAN APPROVAL POINTS

Activity	Req.'d	D-Code	Activitiy	Req.'d	D-Code
1. Receipt of Plan Approval Documents	Yes		12. Witness Gas Testing	No	
2. Review of Plan Approval Documents	Yes	DVR	13. Witness Drift Testing	No	
3. Material Traceability Verification	Yes	*"NV Cert's"*	14. Witness Functional / Performance Testing	No	
4. Review of WPS / PQR	No	WPR	15. Witness Load / Lift Testing	No	
5. Witness Weld Start-up	---	*"See 17"*	16. Witness Assembly	No	
6. Review of Welder Qualifications	Yes	SL	17. Witness WPT Test Coupons *(Pt. 4, Ch. 7, Sec. 8, D401)*	Yes	SR
7. Review of NDT Personnel Qualifications	Yes	SL	18. Review of Final Equipment Data Books	Yes	PC
8. Witness or Review NDT (MT, PT, UT, etc.)	Yes	SR	19. Hard Stamp of Vessels (with DNV "NV" Stamp)	Yes	
9. Verify Dimensions *(Pt. 4, Ch. 7, Sec. 8, B300)*	Yes	SL	20.		
10. Review of M&TE Calibration Records	Yes	SL	21.		
11. Witness Hydrostatic Testing	Yes	SR	22.		

DELIVERABLES / CODES

Document	Code	Document	Code
Design Verification Report	DVR	Weld Procedure Review Letter	WPR
Type Approval Certificate	TAC	Survey Activity Log	SL
Survey Report	SR		
Product Certificate	PC		
CG3 Certificate	CG3		
2.22 / 2.7-1 Certificate	LAC		

Page 2 of 3

Fig D.4: DNV Pre-Production Meeting Report Page 2

Document No.: ANMUS467/PPXXXX/skel /2011-7-27-A

(Continued)

COMMENTS:

1. Reference – P.O. to Iso-Therm, Inc. – No. – 149647 / 19309
2. Iso-Therm's Inspection and Test Plans (ITP) were "marked up" during this Pre-Production Meeting, and are to be revised / re-submitted to DNV after comments have been incorporated.
3. Nozzle Reinforcement Calculations can be according to ASME Section VIII, Division 1 as allowed by DNV Rules for Ships - Pt. 4, Ch. 7, Sec. 4, D103
4. WPS's, PQR's and Welder Qualifications may be qualified according to ASME Section IX, as allowed by DNV Rules for Ships – Pt. 2, Ch. 3
5. Isotherm, Inc.'s – WPS No.'s – 10, 21, 23, 24 and 25 have been previously DNV reviewed and approved.

Signed: **Principle Surveyor**	**Date: 2011-7-27**
Distribution: Isotherm, Inc. – Adnan Ayub Isotherm, Inc. – Warren Patterson	**E-mail Address:** adnan@iso-therm.com warren@iso-therm.com

Page 3 of 3

Fig D.5: DNV Pre-Production Meeting Report Page 3

DNV Calculations

	American Units		SI Units	
Outside Vessel Diameter	42	in.	1066.8	mm
Proposed Shell/Head Thickness	0.5	in.	12.7	mm
Inside Vessel Diameter	41	in.	1041.4	mm
Max. Design Temperature	200	F	93.33333	C
MDMT	-20	F	-28.8889	C
Design Pressure	250	psig	1723689	Pa
Height of Liquid	6	in.	0.1524	m
Density of Liquid Refrigerant	40.29	lbm/cu ft	0.645384	t/cubic m
			645.3838	kg/cubic m
std acceleration of gravity			9.81	m/s^2
Calculating pressure				
1st Value			1723689	Pa
			1723.689	kPa
			17.23689	bar
2nd Value			1672.943	kPa
			16.72943	bar
Greater Value required for Calculating Pressure			17.23689	bar

B500 Nominal Design Stress

In this case: Use for those pressure vessels operating at a temperature higher than 50 C

MIN $(R_{eH}/1.8, R_{et}/1.6, R_m/2.7, R_{m/100000}/1.6)$

For Shell and Heads: Material properties shall be from that of NV460-1FN (SA516-70)

R_{eH}

R_{et}

R_m

$R_{m/100000}$

American Units

σ_t

Shell Thickness

For carbon and low alloy-steel, shell thickness shall not be less than

Fig D.6: DNV Calculations

DET NORSKE VERITAS

Certificate No
HOU-11-8302

CERTIFICATE FOR PRESSURE VESSEL

Manufacturer:	Isotherm Inc., Arlington, Texas USA
Manufacturer's order No.:	10080A
Purchaser:	
Purchaser's order No.:	
The product is intended for	
Yard:	
Yard No.:	52, 53
Name of vessel:	----
DNV Id. No.:	

THIS IS TO CERTIFY:

that the product:	Two (2) Spray Chillers with capacity of min. 1300kW at -5°C with a LMTD of 4.5°C. Seawater flow 9000 m3/h.		
Type designation:	Model No. - ZSC-4214E		
Pressure vessel class:	☒ Class I	☐ Class II	☐ Class III
Design pressure (bar):	Shell side: 17.24	Tube side: n/a	
Design temperature max/min (degC):	Shell side: 93.3 / -29	Tube side:	
Serial No(s):	10164X & 10165X		
Intended for the following service:	NH3 (Ammonia)		

Has been built and tested in accordance with the relevant requirements of:

DNV Rules for Classification: ☒ Ships ☐ HSLC ☐ Naval ☐ Offshore
☐ Other standards:

Remarks (if more than one line, use page 2):

The product was marked: HOU-11-8302 (NV Stamp) On: Name plate of Vessel

This field is only to be filled in when the certification is based on a Manufacturing Survey Arrangement (MSA).

The undersigned manufacturer declares that the product/system has been built and tested in accordance with the specification/standard stated above and the conditions referred to in
Manufacturing Survey Arrangement No:
Quality System Certificate No:

For Manufacturer:

Place:

Date:

(name)
(title)

This Certificate is only valid when signed by a DNV surveyor.

Digitally Signed By:
Location: DNV Houston, USA
Signing Date: 3/14/2012
For Det Norske Veritas AS

Place: Houston, USA

Date: 2012-03-14

Surveyor

If any person suffers loss or damage which is proved to have been caused by any negligent act or omission of Det Norske Veritas, then Det Norske Veritas shall pay compensation to such person for his proved direct loss or damage. However, the compensation shall not exceed an amount equal to ten times the fee charged for the service in question, provided that the maximum compensation shall never exceed USD 2 million. In this provision "Det Norske Veritas" shall mean the Foundation Det Norske Veritas as well as all its subsidiaries, directors, officers, employees, agents and any other acting on behalf of Det Norske Veritas.

DET NORSKE VERITAS AS, Veritasveien 1, NO-1322 Høvik, Norway, Tel.: +47 67 57 99 00, Fax: +47 67 57 99 11, Org.No. NO 945 748 931 MVA www.dnv.com
Form No.: 74.03a Issue: April 2010 Page 1 of 2

Fig D.7: DNV Product Certificate of Job 10080

Certificate No
HOU-13-02567

DET NORSKE VERITAS

CERTIFICATE FOR PRESSURE VESSEL

Manufacturer:	Isotherm Inc., Arlington, Texas USA
Manufacturer's order No.:	12098A&B
Purchaser:	--
Purchaser's order No.:	--
The product is intended for	
Yard:	Unknown
Yard No.:	Unknown
Name of vessel:	"STOCK"
DNV Id. No.:	--

THIS IS TO CERTIFY:

that the product:	Two (2) Shell & tube refrigerant condenser	
Type designation:	Model No. SX-2210E & SX1812E	
Pressure vessel class:	☒ Class I ☐ Class II	☐ Class III
Design pressure (bar):	Shell side: 17.2	Tube side: 1
Design temperature max/min (degC):	Shell side: 93.3 / -9.4	Tube side: -
Serial No(s):	12156X & 12157X	
Intended for the following service:	NH3 (Ammonia) / Seawater	

Has been built and tested in accordance with the relevant requirements of:
DNV Rules for Classification: ☒ Ships ☐ HSLC ☐ Naval ☐ Offshore
☐ Other standards:

Remarks (if more than one line, use page 2):

The product was marked: HOU-13-02567 (NV Stamp) On: Name plate of Vessel

This field is only to be filled in when the certification is based on a Manufacturing Survey Arrangement (MSA).

The undersigned manufacturer declares that the product/system has been built and tested in accordance with the specification/standard stated above and the conditions referred to in
Manufacturing Survey Arrangement No:
Quality System Certificate No:

For Manufacturer:
Place:
Date:

(name)
(title)

This Certificate is only valid when signed by a DNV surveyor.

Digitally Signed By:
Location: DNV Houston, USA
Signing Date: 5/12/2013
For Det Norske Veritas AS

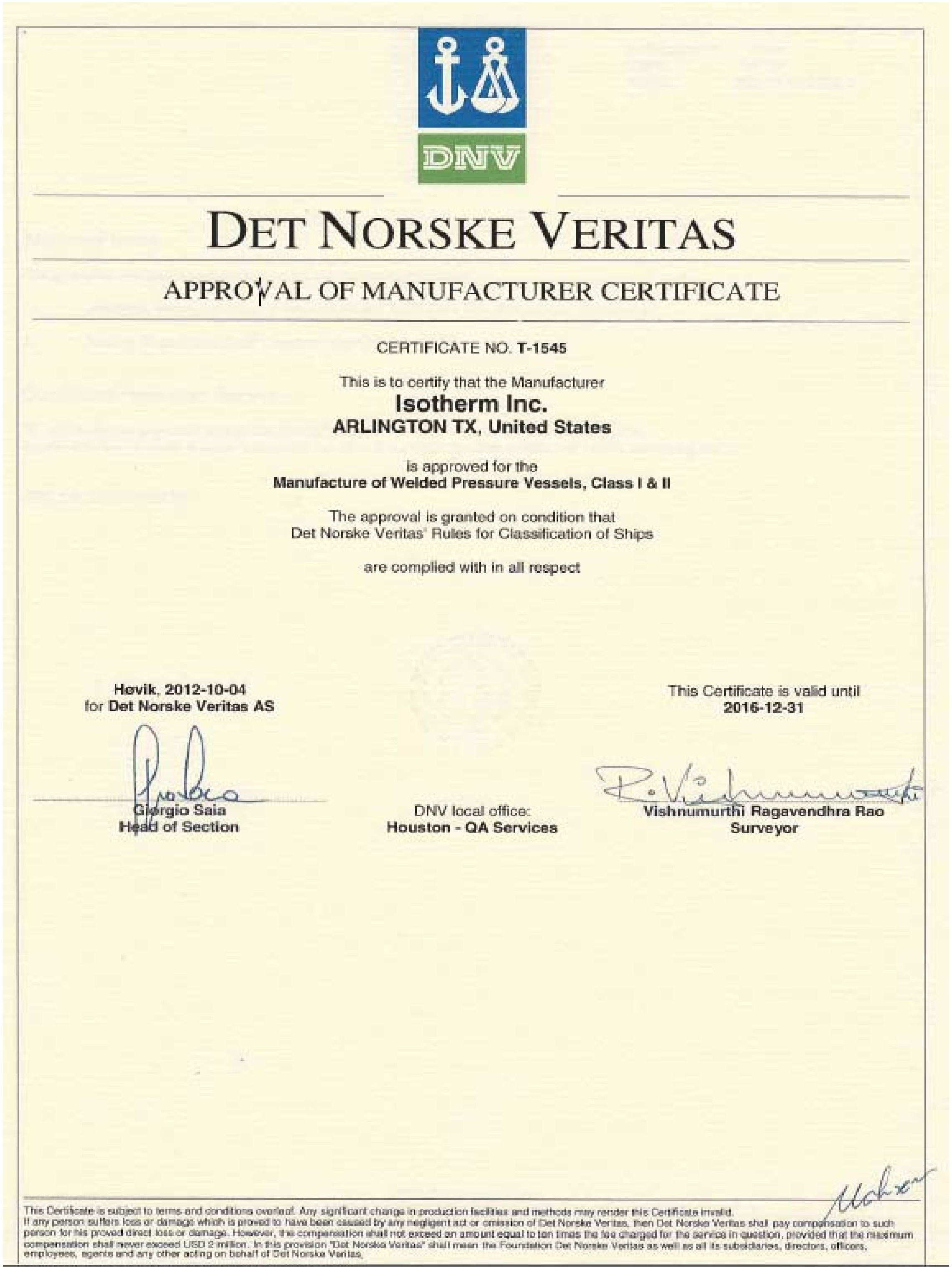
Place: Houston, USA
Date: 2013-05-12

Surveyor

If any person suffers loss or damage which is proved to have been caused by any negligent act or omission of Det Norske Veritas, then Det Norske Veritas shall pay compensation to such person for his proved direct loss or damage. However, the compensation shall not exceed an amount equal to ten times the fee charged for the service in question, provided that the maximum compensation shall never exceed USD 2 million. In this provision "Det Norske Veritas" shall mean the Foundation Det Norske Veritas as well as all its subsidiaries, directors, officers, employees, agents and any other acting on behalf of Det Norske Veritas.

DET NORSKE VERITAS AS, Veritasveien 1, NO-1322 Høvik, Norway, Tel.: +47 67 57 99 00, Fax: +47 67 57 99 11, Org.No. NO 945 748 931 MVA www.dnv.com
Form No.: 74.03a Issue: April 2010 Page 1 of 2

Fig D.8: DNV Product Certificate for SX Chiller



DNV

DET NORSKE VERITAS

APPROVAL OF MANUFACTURER CERTIFICATE

CERTIFICATE NO. **T-1545**

This is to certify that the Manufacturer

Isotherm Inc.

ARLINGTON TX, United States

is approved for the

Manufacture of Welded Pressure Vessels, Class I & II

The approval is granted on condition that
Det Norske Veritas' Rules for Classification of Ships

are complied with in all respect

Høvik, 2012-10-04
for **Det Norske Veritas AS**

This Certificate is valid until
2016-12-31

Giorgio Saia
Head of Section

DNV local office:
Houston - QA Services

Vishnumurthi Ragavendhra Rao
Surveyor

This Certificate is subject to terms and conditions overleaf. Any significant change in production facilities and methods may render this Certificate invalid.
If any person suffers loss or damage which is proved to have been caused by any negligent act or omission of Det Norske Veritas, then Det Norske Veritas shall pay compensation to such person for his proved direct loss or damage. However, the compensation shall not exceed an amount equal to ten times the fee charged for the service in question, provided that the maximum compensation shall never exceed USD 2 million. In this provision "Det Norske Veritas" shall mean the Foundation Det Norske Veritas as well as all its subsidiaries, directors, officers, employees, agents and any other acting on behalf of Det Norske Veritas.

Fig D.9: Approval of Manufacturer Certificate

APPENDIX E

ISOTHERM DOCUMENTATION

FINAL INSPECTION

JOB NO: 11027A

SERIAL NO: 11041X

SHELL SIDE:				(REF.) / REMARKS:
A	NOZZLE LOCATION AND ORIENTATION		☑	(FAB. DWG) /
B	SUPPORT LOCATION		☑	(FAB. DWG) /
C	NP BRACKET LOCATION		☑	(FAB. DWG) /
D	WELD CLEAN-UP	Release ☑	Hold ☐	(VISUAL) /
E	SANDBLAST	Yes ☑	No ☐	(CUST. SPEC.) /
F	NAMEPLATE AFFIXED		☑	(S/N MATCH) /
G	NITROGEN CHARGE	Yes ☑	No ☐	(CUST. SPEC.) /

TUBE SIDE:				(REF.) / REMARKS:
A	HEAD LOCATION		☐	(FAB. DWG) /
B	NOZZLE LOCATION AND ORIENTATION		☐	(FAB. DWG) /
C	WELD CLEAN-UP	Release ☐	Hold ☐	(VISUAL) /
D	SANDBLAST	Yes ☐	No ☐	(CUST. SPEC.) /
E	COATING	Yes ☐	No ☐	(CUST. SPEC.) /
F	NITROGEN CHARGE	Yes ☐	No ☐	(CUST. SPEC.) /

OVERALL:				
A	PAINT TYPE	Primer ☑	Other ☐	Describe:
B	PAINT QUALITY			
C	SHIPPED	As is ☑	Other ☐	Describe:

REMARKS:

INSPECTION PERFORMED BY: 7-19-11 WP [signature]
(Date, Initial)

Fig E.1: Final Inspection Checklist

INSPECTION CHECKLIST

JOB NUMBER: 11027A		DESIGN SPECIFICATIONS:	
SERIAL NUMBER: 11042X		SHELL SIDE	TUBE SIDE
N	CAPACITY (cu.ft) if stamped UM		
B	DESIGN PRESSURE (psig)	250	
N	DESIGN TEMPERATURE (deg F)	200	
	MAT'LS OF CONSTRUCTION MDMT Clause:	UCS66(a)	

No	INSPECTION POINT TYPE*	Q.C.	Date	A.I.	Date
1	DESIGN CALCULATIONS	WP	5-6-11	[illegible]	[illegible]
2	MILL TEST REPORTS	WP	7-11-11		
3	MATERIAL IDENTIFICATION STAMPING OF THE BELOW LISTED				
3a	FLAT HEAD CHANNEL COVERS (if applicable)	N/A			
3b	ELLIP. CHANNEL and/or SHELL COVERS (if formed plate)	N/A			
3c	FLANGES (if machined plate)	N/A			
3d	TUBESHEETS (if applicable)	WP	7-11-11		
3f	SHELLS (if rolled plate)	N/A			
4	OPENINGS	WP	7-11-11		
5	FILLET WELD SIZE	WP	7-15-11		
6	WELD SEAM REINFORCEMENT	N/A			
7	FIT UP /INTERNAL	WP	7-11-11		
8	OVERALL WELD QUALITY:(Visual Insp.) (PT) (RT- 1, 2, (3) 4)				
9	WELDER IDENTIFICATION STAMPING (list):	WP	7-15-11		
10	TUBE TO TSHT JT: WELD QUALITY (if applicable)	N/A			
11	TUBE TO TSHT JT:TUBES EXPANDED @ ft-lbs of TORQUE				
12	UNIT IDENTIFICATION STAMPING (serial number)				
13	Pneu / Hydro PR. TEST on S/S @ 275 psig.	WP	7-19-11		
14	Pneu / Hydro PR. TEST on T/S @ EXEMPT psig.				
15	NAMEPLATE INFORMATION	WP	7-11-11		
16	MANUFACTURERS DATA REPORT	WP	7-19-11		

REMARKS:

Fig E.2: Inspection Checklist

ISOTHERM, INC. **LIQUID PENETRANT EXAMINATION RECORD**

PROCEDURE USED:	ISO-PT 1 REVA				
PRODUCTS USED:	KCI, INC. WELD SHIELD				
CLEANER:	NDT FAULT CHECK CLEANER				
PENETRANT:	NDT FAULT CHECK PENETRANT				
DEVELOPER:	NDT FAULT CHECK DEVELOPER				
NAME OF EXAMINER:		DATE	7-19-11	TIME	2:00
LIGHT SOURCE:	2-D CELL MAG-LITE				
DRAWING NUMBER:	11027A	SERIAL NUMBER	11041X		

RECORD OF INDICATION (DESCRIPTION AND/ OR LOCATION)

NON-REJECTABLE	THICKNESS	MAT SPEC.	LOCATION	REJECTABLE	THICKNESS	MAT. SPEC	LOCATION

Fig E.3: NDE (Liquid Penetrant) Examination Record

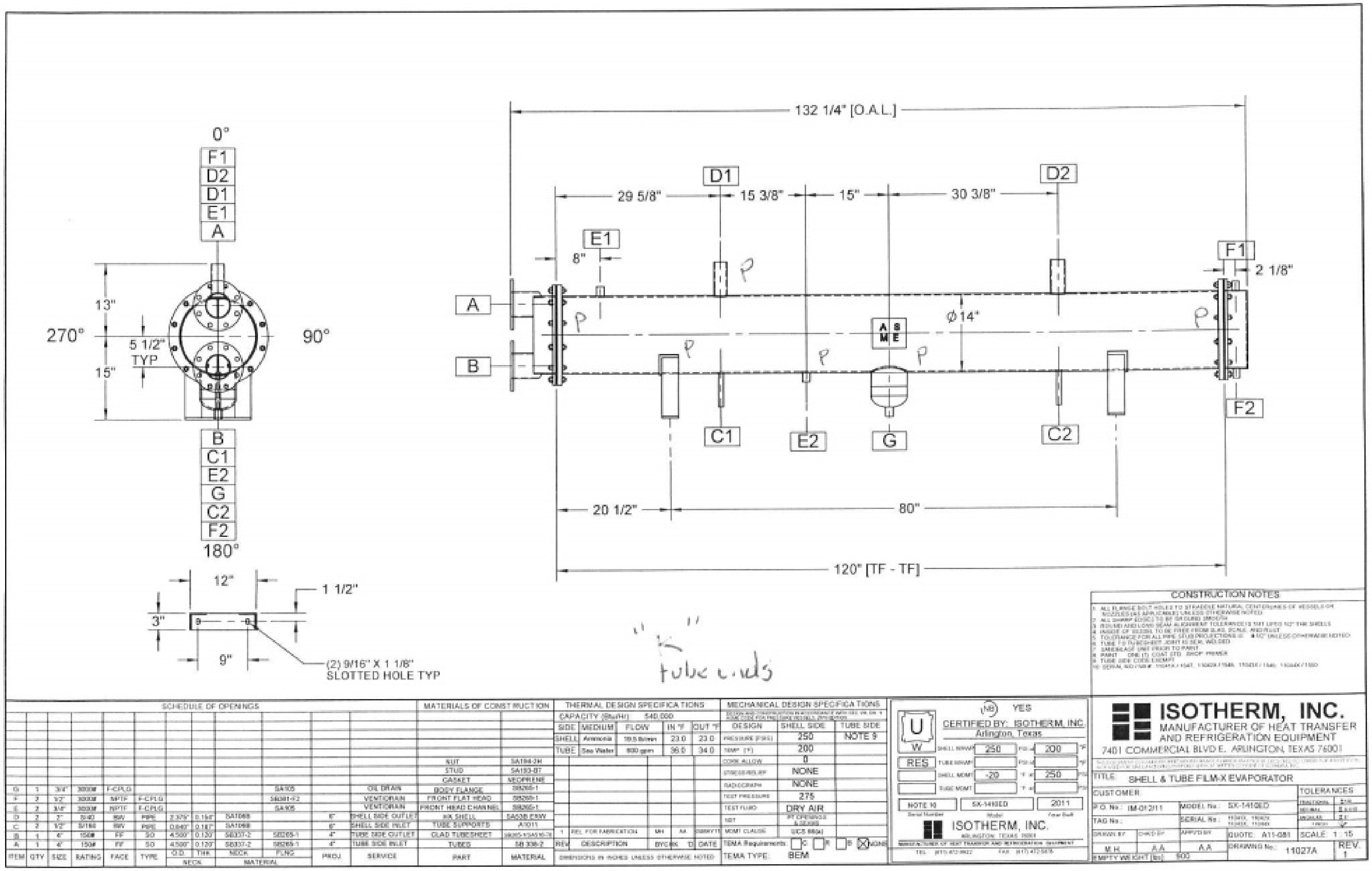


Fig E.4: Weld Map Record

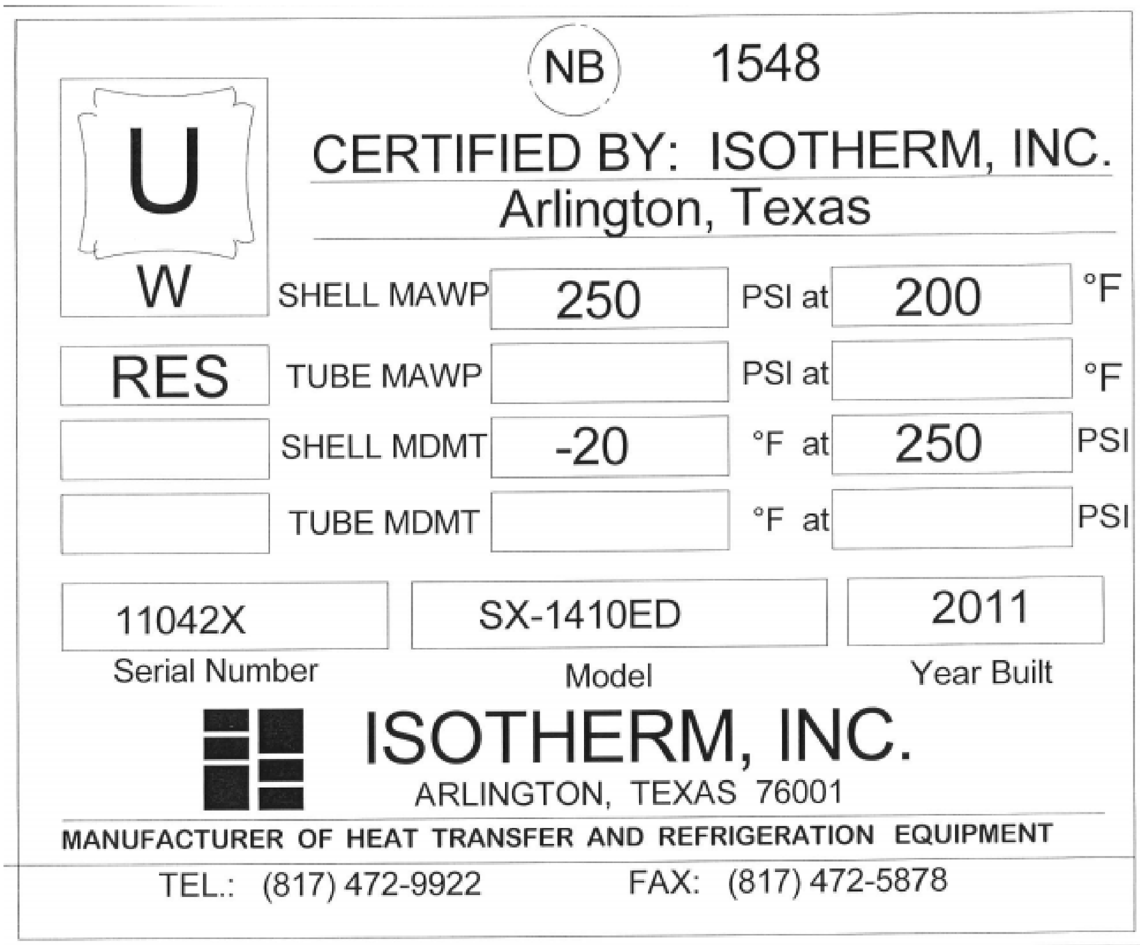


Fig E.5: Nameplate Drawing

FORM U-1A MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS

(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1

1. Manufactured and certified by **Isotherm, Inc., 7401 Commercial Blvd. East, Arlington, Texas, 76001**
(Name and address of manufacturer)

2. Manufactured for
(Name and address of purchaser)

3. Location of Installation **Not Known**
(Name and address)

4. Type **Vertical** (Horizontal or vertical, tank) 13163V (Manufacturer's serial number) - (CRN) **13070A, Rev 1** (Drawing number) 1986 (National Board number) **2013** (Year built)

5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to ASME Rules, Section VIII, Division 1 **2010** (year) to **2011** [Addenda, if applicable (Date)]
- (Code Case numbers) - (Special Service per UG-120(d))

6. Shell: **SA516-70** (Material spec. number, grade) **0.500"** (Nominal thickness) **0 in** (Corr. allow.) **4' 5.000" (OD)** (Inner diameter) **9' 4.250"** [Length (overall)]

7. Seams: **Sngl Butt, Type 1** [Long. (welded, dbl., sngl., lap, butt)] **None** R.T.(Spot or Full) **70%** Eff.(%) - (H.T. temp) - Time (hr) **Sngl Butt, Type 1** [Girth. (welded, dbl., sngl., lap, **None** [R.T. (spot or full)] **70%** Eff(%) **1** No. of Courses

8. Heads: (a) Material **SA516-70** (Spec. no., grade) (b) Material **SA516-70** (Spec. no., grade)

	Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)	Top	0.460"	0	N/A	N/A	2:1	N/A	N/A	N/A	Concave
(b)	Bottom	0.460"	0	N/A	N/A	2:1	N/A	N/A	N/A	Concave

If removable, bolts used (describe other fastenings) N/A
(Material spec. number, grade, size, number)

9. MAWP **85/250** (Internal) **N/A** (External) at max. temp. **200 °F** (Internal) **N/A** (External)

Min. design metal temp. **-50/20** at **85/250**. Hydro, pneu., or comb. test pressure **PNEU. at 275 psi**

Proof test -

10. Nozzles, inspection and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc)	No.	Diameter or Size	Type	Material: Nozzle	Material: Flange	Nozzle Thickness: Nom.	Nozzle Thickness: Corr.	Reinforcement Material	Attachment Details: Nozzle	Attachment Details: Flange	Location (Insp. Open.)
Inlet	1	12"	WE	SA53B-ERW		0.375"	0	Inherent	Welded		
Outlet	1	14"	WE	SA53B-ERW		0.375"	0	Inherent	Welded		
Pump Suction	2	5"	WE	SA106B		0.258"	0	Inherent	Welded		
Liquid Make-up	1	1 1/2"	WE	SA106B		0.200"	0	Inherent	Welded		
Level Column	2	1 1/4"	WE	SA106B		0.191"	0	Inherent	Welded		

Additional Nozzles - See Attached U-4...

11. Supports: Skirt **No** (Yes or no) Lugs - (Number) Legs **4** (Number) Other **N/A** (Describe) Attached **Welded to Item 6** (Where and how)

12. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors, have been furnished for the following items of the report:
N/A
(Name of part, item number, Manufacturer's name and identifying stamp)

Model: VPR-5412 for non-corrosive, non-lethal service. Pressure relief devices by others. No inspection openings per UG 46(a). UG 22(a) only considered in design.

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. "U" Certificate of Authorization No. **31095** expires **June 17, 2014**

Date **11/22/2013** Co. name **Isotherm, Inc.** (Manufacturer) Signed Warren E. Patterson (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by Isotherm, Inc. at 7401 Commercial Blvd. East, Arlington, Texas, 76001 I, the undersigned, holding a valid commission issued by The National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province TEXAS and employed by OneCIS Insurance Company, of Lynn, MA have inspected the component described in this Manufacturer's Data Report on December 6, 2013 and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 12/08/2013 Signed Richard Nelson (Authorized Inspector) Commissions 9441A (National Board (incl. endorsements), State, Province and number)

1864024 exec v6.2.66 *Form and version: U1A-17*

Fig E.6: ASME Data Report

BACK TO MAIN

Engineering Time Sheet
Week of 7/5/13

Job #	Assigned to	Date Assigned	Completed	Net Days	Next Job #	Comments
13055A	J.B.	6/28/2013	7/2/2013	2	13035B	
13035B	J.B.	7/2/2013	7/2/2013	1	13035C	
13035C	J.B.	7/2/2013			13024B	Even though SX-1410ED was made before, old design was given; modifications required to reflect current design
13024B	J.B.	3/12/2013	See Notes		13024A	Detail dwgs are complete and have been all approved by TR for proceeding for fabrication; setup of brown folder and data reports are pending.
13024A	J.B.	4/8/2013			13024A	Was originally assigned to AKH; detail dwgs to be checked by AA; due date to be sent to client: 7/3/13; dwgs in SI units req'd
13035D	W.K.	7/2/2013			13035E	Use 13055B for reference; to be released
13035E	W.K.	7/2/2013				Use 13054B for reference; to be released
13048A	J.C.	7/1/2013			13056A	Was originally assigned to J.B. on 6/24/13; given to J.C. 7/1/13; working on detail dwgs
13056A	J.C.					Waiting for client to respond about old dwg made during Thermofluid
13041A	A.M.	7/2/2013			13042A	Project on urgent basis; shall use 11038A as reference, with few changes; recently received changes in thermal design by ZA on 6/28/13
13042A	A.M.	7/2/2013			13024C	Project on urgent basis; shall use 11045A as reference, w/ few changes; recently received changes in thermal design by ZA on 6/28/13
13024C	A.M.	4/8/2013				Was originally assigned to AKH; detail dwgs to be checked by AA; due date to be sent to client: 7/3/13; dwgs in SI units req'd
13040A-D	A.G.					

Fig E.7: Engineering Time Sheet

APPENDIX F

SALES DOCUMENTATION

Date of Inquiry	Date Quoted	Quote #	Type	Qty	Rev.	Price	Status	If Lost, Why?
12/23/2014	1/6/2015	AA15-001	ZKU, ZEX	2	0	$73,430	Lost	Project dead
1/5/2015	1/9/2015	AA15-002	ISO	1	0	$5,700	Open	
12/12/2014	1/12/2015	AA15-003	ZFC	1	0	$77,899	Lost	End user cancelled
1/10/2015	1/12/2015	AA15-004	Vess	6	0	$89,546	Won	
1/8/2015	1/14/2015	AA15-005	ZKU	1		$76,890	Hold	
1/9/2015	1/15/2015	AA15-006	ZKU	1	0	$112,470	Hold	
1/7/2015	1/16/2015	AA15-007	Retest, Retube	2	0	$4,000	Won	
1/15/2015	1/22/2015	AA15-008	Vess	1	0	$6,513	Lost	Project dead
		AA15-009				$28,895		
1/26/2015	1/30/2015	AA15-010	Vess					
1/29/2015	2/4/2015	AA15-011	ZEX, ZKU, ZEU	7	0	$620,232	Lost	
1/29/2015	2/6/2015	AA15-012						
1/28/2015	2/6/2015	AA15-013	ZE	2	0	$13,972	Lost	Although client did not get job, we were higher than competitor

Fig F.1: Quotation Status Template