



PROJECT NO.		PO NO.	P-5675-02
PACKAGE ENGINEER	Paul Forgang	PROCUREMENT	Shannon Wall

VENDOR NAME	Ecodyne		
VENDOR DOCUMENT NO.	32125-A-4912-01	VENDOR REV NO.	A
PO DOCUMENT NO.	VP-CL03A-M-000-0004	PO SUBMISSION NO.	0
VDC NO.	R0005		
DOCUMENT TITLE	AFTER FILTER VESSEL		
EQUIPMENT TAGS			

REVIEW AND APPROVAL

This review / acceptance does NOT relieve the contractor / vendor from any obligations under the applicable agreement (ie. contract, service order, purchase order) including, but not limited to, all warranty obligations.

- ☐ A1 NOT SUITABLE TO INITIATE FABRICATION. MODIFY AS NOTED, RESUBMIT FOR REVIEW.
- ☐ B1 SUITABLE TO INITIATE FABRICATION AS NOTED. MODIFY AS NOTED, RESUBMIT FOR REVIEW.
- ☐ C1 SUITABLE TO FABRICATE TO COMPLETION AS NOTED. SUBMIT FINAL DOCUMENTS INCLUDING AS-BUILTS AS REQUIRED.
- ☐ D1 SUITABLE TO FABRICATE TO COMPLETION. SUBMIT FINAL DOCUMENTS INCLUDING AS-BUILT DOCUMENTS AS REQUIRED.
- ☐ E1 NOT SUITABLE AS FINAL DOCUMENTS AS NOTED. MODIFY AS NOTED AND RESUBMIT.
- ☒ F1 SUITABLE AS FINAL DOCUMENTS. NO FURTHER RESUBMITTAL REQUIRED (UNLESS REVISED BY VENDOR).
- ☐ VX VENDOR DOCUMENT CANCELLED.

DATE April 9, 2015

Paul Forgang
NAME

Paul Forgang
SIGNATURE

REVIEW COMMENTS (If there is insufficient room on the document for comments, add them below)

MANUFACTURER'S DATA BOOK

**AFTER FILTER VESSEL
3A-F-208 A-G**

**MEG Energy Corporation
Christina Lake Phase 3A**

c/o SNC-Lavalin

PO No. P-5675-02

**32125-A-4912-01
Rev A**

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

B56 - Traffic & Logistics

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Material Safety Data Sheets

MATERIAL SAFETY DATA SHEET

ERVIN

ERVIN INDUSTRIES, INC. 3893 RESEARCH PARK DRIVE ANN ARBOR, MI 48108-2217		TELEPHONE: (734) 769-4600 FAX: (734) 663-0136
Revision Date: 12/9/09	Replaces Date: 5/28/2008	Revision Level: S
PREPARED BY: Dennis Scharer		Ervin Industries

SECTION I	PRODUCT IDENTIFICATION
Product Name	Chemical Family
AMASTEEL SHOT AMASTEEL GRIT	AMABRASIVE (SHOT / GRIT MIX) FERROUS

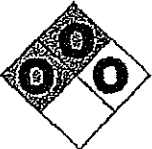
SECTION II	COMPOSITION / INGREDIENTS			
Chemical Name	CAS Registry No	% Weight	ACGIH - TLV (mg/m ³)	OSHA - PEL (mg/m ³)
Iron - Fe Oxide fume as Fe	7439-89-6	>96	5	10
Carbon - C	7440-44-0	<1.2	none estab.	none estab.
Manganese - Mn Elemental, Inorganic Compounds as Mn Fume as Mn	7439-96-5	<1.3	0.2 none estab.	5 (ceiling) 5 (ceiling)
Silicon - Si as total dust Respirable fraction	7440-21-3	<1.2	10 none estab.	15 5
Chromium - Cr Elemental, Inorganic Compounds as Cr metal Cr II compounds - as Cr Cr III compounds - as Cr Cr VI compounds - water soluble Cr VI compounds - insoluble Chromic Acid and Chromates as CrO ₃ Cr VI (hexavalent chromium) in product as shipped	7440-47-3	<0.25	0.5 none estab. 0.5 0.05 0.01 none estab. 0.05 & 0.01	1 0.5 0.5 5 ug 5 ug 0.1 (ceiling) 5 ug /2.5 action
Copper - Cu Fume Dust & mists	7440-50-8	<0.25	0.2 1	0.1 1
Nickel - Ni Elemental metal Insoluble as Ni Soluble compounds as Ni	7440-02-0	<0.20	1.5 0.1 0.2	1 1

SECTION III	PHYSICAL DATA
Cast steel shot and grit are non-hazardous as received. Fine metallic dust is generated as the abrasive breaks down from impact and wear during normal use. Since the ferrous content is >96%, dust or fumes will consist mainly of iron or iron oxide. In addition, the fine steel dust created can be a mild explosion hazard (see section V).	
Boiling Point - 2850-3150 Degrees C Specific Gravity (at 60 Degrees F) >7.6 % Volatile by Volume - Not Applicable Appearance and Odor - Spherical - no odor	Melting Point - 1371-1483 Degrees C Vapor Pressure - Not Applicable pH - Not Applicable Percent Solid by Weight - 100%

SECTION IV	REACTIVITY DATA
Stability - Stable Shot will break down into progressively smaller particles and dust during normal use.	Hazardous decomposition products - None Hazardous Polymerization - will not occur

MATERIAL SAFETY DATA SHEET

ERVIN

SECTION V FIRE AND EXPLOSION HAZARD DATA	
Flash Point - Not Applicable	Auto Ignition Temperature (solid iron exposed to Oxygen) -930 degree C
Flammability Limits - Not Applicable	Cast steel shot will not burn or explode
A mild fire or explosion hazard situation may be created from fine metal dust. Fire Extinguishing method for dust created due to use - use Class D extinguishing agents or dry sand to exclude air. Do not use water or other liquids, or foam.	
 <p>NFPA Hazard Rating: 0 = Insignificant 1 = Slight 2 = Moderate 3 = High 4 = Extreme</p> <p>Health (blue) = 0 Flammability (red) = 0 Reactivity (yellow) = 0 Special (colorless)</p>	

SECTION VI HEALTH HAZARD DATA	
<p>Emergency and First Aid Procedure - If inhaled, move out of area into fresh air. Flush eyes with running water, have any remaining particles removed from eyes by a qualified medical person; call 911 for immediate medical assistance.</p> <p>The end user should have an industrial hygiene evaluation to determine the proper personal protective equipment for each application or blasting operation. Threshold Limit Values - Permissible Exposure Limits - see Section II</p> <p>Primary Routes of entry - inhalation of dust or dust particles in eyes. Target Organs - Lung for chromium and lung & nasal for Nickel. Metallic Nickel is reasonably anticipated to be a human carcinogen.</p> <p>Over exposure to dust and fumes may cause mouth, eye, and nose irritation. Prolonged overexposure to manganese dust or fume affects the central nervous system. Prolonged overexposure to iron oxide fume can cause siderosis, or "iron pigmentation" of the lung. It can be seen on a chest x-ray but causes little or no disability.</p> <p>Fumes generated by welding or flame cutting a surface containing new or used abrasive or the dust created by use of the abrasive may convert a small portion of chromium to hexavalent chromium. IARC reports welding fumes are possibly carcinogenic to humans.</p>	

SECTION VII PERSONAL PROTECTION INFORMATION	
Ventilation - General ventilation and local exhaust should be provided to keep the dust levels below the limits shown in Section II.	
Respiratory protection - If an industrial hygiene evaluation shows dust exceeds OSHA PEL's indicated in Section II, a NIOSH approved respirator with appropriate filters should be worn as determined by the end user.	
Eye protection - Approved safety glasses w/side shields should always be worn. Other protective equipment determined by the end user.	

SECTION VIII SPILL / LEAK PROCEDURES AND WASTE DETERMINATION	
Shot spilled or leaked onto floors can create hazardous walking conditions. When cleaning up quantities of dust; if exceeding OSHA permissible exposure limits, an approved respirator with appropriate filters should be used.	
Dust from blasting or peening operations always contain contaminants. The dust must be tested to determine if it is hazardous or non-hazardous waste. After such determination, the dust must be disposed of according to appropriate local, State or Federal regulations.	

SECTION IX SPECIAL PRECAUTIONS	
Precautions to be taken in handling and storing - Keep dry to reduce rusting. Observe maximum floor loading limitations.	

SECTION X TRANSPORTATION		
DOT Classification - Not a regulated material	Proper Shipping Name - N/A	DOT ID # - Not regulated

SECTION XI REGULATORY	
a) CERCLA Hazardous Substance	___ yes ___X___ no
b) SARA, Title III, Extremely Hazardous Substance	___ yes ___X___ no
c) Toxic Chemical Release Report	___X___ yes ___ no
Nickel & Manganese are subject to requirements of Section 313 of the Community Right-to-know Act of 1986 & 40CFR Part 372.	

The information presented here has been compiled from sources considered to be reliable and accurate to the best of our knowledge and belief, but is not guaranteed to be so.

MATERIAL SAFETY DATA SHEET

THE CORTEC CORPORATION

4119 WHITE BEAR PARKWAY

ST. PAUL, MINNESOTA 55110

PHONE: 651-429-1100 OR TOLL FREE 1-800-4-CORTEC

FAX: 651-429-1122

EMERGENCY PHONE NO.: CHEMTREC (FOR SPILL, LEAK, FIRE, EXPOSURE OR ACCIDENT): 1-800-424-9300 (DAY OR NIGHT)

***** VpCI™-337 *****

SECTION I - PRODUCT IDENTIFICATION

PRODUCT NAME: **VpCI™-337**

PRODUCT DESCRIPTION: A proprietary blend of corrosion inhibitors in a water carrier.

SECTION II - HAZARDOUS INGREDIENTS

INGREDIENT NAME(S)	WEIGHT PERCENT	OCCUPATIONAL EXPOSURE LIMITS	
		TLV OR PEL	ORAL LD-50
N.A.	-	-	-

Carcinogenic: OSHA = no NTP = no IARC = no

SECTION III - PHYSICAL DATA

COLOR: Clear to hazy amber PHYSICAL FORM: Liquid

NON-VOLATILE (weight): 27-31% ODOR: Characteristic

FREEZING POINT: N.E. BOILING RANGE: N.E.

pH: 8.2-8.8 (Neat) MELTING RANGE: N.A.

EVAPORATION RATE: N.E. VAPOR PRESSURE: N.E.

VAPOR DENSITY: Lighter than air

DENSITY: 8.7-8.8 lb/gal (1.04-1.06 kg/l)

SECTION IV - FIRE AND EXPLOSION DATA

HMIS FLAMMABILITY RATING: 1

FLASH POINT: >200°F (93°C)

FLAMMABLE LIMITS: LEL: N.E. UEL: N.E.

EXTINGUISHING MEDIA: Water, carbon dioxide or other dry chemical fire fighting agents.

UNUSUAL FIRE AND EXPLOSION HAZARDS: None.

SPECIAL FIRE FIGHTING PROCEDURES: Firefighters should wear self-contained breathing apparatus.

SECTION V - HEALTH HAZARD DATA

EMERGENCY AND FIRST AID PROCEDURES:

Eye Contact: Flush eyes with large amounts of water. Consult a physician. Skin Contact: Wash affected area with soap and water. If irritation persists, consult a physician. Inhalation: Remove to an uncontaminated area, administer oxygen if necessary. If victim has stopped breathing begin CPR. Get medical attention. Ingestion: If swallowed, give water or milk and induce vomiting. Get immediate

medical attention.

MEDICAL CONDITIONS PRONE TO AGGRAVATION BY

EXPOSURE: None known

PRIMARY ROUTES OF ENTRY: Inhalation, skin and eye contact.

HEALTH HAZARDS (acute and chronic) / EFFECTS OF OVEREXPOSURE:

1. Contact of eye tissues with liquid and/or high vapor concentrations can be irritating.
2. Repeated or prolonged contact with liquid may cause mild skin irritation.
3. Inhalation of product vapors and/or particle mists resulting from the use of this product should be avoided.
4. Ingestion of this product may be harmful.

SECTION VI - REACTIVITY DATA

STABILITY: Stable

HAZARDOUS POLYMERIZATION: Will not occur.

HAZARDOUS DECOMPOSITION PRODUCTS: Oxides of carbon and nitrogen.

INCOMPATIBILITY: Strong acids, alkalis and oxidizing agents.

CONDITIONS TO AVOID: Contact with incompatible materials.

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Absorb on sweeping compound or other absorbent material.

WASTE DISPOSAL: Incinerate or dispose of in accordance with existing Federal, State and Local environmental regulations.

SECTION VIII - SAFE HANDLING AND USE INFORMATION

RESPIRATORY PROTECTION: A NIOSH approved respirator to remove vapors or mists.

PROTECTIVE GLOVES: Chemical resistant rubber or plastic.

EYE PROTECTION: Safety goggles.

OTHER PROTECTIVE EQUIPMENT: Eye wash station.

SECTION IX - SPECIAL PRECAUTIONS AND STORAGE DATA

PRECAUTIONS TO BE TAKEN IN HANDLING: Avoid contact with eyes. Avoid excessive inhalation of liquid vapors or particle mists. Use in a well-ventilated environment. Workers should thoroughly wash hands with soap and water prior to eating, drinking, smoking and using lavatory.

PRECAUTIONS TO BE TAKEN IN STORING: Keep containers tightly closed.

SECTION X - SHIPPING DATA

DOT/IMDG/IATA SHIPPING NAME: N.A.

U.N. / N.A. NUMBER: N.A.

DOT/IMDG/IATA HAZARD CLASS.: N.A.

T.S.C.A. STATUS: Listed

DOT/IMDG/IATA REQUIRED LABELS: N.A.

TECHNICAL SHIPPING NAME: N.A.

FREIGHT CLASS BULK: Same as above

LTL: 65 TL: 35 MW: 36

PREPARED BY: Margarita Kharshan, R&D Manager

APPROVED BY: Boris Miksic, President/CEO

DATE PREPARED: 9/18/01 SUPERSEDES: 6/26/98

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MATERIAL SAFETY DATA SHEET

THE CORTEC CORPORATION

4119 WHITE BEAR PARKWAY

ST. PAUL, MINNESOTA 55110

PHONE: 651-429-1100 OR TOLL FREE 1-800-4-CORTEC

FAX: 651-429-1122

EMERGENCY PHONE NO.: CHEMTREC (FOR SPILL, LEAK, FIRE, EXPOSURE OR ACCIDENT): 1-800-424-9300 (DAY OR NIGHT)

*****VCI-368*****

SECTION I - PRODUCT IDENTIFICATION

PRODUCT NAME: **VCI-368**

PRODUCT DESCRIPTION: A proprietary solvent deposited petroleum-based barrier coating containing corrosion inhibitors.

SECTION II - HAZARDOUS INGREDIENTS

INGREDIENT NAME(S)	WEIGHT PERCENT	OCCUPATIONAL EXPOSURE LIMITS		
		TLV OR PEL		ORAL LD-50
Mineral Spirits	35-40	100 ppm (ACGIH)	N.E.	

Carcinogenic: OSHA = no NTP = no IARC = no

SECTION III - PHYSICAL DATA

COLOR: Dark brown PHYSICAL FORM: Viscous liquid

NON-VOLATILE (weight): 57-61% ODOR: Solvent

FREEZING POINT: N.E. BOILING RANGE: N.E. pH: N.E. VAPOR PRESSURE: N.E.

EVAPORATION RATE: N.E. MELTING RANGE: N.A.

VAPOR DENSITY: N.E.

DENSITY: 7.4-7.6 lb/gal (0.88-0.91 kg/l)

SECTION IV - FIRE AND EXPLOSION DATA

HMIS FLAMMABILITY RATING: 2

FLASH POINT: 158°F (70°C) TCC

FLAMMABLE LIMITS: LEL: N.E. UEL: N.E.

EXTINGUISHING MEDIA: Carbon dioxide or other dry chemical fire fighting agents.

UNUSUAL FIRE AND EXPLOSION HAZARDS: None.

SPECIAL FIRE FIGHTING PROCEDURES: Firefighters should wear self-contained breathing apparatus.

SECTION V - HEALTH HAZARD DATA

EMERGENCY AND FIRST AID PROCEDURES:

Eye Contact: Flush eyes with water for at least 15 minutes. Consult a physician. Skin Contact: Wash affected area with soap and water. If irritation persists, consult a physician. Inhalation: Remove to an uncontaminated area, administer oxygen if necessary. If victim has stopped breathing begin CPR. Get medical attention. Ingestion: Do not induce vomiting. Get immediate medical attention.

MEDICAL CONDITIONS PRONE TO AGGRAVATION BY

EXPOSURE: None known PRIMARY ROUTES OF ENTRY: Inhalation, skin and eye contact. HEALTH HAZARDS (acute and chronic) / EFFECTS OF OVEREXPOSURE:

1. Eye contact with this product can cause irritation, redness, and tearing and blurred vision.
2. Repeated or prolonged skin contact can cause moderate irritation and defatting of the skin possibly leading to dermatitis.
3. Excessive inhalation of solvent vapors from this product can cause nasal and respiratory irritation, dizziness, weakness, fatigue, nausea, headache and possible unconsciousness. An LD-50 value for inhalation of mineral spirit vapors is listed in literature as 3,400 ppm for four hours in laboratory animals.
4. Ingestion of this material can cause gastrointestinal irritation. Also, aspiration of this material into the lungs can cause chemical pneumonia.

SECTION VI - REACTIVITY DATA

STABILITY: Stable

HAZARDOUS POLYMERIZATION: Will not occur

HAZARDOUS DECOMPOSITION PRODUCTS: Oxides of carbon and nitrogen and sulfur.

INCOMPATIBILITY: Strong acids, Alkalis and oxidizing agents.

CONDITIONS TO AVOID: Contact with incompatible materials.

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Absorb on sweeping compound or other absorbent material. Keep petroleum out of streams and waterways.

WASTE DISPOSAL: Incinerate or dispose of in accordance with existing Federal, State and Local environmental regulations.

SECTION VIII - SAFE HANDLING AND USE INFORMATION

RESPIRATORY PROTECTION: A NIOSH approved respirator to remove vapors or particle mists when necessary.

PROTECTIVE GLOVES: Chemical resistant rubber or plastic.

EYE PROTECTION: Safety goggles.

OTHER PROTECTIVE EQUIPMENT: Not required.

SECTION IX - SPECIAL PRECAUTIONS AND STORAGE DATA

PRECAUTIONS TO BE TAKEN IN HANDLING: Avoid eye and skin contact. Avoid inhalation of particle mists.

PRECAUTIONS TO BE TAKEN IN STORING: Completely drain empty drums, properly bung and promptly dispose in an environmentally safe manner and in accordance with governmental regulations. Recycle drums only through qualified reprocessing organizations.

SECTION X - SHIPPING DATA

DOT/IATA/IMDG SHIPPING NAME: N.A.

U.N. / N.A. NUMBER: N.A.

DOT/IATA/IMDG HAZARD CLASS: N.A.

T.S.C.A. STATUS: Listed

DOT/IATA/IMDG REQUIRED LABELS: N.A.

TECHNICAL SHIPPING NAME: N.A.

PREPARED BY: Margarita Kharshan, R&D Manager

APPROVED BY: Boris Mksic, President/CEO

DATE PREPARED: 11/17/99 SUPERSEDES: 4/8/99

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N.E. = NOT ESTABLISHED N.A. = NOT APPLICABLE


PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Special Transportation & Site Storage Requirements

Number of vessels: 7
 Tags: 3A-F-208 A to G

Reference drawing: 32125-D-2202-01

Index:
 Cover page 1 page
 Rust Preventive Treatment Procedure 1 page
 VpCI-337 cat sheet 1 page
 VpCI-368 cat sheet 1 page

TITLE						CUSTOMER		
RUST PREVENTIVE SPEC, AFTER FILTERS						MEG Energy Corporation c/o SNC-Lavalin Christina Lake Phase 3A		
						PO No. P-5675-02		
SCALE - N/A						 ECODYNE Limited <small>A Marmont Water/Berkshire Hathaway Company</small>		
						BY	DATE	<small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small> DWG. NO. 32125-A-1023 REV. B
B	13 June 2013	ADDED CAT SHEETS	AV	1/12	DRN	AV	APR 26 2013	
A	APR 26 2013	FIRST ISSUE	AV		CHKD	1/12	13 June 2013	
REV	DATE	REMARKS	BY	CHKD	APPD	AV	13 June 2013	

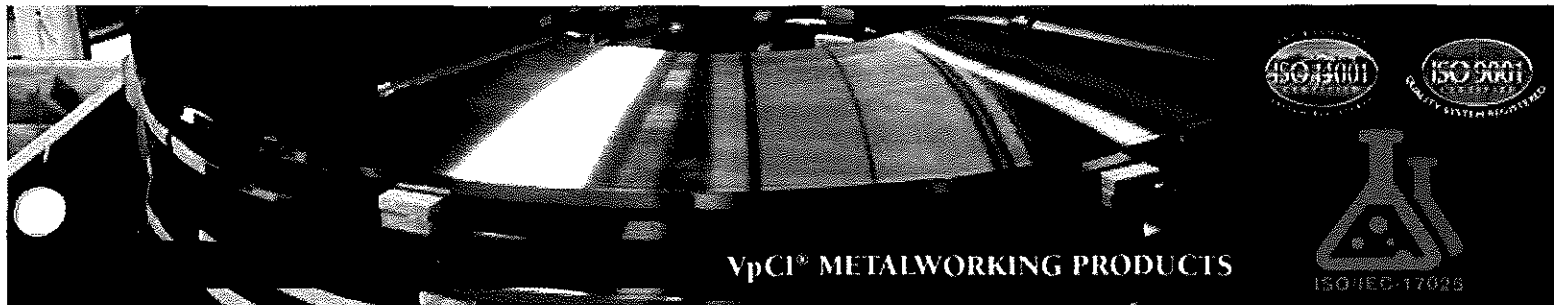
Rust Preventive Treatment

Vapour Phase Corrosion Inhibitors (VpCI):

NOTE: Vapour Phase Corrosion Inhibitors (sometimes called Volatile Corrosion Inhibitors) protect metals against corrosion by chemically preventing the corrosion reaction from taking place. (Compared to barriers like paint, which prevent the corrosion causing chemicals from reaching the metal). Because they are volatile, the inhibiting chemicals can move out from the film or package and eventually forming a film on the metal. Therefore even metal parts that have not been coated will receive the same corrosion protection as parts which are in direct contact with the inhibitor at the time of packaging.

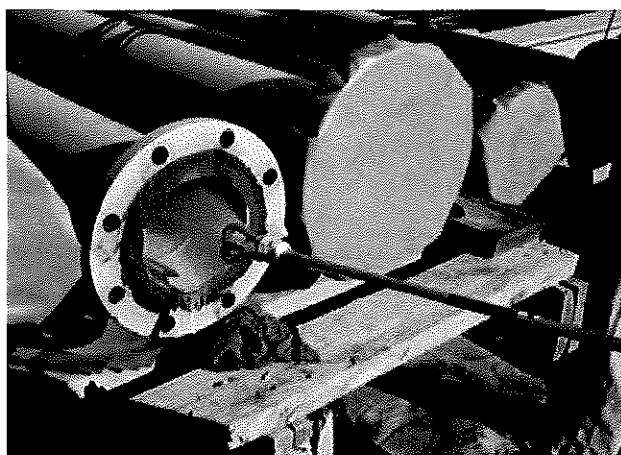
Cortec VpCI-337 is applied to interior vessel surfaces by fogging technique.
Cortec VpCI-368 aerosol is applied to all the bare flange faces.
All the nozzles are blanked off with gaskets for storage.
Vessels are to be stored outdoors after insulation and cladding.

Reference the attached products catalogue sheets.



VpCI® METALWORKING PRODUCTS

VpCI®-337/337 Winterized



PRODUCT DESCRIPTION

VpCI-337 is a ready-to-use waterborne corrosion inhibitor for indoor use. Vapor phase corrosion inhibitors in VpCI-337 migrate and protect metal surfaces, resulting in time and cost savings. The VpCI-337 is used to protect edges of coils and stacks or to fog void spaces, tanks, containers, packages, and enclosures. These labor-saving techniques use a minimum of product to protect large areas or volumes. VpCI-337 is effective on ferrous and non-ferrous metals as well as aluminum, plated steels, and copper. VpCI-337 is consistently successful in providing protection to the basic metals, metalworking, and packaging industries.

In most cases, products protected by VpCI-337 are ready-to-use. No degreasing or stripping is necessary by most end users. The metal will retain a clean, rust-free surface. In most cases, the thin protective film will not affect paintability, conductivity, appearance, or any other important property of metals or alloys.

VpCI-337 is also available in a cold weather version. VpCI-337 Winterized has a lower freezing point for the convenience of application and storage in cold temperatures.

FEATURES

- Biodegradable (87% biodegradation in 28 days)
- Contains vapor phase inhibitors which provide multimetal corrosion protection
- Leaves a thin, self-healing film that is environmentally approved for use
- Ready-to-use
- Protection is immediate, convenient to apply, and easy to remove if required
- Gives up to 12 months indoor protection

TYPICAL APPLICATIONS

- In-process protection
- Edge spray of coils and sheet stock
- Into void spaces
- Double wall void spaces
- Fogging

TYPICAL PROPERTIES

VpCI-337

Appearance	Clear to hazy amber liquid
Carrier	Water
Coverage	935-1870 ft ² /gal (23-46 m ² /l)
Film Type	Thin, soft film
Film Thickness	0.25-0.5 mil (6.3-12.5 microns)
Flash Point	> 200 F (93 C)
Freeze Point	32 F (0 C)
Non-volatile Content	28-33%
pH	8.2-8.8
Weight per Gallon	8.7-8.9 lb/gal (1.04-1.06 kg/l)

VpCI-337 Winterized

Carrier	Water + Ethylene Glycol
Freeze Point	-26 F (-32 C)
Non-volatile Content	20-25%
pH	8.0-8.3
Weight per Gallon	8.8-9.0 lb/gal (1.05-1.08 kg/l)

Note: Product may become hazy after a few days.



METALS PROTECTED

- Hot/cold-rolled steel
- Silicon steel
- Stainless steel
- Cast iron
- Zinc
- Aluminum
- Copper
- Brass

APPLICATION

Material Handling:

Fog or mist without dilution into containers, boxes, crates, and shrouded packages at a rate of 1 oz./ft³ (1 L/m³) of enclosed space. Spray on cardboard, wood pallets, closed and open cell foams, and other packaging materials. Always spray VpCI-337 uniformly within enclosure and allow direct access of vapors to metal surfaces to be protected.

Product Preparation:

Mix thoroughly if separation or settling has occurred.

Methods for Monitoring Solution:

Refractometer, pH

Dry Time:

VpCI-337

< 45 minutes

VpCI-337 Winterized

3 hours

Product Cleanup:

Use soap and water to clean equipment.

PACKAGING AND STORAGE

VpCI-337 is packaged in 10-14 oz. net wt. (284-397g) recyclable aluminum cans (12/carton), 5 gallon (19 liter) plastic pails, 55 gallon (208 liter) metal drums, totes, and bulk.

Minimum storage temperature: 12 F (-12 C)

Maximum storage temperature: 120 F (49 C)

VpCI-337 Winterized is packaged in 5 gallon (19 liter) plastic pails, 55 gallon (208 liter) metal drums, totes, and bulk.

Minimum storage temperature: -26 F (-32 C)

Maximum storage temperature: 120 F (49 C)

Shelf life is 24 months.

FOR INDUSTRIAL USE ONLY

KEEP OUT OF REACH OF CHILDREN

KEEP CONTAINER TIGHTLY CLOSED

NOT FOR INTERNAL CONSUMPTION

CONSULT MATERIAL SAFETY DATA SHEET FOR MORE INFORMATION

LIMITED WARRANTY

All statements, technical information and recommendations contained herein are based on tests Cortec Corporation believes to be reliable, but the accuracy or completeness thereof is not guaranteed.

Cortec Corporation warrants Cortec products will be free from defects when shipped to customer. Cortec Corporation's obligation under this warranty shall be limited to replacement of product that proves to be defective. To obtain replacement product under this warranty, the customer must notify Cortec Corporation of the claimed defect within six months after shipment of product to customer. All freight charges for replacement products shall be paid by customer.

Cortec Corporation shall have no liability for any injury, loss or damage arising out of the use of or the inability to use the products.

BEFORE USING A PRODUCT, USER SHALL DETERMINE THE RESPONSIBILITY FOR THE PRODUCT TO BE USED IN THE INTENDED USE, AND THE USER ASSUMES ALL RISKS AND LIABILITY WITH RESPECT TO CONNECTION THEREWITH. NO REPRESENTATION OR RECOMMENDATION NOT CONTAINED HEREIN SHALL HAVE ANY FORCE OR EFFECT UNLESS IN A WRITTEN DOCUMENT SIGNED BY AN OFFICER OF Cortec Corporation.

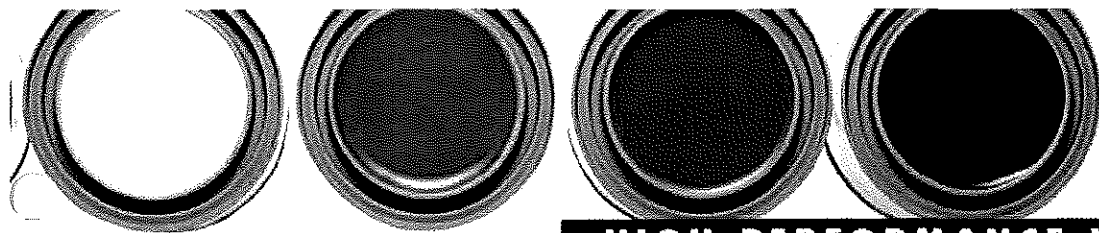
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4119 White Bear Parkway, St. Paul, MN 55110 USA
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Internet http://www.cortecvci.com

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HIGH PERFORMANCE VpCI™ COATINGS

VpCI®-368

PRODUCT DESCRIPTION

VpCI-368 is a time-proven coating that provides excellent protection to metal substrates exposed to harsh outdoor conditions. VpCI-368 leaves a firm, wax-like film that can be removed by mineral spirits or alkaline cleaners such as Cortec® VpCI-414.

FEATURES

- Flexible
- Excellent salt spray protection
- Excellent outdoor protection
- Multimetal protection
- Excellent UV resistance
- Moisture displacing
- Cured film is heat stable up to 392°F (200°C)
- Conforms to MIL-PRF-16173E (Grades 1 and 2)
- NATO 6850-66-132-5848
- NATO 6850-66-132-6099
- NSN 8030-00-062-6950
- NSN 8030-00-231-2345
- NSN 8030-00-244-1300
- NSN 8030-01-470-2601

TYPICAL APPLICATIONS

- Pipe coating
- Parts storage
- Underbody coating
- Wire rope
- Steel plate
- Machined parts

METALS PROTECTED

- Carbon Steel
- Stainless Steel
- Copper
- Aluminum
- Cast Iron

PROTECTION PROPERTIES

	ASTM	DFT	Carbon Steel (1010)
Salt Spray	B-117	2-3 mils (50-75 microns)	900-1500 hr.
Prohesion	G-85	4-7 mils (100-175 microns)	2000 hr.
Humidity	D-1748	2-3 mils (50-75 microns)	2500+ hr.

APPLICATION

VpCI-368 may be applied by brushing or spraying. A film thickness of at least 2-3 mils (50-70 microns) is recommended for uncovered outdoor storage.

Surface Preparation:

NACE	SSPC	ARS
3 or 4	6 or 7	High B-2

Product Cleanup:

- Use solvents or mineral spirits for cleanup of equipment.
- Solvent, wax strippers, or alkaline cleaners such as VpCI-414 can be used for clean up of overspray.

TYPICAL PROPERTIES

Appearance	Dark brown viscous liquid
Coverage	300-330 ft ² /gal @ 3 mils (7-8 m ² /l @ 75 microns)
Dry Film Time	12-24 hours
Drying to Touch Time	0.5-3 hours
Film Type	Firm, wax-like
Removal Method	Petroleum solvents
Carrier	Mineral spirits
Shelf Life	24 months @ 75°F (24°C)
Non-volatile Content	57-62%
Viscosity at 23°C	600-5,000 cps (6 rpm) Spindle #2
VOC	2.9-3.1 lb/gal (347-372 g/l)
Density	7.4-7.7 lb/gal (0.89-0.92 kg/l)

Note: Coating dry time is affected by temperature, air-flow and humidity.

PACKAGING AND STORAGE

VpCI-368 is available in 5 gallon (19 liter) steel pails, 55 gallon (208 liter) metal drums, totes, and bulk.

Available as CorShield® VpCI-368 in 11 oz. (312 g) aerosol cans.



RECOMMENDED SPRAY EQUIPMENT

This information is based on spraying VpCI-368 at 3 parts concentrate to 1 part mineral spirits. A ready-to-use version of VpCI-368 is also available. The viscosity range is between 100-1,000 cps. If using a dilution other than this, please consult a Cortec or Graco representative.

Model	510 Airless/AA Plus
Pump	30:1 President
Tip	0.011-0.015 in (0.028-0.038 cm)
Cap	Standard
Filter	60 Mesh High Pressure
Air Pressure	80 psi
Fluid Hose	3/8" x 10' with 1/4" whip hose for ease of handling
Fluid Pressure (Supply/Gun)	2000/1700 psi (138/117 bar)

The minimum fluid atomization pressure required is 1500 psi (103 bar), which gives 2-4 mils (50-100 microns) WFT/pass.

FOR INDUSTRIAL USE ONLY

KEEP OUT OF REACH OF CHILDREN

KEEP CONTAINER TIGHTLY CLOSED

NOT FOR INTERNAL CONSUMPTION

CONSULT MATERIAL SAFETY DATA SHEET FOR MORE INFORMATION

LIMITED WARRANTY

All statements, technical information and recommendations contained herein are based on tests Cortec Corporation believes to be reliable, but the accuracy or completeness thereof is not guaranteed.

Cortec Corporation warrants Cortec® products will be free from defects when shipped to customer. Cortec Corporation's obligation under this warranty shall be limited to replacement of product that proves to be defective. To obtain replacement product under this warranty, the customer must notify Cortec Corporation of the claimed defect within six months after shipment of product to customer. All freight charges for replacement products shall be paid by customer.

Cortec Corporation shall have no liability for any injury, loss or damage arising out of the use of or the inability to use the products.


BEFORE USING, USER SHALL DETERMINE THE SUITABILITY OF THE PRODUCT FOR ITS INTENDED USE, AND USER ASSUMES ALL RISK AND LIABILITY WHATSOEVER IN CONNECTION THEREWITH. No representation or recommendation not contained herein shall have any force or effect unless in a written document signed by an officer of Cortec Corporation.

THE FOREGOING WARRANTY IS EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES, EXPRESS, IMPLIED OR STATUTORY, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTY OF MERCHANTABILITY OR OF FITNESS FOR A PARTICULAR PURPOSE. IN NO CASE SHALL CORTEC CORPORATION BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.



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Note:

1. Bolt Torque values for Nitrile lining is still to be confirmed.
2. Nitrile rubber will start to stiffen around -17°C (0°F). The glass transition temperature is -25°C (-13°F) and the brittle temperature is -40°C (-40°F). There is increased the risk of the lining cracking from any mechanical impact at temperature below -15°C. Lined vessel should not be exposed to sudden large temperature gradient which could cause cracking from expansion or contraction. Inspection (visual and spark test) of lining will be required prior to putting vessel in service.

PRELIMINARY

TITLE STORAGE & INSTALLATION INSTRUCTIONS For AFTER FILTERS AND WAC VESSELS						CUSTOMER MEG Energy Corporation c/o SNC Lavalin Christina Lake Phase 3A			
SCALE -						ECODYNE Limited  A Marmon Water/Berkshire Hathaway Company <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED, IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>			
						BY	DATE	DWG. NO. 32125-A-5002	REV. A
A	2014 Nov 18	FIRST ISSUE	ELG	WHD	DRN	ELG	2014 Nov 18		
REV	DATE	REMARKS	BY	CHKD	APPD	ELG	2014 Nov 18		

ECODYNE JOB NO. 12-32125
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1.0 STORAGE AND INSTALLATION

All material received at the storage facility must be checked for visual and hidden damage, as well as for shortages. Identification tags or markings are to be protected and re-marked, if necessary. All damages and shortages must be reported to Ecodyne within ten (10) days of receipt.

ECODYNE LIMITED
4475 Corporate Drive
Burlington, Ontario
L7L 5T9 - CANADA

TELEPHONE: (905) 332-1404
FAX: (905) 332-6586
ATTENTION: Engineering Dept.

Short term storage is defined as a period not exceeding six (6) months from receipt at site to installation of equipment. **Long term storage** is defined as a period exceeding six (6) months, but not exceeding 36 months from receipt at site to installation of equipment. Storage requirements vary for different types of equipment, both in the short term and the long term. Also, since it is difficult to assess the specific site conditions where the storage is to take place, the requirements described herein are not to be substituted for good warehousing practice and protection. These requirements should be considered as a minimum and failure to comply with these minimum requirements will void the warranty. In addition, the Operating Instruction Manuals may include storage recommendations from manufacturers of standard equipment. Where this information is provided, we recommend that it be followed. In addition, it is highly recommended that all received material on the project be stored together as a unit and not mixed with other material.

The following installation guidelines are intended to provide an overview of the major components to be erected, with particular emphasis on unusual requirements pertaining to custom designed equipment. These guidelines are not intended to replace good construction practice nor are they intended to describe detailed erection procedures associated with standard equipment. The field construction personnel should familiarize themselves with the detailed Ecodyne Bill of Materials, subvendor literature and manufacturing/construction drawings prior to commencing any section of the work.

THESE ARE RECOMMENDATIONS AND IT SHOULD NOT BE CONSIDERED THAT BY ESTABLISHING THESE REQUIREMENTS ECODYNE ASSUMES ANY IMPLIED RESPONSIBILITY FOR THE EQUIPMENT DURING STORAGE AND INSTALLATION.

The storage and installation guidelines are presented in the following sections for each category of equipment:

- short term storage recommendations,
- long term storage recommendations,
- installation guidelines.

JOB# 12-32125

1.0 STORAGE AND INSTALLATION (CONTINUED)

1.1 Pressure Vessels

Equipment Supplied

- FILTER VESSELS (3A-F-208 A-G)
- WAC VESSELS (3A-V-211 A-F)

Short-Term Storage: Pressure Vessels

- Inspect equipment upon receipt and advise Ecodyne of any damage or shortages.
- All equipment should be stored in original shipping packaging, preferably indoors, until required for installation.
- Rubber-lined vessels may be stored outdoors if covered with protective tarpaulins for shade. Ensure an air gap between tarpaulin and vessel for airflow by using blocks and anchoring tarpaulin with rope. Vessels can be handled at temperatures below freezing, however extreme care must be taken not to bump the vessels as rubber is quite brittle at low temperatures (vessels should not be handled below -15 Deg C).
- Ensure that opening blanks are intact, if not secure.
- Inspect for external damage and touch-up exposed surfaces as required. Apply anticorrosion compound such as Tectyle 846 Class 1 or equal on all vessel hardware as required (interval of 2-3 months).
- After rubber-lined vessels are standing upright, they must be wet stored (see Long-Term Storage).

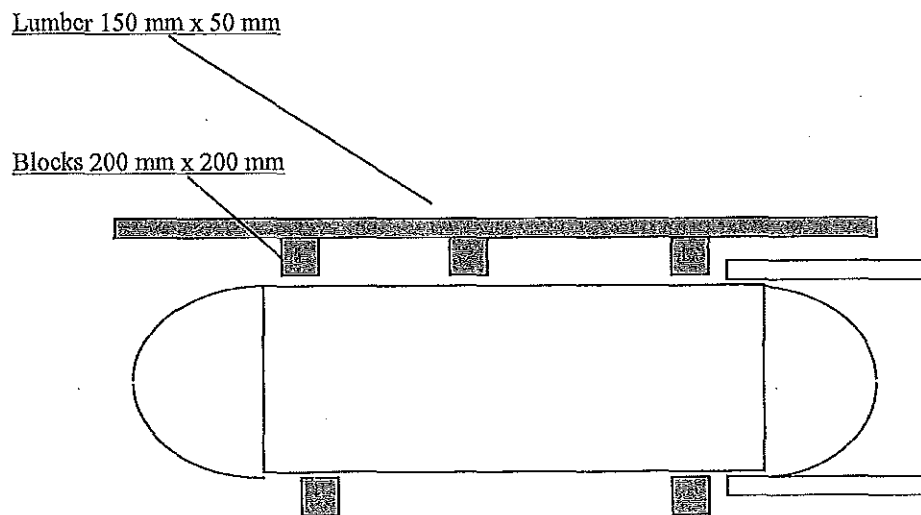
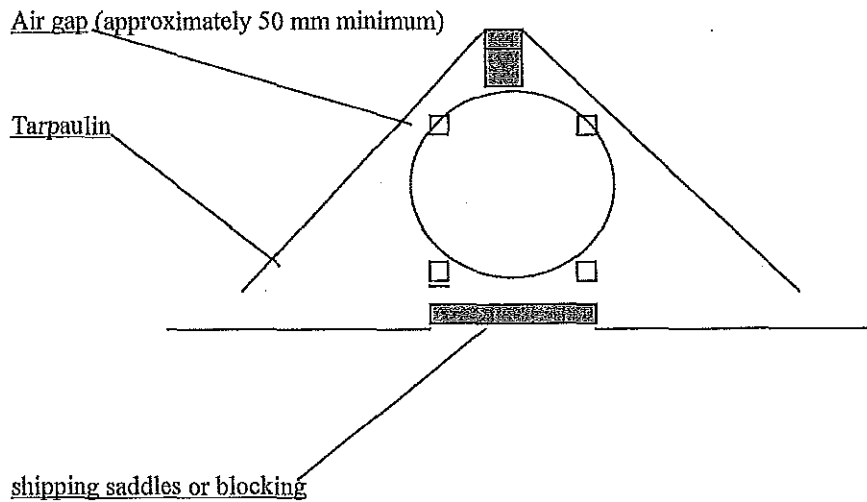
Note: When lifting pressure vessels, falling lug must be used to prevent any loading on the vessel legs until the vessel is in the vertical position. Also use spreader bar or long slings to avoid damage to lifting lugs. Refer to lifting diagrams, 32125-D-2201 and 32125-D-2202.

Long-Term Storage: Pressure Vessels

- Follow short-term recommendations.
- Consideration can be given to filling the vessels with nitrogen which can reduce 'ageing' of rubber by oxidation. The condition of rubber lining after a very long storage and exposure to the elements cannot be predicted.

Note: Vessel lining have been inspected by Ecodyne, and tested by the lining installation contractor. Contact Ecodyne if there is any indication the lining is damaged or needs to be re-tested. Excessive spark testing or spark testing at excessive voltage can damage or shorten the life of the lining and WILL VOID THE WARRANTY.

SUGGESTED BLOCKING AND TARPAULIN TO SHADE RUBBER LINED VESSELS



1.1 Pressure Vessels (Continued)

Installation Guidelines:

- Place the vessels complete on foundations - level, shim, and align to the correct orientation and anchor. Do not grout or final anchor until piping is connected.
- Connect pipe, beginning with directly bolted connections at the bottom. Adjust vessel alignment if necessary to achieve this first key connection.
- Ensure the units are properly aligned with adjacent units prior to final anchoring. Fit, bolt up and field weld the final connecting spools and any ship loose components or piping on all vessels. No excessive stress should be on the vessel connections. After the vessels are connected to the pipe racks, they may be grouted or welded as desired. It is recommended that the skid bases be filled with concrete to prevent trapping debris or water.
- Ensure vessel internals and piping bolting are tightened as loosening can occur during shipment (see Note below).
- Tighten up any bolting on the piping skid that may have loosened during shipment.
- Flush vessels and associated piping to remove any debris before loading media.
- Load vessel media according to the Media Installation Instructions.

Note: Internal check of the vessels should be done with an Ecodyne representative present. Internals must be checked prior to loading of media.

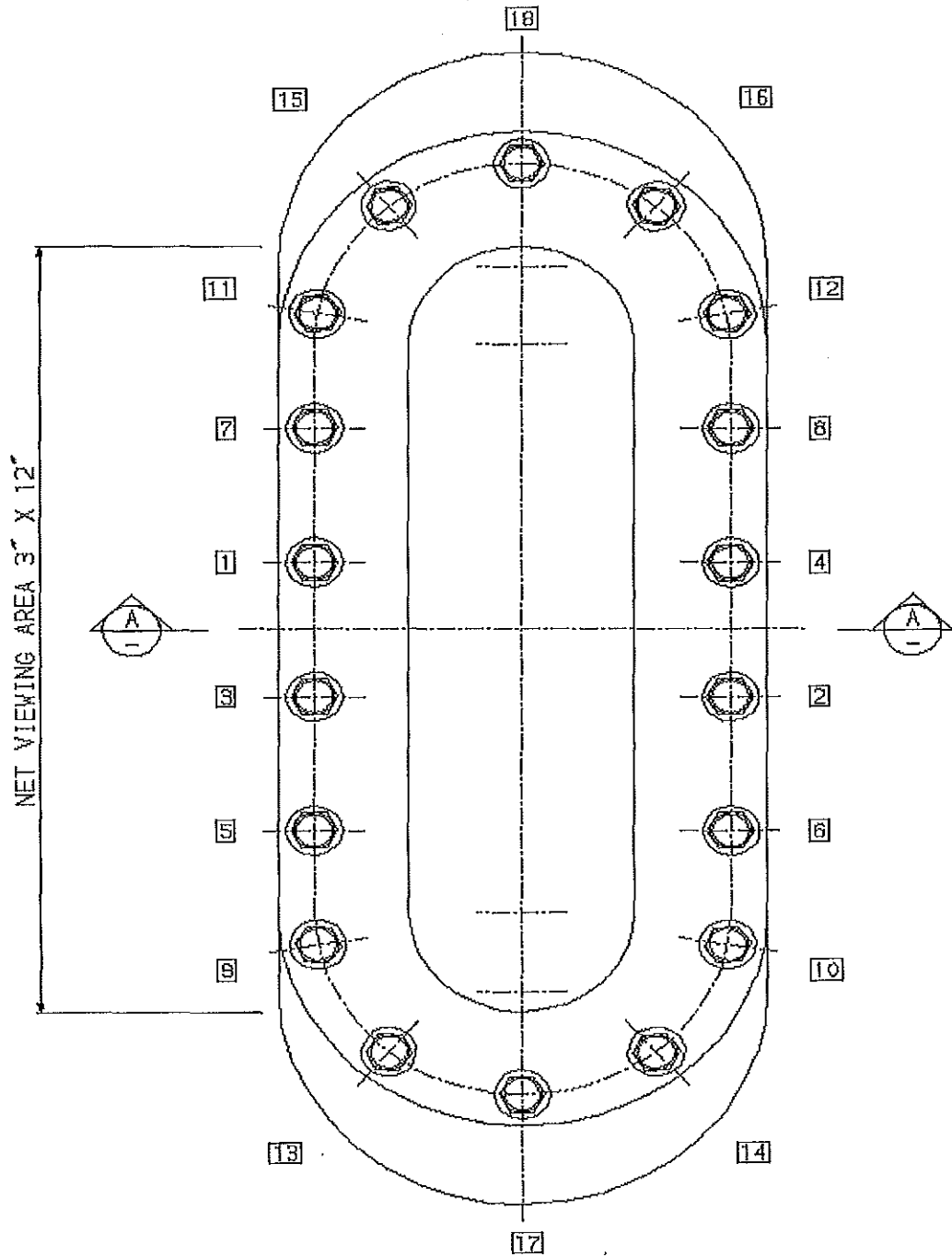
External & Internal Bolting

RECOMMENDED BOLTING TORQUES* – RUBBER LINED FLANGES

BOLT DIA. (inches)	PAD DIA. (inches)	Semi –hard Rubber Lining			
		P ≤ 100 PSI (690 kPa)		P ≥ 150 PSI (1034 kPa)	
		m-N	Ft-lb	m-N	Ft-lb
1/2	3" x 12" sight window	40	30	40	30
5/8	2	40	30	50	40
5/8	3	50	40	70	50
5/8	4	40	30	50	40
3/4	6	50	40	70	50
3/4	8	80	60	90	70
7/8	10	80	60	90	70
7/8	12	110	80	130	100
3/4	18	110	80	125	95
1	14	120	90	150	110
1	18	150	110	165	120
1 1/8	20	150	110	180	130
1 1/4	24	180	130	200	150

- *(a) Use a thread lubricant or Teflon coated bolt and a 1/8" thick full-face soft gasket, 60 Shore A Durometer. Chart is based on full faced contact up to flange O.D. (except sight window). Reduce values proportionally if there is less contact area.
- (b) Bolt torque shall not exceed the maximum allowable values (otherwise the rubber lining on the flange face may crack or delaminate). Bolt torque shall be uniformly applied such that the gasket is uniformly but moderately pre-compressed, and just starts to extrude from the flanged joint. Bring the torque up in stages, in a balanced manner, first applying half the design torque at N, S, W, E, then NNE, SSW, SNW, NSE, then NNW, SSE, NSW, SNE, repeating at full design torque in the same progression, and then repeating once again. Check that the gasket is firmly in place all around by using pliers to tug at the protruding parts, and if loose anywhere then applied torques may be increased up to 50%, then 100% above design values, following the same method as specified above but starting at the point of largest gap.
- (c) 'P' refers to the vessel design pressure. **For this project P=1345 kPag.**
- (d) Recommended torques for pressure ≥1034 kPa (50 psi) may be increased up to 20% for soft rubber and up to 33% for semi-hard rubber, over the above recommended if these torques fail to seal. For 690kPa (100 psi) applications, it is recommended that the lower torques be first applied to determine if the joints seal at the lower values.
- (e) If a seal is not achieved at the increased torque values, the joint shall be unbolted, inspected for irregularities, and buffed flat if necessary.

**Limited by bolt stress to 172,370 kPa (25,000 psi) at root of thread, which may be increased, if required per (d) above.



FRONTAL VIEW

(THE NO'S INDICATES BOLT
TIGHTENING SEQUENCE)

JOB# 12-32125

2.0 DRAWINGS REQUIRED FOR INSTALLATION

AFTER FILTERS, TAG: 3A-F-208, A-G
WAC VESSELS, TAG: 3A-V-211, A-F

FOUNDATION DETAILS	32125-D-2002-01
VESSEL ASSEMBLY-WAC	32125-D-2201-01
VESSEL ASSEMBLY-AFTER FILTER	32125-D-2202-01
CROSS SECTION-WAC	32125-A4-2050-01
CROSS SECTION-AFTER FILTER	32125-A4-2051-01

3.0 APPENDIX

ADDITIONAL CONSIDERATIONS FOR HANDLING AND STORING OF RUBBER LINED VESSELS AT LOW TEMPERATURE.

This applies where Rubber Lined vessels are shipped, received, moved or stored at temperatures below freezing. It also applies to rubber lined piping.

Rubber linings become brittle and may be easily damaged at low temperatures. This is particularly important for hard and semi hard linings. Chlorobutyl rubbers are softer and less brittle than semi hard rubbers, but are fragile at extremely low temperature. The fragility of rubber linings depends significantly on the substrate, i.e. on the rigidity and thermal properties of the pressure vessel or tank to which they are applied.

Note that even though the site might be hot, shipping and handling procedure applicable to cold weather might also apply if shipping from Ontario in winter.

SHIPPING AND HANDLING: Rubber Lined Pressure Vessels or Tanks

Nitrile rubber (Polymeric 2048).

The manufacturer of this rubber has recommended that vessels lined with this rubber are not handled at temperature below -17C. Ecodyne has successfully shipped pressure vessels lined with other semi-hard rubber at lower temperature than that, but has no experience with 2048. Extreme caution is needed loading and unloading the vessels below freezing temperature (0C).

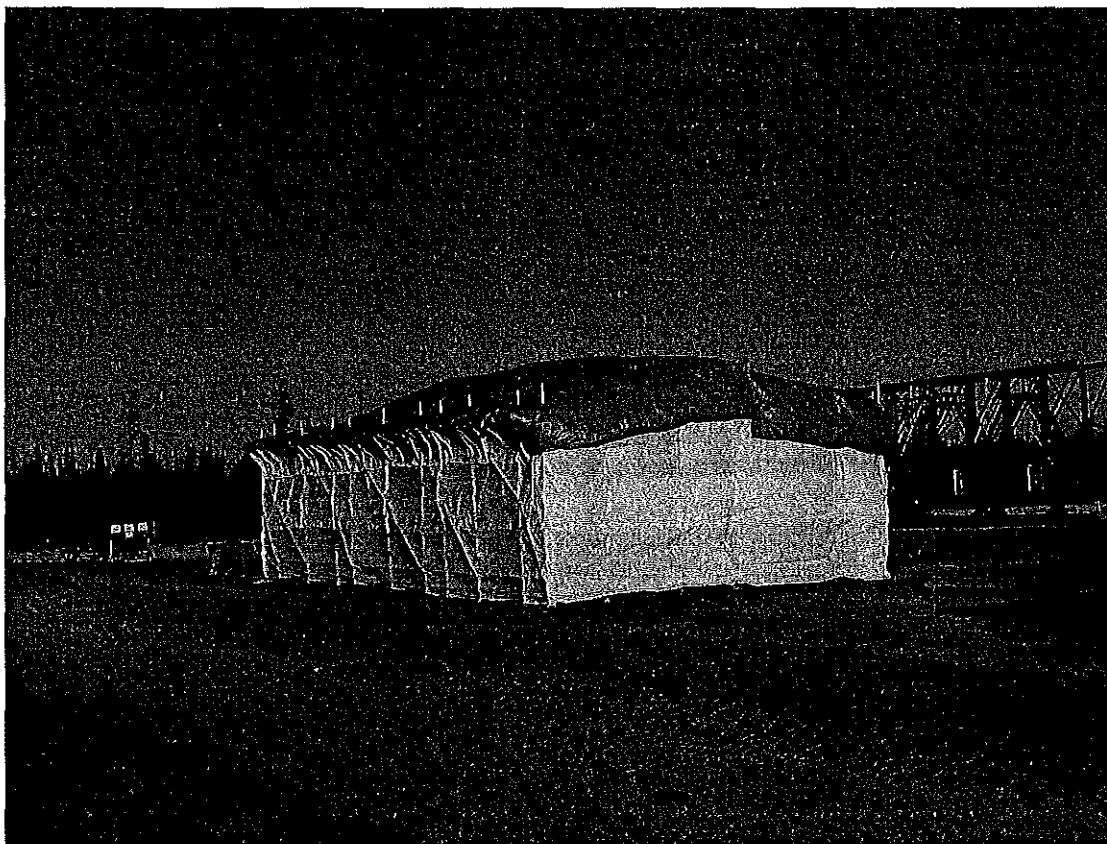
At any temperature between -0C and -15C the following special precautions apply:

- Do not bump the vessels or subject to sudden lifting or placement on shipping saddles. *(This means for example, do not use forklift or heavy machinery which might impact the vessel to push the vessels into position or when lowering onto anchor-bolts. Also, do not use crane at high speed which could jerk the lifting chains on lifting lugs, or suddenly drop the vessel onto saddles or the ground.)*
- Do not hammer or use any method involving impact, or any method involving force on the vessel shell or attachments, to position the vessel.
- Do not remove any attachments or any covers from flange faces, manways, etc.
- Do not connect any piping or attachments to the vessel.
- Do not open the vessel or perform any internal inspections.

We do not recommend handling these vessels at all below -15C.

- All the above warnings for temperatures between freezing and -15C will apply.
- Protect the vessel against sudden and extreme temperature changes, e.g. provide indoor storage or shelter. (refer to photograph for an example).

ECODYNE Limited
STORAGE & INSTALLATION MANUAL



JOB# 12-32125

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Q56 – Quality Management


PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Inspection & Test Plan

INSPECTION & TEST PLAN

AFTER FILTER VESSEL

3A-F-208 A


TITLE INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 A					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
					SCALE - N/A			 ECODYNE Limited <small>A Marmon Water/Berkshire Hathaway Company</small> <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>	
						BY	DATE		
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; Material clarifications	TM	AV	DRN	TM	11/12 2012		
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012		
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012	DWG. NO. <div style="text-align: center; font-size: 1.2em;">32125-A-4351</div>	
								REV. <div style="text-align: center; font-size: 1.2em;">B</div>	

W.O. 12-32

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 A Drawing Number: 32125-A-4351 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor										
No.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT											
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC			
1.	Drawings	Document Log 	* confirm scope and the fabrication and inspection drawings are the latest revision * Calculations have been provided for approval * Pre-fabrication meeting - SNC / MEG <i>Surveillance Level 3</i>	Latest Revisions <i>Specifications</i> 32125-A-2015 Pressure Vessel (includes 085354-3010-PV-10, 085354-3010-PV-24 & 085354-4060-PS-001) 32125-A-2017 Welding (includes 085354-3010-EW-20) Registered in Province of Alberta	R	05-08-13	R	5-17-13							-	
					W	05-09-13	R									
					W	05-08-13	W			W						
2.	Weld Procedures	ASME Section IX	* confirm that the weld procedures, weld repair procedures and procedure maps, used for the fabrication, have been approved * randomly check that the approved weld procedures are being applied - check amperage and voltage during operation	Approval records / stamp for the procedures	W	05-08-13	R	5-12-13	R							yes
					W	05-08-13	R			R						

INSPECTION & TEST PLAN

ECODYNE Limited

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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
3.	Welder Qualification	ASME Section IX	* all pressure containing welds have been identified with the welder symbol (either through the physical stamping of the weld or recording a welder identification map) {welder maps are to be submitted with the final documentation} * confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records	Welder Symbol Welder Qualification / welder qualification continuity log	W	8-13/13	R	5-17-13	R	5-9/13				yes
					R	8-13/13	R	5-17-13	R	5-9/13				

INSPECTION & TEST PLAN

ECODYNE Limited

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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date
4.	Materials	Detail Drawing	* confirm that all materials are in accordance with the drawing requirements * all vessel materials, including attachments, have traceable material test reports - normalized plate - confirm chemical & mechanical properties △	Material Test Reports △ MTC 3.1B EN10204 ASME Section II Lift lug materials to be suitable for -45° C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W	05-10-13	R	05-17-13	R	05-19-13	yes	
5.	Vessel Heads	Drawing	* confirm that the vessel heads are as detailed in the drawing - thickness has been checked for conformance to the calculations and drawing - report any differences to Ecodyne immediately * the head manufacturer has provided certification and Data Report	ASME Section VIII Certificate of Conformance U-2A (2-piece heads)	W	05-16-13	R	05-17-13	R	05-19-13	-	
					W	05-10-13	R	05-17-13	R	05-19-13	yes	

INSPECTION & TEST PLAN

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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
6.	Fabrication Fit-up	ASME	* misalignment, as a result of variation in the thickness of the head to the shell, has a 3:1 taper when greater than allowable	ASME Section VIII									
a	* Strainer plate has been welded & drilled in accordance with drawing			Nozzles are to be located clear of vessel long & circ seams	W	5-10-13	M	5-17-13	M/V		5/9/13		
b	* Top & Bottom heads laid out and nozzles fit & welded		* the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33		W	5-10-13	M	5-17-13	M/V		5/9/13		
c	* Shell plate rolled to match the diameter of the heads and the long seam welded		* full penetration welding is required for the two piece strainer plate		W	5-10-13	V		M/V		5/9/13		
d	* Fit and weld the shell course to the head												
e	* Strainer plate fit & full penetration welded to the shell												
f	* fit & weld shell repads and nozzles												
g	* fit closing head to shell section												
h	* fit legs, clips, etc.												

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
7.	Weld Profile	ASME	* confirm that the weld profile and reinforcement are in accordance with UW 35 * all weld defects and spatter has been removed * all pressure component edges have a minimum radius of 3 mm * all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted) * leg attachment weld is carried around to the inside of the flanges	ASME Section VIII	W	5/5/13	M	5/7/13	M/V	5/9/13			
					W	5/5/13	M		M/V	5/17/13			
					W	5/5/13	M		M/V	5/17/13			
					W	5/5/13	M	5/17/13	M/V	5/17/13			
					W	5/5/13	M		M/V	5/17/13			

INSPECTION & TEST PLAN

ECODYNE Limited

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NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
8.	Visual & Dimensions	Drawings	* all drawing dimensions have been checked - confirm over-all dimensions - nozzle pipe schedules are per the calculations - nozzles and pads are in the correct elevation and orientation - projection is correct - bolt hole rotation and hole number is correct - nozzles are level - strainer plate thickness & hole locations are as detailed - clips are as detailed and in the correct orientation and elevation - anchor bolt hole locations are correct	* ASME Code Drawing tolerances	W	05-15-13	W	05-17-13	W	05-17-13	MEG	12/3/13	yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 A Drawing Number: 32125-A-4351 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
9.	NDE	Drawing	* All NDE has been performed in accordance with the Code and calculations including all repairs - RT to include all joint intersections plus additional spot in each long & circ & 100% of long seam of nozzles fabricated from rolled plate - MPT lift lug welds * NDE technicians are qualified to the applicable association and have current validation - interpretation has been performed by a minimum of CGSB & SNT Level II technician in the appropriate NDE method	ASME Section VIII ASME Section V Production Hardness testing is not required	W	15-15-13	V/R	17-15-13	M/R	17-15-13			yes
					V	16-05-16-13	R	17-05-17-13	M/R	17-15-13			
10. a	Hydrostatic Test	Drawings	* Test pressure and temperature are in compliance with UG 99 - test duration min of 1 hour	ASME Section VIII	W	18-23-13	V/R		W	10-10-13			yes
b	Pneumatic Test	drawing	* Reinforcing pads with weep holes are soap / air tested - two weep holes required on nozzles greater than 10" - fabricator to provide 3" - 1/4" diameter nipples in weep holes		W	18-23-13	V/R	18-05-23-13	W	10-10-13			yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 A Drawing Number: 32125-A-4351 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor														
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT															
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC							
11.	Preparation for Shipment to the Coating Shop <i>(note that coating, installation of internals and insulation are to be completed at the coating shop)</i>	Drawings	<ul style="list-style-type: none"> * all interior hardware has been supplied as detailed on the drawings (including resin removal blind flange & hardware) * vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification * vessel has been prepared for shipment - flanges have been protected from impact with plastic, metal or 6mm plywood covers attached in a minimum of 4 locations - vessel has been properly supported 	Quality Requirements 32125-A-4200 Nameplate in SI units	W	8-27-13	V	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13
					W	8-27-13	V	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13
					W	8-27-13	V	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13	W	8-27-13

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
 ECODYNE JOB: 32125
 REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 A Drawing Number: 32125-A-4351 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT									
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
12.	Documents	Purchase Req	* all quality documents have been checked for accuracy and completeness with the following documents submitted to Ecodyne - ASME Data Reports - ABSA Letter - Nameplate copy - MTR / Map - Welder Qualification - NDE reports - Visual & Dimensional report - Hydro report/chart - ITP & Traveler - NCR & resolution	Drawings & Code Ecodyne is responsible for assembly of documentation in accordance with project requirements	W	5-23-13	R	5-23-13	M/R				10/6/13	yes
13.	Inspection Release to the Coating Shop (for coating & installation of inlet & strainers)	Purchase Order	* confirm that all work has been done per the purchase order and all referenced drawings and specifications - ITP signed off	Drawings & Code	H	5-23-13	H	5-23-13	H				10/6/13	yes

LESENA STEEL LTD

PROGRAM DOCUMENTATION

CUSTOMER:	ECODYNE LTD.	Date:	MARCH / 05 //2013
JOB No:	12-32 A	P. O. No:	321253503
OWNER:	MEG ENERGY CORP.		
SERIAL No:	0411		
C.R.N. No:	W1159.2	N.B.:	-----
DRAWING No:	32125-D-2202-01 REV. E		
VESSEL TYPE:	AFTER FILTER	EQUIPMENT No:	3A-F-208 A
CODE:	ASME SECTION VIII, DIV.1, 2010 EDITION + 2011 ADDENDUM		
DESIGN PRESSURE:	1041 kPa (g) & F.V	M.D.M.T.:	-29 °C @ 103 kPa (g)
DESIGN TEMPERATURE:	120 °C		
HYDROSTATIC PRESSURE:	1354 kPa (g) in HORIZONTAL POSITION		
WELD PROCEDURE:	SMAW-16, 16.2 , SAW-45 & FCAW 40		
SHELL THICKNESS AND MATERIAL SPEC.:	19.05 mm NOM - SA - 516 – 70N		
HEADS THICKNESS AND MATERIAL SPEC.:	TOP: 18.22 mm MIN. & BTM.: 19.05 mm MIN - SA - 516 – 70N		
FINAL INSPECTION:	05/17/2013		
WELDER (S):	L1,2,5,7,8 & 9		
RADIOGRAPH:	LONG SEAM 100% PER UW-11(a),CIRC.SEAMS SPOT 85% PER UW(a)(5)(b);STAMPER RT-2		
DATE COMPLETED:	05/23/2013		
DATE SHIPPED:	05/27/2013		
AFFIDAVIT MAILED:			
U-IA DATA FORM MAILED:			
REMARKS:			

QA - 20

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 A

VESSEL TYPE: AFTER FILTER

SERIAL No: 0411

APPROVED BY QA: Arie Willemssen

CRN: W1159.2


	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	<i>AW</i> 3/5/13	<i>R</i> MAR 27.13	<i>SYURAH (SNC MEG)</i>	24/4/13
Welding Procedures	<i>AW</i> 3/5/13	<i>R</i> MAR 27.13	<i>SYURAH</i>	24/4/13
CRN		<i>R</i> MAY 28.13	<i>SYURAH</i>	24/4/13
Welder Qualifications	<i>AW</i> 3/5/13	<i>R</i> MAY 28.12	<i>SYURAH</i>	24/4/13
Out of Roundness (UG - 80)	<i>AW</i> 05.10.13	<i>V</i> MAY 10.2013	<i>SYURAH</i>	17/5/13
Materials	<i>AW</i> 05/10/13	<i>R</i> MAY 10.2013	<i>SYURAH</i>	17/5/13
Internal	<i>AW</i> 05.10.13	<i>V</i> MAY 10.2013	<i>SYURAH</i>	17/5/13
Dimensional	<i>AW</i> 05/17/13	<i>V</i> 2	<i>SYURAH</i>	17/5/13
Other:				
Repair-by-weld-procedure				
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	<i>AW</i> 05/17/13	<i>R</i> MAY 28.13	<i>SYURAH</i>	17/5/13
Arc Strikes, Gouges	<i>AW</i> 05/17/13			
Supports	<i>AW</i> 05/17/13			
Heat Treatment	---	---		
Final	<i>AW</i> 05/23/13	<i>H</i> MAY 28.13	<i>SYURAH</i>	5/9/13
Hydrostatic Test	<i>AW</i> 05/23/13	<i>H</i> MAY 23.13	<i>SYURAH</i>	5/9/13
Name Plate Stamping	<i>AW</i> 05/23/13	<i>H</i> MAY 23.13	<i>SYURAH</i>	5/9/13
Data Reports		<i>H</i> MAY 23.13	<i>SYURAH</i>	5/9/13
Paint	---	---	<i>SYURAH</i>	5/9/13
Preparation for Shipment				
Remarks: <i>AW (PREP) FOR SHIPMENT</i>				

QA - 21 A

INSPECTION & TEST PLAN

AFTER FILTER VESSEL

3A-F-208 B

TITLE INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 B						Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02			
SCALE - N/A						 A Marmon Water/Berkshire Hathaway Company <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>			
						BY	DATE	DWG. NO. <div style="text-align: center; font-size: 1.2em;">32125-A-4352</div>	REV. <div style="text-align: center; font-size: 1.2em;">B</div>
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; Material clarifications	TM	AV	DRN	TM	11/12 2012		
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012		
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012		

W.O. 12-32

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 B Drawing Number: 32125-A-4352 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
No.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
1.	Drawings	Document Log △	* confirm scope and the fabrication and inspection drawings are the latest revision * Calculations have been provided for approval * Pre-fabrication meeting - SNC / MEG <i>Surveillance Level 3</i>	Latest Revisions <i>Specifications</i> 32125-A-2015 Pressure Vessel (includes 085354-3010-PV-10, 085354-3010-PV-24 & 085354-4060-PS-001) 32125-A-2017 Welding (includes 085354-3010-EW-20) Registered in Province of Alberta	R	5-9-13	R	5-9-13	7	5-9-13			-
					W	5-9-13	R		5-9-13				
					W	5-9-13	W		W				
2.	Weld Procedures	ASME Section IX	* confirm that the weld procedures, weld repair procedures and procedure maps, used for the fabrication, have been approved * randomly check that the approved weld procedures are being applied - check amperage and voltage during operation	Approval records / stamp for the procedures	W	5-9-13	R	5-9-13	R	5-9-13			yes
					W	5-9-13	R	5-9-13	R	5-9-13			

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 B Drawing Number: 32125-A-4352 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Welder Qualification	ASME Section IX	* all pressure containing welds have been identified with the welder symbol (either through the physical stamping of the weld or recording a welder identification map) {welder maps are to be submitted with the final documentation} * confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records	Welder Symbol Welder Qualification / welder qualification continuity log	W	5/10/13	R	5/15/13	R	5/9/13			yes
					R	5/14/13	R	5/15/13	R	5/9/13			

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 B Drawing Number: 32125-A-4352 REVISION: B					TC: Test Certificate Required H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
4.	Materials	Detail Drawing <div>△</div>	* confirm that all materials are in accordance with the drawing requirements * all vessel materials, including attachments, have traceable material test reports - normalized plate - confirm chemical & mechanical properties	Material Test Reports △ MTC 3.1B EN10204 ASME Section II Lift lug materials to be suitable for -45° C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W	<div>05.10.13</div>	R	<div>7</div>	R	<div>5/9/13</div>			yes
					W	<div>05.10.13</div>	R	<div>5.15.13</div>	R	<div>5/9/13</div>			
								<div>J</div>	R	<div>5/9/13</div>			
5.	Vessel Heads	Drawing	* confirm that the vessel heads are as detailed in the drawing - thickness has been checked for conformance to the calculations and drawing - report any differences to Ecodyne immediately * the head manufacturer has provided certification and Data Report	ASME Section VIII Certificate of Conformance U-2A (2-piece heads)	W	<div>05.10.13</div>	R	<div>7</div>	R	<div>5/9/13</div>			-
					W	<div>05.10.13</div>	R	<div>5.15.13</div>	R	<div>5/9/13</div>			yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 B Drawing Number: 32125-A-4352 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor									
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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
6.	Fabrication Fit-up	ASME	* misalignment, as a result of variation in the thickness of the head to the shell, has a 3:1 taper when greater than allowable	ASME Section VIII										
a	* Strainer plate has been welded & drilled in accordance with drawing			Nozzles are to be located clear of vessel long & circ seams	W	5/10/13	M			M/V		5/19/13		
b	* Top & Bottom heads laid out and nozzles fit & welded				W	5/10/13	M			M/V		5/19/13		
c	* Shell plate rolled to match the diameter of the heads and the long seam welded							5-15/13						
d	* Fit and weld the shell course to the head				W	5/10/13	V			M/V		5/19/13		
e	* Strainer plate fit & full penetration welded to the shell													
f	* fit & weld shell repads and nozzles													
g	* fit closing head to shell section													
h	* fit legs, clips, etc.													

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
 ECODYNE JOB: 32125
 REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 B Drawing Number: 32125-A-4352 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT									
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
7.	Weld Profile	ASME	* confirm that the weld profile and reinforcement are in accordance with UW 35 * all weld defects and spatter has been removed * all pressure component edges have a minimum radius of 3 mm * all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted) * leg attachment weld is carried around to the inside of the flanges	ASME Section VIII	W	05-15-13	M		M/V					
					W	05-15-13	M		M/V					
					W	05-15-13	M		M/V					
					W	05-15-13	M	5-17-13	M/V					
					W	05-15-13	M		M/V					

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
 ECODYNE JOB: 32125
 REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 B Drawing Number: 32125-A-4352 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
8.	Visual & Dimensions	Drawings	* all drawing dimensions have been checked - confirm over-all dimensions - nozzle pipe schedules are per the calculations - nozzles and pads are in the correct elevation and orientation - projection is correct - bolt hole rotation and hole number is correct - nozzles are level - strainer plate thickness & hole locations are as detailed - clips are as detailed and in the correct orientation and elevation - anchor bolt hole locations are correct	* ASME Code Drawing tolerances	W	JB 05/17/13	W	JB 05.17.13	W	W	W	W	yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 B Drawing Number: 32125-A-4352 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
9.	NDE	Drawing	* All NDE has been performed in accordance with the Code and calculations including all repairs - RT to include all joint intersections plus additional spot in each long & circ & 100% of long seam of nozzles fabricated from rolled plate - MPT lift lug welds * NDE technicians are qualified to the applicable association and have current validation - interpretation has been performed by a minimum of CGSB & SNT Level II technician in the appropriate NDE method	ASME Section VIII ASME Section V Production Hardness testing is not required	W	15/17/13	V/R	15/17/13	M/R	17/5/13			yes
					V	15/17/13	R	15/17/13	M/R	17/5/13			
10. a	Hydrostatic Test	Drawings	* Test pressure and temperature are in compliance with UG 99 - test duration min of 1 hour	ASME Section VIII	W	15/17/13	V/R	15/17/13	W	17/5/13			yes
b	Pneumatic Test	drawing	* Reinforcing pads with weep holes are soap / air tested - two weep holes required on nozzles greater than 10" - fabricator to provide 3" - 1/4" diameter nipples in weep holes		W	15/17/13	V/R	15/17/13	W	17/5/13			yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 B Drawing Number: 32125-A-4352 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor										
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT											
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC			
11.	Preparation for Shipment to the Coating Shop <i>(note that coating, installation of internals and insulation are to be completed at the coating shop)</i>	Drawings	* all interior hardware has been supplied as detailed on the drawings (including resin removal blind flange & hardware) * vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification * vessel has been prepared for shipment - flanges have been protected from impact with plastic, metal or 6mm plywood covers attached in a minimum of 4 locations - vessel has been properly supported	Quality Requirements 32125-A-4200 Nameplate in SI units	W	05/21/13	V	05/21/13	W	05/21/13	W	05/21/13	W	05/21/13	W	05/21/13
					W	05/21/13	V	05/21/13	W	05/21/13	W	05/21/13	W	05/21/13	W	05/21/13
					W	05/21/13	V	05/21/13	W	05/21/13	W	05/21/13	W	05/21/13	W	05/21/13

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 B Drawing Number: 32125-A-4352 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT									
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
12.	Documents	Purchase Req	* all quality documents have been checked for accuracy and completeness with the following documents submitted to Ecodyne - ASME Data Reports - ABSA Letter - Nameplate copy - MTR / Map - Welder Qualification - NDE reports - Visual & Dimensional report - Hydro report/chart - ITP & Traveler - NCR & resolution	Drawings & Code Ecodyne is responsible for assembly of documentation in accordance with project requirements	W	JB 05/17/13	R	JB 5-21/13	M/R				JA 10/6/13	yes
13.	Inspection Release to the Coating Shop (for coating & installation of inlet & strainers)	Purchase Order	* confirm that all work has been done per the purchase order and all referenced drawings and specifications - ITP signed off	Drawings & Code	H	JB 05/17/13	H	JB 5-21/13	H				JA 10/6/13	yes

LESENA STEEL LTD

PROGRAM DOCUMENTATION

CUSTOMER:	ECODYNE LTD.	Date:	MARCH / 05 //2013
JOB No:	12-32 B	P. O. No:	321253503
OWNER:	MEG ENERGY CORP.		
SERIAL No:	0412		
C.R.N. No:	W1159.2	N.B.:	-----
DRAWING No:	32125-D-2202-01 REV. E		
VESSEL TYPE:	AFTER FILTER	EQUIPMENT No:	3A-F-208 B
CODE:	ASME SECTION VIII, DIV.1, 2010 EDITION + 2011 ADDENDUM		
DESIGN PRESSURE:	1041 kPa (g) & F.V	M.D.M.T.:	-29 °C @ 103 kPa (g)
DESIGN TEMPERATURE:	120 °C		
HYDROSTATIC PRESSURE:	1354 kPa (g) in HORIZONTAL POSITION		
WELD PROCEDURE:	SMAW-16, 16.2 , SAW-45 & FCAW 40		
SHELL THICKNESS AND MATERIAL SPEC.:	19.05 mm NOM - SA - 516 – 70N		
HEADS THICKNESS AND MATERIAL SPEC.:	TOP: 18.22 mm MIN. & BTM.: 19.05 mm MIN - SA - 516 – 70N		
FINAL INSPECTION:	05/17/2013		
WELDER (S):	L1,2,5,7,8 & 9		
RADIOGRAPH:	LONG SEAM 100% PER UW-11(a),CIRC.SEAMS SPOT 85% PER UW(a)(5)(b);STAMPER RT-2		
DATE COMPLETED:	05/17/2013		
DATE SHIPPED:	05/21/2013		
AFFIDAVIT MAILED:			
U-IA DATA FORM MAILED:			
REMARKS:			

QA - 20

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 B

VESSEL TYPE: AFTER FILTER

SERIAL No: 0412

APPROVED BY QA: Arie Willemsen

CRN: W1159.2

	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	AW 3/5/13	R 2 MAR 07.13	AT	24/4/13
Welding Procedures	AW 3/5/13	R 2 MAR 07.13	AT	24/4/13
CRN		R	AT	24/4/13
Welder Qualifications	AW 3/5/13	R	AT	24/4/13
Out of Roundness (UG - 80)	05.10/13	V 2 MAY 10.2013	AT	17/5/13
Materials	JB 05/11/13	R 2 MAY 10.2013	AT	17/5/13
Internal	JB 05/11/13	H 2 MAY 10.2013	AT	17/5/13
Dimensional	JB 05/17/13	V 05/17/2013	AT	17/5/13
Other:				
Repair-by-weld-procedure	—			
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	JB 05/17/2013	R 05/17/2013	AT	17/5/13
Arc Strikes, Gouges	JB 05/17/2013			
Supports	JB 05/17/2013			
Heat Treatment	---	---		
Final	JB 05/17/2013	H	AT	17/5/13
Hydrostatic Test	JB 05/17/2013	H	AT	17/5/13
Name Plate Stamping	JB 05/17/2013	H	AT	17/5/13
Data Reports	JB 05/17/2013	H	AT	17/5/13
Paint	---	---		
Preparation for Shipment				
Remarks:				

QA - 21 A

LESENA STEEL LTD

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 B

VESSEL TYPE: AFTER FILTER

SERIAL No: 0412

DIMENSIONS: 3962mm OD x 2540mm T/T

DWG. No: 32125-D-2202-01 rev.D

W. P.: 1041 kPa (g) T.P.: 1354 kPa (g)

C.R.N. No: W1159.2

PRE-REVIEWED BY A. I. ~~FE~~ MAR 07, 2013

DATE: FEB/4/2013

APPROVED BY QC: Ar

ARIE WILLEMSSEN


[illegible]

QA - 21

INSPECTION & TEST PLAN

AFTER FILTER VESSEL

3A-F-208 C

TITLE INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 C					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
SCALE - N/A					 ECODYNE Limited <small>A Marmon Water/Berkshire Hathaway Company</small> <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>				
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; Material clarifications	TM	AV	DRN	TM	11/12 2012	DWG. NO. 32125-A-4353	REV. B
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012		
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012		

W.O. 12-32

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 C Drawing Number: 32125-A-4353 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor									
No.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT									
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
1.	Drawings	Document Log	* confirm scope and the fabrication and inspection drawings are the latest revision * Calculations have been provided for approval * Pre-fabrication meeting - SNC / MEG <i>Surveillance Level 3</i>	Latest Revisions <i>Specifications</i> 32125-A-2015 Pressure Vessel (includes 085354-3010-PV-10, 085354-3010-PV-24 & 085354-4060-PS-001) 32125-A-2017 Welding (includes 085354-3010-EW-20) Registered in Province of Alberta	R	5-9-13	R	5-27-13						
					W	5-9-13	R							
					W	5-9-13	W		W			5/9/13		
2.	Weld Procedures	ASME Section IX	* confirm that the weld procedures, weld repair procedures and procedure maps, used for the fabrication, have been approved * randomly check that the approved weld procedures are being applied - check amperage and voltage during operation	Approval records / stamp for the procedures	W	5-9-13	R	5-27-13	R			5/9/13		yes
					W	5-9-13	R		R			5/9/13		

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 C Drawing Number: 32125-A-4353 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Welder Qualification	ASME Section IX	* all pressure containing welds have been identified with the welder symbol (either through the physical stamping of the weld or recording a welder identification map) {welder maps are to be submitted with the final documentation} * confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records	Welder Symbol Welder Qualification / welder qualification continuity log	W	5-14-13	R	5-27-13	R	5-19-13			yes
					R	5-10-13	R		R	5-19-13			

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

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NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
4.	Materials	Detail Drawing	* confirm that all materials are in accordance with the drawing requirements * all vessel materials, including attachments, have traceable material test reports - normalized plate - confirm chemical & mechanical properties <div>△</div>	Material Test Reports △ MTC 3.1B EN10204 ASME Section II Lift lug materials to be suitable for -45° C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W	<div>5/10/13</div>	R	<div>7</div>	R		<div>AT 5/9/13</div>	yes	
					W	<div>5/10/13</div>	R	<div>5/27/13</div>	R		<div>AT 5/9/13</div>		
									R		<div>AT 5/9/13</div>		
5.	Vessel Heads	Drawing	* confirm that the vessel heads are as detailed in the drawing - thickness has been checked for conformance to the calculations and drawing - report any differences to Ecodyne immediately * the head manufacturer has provided certification and Data Report	ASME Section VIII Certificate of Conformance U-2A (2-piece heads)	W	<div>5/10/13</div>	R	<div>7</div>	R		<div>AT 5/9/13</div>	-	
					W	<div>5/10/13</div>	R	<div>5/27/13</div>	R		<div>AT 5/9/13</div>	yes	

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 C Drawing Number: 32125-A-4353 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
6.	Fabrication Fit-up	ASME	* misalignment, as a result of variation in the thickness of the head to the shell, has a 3:1 taper when greater than allowable	ASME Section VIII									
a	* Strainer plate has been welded & drilled in accordance with drawing				W	5/27/13	M		M/V		5/9/13		
b	* Top & Bottom heads laid out and nozzles fit & welded			Nozzles are to be located clear of vessel long & circ seams	W	5/27/13	M	5/27/13	M/V		5/9/13		
c	* Shell plate rolled to match the diameter of the heads and the long seam welded												
d	* Fit and weld the shell course to the head				W	5/27/13	V		M/V		5/9/13		
e	* Strainer plate fit & full penetration welded to the shell												
f	* fit & weld shell repads and nozzles												
g	* fit closing head to shell section												
h	* fit legs, clips, etc.												

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
 ECODYNE JOB: 32125
 REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 C Drawing Number: 32125-A-4353 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT									
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
7.	Weld Profile	ASME	* confirm that the weld profile and reinforcement are in accordance with UW 35 * all weld defects and spatter has been removed * all pressure component edges have a minimum radius of 3 mm * all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted) * leg attachment weld is carried around to the inside of the flanges	ASME Section VIII	W	5/27/13	M	5/27/13	M/V				5/27/13	
					W	5/27/13	M		M/V				5/27/13	
					W	5/27/13	M	5/27/13	M/V				5/27/13	
					W	5/27/13	M		M/V				5/27/13	
					W	5/27/13	M		M/V				5/27/13	

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
 ECODYNE JOB: 32125
 REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 C Drawing Number: 32125-A-4353 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
8.	Visual & Dimensions	Drawings	* all drawing dimensions have been checked - confirm over-all dimensions - nozzle pipe schedules are per the calculations - nozzles and pads are in the correct elevation and orientation - projection is correct - bolt hole rotation and hole number is correct - nozzles are level - strainer plate thickness & hole locations are as detailed - clips are as detailed and in the correct orientation and elevation - anchor bolt hole locations are correct	* ASME Code Drawing tolerances	W	5/12/13	W	5-27/13	W					yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 C Drawing Number: 32125-A-4353 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
9.	NDE	Drawing	* All NDE has been performed in accordance with the Code and calculations including all repairs - RT to include all joint intersections plus additional spot in each long & circ & 100% of long seam of nozzles fabricated from rolled plate - MPT lift lug welds * NDE technicians are qualified to the applicable association and have current validation - interpretation has been performed by a minimum of CGSB & SNT Level II technician in the appropriate NDE method	ASME Section VIII ASME Section V Production Hardness testing is not required	W	05/27/13	V/R	5-27/13	M/R				yes
					V	5/27/13	R		M/R				yes
10. a	Hydrostatic Test	Drawings	* Test pressure and temperature are in compliance with UG 99 - test duration min of 1 hour	ASME Section VIII	W	05/27/13	V/R		W				yes
b	Pneumatic Test	drawing	* Reinforcing pads with weep holes are soap / air tested - two weep holes required on nozzles greater than 10" - fabricator to provide 3" - 1/4" diameter nipples in weep holes		W	05/28/13	V/R	5-28/13	W				yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 C Drawing Number: 32125-A-4353 REVISION: B				TC: Test Certificate Required H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor											
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT										
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC		
11.	Preparation for Shipment to the Coating Shop <i>(note that coating, installation of internals and insulation are to be completed at the coating shop)</i>	Drawings	* all interior hardware has been supplied as detailed on the drawings (including resin removal blind flange & hardware) * vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification * vessel has been prepared for shipment - flanges have been protected from impact with plastic, metal or 6mm plywood covers attached in a minimum of 4 locations - vessel has been properly supported	Quality Requirements 32125-A-4200 Nameplate in SI units	W	5-28/13	V	5-28/13	W	5-28/13	W	5-28/13	W	5-28/13	TC

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
 ECODYNE JOB: 32125
 REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 C Drawing Number: 32125-A-4353 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
12.	Documents	Purchase Req	* all quality documents have been checked for accuracy and completeness with the following documents submitted to Ecodyne - ASME Data Reports - ABSA Letter - Nameplate copy - MTR / Map - Welder Qualification - NDE reports - Visual & Dimensional report - Hydro report/chart - ITP & Traveler - NCR & resolution	Drawings & Code Ecodyne is responsible for assembly of documentation in accordance with project requirements	W	<i>[Signature]</i> 5-28-13	R	<i>[Signature]</i> 5-28-13	M/R				<i>[Signature]</i> 10/6/13	yes
13.	Inspection Release to the Coating Shop (for coating & installation of inlet & strainers)	Purchase Order	* confirm that all work has been done per the purchase order and all referenced drawings and specifications - ITP signed off	Drawings & Code	H	<i>[Signature]</i> 5-28-13	H	<i>[Signature]</i> 5-28-13	H				<i>[Signature]</i> 10/6/13	yes

LESENA STEEL LTD

PROGRAM DOCUMENTATION

CUSTOMER:	ECODYNE LTD.	Date:	MARCH / 05 //2013
JOB No:	12-32 C	P. O. No:	321253503
OWNER:	MEG ENERGY CORP.		
SERIAL No:	0413		
C.R.N. No:	W1159.2	N.B.:	-----
DRAWING No:	32125-D-2202-01 REV. E		
VESSEL TYPE:	AFTER FILTER	EQUIPMENT No:	3A-F-208 C
CODE:	ASME SECTION VIII, DIV.1, 2010 EDITION + 2011 ADDENDUM		
DESIGN PRESSURE:	1041 kPa (g) & F.V	M.D.M.T.:	-29 °C @ 103 kPa (g)
DESIGN TEMPERATURE:	120 °C		
HYDROSTATIC PRESSURE:	1354 kPa (g) in HORIZONTAL POSITION		
WELD PROCEDURE:	SMAW-16, 16.2 , SAW-45 & FCAW 40		
SHELL THICKNESS AND MATERIAL SPEC.:	19.05 mm NOM - SA - 516 - 70N		
HEADS THICKNESS AND MATERIAL SPEC.:	TOP: 18.22 mm MIN. & BTM.: 19.05 mm MIN - SA - 516 - 70N		
FINAL INSPECTION:	05/28/2013		
WELDER (S):	L1,2,5,7,8 & 9		
RADIOGRAPH:	LONG SEAM 100% PER UW-11(a),CIRC.SEAMS SPOT 85% PER UW(a)(5)(b);STAMPER RT-2		
DATE COMPLETED:	05/28/2013		
DATE SHIPPED:	05/31/2013		
AFFIDAVIT MAILED:			
U-IA DATA FORM MAILED:			
REMARKS:			

QA - 20

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 C

VESSEL TYPE: AFTER FILTER

SERIAL No: 0413

APPROVED BY QA: Arie Willemssen

CRN: W1159.2

	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	<i>AW</i> 3/5/13	<i>R</i> MAY 20.13		
Welding Procedures	<i>AW</i> 3/5/13	<i>R</i> MAY 20.13		
CRN		<i>R</i> MAY 28.13		
Welder Qualifications	<i>AW</i> 3/5/13	<i>R</i> MAY 28.13		
Out of Roundness (UG - 80)	<i>AW</i> 05/22/13	<i>V</i> 05/22/2013		
Materials	<i>AW</i> 05/22/13	<i>R</i> 05/22/2013		
Internal	<i>AW</i> 05/22/13	<i>H</i> 05/22/2013		
Dimensional	<i>AW</i> 05/22/13	<i>V</i> MAY 28.13		
Other:				
Repair-by-weld-procedure				
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	<i>AW</i> 05-28-13	<i>R</i> MAY 28.13		
Arc Strikes, Gouges	<i>AW</i> 05-28-13			
Supports	<i>AW</i> 05-28-13			
Heat Treatment	---	---		
Final	<i>AW</i> 05-28-13	<i>H</i> MAY 28.13		
Hydrostatic Test	<i>AW</i> 05-28-13	<i>H</i> MAY 28.13		
Name Plate Stamping	<i>AW</i> 05-28-13	<i>H</i> MAY 28.13		
Data Reports	<i>AW</i> 05-28-13	<i>H</i> MAY 28.13		
Paint	---	---		
Preparation for Shipment				
Remarks:				

QA - 21 A

LESENA STEEL LTD

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 C

VESSEL TYPE: AFTER FILTER

SERIAL No: 0413

DIMENSIONS: 3962mm OD x 2540mm T/T

DWG. No: 32125-D-2202-01 rev.D

W. P.: 104 kPa (g) T.P.: 1354 kPa (g)

C.R.N. No: W1159.2

PRE-REVIEWED BY A. I. Dec 14/2007, 13

DATE: FEB/4/2013

APPROVED BY QC: *TR*

ARIE WILLEMSSEN


[illegible]

QA - 21

INSPECTION & TEST PLAN

AFTER FILTER VESSEL

3A-F-208 D


TITLE INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 D					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
					SCALE - N/A			 ECODYNE Limited <small>A Marmon Water/Berkshire Hathaway Company</small> <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>	
						BY	DATE		
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REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012	DWG. NO. <div style="text-align: center; font-size: 1.2em;">32125-A-4354</div>	
								REV. B	

W.O. 12.32

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 D Drawing Number: 32125-A-4354 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor											
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1.	Drawings	Document Log 	* confirm scope and the fabrication and inspection drawings are the latest revision * Calculations have been provided for approval * Pre-fabrication meeting - SNC / MEG <i>Surveillance Level 3</i>	Latest Revisions <i>Specifications</i> 32125-A-2015 Pressure Vessel (includes 085354-3010-PV-10, 085354-3010-PV-24 & 085354-4060-PS-001) 32125-A-2017 Welding (includes 085354-3010-EW-20) Registered in Province of Alberta	R	8-5-13	R	8-8								
					W	8-5-13	R	8-8								
					W	8-5-13	W	8-8	W							
2.	Weld Procedures	ASME Section IX	* confirm that the weld procedures, weld repair procedures and procedure maps, used for the fabrication, have been approved * randomly check that the approved weld procedures are being applied - check amperage and voltage during operation	Approval records / stamp for the procedures	W	8-5-13	R	8-8	R						yes	
					W	8-5-13	R	8-8	R							

INSPECTION & TEST PLAN

ECODYNE Limited



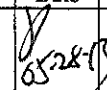

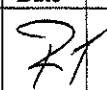




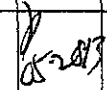

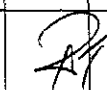
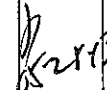

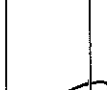
PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 D Drawing Number: 32125-A-4354 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Welder Qualification	ASME Section IX	* all pressure containing welds have been identified with the welder symbol (either through the physical stamping of the weld or recording a welder identification map) {welder maps are to be submitted with the final documentation} * confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records	Welder Symbol Welder Qualification / welder qualification continuity log	W	5/10/13	R	5/10/13	R	5/10/13	5/10/13	5/10/13	yes
					R	5/10/13	R	5/10/13	R	5/10/13	5/10/13	5/10/13	

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
4.	Materials	Detail Drawing 	* confirm that all materials are in accordance with the drawing requirements * all vessel materials, including attachments, have traceable material test reports - normalized plate - confirm chemical & mechanical properties	Material Test Reports  MTC 3.1B EN10204 ASME Section II Lift lug materials to be suitable for -45° C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W		R		R		5/9/13	yes	
					W		R		R		5/9/13		
								R		5/9/13			
5.	Vessel Heads	Drawing	* confirm that the vessel heads are as detailed in the drawing - thickness has been checked for conformance to the calculations and drawing - report any differences to Ecodyne immediately * the head manufacturer has provided certification and Data Report	ASME Section VIII Certificate of Conformance U-2A (2-piece heads)	W		R		R		5/9/13	-	
					W		R		R		5/9/13		yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
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6.	Fabrication Fit-up	ASME	* misalignment, as a result of variation in the thickness of the head to the shell, has a 3:1 taper when greater than allowable	ASME Section VIII									
a	* Strainer plate has been welded & drilled in accordance with drawing				W	8-28-13	M	8-28-13	M/V		8-28-13		
b	* Top & Bottom heads laid out and nozzles fit & welded		* the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33	Nozzles are to be located clear of vessel long & circ seams	W	8-28-13	M	8-28-13	M/V		8-28-13		
c	* Shell plate rolled to match the diameter of the heads and the long seam welded												
d	* Fit and weld the shell course to the head		* full penetration welding is required for the two piece strainer plate		W	8-28-13	V	8-28-13	M/V		8-28-13		
e	* Strainer plate fit & full penetration welded to the shell												
f	* fit & weld shell repads and nozzles												
g	* fit closing head to shell section												
h	* fit legs, clips, etc.												

INSPECTION & TEST PLAN

ECODYNE Limited





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ECODYNE JOB: 32125
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7.	Weld Profile	ASME	* confirm that the weld profile and reinforcement are in accordance with UW 35 * all weld defects and spatter has been removed * all pressure component edges have a minimum radius of 3 mm * all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted) * leg attachment weld is carried around to the inside of the flanges	ASME Section VIII	W	8-28-13	M	SS	M/V				8/10/6/13
					W	8-28-13	M	SS	M/V				8/10/6/13
					W	8-28-13	M	SS	M/V				8/10/6/13
					W	8-28-13	M	SS	M/V				8/10/6/13
					W	8-28-13	M	SS	M/V				8/10/6/13

INSPECTION & TEST PLAN

ECODYNE Limited

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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
8.	Visual & Dimensions	Drawings	* all drawing dimensions have been checked - confirm over-all dimensions - nozzle pipe schedules are per the calculations - nozzles and pads are in the correct elevation and orientation - projection is correct - bolt hole rotation and hole number is correct - nozzles are level - strainer plate thickness & hole locations are as detailed - clips are as detailed and in the correct orientation and elevation - anchor bolt hole locations are correct	* ASME Code Drawing tolerances	W	 8/30/13	W		W				yes

INSPECTION & TEST PLAN

ECODYNE Limited

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ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
9.	NDE	Drawing	* All NDE has been performed in accordance with the Code and calculations including all repairs - RT to include all joint intersections plus additional spot in each long & circ & 100% of long seam of nozzles fabricated from rolled plate - MPT lift lug welds * NDE technicians are qualified to the applicable association and have current validation - interpretation has been performed by a minimum of CGSB & SNT Level II technician in the appropriate NDE method	ASME Section VIII ASME Section V Production Hardness testing is not required	W	5-30/13	V/R	5-30/13	M/R			5-30/13	yes
					V	5-30/13	R	5-30/13	M/R			5-30/13	
10. a	Hydrostatic Test	Drawings	* Test pressure and temperature are in compliance with UG 99 - test duration min of 1 hour	ASME Section VIII	W	5-30/13	V/R		W			5-30/13	yes
b	Pneumatic Test	drawing	* Reinforcing pads with weep holes are soap / air tested - two weep holes required on nozzles greater than 10" - fabricator to provide 3" - 1/4" diameter nipples in weep holes		W	5-30/13	V/R	5-30/13	W			5-30/13	yes

INSPECTION & TEST PLAN

ECODYNE Limited

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ECODYNE JOB: 32125
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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC					
11.	Preparation for Shipment to the Coating Shop <i>(note that coating, installation of internals and insulation are to be completed at the coating shop)</i>	Drawings	<ul style="list-style-type: none"> * all interior hardware has been supplied as detailed on the drawings (including resin removal blind flange & hardware) * vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification * vessel has been prepared for shipment - flanges have been protected from impact with plastic, metal or 6mm plywood covers attached in a minimum of 4 locations - vessel has been properly supported 	Quality Requirements 32125-A-4200 Nameplate in SI units	W	06/31/13	V	7	W	06/31/13	W	06/31/13	W	06/31/13	W	06/31/13	W	06/31/13
					W	06/31/13	V	5/31/13	W		W	06/31/13	W	06/31/13	W	06/31/13	W	06/31/13
					W	06/31/13	V		W	06/31/13	W	06/31/13	W	06/31/13	W	06/31/13	W	06/31/13

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
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AFTER FILTER VESSEL 3A-F-208 D Drawing Number: 32125-A-4354 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
12.	Documents	Purchase Req	* all quality documents have been checked for accuracy and completeness with the following documents submitted to Ecodyne - ASME Data Reports - ABSA Letter - Nameplate copy - MTR / Map - Welder Qualification - NDE reports - Visual & Dimensional report - Hydro report/chart - ITP & Traveler - NCR & resolution	Drawings & Code Ecodyne is responsible for assembly of documentation in accordance with project requirements	W	<i>[Signature]</i> 06/03/13	R	<i>[Signature]</i> 5/31/13	M/R			<i>[Signature]</i> 10/6/13	yes
13.	Inspection Release to the Coating Shop (for coating & installation of inlet & strainers)	Purchase Order	* confirm that all work has been done per the purchase order and all referenced drawings and specifications - ITP signed off	Drawings & Code	H	<i>[Signature]</i> 06/03/13	H	<i>[Signature]</i> 5/31/13	H			<i>[Signature]</i> 10/6/13	yes

LESENA STEEL LTD

PROGRAM DOCUMENTATION

CUSTOMER:	ECODYNE LTD.	Date:	MARCH / 05 //2013
JOB No:	12-32 D	P. O. No:	321253503
OWNER:	MEG ENERGY CORP.		
SERIAL No:	0414		
C.R.N. No:	W1159.2	N.B.:	-----
DRAWING No:	32125-D-2202-01 REV. E		
VESSEL TYPE:	AFTER FILTER	EQUIPMENT No:	3A-F-208 D
CODE:	ASME SECTION VIII, DIV.1, 2010 EDITION + 2011 ADDENDUM		
DESIGN PRESSURE:	1041 kPa (g) & F.V	M.D.M.T.:	-29 °C @ 103 kPa (g)
DESIGN TEMPERATURE:	120 °C		
HYDROSTATIC PRESSURE:	1354 kPa (g) in HORIZONTAL POSITION		
WELD PROCEDURE:	SMAW-16, 16.2 , SAW-45 & FCAW 40		
SHELL THICKNESS AND MATERIAL SPEC.:	19.05 mm NOM - SA - 516 - 70N		
HEADS THICKNESS AND MATERIAL SPEC.:	TOP: 18.22 mm MIN. & BTM.: 19.05 mm MIN - SA - 516 - 70N		
FINAL INSPECTION:	05/28/2013		
WELDER (S):	L1,2,5,7,8 & 9		
RADIOGRAPH:	LONG SEAM 100% PER UW-11(a),CIRC.SEAMS SPOT 85% PER UW(a)(5)(b);STAMPER RT-2		
DATE COMPLETED:	06/03/2013		
DATE SHIPPED:	06/04/2013		
AFFIDAVIT MAILED:			
U-IA DATA FORM MAILED:			
REMARKS:			

QA - 20

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 D

VESSEL TYPE: AFTER FILTER

SERIAL No: 0414

APPROVED BY QA: Arie Willemssen

CRN: W 1159.2

	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	<i>AW</i> 3/5/13	<i>R</i> MAR 07.13		
Welding Procedures	<i>AW</i> 3/5/13	<i>R</i> MAR 02.13		
CRN		<i>R</i> JUN 03.13		
Welder Qualifications	<i>AW</i> 3/5/13	<i>R</i> JUN 03.13		
Out of Roundness (UG - 80)	<i>05-28/13</i>	<i>✓</i> MAY 28.13		
Materials	<i>05-28/13</i>	<i>R</i> JUN 03.13		
Internal	<i>05-28/13</i>	<i>11/2</i> MAY 28.13		
Dimensional	<i>05-130/13</i>	<i>✓</i> JUN 03.13		
Other:				
Repair-by-weld-procedure				
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	<i>MR</i> 06-03-13	<i>R</i> JUN 03.13		
Arc Strikes, Gouges	<i>MR</i> 06-03-13			
Supports	<i>MR</i> 06-07-13			
Heat Treatment	---	---		
Final	<i>MR</i> 06-03-13	<i>MR</i> JUN 03.13		
Hydrostatic Test	<i>MR</i> 06-03-13	<i>MR</i> JUN 03.13		
Name Plate Stamping	<i>MR</i> 06-03-13	<i>MR</i> JUN 03.13		
Data Reports	<i>MR</i> 06-03-13	<i>MR</i> JUN 03.13		
Paint	---	---		
Preparation for Shipment				
Remarks:				

QA - 21 A

LESENA STEEL LTD

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 D

VESSEL TYPE: AFTER FILTER

SERIAL No: 0414

DIMENSIONS: 3962mm OD x 2540mm T/T

DWG. No: 32125-D-2202-01 rev.D

W. P.: 1041 kPa (g) T.P.: 1354 kPa (g)

C.R.N. No: W1159.2

PRE-REVIEWED BY A. I. R. M. 11/02/07.13

DATE: FEB/4/2013

APPROVED BY QC: AW
ARIE WILLEMSSEN


[illegible]

QA - 21

INSPECTION & TEST PLAN

AFTER FILTER VESSEL

3A-F-208 E

TITLE INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 E					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02					
					SCALE - N/A			 ECODYNE Limited <small>A Marmon Water/Berkshire Hathaway Company</small> <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>		
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; Material clarifications	TM	AV	DRN	TM	11/12 2012	DWG. NO. 32125-A-4355		REV. B
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012			
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012			

W.O. 12-32

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL
3A-F-208 E
Drawing Number: 32125-A-4355
REVISION: B

TC: Test Certificate Required

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					FAB	Sign/ Date	ECO	Sign/ Date	SNC	Sign/ Date	MEG	Sign/ Date	TC	
1.	Drawings	Document Log <div>△</div>	* confirm scope and the fabrication and inspection drawings are the latest revision * Calculations have been provided for approval * Pre-fabrication meeting - SNC / MEG <i>Surveillance Level 3</i>	Latest Revisions <i>Specifications</i> 32125-A-2015 Pressure Vessel (includes 085354-3010-PV-10, 085354-3010-PV-24 & 085354-4060-PS-001) 32125-A-2017 Welding (includes 085354-3010-EW-20) Registered in Province of Alberta	R	5-9-13	R							-
					W	5-9-13	R	5-29-13						
					W	5-9-13	W		W					
2.	Weld Procedures	ASME Section IX	* confirm that the weld procedures, weld repair procedures and procedure maps, used for the fabrication, have been approved * randomly check that the approved weld procedures are being applied - check amperage and voltage during operation	Approval records / stamp for the procedures	W		R	5-29-13	R					yes
					W		R		R					

INSPECTION & TEST PLAN

ECODYNE Limited

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3.	Welder Qualification	ASME Section IX	* all pressure containing welds have been identified with the welder symbol (either through the physical stamping of the weld or recording a welder identification map) {welder maps are to be submitted with the final documentation} * confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records	Welder Symbol Welder Qualification / welder qualification continuity log	W	5/5/13	R	5/9/13	R	5/9/13			yes
					R	5/8/13	R	5-9/13	R	5/9/13			

INSPECTION & TEST PLAN

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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date
4.	Materials	Detail Drawing	* confirm that all materials are in accordance with the drawing requirements * all vessel materials, including attachments, have traceable material test reports - normalized plate - confirm chemical & mechanical properties △	Material Test Reports △ MTC 3.1B EN10204 ASME Section II Lift lug materials to be suitable for -45° C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W	6-02/13	R	6-02/13	R	5/9/13		yes
					W	6-02/13	R	6-02/13	R	5/9/13		
									R	5/9/13		
5.	Vessel Heads	Drawing	* confirm that the vessel heads are as detailed in the drawing - thickness has been checked for conformance to the calculations and drawing - report any differences to Ecodyne immediately * the head manufacturer has provided certification and Data Report	ASME Section VIII Certificate of Conformance U-2A (2-piece heads)	W	6-02/13	R	6-02/13	R	5/9/13		-
					W	6-02/13	R	6-02/13	R	5/9/13		yes

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6.	Fabrication Fit-up	ASME	* misalignment, as a result of variation in the thickness of the head to the shell, has a 3:1 taper when greater than allowable	ASME Section VIII									
a	* Strainer plate has been welded & drilled in accordance with drawing			Nozzles are to be located clear of vessel long & circ seams	W	6.07/13	M	6.04/13	M/V		5/9/12		-
b	* Top & Bottom heads laid out and nozzles fit & welded		* the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33		W	6.07/13	M	6.04/13	M/V		5/9/13		
c	* Shell plate rolled to match the diameter of the heads and the long seam welded												
d	* Fit and weld the shell course to the head		* full penetration welding is required for the two piece strainer plate		W	6.07/13			M/V		5/9/13		
e	* Strainer plate fit & full penetration welded to the shell												
f	* fit & weld shell repads and nozzles												
g	* fit closing head to shell section												
h	* fit legs, clips, etc.												

INSPECTION & TEST PLAN

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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
7.	Weld Profile	ASME	* confirm that the weld profile and reinforcement are in accordance with UW 35 * all weld defects and spatter has been removed * all pressure component edges have a minimum radius of 3 mm * all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted) * leg attachment weld is carried around to the inside of the flanges	ASME Section VIII	W	6-03-13	M	6-10-13	M/V				10/6/13	
					W	6-03-13	M		M/V				10/6/13	
					W	6-03-13	M		M/V				10/6/13	
					W	6-03-13	M	6-10-13	M/V				10/6/13	
					W	6-03-13	M		M/V				10/6/13	

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
 ECODYNE JOB: 32125
 REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 E Drawing Number: 32125-A-4355 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT									
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
8.	Visual & Dimensions	Drawings	* all drawing dimensions have been checked - confirm over-all dimensions - nozzle pipe schedules are per the calculations - nozzles and pads are in the correct elevation and orientation - projection is correct - bolt hole rotation and hole number is correct - nozzles are level - strainer plate thickness & hole locations are as detailed - clips are as detailed and in the correct orientation and elevation - anchor bolt hole locations are correct	* ASME Code Drawing tolerances	W	06-07-17	W	6-10-13	W			W	10/6/13	yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 E Drawing Number: 32125-A-4355 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
9.	NDE	Drawing	* All NDE has been performed in accordance with the Code and calculations including all repairs - RT to include all joint intersections plus additional spot in each long & circ & 100% of long seam of nozzles fabricated from rolled plate - MPT lift lug welds * NDE technicians are qualified to the applicable association and have current validation - interpretation has been performed by a minimum of CGSB & SNT Level II technician in the appropriate NDE method	ASME Section VIII ASME Section V Production Hardness testing is not required	W	06-07-13	V/R	06-07-13	M/R			06-07-13	yes
					V	06-07-13	R	06-10-13	M/R			06-10-13	
10. a	Hydrostatic Test	Drawings	* Test pressure and temperature are in compliance with UG 99 - test duration min of 1 hour	ASME Section VIII	W	06-12-13	V/R		W			06-12-13	yes
b	Pneumatic Test	drawing	* Reinforcing pads with weep holes are soap / air tested - two weep holes required on nozzles greater than 10" - fabricator to provide 3" - 1/4" diameter nipples in weep holes		W	06-12-13	V/R		W			06-12-13	yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 E Drawing Number: 32125-A-4355 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
11.	Preparation for Shipment to the Coating Shop (note that coating, installation of internals and insulation are to be completed at the coating shop)	Drawings	* all interior hardware has been supplied as detailed on the drawings (including resin removal blind flange & hardware) * vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification * vessel has been prepared for shipment - flanges have been protected from impact with plastic, metal or 6mm plywood covers attached in a minimum of 4 locations - vessel has been properly supported	Quality Requirements 32125-A-4200 Nameplate in SI units	W	06/12/13	V		W		W	06/10/13	
					W	06/12/13	V		W		W	06/10/13	
					W	06/12/13	V		W		W	06/10/13	

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 E Drawing Number: 32125-A-4355 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
12.	Documents	Purchase Req	* all quality documents have been checked for accuracy and completeness with the following documents submitted to Ecodyne - ASME Data Reports - ABSA Letter - Nameplate copy - MTR / Map - Welder Qualification - NDE reports - Visual & Dimensional report - Hydro report/chart - ITP & Traveler - NCR & resolution	Drawings & Code Ecodyne is responsible for assembly of documentation in accordance with project requirements	W	<i>W</i> 06-12-13	R	<i>R</i>	M/R		<i>W</i>	10/6/13	yes
13.	Inspection Release to the Coating Shop (for coating & installation of inlet & strainers)	Purchase Order	* confirm that all work has been done per the purchase order and all referenced drawings and specifications - ITP signed off	Drawings & Code	H	<i>H</i>	H	<i>H</i>	H		<i>H</i>	10/6/13	yes

* Signed by *ERAN*
06-10/13

LESENA STEEL LTD

PROGRAM DOCUMENTATION

CUSTOMER:	ECODYNE LTD.	Date:	MARCH / 05 //2013
JOB No:	12-32 E	P. O. No:	321253503
OWNER:	MEG ENERGY CORP.		
SERIAL No:	0415		
C.R.N. No:	W1159.2	N.B.:	-----
DRAWING No:	32125-D-2202-01 REV. E		
VESSEL TYPE:	AFTER FILTER	EQUIPMENT No:	3A-F-208 E
CODE:	ASME SECTION VIII, DIV.1, 2010 EDITION + 2011 ADDENDUM		
DESIGN PRESSURE:	1041 kPa (g) & F.V	M.D.M.T.:	-29 °C @ 103 kPa (g)
DESIGN TEMPERATURE:	120 °C		
HYDROSTATIC PRESSURE:	1354 kPa (g) in HORIZONTAL POSITION		
WELD PROCEDURE:	SMAW-16, 16.2 , SAW-45 & FCAW 40		
SHELL THICKNESS AND MATERIAL SPEC.:	19.05 mm NOM - SA - 516 – 70N		
HEADS THICKNESS AND MATERIAL SPEC.:	TOP: 18.22 mm MIN. & BTM.: 19.05 mm MIN - SA - 516 – 70N		
FINAL INSPECTION:	06/10/2013		
WELDER (S):	L1,2,5,7,8 & 9		
RADIOGRAPH:	LONG SEAM 100% PER UW-11(a),CIRC.SEAMS SPOT 85% PER UW(a)(5)(b);STAMPER RT-2		
DATE COMPLETED:	06/12/2013		
DATE SHIPPED:	06/14/2013		
AFFIDAVIT MAILED:			
U-IA DATA FORM MAILED:			
REMARKS:			

QA - 20

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 E

VESSEL TYPE: AFTER FILTER

SERIAL No: 0415

APPROVED BY QA: Arie Willemsen

CRN: W1159.2

	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	<i>AW</i> 3/5/13	<i>R</i> MAR 07.13		
Welding Procedures	<i>AW</i> 3/5/13	<i>R</i> MAR 07.13		
CRN		<i>R</i> JUN 12.13		
Welder Qualifications	<i>AW</i> 3/5/13	<i>R</i> JUN 12.13		
Out of Roundness (UG - 80)	<i>AW</i> 06.07.13	<i>R</i> JUN 07.13		
Materials	<i>AW</i> 06.17.13	<i>R</i> JUN 07.13		
Internal	<i>AW</i> 06.07.13	<i>R</i> JUN 07.13		
Dimensional	<i>AW</i> 06.12.13	<i>R</i> JUN 12.13		
Other:	-			
Repair-by-weld-procedure	-			
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	<i>AW</i> 06.12.13	<i>R</i> JUN 12.13		
Arc Strikes, Gouges	<i>AW</i> 06.12.13			
Supports	<i>AW</i> 06.12.13			
Heat Treatment	---	---		
Final	<i>AW</i> 06.12.13	<i>H</i> JUN 12.13		
Hydrostatic Test	<i>AW</i> 06.12.13	<i>H</i> JUN 12.13		
Name Plate Stamping	<i>AW</i> 06.12.13	<i>H</i> JUN 12.13		
Data Reports	<i>AW</i> 06.12.13	<i>H</i> JUN 12.13		
Paint	---	---		
Preparation for Shipment	<i>AW</i> 06.12.13			
Remarks:				

QA - 21 A

LESENA STEEL LTD

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 E

VESSEL TYPE: AFTER FILTER

SERIAL No: 0415

DIMENSIONS: 3962mm OD x 2540mm T/T

DWG. No: 32125-D-2202-01 rev.E

W. P.: 10.41 kPa (g) T.P.: 1354 kPa (g)

C.R.N. No: W1159.2

PRE-REVIEWED BY A. I. ~~2~~ MAR 02.13

DATE: FEB/4/2013

APPROVED BY QC: Av

ARIE WILLEMSSEN

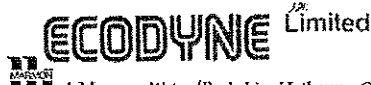
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QA - 21

INSPECTION & TEST PLAN

AFTER FILTER VESSEL

3A-F-208 F

TITLE INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 F					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
SCALE - N/A					 <small>A Marmon Water/Berkshire Hathaway Company</small> <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>				
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; Material clarifications	TM	AV	DRN	TM	11/12 2012	DWG. NO. 32125-A-4356	REV. B
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012		
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012		

W.O. 12-32

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 F Drawing Number: 32125-A-4356 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor									
No.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT										
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC		
1.	Drawings	Document Log	<ul style="list-style-type: none"> * confirm scope and the fabrication and inspection drawings are the latest revision * Calculations have been provided for approval * Pre-fabrication meeting - SNC / MEG <i>Surveillance Level 3</i> 	<p>Latest Revisions</p> <p><i>Specifications</i> 32125-A-2015 Pressure Vessel (includes 085354-3010-PV-10, 085354-3010-PV-24 & 085354-4060-PS-001) 32125-A-2017 Welding (includes 085354-3010-EW-20)</p> <p>Registered in Province of Alberta</p>	R	5/8/13	R	5/9/13							
					W	5/8/13	R	5/9/13							
					W	5/8/13	W	5/9/13	W						
2.	Weld Procedures	ASME Section IX	<ul style="list-style-type: none"> * confirm that the weld procedures, weld repair procedures and procedure maps, used for the fabrication, have been approved * randomly check that the approved weld procedures are being applied - check amperage and voltage during operation 	Approval records / stamp for the procedures	W	5/8/13	R	5/9/13	R						yes
					W	5/8/13	R	5/9/13	R						

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL
3A-F-208 F
Drawing Number: 32125-A-4356
REVISION: B

TC: Test Certificate Required

H: Hold Point (do not fab past this point until accepted)
W: Witness Point (notification is required per the PO)
R: Review of Documents
V: Verification that the work has been satisfactorily completed
M: Monitor

NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Welder Qualification	ASME Section IX	* all pressure containing welds have been identified with the welder symbol (either through the physical stamping of the weld or recording a welder identification map) {welder maps are to be submitted with the final documentation} * confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records	Welder Symbol Welder Qualification / welder qualification continuity log	W	5/10/13	R	5/9/13	R	5/9/13	5/9/13	5/9/13	yes
					R	5/10/13	R	5/9/13	R	5/9/13	5/9/13	5/9/13	

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 F Drawing Number: 32125-A-4356 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
4.	Materials	Detail Drawing	* confirm that all materials are in accordance with the drawing requirements * all vessel materials, including attachments, have traceable material test reports - normalized plate - confirm chemical & mechanical properties △	Material Test Reports △ MTC 3.1B EN10204 ASME Section II Lift lug materials to be suitable for -45° C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W	6/17/13	R	5-9/13	R	5/9/13			yes
					W	6/17/13	R	5-9/13	R	5/9/13			
5.	Vessel Heads	Drawing	* confirm that the vessel heads are as detailed in the drawing - thickness has been checked for conformance to the calculations and drawing - report any differences to Ecodyne immediately * the head manufacturer has provided certification and Data Report	ASME Section VIII Certificate of Conformance U-2A (2-piece heads)	W	6/17/13	R	5-9/13	R	5/9/13			-
					W	6/17/13	R	5-9/13	R	5/9/13			yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 F Drawing Number: 32125-A-4356 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
No.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
6.	Fabrication Fit-up	ASME	* misalignment, as a result of variation in the thickness of the head to the shell, has a 3:1 taper when greater than allowable	ASME Section VIII									
a	* Strainer plate has been welded & drilled in accordance with drawing			Nozzles are to be located clear of vessel long & circ seams	W	5/17/13	M		M/V		RT 5/9/13		
b	* Top & Bottom heads laid out and nozzles fit & welded		* the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33		W	5/17/13	M		M/V		RT 5/9/13		
c	* Shell plate rolled to match the diameter of the heads and the long seam welded		* full penetration welding is required for the two piece strainer plate					5-9-13					
d	* Fit and weld the shell course to the head				W	5/17/13	V		M/V		RT 5/9/13		
e	* Strainer plate fit & full penetration welded to the shell												
f	* fit & weld shell repads and nozzles												
g	* fit closing head to shell section												
h	* fit legs, clips, etc.												

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 F Drawing Number: 32125-A-4356 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
7.	Weld Profile	ASME	* confirm that the weld profile and reinforcement are in accordance with UW 35 * all weld defects and spatter has been removed * all pressure component edges have a minimum radius of 3 mm * all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted) * leg attachment weld is carried around to the inside of the flanges	ASME Section VIII	W	6/17/13	M	6/17/13	M/V		6/17/13		
					W	6/17/13	M		M/V		6/17/13		
					W	6/17/13	M		M/V		6/17/13		
					W	6/17/13	M	6/24/13	M/V		6/17/13		
					W	6/17/13	M		M/V		6/17/13		

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 F Drawing Number: 32125-A-4356 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT									
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
8.	Visual & Dimensions	Drawings	* all drawing dimensions have been checked - confirm over-all dimensions - nozzle pipe schedules are per the calculations - nozzles and pads are in the correct elevation and orientation - projection is correct - bolt hole rotation and hole number is correct - nozzles are level - strainer plate thickness & hole locations are as detailed - clips are as detailed and in the correct orientation and elevation - anchor bolt hole locations are correct	* ASME Code Drawing tolerances	W	06/24/13	W	7/6/24/13	W					yes

NOT ON ON
AVR-00036
INS. 24/13

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 F Drawing Number: 32125-A-4356 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
9.	NDE	Drawing	* All NDE has been performed in accordance with the Code and calculations including all repairs - RT to include all joint intersections plus additional spot in each long & circ & 100% of long seam of nozzles fabricated from rolled plate - MPT lift lug welds * NDE technicians are qualified to the applicable association and have current validation - interpretation has been performed by a minimum of CGSB & SNT Level II technician in the appropriate NDE method	ASME Section VIII ASME Section V Production Hardness testing is not required	W	6/25/13	V/R	6/24/13	M/R	6/24/13			yes
10. a	Hydrostatic Test	Drawings	* Test pressure and temperature are in compliance with UG 99 - test duration min of 1 hour	ASME Section VIII	W	6/27/13	V/R		W	6/26/13			yes
b	Pneumatic Test	drawing	* Reinforcing pads with weep holes are soap / air tested - two weep holes required on nozzles greater than 10" - fabricator to provide 3" - 1/4" diameter nipples in weep holes		W	6/27/13	V/R		W	6/27/13			yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 F Drawing Number: 32125-A-4356 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
11.	Preparation for Shipment to the Coating Shop (note that coating, installation of internals and insulation are to be completed at the coating shop)	Drawings	<ul style="list-style-type: none"> * all interior hardware has been supplied as detailed on the drawings (including resin removal blind flange & hardware) * vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification * vessel has been prepared for shipment - flanges have been protected from impact with plastic, metal or 6mm plywood covers attached in a minimum of 4 locations - vessel has been properly supported 	Quality Requirements 32125-A-4200 Nameplate in SI units	W	6/27/13	V		W		W	6/26/13	
					W	6/27/13	V		W		W		
					W	6/27/13	V		W		W		

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 F Drawing Number: 32125-A-4356 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT									
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
12.	Documents	Purchase Req	* all quality documents have been checked for accuracy and completeness with the following documents submitted to Ecodyne - ASME Data Reports - ABSA Letter - Nameplate copy - MTR / Map - Welder Qualification - NDE reports - Visual & Dimensional report - Hydro report/chart - ITP & Traveler - NCR & resolution	Drawings & Code Ecodyne is responsible for assembly of documentation in accordance with project requirements	W	6-27-13	R		M/R					yes
13.	Inspection Release to the Coating Shop (for coating & installation of inlet & strainers)	Purchase Order	* confirm that all work has been done per the purchase order and all referenced drawings and specifications - ITP signed off	Drawings & Code	H	6-27-13	H		H					yes

LESENA STEEL LTD

PROGRAM DOCUMENTATION

CUSTOMER:	ECODYNE LTD.	Date:	MARCH / 05 //2013
JOB No:	12-32 F	P. O. No:	321253503
OWNER:	MEG ENERGY CORP.		
SERIAL No:	0416		
C.R.N. No:	W1159.2	N.B.:	-----
DRAWING No:	32125-D-2202-01 REV. E		
VESSEL TYPE:	AFTER FILTER	EQUIPMENT No:	3A-F-208 F
CODE:	ASME SECTION VIII, DIV.1, 2010 EDITION + 2011 ADDENDUM		
DESIGN PRESSURE:	1041 kPa (g) & F.V	M.D.M.T.:	-29 °C @ 103 kPa (g)
DESIGN TEMPERATURE:	120 °C		
HYDROSTATIC PRESSURE:	1354 kPa (g) in HORIZONTAL POSITION		
WELD PROCEDURE:	SMAW-16, 16.2 , SAW-45 & FCAW 40		
SHELL THICKNESS AND MATERIAL SPEC.:	19.05 mm NOM - SA - 516 – 70N		
HEADS THICKNESS AND MATERIAL SPEC.:	TOP: 18.22 mm MIN. & BTM.: 19.05 mm MIN - SA - 516 – 70N		
FINAL INSPECTION:	06/27/2013		
WELDER (S):	L1,2,4,5,6,7,8 & 9		
RADIOGRAPH:	LONG SEAM 100% PER UW-11(a),CIRC.SEAMS SPOT 85% PER UW(a)(5)(b);STAMPER RT-2		
DATE COMPLETED:	06/27/2013		
DATE SHIPPED:	06/28/2013		
AFFIDAVIT MAILED:			
U-IA DATA FORM MAILED:			
REMARKS:			

QA - 20

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 F

VESSEL TYPE: AFTER FILTER

SERIAL No: 0416

APPROVED BY QA: Arie Willemsen

CRN: W1159.2

	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	<i>AW</i> 3/5/13	<i>RZ</i> MAR 07.13		
Welding Procedures	<i>AW</i> 3/5/13	<i>RZ</i> MAR 07.13		
CRN	<i>AW</i> 06.12.13	<i>RZ</i> JUN 27.13		
Welder Qualifications	<i>AW</i> 3/5/13	<i>RZ</i> JUN 27.13		
Out of Roundness (UG - 80)	<i>AW</i> 06.14.13	<i>VS</i> JUN 18.13		
Materials	<i>AW</i> 06.18.13	<i>RZ</i> JUN 18.13		
Internal	<i>AW</i> 06.18.13	<i>VS</i> JUN 18.13		
Dimensional	<i>AW</i> 06.19.13	<i>VS</i> JUN 27.13		
Other:				
Repair-by-weld-procedure				
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	<i>AW</i> 06.27.13	<i>RZ</i> JUN 27.13		
Arc Strikes, Gouges	<i>AW</i> 06.27.13			
Supports	<i>AW</i> 06.27.13			
Heat Treatment	---	---		
Final	<i>AW</i> 06.27.13	<i>VS</i> JUN 27.13		
Hydrostatic Test	<i>AW</i> 06.27.13	<i>VS</i> JUN 27.13		
Name Plate Stamping	<i>AW</i> 06.27.13	<i>VS</i> JUN 27.13		
Data Reports	<i>AW</i> 06.27.13	<i>VS</i> JUN 27.13		
Paint	---	---		
Preparation for Shipment	<i>AW</i> 06.27.13			
Remarks:				

QA - 21 A

LESENA STEEL LTD

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 F

VESSEL TYPE: AFTER FILTER

SERIAL No: 0416

DIMENSIONS: 3962mm OD x 2540mm T/T

DWG. No: 32125-D-2202-01 rev E

W. P.: 1041 kPa (g) T.P.: 1354 kPa (g)

C.R.N. No: W1159.2

PRE-REVIEWED BY A. I. ~~Zec~~ H207.13

DATE: FEB/4/2013

APPROVED BY QC: *AN*

ARIE WILLEMSSEN


[illegible]

QA - 21

INSPECTION & TEST PLAN

AFTER FILTER VESSEL

3A-F-208 G

TITLE INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 G						Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02			
SCALE - N/A						 <small>A Marmon Water/Berkshire Hathaway Company</small>			
<small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>						DWG. NO. 32125-A-4357			
REV						REV. B			

REV	DATE	REMARKS	BY	CHKD	APPD	TM	DATE
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; Material clarifications	TM	AV	DRN	TM	11/12 2012
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012

W. O. 12-32

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 G Drawing Number: 32125-A-4357 REVISION: B				TC: Test Certificate Required H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor										
No.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT									
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
1.	Drawings	Document Log <div>△</div>	* confirm scope and the fabrication and inspection drawings are the latest revision * Calculations have been provided for approval * Pre-fabrication meeting - SNC / MEG Surveillance Level 3	Latest Revisions Specifications 32125-A-2015 Pressure Vessel (includes 085354-3010-PV-10, 085354-3010-PV-24 & 085354-4060-PS-001) 32125-A-2017 Welding (includes 085354-3010-EW-20) Registered in Province of Alberta	R	5-9-13	R	5-9-13						-
					W	5-9-13	R	5-9-13						
					W	5-9-13	W		W		5-9-13			
2.	Weld Procedures	ASME Section IX	* confirm that the weld procedures, weld repair procedures and procedure maps, used for the fabrication, have been approved * randomly check that the approved weld procedures are being applied - check amperage and voltage during operation	Approval records / stamp for the procedures	W	5-9-13	R	5-9-13	R		5-9-13			yes
					W	5-9-13	R	5-9-13	R		5-9-13			

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 G Drawing Number: 32125-A-4357 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Welder Qualification	ASME Section IX	* all pressure containing welds have been identified with the welder symbol (either through the physical stamping of the weld or recording a welder identification map) {welder maps are to be submitted with the final documentation} * confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records	Welder Symbol Welder Qualification / welder qualification continuity log	W	5/13/13	R	7	R	5/9/13			yes
					R	5/13/13	R	5-9/13	R	5/9/13			

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 G Drawing Number: 32125-A-4357 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
4.	Materials	Detail Drawing	* confirm that all materials are in accordance with the drawing requirements * all vessel materials, including attachments, have traceable material test reports - normalized plate - confirm chemical & mechanical properties Δ	Material Test Reports Δ MTC 3.1B EN10204 ASME Section II Lift lug materials to be suitable for -45° C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W	6-14-13	R	5-9-13	R	5-9-13	MEG	5-9-13	yes
5.	Vessel Heads	Drawing	* confirm that the vessel heads are as detailed in the drawing - thickness has been checked for conformance to the calculations and drawing - report any differences to Ecodyne immediately * the head manufacturer has provided certification and Data Report	ASME Section VIII Certificate of Conformance U-2A (2-piece heads)	W	6-14-13	R	5-9-13	R	5-9-13	MEG	5-9-13	-
					W	6-14-13	R	5-9-13	R	5-9-13	MEG	5-9-13	yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 G Drawing Number: 32125-A-4357 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
No.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
6.	Fabrication Fit-up	ASME	* misalignment, as a result of variation in the thickness of the head to the shell, has a 3:1 taper when greater than allowable	ASME Section VIII									
a	* Strainer plate has been welded & drilled in accordance with drawing			Nozzles are to be located clear of vessel long & circ seams	W	06/14/13	M		M/V		RT 5/9/13		
b	* Top & Bottom heads laid out and nozzles fit & welded		* the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33		W	06/14/13	M	5-9/13	M/V		RT 5/9/13		
c	* Shell plate rolled to match the diameter of the heads and the long seam welded		* full penetration welding is required for the two piece strainer plate		W	06/14/13	V		M/V		RT 5/9/13		
d	* Fit and weld the shell course to the head												
e	* Strainer plate fit & full penetration welded to the shell												
f	* fit & weld shell repads and nozzles												
g	* fit closing head to shell section												
h	* fit legs, clips, etc.												

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 G Drawing Number: 32125-A-4357 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
7.	Weld Profile	ASME	* confirm that the weld profile and reinforcement are in accordance with UW 35 * all weld defects and spatter has been removed * all pressure component edges have a minimum radius of 3 mm * all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted) * leg attachment weld is carried around to the inside of the flanges	ASME Section VIII	W	6/18/13	M	6/18/13	M/V		RT 5/9/13		-
					W	6/18/13	M		M/V		RT 5/9/13		
					W		M		M/V		RT 5/9/13		
					W	6/18/13	M	6-9/13	M/V		RT 5/9/13		
					W	6/18/13	M		M/V		RT 6/20/13		

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 G Drawing Number: 32125-A-4357 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT									
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
8.	Visual & Dimensions	Drawings	* all drawing dimensions have been checked - confirm over-all dimensions - nozzle pipe schedules are per the calculations - nozzles and pads are in the correct elevation and orientation - projection is correct - bolt hole rotation and hole number is correct - nozzles are level - strainer plate thickness & hole locations are as detailed - clips are as detailed and in the correct orientation and elevation - anchor bolt hole locations are correct	* ASME Code Drawing tolerances	W	6/18/13	W	6-19/13	W					yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 G Drawing Number: 32125-A-4357 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
9.	NDE	Drawing	* All NDE has been performed in accordance with the Code and calculations including all repairs - RT to include all joint intersections plus additional spot in each long & circ & 100% of long seam of nozzles fabricated from rolled plate - MPT lift lug welds * NDE technicians are qualified to the applicable association and have current validation - interpretation has been performed by a minimum of CGSB & SNT Level II technician in the appropriate NDE method	ASME Section VIII ASME Section V Production Hardness testing is not required	W	6/19/13	V/R	6/19/13	M/R	6/20/13			yes
10. a	Hydrostatic Test	Drawings	* Test pressure and temperature are in compliance with UG 99 - test duration min of 1 hour	ASME Section VIII	W	6/20/13	V/R		W	6/20/13			yes
b	Pneumatic Test	drawing	* Reinforcing pads with weep holes are soap / air tested - two weep holes required on nozzles greater than 10" - fabricator to provide 3" - 1/4" diameter nipples in weep holes		W	6/20/13	V/R		W	6/20/13			yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 G Drawing Number: 32125-A-4357 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
11.	Preparation for Shipment to the Coating Shop (note that coating, installation of internals and insulation are to be completed at the coating shop)	Drawings	<ul style="list-style-type: none"> * all interior hardware has been supplied as detailed on the drawings (including resin removal blind flange & hardware) * vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification * vessel has been prepared for shipment - flanges have been protected from impact with plastic, metal or 6mm plywood covers attached in a minimum of 4 locations - vessel has been properly supported 	Quality Requirements 32125-A-4200 Nameplate in SI units	W	06-20-13	V		W		W	6/21/13	
					W	06-20-13	V		W		W		
					W	06-20-13	V		W		W		

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 G Drawing Number: 32125-A-4357 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	INSPECTION & CONTROL POINT								
					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
12.	Documents	Purchase Req	* all quality documents have been checked for accuracy and completeness with the following documents submitted to Ecodyne - ASME Data Reports - ABSA Letter - Nameplate copy - MTR / Map - Welder Qualification - NDE reports - Visual & Dimensional report - Hydro report/chart - ITP & Traveler - NCR & resolution	Drawings & Code Ecodyne is responsible for assembly of documentation in accordance with project requirements	W	6/26/13	R		M/R		6/20/13		yes
13.	Inspection Release to the Coating Shop (for coating & installation of inlet & strainers)	Purchase Order	* confirm that all work has been done per the purchase order and all referenced drawings and specifications - ITP signed off	Drawings & Code	H	6/20/13	H		H		6/20/13		yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

AFTER FILTER VESSEL 3A-F-208 G Drawing Number: 32125-A-4357 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
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					FAB	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
12.	Documents	Purchase Req	* all quality documents have been checked for accuracy and completeness with the following documents submitted to Ecodyne - ASME Data Reports - ABSA Letter - Nameplate copy - MTR / Map - Welder Qualification - NDE reports - Visual & Dimensional report - Hydro report/chart - ITP & Traveler - NCR & resolution	Drawings & Code Ecodyne is responsible for assembly of documentation in accordance with project requirements	W	6/26/13	R			M/R	6/20/13			yes
13.	Inspection Release to the Coating Shop (for coating & installation of inlet & strainers)	Purchase Order	* confirm that all work has been done per the purchase order and all referenced drawings and specifications - ITP signed off	Drawings & Code	H	6/20/13	H			H	6/20/13			yes

LESENA STEEL LTD

PROGRAM DOCUMENTATION

CUSTOMER:	ECODYNE LTD.	Date:	MARCH / 05 //2013
JOB No:	12-32 G	P. O. No:	321253503
OWNER:	MEG ENERGY CORP.		
SERIAL No:	0417		
C.R.N. No:	W1159.2	N.B.:	-----
DRAWING No:	32125-D-2202-01 REV. E		
VESSEL TYPE:	AFTER FILTER	EQUIPMENT No:	3A-F-208 G
CODE:	ASME SECTION VIII, DIV.1, 2010 EDITION + 2011 ADDENDUM		
DESIGN PRESSURE:	1041 kPa (g) & F.V	M.D.M.T.:	-29 °C @ 103 kPa (g)
DESIGN TEMPERATURE:	120 °C		
HYDROSTATIC PRESSURE:	1354 kPa (g) in HORIZONTAL POSITION		
WELD PROCEDURE:	SMAW-16, 16.2 , SAW-45 & FCAW 40		
SHELL THICKNESS AND MATERIAL SPEC.:	19.05 mm NOM - SA - 516 - 70N		
HEADS THICKNESS AND MATERIAL SPEC.:	TOP: 18.22 mm MIN. & BTM.: 19.05 mm MIN - SA - 516 - 70N		
FINAL INSPECTION:	06/20/2013		
WELDER (S):	L1,2,4,5,7,8 & 9		
RADIOGRAPH:	LONG SEAM 100% PER UW-11(a),CIRC.SEAMS SPOT 85% PER UW(a)(5)(b);STAMPER RT-2		
DATE COMPLETED:	06/20/2013		
DATE SHIPPED:	06/21/2013		
AFFIDAVIT MAILED:			
U-IA DATA FORM MAILED:			
REMARKS:			

QA - 20

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD.

JOB No: 12-32 G

VESSEL TYPE: AFTER FILTER

SERIAL No: 0417

APPROVED BY QA: Arie Willemssen

CRN: W1159.2

	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	<i>Av</i> 3/5/13	<i>R</i> MAR 07.13		
Welding Procedures	<i>Av</i> 3/5/13	<i>R</i> MAR 02.13		
CRN	<i>Av</i> 06.20.13	<i>R</i> JUN 20.13		
Welder Qualifications	<i>Av</i> 3/5/13	<i>R</i> JUN 20.13		
Out of Roundness (UG - 80)	<i>Av</i> 06.18.13	<i>R</i> JUN 18.13		
Materials	<i>Av</i> 06.18.13	<i>R</i> JUN 18.13		
Internal	<i>Av</i> 06.18.13	<i>R</i> JUN 18.13		
Dimensional	<i>Av</i> 06.19.13	<i>R</i> JUN 20.13		
Other:				
Repair-by-weld-procedure				
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	<i>Av</i> 06.19.13	<i>R</i> JUN 20.13		
Arc Strikes, Gouges	<i>Av</i> 06.19.13			
Supports	<i>Av</i> 06.19.13			
Heat Treatment	---	---		
Final	<i>Av</i> 06.20.13	<i>R</i> JUN 20.13		
Hydrostatic Test	<i>Av</i> 06.20.13	<i>R</i> JUN 20.13		
Name Plate Stamping	<i>Av</i> 06.20.13	<i>R</i> JUN 20.13		
Data Reports	<i>Av</i> 06.20.13	<i>R</i> JUN 20.13		
Paint	---	---		
Preparation for Shipment	<i>Av</i> 06.20.13			
Remarks:				

QA - 21 A

LESENA STEEL LTD

TRAVELER / QUALITY CONTROL CHECK LIST


CUSTOMER: ECODYNE LTD.

JOB No: 12-32 G

VESSEL TYPE: AFTER FILTER

SERIAL No: 0417

DIMENSIONS: 3962mm OD x 2540mm T/T

DWG. No: 32125-D-2202-01 rev. 

W. P.: 1041 kPa (g) T.P.: 1354 kPa (g).

C.R.N. No: W1159.2

PRE-REVIEWED BY A. I. 1910202.13

DATE: FEB/4/2013

APPROVED BY QC:

ARIE WILLEMSSEN


[illegible]

QA - 21

INSPECTION & TEST PLAN

LINING & COATING

Filter & WAC Vessels

TITLE INSPECTION & TEST PLAN LINING & COATING Filter & WAC Vessels					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
					SCALE - N/A			 ECODYNE Limited A Marmon Water/Berkshire Hathaway Company <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>	
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; MEG shipping protection proc	TM	AV	DRN	TM	11/12 2012	DWG. NO. 32125-A-4501	REV. B
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012		
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012		

INSPECTION & TEST PLAN



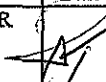

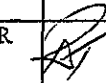


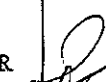
ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: POP-5675-02

LINING & COATING
Filter & WAC Vessels
DRAWING NUMBER: 32125-A-4501
REVISION: B

TC: Test Certificate Required

H: Hold Point (do not fab past this point until accepted)
W: Witness Point (notification required per PO)
R: Review of Documents
V: Verification that work has been satisfactorily completed
M: Monitor

No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point							
					APP	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date
1.	Drawings & Specifications	Document Log △	* confirm that the fabrication and inspection drawings are the latest revision - SNC/MEG Surveillance Level 3	Latest Revision Specification: 32125-A-2020 (RL spec) (includes 085354-3010-RL-60 & 085354-3010-RL-70) 32125-A-2013 (coating spec) (includes 085354-3010-PC-50) NACE	R		R 		R 	5/5/2013		-
2.	Materials	Detail Drawings	* confirm that the material is as detailed on the drawing * confirm that the materials are not past expiry dates and do not appear unusable	Material Identification on Product Labels	W		R		R 	5/5/2013		-
					W		R 		R 	5/5/2013		-

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

LINING & COATING Filter & WAC Vessels DRAWING NUMBER: 32125-A-4501 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					APP	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Interior Surface Preparation for WAC Vessels	Drawings Devon spec NACE	* Visual inspection of interior carbon steel areas to confirm all areas to be lined have been blasted - blast profile has been checked for compliance to the rubber / coating manufacturer's data sheet & drawing / specification - record the results of the profile comparator * Daily log has been maintained to record all pertinent information	SSPC SP-5	W		R		M/R	<i>[Signature]</i> 5/9/13			yes
					W		R		M/R	<i>[Signature]</i> 5/9/13			

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

LINING & COATING Filter & WAC Vessels DRAWING NUMBER: 32125-A-4501 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point									
					APP	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
4.	Interior Lining of WAC Vessels	Drawings	<ul style="list-style-type: none"> * Confirm the material by checking documentation and batch numbers * lining thickness has been confirmed <ul style="list-style-type: none"> - 1/4 inch * Visual inspection of the lined surfaces with all detrimental defects (blisters, voids, etc.) corrected <ul style="list-style-type: none"> - lining has completely covered all interior surfaces that are not alloy * Continuity of the entire lining checked with a High Voltage Spark Tester (voltage per data sheet) <ul style="list-style-type: none"> - Pin Hole Free * Check the hardness of the lining is in conformance with the data sheet * Record critical information in daily log 	Rubber Data Sheets N/A	V/R	8	R		M/R					
					W		V		M/R					
					W		W		W					
					W		W		W				yes	
					W		V/R		V/W					
					W		R		R					

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

LINING & COATING Filter & WAC Vessels DRAWING NUMBER: 32125-A-4501 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor							
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					APP	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
5.	Exterior Surface Preparation of Filter & WAC Vessels	Drawings	* Confirm material by checking documentation and batch numbers * Visual inspection to confirm all areas have been blasted to the appropriate blast condition * Blast profile has been checked for compliance to the equipment detail drawing & paint manufacturer's data sheet - record the results of the profile comparator * Daily log has been maintained to record all pertinent information	SSPC SP10	W	<i>P_m</i>	V		R/V	<i>AT</i>			
				Paint Manufacturer Data Sheets	W	<i>P_m</i>	R		R/V	<i>AT</i>			
					W	<i>P_m</i>	R		R/V	<i>AT</i>			
					W	<i>P_m</i>	R		R/V	<i>AT</i>			
6.	Exterior lining & coating of Filter & WAC Vessels	Drawings	*Visual inspection to confirm all areas are free of detrimental paint defects and inclusions *Thickness checked in accordance with SSPC PA-2. * Daily log has been maintained to record all pertinent information (see above)	Lining & coating Data Sheets	W	<i>P_m</i>	W		W	<i>AT</i>		yes	
				SSPC PA-2	W	<i>P_m</i>	R		M/V	<i>AT</i>			
				Drawings/ Specification	W	<i>P_m</i>	R		R/V	<i>AT</i>			

Sept. 4/13 (7) After Filters *P_m*

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02


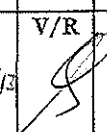

LINING & COATING Filter & WAC Vessels DRAWING NUMBER: 32125-A-4501 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor									
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point									
					APP	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
5.	Vessel Internal Installation for Filters & WAC Vessels	Drawings	* Inlet hub/lateral distributor is installed in accordance with the assembly detail drawings. - all hardware and gasket material is correct and assembled as detailed * Strainers are assembled as detailed - Filter Vessels with stainless steel / WAC Vessels with PVDF (Kynar) - confirm proper torque and seat - confirm strainers are properly seated (T-Bolt properly engages in strainer hole) with a maximum gap of 0.010" between the strainer plate and the strainer cap	Drawings - proper assembly & hardware Connections that are located in the media zone that have openings greater than 0.010" are to be corrected	W	9/24/13	W		W					
					W	9/24/13	W		W					

9/24/13 After Filters

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02



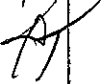


LINING & COATING Filter & WAC Vessels DRAWING NUMBER: 32125-A-4501 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point									
					APP	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
8.	Preparation for Shipment	Drawings	* Vessels are not shipping to Ecodyne (i.e. shipping direct to site after insulating) - flange faces of Filter Vessels are coated with an easily removable rust preventative coating (not applicable for lined WAC Vessels) - all flanges are protected with blind flanges - all hardware has been supplied and properly assembled as detailed on the drawings - sight glasses have been installed and hardware with proper torque (note must be checked again after transport) - interior is free from debris (Filter Vessels bare & clean / WAC Vessels lined) - vessel identification markings, nameplate, etc. have been checked for accuracy - repad weep holes have extensions installed - equipment has been properly supported to prevent damage during shipping	32125-A-4200 & MEG shipping protection procedure 085354-3010-PG-10	W	 9/24/13	V/R		W					-

9/24/13 After Filters *Pn*

INSPECTION & TEST PLAN

ECODYNE Limited


PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

LINING & COATING Filter & WAC Vessels DRAWING NUMBER: 32125-A-4501 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point									
					APP	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
9.	Documentation	Purchase Requisition	* all quality documents have been checked for accuracy and completeness with the following documents provided to Ecodyne for the final Quality Dossier - Lining & coating certification - ITP and Checklists	Drawings & Standards	W	 9/24/13 After Filter	R			M/R				yes
10.	Inspection Release	Purchase Order	* confirm that all work identified in the purchase order, drawings, specifications and ITP have been satisfactorily completed - ITP signed	Purchase Order	H	 9/24/13 After Filter	H			H				-

INSPECTION & TEST PLAN

INSULATION - Filter & ~~WAC~~ Vessels

100% July 26 2013
VESSEL 208A

TITLE INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
					SCALE - N/A			 ECODYNE Limited A Marmon Water/Berkshire Hathaway Company <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>	
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; MEG shipping protection proc	TM	AV	DRN	TM	11/12 2012		
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012		
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012	DWG. NO. 32125-A-4502	
								REV.	B

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels Drawing Number: 32125-A-4502 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
1.	Drawings & Specifications	Document Log △	* confirm that the fabrication and inspection drawings are the latest revision - SNC/MEG Surveillance Level 3	Latest Revision Specifications 32125-A-2017 (includes 085354-3010- IN-00)	R	SB June 18 2013	R	6-18/13	R			30/7/13	
2.	Materials	Detail Drawings	* all insulation, caulking, jacketing and hardware materials in accordance with specification - 38mm mineral wool & insulation blanket for manways - Filter Vessels with corrugated aluminum - 0.5mm thick / WAC Vessels with stainless steel cladding - 0.25mm thick - ss clips, bands, screws (Robertson head) - all insulation materials shall have a flame spread classification not to exceed 25 when test in accordance with ASTM E84	Material Identification on Product Labels & data sheets	R/W	SB June 15 2013	R	6-18/13	R			30/7/13	yes

INSPECTION & TEST PLAN

ECODYNE Limited


PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels DRAWING NUMBER: 32125-A-4502 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor							
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Installation	Drawings	* Installation in accordance with specification	specification	W	SB Jul 18 2013	R 9/29/13		M/V		SA 30/7/13		
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W	SB Jul 26 2013	V/R 9/29/13		M/V		SA 30/7/13		
5.	Preparation for Shipment	Drawings	* Vessels equipment properly supported and suitably protected	32125-A-4200 & MEG shipping protection procedure 085354-3010-PG-10	W	SB Jul 26 2013	V/R 9/29/13		W		SA		
6.	Documentation	Purchase Requisition	* all quality documents have been checked for accuracy and completeness with copies of the following documents provided to Ecodyne - Material certifications - ITP	Drawings & Code	W	SB Jul 26 2013	R 9/29/13		R		SA		yes
7.	Inspection Release	Purchase Order	* confirm that all work identified in the purchase order, drawings, specifications and ITP have been satisfactorily completed - ITP signed	Purchase Order	H	SB Jul 26 2013	H 9/29/13		H		SA		

INSPECTION & TEST PLAN

INSULATION – Filter & WAC Vessels

100% Jun 26 2013
VESSEL 208 B

TITLE INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02					
					SCALE - N/A			 ECODYNE Limited A Marmon Water/Berkshire Hathaway Company <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>		
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; MEG shipping protection proc	TM	AV	DRN	TM	11/12 2012	DWG. NO. 32125-A-4502		REV. B
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012			
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012			

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MBG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels Drawing Number: 32125-A-4502 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor						
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point							
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date
1.	Drawings & Specifications	Document Log △	* confirm that the fabrication and inspection drawings are the latest revision - SNC/MEG Surveillance Level 3	Latest Revision Specifications 32125-A-2017 (includes 085354-3010-IN-00)	R	SB JUNE 18 2013	R	6/25/13	R	30/7/13		
2.	Materials	Detail Drawings	* all insulation, caulking, jacketing and hardware materials in accordance with specification - 38mm mineral wool & insulation blanket for manways - Filter Vessels with corrugated aluminum - 0.5mm thick / WAC Vessels with stainless steel cladding - 0.25mm thick - ss clips, bands, screws (Robertson head) - all insulation materials shall have a flame spread classification not to exceed 25 when test in accordance with ASTM E84	Material Identification on Product Labels & data sheets	R/W	SB JUL 15 2013	R	6/25/13	R	30/7/13	yes	

INSPECTION & TEST PLAN

ECODYNE Limited


PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels DRAWING NUMBER: 32125-A-4502 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Installation	Drawings	* Installation in accordance with specification	specification	W	SB JUL 18, 2013	R	7/29/13	M/V			30/7/13	
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W	SB JUL 26, 2013	V/R	7/29/13	M/V			30/7/13	
5.	Preparation for Shipment	Drawings	* Vessels equipment properly supported and suitably protected	32125-A-4200 MEG shipping protection procedure 085354-3010-PG-10	W	SB JUL 26, 2013	V/R	7/29/13	W				
6.	Documentation	Purchase Requisition	* all quality documents have been checked for accuracy and completeness with copies of the following documents provided to Ecodyne - Material certifications - ITP	Drawings & Code	W	SB JUL 26, 2013	R	7/29/13	R				yes
7.	Inspection Release	Purchase Order	* confirm that all work identified in the purchase order, drawings, specifications and ITP have been satisfactorily completed - ITP signed	Purchase Order	H	SB JUL 26, 2013	H	7/29/13	H				

INSPECTION & TEST PLAN

INSULATION - Filter & WAC Vessels

100% COMPLETE AUGUST 1 2013
VESSEL 208C

TITLE INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
SCALE - N/A					 ECODYNE Limited <small>A Marmon Water/Berkshire Hathaway Company</small> <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>				
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; MEG shipping protection proc	TM	AV	DRN	TM	11/12 2012	DWG. NO. 32125-A-4502	REV. B
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012		
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012		

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels Drawing Number: 32125-A-4502 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor									
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point									
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
1.	Drawings & Specifications	Document Log △	* confirm that the fabrication and inspection drawings are the latest revision - SNC/MEG Surveillance Level 3	Latest Revision Specifications 32125-A-2017 (includes 085354-3010-IN-00)	R	SB June 18 2013	R	8-18/13	R	AT				
2.	Materials	Detail Drawings	* all insulation, caulking, jacketing and hardware materials in accordance with specification - 38mm mineral wool & insulation blanket for manways - Filter Vessels with corrugated aluminum - 0.5mm thick / WAC Vessels with stainless steel cladding - 0.25mm thick - ss clips, bands, screws (Robertson head) - all insulation materials shall have a flame spread classification not to exceed 25 when test in accordance with ASTM E84	Material Identification on Product Labels & data sheets	R/W	SB June 15 2013	R	8-18/13	R	AT				yes

INSPECTION & TEST PLAN

ECODYNE Limited


PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels DRAWING NUMBER: 32125-A-4502 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Installation	Drawings	* Installation in accordance with specification	specification	W	JUL 29 2013	R	8-18/13	M/V				
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W	AUG 1 2013	V/R	8-18/13	M/V				
5.	Preparation for Shipment	Drawings	* Vessels equipment properly supported and suitably protected	32125-A-4200 MEG shipping protection procedure Δ 085354-3010-PG-10	W	AUG 1 2013	V/R	8-18/13	W				
6.	Documentation	Purchase Requisition	* all quality documents have been checked for accuracy and completeness with copies of the following documents provided to Ecodyne - Material certifications - ITP	Drawings & Code	W	AUG 1 2013	R	8-18/13	R				yes
7.	Inspection Release	Purchase Order	* confirm that all work identified in the purchase order, drawings, specifications and ITP have been satisfactorily completed - ITP signed	Purchase Order	H	AUG 1 2013	H	8-18/13	H				

INSPECTION & TEST PLAN

INSULATION – Filter & WAC Vessels

100% COMPLETE AUGUST 8 2013
VESSEL 208D

TITLE INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
					SCALE - N/A			 ECODYNE Limited A Marmon Water/Berkshire Hathaway Company <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>	
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; MEG shipping protection proc	TM	AV	DRN	TM	11/12 2012		
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012	DWG. NO. 32125-A-4502	REV. B
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012		

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels Drawing Number: 32125-A-4502 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point									
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
1.	Drawings & Specifications	Document Log △	* confirm that the fabrication and inspection drawings are the latest revision - SNC/MEG Surveillance Level 3	Latest Revision Specifications 32125-A-2017 (includes 085354-3010-IN-00)	R	SB Juw R 2013	R 7-18/13		R	7-18/13				
2.	Materials	Detail Drawings	* all insulation, caulking, jacketing and hardware materials in accordance with specification - 38mm mineral wool & insulation blanket for manways - Filter Vessels with corrugated aluminum - 0.5mm thick / WAC Vessels with stainless steel cladding - 0.25mm thick - ss clips, bands, screws (Robertson head) - all insulation materials shall have a flame spread classification not to exceed 25 when test in accordance with ASTM E84	Material Identification on Product Labels & data sheets	R/W	SB Juw R 2013	R 7-18/13		R	7-18/13				yes

INSPECTION & TEST PLAN

ECODYNE Limited


PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels DRAWING NUMBER: 32125-A-4502 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Installation	Drawings	* Installation in accordance with specification	specification	W	AUG 6 2013	R	8-6/13	M/V				
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W	AUG 8 2013	V/R	8-6/13	M/V				
5.	Preparation for Shipment	Drawings	* Vessels equipment properly supported and suitably protected	32125-A-4200 & MEG shipping protection procedure 085354-3010-PG-10	W	AUG 8 2013	V/R	8-6/13	W				
6.	Documentation	Purchase Requisition	* all quality documents have been checked for accuracy and completeness with copies of the following documents provided to Ecodyne - Material certifications - ITP	Drawings & Code	W	AUG 8 2013	R	8-6/13	R				yes
7.	Inspection Release	Purchase Order	* confirm that all work identified in the purchase order, drawings, specifications and ITP have been satisfactorily completed - ITP signed	Purchase Order	H	AUG 8 2013	H	8-6/13	H				

INSPECTION & TEST PLAN

INSULATION – Filter & WAC Vessels

VESSEL 208E

TITLE INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
					SCALE - N/A			 ECODYNE Limited A Marmon Water/Berkshire Hathaway Company <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>	
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; MEG shipping protection proc	TM	AV	DRN	TM	11/12 2012	DWG. NO. 32125-A-4502	REV. B
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012		
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012		

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels Drawing Number: 32125-A-4502 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
1.	Drawings & Specifications	Document Log △	* confirm that the fabrication and inspection drawings are the latest revision - SNC/MEG Surveillance Level 3	Latest Revision Specifications 32125-A-2017 (includes 085354-3010-IN-00)	R	SB June 18 2015	R	7-15/13	R	7-15/13			
2.	Materials	Detail Drawings	*all insulation, caulking, jacketing and hardware materials in accordance with specification - 38mm mineral wool & insulation blanket for manways - Filter Vessels with corrugated aluminum - 0.5mm thick / WAC Vessels with stainless steel cladding - 0.25mm thick - ss clips, bands, screws (Robertson head) - all insulation materials shall have a flame spread classification not to exceed 25 when test in accordance with ASTM E84	Material Identification on Product Labels & data sheets	R/W	SB July 15 2015	R	7-15/13	R	7-15/13			yes

INSPECTION & TEST PLAN

ECODYNE Limited


PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels DRAWING NUMBER: 32125-A-4502 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Installation	Drawings	* Installation in accordance with specification	specification	W SB	AUG 28 2013	R SB	8-23/13	M/V		SB		
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W SB	AUG 28 2013	V/R SB	8-23/13	M/V		SB		
5.	Preparation for Shipment	Drawings	* Vessels equipment properly supported and suitably protected	32125-A-4200 MEG shipping protection procedure 085354-3010-PG-10	W SB	AUG 28 2013	V/R SB	8-23/13	W		SB		
6.	Documentation	Purchase Requisition	* all quality documents have been checked for accuracy and completeness with copies of the following documents provided to Ecodyne - Material certifications - ITP	Drawings & Code	W SB	AUG 28 2013	R SB	8-23/13	R		SB		yes
7.	Inspection Release	Purchase Order	* confirm that all work identified in the purchase order, drawings, specifications and ITP have been satisfactorily completed - ITP signed	Purchase Order	H SB	AUG 28 2013	H SB	8-23/13	H				

INSPECTION & TEST PLAN

INSULATION – Filter & WAC Vessels

VESSEL 208 F

TITLE INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
					SCALE - N/A			 <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>	
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; MEG shipping protection proc	TM	AV	DRN	TM	11/12 2012		
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012		
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012		

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels Drawing Number: 32125-A-4502 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point									
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC	
1.	Drawings & Specifications	Document Log △	* confirm that the fabrication and inspection drawings are the latest revision - SNC/MEG Surveillance Level 3	Latest Revision Specifications 32125-A-2017 (includes 085354-3010-IN-00)	R	SB Juw 18 2015	R Juw 18 2015		R					
2.	Materials	Detail Drawings	* all insulation, caulking, jacketing and hardware materials in accordance with specification - 38mm mineral wool & insulation blanket for manways - Filter Vessels with corrugated aluminum - 0.5mm thick / WAC Vessels with stainless steel cladding - 0.25mm thick - ss clips, bands, screws (Robertson head) - all insulation materials shall have a flame spread classification not to exceed 25 when test in accordance with ASTM E84	Material Identification on Product Labels & data sheets	R/W	SB Juw 18 2015	R Juw 18 2015		R					yes

INSPECTION & TEST PLAN

ECODYNE Limited


PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels DRAWING NUMBER: 32125-A-4502 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Installation	Drawings	* Installation in accordance with specification	specification	W SB	AUG 8 2013	R	8-28/13	M/V				
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W SB	AUG 8 2013	R	8-28/13	M/V				
5.	Preparation for Shipment	Drawings	* Vessels equipment properly supported and suitably protected	32125-A-4200 MEG shipping protection procedure 085354-3010-PG-10	W SB	AUG 28 2013	V/R	8-28/13	W				
6.	Documentation	Purchase Requisition	* all quality documents have been checked for accuracy and completeness with copies of the following documents provided to Ecodyne - Material certifications - ITP	Drawings & Code	W SB	AUG 28 2013	R	8-28/13	R				yes
7.	Inspection Release	Purchase Order	* confirm that all work identified in the purchase order, drawings, specifications and ITP have been satisfactorily completed - ITP signed	Purchase Order	H SB	AUG 28 2013	H	8-28/13	H				

INSPECTION & TEST PLAN

INSULATION – Filter & WAC Vessels

VESSEL 208 G

TITLE INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels					Customer: MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02				
					SCALE - N/A			 ECODYNE Limited <small>A Marmon Water/Berkshire Hathaway Company</small> <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>	
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; MEG shipping protection proc	<i>TM</i>	<i>AV</i>	DRN	TM	11/12 2012	DWG. NO. 32125-A-4502	REV. B
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012		
REV	DATE	REMARKS	BY	CHKD	APPD	TM	11/12 2012		

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels Drawing Number: 32125-A-4502 REVISION: B				TC: Test Certificate Required		H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification is required per the PO) R: Review of Documents V: Verification that the work has been satisfactorily completed M: Monitor							
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
1.	Drawings & Specifications	Document Log △	* confirm that the fabrication and inspection drawings are the latest revision - SNC/MEG Surveillance Level 3	Latest Revision Specifications 32125-A-2017 (includes 085354-3010-IN-00)	R	June 18 2013 SB	R	8-15/13	R	8-15/13			
2.	Materials	Detail Drawings	* all insulation, caulking, jacketing and hardware materials in accordance with specification - 38mm mineral wool & insulation blanket for manways - Filter Vessels with corrugated aluminum - 0.5mm thick / WAC Vessels with stainless steel cladding - 0.25mm thick - ss clips, bands, screws (Robertson head) - all insulation materials shall have a flame spread classification not to exceed 25 when test in accordance with ASTM E84	Material Identification on Product Labels & data sheets	R/W	SB July 15 2013	R	8-15/13	R	8-15/13			yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy – Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

INSULATION Filter & WAC Vessels DRAWING NUMBER: 32125-A-4502 REVISION: B				TC: Test Certificate Required	H: Hold Point (do not fab past this point until accepted) W: Witness Point (notification required per PO) R: Review of Documents V: Verification that work has been satisfactorily completed M: Monitor								
No.	Quality Related Activity	Reference Document	Characteristic Verified	Acceptance Criteria	Inspection & Control Point								
					INSUL	Sign/Date	ECO	Sign/Date	SNC	Sign/Date	MEG	Sign/Date	TC
3.	Installation	Drawings	* Installation in accordance with specification	specification	W SB	AUG 19 2013	R P	8-21/13	M/V				
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W SB	AUG 21 2013	V/R P	8-21/13	M/V				
5.	Preparation for Shipment	Drawings	* Vessels equipment properly supported and suitably protected	32125-A-4200 & MEG shipping protection procedure 085354-3010-PG-10	W B	AUG 21 2013	V/R P	8-21/13	W				
6.	Documentation	Purchase Requisition	* all quality documents have been checked for accuracy and completeness with copies of the following documents provided to Ecodyne - Material certifications - ITP	Drawings & Code	W SB	AUG 21 2013	R P	8-21/13	R				yes
7.	Inspection Release	Purchase Order	* confirm that all work identified in the purchase order, drawings, specifications and ITP have been satisfactorily completed - ITP signed	Purchase Order	H SB	AUG 21 2013	H P	8-21/13	H				

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

D51 – Data Sheets

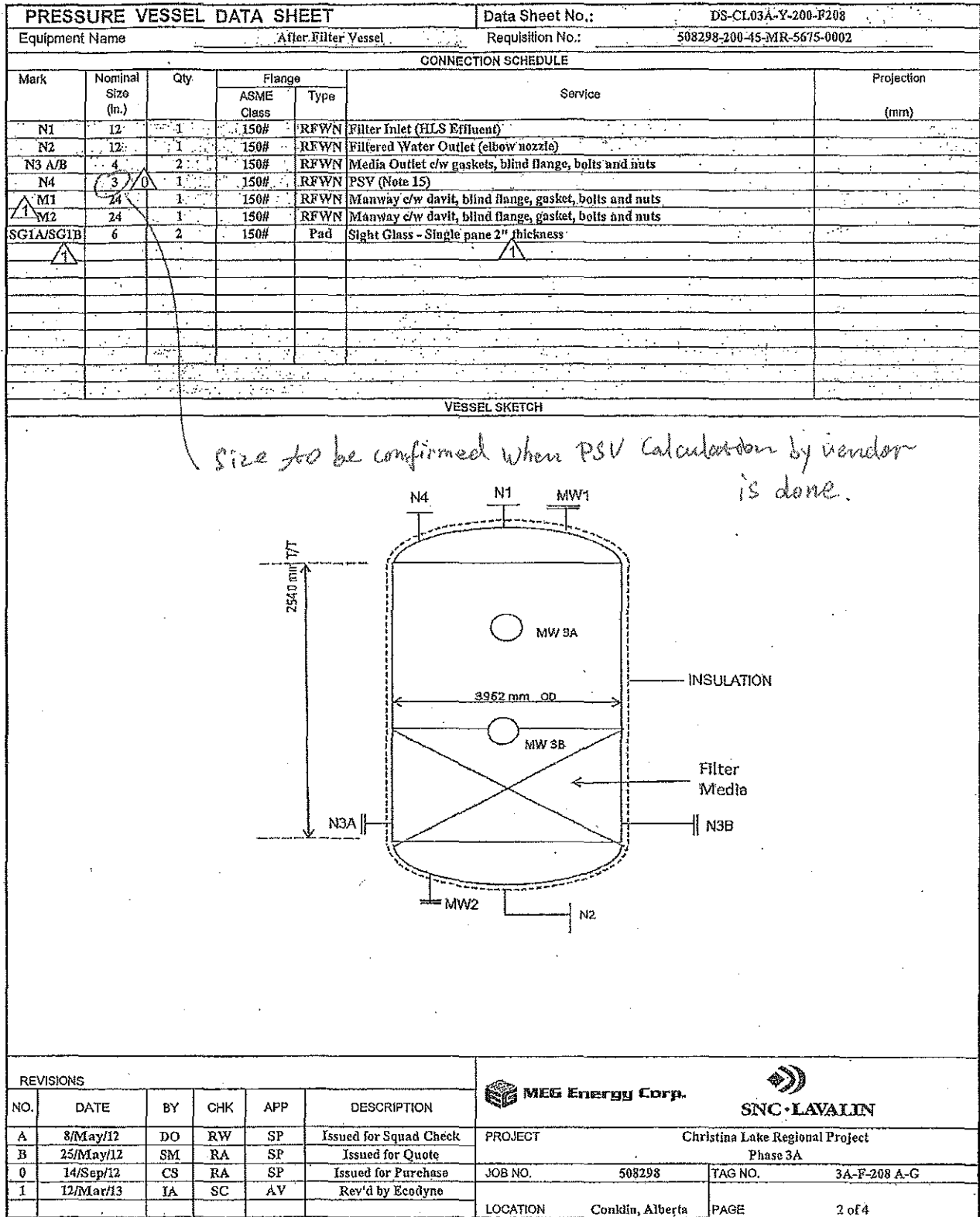
PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Completed Buyer's Equipment Data Sheet

Tags: 3A-F-208 A
 3A-F-208 B
 3A-F-208 C
 3A-F-208 D
 3A-F-208 E
 3A-F-208 F
 3A-F-208 G

				TITLE Data Sheet After Filter Vessel				CUSTOMER MEG ENERGY CORP. CHRISTINA LAKE FACILITY PHASE 3A ENGINEERS: SNC - LAVALIN PO. No. P-5675-02			
				SCALE: N/A				ECODYNE Limited <small>A Marmon Water/Berkshire Hathaway Company</small> <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>			
C	2013 Mar 12	PAGE 3 PER SNC MARKU PAGE 4 - MEDIA	Shu	AV		BY	DATE	DRAWING NO. 32125-A-2053		REV C	
B	2013 FEB 07	FIRSTREVISION	IA	AV	DRAWN	IA	2012 Nov 22				
A	2012 NOV 22	FIRST ISSUE	IA	AV	CHECKED	AV	2012 Nov 22				
REV	DATE	REMARKS	BY	CHKD	APPROVED	TB	2013 Feb 7				

PRESSURE VESSEL DATA SHEET						Data Sheet No.: DS-CL03A-Y-200-F208			
Equipment Name After Filter Vessel						Requisition No.: 508298-200-45-MR-5675-0002			
DESIGN DATA						PAINTING & INSULATION			
Service HLS effluent water filtration						External Surface Preparation Per spec 085354-3010-PC-50 (D2)			
Operating Temperature 80.0 / 105 °C		Pressure 755.0 kPag		Internal Surface Preparation N/A		Structural Surface Preparation Per spec 085354-3010-PC-50 (S3) (Note 10)			
Design Temp. Min.: 5.0 °C		Max.: 120.0 °C		Vessel External Prime per spec 085354-3010-PC-50 (D2)		Vessel Internal Prime N/A			
Design Pressure @ Minimum Temperature: 1034 / FV kPag		@ Maximum Temperature: 1034 / FV kPag		Structural Prime Per spec 085354-3010-PC-50 (S3) (Note 10)		Vessel External Finish N/A			
Sour Service N/A		Lethal Service N/A		Vessel Internal Finish N/A		Structural Finish Per spec 085354-3010-PC-50 (S3) (Note 10)			
New Vessel MAWP Limited by 1 Top Head @ 1037.0 kPag		Corrosion Allowance - Shell / Heads 3.2 / 3.2 mm		External Insulation - Shell Per spec 085354-3010-IN-00 (Note 8)		External Insulation - Heads Per spec 085354-3010-IN-00 (Note 8)			
Wall Thickness - Shell / Heads 19.1 / 18.22/19.05 mm		Joint Efficiency - Shell / Heads 1.0 / 1.0		Internal Insulation N/A		External Cladding Per spec 085354-3010-IN-00			
Registration Alberta		Design Code ASME Sec VIII Div 1		Insulation - Bottom Head Per spec 085354-3010-IN-00		Insulation - Skirt N/A			
Code Stamp Yes, U Stamp		Orientation Vertical		Fireproofing - Skirt N/A		Fireproofing - Saddles N/A			
Post Weld Heat Treatment per Code		Head Type 2:1 Semi-elliptical		QUALITY CONTROL / INSPECTION / TESTING					
Allowable Stress @ Design Temperature Per Code kPa		Ambient Temperature 10 / 39 °C							
Max Wind Speed Indoor m/s		Minimum Metal Design Temperature -29 °C							
Fluid HLS Effluent Water		Fluid Density 955 kg/m³							
MATERIALS						Hydrotest Pressure Per Code kPag			
Shell SA516 - 70N		Repads SA516 - 70N		Hydrotest Medium Water					
Heads SA516 - 70N		Fittings SA105N/SA234 WPB		Hydrotest Duration 1 hr. minimum hrs					
Trays N/A		Supports 1 SA516-70N(R-Pads)		Radiographic Inspection RT2					
Bolts/Nuts SA193 B7/A194 2H		Flanges SA105 N		Ultrasonic Inspection per spec 085354-3010-EW-20					
Nozzle-Necks A106 - B		Gaskets SPW SS 316		Magnetic Particle Inspection per spec 085354-3010-EW-20					
Internal Lining N/A		Pipe SA106 - B		Dye Penetrant Inspection per spec 085354-3010-EW-20					
Internals SS 316L (Note 7)		Mist Eliminator N/A		Material Mill Test Reports 100% Traceability					
Structural Attachments - External 1 SA516 - 70N (Poison pads only)		Structural Attachments - Internal 1 SA516 - 70N (Poison pads only)		Post Weld Heat Treatment Records Per MR Section III					
Material Impact Test Required Per Code		Certified Elevated Temp Tests Req'd No		Hydrotest Reports Per MR Section III					
DIMENSIONAL/SHIPPING DATA						Radiographic Inspection Reports Per MR Section III			
Vessel Size 3962 mm OD x 2540 mm T/T		Boot/Gas Dome 14674 mm ID x 0.95 m		Ultrasonic Inspection Reports Per MR Section III		Magnetic Particle Inspection Reports Per MR Section III			
Capacity 46.74 m³		Weight - Empty 26100 kg		Dye Penetrant Inspection Reports Per MR Section III		Fabricator Quality Control Manual Per MR Section III			
Centerline/Bottom Seam Elevation 0.95 m		Weight - Hydrotest 71630 kg		Shop Inspection by Owner Yes		Welding Procedure Review/Approval Per MR Section III			
Weight - Operatg 83100 kg		Weight - Shipping 26100 kg		O/A Shipping Dimensions (LxWxH) 6.5 x 4.5 x 4.5 m		Nozzle Covers/Connection Plugs Yes			
Shipping Cradles As required by shipping		Ocean Transport Protection NA		NOTES					
ACCESSORIES BY FABRICATOR									
Manway Davits Y		Ladders N						1. To be specified / confirmed by Seller.	
Ladder and Platform Clips N		Platforms N						2. All nozzles shall be flush with vessel inside surface.	
Pipe Support and Guide Clips Y		Lifting Lugs Y						3. Seller shall design and install all the internals.	
Insulation Supports Y		Pipe Coll N						4. National Board registration req'd for vessels fabricated outside Canada.	
Insulation Supports Bottom Head Y		Anodes N						5. ABSA registration is required to obtain CRN for all vessels.	
Fireproofing Supports N		Nameplate Y						6. Structural attachments are defined as any non-pressure part welded directly to the shell or head of the filter vessel.	
Legs Y		Mist Eliminator N						7. Ambient temperatures are for filter package indoor building location.	
Tray/Packing Supports N		Vortex Breaker N						8. Removable internals shall be fabricated from SS 316L.	
Manway Internal Grab Rungs N		Grounding Lugs Y		9. 38 mm (hot) mineral fiber c/w 0.8 mm corrugated aluminum cladding shall be provided and installed by Seller.					
Siphon Drains on Nozzles				10. Seller shall provide a minimum of two (2) grounding lugs		10. Uninsulated surfaces including vessel legs, davits, lugs and clips			
REVISIONS									
NO.	DATE	BY	CHK	APP	DESCRIPTION	PROJECT Christina Lake Regional Project Phase 3A			
A	8/May/12	DO	RW	SP	Issued for Squad Check	JOB NO.	508298		
B	25/May/12	SM	RA	SP	Issued for Quote	TAG NO.	3A-F-208 A-G		
0	14/Sep/12	CS	RA	SP	Issued for Purchase	LOCATION	Conklin, Alberta		
1	22/Nov/12	IA	AV		Rev'd by Ecadyne	PAGE	1 of 4		



PRESSURE VESSEL DATA SHEET				Data Sheet No.: DS-CL03A-Y-200-F208	
Equipment Name		After Filter Vessel		Requisition No.: 508298-200-45-MR-5675-0002	
PROCESS CONDITIONS					
	Minimum	Normal	Maximum	Comments	
Flow Conditions					
No. After Filter vessels	6	7	7	Operating in parallel	
Design inlet flow rate per filter, Am ³ /h	35	142	166	Max. flow occurs with 1 filter in backwash	
Actual flow rate - package, Am ³ /h	0	995	995	0	
Inlet Conditions					
Fluid	HLS Effluent Water				
Type of Solids	Lime/Magox Solids				
Pressure, kPag		755	1034	0	
Temperature, °C	5	105	120		
Solids loading @ Inlet, NTU			< 50		NTU (Nephelometric Turbidity Unit)
Corrosive contaminants, mg/L		< 2700			Chloride
Water S.G. @ normal operating temp.		0.955			
Viscosity @ normal operating temp., cP		0.267			
Pressure Drop					
Across filter - clean @ max. flow, kPa	15.0	21	25	0	
Across filter - dirty @ max. flow, kPa		45	50	1	
Max allowable across Filter, kPa			70	2	by Others (Note 21)
Outlet Conditions					
Pressure, kPag		730	0		Vessel only
Solids loading @ outlet, NTU			< 2		NTU (Nephelometric Turbidity Unit)
TSS @ outlet, mg/L			< 5		TSS (Total Suspended Solids)
Backwash Cycle					
Frequency	Once / Day / Filter				
Fluid	Heated Clear Water @ 80°C				
* Indicates information to be provided/ confirmed by Seller.					
11) During normal operations, the flow shall be distributed to all 7 filters. While one is in backwash mode, rest 6 filters will process the total flow. 12) Reference the sequence chart for duration and flow rate of backwash. 13) Turndown depends on system design (by others). Unit turndown expected is 3 to 1 14) Seller shall supply first fill of media per details on page 4. 15) Relief valve shall be sized by Seller (Fire case to be included in sizing review). API & ASME to be reviewed and greater size to be selected. 16) All sight glasses shall be single glass and shall be supplied by Seller. 17) Seller shall confirm sizes and quantity of all connections. 18) Seller to confirm / optimise filter media data. 19) All open/close valves to be slow opening/closing (28 sec). To be supplied by others. 20) Control valves: One FCV per vessel to control equal flow to each vessel. To be supplied by others. 21) Maximum pressure drop across filter; one unit in backwash, remaining vessels at package design flow. 22) Vessels located indoors					
REVISIONS					
NO.	DATE	BY	CHK	APP	DESCRIPTION
A	8/May/12	DO	RW	SP	Issued for Squad Check
B	25/May/12	SM	RA	SP	Issued for Quote
0	14/Sep/12	CS	RA	SP	Issued for Purchase
1	7/Feb/13	IA	SC	AV	Rev'd by Ecodyne
2	12/Mar/13	IA	SC	AV	Rev'd by Ecodyne
MEG Energy Corp. SNC-LAVALIN					
			PROJECT Christina Lake Regional Project Phase 3A		
			JOB NO. 508298	TAG NO.	3A-F-208 A-G
			LOCATION Conklin, Alberta	PAGE	3 of 4

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

H51 – General Arrangement/Outline Drawings

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Dimensional Outline Drawing & BOM

TITLE PROJECT BILL OF MATERIAL Tags: 3A-F-208 A to G 3A-V-211 A to F				CUSTOMER MEG Energy Corporation c/o SNC-Lavalin Christina Lake Phase 3A PO No. P-5675-02			
				SCALE: N/A		ECODYNE Limited <small>A Mannion Water/Berkshire Hathaway Company</small>	
						BY	DATE
				DRAWN		AV	2013 07 June
A	2013 07 June	FIRST ISSUE	AV	16	CHECKED	16	2013 12 June
REV	DATE	REMARKS	BY	CHKD	APPROVED	AV	2013 10 June
						DRAWING NO. 32125-A-1010	
						REV A	

page 1 of 2

Tag No.	Qty	Description	Application	Dwg. No.	Approx. Weight (kg)
3A-F-208 A to G	7	Vessel	After Filter	32125-D-2202-01	26,100
3A-V-211 A to F	6	Vessel	WAC	32125-D-2201-01	25,000
N/A	7	Ladder	After Filter	32125-D-2252-01/02	79
N/A	6	Ladder	WAC	32125-D-2251-01/02	66
N/A	13 m ³	Media - Anthracite	After Filter	N/A	TBD
N/A	14	Insulation Blankets (manways only)	After Filter	32125-A-2017	TBD
N/A	12	Insulation Blankets (manways only)	WAC	32125-A-2017	TBD

page 2 of 2

32125-A-1010 Project BOM

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Allowable Nozzle External Forces & Moments

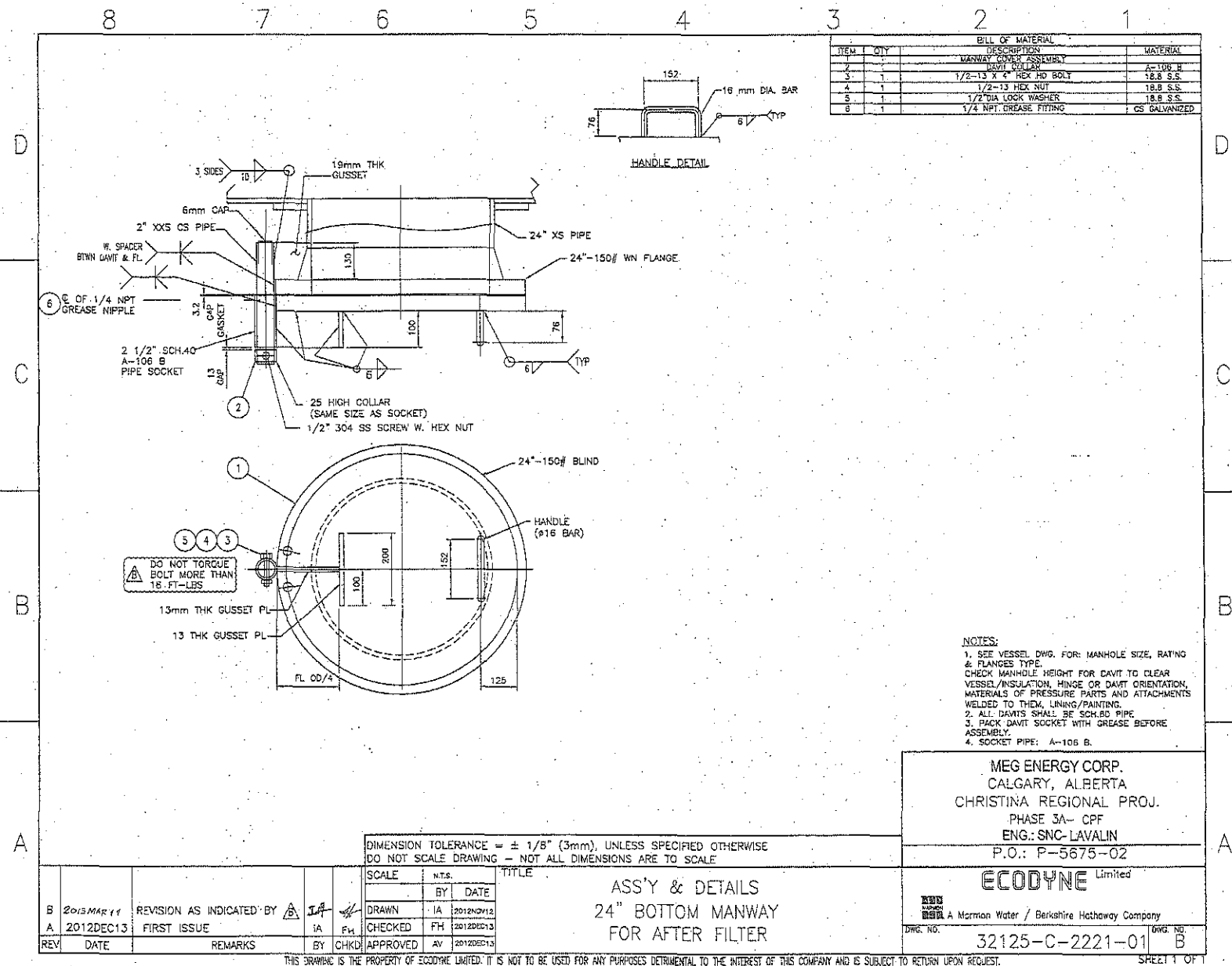
Not Applicable

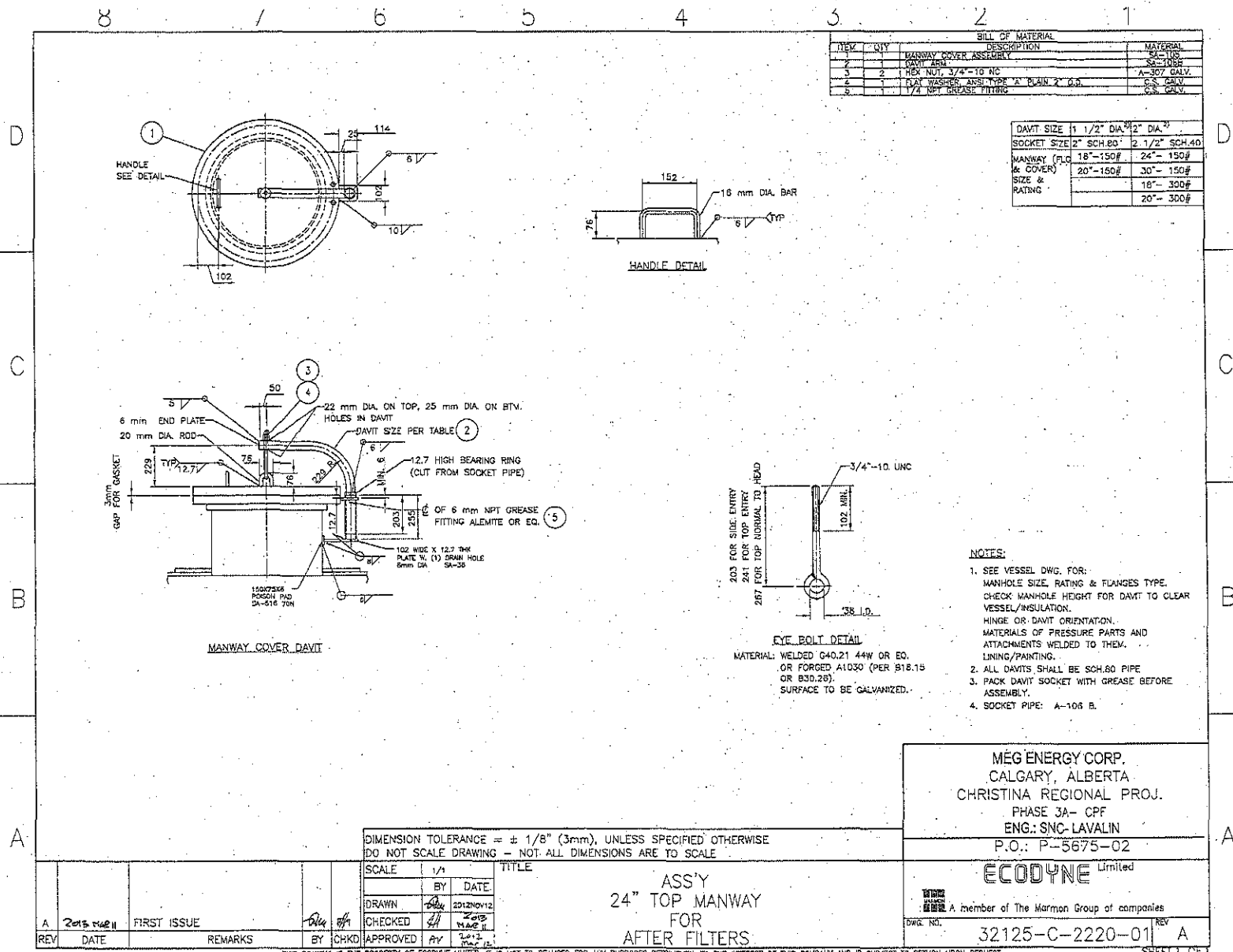
PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

J51 – Detail Component & Sectional Drawings

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

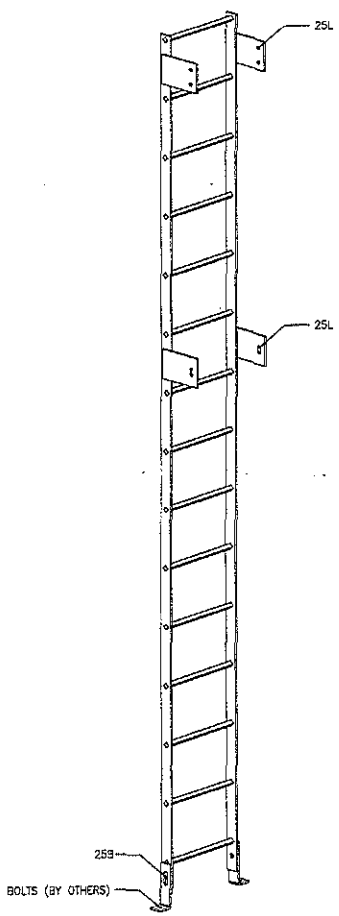
Equipment Detail Drawings c/w BOM





PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Ladder, Stairway, Platform & Handrail Drawings



SHIPPING LIST			
QTY	TAG		REMARK
6 SETS	25L	3/4" x 1 3/4" LG BOLT SET	LADDER TO VESSEL
2 SETS	25B	3/4" x 1 3/4" LG BOLT SET	LADDER TO FOOT
1		LADDER	

(EACH SET CONSIST OF 1 BOLT, 1 NUT & 2 FLATWASHERS)

NOTES:

1. FABRICATION SHALL CONFORM TO THE REQUIREMENTS OF CSA W59 AND FABRICATION TOLERANCE ±.2 (±1/8") U.N.O. & 32125-A-2017.
2. ALL WELDS CONTINUOUS ALL AROUND; ALL BUTT WELDS - FULL PENETRATION, ALL FLARE GROOVE WELDS - FULL DEPTH AT T JOINT OR FULL PENETRATION AT BUTT JOINT. MIN. FILLET WELD IS 5mm (3/16")
3. MATERIALS:
- BARS, PLATES, STRUCTURAL SHAPES - CSA G40.21 GR. 44W.
BOLTING: A325 GALV. IF > 1"
A307 ZINC PLATED IF 5/8"
F436 WASHERS GALV.
ALL BOLT SETS CONSIST OF 1-BOLT, 1 NUT, AND 2 WASHERS (OR BEVELED WASHERS IF ON THE UNDERSIDE OF CHANNEL FLANGE)
4. ALL COMPONENTS SHALL HAVE SURFACE FINISHED PER SPEC. 32125-A4-2013, (INCLUDING CLIENT SPEC. 2975-M010)
5. ALL SHARP CORNERS AND BURRS SHALL BE GROUND SMOOTH.
6. TO ENSURE PROPER ERECTION ECODYNE SHOP IS TO TRIAL FIT ALL COMPONENTS AND MATCH MARK PRIOR TO COATING
7. ON ALL BOLTED CONNECTIONS USE HEAVY HEX. HD. MACH. BOLT C/W (2) TYPE "A" FLAT WASHER AND (1) HEAVY HEX NUT UNLESS OTHERWISE NOTED.
8. FABRICATOR IS TO SUPPLY ALL HARDWARE WITH 10% EXTRA
9. SEE PURCHASE REQUISITION FOR QUANTITY REQUIRED.
10. SCOPE: PREP-PER SSPC SP6 COMMERCIAL BLAST AND PAINTING WITH CARBOLINE 859, 2-4 MILS DFT. APPLY (2) LAYERS OF 1.5-2.5 MILS CARBOLINE 134HG COLOUR FS 13591 SAFETY YELLOW.

SHIPPING WEIGHT = 174 POUNDS

REFERENCE DRAWINGS:

PAINT SPECIFICATION..... 32125-A4-2013

MEG ENERGY CORP.
CALGARY, ALBERTA
CHRISTINA REGIONAL PROJ.
PHASE 3A-CPF
ENG.: SNC-LAVALIN
P.O.: P-5675-02

ECODYNE Limited

A Murrum Water / Berkshire Hathaway Company
DWG. NO. 32125-D-2252-01 REV A

DIMENSION TOLERANCE = ±1/8" (3mm), UNLESS SPECIFIED OTHERWISE
DO NOT SCALE DRAWING - NOT ALL DIMENSIONS ARE TO SCALE

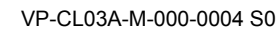
SCALE	BY	DATE
DRAWN	SP	2013MR17
CHECKED	SP	2013MAY15
APPROVED	AV	2013MAY15

DETAIL & ASS'Y
LADDER
AFTER FILTER

REV	DATE	REMARKS	BY	CHKD	REV	DATE	REMARKS	BY	CHKD	REV	DATE	REMARKS	BY	CHKD

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SHEET 1 OF 1



PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02


Weld Location Plan

AFTER FILTERS
3A-F-208 A to G
Weld Map
ASME Vessels

Contents:

Cover
Weld Map Listing Procedures
Weld Map Diagrams

1 Page
1 Page
1 Page

				Title Weld Map After Filters 3A-F-208 A to G P.O.# P-5675-02			Customer MEG ENERGY CORP. CALGARY, ALBERTA CHRISTINA REGIONAL PROJ. PHASE 3A- CPF ENG.: SNC- LAVALIN		
				SCALE -			ECODYNE Limited  A Marmon Water/Berkshire Hathaway Company <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>		
					BY	DATE			
				DRN	VEN	FEB 20 2013			
A	FEB 20 2013	FIRST ISSUE	VEN	CHKD	AV	FEB 20 2013	DWG. NO.	REV.	
REV	DATE	REMARKS	BY	CHKD	APPD	FEB 20 2013	32125-A-2904	A	

LESENA STEEL LTD.

WELD MAP

Rev. 1

Date: FEB. 12/2013

Prepared By: Arie Willemssen

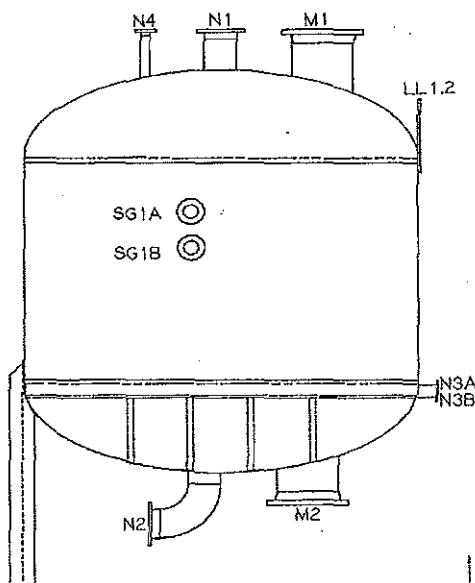
Job No.: 12-32 A - G

Drawing No.: 32125-D--2202-01, Rev D

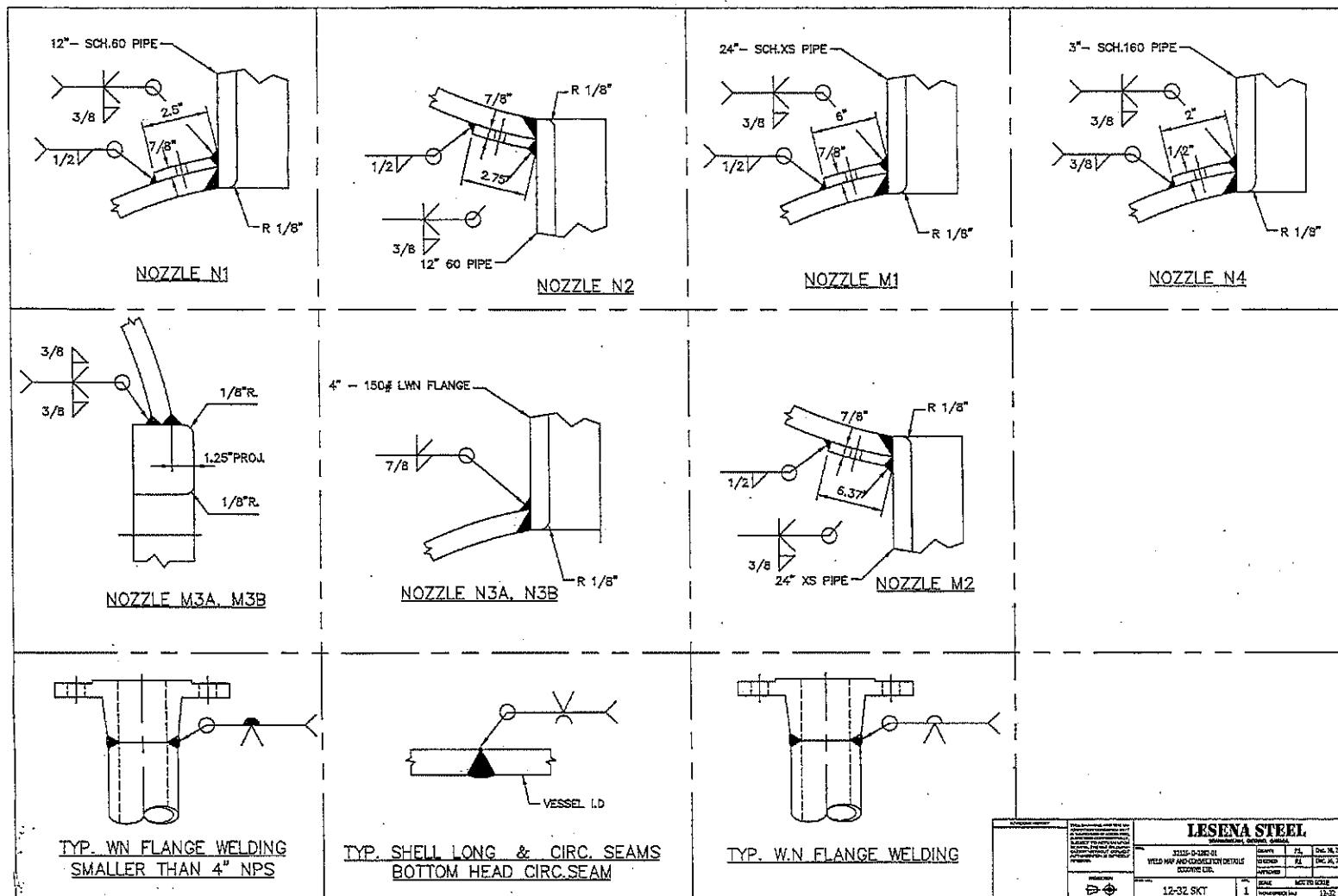
Pages: 1 of 1

AFTER FILTER VESSEL

REPAIR PROCEDURE:- WPS 16 SMAW or Original WPS



JOINTS	WPS	PROCESS	FILLER	BASE METALS
Longitudinal & Circumferential Seams	45	SAW, AUTOMATIC	F7A2-EM12K (L61-F860)	P1 to P1
Manway to Top & Bottom Head	16 or 40	SMAW or FCAW	E7018-1 E-71T-1, KOBE DW50	P1 to P1
Flange to Nozzle, Nozzle to Head N4, N3A, N3B	16.2	SMAW	E7018-1 (ROOT: E6010)	P1 to P1
Flange to Nozzle, Nozzle to Head or Shell, Nozzles over 6" dia.	16 or 40	SMAW or FCAW	E7018-1 E-71T-1, KOBE DW50	P1 to P1
Reinforcing Pad to Pipe, Reinforcing Pad to Shell, Top & Bottom Heads	16 or 40	SMAW or FCAW	E7018-1 E-71T-1, KOBE DW50	P1 to P1
Strainer Plate to Bottom Head; Lifting Lugs to Top Head, Shell & Brackets to Shell or Heads (All Non-Pressure Parts)	16 or 40	SMAW or FCAW	E7018-1 E-71T-1, KOBE DW50	P1 to P1




PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Non-Destructive Examination Location Plan

AFTER FILTERS
3A-F-208 A to G
NDE Map
ASME Vessels

Contents:
Cover
NDE Map

1 Page
1 Page

Title				Customer			
NDE Map After Filters 3A-F-208 A to G P.O.# P-5675-02				MEG ENERGY CORP. CALGARY, ALBERTA CHRISTINA REGIONAL PROJ. PHASE 3A- CPF ENG.: SNC- LAVALIN			
				SCALE -		ECODYNE Limited  A Marmon Water/Berkshire Hathaway Company <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>	
					BY	DATE	
				DRN	VEN	FEB 20 2013	
A	FEB 20 2013	FIRST ISSUE	VEN	CHKD	TB	FEB 20 2013	
REV	DATE	REMARKS	BY	CHKD	APPD	FEB 20 2013	
						DWG. NO.	REV.
						32125-A-2906	A

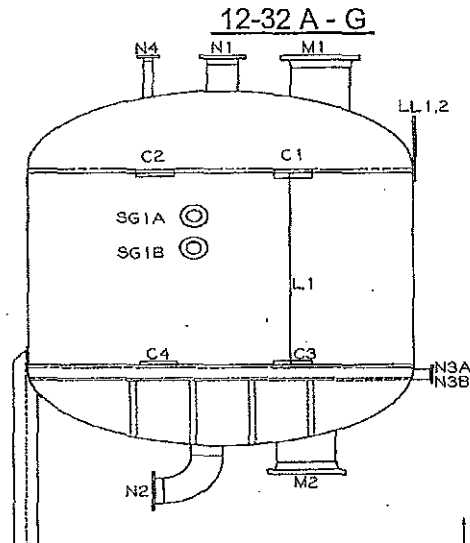
LESENA STEEL LTD

NDE MAP

CUSTOMER: ECODYNE Ltd. CRN No: V2929.2
 VESSEL TYPE: AFTER FILTER VESSEL JOB No: 12-32 A - G
TOP, -18.22 mm MIN.* SERIAL No: 0411-0417
 HEAD THK.: BTM, -19.05 mm MIN.* SHELLTHK.: 19.05 mm NOM.* DATE: Dec. 18, 2012
 CODE ACCEPTANCE LEVEL: RT-2
 CIRCUMFERENTIAL SEAMS: SPOT LONGITUDINAL SEAM: FULL

FULL ON LONGITUDINAL SEAM & FOUR (4) SPOTS ON HEAD / SHELL CIRCUMFERENTIAL SEAM JOINTS AS SHOWN ON MAP.

* THIS INFORMATION PLUS WELD I.D. MUST BE ON ALL FILMS.



12-32 A	L1	C1	C2	C3	C4
12-32 B	L1	C1	C2	C3	C4
12-32 C	L1	C1	C2	C3	C4
12-32 D	L1	C1	C2	C3	C4
12-32 E	L1	C1	C2	C3	C4
12-32 F	L1	C1	C2	C3	C4
32-32 G	L1	C1	C2	C3	C4

MPI : ALL AREAS WHERE TEMPORARY ATTACHMENTS HAVE BEEN REMOVED AND
 ARC STRIKES HAVE OCCURRED

MPI: LIFTING LUGS

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Lifting, Tailing Lug Drawings

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

K51 – System Diagrams & Schedules

		1		2		3		4		5		6		7		8			
		AFTER FILTER 3A-F-208A (NOTE 5)								COMMON		PUMPS RUNNING		GENERAL NOTES		LEGEND			
		VALVES		OPERATION															
		DESCRIPTION		TAG		SOURCE													
A	BACKWASH SEQUENCE	ACCUM TIME (MIN)	STEP NO.	STEP TIME (MIN)	FLOW IN/SH	FLOW GPM/SPH	DESCRIPTION	TAG	SOURCE	3A-VV-20811	3A-VV-20815	3A-VV-20813	3A-VV-20812	3A-VV-20814	3A-FV-20802	3A-FV-20801	3A-FV-20803	REMARKS	
		-	1	1.0	-	-	CLOSURE	-	-	-	-	-	-	-	-	-	-	-	-
		-	2	10.0	430	1683	BACKWASH	-	HEATED CLEARWATER WATER	-	-	X	X	-	-	-	-	-	NOTE 4
		-	3	2.0	-	-	BED SETTLE	-	-	-	-	-	-	-	-	-	-	-	-
B	BACKWASH SEQUENCE	-	4	5.0	142	625	BED RINSE	-	TREATED WATER	X	-	-	X	-	-	-	-	NOTE 6	
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C	SERVICE STATUS	-	-	-	-	-	OFF	-	-	-	-	-	-	-	-	-	-	-	
		-	-	-	142	625	SERVICE	-	TREATED WATER	X	X	-	-	-	-	-	-	-	-
		-	-	-	-	-	BACKWASH (SEE ABOVE)	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D	SERVICE STATUS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

NOTES:

- 1) ALL TIMES AND FLOWS SHOWN ARE NOMINAL SETTINGS TO BE CONFIRMED IN THE FIELD.
- 2) SEQUENCE AND TAG NUMBERS ARE FOR FILTER 3A-F-208. FUTURE GAS SCOURING IS NOT SHOWN ABOVE.
- 3) SERVICE FLOW MAX 6 FILTERS ON LINE 168 FOR PER VESSEL. NORMAL 7 FILTERS ON LINE 142 FOR PER VESSEL.
- 4) BACKWASH SYSTEM DESIGN FLOW IS 540 m³/H (2278 gpm). EXPECTED BACKWASH FLOW IS 430 m³/H AT 80 °C. FOR LOWER TEMPERATURES, ADJUST FLOW ACCORDINGLY TO AVOID LOSS OF MEDIA (TO BE OPTIMIZED IN FIELD).
- 5) RINSE STEP IS USED WHEN BLOWDOWN WATER IS USED FOR BACKWASHING THE AFTER FILTER. RINSE OUTLET IS OUTSIDE OF PACKAGE SCOPE.
- 6) SEQUENCE SHOWN IS FOR 3A-F-208A (TYPICAL OF SEVEN). ONLY ONE FILTER IS IN BACKWASH AT A TIME.

TABLE 1

WATER TEMP °C	BACKWASH FLOW m ³ /H	BACKWASH FLOW GPM	STEP TIME (min)
60	325	1431	10.0
40	234	1030	10.0
20	152	670	15.0
10	117	515	15.0

REVISIONS:

REV	DATE	REMARKS
C	MAR.13/13	REV'D WHERE INDICATED
B	FEB.11/13	REV'D WHERE INDICATED
A	NOV.22/12	FIRST ISSUE

SCALE: 1:1

TITLE: VALVE & MOTOR SEQUENCE CHART AFTER FILTER 3A-F-208

DATE: NOV.22/12

BY: SA

CHECKED: SS

APPROVED: AV

ECODYNE Limited

A member of The Marmion Group of companies

DWG. NO. 32125-B-3052-01

REV C

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

L51 – Calculations, Simulations & Analyses

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Mechanical Design Calculations

Attached document: 12-32 CAL-R2, 146 pages

Tags: 3A-F-208 A-G


				TITLE After Filter Pressure Vessel And Nozzle Load Calculations			CUSTOMER MEG Energy Corporation c/o SNC Lavalin Christina Lake Phase 3A PO No. P-5675-02		
				SCALE -			 ECODYNE Limited <small>A Maxmon Water/Berkshire Hathaway Company</small> <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>		
						BY	DATE		
B	2013 Mar 28	PER CLIENT MARK-UP AND UPDATED VESSEL DRAWING	VEN	RJ	DRN	VEN	2013 Jan 15	DWG. NO. 32125-A-2902	REV. B
A	2013 Jan 15	FIRST ISSUE	AV	RJ	CHKD	RJ	2013 Mar 28		
REV	DATE	REMARKS	BY	CHKD	APPD	AAV	2013 Mar 28		

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2. Pressure Summary
3. Hydrostatic Test
4. Nozzle Schedule
5. Nozzle Summary
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9. 3962 mm O.D. SHELL
10. BOTTOM HEAD
11. WATER INLET (N1)
12. WATER OUTLET (N2)
13. MEDIA REMOVAL (N3A)
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15. PSV/VENT (N4)
16. TOP MANWAY (M1)
17. BOTTOM MANWAY (M2)
18. SIGHT GLASS (SG1A)
19. SIGHT GLASS (SG1B)
20. Seismic Code
21. SUPPORT LEG
22. LIFTING LUG

Settings Summary**COMPRESS 2013 Build 7300****Units: SI****Datum Line Location: -102.00 mm from bottom seam****Design**

ASME Section VIII Division 1, 2010 Edition, A11 Addenda Metric

Design or Rating:	Get Thickness from Pressure
Minimum thickness:	1.5 mm per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	Vessel MAWP
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.00
Skirt/legs stress increase:	1.0
Minimum nozzle projection:	12.7 mm
Juncture calculations for $\alpha > 30$ only:	Yes
Preheat P-No 1 Materials $> 1.25"$ and $\leq 1.50"$ thick:	No
UG-37(a) shell tr calculation considers longitudinal stress:	No
Butt welds are tapered per Figure UCS-66.3(a).	

Hydro/Pneumatic Test

Shop Hydrotest Pressure:	1.3 times vessel MAWP
Test liquid specific gravity:	1.00
Field Hydrotest Pressure:	1.3 times vessel MAWP
Wind load present @ field:	33% of design
Maximum stress during test:	90% of yield

Required Marking - UG-116

UG-116(e) Radiography:	RT4
UG-116(f) Postweld heat treatment:	None

Code Cases\Interpretations

Use Code Case 2547:	No
Apply interpretation VIII-1-83-66:	Yes
Apply interpretation VIII-1-86-175:	Yes
Apply interpretation VIII-1-01-37:	Yes
No UCS-66.1 MDMT reduction:	No
No UCS-68(c) MDMT reduction:	No
Disallow UG-20(f) exemptions:	No

R2

3/25/2013

UG-22 Loadings

UG-22(a) Internal or External Design Pressure :	Yes
UG-22(b) Weight of the vessel and normal contents under operating or test conditions:	Yes
UG-22(c) Superimposed static reactions from weight of attached equipment (external loads):	Yes
UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	Yes
UG-22(f) Wind reactions:	No
UG-22(f) Seismic reactions:	Yes
UG-22(j) Test pressure and coincident static head acting during the test:	Yes

Note: UG-22(b),(c) and (f) loads only considered when supports are present.

Pressure Summary**Pressure Summary for Chamber bounded by BOTTOM HEAD and TOP HEAD**

Identifier	P Design (kPa)	T Design (°C)	MAWP (kPa)	MAP (kPa)	MAEP (kPa)	T _e external (°C)	MDMT (°C)	MDMT Exemption		Impact Tested
<u>TOP HEAD</u>	1,034	120	1,041.57	1,279.83	224.31	120	-42.1	Note 1		No
<u>Straight Flange on TOP HEAD</u>	1,034	120	1,313.95	1,553.46	354.46	120	-48	Note 2		No
<u>3962 mm O.D. SHELL</u>	1,034	120	1,069.57	1,332.18	221.4	120	-42.46	Note 3		No
<u>Straight Flange on BOTTOM HEAD</u>	1,034	120	1,289.56	1,553.46	354.46	120	-48	Note 5		No
<u>BOTTOM HEAD</u>	1,034	120	1,065.8	1,338.64	250.06	120	-42.26	Note 4		No
<u>SUPPORT LEG</u>	1,034	120	1,041.57	N/A	N/A	N/A	N/A	N/A		N/A
<u>TOP MANWAY (M1)</u>	1,034	120	1,041.57	1,041.57	224.31	120	-47.9	Nozzle	Note 6	No
								Pad	Note 7	No
<u>BOTTOM MANWAY (M2)</u>	1,034	120	1,041.57	1,041.57	250.06	120	-47.36	Nozzle	Note 8	No
								Pad	Note 9	No
<u>WATER INLET (N1)</u>	1,034	120	1,041.57	1,041.57	224.31	120	-47.9	Nozzle	Note 10	No
								Pad	Note 11	No
<u>WATER OUTLET (N2)</u>	1,034	120	1,041.57	1,041.57	250.06	120	-47.26	Nozzle	Note 12	No
								Pad	Note 13	No
<u>MEDIA REMOVAL (N3A)</u>	1,034	120	1,041.57	1,041.57	250.06	120	-29	Note 14		No
<u>MEDIA REMOVAL (N3B)</u>	1,034	120	1,041.57	1,041.57	250.06	120	-29	Note 14		No
<u>PSV/VENT (N4)</u>	1,034	120	1,041.57	1,041.57	224.31	120	-48	Nozzle	Note 15	No
								Pad	Note 16	No
<u>SIGHT GLASS (SG1A)</u>	1,034	120	1,041.57	1,041.57	221.4	120	-43.36	Note 17		No
<u>SIGHT GLASS (SG1B)</u>	1,034	120	1,041.57	1,041.57	221.4	120	-43.16	Note 18		No

Chamber design MDMT is -28.89 °C

Chamber rated MDMT is -29 °C @ 1,041.57 kPa

Chamber MAWP hot & corroded is 1,041.57 kPa @ 120 °C

Chamber MAP cold & new is 1,041.57 kPa @ 10 °C

Chamber MAEP is 221.4 kPa @ 120 °C

Vacuum rings did not govern the external pressure rating.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Material impact test exemption temperature from Fig UCS-66M Curve D = -42.1 °C	UCS-66 governing thickness = 18.22 mm
2.	Material impact test exemption temperature from Fig UCS-66M Curve D = -38 °C Fig UCS-66.1M MDMT reduction = 11.4 °C, (coincident ratio = 0.7956) Rated MDMT of -49.4 °C is limited to -48 °C by UCS-66(b)(2)	UCS-66 governing thickness = 22.2 mm
3.	Material impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C Fig UCS-66.1M MDMT reduction = 1.4 °C, (coincident ratio = 0.9748)	UCS-66 governing thickness = 19.05 mm
4.	Material impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C Fig UCS-66.1M MDMT reduction = 1.2 °C, (coincident ratio = 0.9784)	UCS-66 governing thickness = 19.05 mm
5.	Material impact test exemption temperature from Fig UCS-66M Curve D = -38 °C Fig UCS-66.1M MDMT reduction = 10.4 °C, (coincident ratio = 0.8139) Rated MDMT of -48.4 °C is limited to -48 °C by UCS-66(b)(2)	UCS-66 governing thickness = 22.2 mm
6.	Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.3331).	
7.	Pad impact test exemption temperature from Fig UCS-66M Curve D = -42.1 °C Fig UCS-66.1M MDMT reduction = 5.8 °C, (coincident ratio = 0.8968)	UCS-66 governing thickness = 18.22 mm.
8.	Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.3478).	
9.	Pad impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C Fig UCS-66.1M MDMT reduction = 6.3 °C, (coincident ratio = 0.8872)	UCS-66 governing thickness = 19.05 mm.
10.	Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.2293).	
11.	Pad impact test exemption temperature from Fig UCS-66M Curve D = -42.1 °C Fig UCS-66.1M MDMT reduction = 5.8 °C, (coincident ratio = 0.8957)	UCS-66 governing thickness = 18.22 mm.
12.	Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.2334).	
13.	Pad impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C Fig UCS-66.1M MDMT reduction = 6.2 °C, (coincident ratio = 0.889)	UCS-66 governing thickness = 19.05 mm.
14.	Nozzle is impact test exempt per UG-20(f)	UCS-66 governing thickness = 19.05 mm.
15.	Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.1458).	
16.	Pad impact test exemption temperature from Fig UCS-66M Curve D = -48 °C Fig UCS-66.1M MDMT reduction = 5.8 °C, (coincident ratio = 0.8963) Rated MDMT of -53.8 °C is limited to -48 °C by UCS-66(b)(2)	UCS-66 governing thickness = 12.7 mm.
17.	Nozzle impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C Fig UCS-66.1M MDMT reduction = 2.3 °C, (coincident ratio = 0.9585)	UCS-66 governing thickness = 19.05 mm.
18.	Nozzle impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C Fig UCS-66.1M MDMT reduction = 2.1 °C, (coincident ratio = 0.9629)	UCS-66 governing thickness = 19.05 mm.

Design notes are available on the [Settings Summary](#) page.

Hydrostatic Test

Shop test pressure determination for Chamber bounded by BOTTOM HEAD and TOP HEAD based on MAWP per UG-99(b)

Shop hydrostatic test gauge pressure is 1,354.04 kPa at 10 °C (the chamber MAWP = 1,041.57 kPa)

The shop test is performed with the vessel in the horizontal position.

Identifier	Local test pressure kPa	Test liquid static head kPa	UG-99(b) stress ratio	UG-99(b) pressure factor	Stress during test MPa	Allowable test stress MPa	Stress excessive?
TOP HEAD (1)	1,392.44	38.4	1	1.30	135.003	235.8	No
Straight Flange on TOP HEAD	1,392.4	38.36	1	1.30	123.552	235.8	No
3962 mm O.D. SHELL	1,392.37	38.33	1	1.30	144.094	235.8	No
Straight Flange on BOTTOM HEAD	1,392.4	38.36	1	1.30	123.552	235.8	No
BOTTOM HEAD	1,392.43	38.39	1	1.30	129.065	235.8	No
BOTTOM MANWAY (M2)	1,370.09	16.05	1	1.30	157.718	351	No
MEDIA REMOVAL (N3A)	1,380.99	26.96	1	1.30	145.856	351	No
MEDIA REMOVAL (N3B)	1,363.96	9.92	1	1.30	144.057	351	No
PSV/VENT (N4)	1,368.25	14.22	1	1.30	115.187	351	No
SIGHT GLASS (SG1A)	1,387.53	33.49	1	1.30	142.901	351	No
SIGHT GLASS (SG1B)	1,387.53	33.49	1	1.30	142.901	351	No
TOP MANWAY (M1)	1,366.11	12.08	1	1.30	166.705	351	No
WATER INLET (N1)	1,374.65	20.62	1	1.30	126.599	351	No
WATER OUTLET (N2)	1,376.14	22.11	1	1.30	136.337	351	No

Notes:

- (1) TOP HEAD limits the UG-99(b) stress ratio.
- (2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
- (3) $1.5 \cdot 0.9 \cdot S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L .
- (4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The test temperature of 10 °C is warmer than the minimum recommended temperature of -12 °C so the brittle fracture provision of UG-99(h) has been met.

Field test pressure determination for Chamber bounded by BOTTOM HEAD and TOP HEAD based on MAWP per UG-99(b)

Field hydrostatic test gauge pressure is 1,354.04 kPa at 10 °C (the chamber MAWP = 1,041.57 kPa)

The field test is performed with the vessel in the vertical position.

Identifier	Local test pressure kPa	Test liquid static head kPa	UG-99(b) stress ratio	UG-99(b) pressure factor	Stress during test MPa	Allowable test stress MPa	Stress excessive?
TOP HEAD (1)	1,368.73	14.7	1	1.30	132.704	235.8	No
Straight Flange on TOP HEAD	1,368.73	14.7	1	1.30	121.452	235.8	No
3962 mm O.D. SHELL	1,392.12	38.09	1	1.30	144.069	235.8	No
Straight Flange on BOTTOM HEAD	1,393.12	39.09	1	1.30	123.616	235.8	No
BOTTOM HEAD	1,402.74	48.7	1	1.30	130.02	235.8	No
BOTTOM MANWAY (M2)	1,406.35	52.31	1	1.30	161.892	351	No
MEDIA REMOVAL (N3A)	1,394.37	40.33	1	1.30	147.269	351	No
MEDIA REMOVAL (N3B)	1,394.37	40.33	1	1.30	147.269	351	No
PSV/VENT (N4)	1,359.19	5.16	1	1.30	114.424	351	No
SIGHT GLASS (SG1A)	1,374.07	20.03	1	1.30	141.514	351	No
SIGHT GLASS (SG1B)	1,378.87	24.83	1	1.30	142.009	351	No
TOP MANWAY (M1)	1,359.83	5.79	1	1.30	165.937	351	No
WATER INLET (N1)	1,358.44	4.4	1	1.30	125.106	351	No
WATER OUTLET (N2)	1,408.55	54.51	1	1.30	139.547	351	No

Notes:

(1) TOP HEAD limits the UG-99(b) stress ratio.

(2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.

(3) $1.5 \times 0.9 \times S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L .

The test temperature of 10 °C is warmer than the minimum recommended temperature of -12 °C so the brittle fracture provision of UG-99(h) has been met.

Nozzle Schedule

Nozzle mark	Service	Size	Materials		Impact Tested	Normalized	Fine Grain	Flange	Blind
<u>M1</u>	TOP MANWAY	NPS 24 XS DN 600	Nozzle	SA-106 B Smls. Pipe	No	No	No	NPS 24 Class 150 WN A105	NPS 24 Class 150 A105
			Pad	SA-516 70	No	Yes	Yes		
<u>M2</u>	BOTTOM MANWAY	NPS 24 XS DN 600	Nozzle	SA-106 B Smls. Pipe	No	No	No	NPS 24 Class 150 WN A105	NPS 24 Class 150 A105
			Pad	SA-516 70	No	Yes	Yes		
<u>N1</u>	WATER INLET	NPS 12 Sch 60 DN 300	Nozzle	SA-106 B Smls. Pipe	No	No	No	NPS 12 Class 150 WN A105	No
			Pad	SA-516 70	No	Yes	Yes		
<u>N2</u>	WATER OUTLET	NPS 12 Sch 60 DN 300	Nozzle	SA-106 B Smls. Pipe	No	No	No	NPS 12 Class 150 WN A105	No
			Pad	SA-516 70	No	Yes	Yes		
<u>N3A</u>	MEDIA REMOVAL	139.7 OD x 19.05	Nozzle	SA-105	No	No	No	NPS 4 Class 150 LWN A105	NPS 4 Class 150 A105
<u>N3B</u>	MEDIA REMOVAL	139.7 OD x 19.05	Nozzle	SA-105	No	No	No	NPS 4 Class 150 LWN A105	NPS 4 Class 150 A105
<u>N4</u>	PSV/VENT	NPS 3 Sch 160 DN 80	Nozzle	SA-106 B Smls. Pipe	No	No	No	NPS 3 Class 150 WN A105	No
			Pad	SA-516 70	No	Yes	Yes		
<u>SG1A</u>	SIGHT GLASS	255 OD x 54.5	Nozzle	SA-516 70	No	Yes	Yes	N/A	No
<u>SG1B</u>	SIGHT GLASS	255 OD x 54.5	Nozzle	SA-516 70	No	Yes	Yes	N/A	No

Nozzle Summary

Nozzle mark	OD (mm)	t_n (mm)	Req t_n (mm)	$A_1?$	$A_2?$	Shell			Reinforcement Pad		Corr (mm)	A/A_r (%)
						Nom t (mm)	Design t (mm)	User t (mm)	Width (mm)	t_{pad} (mm)		
<u>M1</u>	609.6	12.7	6.88	Yes	Yes	18.22*	16.67		152.4	22.2	3.2	100.4
<u>M2</u>	609.6	12.7	6.8	Yes	Yes	19.05*	17.26		161.92	22.2	3.2	104.3
<u>N1</u>	323.85	14.27	13.18	Yes	Yes	18.22*	16.65		63.5	22.2	3.2	107.7
<u>N2</u>	323.85	14.27	13.18	Yes	Yes	19.05*	17.29		69.85	22.2	3.2	105.1
<u>N3A</u>	139.7	19.05	8.93	Yes	Yes	19.05*	18.59		N/A	N/A	3.2	104.6
<u>N3B</u>	139.7	19.05	8.93	Yes	Yes	19.05*	18.59		N/A	N/A	3.2	104.6
<u>N4</u>	88.9	11.13	9.14	Yes	Yes	18.22*	16.66		50.8	12.7	3.2	128.7
<u>SG1A</u>	255	54.5	11.31	Yes	Yes	19.05	18.39		N/A	N/A	3.2	127.9
<u>SG1B</u>	255	54.5	11.31	Yes	Yes	19.05	18.46		N/A	N/A	3.2	127.0

t_n : Nozzle thickness

Req t_n : Nozzle thickness required per UG-45/UG-16

Nom t: Vessel wall thickness

Design t: Required vessel wall thickness due to pressure + corrosion allowance per UG-37

User t: Local vessel wall thickness (near opening)

A_a : Area available per UG-37, governing condition

A_r : Area required per UG-37, governing condition

Corr: Corrosion allowance on nozzle wall

* Head minimum thickness after forming

Thickness Summary

Component Identifier	Material	Diameter (mm)	Length (mm)	Nominal t (mm)	Design t (mm)	Total Corrosion (mm)	Joint E	Load
<u>TOP HEAD</u>	SA-516 70	3,962 OD	999.61	18.22*	18.12	3.2	1.00	Internal
<u>Straight Flange on TOP HEAD</u>	SA-516 70	3,962 OD	51	22.2	18.21	3.2	1.00	Internal
<u>3962 mm O.D. SHELL</u>	SA-516 70	3,962 OD	2,387	19.05	18.54	3.2	1.00	Internal
<u>Straight Flange on BOTTOM HEAD</u>	SA-516 70	3,962 OD	102	22.2	18.56	3.2	1.00	Internal
<u>BOTTOM HEAD</u>	SA-516 70	3,962 OD	1,000.03	19.05*	18.6	3.2	1.00	Internal

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

Seismic: Combined longitudinal stress of pressure + weight + seismic governs

Weight Summary

Component	Weight (kg) Contributed by Vessel Elements										Surface Area m ²
	Metal New*	Metal Corroded*	Insulation	Insulation Supports	Lining	Piping + Liquid	Operating Liquid		Test Liquid		
							New	Corroded	New	Corroded	
TOP HEAD	2,618.4	2,166.2	171	9.1	208.6	0	8,668.1	8,725.7	8,562.1	8,566	19.27
3962 mm O.D. SHELL	4,396.9	3,661.2	292.1	9.1	358.6	0	28,655.4	28,749.3	28,655.4	28,655.4	29.61
BOTTOM HEAD	2,837.9	2,371	177.2	9.1	218.9	0	9,246.2	9,306.2	9,134.8	9,138.3	19.88
SUPPORT LEG	888	888	0	0	0	0	0	0	0	0	15.69
TOTAL:	10,741.2	9,086.5	640.3	27.2	786.1	0	46,569.7	46,781.2	46,352.3	46,359.8	84.44

* Shells with attached nozzles have weight reduced by material cut out for opening.

Component	Weight (kg) Contributed by Attachments										Surface Area m ²
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays	Tray Supports	Rings & Clips	Vertical Loads	
	New	Corroded	New	Corroded							
<u>TOP HEAD</u>	0	0	659.1	608.6	39.5	0	0	0	0	0	2.98
<u>3962 mm O.D. SHELL</u>	0	0	33.4	29.4	1,848.7	0	0	0	102.5	10,474*	0.52
<u>BOTTOM HEAD</u>	0	0	656.7	621.6	79	0	0	0	20.6	10,409*	3.1
<u>SUPPORT LEG</u>	0	0	0	0	0	0	0	0	0	0	0
TOTAL:	0	0	1,349.2	1,259.6	1,967.2	0	0	0	123.1	20,883*	6.61

* This number includes vertical loads which are not present in all conditions.

* Nozzle weight includes lining.

Vessel operating weight, Corroded: 81,554 kg
 Vessel operating weight, New: 83,087 kg
 Vessel empty weight, Corroded: 26,210 kg
 Vessel empty weight, New: 27,954 kg
 Vessel test weight, New: 63,898 kg
 Vessel test weight, Corroded: 62,161 kg
 Vessel surface area: 91.05 m²

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 25,987 kg
 Center of Gravity: 636.47 mm

Vessel Capacity

Vessel Capacity** (New): 46,134 liters
 Vessel Capacity** (Corroded): 46,134 liters

**The vessel capacity does not include volume of nozzle, piping or other attachments.

TOP HEAD**ASME Section VIII, Division 1, 2010 Edition, A11 Addenda Metric**

Component: Ellipsoidal Head
 Material Specification: SA-516 70 (II-D Metric p.18, ln. 19)
 Material impact test exemption temperature from Fig UCS-66M Curve D = -42.1 °C
 UCS-66 governing thickness = 18.22 mm

Internal design pressure: $P = 1,034 \text{ kPa @ } 120 \text{ °C}$
 External design pressure: $P_e = 103.42 \text{ kPa @ } 120 \text{ °C}$

Static liquid head:

$P_s = 14.2 \text{ kPa}$ (SG=1, $H_s=1449 \text{ mm}$ Operating head)
 $P_{th} = 38.4 \text{ kPa}$ (SG=1, $H_s=3919.21 \text{ mm}$ Horizontal test head)
 $P_v = 14.2 \text{ kPa}$ (SG=1, $H_s=1449 \text{ mm}$ Vertical test head)

Corrosion allowance: Inner C = 3.2 mm Outer C = 0 mm

Design MDMT = -28.89 °C No impact test performed
 Rated MDMT = -42.1 °C Material is normalized
 Material is produced to fine grain practice
 PWHT is not performed
 Do not Optimize MDMT / Find MAWP

Radiography: Category A joints - Full UW-11(a) Type 1
 Head to shell seam - Spot UW-11(a)(5)(b) Type 1

Estimated weight*: new = 2,618.4 kg corr = 2,166.2 kg
 Capacity*: new = 8,427.2 liters corr = 8,427.2 liters
 * includes straight flange

Outer diameter = 3962 mm
 Minimum head thickness = 18.22 mm
 Head ratio D/2h = 2 (new)
 Head ratio D/2h = 1.9968 (corroded)
 Straight flange length L_{sf} = 51 mm
 Nominal straight flange thickness t_{sf} = 22.2 mm

Insulation thk*: 38 mm density: 256.2965 kg/m³ weight: 170.9506 kg
 Insulation support ring spacing: 2,438.4 mm individual weight: 9.0718 kg total weight: 9.0718 kg
 Lining/ref thk*: 6.35 mm density: 1,922.214 kg/m³ weight: 208.6338 kg
 * includes straight flange if applicable

Results Summary

The governing condition is internal pressure.
 Minimum thickness per UG-16 = 1.5 mm + 3.2 mm = 4.7 mm
 Design thickness due to internal pressure (t) = 18.12 mm
 Design thickness due to external pressure (t_e) = 13.41 mm
 Maximum allowable working pressure (MAWP) = 1,041.57 kPa
 Maximum allowable pressure (MAP) = 1,279.83 kPa

Maximum allowable external pressure (MAEP) = 224.31 kPa

K (Corroded)

$$K = (1/6) * [2 + (D / (2 * h))^2] = (1/6) * [2 + (3,931.96 / (2 * 984.59))^2] = 0.997835$$

K (New)

$$K = (1/6) * [2 + (D / (2 * h))^2] = (1/6) * [2 + (3,925.56 / (2 * 981.39))^2] = 1$$

Design thickness for internal pressure, (Corroded at 120 °C) Appendix 1-4(c)

$$\begin{aligned} t &= P * D_o * K / (2 * S * E + 2 * P * (K - 0.1)) + \text{Corrosion} \\ &= 1,048.2 * 3,962 * 0.997835 / (2 * 138,000 * 1 + 2 * 1,048.2 * (0.997835 - 0.1)) + 3.2 \\ &= 18.11 \text{ mm} \end{aligned}$$

The head internal pressure design thickness is 18.12 mm.

Maximum allowable working pressure, (Corroded at 120 °C) Appendix 1-4(c)

$$\begin{aligned} P &= 2 * S * E * t / (K * D_o - 2 * t * (K - 0.1)) - P_s \\ &= 2 * 138,000 * 1 * 15.02 / (0.997835 * 3,962 - 2 * 15.02 * (0.997835 - 0.1)) - 14.2 \\ &= 1,041.57 \text{ kPa} \end{aligned}$$

The maximum allowable working pressure (MAWP) is 1,041.57 kPa.

Maximum allowable pressure, (New at 10 °C) Appendix 1-4(c)

$$\begin{aligned} P &= 2 * S * E * t / (K * D_o - 2 * t * (K - 0.1)) - P_s \\ &= 2 * 138,000 * 1 * 18.22 / (1 * 3,962 - 2 * 18.22 * (1 - 0.1)) - 0 \\ &= 1,279.83 \text{ kPa} \end{aligned}$$

The maximum allowable pressure (MAP) is 1,279.83 kPa.

Design thickness for external pressure, (Corroded at 120 °C) UG-33(d)

Equivalent outside spherical radius (R_o)

$$\begin{aligned} R_o &= K_o * D_o \\ &= 0.8918 * 3,962 \\ &= 3,533.3 \text{ mm} \end{aligned}$$

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (3,533.3 / 10.21) \\ &= 0.000361 \end{aligned}$$

From Table CS-2 $B = 35.7978$
Metric: MPa

$$\begin{aligned} P_a &= B / (R_o / t) \\ &= 35,797.83 / (3,533.3 / 10.21) \\ &= 103.4213 \text{ kPa} \end{aligned}$$

$$t = 10.21 \text{ mm} + \text{Corrosion} = 10.21 \text{ mm} + 3.2 \text{ mm} = 13.41 \text{ mm}$$

Check the external pressure per UG-33(a)(1) Appendix 1-4(c)

$$\begin{aligned}
 t &= 1.67 \cdot P_o \cdot D_o \cdot K / (2 \cdot S \cdot E + 2 \cdot 1.67 \cdot P_o \cdot (K - 0.1)) + \text{Corrosion} \\
 &= 1.67 \cdot 103.42 \cdot 3,962 \cdot 0.997835 / (2 \cdot 138,000 \cdot 1 + 2 \cdot 1.67 \cdot 103.42 \cdot (0.997835 - 0.1)) + \\
 &= 3.2 \\
 &= 5.67 \text{ mm}
 \end{aligned}$$

The head external pressure design thickness (t_o) is 13.41 mm.

Maximum Allowable External Pressure, (Corroded at 120 °C) UG-33(d)

Equivalent outside spherical radius (R_o)

$$\begin{aligned}
 R_o &= K_o \cdot D_o \\
 &= 0.8918 \cdot 3,962 \\
 &= 3,533.3 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (3,533.3 / 15.02) \\
 &= 0.000531
 \end{aligned}$$

From Table CS-2 B = 52.768
Metric: MPa

$$\begin{aligned}
 P_a &= B / (R_o / t) \\
 &= 52,767.98 / (3,533.3 / 15.02) \\
 &= 224.3097 \text{ kPa}
 \end{aligned}$$

Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(c)

$$\begin{aligned}
 P &= 2 \cdot S \cdot E \cdot t / ((K \cdot D_o - 2 \cdot t \cdot (K - 0.1)) \cdot 1.67) - P_{s2} \\
 &= 2 \cdot 138,000 \cdot 1 \cdot 15.02 / ((0.997835 \cdot 3,962 - 2 \cdot 15.02 \cdot (0.997835 - 0.1)) \cdot 1.67) - 0 \\
 &= 632.19 \text{ kPa}
 \end{aligned}$$

The maximum allowable external pressure (MAEP) is 224.31 kPa.

% Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 EFE &= (75 \cdot t / R_i) \cdot (1 - R_i / R_o) \\
 &= (75 \cdot 22.2 / 678.45) \cdot (1 - 678.45 / \infty) \\
 &= 2.4541\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

3962 mm O.D. SHELL

ASME Section VIII Division 1, 2010 Edition, A11 Addenda Metric

Component: Cylinder
 Material specification: SA-516 70 (II-D Metric p. 18, In. 19)
 Material impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C
 Fig UCS-66.1M MDMT reduction = 1.4 °C, (coincident ratio = 0.9748)
 UCS-66 governing thickness = 19.05 mm

Internal design pressure: $P = 1,034 \text{ kPa @ } 120 \text{ °C}$
 External design pressure: $P_e = 103.42 \text{ kPa @ } 120 \text{ °C}$

Static liquid head:

$P_s = 38.09 \text{ kPa}$ (SG = 1, $H_s = 3,887 \text{ mm}$, Operating head)
 $P_{th} = 38.33 \text{ kPa}$ (SG = 1, $H_s = 3,912.03 \text{ mm}$, Horizontal test head)
 $P_v = 38.09 \text{ kPa}$ (SG = 1, $H_s = 3,887 \text{ mm}$, Vertical test head)

Corrosion allowance Inner C = 3.2 mm Outer C = 0 mm

Design MDMT = -28.89 °C No impact test performed
 Rated MDMT = -42.46 °C Material is normalized
 Material is produced to Fine Grain Practice
 PWHT is not performed

Radiography: Longitudinal joint - Full UW-11(a) Type 1
 Top circumferential joint - Spot UW-11(a)(5)(b) Type 1
 Bottom circumferential joint - Spot UW-11(a)(5)(b) Type 1

Estimated weight New = 4,396.9 kg corr = 3,661.2 kg
 Capacity New = 28,678.89 liters corr = 28,678.89 liters

OD	=	3,962 mm			
Length	=	2,387 mm			
L_c					
t	=	19.05 mm			
Insulation thk:	38 mm	density:	256.3 kg/m ³	Weight:	292.1 kg
Insulation Support	2,438.4 mm	Individual Support	9.1 kg	Total Support	9.1 kg
Spacing:		Weight:		Weight:	
Lining/Refractory thickness:	6.35 mm	density:	1,922.21 kg/m ³	Weight:	358.6 kg

Design thickness, (at 120 °C) Appendix 1-1

$$\begin{aligned}
 t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\
 &= 1,072.09 \cdot 1,981 / (138,000 \cdot 1.00 + 0.40 \cdot 1,072.09) + 3.2 \\
 &= 18.54 \text{ mm}
 \end{aligned}$$

Maximum allowable working pressure, (at 120 °C) Appendix 1-1

$$\begin{aligned}
 P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\
 &= 138,000 \cdot 1.00 \cdot 15.85 / (1,981 - 0.40 \cdot 15.85) - 38.09 \\
 &= 1,069.57 \text{ kPa}
 \end{aligned}$$

Maximum allowable pressure, (at 10 °C) Appendix 1-1

$$\begin{aligned}
 P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) \\
 &= 138,000 \cdot 1.00 \cdot 19.05 / (1,981 - 0.40 \cdot 19.05) \\
 &= 1,332.18 \text{ kPa}
 \end{aligned}$$

External Pressure, (Corroded & at 120 °C) UG-28(c)

$$\begin{aligned}
 L / D_o &= 3,196.26 / 3,962 = 0.8067 \\
 D_o / t &= 3,962 / 11.54 = 343.4494 \\
 \text{From table G:} \quad A &= 0.000269 \\
 \text{From table CS-2} \quad B &= 26.64 \text{ MPa} \\
 \text{Metric:}
 \end{aligned}$$

$$\begin{aligned}
 P_a &= 4 \cdot B / (3 \cdot (D_o / t)) \\
 &= 4 \cdot 26,640 / (3 \cdot (3,962 / 11.54)) \\
 &= 103.42 \text{ kPa}
 \end{aligned}$$

Design thickness for external pressure $P_a = 103.42 \text{ kPa}$

$$t_a = t + \text{Corrosion} = 11.54 + 3.2 = 14.74 \text{ mm}$$

Maximum Allowable External Pressure, (Corroded & at 120 °C) UG-28(c)

$$\begin{aligned}
 L / D_o &= 3,196.26 / 3,962 = 0.8067 \\
 D_o / t &= 3,962 / 15.85 = 249.9748 \\
 \text{From table G:} \quad A &= 0.000418 \\
 \text{From table CS-2} \quad B &= 41.508 \text{ MPa} \\
 \text{Metric:}
 \end{aligned}$$

$$\begin{aligned}
 P_a &= 4 \cdot B / (3 \cdot (D_o / t)) \\
 &= 4 \cdot 41,508.05 / (3 \cdot (3,962 / 15.85)) \\
 &= 221.4 \text{ kPa}
 \end{aligned}$$

% Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 \text{EFE} &= (50 \cdot t / R_i) \cdot (1 - R_i / R_o) \\
 &= (50 \cdot 19.05 / 1,971.48) \cdot (1 - 1,971.48 / \infty) \\
 &= 0.4831\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

External Pressure + Weight + Seismic Loading Check (Bergman, ASME paper 54-A-104)

$$\begin{aligned}
 P_v &= W / (2 \cdot \pi \cdot R_m) + M / (\pi \cdot R_m^2) \\
 &= 98.03 \cdot 17,381.9 / (2 \cdot \pi \cdot 1,973.08) + 10000 \cdot 34,208.7 / (\pi \cdot 1,973.08^2) \\
 &= 165.4676 \text{ N/cm} \\
 \alpha &= P_v / (P_e \cdot D_o) \\
 &= 100 \cdot 165.4676 / (103.42 \cdot 3,962) \\
 &= 0.0404 \\
 n &= 7 \\
 m &= 1.23 / (L / D_o)^2
 \end{aligned}$$

$$= 1.23 / (3,196.26 / 3,962)^2$$

$$= 1.8900$$

$$\text{Ratio } P_e = (n^2 - 1 + m + m \cdot \alpha) / (n^2 - 1 + m)$$

$$= (7^2 - 1 + 1.8900 + 1.8900 \cdot 0.0404) / (7^2 - 1 + 1.8900)$$

$$= 1.0015$$

Ratio $P_e \cdot P_o \leq$ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight + Seismic Loading Check at Bottom Seam(Bergman, ASME paper 54-A-104)

$$P_v = W / (2 \cdot \pi \cdot R_m) + M / (\pi \cdot R_m^2)$$

$$= 98.03 \cdot 62,474.3 / (2 \cdot \pi \cdot 1,973.08) + 10000 \cdot 5,638.6 / (\pi \cdot 1,973.08^2)$$

$$= -489.5850 \text{ N/cm}$$

$$\alpha = P_v / (P_o \cdot D_o)$$

$$= 100 \cdot -489.5850 / (103.42 \cdot 3,962)$$

$$= -0.1195$$

$$n = 7$$

$$m = 1.23 / (L / D_o)^2$$

$$= 1.23 / (3,196.26 / 3,962)^2$$

$$= 1.8900$$

$$\text{Ratio } P_e = (n^2 - 1 + m + m \cdot \alpha) / (n^2 - 1 + m)$$

$$= (7^2 - 1 + 1.8900 + 1.8900 \cdot -0.1195) / (7^2 - 1 + 1.8900)$$

$$= 1.0000$$

Ratio $P_e \cdot P_o \leq$ MAEP design cylinder thickness is satisfactory.

Design thickness = 18.54 mm

The governing condition is due to internal pressure.

The cylinder thickness of 19.05 mm is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (kPa)	Allowable Stress Before UG-23 Stress Increase (MPa)		Temperature (°C)	Corrosion C (mm)	Location	Load	Req'd Thk Due to Tension (mm)	Req'd Thk Due to Compression (mm)
		S _t	S _c						
Operating, Hot & Corroded	1,034	138	84.8	120	3.2	Top	Seismic	7.27	7.23
						Bottom	Seismic	7.71	7.71
Operating, Hot & New	1,034	138	89.29	120	0	Top	Seismic	7.25	7.21
						Bottom	Seismic	7.7	7.7
Hot Shut Down, Corroded	0	138	84.8	120	3.2	Top	Seismic	0.13	0.2
						Bottom	Seismic	0.36	0.35
Hot Shut Down, New	0	138	89.29	120	0	Top	Seismic	0.13	0.2
						Bottom	Seismic	0.36	0.36
Empty, Corroded	0	138	84.8	21.11	3.2	Top	Seismic	0.15	0.18
						Bottom	Seismic	0.09	0.09
Empty, New	0	138	89.29	21.11	0	Top	Seismic	0.15	0.18
						Bottom	Seismic	0.1	0.09
Vacuum	-103.42	138	84.8	120	3.2	Top	Seismic	1.33	1.39
						Bottom	Seismic	0.61	0.62
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	138	84.8	120	3.2	Top	Weight	0.16	0.17
						Bottom	Weight	0.36	0.36

BOTTOM HEAD**ASME Section VIII, Division 1, 2010 Edition, A11 Addenda Metric**

Component: Ellipsoidal Head
 Material Specification: SA-516 70 (II-D Metric p.18, In. 19)
 Material impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C
 Fig UCS-66.1M MDMT reduction = 1.2 °C, (coincident ratio = 0.9784)
 UCS-66 governing thickness = 19.05 mm

Internal design pressure: $P = 1,034 \text{ kPa @ } 120 \text{ °C}$
 External design pressure: $P_e = 103.42 \text{ kPa @ } 120 \text{ °C}$

Static liquid head:

$P_s = 48.73 \text{ kPa}$ (SG=1, $H_s=4973.18 \text{ mm}$ Operating head)
 $P_{th} = 38.39 \text{ kPa}$ (SG=1, $H_s=3918.38 \text{ mm}$ Horizontal test head)
 $P_v = 48.7 \text{ kPa}$ (SG=1, $H_s=4969.98 \text{ mm}$ Vertical test head)

Corrosion allowance: Inner C = 3.2 mm Outer C = 0 mm

Design MDMT = -28.89 °C No impact test performed
 Rated MDMT = -42.26 °C Material is normalized
 Material is produced to fine grain practice
 PWHT is not performed
 Do not Optimize MDMT / Find MAWP

Radiography: Category A joints - Full UW-11(a) Type 1
 Head to shell seam - Spot UW-11(a)(5)(b) Type 1

Estimated weight*: new = 2,837.9 kg corr = 2,371 kg
 Capacity*: new = 9,028 liters corr = 9,028 liters
 * includes straight flange

Outer diameter = 3962 mm
 Minimum head thickness = 19.05 mm
 Head ratio D/2h = 2 (new)
 Head ratio D/2h = 1.9967 (corroded)
 Straight flange length L_{sf} = 102 mm
 Nominal straight flange thickness t_{sf} = 22.2 mm

Insulation thk*: 38 mm density: 256.2965 kg/m³ weight: 177.2262 kg
 Insulation support ring spacing: 2,438.4 mm individual weight: 9.0718 kg total weight: 9.0718 kg
 Lining/ref thk*: 6.35 mm density: 1,922.214 kg/m³ weight: 218.9171 kg
 * includes straight flange if applicable

Results Summary

The governing condition is internal pressure.
 Minimum thickness per UG-16 = 1.5 mm + 3.2 mm = 4.7 mm
 Design thickness due to internal pressure (t) = 18.6 mm
 Design thickness due to external pressure (t_e) = 13.41 mm
 Maximum allowable working pressure (MAWP) = 1,065.8 kPa

Maximum allowable pressure (MAP) = 1,338.64 kPa
 Maximum allowable external pressure (MAEP) = 250.06 kPa

K (Corroded)

$$K = (1/6) * [2 + (D / (2 * h))^2] = (1/6) * [2 + (3,930.3 / (2 * 984.18))^2] = 0.997834$$

K (New)

$$K = (1/6) * [2 + (D / (2 * h))^2] = (1/6) * [2 + (3,923.9 / (2 * 980.98))^2] = 1$$

Design thickness for internal pressure, (Corroded at 120 °C) Appendix 1-4(c)

$$\begin{aligned} t &= P D_o K / (2 S E + 2 P (K - 0.1)) + \text{Corrosion} \\ &= 1,082.73 * 3,962 * 0.997834 / (2 * 138,000 * 1 + 2 * 1,082.73 * (0.997834 - 0.1)) + 3.2 \\ &= 18.6 \text{ mm} \end{aligned}$$

The head internal pressure design thickness is 18.6 mm.

Maximum allowable working pressure, (Corroded at 120 °C) Appendix 1-4(c)

$$\begin{aligned} P &= 2 S E t / (K D_o - 2 t (K - 0.1)) - P_s \\ &= 2 * 138,000 * 1 * 15.85 / (0.997834 * 3,962 - 2 * 15.85 * (0.997834 - 0.1)) - 48.73 \\ &= 1,065.8 \text{ kPa} \end{aligned}$$

The maximum allowable working pressure (MAWP) is 1,065.8 kPa.

Maximum allowable pressure, (New at 10 °C) Appendix 1-4(c)

$$\begin{aligned} P &= 2 S E t / (K D_o - 2 t (K - 0.1)) - P_s \\ &= 2 * 138,000 * 1 * 19.05 / (1 * 3,962 - 2 * 19.05 * (1 - 0.1)) - 0 \\ &= 1,338.64 \text{ kPa} \end{aligned}$$

The maximum allowable pressure (MAP) is 1,338.64 kPa.

Design thickness for external pressure, (Corroded at 120 °C) UG-33(d)

Equivalent outside spherical radius (R_o)

$$\begin{aligned} R_o &= K_o D_o \\ &= 0.8914 * 3,962 \\ &= 3,531.84 \text{ mm} \end{aligned}$$

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (3,531.84 / 10.2) \\ &= 0.000361 \end{aligned}$$

From Table CS-2 $B = 35.7978$
 Metric: MPa

$$\begin{aligned} P_a &= B / (R_o / t) \\ &= 35,797.85 / (3,531.84 / 10.2) \\ &= 103.4214 \text{ kPa} \end{aligned}$$

$$t = 10.2 \text{ mm} + \text{Corrosion} = 10.2 \text{ mm} + 3.2 \text{ mm} = 13.4 \text{ mm}$$

Check the external pressure per UG-33(a)(1) Appendix 1-4(c)

$$\begin{aligned}
 t &= 1.67 \cdot P_e \cdot D_o \cdot K / (2 \cdot S \cdot E + 2 \cdot 1.67 \cdot P_e \cdot (K - 0.1)) + \text{Corrosion} \\
 &= 1.67 \cdot 103.42 \cdot 3,962 \cdot 0.997834 / (2 \cdot 138,000 \cdot 1 + 2 \cdot 1.67 \cdot 103.42 \cdot (0.997834 - 0.1)) + \\
 &= 3.2 \\
 &= 5.67 \text{ mm}
 \end{aligned}$$

The head external pressure design thickness (t_e) is 13.4 mm.

Maximum Allowable External Pressure, (Corroded at 120 °C) UG-33(d)

Equivalent outside spherical radius (R_o)

$$\begin{aligned}
 R_o &= K_o \cdot D_o \\
 &= 0.8914 \cdot 3,962 \\
 &= 3,531.84 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (3,531.84 / 15.85) \\
 &= 0.000561
 \end{aligned}$$

From Table CS-2 B = 55.7213
Metric: MPa

$$\begin{aligned}
 P_a &= B / (R_o / t) \\
 &= 55,721.34 / (3,531.84 / 15.85) \\
 &= 250.0571 \text{ kPa}
 \end{aligned}$$

Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(c)

$$\begin{aligned}
 P &= 2 \cdot S \cdot E \cdot t / ((K \cdot D_o - 2 \cdot t \cdot (K - 0.1)) \cdot 1.67) - P_{s2} \\
 &= 2 \cdot 138,000 \cdot 1 \cdot 15.85 / ((0.997834 \cdot 3,962 - 2 \cdot 15.85 \cdot (0.997834 - 0.1)) \cdot 1.67) - 0 \\
 &= 667.38 \text{ kPa}
 \end{aligned}$$

The maximum allowable external pressure (MAEP) is 250.06 kPa.

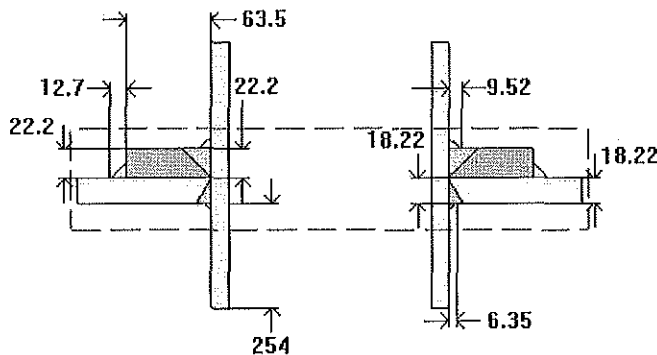
% Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 EFE &= (75 \cdot t / R_i) \cdot (1 - R_i / R_o) \\
 &= (75 \cdot 22.2 / 678.16) \cdot (1 - 678.16 / \infty) \\
 &= 2.4552\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

WATER INLET (N1)

ASME Section VIII Division 1, 2010 Edition, A11 Addenda Metric



$$\begin{aligned}
 t_{w(\text{lower})} &= 18.22 \text{ mm} \\
 \text{Leg}_{41} &= 9.53 \text{ mm} \\
 t_{w(\text{upper})} &= 22.2 \text{ mm} \\
 \text{Leg}_{42} &= 12.7 \text{ mm} \\
 \text{Leg}_{43} &= 6.35 \text{ mm} \\
 h_{\text{new}} &= 254 \text{ mm} \\
 D_p &= 450.85 \text{ mm} \\
 t_e &= 22.2 \text{ mm}
 \end{aligned}$$

Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	TOP HEAD
Orientation:	0°
End of nozzle to datum line:	3,989 mm
Calculated as hillside:	No
Distance to head center, R:	0 mm
Passes through a Category A joint:	No

Nozzle

Material specification:	SA-106 B Smls. Pipe (II-D Metric p. 10, In. 40)
Description:	NPS 12 Sch 60 DN 300
Inside diameter, new:	295.3 mm
Nominal wall thickness:	14.27 mm
Corrosion allowance:	3.2 mm
Projection available outside vessel, Lpr:	338.43 mm
Internal projection, h_{new} :	254 mm
Projection available outside vessel to flange face, Lf:	452.73 mm
Local vessel minimum thickness:	18.22 mm
Liquid static head included:	4.5816 kPa
Longitudinal joint efficiency:	1

Reinforcing Pad

Material specification:	SA-516 70 (II-D Metric p. 18, In. 19) (normalized)
Diameter:	450.85 mm
Is split:	No

ASME B16.5-2009 Flange

Description:	NPS 12 Class 150 WN A105
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WO. 12-32

32125-D-2202-01

23/146

Bolt Material:	SA-193 B7 Bolt \leq 64 (II-D Metric p. 334, ln. 32)
Blind included:	No
Rated MDMT:	-48°C per UCS-66(b)(1)(b)
Liquid static head:	0 kPa
MAWP rating:	1,694 kPa @ 120°C
MAP rating:	1,960 kPa @ 10°C
Hydrotest rating:	3,000 kPa @ 10°C
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1

R2

3/25/2013

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 1,046.15 kPa @ 120 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
41.0175	44.1876	4.6781	6.249	2.6511	28.194	2.4155	11.53	12.49

UG-41 Weld Failure Path Analysis Summary (N)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength	Weld load W ₃₋₃	Path 3-3 strength
505.581	508.273	1,057.615	173.154	2,265.967	584.489	1,440.724

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg ₄₁)	6	6.67	weld size is adequate
Pad to shell fillet (Leg ₄₂)	7.51	8.89	weld size is adequate
Nozzle to pad groove (Upper)	7.75	22.2	weld size is adequate

Calculations for internal pressure 1,046.15 kPa @ 120 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.2293).
External nozzle loadings per UG-22 govern the coincident ratio used.

Pad impact test exemption temperature from Fig UCS-66M Curve D = -42.1 °C
Fig UCS-66.1M MDMT reduction = 5.8 °C, (coincident ratio = 0.8957).

Nozzle UCS-66 governing thk: 12.49 mm

Nozzle rated MDMT: -105 °C

Pad UCS-66 governing thickness: 18.22 mm

Pad rated MDMT: -47.9 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(301.7, 150.85 + (14.27 - 3.2) + (18.22 - 3.2)) \\
 &= 301.7 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(18.22 - 3.2), 2.5*(14.27 - 3.2) + 22.2) \\
 &= 37.55 \text{ mm}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(18.22 - 3.2), 2.5*(14.27 - 3.2 - 3.2)) \\
 &= 19.69 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P*R_n / (S_n*E - 0.6*P) \\
 &= 1,046.1486*150.85 / (118,000*1 - 0.6*1,046.1486) \\
 &= 1.34 \text{ mm}
 \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned}
 t_r &= P*K_1*D_o / (2*S*E + 0.8*P) \\
 &= 1,046.1486*0.8985*3,962 / (2*138,000*1 + 0.8*1,046.1486) \\
 &= 13.45 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 138$, $S_p = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8551$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned}
 A &= d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}) \\
 &= (301.7*13.45*1 + 2*11.07*13.45*1*(1 - 0.8551)) / 100 \\
 &= \underline{41.0175} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{4.6781} \text{ cm}^2$$

$$\begin{aligned}
 &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\
 &= (301.7*(1*15.02 - 1*13.45) - 2*11.07*(1*15.02 - 1*13.45)*(1 - 0.8551)) / 100 \\
 &= 4.6781 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\
 &= (2*(15.02 + 11.07)*(1*15.02 - 1*13.45) - 2*11.07*(1*15.02 - 1*13.45)*(1 - 0.8551)) / 100 \\
 &= 0.7677 \text{ cm}^2
 \end{aligned}$$

A_2 = smaller of the following= 6.249 cm²

$$\begin{aligned}
 &= 5*(t_n - t_m)*f_{r2}*t \\
 &= (5*(11.07 - 1.34)*0.8551*15.02) / 100 \\
 &= 6.249 \text{ cm}^2 \\
 &= 2*(t_n - t_m)*(2.5*t_n + t_e)*f_{r2} \\
 &= (2*(11.07 - 1.34)*(2.5*11.07 + 22.2)*0.8551) / 100 \\
 &= 8.3026 \text{ cm}^2
 \end{aligned}$$

A_3 = smaller of the following= 2.6511 cm²

$$\begin{aligned}
 &= 5*t_i*f_{r2} \\
 &= (5*15.02*7.87*0.8551) / 100 \\
 &= 5.0566 \text{ cm}^2 \\
 &= 5*t_i*f_{r2} \\
 &= (5*7.87*7.87*0.8551) / 100 \\
 &= 2.6511 \text{ cm}^2 \\
 &= 2*h*t_i*f_{r2} \\
 &= (2*250.8*7.87*0.8551) / 100 \\
 &= 33.7747 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2*f_{r3} \\
 &= (9.53^2*0.8551) / 100 \\
 &= 0.7755 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{42} &= \text{Leg}^2*f_{r4} \\
 &= (12.7^2*1) / 100 \\
 &= 1.6129 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2*f_{r2} \\
 &= (1.78^2*0.8551) / 100 \\
 &= 0.0271 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\
 &= ((450.85 - 301.7 - 2*11.07)*22.2*1) / 100 \\
 &= 28.194 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5 \\
 &= 4.6781 + 6.249 + 2.6511 + 0.7755 + 1.6129 + 0.0271 + 28.194
 \end{aligned}$$

$$= 44.1876 \text{ cm}^2$$

As Area \geq A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \text{lesser of } 19 \text{ mm or } t_n \text{ or } t_e = 11.07 \text{ mm}$

$$t_{c(\min)} = \text{lesser of } 6 \text{ mm or } 0.7 * t_{\min} = 6 \text{ mm}$$

$$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 9.53 = 6.67 \text{ mm}$$

Outer fillet: $t_{\min} = \text{lesser of } 19 \text{ mm or } t_o \text{ or } t = 15.02 \text{ mm}$

$$t_{w(\min)} = 0.5 * t_{\min} = 7.51 \text{ mm}$$

$$t_{w(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 12.7 = 8.89 \text{ mm}$$

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned} t_{a \text{ UG-27}} &= P * R / (S * E - 0.6 * P) + \text{Corrosion} \\ &= 1,046.1486 * 150.85 / (118,000 * 1 - 0.6 * 1,046.1486) + 3.2 \\ &= 4.54 \text{ mm} \end{aligned}$$

$$t_{a \text{ UG-22}} = 5.33 \text{ mm}$$

$$\begin{aligned} t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\ &= \max[4.54, 5.33] \\ &= 5.33 \text{ mm} \end{aligned}$$

$$t_{b1} = 18.08 \text{ mm}$$

$$\begin{aligned} t_{b1} &= \max[t_{b1}, t_{b \text{ UG16}}] \\ &= \max[18.08, 4.7] \\ &= 18.08 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b1}] \\ &= \min[11.53, 18.08] \\ &= 11.53 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a, t_b] \\ &= \max[5.33, 11.53] \\ &= 11.53 \text{ mm} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 * 14.27 = 12.49 \text{ mm}$

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45 and UW-15(c)

$$\text{Groove weld in tension: } 0.74 \times 138 = 102.12 \text{ MPa}$$

$$\text{Nozzle wall in shear: } 0.7 \times 118 = 82.6 \text{ MPa}$$

$$\text{Inner fillet weld in shear: } 0.49 \times 118 = 57.82 \text{ MPa}$$

$$\text{Outer fillet weld in shear: } 0.49 \times 138 = 67.62 \text{ MPa}$$

$$\text{Upper groove weld in tension: } 0.74 \times 138 = 102.12 \text{ MPa}$$

$$\text{Lower fillet weld in shear: } 0.49 \times 118 = 57.82 \text{ MPa}$$

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi / 2) \times \text{Nozzle OD} \times \text{Leg} \times S_f = (\pi / 2) \times 323.85 \times 9.53 \times 57.82 = 280,160.5 \text{ N}$$

(2) Outer fillet weld in shear

$$(\pi / 2) \times \text{Pad OD} \times \text{Leg} \times S_o = (\pi / 2) \times 450.85 \times 12.7 \times 67.62 = 608,178.28 \text{ N}$$

(3) Nozzle wall in shear

$$(\pi / 2) \times \text{Mean nozzle dia} \times t_n \times S_n = (\pi / 2) \times 312.78 \times 11.07 \times 82.6 = 449,436.31 \text{ N}$$

(4) Groove weld in tension

$$(\pi / 2) \times \text{Nozzle OD} \times t_w \times S_g = (\pi / 2) \times 323.85 \times 15.02 \times 102.12 = 780,248.65 \text{ N}$$

(5) Lower fillet weld in shear

$$(\pi / 2) \times \text{Nozzle OD} \times \text{Leg} \times S_f = (\pi / 2) \times 323.85 \times 1.78 \times 57.82 = 52,296.63 \text{ N}$$

(6) Upper groove weld in tension

$$(\pi / 2) \times \text{Nozzle OD} \times t_w \times S_g = (\pi / 2) \times 323.85 \times 22.2 \times 102.12 = 1,153,261.07 \text{ N}$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 \times t_n \times f_{r1} \times (E_1 \times t - F \times t_r)) \times S_v \\ &= (4,101.7539 - 467.8055 + 2 \times 11.07 \times 0.8551 \times (1 \times 15.02 - 1 \times 13.45)) \times 138 \\ &= \underline{505,581.34 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) \times S_v \\ &= (624.902 + 2,819.4 + 77.5482 + 161.29) \times 138 \\ &= \underline{508,273.42 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 \times t_n \times t \times f_{r1}) \times S_v \\ &= (624.902 + 265.1074 + 77.5482 + 2.7097 + 2 \times 11.07 \times 15.02 \times 0.8551) \times 138 \\ &= \underline{173,154.19 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \times t_n \times t \times f_{r1}) \times S_v \\ &= (624.902 + 265.1074 + 2,819.4 + 77.5482 + 161.29 + 2.7097 + 2 \times 11.07 \times 15.02 \times 0.8551) \times 138 \\ &= \underline{584,489.47 \text{ N}} \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 505,581.34 \text{ N}$

Path 1-1 through (2) & (3) = $608,178.28 + 449,436.31 = \underline{1,057,614.59}$ N
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2-2} = 173,154.19$ N

Path 2-2 through (1), (4), (5), (6) = $280,160.5 + 780,248.65 + 52,296.63 + 1,153,261.07 = \underline{2,265,966.84}$ N
Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3-3} = 505,581.34$ N

Path 3-3 through (2), (4), (5) = $608,178.28 + 780,248.65 + 52,296.63 = \underline{1,440,723.56}$ N
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load: $P_r = -9,880 \text{ N}$
 Circumferential moment: $M_1 = 12,390 \text{ N-m}$
 Circumferential shear: $V_2 = 12,100 \text{ N}$
 Longitudinal moment: $M_2 = 12,390 \text{ N-m}$
 Longitudinal shear: $V_1 = 12,100 \text{ N}$
 Torsion moment: $M_t = 17,520 \text{ N-m}$
 Internal pressure: $P = 1,046.15 \text{ kPa}$
 Head yield stress: $S_y = 236 \text{ MPa}$

Maximum stresses due to the applied loads at the pad edge (includes pressure)

Mean dish radius $R_m = 3,554.18 \text{ mm}$

$$U = r_o / \text{Sqr}(R_m * t) = 0.976$$

Pressure stress intensity factor, $I = 1$ (derived from PVP-Vol. 399, pages 77-82)

$$\text{Local pressure stress} = I * P * R_i / (2 * t) = 123.52 \text{ MPa}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 266.86 \text{ MPa}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = \pm 3 * S = \pm 414 \text{ MPa}$$

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 145.62 \text{ MPa}$$

$$\text{Allowable local primary membrane stress } (P_L) = \pm 1.5 * S = \pm 207 \text{ MPa}$$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the pad edge per WRC Bulletin 107									
Figure	value	A _u	A _l	B _u	B _l	C _u	C _l	D _u	D _l
SR-2*	0.0684	2.992	2.992	2.992	2.992	2.992	2.992	2.992	2.992
SR-2	0.0366	9.618	-9.618	9.618	-9.618	9.618	-9.618	9.618	-9.618
SR-3*	0.0804	0	0	0	0	-19.112	-19.112	19.112	19.112
SR-3	0.0781	0	0	0	0	-111.392	111.392	111.392	-111.392
SR-3*	0.0804	-19.112	-19.112	19.112	19.112	0	0	0	0
SR-3	0.0781	-111.392	111.392	111.392	-111.392	0	0	0	0
Pressure stress*		123.52	123.52	123.52	123.52	123.52	123.52	123.52	123.52
Total O _x stress		5.626	209.173	266.634	24.614	5.626	209.173	266.634	24.614
Membrane O _x stress*		107.4	107.4	145.624	145.624	107.4	107.4	145.624	145.624
SR-2*	0.0212	0.931	0.931	0.931	0.931	0.931	0.931	0.931	0.931
SR-2	0.011	2.889	-2.889	2.889	-2.889	2.889	-2.889	2.889	-2.889
SR-3*	0.0242	0	0	0	0	-5.75	-5.75	5.75	5.75
SR-3	0.0235	0	0	0	0	-33.515	33.515	33.515	-33.515
SR-3*	0.0242	-5.75	-5.75	5.75	5.75	0	0	0	0
SR-3	0.0235	-33.515	33.515	33.515	-33.515	0	0	0	0
Pressure stress*		123.52	123.52	123.52	123.52	123.52	123.52	123.52	123.52
Total O _y stress		88.074	149.327	166.605	93.796	88.074	149.327	166.605	93.796
Membrane O _y stress*		118.7	118.7	130.201	130.201	118.7	118.7	130.201	130.201
Shear from M _t		3.654	3.654	3.654	3.654	3.654	3.654	3.654	3.654
Shear from V ₁		0	0	0	0	-1.138	-1.138	1.138	1.138
Shear from V ₂		1.138	1.138	-1.138	-1.138	0	0	0	0
Total Shear stress		4.792	4.792	2.517	2.517	2.517	2.517	4.792	4.792
Combined stress (P _L +P _b +Q)		88.349	209.552	266.696	93.886	88.149	209.277	266.862	94.127

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

Mean dish radius $R_m = 3,554.18$ mm

$$U = r_o / \text{Sqr}(R_m \cdot t) = 0.445$$

Pressure stress intensity factor, $I = 0.47135$ (derived from PVP-Vol. 399, pages 77-82)

$$\text{Local pressure stress} = I \cdot P \cdot R_i / (2 \cdot t) = 58.219 \text{ MPa}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 109.39 \text{ MPa}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = \pm 3 \cdot S = \pm 414 \text{ MPa}$$

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 63 \text{ MPa}$$

$$\text{Allowable local primary membrane stress } (P_L) = \pm 1.5 \cdot S = \pm 207 \text{ MPa}$$

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The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the nozzle OD per WRC Bulletin 107									
Figure	value	A _u	A _l	B _u	B _l	C _u	C _l	D _u	D _l
SR-2*	0.1465	1.048	1.048	1.048	1.048	1.048	1.048	1.048	1.048
SR-2	0.0933	3.992	-3.992	3.992	-3.992	3.992	-3.992	3.992	-3.992
SR-3*	0.1518	0	0	0	0	-3.73	-3.73	3.73	3.73
SR-3	0.285	0	0	0	0	-42.051	42.051	42.051	-42.051
SR-3*	0.1518	-3.73	-3.73	3.73	3.73	0	0	0	0
SR-3	0.285	-42.051	42.051	42.051	-42.051	0	0	0	0
Pressure stress*	58.219	58.219	58.219	58.219	58.219	58.219	58.219	58.219	58.219
Total O _x stress	17.478	93.596	109.041	16.954	17.478	93.596	109.041	16.954	
Membrane O _x stress*	55.537	55.537	62.997	62.997	55.537	55.537	62.997	62.997	
SR-2*	0.0439	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
SR-2	0.0284	1.213	-1.213	1.213	-1.213	1.213	-1.213	1.213	-1.213
SR-3*	0.0463	0	0	0	0	-1.138	-1.138	1.138	1.138
SR-3	0.0872	0	0	0	0	-12.866	12.866	12.866	-12.866
SR-3*	0.0463	-1.138	-1.138	1.138	1.138	0	0	0	0
SR-3	0.0872	-12.866	12.866	12.866	-12.866	0	0	0	0
Pressure stress*	58.219	58.219	58.219	58.219	58.219	58.219	58.219	58.219	58.219
Total O _y stress	45.74	69.044	73.746	45.588	45.74	69.044	73.746	45.588	
Membrane O _y stress*	57.392	57.392	59.667	59.667	57.392	57.392	59.667	59.667	
Shear from M _t	2.854	2.854	2.854	2.854	2.854	2.854	2.854	2.854	2.854
Shear from V ₁	0	0	0	0	-0.641	-0.641	0.641	0.641	
Shear from V ₂	0.641	0.641	-0.641	-0.641	0	0	0	0	
Total Shear stress	3.496	3.496	2.213	2.213	2.213	2.213	3.496	3.496	
Combined stress (P _L +P _b +Q)	46.167	94.086	109.178	45.761	45.912	93.796	109.385	46.009	

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\begin{aligned}\sigma_{n(P_m)} &= P \cdot R_i / (2 \cdot t_n) - P_r / (\pi \cdot (R_o^2 - R_i^2)) + M \cdot R_o / I \\ &= 1,046.15 / 1000 \cdot 150.85 / (2 \cdot 9.29) - 9,880 / (\pi \cdot (161.93^2 - 150.85^2)) + 1.7522 \text{E}+07 \cdot 161.93 / 1.3324 \text{E}+08 \\ &= 30.695 \text{ MPa}\end{aligned}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable ($\leq S = 118 \text{ MPa}$)

Shear stress in the nozzle wall due to external loads

$$\begin{aligned}\sigma_{\text{shear}} &= (V_L^2 + V_o^2)^{0.5} / (\pi \cdot R_i \cdot t_n) \\ &= (12,100^2 + 12,100^2)^{0.5} / (\pi \cdot 150.85 \cdot 11.07) \\ &= 3.26 \text{ MPa}\end{aligned}$$

$$\begin{aligned}\sigma_{\text{torsion}} &= M_t / (2 \cdot \pi \cdot R_i^2 \cdot t_n) \\ &= 17,520 / (2 \cdot \pi \cdot 150.85^2 \cdot 11.07)\end{aligned}$$

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$$= 11.064 \text{ MPa}$$

$$\begin{aligned}\sigma_{\text{total}} &= \sigma_{\text{shear}} + \sigma_{\text{torsion}} \\ &= 3.26 + 11.064 \\ &= 14.325 \text{ MPa}\end{aligned}$$

UG-45: The total combined shear stress (14.325 MPa) is below than the allowable ($0.7 \cdot S_n = 0.7 \cdot 118 = 82.6 \text{ MPa}$)

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For $P_e = 224.31$ kPa @ 120 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
22.898	39.3231	--	6.0626	2.6511	28.194	2.4155	6.41	12.49

UG-41 Weld Failure Path Analysis Summary

Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary

Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg ₄₁)	6	6.67	weld size is adequate
Pad to shell fillet (Leg ₄₂)	7.51	8.89	weld size is adequate
Nozzle to pad groove (Upper)	7.75	22.2	weld size is adequate

Calculations for external pressure 224.31 kPa @ 120 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(301.7, 150.85 + (14.27 - 3.2) + (18.22 - 3.2)) \\
 &= 301.7 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_a) \\
 &= \text{MIN}(2.5*(18.22 - 3.2), 2.5*(14.27 - 3.2) + 22.2) \\
 &= 37.55 \text{ mm}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(18.22 - 3.2), 2.5*(14.27 - 3.2 - 3.2)) \\
 &= 19.69 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_m = 1.63$ mm

From UG-37(d)(1) required thickness $t_r = 15.02$ mm

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 118$, $S_v = 138$, $S_p = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8551$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned} A &= 0.5(d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) \\ &= (0.5(301.7 \cdot 15.02 \cdot 1 + 2 \cdot 11.07 \cdot 15.02 \cdot 1 \cdot (1 - 0.8551))) / 100 \\ &= \underline{22.898} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = 0 \text{ cm}^2$

$$\begin{aligned} &= d(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= (301.7 \cdot (1 \cdot 15.02 - 1 \cdot 15.02) - 2 \cdot 11.07 \cdot (1 \cdot 15.02 - 1 \cdot 15.02) \cdot (1 - 0.8551)) / 100 \\ &= 0 \text{ cm}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= (2 \cdot (15.02 + 11.07) \cdot (1 \cdot 15.02 - 1 \cdot 15.02) - 2 \cdot 11.07 \cdot (1 \cdot 15.02 - 1 \cdot 15.02) \cdot (1 - 0.8551)) / 100 \\ &= 0 \text{ cm}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{6.0626} \text{ cm}^2$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= (5 \cdot (11.07 - 1.63) \cdot 0.8551 \cdot 15.02) / 100 \\ &= 6.0626 \text{ cm}^2 \\ &= 2 \cdot (t_n - t_m) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2} \\ &= (2 \cdot (11.07 - 1.63) \cdot (2.5 \cdot 11.07 + 22.2) \cdot 0.8551) / 100 \\ &= 8.0548 \text{ cm}^2 \end{aligned}$$

$A_3 = \text{smaller of the following} = \underline{2.6511} \text{ cm}^2$

$$\begin{aligned} &= 5 \cdot t_i \cdot t_r \cdot f_{r2} \\ &= (5 \cdot 15.02 \cdot 7.87 \cdot 0.8551) / 100 \\ &= \underline{5.0566} \text{ cm}^2 \\ &= 5 \cdot t_i \cdot t_r \cdot f_{r2} \\ &= (5 \cdot 7.87 \cdot 7.87 \cdot 0.8551) / 100 \\ &= \underline{2.6511} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned}
 &= 2 \cdot h \cdot t_f \cdot f_{r2} \\
 &= (2 \cdot 250.8 \cdot 7.87 \cdot 0.8551) / 100 \\
 &= \underline{33.7747} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r3} \\
 &= (9.53^2 \cdot 0.8551) / 100 \\
 &= \underline{0.7755} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{42} &= \text{Leg}^2 \cdot f_{r4} \\
 &= (12.7^2 \cdot 1) / 100 \\
 &= \underline{1.6129} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 \cdot f_{r2} \\
 &= (1.78^2 \cdot 0.8551) / 100 \\
 &= \underline{0.0271} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_5 &= (D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4} \\
 &= ((450.85 - 301.7 - 2 \cdot 11.07) \cdot 22.2 \cdot 1) / 100 \\
 &= \underline{28.194} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5 \\
 &= 0 + 6.0626 + 2.6511 + 0.7755 + 1.6129 + 0.0271 + 28.194 \\
 &= \underline{39.3231} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t_e = 11.07 \text{ mm} \\
 t_{c(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = \underline{6} \text{ mm} \\
 t_{c(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 9.53 = 6.67 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_e \text{ or } t = 15.02 \text{ mm} \\
 t_{w(\min)} &= 0.5 \cdot t_{\min} = \underline{7.51} \text{ mm} \\
 t_{w(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 12.7 = 8.89 \text{ mm}
 \end{aligned}$$

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$t_{a \text{ UG-28}} = 4.83 \text{ mm}$$

$$t_{a \text{ UG-22}} = 4.53 \text{ mm}$$

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$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-28}}, t_{a \text{ UG-22}}] \\
 &= \max[4.83, 4.53] \\
 &= 4.83 \text{ mm}
 \end{aligned}$$

$$t_{b2} = 6.41 \text{ mm}$$

$$\begin{aligned}
 t_{b2} &= \max[t_{b2}, t_{b \text{ UG16}}] \\
 &= \max[6.41, 4.7] \\
 &= 6.41 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_b &= \min[t_{b3}, t_{b2}] \\
 &= \min[11.53, 6.41] \\
 &= 6.41 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_{\text{UG-45}} &= \max[t_a, t_b] \\
 &= \max[4.83, 6.41] \\
 &= 6.41 \text{ mm}
 \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 \times 14.27 = 12.49 \text{ mm}$

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 120 °C) UG-28(c)

$$\begin{aligned}
 L / D_o &= 452.73 / 323.85 = 1.3980 \\
 D_o / t &= 323.85 / 1.63 = 198.2439 \\
 \text{From table G:} \quad A &= 0.000337 \\
 \text{From table CS-2} \quad B &= 33.3504 \text{ MPa} \\
 \text{Metric:}
 \end{aligned}$$

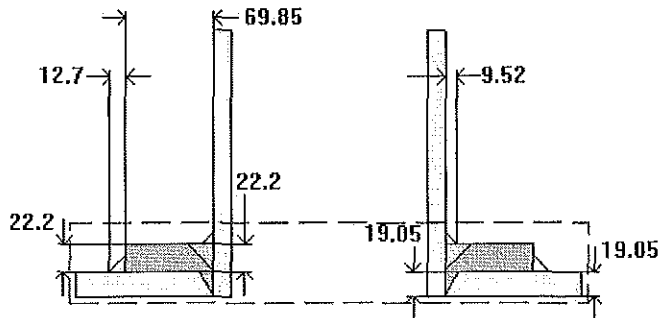
$$\begin{aligned}
 P_a &= 4 \cdot B / (3 \cdot (D_o / t)) \\
 &= 4 \cdot 33,350.43 / (3 \cdot (323.85 / 1.63)) \\
 &= 224.31 \text{ kPa}
 \end{aligned}$$

Design thickness for external pressure $P_a = 224.31 \text{ kPa}$

$$t_a = t + \text{Corrosion} = 1.63 + 3.2 = 4.83 \text{ mm}$$

WATER OUTLET (N2)

ASME Section VIII Division 1, 2010 Edition, A11 Addenda Metric



$$\begin{aligned}
 t_{w(\text{lower})} &= 19.05 \text{ mm} \\
 \text{Leg}_{41} &= 9.53 \text{ mm} \\
 t_{w(\text{upper})} &= 22.2 \text{ mm} \\
 \text{Leg}_{42} &= 12.7 \text{ mm} \\
 D_p &= 463.79 \text{ mm} \\
 t_e &= 22.2 \text{ mm}
 \end{aligned}$$

Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	BOTTOM HEAD
Orientation:	180°
End of nozzle to datum line:	-1,574 mm
Calculated as hillside:	Yes
Distance to head center, R:	152 mm
Passes through a Category A joint:	No

Nozzle

Material specification:	SA-106 B Smls. Pipe (II-D Metric p. 10, ln. 40)
Description:	NPS 12 Sch 60 DN 300
Inside diameter, new:	295.3 mm
Nominal wall thickness:	14.27 mm
Corrosion allowance:	3.2 mm
Opening chord length:	301.93 mm
Projection available outside vessel, L _{pr} :	459.69 mm
Projection available outside vessel to flange face, L _f :	573.99 mm
Local vessel minimum thickness:	19.05 mm
Liquid static head included:	54.3224 kPa
Longitudinal joint efficiency:	1

Reinforcing Pad

Material specification:	SA-516 70 (II-D Metric p. 18, ln. 19) (normalized)
Diameter:	463.79 mm
Is split:	No

ASME B16.5-2009 Flange

Description:	NPS 12 Class 150 WN A105
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WO. 12-32

32125-D-2202-01

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Bolt Material:	SA-193 B7 Bolt \leq 64 (II-D Metric p. 334, ln. 32)
Blind included:	No
Rated MDMT:	-48 °C per UCS-66(b)(1)(b)
Liquid static head:	54.5086 kPa
MAWP rating:	1,694 kPa @ 120 °C
MAP rating:	1,960 kPa @ 10 °C
Hydrotest rating:	3,000 kPa @ 10 °C
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1

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Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 1,095.89 kPa @ 120 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
42.9946	45.2076	5.2561	6.5497	--	31.0134	2.3884	11.53	12.49

UG-41 Weld Failure Path Analysis Summary (N)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength	Weld load W ₃₋₃	Path 3-3 strength
525.389	551.330	1,075.072	142.514	2,256.788	592.757	1,449.002

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg ₄₁)	6	6.67	weld size is adequate
Pad to shell fillet (Leg ₄₂)	7.92	8.89	weld size is adequate
Nozzle to pad groove (Upper)	7.75	22.2	weld size is adequate

Calculations for internal pressure 1,095.89 kPa @ 120 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.2334).
External nozzle loadings per UG-22 govern the coincident ratio used.

Pad impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C
Fig UCS-66.1M MDMT reduction = 6.2 °C, (coincident ratio = 0.889).

Nozzle UCS-66 governing thk: 12.49 mm

Nozzle rated MDMT: -105 °C

Pad UCS-66 governing thickness: 19.05 mm

Pad rated MDMT: -47.26 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(301.93, 150.96 + (14.27 - 3.2) + (19.05 - 3.2)) \\
 &= 301.93 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(19.05 - 3.2), 2.5*(14.27 - 3.2) + 22.2) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P*R_n / (S_n*E - 0.6*P) \\
 &= 1,095.8895*150.85 / (118,000*1 - 0.6*1,095.8895) \\
 &= 1.41 \text{ mm}
 \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned}
 t_r &= P*K_1*D_o / (2*S*E + 0.8*P) \\
 &= 1,095.8895*0.8985*3,962 / (2*138,000*1 + 0.8*1,095.8895) \\
 &= 14.09 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 138$, $S_p = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8551$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned}
 A &= d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}) \\
 &= (301.93*14.09*1 + 2*11.07*14.09*1*(1 - 0.8551)) / 100 \\
 &= \underline{42.9946} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{5.2561} \text{ cm}^2$$

$$\begin{aligned}
 &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\
 &= (301.93*(1*15.85 - 1*14.09) - 2*11.07*(1*15.85 - 1*14.09)*(1 - 0.8551)) / 100 \\
 &= 5.2561 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\
 &= (2*(15.85 + 11.07)*(1*15.85 - 1*14.09) - 2*11.07*(1*15.85 - 1*14.09)*(1 - 0.8551)) / 100 \\
 &= 0.891 \text{ cm}^2
 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{6.5497} \text{ cm}^2$$

$$\begin{aligned}
 &= 5(t_n - t_m) \cdot f_{r2} \cdot t \\
 &= (5(11.07 - 1.41) \cdot 0.8551 \cdot 15.85) / 100 \\
 &= 6.5497 \text{ cm}^2 \\
 \\
 &= 2(t_n - t_m) \cdot (2.5t_n + t_e) \cdot f_{r2} \\
 &= (2(11.07 - 1.41) \cdot (2.5 \cdot 11.07 + 22.2) \cdot 0.8551) / 100 \\
 &= 8.2458 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r3} \\
 &= (9.53^2 \cdot 0.8551) / 100 \\
 &= \underline{0.7755} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{42} &= \text{Leg}^2 \cdot f_{r4} \\
 &= (12.7^2 \cdot 1) / 100 \\
 &= \underline{1.6129} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_5 &= (D_p - d - 2t_n) \cdot t_e \cdot f_{r4} \\
 &= ((463.79 - 324.09) \cdot 22.2 \cdot 1) / 100 \\
 &= \underline{31.0134} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
 &= 5.2561 + 6.5497 + 0.7755 + 1.6129 + 31.0134 \\
 &= \underline{45.2076} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t_e = 11.07 \text{ mm} \\
 t_{c(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = \underline{6} \text{ mm} \\
 t_{c(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 9.53 = 6.67 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_e \text{ or } t = 15.85 \text{ mm} \\
 t_{w(\min)} &= 0.5 \cdot t_{\min} = \underline{7.92} \text{ mm} \\
 t_{w(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 12.7 = 8.89 \text{ mm}
 \end{aligned}$$

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned}
 t_{a \text{ UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\
 &= 1,096.0756 \cdot 150.85 / (118,000 \cdot 1 - 0.6 \cdot 1,096.0756) + 3.2 \\
 &= 4.61 \text{ mm}
 \end{aligned}$$

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$$t_{aUG-22} = 5.37 \text{ mm}$$

$$\begin{aligned} t_a &= \max[t_{aUG-27}, t_{aUG-22}] \\ &= \max[4.61, 5.37] \\ &= 5.37 \text{ mm} \end{aligned}$$

$$t_{b1} = 18.79 \text{ mm}$$

$$\begin{aligned} t_{b1} &= \max[t_{b1}, t_{bUG16}] \\ &= \max[18.79, 4.7] \\ &= 18.79 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b1}] \\ &= \min[11.53, 18.79] \\ &= 11.53 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_{UG-45} &= \max[t_a, t_b] \\ &= \max[5.37, 11.53] \\ &= 11.53 \text{ mm} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 14.27 = 12.49 \text{ mm}$

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45 and UW-15(c)

$$\text{Groove weld in tension: } 0.74 \cdot 138 = 102.12 \text{ MPa}$$

$$\text{Nozzle wall in shear: } 0.7 \cdot 118 = 82.6 \text{ MPa}$$

$$\text{Inner fillet weld in shear: } 0.49 \cdot 118 = 57.82 \text{ MPa}$$

$$\text{Outer fillet weld in shear: } 0.49 \cdot 138 = 67.62 \text{ MPa}$$

$$\text{Upper groove weld in tension: } 0.74 \cdot 138 = 102.12 \text{ MPa}$$

Strength of welded joints:

$$\begin{aligned} (1) \text{ Inner fillet weld in shear} \\ (\pi / 2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = (\pi / 2) \cdot 323.85 \cdot 9.53 \cdot 57.82 = 280,160.5 \text{ N} \end{aligned}$$

$$\begin{aligned} (2) \text{ Outer fillet weld in shear} \\ (\pi / 2) \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = (\pi / 2) \cdot 463.79 \cdot 12.7 \cdot 67.62 = 625,635.56 \text{ N} \end{aligned}$$

$$\begin{aligned} (3) \text{ Nozzle wall in shear} \\ (\pi / 2) \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = (\pi / 2) \cdot 312.78 \cdot 11.07 \cdot 82.6 = 449,436.31 \text{ N} \end{aligned}$$

$$\begin{aligned} (4) \text{ Groove weld in tension} \\ (\pi / 2) \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = (\pi / 2) \cdot 323.85 \cdot 15.85 \cdot 102.12 = 823,366.07 \text{ N} \end{aligned}$$

$$\begin{aligned} (6) \text{ Upper groove weld in tension} \\ (\pi / 2) \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = (\pi / 2) \cdot 323.85 \cdot 22.2 \cdot 102.12 = 1,153,261.07 \text{ N} \end{aligned}$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned}
 W &= (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v \\
 &= (4,299.4557 - 525.6119 + 2*11.07*0.8551*(1*15.85 - 1*14.09))*138 \\
 &= \underline{525,389.29 \text{ N}}
 \end{aligned}$$

$$\begin{aligned}
 W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42})*S_v \\
 &= (654.9664 + 3,101.34 + 77.5482 + 161.29)*138 \\
 &= \underline{551,330.04 \text{ N}}
 \end{aligned}$$

$$\begin{aligned}
 W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*f_{r1})*S_v \\
 &= (654.9664 + 0 + 77.5482 + 0 + 2*11.07*15.85*0.8551)*138 \\
 &= \underline{142,513.73 \text{ N}}
 \end{aligned}$$

$$\begin{aligned}
 W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*f_{r1})*S_v \\
 &= (654.9664 + 0 + 3,101.34 + 77.5482 + 161.29 + 0 + 2*11.07*15.85*0.8551)*138 \\
 &= \underline{592,756.73 \text{ N}}
 \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 525,389.29 \text{ N}$

Path 1-1 through (2) & (3) = $625,635.56 + 449,436.31 = \underline{1,075,071.87 \text{ N}}$

Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2-2} = 142,513.73 \text{ N}$

Path 2-2 through (1), (4), (6) = $280,160.5 + 823,366.07 + 1,153,261.07 = \underline{2,256,787.63 \text{ N}}$

Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3-3} = 525,389.29 \text{ N}$

Path 3-3 through (2), (4) = $625,635.56 + 823,366.07 = \underline{1,449,001.62 \text{ N}}$

Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load: $P_r = -9,880 \text{ N}$
 Circumferential moment: $M_1 = 12,390 \text{ N-m}$
 Circumferential shear: $V_2 = 12,100 \text{ N}$
 Longitudinal moment: $M_2 = 12,390 \text{ N-m}$
 Longitudinal shear: $V_1 = 12,100 \text{ N}$
 Torsion moment: $M_t = 17,520 \text{ N-m}$
 Internal pressure: $P = 1,095.89 \text{ kPa}$
 Head yield stress: $S_y = 236 \text{ MPa}$

Maximum stresses due to the applied loads at the pad edge (includes pressure)

Mean dish radius $R_m = 3,554.59 \text{ mm}$

$$U = r_o / \text{Sqr}(R_m * t) = 0.976$$

Pressure stress intensity factor, $I = 1$ (derived from PVP-Vol. 399, pages 77-82)

$$\text{Local pressure stress} = I * P * R_i / (2 * t) = 122.616 \text{ MPa}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 248.24 \text{ MPa}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = +3 * S = +414 \text{ MPa}$$

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 142.01 \text{ MPa}$$

$$\text{Allowable local primary membrane stress } (P_L) = +1.5 * S = +207 \text{ MPa}$$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the pad edge per WRC Bulletin 107									
Figure	value	A _u	A _l	B _u	B _l	C _u	C _l	D _u	D _l
SR-2*	0.0684	2.689	2.689	2.689	2.689	2.689	2.689	2.689	2.689
SR-2	0.0366	8.639	-8.639	8.639	-8.639	8.639	-8.639	8.639	-8.639
SR-3*	0.0804	0	0	0	0	-16.706	-16.706	16.706	16.706
SR-3	0.0781	0	0	0	0	-97.375	97.375	97.375	-97.375
SR-3*	0.0804	-16.706	-16.706	16.706	16.706	0	0	0	0
SR-3	0.0781	-97.375	97.375	97.375	-97.375	0	0	0	0
Pressure stress*		122.616	122.616	122.616	122.616	122.616	122.616	122.616	122.616
Total O _x stress		19.864	197.335	248.025	35.998	19.864	197.335	248.025	35.998
Membrane O _x stress*		108.599	108.599	142.011	142.011	108.599	108.599	142.011	142.011
SR-2*	0.0212	0.834	0.834	0.834	0.834	0.834	0.834	0.834	0.834
SR-2	0.011	2.592	-2.592	2.592	-2.592	2.592	-2.592	2.592	-2.592
SR-3*	0.0242	0	0	0	0	-5.026	-5.026	5.026	5.026
SR-3	0.0235	0	0	0	0	-29.296	29.296	29.296	-29.296
SR-3*	0.0242	-5.026	-5.026	5.026	5.026	0	0	0	0
SR-3	0.0235	-29.296	29.296	29.296	-29.296	0	0	0	0
Pressure stress*		122.616	122.616	122.616	122.616	122.616	122.616	122.616	122.616
Total O _y stress		91.721	145.128	160.365	96.589	91.721	145.128	160.365	96.589
Membrane O _y stress*		118.424	118.424	128.477	128.477	118.424	118.424	128.477	128.477
Shear from M _t		3.275	3.275	3.275	3.275	3.275	3.275	3.275	3.275
Shear from V ₁		0	0	0	0	-1.048	-1.048	1.048	1.048
Shear from V ₂		1.048	1.048	-1.048	-1.048	0	0	0	0
Total Shear stress		4.323	4.323	2.227	2.227	2.227	2.227	4.323	4.323
Combined stress (P _L +P _b +Q)		91.983	197.693	248.08	96.671	91.79	197.431	248.239	96.899

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

Mean dish radius $R_m = 3,554.59$ mm

$$U = r_o / \text{Sqr}(R_m \cdot t) = 0.44$$

Pressure stress intensity factor, $I = 0.51997$ (derived from PVP-Vol. 399, pages 77-82)

$$\text{Local pressure stress} = I \cdot P \cdot R_i / (2 \cdot t) = 63.756 \text{ MPa}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 113.02 \text{ MPa}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = +3 \cdot S = +414 \text{ MPa}$$

The maximum combined stress ($P_L + P_b + Q$) is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 68.31 \text{ MPa}$$

$$\text{Allowable local primary membrane stress } (P_L) = +1.5 \cdot S = +207 \text{ MPa}$$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the nozzle OD per WRC Bulletin 107									
Figure	value	A _u	A _l	B _u	B _l	C _u	C _l	D _u	D _l
SR-2*	0.148	1.007	1.007	1.007	1.007	1.007	1.007	1.007	1.007
SR-2	0.0946	3.875	-3.875	3.875	-3.875	3.875	-3.875	3.875	-3.875
SR-3*	0.1526	0	0	0	0	-3.551	-3.551	3.551	3.551
SR-3	0.29	0	0	0	0	-40.493	40.493	40.493	-40.493
SR-3*	0.1526	-3.551	-3.551	3.551	3.551	0	0	0	0
SR-3	0.29	-40.493	40.493	40.493	-40.493	0	0	0	0
Pressure stress*	63.756	63.756	63.756	63.756	63.756	63.756	63.756	63.756	63.756
Total O _x stress	24.594	97.83	112.681	23.945	24.594	97.83	112.681	23.945	
Membrane O _x stress*	61.212	61.212	68.313	68.313	61.212	61.212	68.313	68.313	
SR-2*	0.0444	0.303	0.303	0.303	0.303	0.303	0.303	0.303	0.303
SR-2	0.0288	1.179	-1.179	1.179	-1.179	1.179	-1.179	1.179	-1.179
SR-3*	0.0466	0	0	0	0	-1.082	-1.082	1.082	1.082
SR-3	0.0884	0	0	0	0	-12.342	12.342	12.342	-12.342
SR-3*	0.0466	-1.082	-1.082	1.082	1.082	0	0	0	0
SR-3	0.0884	-12.342	12.342	12.342	-12.342	0	0	0	0
Pressure stress*	63.756	63.756	63.756	63.756	63.756	63.756	63.756	63.756	63.756
Total O _y stress	51.814	74.139	78.662	51.621	51.814	74.139	78.662	51.621	
Membrane O _y stress*	62.977	62.977	65.142	65.142	62.977	62.977	65.142	65.142	
Shear from M _t	2.792	2.792	2.792	2.792	2.792	2.792	2.792	2.792	2.792
Shear from V ₁	0	0	0	0	-0.627	-0.627	0.627	0.627	
Shear from V ₂	0.627	0.627	-0.627	-0.627	0	0	0	0	
Total Shear stress	3.42	3.42	2.165	2.165	2.165	2.165	3.42	3.42	
Combined stress (P _L +P _b +Q)	52.235	98.312	112.819	51.787	51.986	98.023	113.019	52.035	

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\begin{aligned}\sigma_{n(P_m)} &= P \cdot R_i / (2 \cdot t_n) - P_r / (\pi \cdot (R_o^2 - R_i^2)) + M \cdot R_o / I \\ &= 1,095.89 / 1000 \cdot 150.85 / (2 \cdot 9.29) - 9,880 / (\pi \cdot (161.93^2 - 150.85^2)) + 1.7522 \text{E}+07 \cdot 161.93 / 1.3324 \text{E}+08 \\ &= 31.099 \text{ MPa}\end{aligned}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable ($\leq S = 118 \text{ MPa}$)

Shear stress in the nozzle wall due to external loads

$$\begin{aligned}\sigma_{\text{shear}} &= (V_L^2 + V_c^2)^{0.5} / (\pi \cdot R_i \cdot t_n) \\ &= (12,100^2 + 12,100^2)^{0.5} / (\pi \cdot 150.85 \cdot 11.07) \\ &= 3.26 \text{ MPa}\end{aligned}$$

$$\begin{aligned}\sigma_{\text{torsion}} &= M_t / (2 \cdot \pi \cdot R_i^2 \cdot t_n) \\ &= 17,520 / (2 \cdot \pi \cdot 150.85^2 \cdot 11.07)\end{aligned}$$

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$$= 11.064 \text{ MPa}$$

$$\begin{aligned}\sigma_{\text{total}} &= \sigma_{\text{shear}} + \sigma_{\text{torsion}} \\ &= 3.26 + 11.064 \\ &= 14.325 \text{ MPa}\end{aligned}$$

UG-45: The total combined shear stress (14.325 MPa) is below than the allowable ($0.7 \cdot S_n = 0.7 \cdot 118 = 82.6 \text{ MPa}$)

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For $P_e = 250.06 \text{ kPa @ } 120^\circ \text{C}$ The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
24.1817	39.634	--	6.2322	--	31.0134	2.3884	6.78	12.49

UG-41 Weld Failure Path Analysis Summary

Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary

Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg ₄₁)	6	6.67	weld size is adequate
Pad to shell fillet (Leg ₄₂)	7.92	8.89	weld size is adequate
Nozzle to pad groove (Upper)	7.75	22.2	weld size is adequate

Calculations for external pressure 250.06 kPa @ 120 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(301.93, 150.96 + (14.27 - 3.2) + (19.05 - 3.2)) \\
 &= 301.93 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5 \cdot (19.05 - 3.2), 2.5 \cdot (14.27 - 3.2) + 22.2) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_m = 1.88 \text{ mm}$

From UG-37(d)(1) required thickness $t_r = 15.85 \text{ mm}$

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 118$, $S_v = 138$, $S_p = 138 \text{ MPa}$

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

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$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8551$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned} A &= 0.5 * (d * t_r * F + 2 * t_n * t_r * F * (1 - f_{r1})) \\ &= (0.5 * (301.93 * 15.85 * 1 + 2 * 11.07 * 15.85 * 1 * (1 - 0.8551))) / 100 \\ &= \underline{24.1817} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0} \text{ cm}^2$$

$$\begin{aligned} &= d * (E_1 * t - F * t_r) - 2 * t_n * (E_1 * t - F * t_r) * (1 - f_{r1}) \\ &= (301.93 * (1 * 15.85 - 1 * 15.85) - 2 * 11.07 * (1 * 15.85 - 1 * 15.85) * (1 - 0.8551)) / 100 \\ &= 0 \text{ cm}^2 \\ &= 2 * (t + t_n) * (E_1 * t - F * t_r) - 2 * t_n * (E_1 * t - F * t_r) * (1 - f_{r1}) \\ &= (2 * (15.85 + 11.07) * (1 * 15.85 - 1 * 15.85) - 2 * 11.07 * (1 * 15.85 - 1 * 15.85) * (1 - 0.8551)) / 100 \\ &= 0 \text{ cm}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{6.2322} \text{ cm}^2$$

$$\begin{aligned} &= 5 * (t_n - t_m) * f_{r2} * t \\ &= (5 * (11.07 - 1.88) * 0.8551 * 15.85) / 100 \\ &= 6.2322 \text{ cm}^2 \\ &= 2 * (t_n - t_m) * (2.5 * t_n + t_e) * f_{r2} \\ &= (2 * (11.07 - 1.88) * (2.5 * 11.07 + 22.2) * 0.8551) / 100 \\ &= 7.8471 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 * f_{r3} \\ &= (9.53^2 * 0.8551) / 100 \\ &= \underline{0.7755} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{42} &= \text{Leg}^2 * f_{r4} \\ &= (12.7^2 * 1) / 100 \\ &= \underline{1.6129} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_5 &= (D_p - d - 2 * t_n) * t_e * f_{r4} \\ &= ((463.79 - 324.09) * 22.2 * 1) / 100 \\ &= \underline{31.0134} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
 &= 0 + 6.2322 + 0.7755 + 1.6129 + 31.0134 \\
 &= \underline{39.634 \text{ cm}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t_e = 11.07 \text{ mm} \\
 t_{c(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 * t_{\min} = \underline{6} \text{ mm} \\
 t_{c(\text{actual})} &= 0.7 * \text{Leg} = 0.7 * 9.53 = 6.67 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_e \text{ or } t = 15.85 \text{ mm} \\
 t_{w(\min)} &= 0.5 * t_{\min} = \underline{7.92} \text{ mm} \\
 t_{w(\text{actual})} &= 0.7 * \text{Leg} = 0.7 * 12.7 = 8.89 \text{ mm}
 \end{aligned}$$

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$t_{a \text{ UG-28}} = 5.08 \text{ mm}$$

$$t_{a \text{ UG-22}} = 4.55 \text{ mm}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-28}}, t_{a \text{ UG-22}}] \\
 &= \max[5.08, 4.55] \\
 &= 5.08 \text{ mm}
 \end{aligned}$$

$$t_{b2} = 6.78 \text{ mm}$$

$$\begin{aligned}
 t_{b2} &= \max[t_{b2}, t_{b \text{ UG16}}] \\
 &= \max[6.78, 4.7] \\
 &= 6.78 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_b &= \min[t_{b3}, t_{b2}] \\
 &= \min[11.53, 6.78] \\
 &= 6.78 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_{\text{UG-45}} &= \max[t_a, t_b] \\
 &= \max[5.08, 6.78] \\
 &= 6.78 \text{ mm}
 \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 * 14.27 = 12.49 \text{ mm}$

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 120 °C) UG-28(c)

$$L / D_o = 586.61 / 323.85 = 1.8114$$

$$D_o / t = 323.85 / 1.88 = 172.4849$$

$$\text{From table G: } A = 0.000326$$

$$\text{From table CS-2 } B = 32.3485 \text{ MPa}$$

Metric:

$$P_a = 4 * B / (3 * (D_o / t))$$

$$= 4 * 32,348.52 / (3 * (323.85 / 1.88))$$

$$= 250.06 \text{ kPa}$$

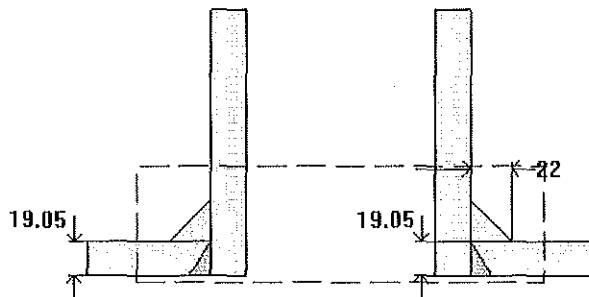
Design thickness for external pressure $P_a = 250.06 \text{ kPa}$

$$t_a = t + \text{Corrosion} = 1.88 + 3.2 = 5.08 \text{ mm}$$

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$$t_{w(\text{lower})} = 19.05 \text{ mm}$$

$$\text{Leg}_{41} = 22 \text{ mm}$$



Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	BOTTOM HEAD
Orientation:	250°
Nozzle center line offset to datum line:	-76 mm
Calculated as hillside:	Yes (perpendicular)
Distance to head center, R:	2,184 mm
Passes through a Category A joint:	No

Nozzle

Material specification:	SA-105 (II-D Metric p. 18, ln. 5)
Inside diameter, new:	101.6 mm
Nominal wall thickness:	19.05 mm
Corrosion allowance:	3.2 mm
Opening chord length:	109.19 mm
Projection available outside vessel, L _{pr} :	179.16 mm
Projection available outside vessel to flange face, L _f :	203.04 mm
Local vessel minimum thickness:	19.05 mm
Liquid static head included:	40.3288 kPa
Longitudinal joint efficiency:	1

ASME B16.5-2009 Flange

Description:	NPS 4 Class 150 LWN A105
Bolt Material:	SA-193 B7 Bolt ≤ 64 (II-D Metric p. 334, ln. 32)
Blind included:	Yes
Rated MDMT:	-48°C per UCS-66(b)(1)(b)
Liquid static head:	39.831 kPa
MAWP rating:	1,694 kPa @ 120°C
MAP rating:	1,960 kPa @ 10°C

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Hydrotest rating:
PWHT performed:

3,000 kPa @ 10°C
No

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Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 1,081.9 kPa @ 120 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
16.803	17.5677	0.5032	12.2245	--	--	4.84	8.93	19.05

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	6	15.4	weld size is adequate

Calculations for internal pressure 1,081.9 kPa @ 120 °C

Nozzle is impact test exempt per UG-20(f).

Nozzle UCS-66 governing thk: 19.05 mm

Nozzle rated MDMT: -29 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(109.19, 54.59 + (19.05 - 3.2) + (19.05 - 3.2)) \\
 &= 109.19 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(19.05 - 3.2), 2.5*(19.05 - 3.2) + 0) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,081.8959 \cdot 54 / (138,000 \cdot 1 - 0.6 \cdot 1,081.8959) \\
 &= 0.42 \text{ mm}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P D_o K / (2 S E + 2 P (K - 0.1)) \\
 &= 1,081.9 \times 3,962 \times 0.997834 / (2 \times 138,000 \times 1 + 2 \times 1,081.9 \times (0.997834 - 0.1)) \\
 &= 15.39 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 138$, $S_v = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned}
 A &= d t_r F + 2 t_n t_r F (1 - f_{r1}) \\
 &= (109.19 \times 15.39 \times 1 + 2 \times 15.85 \times 15.39 \times 1 \times (1 - 1)) / 100 \\
 &= \underline{16.803} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.5032} \text{ cm}^2$$

$$\begin{aligned}
 &= d (E_1 t - F t_r) - 2 t_n (E_1 t - F t_r) (1 - f_{r1}) \\
 &= (109.19 (1 \times 15.85 - 1 \times 15.39) - 2 \times 15.85 (1 \times 15.85 - 1 \times 15.39) (1 - 1)) / 100 \\
 &= 0.5032 \text{ cm}^2 \\
 &= 2 (t + t_n) (E_1 t - F t_r) - 2 t_n (E_1 t - F t_r) (1 - f_{r1}) \\
 &= (2 (15.85 + 15.85) (1 \times 15.85 - 1 \times 15.39) - 2 \times 15.85 (1 \times 15.85 - 1 \times 15.39) (1 - 1)) / 100 \\
 &= 0.2923 \text{ cm}^2
 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{12.2245} \text{ cm}^2$$

$$\begin{aligned}
 &= 5 (t_n - t_m) f_{r2} t \\
 &= (5 (15.85 - 0.42) \times 1 \times 15.85) / 100 \\
 &= 12.2245 \text{ cm}^2 \\
 &= 5 (t_n - t_m) f_{r2} t_n \\
 &= (5 (15.85 - 0.42) \times 1 \times 15.85) / 100 \\
 &= 12.2251 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 f_{r2} \\
 &= (22^2 \times 1) / 100 \\
 &= \underline{4.84} \text{ cm}^2
 \end{aligned}$$

$$\text{Area} = A_1 + A_2 + A_{41}$$

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$$\begin{aligned}
 &= 0.5032 + 12.2245 + 4.84 \\
 &= \underline{17.5677 \text{ cm}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 19 mm or t_n or $t = 15.85$ mm

$t_{c(\min)}$ = lesser of 6 mm or $0.7 \cdot t_{\min} = \underline{6}$ mm

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 22 = 15.4$ mm

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned}
 t_{a \text{ UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\
 &= 1,081.8959 \cdot 54 / (138,000 \cdot 1 - 0.6 \cdot 1,081.8959) + 3.2 \\
 &= 3.62 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\
 &= \max[3.62, 0] \\
 &= 3.62 \text{ mm}
 \end{aligned}$$

$$t_{b1} = 18.59 \text{ mm}$$

$$\begin{aligned}
 t_{b1} &= \max[t_{b1}, t_{b \text{ UG16}}] \\
 &= \max[18.59, 4.7] \\
 &= 18.59 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_b &= \min[t_{b3}, t_{b1}] \\
 &= \min[8.93, 18.59] \\
 &= 8.93 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_{\text{UG-45}} &= \max[t_a, t_b] \\
 &= \max[3.62, 8.93] \\
 &= 8.93 \text{ mm}
 \end{aligned}$$

Available nozzle wall thickness new, $t_n = 19.05$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For $P_e = 250.06 \text{ kPa @ } 120 \text{ }^\circ\text{C}$ The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
8.653	16.7903	--	11.9503	--	--	4.84	6.78	19.05

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	6	15.4	weld size is adequate

Calculations for external pressure 250.06 kPa @ 120 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(109.19, 54.59 + (19.05 - 3.2) + (19.05 - 3.2)) \\
 &= 109.19 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5 \cdot (19.05 - 3.2), 2.5 \cdot (19.05 - 3.2) + 0) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_m = 0.77 \text{ mm}$

From UG-37(d)(1) required thickness $t_r = 15.85 \text{ mm}$

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 138$, $S_v = 138 \text{ MPa}$

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned}
 A &= 0.5(d_t F + 2t_n t_r F(1 - f_{r1})) \\
 &= (0.5(109.19 \cdot 15.85 \cdot 1 + 2 \cdot 15.85 \cdot 15.85 \cdot 1 \cdot (1 - 1))) / 100 \\
 &= \underline{8.653} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 0 cm²

$$\begin{aligned}
 &= d(E_1 t - F t_r) - 2t_n(E_1 t - F t_r)(1 - f_{r1}) \\
 &= (109.19(1 \cdot 15.85 - 1 \cdot 15.85) - 2 \cdot 15.85(1 \cdot 15.85 - 1 \cdot 15.85)(1 - 1)) / 100 \\
 &= 0 \text{ cm}^2 \\
 &= 2(t + t_n)(E_1 t - F t_r) - 2t_n(E_1 t - F t_r)(1 - f_{r1}) \\
 &= (2(15.85 + 15.85)(1 \cdot 15.85 - 1 \cdot 15.85) - 2 \cdot 15.85(1 \cdot 15.85 - 1 \cdot 15.85)(1 - 1)) / 100 \\
 &= 0 \text{ cm}^2
 \end{aligned}$$

A_2 = smaller of the following = 11.9503 cm²

$$\begin{aligned}
 &= 5(t_n - t_m) f_{r2} t \\
 &= (5(15.85 - 0.77) \cdot 1 \cdot 15.85) / 100 \\
 &= 11.9503 \text{ cm}^2 \\
 &= 5(t_n - t_m) f_{r2} t_n \\
 &= (5(15.85 - 0.77) \cdot 1 \cdot 15.85) / 100 \\
 &= 11.9509 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 f_{r2} \\
 &= (22^2 \cdot 1) / 100 \\
 &= \underline{4.84} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0 + 11.9503 + 4.84 \\
 &= \underline{16.7903} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 19 mm or t_n or t = 15.85 mm

$t_{c(\min)}$ = lesser of 6 mm or $0.7 \cdot t_{\min} = \underline{6}$ mm

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 22 = 15.4$ mm

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$t_{a \text{ UG-28}} = 3.97 \text{ mm}$$

$$\begin{aligned} t_a &= \max[t_{a \text{ UG-28}}, t_{a \text{ UG-22}}] \\ &= \max[3.97, 0] \\ &= 3.97 \text{ mm} \end{aligned}$$

$$t_{b2} = 6.78 \text{ mm}$$

$$\begin{aligned} t_{b2} &= \max[t_{b2}, t_{b \text{ UG16}}] \\ &= \max[6.78, 4.7] \\ &= 6.78 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b2}] \\ &= \min[8.93, 6.78] \\ &= 6.78 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a, t_b] \\ &= \max[3.97, 6.78] \\ &= 6.78 \text{ mm} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 19.05 \text{ mm}$

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 120 °C) UG-28(c)

$$L / D_o = 224.18 / 139.7 = 1.6047$$

$$D_o / t = 139.7 / 0.77 = 181.4152$$

From table G: $A = 0.000343$

From table CS-2 $B = 34.0228 \text{ MPa}$

Metric:

$$\begin{aligned} P_a &= 4*B / (3*(D_o / t)) \\ &= 4*34,022.83 / (3*(139.7 / 0.77)) \\ &= 250.05 \text{ kPa} \end{aligned}$$

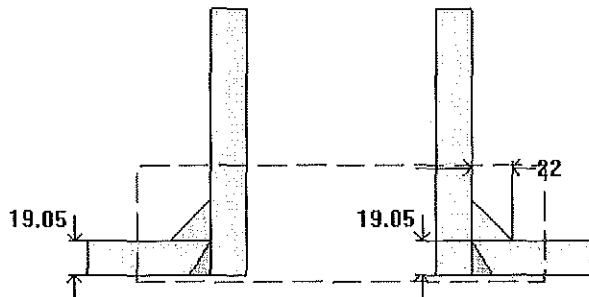
Design thickness for external pressure $P_a = 250.05 \text{ kPa}$

$$t_a = t + \text{Corrosion} = 0.77 + 3.2 = 3.97 \text{ mm}$$

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$$t_{w(lower)} = 19.05 \text{ mm}$$

$$Leg_{41} = 22 \text{ mm}$$



Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	BOTTOM HEAD
Orientation:	60°
Nozzle center line offset to datum line:	-76 mm
Calculated as hillside:	Yes (perpendicular)
Distance to head center, R:	2,184 mm
Passes through a Category A joint:	No

Nozzle

Material specification:	SA-105 (II-D Metric p. 18, ln. 5)
Inside diameter, new:	101.6 mm
Nominal wall thickness:	19.05 mm
Corrosion allowance:	3.2 mm
Opening chord length:	109.19 mm
Projection available outside vessel, Lpr:	179.16 mm
Projection available outside vessel to flange face, Lf:	203.04 mm
Local vessel minimum thickness:	19.05 mm
Liquid static head included:	40.3288 kPa
Longitudinal joint efficiency:	1

ASME B16.5-2009 Flange

Description:	NPS 4 Class 150 LWN A105
Bolt Material:	SA-193 B7 Bolt ≤ 64 (II-D Metric p. 334, ln. 32)
Blind included:	Yes
Rated MDMT:	-48°C per UCS-66(b)(1)(b)
Liquid static head:	39.831 kPa
MAWP rating:	1,694 kPa @ 120°C
MAP rating:	1,960 kPa @ 10°C

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Hydrotest rating:
PWHT performed:

3,000 kPa @ 10°C
No

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Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm ²) For P = 1,081.9 kPa @ 120 °C The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
16.803	17.5677	0.5032	12.2245	--	--	4.84	8.93	19.05

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	6	15.4	weld size is adequate

Calculations for internal pressure 1,081.9 kPa @ 120 °C

Nozzle is impact test exempt per UG-20(f).

Nozzle UCS-66 governing thk: 19.05 mm

Nozzle rated MDMT: -29 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(109.19, 54.59 + (19.05 - 3.2) + (19.05 - 3.2)) \\
 &= 109.19 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(19.05 - 3.2), 2.5*(19.05 - 3.2) + 0) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,081.8959 \cdot 54 / (138,000 \cdot 1 - 0.6 \cdot 1,081.8959) \\
 &= 0.42 \text{ mm}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot D_o \cdot K / (2 \cdot S \cdot E + 2 \cdot P \cdot (K - 0.1)) \\
 &= 1,081.9 \cdot 3,962 \cdot 0.997834 / (2 \cdot 138,000 \cdot 1 + 2 \cdot 1,081.9 \cdot (0.997834 - 0.1)) \\
 &= 15.39 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 138$, $S_v = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= (109.19 \cdot 15.39 \cdot 1 + 2 \cdot 15.85 \cdot 15.39 \cdot 1 \cdot (1 - 1)) / 100 \\
 &= \underline{16.803} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{0.5032} \text{ cm}^2$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= (109.19 \cdot (1 \cdot 15.85 - 1 \cdot 15.39) - 2 \cdot 15.85 \cdot (1 \cdot 15.85 - 1 \cdot 15.39) \cdot (1 - 1)) / 100 \\
 &= 0.5032 \text{ cm}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= (2 \cdot (15.85 + 15.85) \cdot (1 \cdot 15.85 - 1 \cdot 15.39) - 2 \cdot 15.85 \cdot (1 \cdot 15.85 - 1 \cdot 15.39) \cdot (1 - 1)) / 100 \\
 &= 0.2923 \text{ cm}^2
 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{12.2245} \text{ cm}^2$

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\
 &= (5 \cdot (15.85 - 0.42) \cdot 1 \cdot 15.85) / 100 \\
 &= 12.2245 \text{ cm}^2 \\
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= (5 \cdot (15.85 - 0.42) \cdot 1 \cdot 15.85) / 100 \\
 &= 12.2251 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= (22^2 \cdot 1) / 100 \\
 &= \underline{4.84} \text{ cm}^2
 \end{aligned}$$

$$\text{Area} = A_1 + A_2 + A_{41}$$

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$$\begin{aligned}
 &= 0.5032 + 12.2245 + 4.84 \\
 &= \underline{17.5677 \text{ cm}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 19 mm or t_n or $t = 15.85$ mm

$t_{c(\min)}$ = lesser of 6 mm or $0.7 \cdot t_{\min} = \underline{6}$ mm

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 22 = 15.4$ mm

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned}
 t_{a \text{ UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\
 &= 1,081.8959 \cdot 54 / (138,000 \cdot 1 - 0.6 \cdot 1,081.8959) + 3.2 \\
 &= 3.62 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\
 &= \max[3.62, 0] \\
 &= 3.62 \text{ mm}
 \end{aligned}$$

$$t_{b1} = 18.59 \text{ mm}$$

$$\begin{aligned}
 t_{b1} &= \max[t_{b1}, t_{b \text{ UG16}}] \\
 &= \max[18.59, 4.7] \\
 &= 18.59 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_b &= \min[t_{b3}, t_{b1}] \\
 &= \min[8.93, 18.59] \\
 &= 8.93 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_{\text{UG-45}} &= \max[t_a, t_b] \\
 &= \max[3.62, 8.93] \\
 &= 8.93 \text{ mm}
 \end{aligned}$$

Available nozzle wall thickness new, $t_n = 19.05$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm ²) For $P_e = 250.06 \text{ kPa @ } 120^\circ \text{C}$ The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
8.653	16.7903	--	11.9503	--	--	4.84	6.78	19.05

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	6	15.4	weld size is adequate

Calculations for external pressure 250.06 kPa @ 120 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(109.19, 54.59 + (19.05 - 3.2) + (19.05 - 3.2)) \\
 &= 109.19 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5 \cdot (19.05 - 3.2), 2.5 \cdot (19.05 - 3.2) + 0) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_m = 0.77 \text{ mm}$

From UG-37(d)(1) required thickness $t_r = 15.85 \text{ mm}$

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 138$, $S_v = 138 \text{ MPa}$

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned}
 A &= 0.5(d_t F + 2t_n t_r F(1 - f_{r1})) \\
 &= (0.5(109.19 \cdot 15.85 \cdot 1 + 2 \cdot 15.85 \cdot 15.85 \cdot 1(1 - 1))) / 100 \\
 &= \underline{8.653} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 0 cm²

$$\begin{aligned}
 &= d(E_1 t - F t_r) - 2t_n(E_1 t - F t_r)(1 - f_{r1}) \\
 &= (109.19(1 \cdot 15.85 - 1 \cdot 15.85) - 2 \cdot 15.85(1 \cdot 15.85 - 1 \cdot 15.85)(1 - 1)) / 100 \\
 &= 0 \text{ cm}^2 \\
 &= 2(t + t_n)(E_1 t - F t_r) - 2t_n(E_1 t - F t_r)(1 - f_{r1}) \\
 &= (2(15.85 + 15.85)(1 \cdot 15.85 - 1 \cdot 15.85) - 2 \cdot 15.85(1 \cdot 15.85 - 1 \cdot 15.85)(1 - 1)) / 100 \\
 &= 0 \text{ cm}^2
 \end{aligned}$$

A_2 = smaller of the following = 11.9503 cm²

$$\begin{aligned}
 &= 5(t_n - t_m) f_{r2} t \\
 &= (5(15.85 - 0.77) \cdot 1 \cdot 15.85) / 100 \\
 &= 11.9503 \text{ cm}^2 \\
 &= 5(t_n - t_m) f_{r2} t_n \\
 &= (5(15.85 - 0.77) \cdot 1 \cdot 15.85) / 100 \\
 &= 11.9509 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 f_{r2} \\
 &= (22^2 \cdot 1) / 100 \\
 &= \underline{4.84} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0 + 11.9503 + 4.84 \\
 &= \underline{16.7903} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 19 mm or t_n or t = 15.85 mm

$t_{c(\min)}$ = lesser of 6 mm or $0.7 \cdot t_{\min} = \underline{6}$ mm

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 22 = 15.4$ mm

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$t_{a \text{ UG-28}} = 3.97 \text{ mm}$$

$$\begin{aligned} t_a &= \max[t_{a \text{ UG-28}}, t_{a \text{ UG-22}}] \\ &= \max[3.97, 0] \\ &= 3.97 \text{ mm} \end{aligned}$$

$$t_{b2} = 6.78 \text{ mm}$$

$$\begin{aligned} t_{b2} &= \max[t_{b2}, t_{b \text{ UG16}}] \\ &= \max[6.78, 4.7] \\ &= 6.78 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b2}] \\ &= \min[8.93, 6.78] \\ &= 6.78 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a, t_b] \\ &= \max[3.97, 6.78] \\ &= 6.78 \text{ mm} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 19.05 \text{ mm}$

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 120 °C) UG-28(c)

$$L / D_o = 224.18 / 139.7 = 1.6047$$

$$D_o / t = 139.7 / 0.77 = 181.4152$$

From table G: $A = 0.000343$

From table CS-2 $B = 34.0228 \text{ MPa}$

Metric:

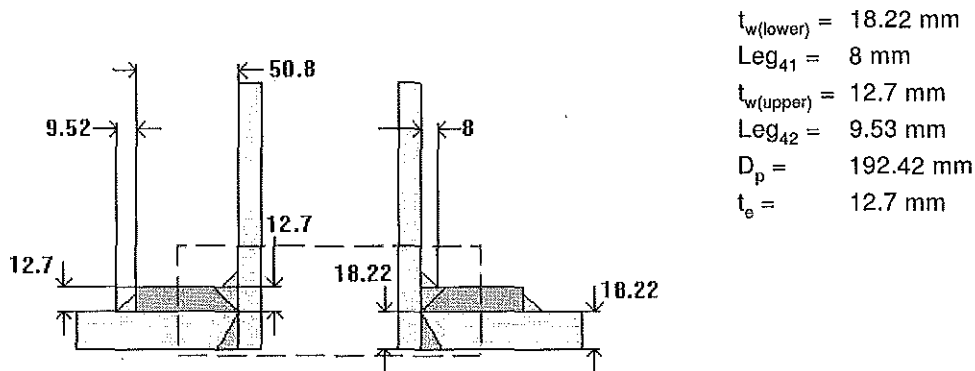
$$\begin{aligned} P_a &= 4*B / (3*(D_o / t)) \\ &= 4*34,022.83 / (3*(139.7 / 0.77)) \\ &= 250.05 \text{ kPa} \end{aligned}$$

Design thickness for external pressure $P_a = 250.05 \text{ kPa}$

$$t_a = t + \text{Corrosion} = 0.77 + 3.2 = 3.97 \text{ mm}$$

PSV/VENT (N4)

ASME Section VIII Division 1, 2010 Edition, A11 Addenda Metric



Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	TOP HEAD
Orientation:	45°
End of nozzle to datum line:	3,989 mm
Calculated as hillside:	Yes
Distance to head center, R:	762 mm
Passes through a Category A joint:	No

Nozzle

Material specification:	SA-106 B Smls. Pipe (II-D Metric p. 10, ln. 40)
Description:	NPS 3 Sch 160 DN 80
Inside diameter, new:	66.65 mm
Nominal wall thickness:	11.13 mm
Corrosion allowance:	3.2 mm
Opening chord length:	74.66 mm
Projection available outside vessel, Lpr:	447.42 mm
Projection available outside vessel to flange face, Lf:	517.27 mm
Local vessel minimum thickness:	18.22 mm
Liquid static head included:	5.3352 kPa
Longitudinal joint efficiency:	1

Reinforcing Pad

Material specification:	SA-516 70 (II-D Metric p. 18, ln. 19) (normalized)
Diameter:	192.42 mm
Is split:	No

ASME B16.5-2009 Flange

Description:	NPS 3 Class 150 WN A105
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WO. 12-32

32125-D-2202-01

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Bolt Material:	SA-193 B7 Bolt ≤ 64 (II-D Metric p. 334, In. 32)
Blind included:	No
Rated MDMT:	-48°C per UCS-66(b)(1)(b)
Liquid static head:	0 kPa
MAWP rating:	1,694 kPa @ 120°C
MAP rating:	1,960 kPa @ 10°C
Hydrotest rating:	3,000 kPa @ 10°C
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1

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Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 1,046.9 kPa @ 120 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
10.3595	13.3284	1.1271	4.2258	--	7.4284	0.5471	8	9.73

UG-41 Weld Failure Path Analysis Summary (N)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength	Weld load W ₃₋₃	Path 3-3 strength
130.320	168.377	277.940	93.959	459.887	196.470	408.861

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg ₄₁)	5.55	5.6	weld size is adequate
Pad to shelf fillet (Leg ₄₂)	6.35	6.67	weld size is adequate
Nozzle to pad groove (Upper)	5.55	12.7	weld size is adequate

Calculations for internal pressure 1,046.9 kPa @ 120 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.1458).
External nozzle loadings per UG-22 govern the coincident ratio used.

Pad impact test exemption temperature from Fig UCS-66M Curve D = -48 °C
Fig UCS-66.1M MDMT reduction = 5.8 °C, (coincident ratio = 0.8963)
Rated MDMT of -53.8 °C is limited to -48 °C by UCS-66(b)(2).

Nozzle UCS-66 governing thk: 9.73 mm
Nozzle rated MDMT: -105 °C
Pad UCS-66 governing thickness: 12.7 mm
Pad rated MDMT: -48 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(74.66, 37.33 + (11.13 - 3.2) + (18.22 - 3.2)) \\
 &= 74.66 \text{ mm}
 \end{aligned}$$

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Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(18.22 - 3.2), 2.5*(11.13 - 3.2) + 12.7) \\
 &= 32.51 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,046.9022 \cdot 36.52 / (118,000 \cdot 1 - 0.6 \cdot 1,046.9022) \\
 &= 0.33 \text{ mm}
 \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned}
 t_r &= P \cdot K_1 \cdot D_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\
 &= 1,046.9022 \cdot 0.8985 \cdot 3,962 / (2 \cdot 138,000 \cdot 1 + 0.8 \cdot 1,046.9022) \\
 &= 13.46 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 138$, $S_p = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8551$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= (74.66 \cdot 13.46 \cdot 1 + 2 \cdot 7.93 \cdot 13.46 \cdot 1 \cdot (1 - 0.8551)) / 100 \\
 &= \underline{10.3595} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{1.1271} \text{ cm}^2$$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= (74.66 \cdot (1 \cdot 15.02 - 1 \cdot 13.46) - 2 \cdot 7.93 \cdot (1 \cdot 15.02 - 1 \cdot 13.46) \cdot (1 - 0.8551)) / 100 \\
 &= 1.1271 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= (2 \cdot (15.02 + 7.93) \cdot (1 \cdot 15.02 - 1 \cdot 13.46) - 2 \cdot 7.93 \cdot (1 \cdot 15.02 - 1 \cdot 13.46) \cdot (1 - 0.8551)) / 100 \\
 &= 0.6787 \text{ cm}^2
 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{4.2258} \text{ cm}^2$$

$$\begin{aligned}
 &= 5(t_n - t_m) \cdot f_{r2} \cdot t \\
 &= (5(7.93 - 0.33) \cdot 0.8551 \cdot 15.02) / 100 \\
 &= 4.8806 \text{ cm}^2 \\
 \\
 &= 2(t_n - t_m) \cdot (2.5t_n + t_e) \cdot f_{r2} \\
 &= (2(7.93 - 0.33) \cdot (2.5 \cdot 7.93 + 12.7) \cdot 0.8551) / 100 \\
 &= 4.2258 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r3} \\
 &= (8^2 \cdot 0.8551) / 100 \\
 &= \underline{0.5471} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{42} &= \text{Leg}^2 \cdot f_{r4} \\
 &= (0^2 \cdot 1) / 100 \\
 &= \underline{0} \text{ cm}^2
 \end{aligned}$$

(Part of the weld is outside of the limits)

$$\begin{aligned}
 A_5 &= (D_p - d - 2t_n) \cdot t_e \cdot f_{r4} \\
 &= ((149.31 - 90.82) \cdot 12.7 \cdot 1) / 100 \\
 &= \underline{7.4284} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
 &= 1.1271 + 4.2258 + 0.5471 + 0 + 7.4284 \\
 &= \underline{13.3284} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t_e = 7.93 \text{ mm} \\
 t_{c(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = \underline{5.55} \text{ mm} \\
 t_{c(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 8 = 5.6 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_e \text{ or } t = 12.7 \text{ mm} \\
 t_{w(\min)} &= 0.5 \cdot t_{\min} = \underline{6.35} \text{ mm} \\
 t_{w(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 9.53 = 6.67 \text{ mm}
 \end{aligned}$$

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$t_{a \text{ UG-27}} = P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion}$$

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$$= 1,046.9022 \times 36.52 / (118,000 \times 1 - 0.6 \times 1,046.9022) + 3.2$$

$$= 3.53 \text{ mm}$$

$$t_{a \text{ UG-22}} = 4.15 \text{ mm}$$

$$t_a = \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}]$$

$$= \max[3.53, 4.15]$$

$$= 4.15 \text{ mm}$$

$$t_{b1} = 18.1 \text{ mm}$$

$$t_{b1} = \max[t_{b1}, t_{b \text{ UG16}}]$$

$$= \max[18.1, 4.7]$$

$$= 18.1 \text{ mm}$$

$$t_b = \min[t_{b3}, t_{b1}]$$

$$= \min[8, 18.1]$$

$$= 8 \text{ mm}$$

$$t_{\text{UG-45}} = \max[t_a, t_b]$$

$$= \max[4.15, 8]$$

$$= 8 \text{ mm}$$

Available nozzle wall thickness new, $t_n = 0.875 \times 11.13 = 9.73 \text{ mm}$

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45 and UW-15(c)

Groove weld in tension: $0.74 \times 138 = 102.12 \text{ MPa}$

Nozzle wall in shear: $0.7 \times 118 = 82.6 \text{ MPa}$

Inner fillet weld in shear: $0.49 \times 118 = 57.82 \text{ MPa}$

Outer fillet weld in shear: $0.49 \times 138 = 67.62 \text{ MPa}$

Upper groove weld in tension: $0.74 \times 138 = 102.12 \text{ MPa}$

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi / 2) \times \text{Nozzle OD} \times \text{Leg} \times S_i = (\pi / 2) \times 88.9 \times 8 \times 57.82 = 64,593.64 \text{ N}$$

(2) Outer fillet weld in shear

$$(\pi / 2) \times \text{Pad OD} \times \text{Leg} \times S_o = (\pi / 2) \times 192.42 \times 9.53 \times 67.62 = 194,675.29 \text{ N}$$

(3) Nozzle wall in shear

$$(\pi / 2) \times \text{Mean nozzle dia} \times t_n \times S_n = (\pi / 2) \times 80.97 \times 7.93 \times 82.6 = 83,264.54 \text{ N}$$

(4) Groove weld in tension

$$(\pi / 2) \times \text{Nozzle OD} \times t_w \times S_g = (\pi / 2) \times 88.9 \times 15.02 \times 102.12 = 214,185.9 \text{ N}$$

(6) Upper groove weld in tension

$$(\pi / 2) \times \text{Nozzle OD} \times t_w \times S_g = (\pi / 2) \times 88.9 \times 12.7 \times 102.12 = 181,107.42 \text{ N}$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned}
 W &= (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v \\
 &= (1,035.9528 - 112.7095 + 2*7.93*0.8551*(1*15.02 - 1*13.46))*138 \\
 &= \underline{130,320.47 \text{ N}}
 \end{aligned}$$

$$\begin{aligned}
 W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42})*S_v \\
 &= (422.5798 + 742.8372 + 54.7096 + 0)*138 \\
 &= \underline{168,377.49 \text{ N}}
 \end{aligned}$$

$$\begin{aligned}
 W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v \\
 &= (422.5798 + 0 + 54.7096 + 0 + 2*7.93*15.02*0.8551)*138 \\
 &= \underline{93,958.72 \text{ N}}
 \end{aligned}$$

$$\begin{aligned}
 W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v \\
 &= (422.5798 + 0 + 742.8372 + 54.7096 + 0 + 0 + 2*7.93*15.02*0.8551)*138 \\
 &= \underline{196,470.27 \text{ N}}
 \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 130,320.47 \text{ N}$

Path 1-1 through (2) & (3) = $194,675.29 + 83,264.54 = \underline{277,939.83 \text{ N}}$

Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2-2} = 93,958.72 \text{ N}$

Path 2-2 through (1), (4), (6) = $64,593.64 + 214,185.9 + 181,107.42 = \underline{459,886.96 \text{ N}}$

Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3-3} = 130,320.47 \text{ N}$

Path 3-3 through (2), (4) = $194,675.29 + 214,185.9 = \underline{408,861.2 \text{ N}}$

Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load: $P_r = -1,510 \text{ N}$
 Circumferential moment: $M_1 = 585 \text{ N-m}$
 Circumferential shear: $V_2 = 1,850 \text{ N}$
 Longitudinal moment: $M_2 = 585 \text{ N-m}$
 Longitudinal shear: $V_1 = 1,850 \text{ N}$
 Torsion moment: $M_t = 825 \text{ N-m}$
 Internal pressure: $P = 1,046.9 \text{ kPa}$
 Head yield stress: $S_y = 236 \text{ MPa}$

Maximum stresses due to the applied loads at the pad edge (includes pressure)

Mean dish radius $R_m = 3,554.18 \text{ mm}$

$$U = r_o / \text{Sqr}(R_m * t) = 0.412$$

Pressure stress intensity factor, $I = 1$ (derived from PVP-Vol. 399, pages 77-82)

$$\text{Local pressure stress} = I * P * R_1 / (2 * t) = 123.602 \text{ MPa}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 152.02 \text{ MPa}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = \pm 3 * S = \pm 414 \text{ MPa}$$

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 126.42 \text{ MPa}$$

$$\text{Allowable local primary membrane stress } (P_L) = \pm 1.5 * S = \pm 207 \text{ MPa}$$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the pad edge per WRC Bulletin 107									
Figure	value	A _u	A _l	B _u	B _l	C _u	C _l	D _u	D _l
SR-2*	0.1564	1.048	1.048	1.048	1.048	1.048	1.048	1.048	1.048
SR-2	0.1019	4.095	-4.095	4.095	-4.095	4.095	-4.095	4.095	-4.095
SR-3*	0.1571	0	0	0	0	-1.765	-1.765	1.765	1.765
SR-3	0.318	0	0	0	0	-21.415	21.415	21.415	-21.415
SR-3*	0.1571	-1.765	-1.765	1.765	1.765	0	0	0	0
SR-3	0.318	-21.415	21.415	21.415	-21.415	0	0	0	0
Pressure stress*		123.602	123.602	123.602	123.602	123.602	123.602	123.602	123.602
Total O _x stress		105.566	140.205	151.926	100.905	105.566	140.205	151.926	100.905
Membrane O _x stress*		122.885	122.885	126.415	126.415	122.885	122.885	126.415	126.415
SR-2*	0.0469	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317
SR-2	0.031	1.248	-1.248	1.248	-1.248	1.248	-1.248	1.248	-1.248
SR-3*	0.0483	0	0	0	0	-0.545	-0.545	0.545	0.545
SR-3	0.0951	0	0	0	0	-6.405	6.405	6.405	-6.405
SR-3*	0.0483	-0.545	-0.545	0.545	0.545	0	0	0	0
SR-3	0.0951	-6.405	6.405	6.405	-6.405	0	0	0	0
Pressure stress*		123.602	123.602	123.602	123.602	123.602	123.602	123.602	123.602
Total O _y stress		118.218	128.532	132.117	116.811	118.218	128.532	132.117	116.811
Membrane O _y stress*		123.375	123.375	124.464	124.464	123.375	123.375	124.464	124.464
Shear from M _t	0.965	0.965	0.965	0.965	0.965	0.965	0.965	0.965	0.965
Shear from V ₁	0	0	0	0	0	-0.414	-0.414	0.414	0.414
Shear from V ₂	0.414	0.414	-0.414	-0.414	0	0	0	0	0
Total Shear stress	1.379	1.379	0.552	0.552	0.552	0.552	1.379	1.379	1.379
Combined stress (P _L +P _b +Q)	118.369	140.363	151.94	116.832	118.238	140.232	152.023	116.928	

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

Mean dish radius $R_m = 3,554.18$ mm

$$U = r_o / \text{Sqr}(R_m \cdot t) = 0.142$$

Pressure stress intensity factor, $I = 0.42229$ (derived from PVP-Vol. 399, pages 77-82)

$$\text{Local pressure stress} = I \cdot P \cdot R_i / (2 \cdot t) = 52.2 \text{ MPa}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 72.53 \text{ MPa}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = \pm 3 \cdot S = \pm 414 \text{ MPa}$$

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 53.04 \text{ MPa}$$

$$\text{Allowable local primary membrane stress } (P_L) = \pm 1.5 \cdot S = \pm 207 \text{ MPa}$$

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The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the nozzle OD per WRC Bulletin 107									
Figure	value	A _u	A _l	B _u	B _l	C _u	C _l	D _u	D _l
SR-2*	0.254	0.496	0.496	0.496	0.496	0.496	0.496	0.496	0.496
SR-2	0.2512	2.965	-2.965	2.965	-2.965	2.965	-2.965	2.965	-2.965
SR-3*	0.1426	0	0	0	0	-0.345	-0.345	0.345	0.345
SR-3	1.096	0	0	0	0	-15.948	15.948	15.948	-15.948
SR-3*	0.1426	-0.345	-0.345	0.345	0.345	0	0	0	0
SR-3	1.096	-15.948	15.948	15.948	-15.948	0	0	0	0
Pressure stress*	52.2	52.2	52.2	52.2	52.2	52.2	52.2	52.2	52.2
Total O _x stress	39.369	65.335	71.954	34.129	39.369	65.335	71.954	34.129	
Membrane O _x stress*	52.352	52.352	53.041	53.041	52.352	52.352	53.041	53.041	
SR-2*	0.0773	0.152	0.152	0.152	0.152	0.152	0.152	0.152	0.152
SR-2	0.0732	0.862	-0.862	0.862	-0.862	0.862	-0.862	0.862	-0.862
SR-3*	0.043	0	0	0	0	-0.103	-0.103	0.103	0.103
SR-3	0.3404	0	0	0	0	-4.957	4.957	4.957	-4.957
SR-3*	0.043	-0.103	-0.103	0.103	0.103	0	0	0	0
SR-3	0.3404	-4.957	4.957	4.957	-4.957	0	0	0	0
Pressure stress*	52.2	52.2	52.2	52.2	52.2	52.2	52.2	52.2	52.2
Total O _y stress	48.153	56.344	58.274	46.636	48.153	56.344	58.274	46.636	
Membrane O _y stress*	52.248	52.248	52.455	52.455	52.248	52.248	52.455	52.455	
Shear from M _l	2.399	2.399	2.399	2.399	2.399	2.399	2.399	2.399	2.399
Shear from V ₁	0	0	0	0	-0.476	-0.476	0.476	0.476	
Shear from V ₂	0.476	0.476	-0.476	-0.476	0	0	0	0	
Total Shear stress	2.875	2.875	1.924	1.924	1.924	1.924	2.875	2.875	
Combined stress (P _L +P _b +Q)	49.008	66.176	72.216	46.926	48.553	65.728	72.533	47.264	

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\begin{aligned}\sigma_{n(P_m)} &= P \cdot R_i / (2 \cdot t_n) - P_r / (\pi \cdot (R_o^2 - R_i^2)) + M \cdot R_o / I \\ &= 1,046.9 / 1000 \cdot 36.52 / (2 \cdot 6.53) - 1,510 / (\pi \cdot (44.45^2 - 36.52^2)) + 827,314.7 \cdot 44.45 / 1,668,246 \\ &= 25.718 \text{ MPa}\end{aligned}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable ($\leq S = 118 \text{ MPa}$)

Shear stress in the nozzle wall due to external loads

$$\begin{aligned}\sigma_{\text{shear}} &= (V_L^2 + V_C^2)^{0.5} / (\pi \cdot R_i \cdot t_n) \\ &= (1,850^2 + 1,850^2)^{0.5} / (\pi \cdot 36.52 \cdot 7.93) \\ &= 2.877 \text{ MPa}\end{aligned}$$

$$\begin{aligned}\sigma_{\text{torsion}} &= M_t / (2 \cdot \pi \cdot R_i^2 \cdot t_n) \\ &= 825 / (2 \cdot \pi \cdot 36.52^2 \cdot 7.93)\end{aligned}$$

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$$= 12.419 \text{ MPa}$$

$$\begin{aligned}\sigma_{\text{total}} &= \sigma_{\text{shear}} + \sigma_{\text{torsion}} \\ &= 2.877 + 12.419 \\ &= 15.296 \text{ MPa}\end{aligned}$$

UG-45: The total combined shear stress (15.296 MPa) is below than the allowable ($0.7 \cdot S_n = 0.7 \cdot 118 = 82.6 \text{ MPa}$)

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For $P_e = 224.31$ kPa @ 120 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
5.7789	11.9168	--	3.9413	--	7.4284	0.5471	6.41	9.73

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg ₄₁)	5.55	5.6	weld size is adequate
Pad to shell fillet (Leg ₄₂)	6.35	6.67	weld size is adequate
Nozzle to pad groove (Upper)	5.55	12.7	weld size is adequate

Calculations for external pressure 224.31 kPa @ 120 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(74.66, 37.33 + (11.13 - 3.2) + (18.22 - 3.2)) \\
 &= 74.66 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(18.22 - 3.2), 2.5*(11.13 - 3.2) + 12.7) \\
 &= 32.51 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 0.84$ mm

From UG-37(d)(1) required thickness $t_r = 15.02$ mm

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 118$, $S_v = 138$, $S_p = 138$ MPa

$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$

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$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8551$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned} A &= 0.5(d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) \\ &= (0.5(74.66 \cdot 15.02 \cdot 1 + 2 \cdot 7.93 \cdot 15.02 \cdot 1 \cdot (1 - 0.8551))) / 100 \\ &= \underline{5.7789} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0} \text{ cm}^2$$

$$\begin{aligned} &= d(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= (74.66(1 \cdot 15.02 - 1 \cdot 15.02) - 2 \cdot 7.93(1 \cdot 15.02 - 1 \cdot 15.02)(1 - 0.8551)) / 100 \\ &= 0 \text{ cm}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= (2(15.02 + 7.93)(1 \cdot 15.02 - 1 \cdot 15.02) - 2 \cdot 7.93(1 \cdot 15.02 - 1 \cdot 15.02)(1 - 0.8551)) / 100 \\ &= 0 \text{ cm}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{3.9413} \text{ cm}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= (5(7.93 - 0.84) \cdot 0.8551 \cdot 15.02) / 100 \\ &= 4.5516 \text{ cm}^2 \\ &= 2 \cdot (t_n - t_m) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2} \\ &= (2(7.93 - 0.84) \cdot (2.5 \cdot 7.93 + 12.7) \cdot 0.8551) / 100 \\ &= 3.9413 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r3} \\ &= (8^2 \cdot 0.8551) / 100 \\ &= \underline{0.5471} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{42} &= \text{Leg}^2 \cdot f_{r4} \\ &= (0^2 \cdot 1) / 100 \\ &= \underline{0} \text{ cm}^2 \end{aligned}$$

(Part of the weld is outside of the limits)

$$\begin{aligned} A_5 &= (D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4} \\ &= ((149.31 - 90.82) \cdot 12.7 \cdot 1) / 100 \\ &= \underline{7.4284} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
 &= 0 + 3.9413 + 0.5471 + 0 + 7.4284 \\
 &= \underline{11.9168 \text{ cm}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t_e = 7.93 \text{ mm} \\
 t_{c(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = \underline{5.55 \text{ mm}} \\
 t_{c(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 8 = 5.6 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_e \text{ or } t = 12.7 \text{ mm} \\
 t_{w(\min)} &= 0.5 \cdot t_{\min} = \underline{6.35 \text{ mm}} \\
 t_{w(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 9.53 = 6.67 \text{ mm}
 \end{aligned}$$

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$t_{a \text{ UG-28}} = 4.04 \text{ mm}$$

$$t_{a \text{ UG-22}} = 3.87 \text{ mm}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-28}}, t_{a \text{ UG-22}}] \\
 &= \max[4.04, 3.87] \\
 &= 4.04 \text{ mm}
 \end{aligned}$$

$$t_{b2} = 6.41 \text{ mm}$$

$$\begin{aligned}
 t_{b2} &= \max[t_{b2}, t_{b \text{ UG16}}] \\
 &= \max[6.41, 4.7] \\
 &= 6.41 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_b &= \min[t_{b3}, t_{b2}] \\
 &= \min[8, 6.41] \\
 &= 6.41 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_{\text{UG-45}} &= \max[t_a, t_b] \\
 &= \max[4.04, 6.41] \\
 &= 6.41 \text{ mm}
 \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 11.13 = 9.73 \text{ mm}$

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 120 °C) UG-28(c)

$$L / D_o = 535.97 / 88.9 = 6.0289$$

$$D_o / t = 88.9 / 0.84 = 106.1560$$

From table G: $A = 0.000181$

From table CS-2 $B = 17.8584 \text{ MPa}$

Metric:

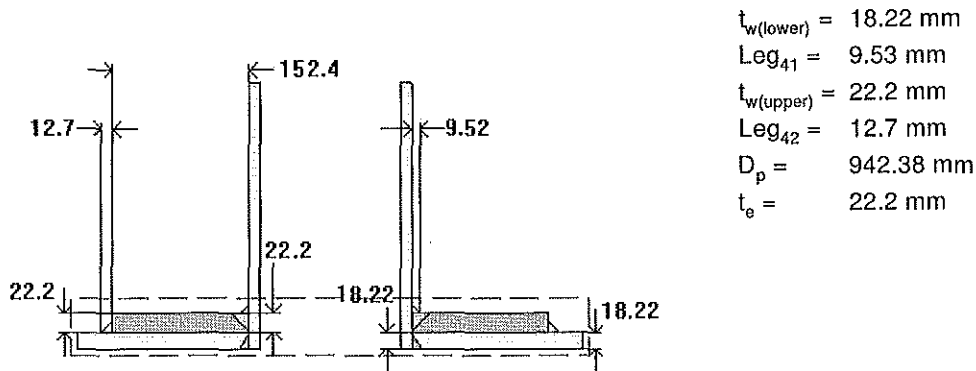
$$\begin{aligned} P_a &= 4*B / (3*(D_o / t)) \\ &= 4*17,858.37 / (3*(88.9 / 0.84)) \\ &= 224.3 \text{ kPa} \end{aligned}$$

Design thickness for external pressure $P_a = 224.3 \text{ kPa}$

$$t_a = t + \text{Corrosion} = 0.84 + 3.2 = 4.04 \text{ mm}$$

TOP MANWAY (M1)

ASME Section VIII Division 1, 2010 Edition, A11 Addenda Metric



$t_{w(lower)} = 18.22 \text{ mm}$
 $Leg_{41} = 9.53 \text{ mm}$
 $t_{w(upper)} = 22.2 \text{ mm}$
 $Leg_{42} = 12.7 \text{ mm}$
 $D_p = 942.38 \text{ mm}$
 $t_o = 22.2 \text{ mm}$

Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	TOP HEAD
Orientation:	0°
End of nozzle to datum line:	3,989 mm
Calculated as hillside:	Yes
Distance to head center, R:	1,016 mm
Passes through a Category A joint:	No

Nozzle

Material specification:	SA-106 B Smls. Pipe (II-D Metric p. 10, In. 40)
Description:	NPS 24 XS DN 600
Inside diameter, new:	584.2 mm
Nominal wall thickness:	12.7 mm
Corrosion allowance:	3.2 mm
Opening chord length:	618.14 mm
Projection available outside vessel, Lpr:	363.63 mm
Projection available outside vessel to flange face, Lf:	516.03 mm
Local vessel minimum thickness:	18.22 mm
Liquid static head included:	5.9681 kPa
Longitudinal joint efficiency:	1

Reinforcing Pad

Material specification:	SA-516 70 (II-D Metric p. 18, In. 19) (normalized)
Diameter:	942.38 mm
Is split:	No

ASME B16.5-2009 Flange

Description:	NPS 24 Class 150 WN A105
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WO. 12-32

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Bolt Material:	SA-193 B7 Bolt \leq 64 (II-D Metric p. 334, ln. 32)
Blind included:	Yes
Rated MDMT:	-48°C per UCS-66(b)(1)(b)
Liquid static head:	0 kPa
MAWP rating:	1,694 kPa @ 120°C
MAP rating:	1,960 kPa @ 10°C
Hydrotest rating:	3,000 kPa @ 10°C
PWHT performed:	No
Circumferential joint radiography:	Spot UW-11(b) Type 1

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Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 1,047.54 kPa @ 120 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
83.6347	83.9972	9.5355	4.4077	--	67.6656	2.3884	5.84	11.11

UG-41 Weld Failure Path Analysis Summary (N)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength	Weld load W ₃₋₃	Path 3-3 strength
1,026,043	1,027,572	2,010,912	105,203	4,166,909	1,061,247	2,739,930

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg ₄₁)	6	6.67	weld size is adequate
Pad to shell fillet (Leg ₄₂)	7.51	8.89	weld size is adequate
Nozzle to pad groove (Upper)	6.65	22.2	weld size is adequate

Calculations for internal pressure 1,047.54 kPa @ 120 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.3331).

Pad impact test exemption temperature from Fig UCS-66M Curve D = -42.1 °C

Fig UCS-66.1M MDMT reduction = 5.8 °C, (coincident ratio = 0.8968).

Nozzle UCS-66 governing thk: 11.11 mm

Nozzle rated MDMT: -105 °C

Pad UCS-66 governing thickness: 18.22 mm

Pad rated MDMT: -47.9 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(618.14, 309.07 + (12.7 - 3.2) + (18.22 - 3.2)) \\
 &= 618.14 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(18.22 - 3.2), 2.5*(12.7 - 3.2) + 22.2)
 \end{aligned}$$

$$= 37.55 \text{ mm}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned} t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\ &= 1,047.5351 \cdot 295.3 / (118,000 \cdot 1 - 0.6 \cdot 1,047.5351) \\ &= 2.64 \text{ mm} \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned} t_r &= P \cdot K_1 \cdot D_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\ &= 1,047.5351 \cdot 0.8985 \cdot 3,962 / (2 \cdot 138,000 \cdot 1 + 0.8 \cdot 1,047.5351) \\ &= 13.47 \text{ mm} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 138$, $S_p = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8551$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= (618.14 \cdot 13.47 \cdot 1 + 2 \cdot 9.5 \cdot 13.47 \cdot 1 \cdot (1 - 0.8551)) / 100 \\ &= \underline{83.6347} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{9.5355} \text{ cm}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= (618.14 \cdot (1 \cdot 15.02 - 1 \cdot 13.47) - 2 \cdot 9.5 \cdot (1 \cdot 15.02 - 1 \cdot 13.47) \cdot (1 - 0.8551)) / 100 \\ &= 9.5355 \text{ cm}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= (2 \cdot (15.02 + 9.5) \cdot (1 \cdot 15.02 - 1 \cdot 13.47) - 2 \cdot 9.5 \cdot (1 \cdot 15.02 - 1 \cdot 13.47) \cdot (1 - 0.8551)) / 100 \\ &= 0.7174 \text{ cm}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{4.4077} \text{ cm}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= (5 \cdot (9.5 - 2.64) \cdot 0.8551 \cdot 15.02) / 100 \\ &= 4.4077 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned}
 &= 2*(t_n - t_m)*(2.5*t_n + t_e)*f_{r2} \\
 &= (2*(9.5 - 2.64)*(2.5*9.5 + 22.2)*0.8551) / 100 \\
 &= 5.3935 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2*f_{r3} \\
 &= (9.53^2*0.8551) / 100 \\
 &= \underline{0.7755} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{42} &= \text{Leg}^2*f_{r4} \\
 &= (12.7^2*1) / 100 \\
 &= \underline{1.6129} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\
 &= ((942.38 - 637.58)*22.2*1) / 100 \\
 &= \underline{67.6656} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
 &= 9.5355 + 4.4077 + 0.7755 + 1.6129 + 67.6656 \\
 &= \underline{83.9972} \text{ cm}^2
 \end{aligned}$$

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t_e = 9.5 \text{ mm} \\
 t_{c(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7*t_{\min} = \underline{6} \text{ mm} \\
 t_{c(\text{actual})} &= 0.7*\text{Leg} = 0.7*9.53 = 6.67 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_e \text{ or } t = 15.02 \text{ mm} \\
 t_{w(\min)} &= 0.5*t_{\min} = \underline{7.51} \text{ mm} \\
 t_{w(\text{actual})} &= 0.7*\text{Leg} = 0.7*12.7 = 8.89 \text{ mm}
 \end{aligned}$$

UG-45 Nozzle Neck Thickness Check (Access Opening)

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned}
 t_{a \text{ UG-27}} &= P*R / (S*E - 0.6*P) + \text{Corrosion} \\
 &= 1,047.5351*295.3 / (118,000*1 - 0.6*1,047.5351) + 3.2 \\
 &= 5.84 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\
 &= \max[5.84, 0]
 \end{aligned}$$

$$= 5.84 \text{ mm}$$

Available nozzle wall thickness new, $t_n = 0.875 \times 12.7 = 11.11 \text{ mm}$

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45 and UW-15(c)

Groove weld in tension: $0.74 \times 138 = 102.12 \text{ MPa}$

Nozzle wall in shear: $0.7 \times 118 = 82.6 \text{ MPa}$

Inner fillet weld in shear: $0.49 \times 118 = 57.82 \text{ MPa}$

Outer fillet weld in shear: $0.49 \times 138 = 67.62 \text{ MPa}$

Upper groove weld in tension: $0.74 \times 138 = 102.12 \text{ MPa}$

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi / 2) \times \text{Nozzle OD} \times \text{Leg} \times S_i = (\pi / 2) \times 609.6 \times 9.53 \times 57.82 = 527,360.92 \text{ N}$$

(2) Outer fillet weld in shear

$$(\pi / 2) \times \text{Pad OD} \times \text{Leg} \times S_o = (\pi / 2) \times 942.38 \times 12.7 \times 67.62 = 1,271,226.21 \text{ N}$$

(3) Nozzle wall in shear

$$(\pi / 2) \times \text{Mean nozzle dia} \times t_n \times S_n = (\pi / 2) \times 600.1 \times 9.5 \times 82.6 = 739,685.65 \text{ N}$$

(4) Groove weld in tension

$$(\pi / 2) \times \text{Nozzle OD} \times t_w \times S_g = (\pi / 2) \times 609.6 \times 15.02 \times 102.12 = 1,468,703.3 \text{ N}$$

(6) Upper groove weld in tension

$$(\pi / 2) \times \text{Nozzle OD} \times t_w \times S_g = (\pi / 2) \times 609.6 \times 22.2 \times 102.12 = 2,170,844.31 \text{ N}$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 \times t_n \times f_{r1} \times (E_1 \times t - F \times t_r)) \times S_v \\ &= (8,363.4683 - 953.5465 + 2 \times 9.5 \times 0.8551 \times (1 \times 15.02 - 1 \times 13.47)) \times 138 \\ &= \underline{1,026,043.39 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) \times S_v \\ &= (440.7733 + 6,766.56 + 77.5482 + 161.29) \times 138 \\ &= \underline{1,027,571.82 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 \times t_n \times f_{r1}) \times S_v \\ &= (440.7733 + 0 + 77.5482 + 0 + 2 \times 9.5 \times 15.02 \times 0.8551) \times 138 \\ &= \underline{105,203.42 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \times t_n \times f_{r1}) \times S_v \\ &= (440.7733 + 0 + 6,766.56 + 77.5482 + 161.29 + 0 + 2 \times 9.5 \times 15.02 \times 0.8551) \times 138 \\ &= \underline{1,061,246.85 \text{ N}} \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 1,026,043.39$ N

Path 1-1 through (2) & (3) = $1,271,226.21 + 739,685.65 = \underline{2,010,911.87}$ N

Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2-2} = 105,203.42$ N

Path 2-2 through (1), (4), (6) = $527,360.92 + 1,468,703.3 + 2,170,844.31 = \underline{4,166,908.53}$ N

Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3-3} = 1,026,043.39$ N

Path 3-3 through (2), (4) = $1,271,226.21 + 1,468,703.3 = \underline{2,739,929.51}$ N

Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For $P_e = 224.31$ kPa @ 120 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
46.6259	74.343	0.0006	4.2884	--	67.6656	2.3884	6.02	11.11

UG-41 Weld Failure Path Analysis Summary

Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary

Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg ₄₁)	6	6.67	weld size is adequate
Pad to shell fillet (Leg ₄₂)	7.51	8.89	weld size is adequate
Nozzle to pad groove (Upper)	6.65	22.2	weld size is adequate

Calculations for external pressure 224.31 kPa @ 120 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(618.12, 309.06 + (12.7 - 3.2) + (18.22 - 3.2)) \\
 &= 618.12 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(18.22 - 3.2), 2.5*(12.7 - 3.2) + 22.2) \\
 &= 37.55 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 2.82$ mm

From UG-37(d)(1) required thickness $t_r = 15.02$ mm

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 118$, $S_v = 138$, $S_p = 138$ MPa

t_{r1} = lesser of 1 or $S_n / S_v = 0.8551$

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$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8551$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned} A &= 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})) \\ &= (0.5*(618.12*15.02*1 + 2*9.5*15.02*1*(1 - 0.8551))) / 100 \\ &= \underline{46.6259} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.0006} \text{ cm}^2$$

$$\begin{aligned} &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= (618.12*(1*15.02 - 1*15.02) - 2*9.5*(1*15.02 - 1*15.02)*(1 - 0.8551)) / 100 \\ &= 0.0006 \text{ cm}^2 \\ &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= (2*(15.02 + 9.5)*(1*15.02 - 1*15.02) - 2*9.5*(1*15.02 - 1*15.02)*(1 - 0.8551)) / 100 \\ &= 0 \text{ cm}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{4.2884} \text{ cm}^2$$

$$\begin{aligned} &= 5*(t_n - t_m)*f_{r2}*t \\ &= (5*(9.5 - 2.82)*0.8551*15.02) / 100 \\ &= 4.2884 \text{ cm}^2 \\ &= 2*(t_n - t_m)*(2.5*t_n + t_e)*f_{r2} \\ &= (2*(9.5 - 2.82)*(2.5*9.5 + 22.2)*0.8551) / 100 \\ &= 5.2477 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^{2*f_{r3}} \\ &= (9.53^{2*0.8551}) / 100 \\ &= \underline{0.7755} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{42} &= \text{Leg}^{2*f_{r4}} \\ &= (12.7^{2*1}) / 100 \\ &= \underline{1.6129} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\ &= ((942.38 - 637.58)*22.2*1) / 100 \\ &= \underline{67.6656} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
 &= 0.0006 + 4.2884 + 0.7755 + 1.6129 + 67.6656 \\
 &= \underline{74.343} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t_e = 9.5 \text{ mm} \\
 t_{c(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 * t_{\min} = \underline{6} \text{ mm} \\
 t_{c(\text{actual})} &= 0.7 * \text{Leg} = 0.7 * 9.53 = 6.67 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_e \text{ or } t = 15.02 \text{ mm} \\
 t_{w(\min)} &= 0.5 * t_{\min} = \underline{7.51} \text{ mm} \\
 t_{w(\text{actual})} &= 0.7 * \text{Leg} = 0.7 * 12.7 = 8.89 \text{ mm}
 \end{aligned}$$

UG-45 Nozzle Neck Thickness Check (Access Opening)

Interpretation VIII-1-83-66 has been applied.

$$t_{a \text{ UG-28}} = 6.02 \text{ mm}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-28}}, t_{a \text{ UG-22}}] \\
 &= \max[6.02, 0] \\
 &= 6.02 \text{ mm}
 \end{aligned}$$

$$\text{Available nozzle wall thickness new, } t_n = 0.875 * 12.7 = 11.11 \text{ mm}$$

The nozzle neck thickness is adequate.

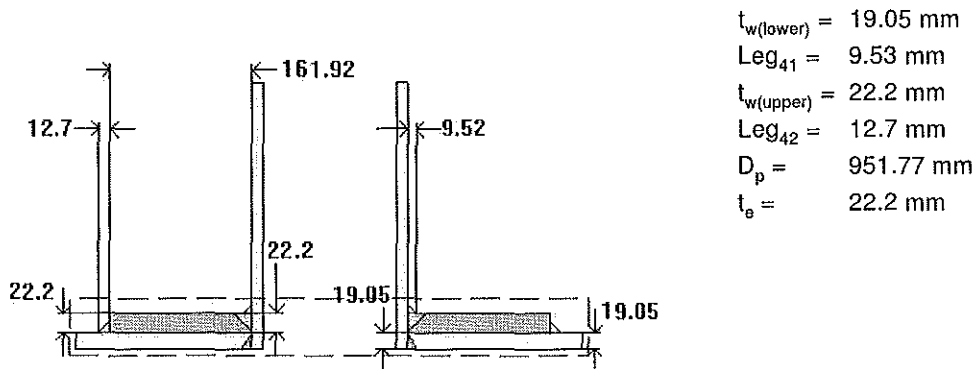
External Pressure, (Corroded & at 120 °C) UG-28(c)

$$\begin{aligned}
 L / D_o &= 703.99 / 609.6 = 1.1548 \\
 D_o / t &= 609.6 / 2.82 = 216.0111 \\
 \text{From table G: } A &= 0.000367 \\
 \text{From table CS-2 } B &= 36.3403 \text{ MPa} \\
 \text{Metric:}
 \end{aligned}$$

$$\begin{aligned}
 P_a &= 4 * B / (3 * (D_o / t)) \\
 &= 4 * 36,340.3 / (3 * (609.6 / 2.82)) \\
 &= 224.31 \text{ kPa}
 \end{aligned}$$

Design thickness for external pressure $P_a = 224.31 \text{ kPa}$

$$t_a = t + \text{Corrosion} = 2.82 + 3.2 = 6.02 \text{ mm}$$

BOTTOM MANWAY (M2)**ASME Section VIII Division 1, 2010 Edition, A11 Addenda Metric**

Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	BOTTOM HEAD
Orientation:	315°
End of nozzle to datum line:	-1,350 mm
Calculated as hillside:	Yes
Distance to head center, R:	863 mm
Passes through a Category A joint:	No

Nozzle

Material specification:	SA-106 B Smls. Pipe (II-D Metric p. 10, In. 40)
Description:	NPS 24 XS DN 600
Inside diameter, new:	584.2 mm
Nominal wall thickness:	12.7 mm
Corrosion allowance:	3.2 mm
Opening chord length:	608.66 mm
Projection available outside vessel, Lpr:	238.1 mm
Projection available outside vessel to flange face, Lf:	390.5 mm
Local vessel minimum thickness:	19.05 mm
Liquid static head included:	52.1271 kPa
Longitudinal joint efficiency:	1

Reinforcing Pad

Material specification:	SA-516 70 (II-D Metric p. 18, In. 19) (normalized)
Diameter:	951.77 mm
Is split:	No

ASME B16.5-2009 Flange

Description:	NPS 24 Class 150 WN A105
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WO. 12-32

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Bolt Material:	SA-193 B7 Bolt <= 64 (II-D Metric p. 334, ln. 32)
Blind included:	Yes
Rated MDMT:	-48°C per UCS-66(b)(1)(b)
Liquid static head:	52.314 kPa
MAWP rating:	1,694 kPa @ 120°C
MAP rating:	1,960 kPa @ 10°C
Hydrotest rating:	3,000 kPa @ 10°C
PWHT performed:	No
Circumferential joint radiography:	Spot UW-11(b) Type 1

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Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 1,093.69 kPa @ 120 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
85.9763	89.6863	10.8316	4.5716	--	71.8947	2.3884	5.95	11.11

UG-41 Weld Failure Path Analysis Summary (N)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength	Weld load W ₃₋₃	Path 3-3 strength
1,041,005	1,088,195	2,023,586	109,326	4,248,071	1,123,731	2,833,766

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg ₄₁)	6	6.67	weld size is adequate
Pad to shell fillet (Leg ₄₂)	7.92	8.89	weld size is adequate
Nozzle to pad groove (Upper)	6.65	22.2	weld size is adequate

Calculations for internal pressure 1,093.69 kPa @ 120 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.3478).

Pad impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C

Fig UCS-66.1M MDMT reduction = 6.3 °C, (coincident ratio = 0.8872).

Nozzle UCS-66 governing thk: 11.11 mm

Nozzle rated MDMT: -105 °C

Pad UCS-66 governing thickness: 19.05 mm

Pad rated MDMT: -47.36 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(608.66, 304.33 + (12.7 - 3.2) + (19.05 - 3.2)) \\
 &= 608.66 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5 \cdot (19.05 - 3.2), 2.5 \cdot (12.7 - 3.2) + 22.2)
 \end{aligned}$$

$$= 39.62 \text{ mm}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned} t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\ &= 1,093.6942 \cdot 295.3 / (118,000 \cdot 1 - 0.6 \cdot 1,093.6942) \\ &= 2.75 \text{ mm} \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned} t_r &= P \cdot K_1 \cdot D_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\ &= 1,093.6942 \cdot 0.8985 \cdot 3,962 / (2 \cdot 138,000 \cdot 1 + 0.8 \cdot 1,093.6942) \\ &= 14.06 \text{ mm} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 138$, $S_p = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8551$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= (608.66 \cdot 14.06 \cdot 1 + 2 \cdot 9.5 \cdot 14.06 \cdot 1 \cdot (1 - 0.8551)) / 100 \\ &= \underline{85.9763} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{10.8316} \text{ cm}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= (608.66 \cdot (1 \cdot 15.85 - 1 \cdot 14.06) - 2 \cdot 9.5 \cdot (1 \cdot 15.85 - 1 \cdot 14.06) \cdot (1 - 0.8551)) / 100 \\ &= 10.8316 \text{ cm}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= (2 \cdot (15.85 + 9.5) \cdot (1 \cdot 15.85 - 1 \cdot 14.06) - 2 \cdot 9.5 \cdot (1 \cdot 15.85 - 1 \cdot 14.06) \cdot (1 - 0.8551)) / 100 \\ &= 0.8574 \text{ cm}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{4.5716} \text{ cm}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= (5 \cdot (9.5 - 2.75) \cdot 0.8551 \cdot 15.85) / 100 \\ &= 4.5716 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned}
 &= 2*(t_n - t_m)*(2.5*t_n + t_e)*f_{r2} \\
 &= (2*(9.5 - 2.75)*(2.5*9.5 + 22.2)*0.8551) / 100 \\
 &= 5.3019 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2*f_{r3} \\
 &= (9.53^2*0.8551) / 100 \\
 &= \underline{0.7755} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{42} &= \text{Leg}^2*f_{r4} \\
 &= (12.7^2*1) / 100 \\
 &= \underline{1.6129} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\
 &= ((951.77 - 627.92)*22.2*1) / 100 \\
 &= \underline{71.8947} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
 &= 10.8316 + 4.5716 + 0.7755 + 1.6129 + 71.8947 \\
 &= \underline{89.6863} \text{ cm}^2
 \end{aligned}$$

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t_e = 9.5 \text{ mm} \\
 t_{c(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7*t_{\min} = \underline{6} \text{ mm} \\
 t_{c(\text{actual})} &= 0.7*\text{Leg} = 0.7*9.53 = 6.67 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_e \text{ or } t = 15.85 \text{ mm} \\
 t_{w(\min)} &= 0.5*t_{\min} = \underline{7.92} \text{ mm} \\
 t_{w(\text{actual})} &= 0.7*\text{Leg} = 0.7*12.7 = 8.89 \text{ mm}
 \end{aligned}$$

UG-45 Nozzle Neck Thickness Check (Access Opening)

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned}
 t_{a \text{ UG-27}} &= P*R / (S*E - 0.6*P) + \text{Corrosion} \\
 &= 1,093.881*295.3 / (118,000*1 - 0.6*1,093.881) + 3.2 \\
 &= 5.95 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\
 &= \max[5.95, 0]
 \end{aligned}$$

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$$= 5.95 \text{ mm}$$

Available nozzle wall thickness new, $t_n = 0.875 \times 12.7 = 11.11 \text{ mm}$

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45 and UW-15(c)

Groove weld in tension: $0.74 \times 138 = 102.12 \text{ MPa}$

Nozzle wall in shear: $0.7 \times 118 = 82.6 \text{ MPa}$

Inner fillet weld in shear: $0.49 \times 118 = 57.82 \text{ MPa}$

Outer fillet weld in shear: $0.49 \times 138 = 67.62 \text{ MPa}$

Upper groove weld in tension: $0.74 \times 138 = 102.12 \text{ MPa}$

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi / 2) * \text{Nozzle OD} * \text{Leg} * S_i = (\pi / 2) * 609.6 * 9.53 * 57.82 = 527,360.92 \text{ N}$$

(2) Outer fillet weld in shear

$$(\pi / 2) * \text{Pad OD} * \text{Leg} * S_o = (\pi / 2) * 951.77 * 12.7 * 67.62 = 1,283,900.31 \text{ N}$$

(3) Nozzle wall in shear

$$(\pi / 2) * \text{Mean nozzle dia} * t_n * S_n = (\pi / 2) * 600.1 * 9.5 * 82.6 = 739,685.65 \text{ N}$$

(4) Groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 609.6 * 15.85 * 102.12 = 1,549,865.49 \text{ N}$$

(6) Upper groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 609.6 * 22.2 * 102.12 = 2,170,844.31 \text{ N}$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * f_{r1} * (E_1 * t - F * t_r)) * S_v \\ &= (8,597.6263 - 1,083.1591 + 2 * 9.5 * 0.8551 * (1 * 15.85 - 1 * 14.06)) * 138 \\ &= \underline{1,041,004.67 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (457.1604 + 7,189.47 + 77.5482 + 161.29) * 138 \\ &= \underline{1,088,194.83 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * f_{r1}) * S_v \\ &= (457.1604 + 0 + 77.5482 + 0 + 2 * 9.5 * 15.85 * 0.8551) * 138 \\ &= \underline{109,325.75 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 * t_n * f_{r1}) * S_v \\ &= (457.1604 + 0 + 7,189.47 + 77.5482 + 161.29 + 0 + 2 * 9.5 * 15.85 * 0.8551) * 138 \\ &= \underline{1,123,730.78 \text{ N}} \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 1,041,004.67$ N

Path 1-1 through (2) & (3) = $1,283,900.31 + 739,685.65 = \underline{2,023,585.96}$ N

Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2-2} = 109,325.75$ N

Path 2-2 through (1), (4), (6) = $527,360.92 + 1,549,865.49 + 2,170,844.31 = \underline{4,248,070.72}$ N

Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3-3} = 1,041,004.67$ N

Path 3-3 through (2), (4) = $1,283,900.31 + 1,549,865.49 = \underline{2,833,765.8}$ N

Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm ²) For $P_e = 250.06 \text{ kPa @ } 120^\circ \text{C}$ The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
48.4523	78.9315	---	4.6484	---	71.8947	2.3884	5.84	11.11

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg ₄₁)	6	6.67	weld size is adequate
Pad to shell fillet (Leg ₄₂)	7.92	8.89	weld size is adequate
Nozzle to pad groove (Upper)	6.65	22.2	weld size is adequate

Calculations for external pressure 250.06 kPa @ 120 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(608.65, 304.32 + (12.7 - 3.2) + (19.05 - 3.2)) \\
 &= 608.65 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5 \cdot (19.05 - 3.2), 2.5 \cdot (12.7 - 3.2) + 22.2) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_m = 2.64 \text{ mm}$

From UG-37(d)(1) required thickness $t_r = 15.85 \text{ mm}$

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 118$, $S_v = 138$, $S_p = 138 \text{ MPa}$

$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$

R2

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$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8551$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8551$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned} A &= 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})) \\ &= (0.5*(608.65*15.85*1 + 2*9.5*15.85*1*(1 - 0.8551))) / 100 \\ &= \underline{48.4523} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = 0 \text{ cm}^2$$

$$\begin{aligned} &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= (608.65*(1*15.85 - 1*15.85) - 2*9.5*(1*15.85 - 1*15.85)*(1 - 0.8551)) / 100 \\ &= 0 \text{ cm}^2 \\ &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= (2*(15.85 + 9.5)*(1*15.85 - 1*15.85) - 2*9.5*(1*15.85 - 1*15.85)*(1 - 0.8551)) / 100 \\ &= 0 \text{ cm}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{4.6484} \text{ cm}^2$$

$$\begin{aligned} &= 5*(t_n - t_m)*f_{r2}*t \\ &= (5*(9.5 - 2.64)*0.8551*15.85) / 100 \\ &= 4.6484 \text{ cm}^2 \\ &= 2*(t_n - t_m)*(2.5*t_n + t_e)*f_{r2} \\ &= (2*(9.5 - 2.64)*(2.5*9.5 + 22.2)*0.8551) / 100 \\ &= 5.3903 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2*f_{r3} \\ &= (9.53^2*0.8551) / 100 \\ &= \underline{0.7755} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{42} &= \text{Leg}^2*f_{r4} \\ &= (12.72^2*1) / 100 \\ &= \underline{1.6129} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\ &= ((951.77 - 627.92)*22.2*1) / 100 \\ &= \underline{71.8947} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
 &= 0 + 4.6484 + 0.7755 + 1.6129 + 71.8947 \\
 &= \underline{78.9315 \text{ cm}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t_e = 9.5 \text{ mm} \\
 t_{c(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 * t_{\min} = \underline{6} \text{ mm} \\
 t_{c(\text{actual})} &= 0.7 * \text{Leg} = 0.7 * 9.53 = 6.67 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 19 \text{ mm or } t_o \text{ or } t = 15.85 \text{ mm} \\
 t_{w(\min)} &= 0.5 * t_{\min} = \underline{7.92} \text{ mm} \\
 t_{w(\text{actual})} &= 0.7 * \text{Leg} = 0.7 * 12.7 = 8.89 \text{ mm}
 \end{aligned}$$

UG-45 Nozzle Neck Thickness Check (Access Opening)

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned}
 t_{a \text{ UG-28}} &= 5.84 \text{ mm} \\
 t_a &= \max[t_{a \text{ UG-28}}, t_{a \text{ UG-22}}] \\
 &= \max[5.84, 0] \\
 &= 5.84 \text{ mm}
 \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 * 12.7 = 11.11 \text{ mm}$

The nozzle neck thickness is adequate.

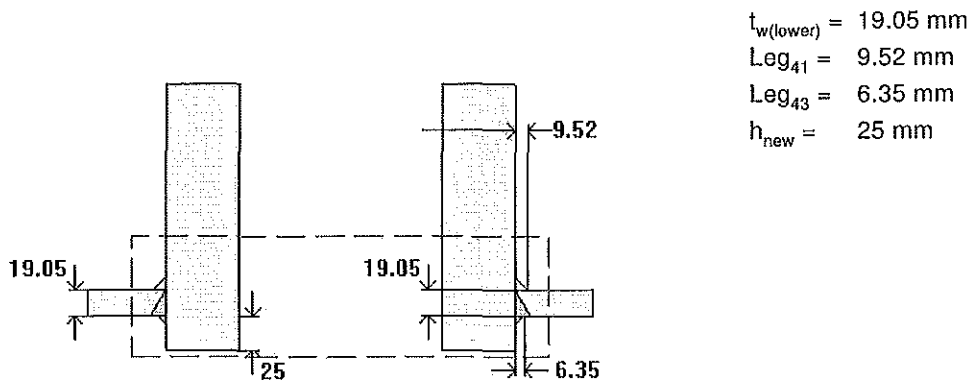
External Pressure, (Corroded & at 120 °C) UG-28(c)

$$\begin{aligned}
 L / D_o &= 542.21 / 609.6 = 0.8895 \\
 D_o / t &= 609.6 / 2.64 = 230.8405 \\
 \text{From table G: } A &= 0.000436 \\
 \text{From table CS-2 } B &= 43.2924 \text{ MPa} \\
 \text{Metric:}
 \end{aligned}$$

$$\begin{aligned}
 P_a &= 4 * B / (3 * (D_o / t)) \\
 &= 4 * 43.29245 / (3 * (609.6 / 2.64)) \\
 &= 250.06 \text{ kPa}
 \end{aligned}$$

Design thickness for external pressure $P_a = 250.06 \text{ kPa}$

$$t_a = t + \text{Corrosion} = 2.64 + 3.2 = \underline{5.84} \text{ mm}$$

SIGHT GLASS (SG1A)**ASME Section VIII Division 1, 2010 Edition, A11 Addenda Metric**

Note: round inside edges per UG-76(c)

Location and Orientation

Located on: 3962 mm O.D. SHELL
 Orientation: 225°
 Nozzle center line offset to datum line: 2,018 mm
 End of nozzle to shell center: 1,993.7 mm
 Passes through a Category A joint: No

Dwg shows 2028
 -10mm will not change the calculation

Nozzle

Material specification: SA-516 70 (II-D Metric p. 18, ln. 19) (normalized)
 Inside diameter, new: 146 mm
 Nominal wall thickness: 54.5 mm
 Corrosion allowance: 3.2 mm
 Projection available outside vessel, Lpr: 12.7 mm
 Internal projection, h_{new} : 25 mm
 Local vessel minimum thickness: 19.05 mm
 Liquid static head included: 20.0279 kPa
 Longitudinal joint efficiency: 1

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm ²) For P = 1,061.59 kPa @ 120 °C The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
27.9921	35.791	1.0013	12.8806	20.971	--	0.9381	11.31	54.5

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	6	6.66	weld size is adequate

Calculations for internal pressure 1,061.59 kPa @ 120 °C

Nozzle impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C
Fig UCS-66.1M MDMT reduction = 2.3 °C, (coincident ratio = 0.9585).

Nozzle UCS-66 governing thk: 19.05 mm

Nozzle rated MDMT: -43.36 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(152.4, 76.2 + (54.5 - 3.2) + (19.05 - 3.2)) \\
 &= 152.4 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2) + 0) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2 - 3.2)) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,061.5949 \cdot 76.2 / (138,000 \cdot 1 - 0.6 \cdot 1,061.5949) \\
 &= 0.59 \text{ mm}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 1,061.5949 \cdot 1,981 / (138,000 \cdot 1 + 0.4 \cdot 1,061.5949) \\
 &= 15.19 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 138$, $S_v = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) + \text{Tapped hole area loss} \\
 &= (152.4 \cdot 15.19 \cdot 1 + 2 \cdot 51.3 \cdot 15.19 \cdot 1 \cdot (1 - 1)) / 100 + 4.8387 \\
 &= \underline{27.9921} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{1.0013} \text{ cm}^2$$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= (152.4 \cdot (1 \cdot 15.85 - 1 \cdot 15.19) - 2 \cdot 51.3 \cdot (1 \cdot 15.85 - 1 \cdot 15.19) \cdot (1 - 1)) / 100 \\
 &= 1.0013 \text{ cm}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= (2 \cdot (15.85 + 51.3) \cdot (1 \cdot 15.85 - 1 \cdot 15.19) - 2 \cdot 51.3 \cdot (1 \cdot 15.85 - 1 \cdot 15.19) \cdot (1 - 1)) / 100 \\
 &= 0.8826 \text{ cm}^2
 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{12.8806} \text{ cm}^2$$

$$\begin{aligned}
 &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\
 &= (2 \cdot (51.3 - 0.59) \cdot 1 \cdot 12.7) / 100 \\
 &= 12.8806 \text{ cm}^2 \\
 &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\
 &= (2 \cdot (51.3 - 0.59) \cdot 1 \cdot 12.7) / 100 \\
 &= 12.8806 \text{ cm}^2
 \end{aligned}$$

$A_3 = \text{smaller of the following} = \underline{20.971} \text{ cm}^2$

$$\begin{aligned}
 &= 5 \cdot t_i \cdot f_{r2} \\
 &= (5 \cdot 15.85 \cdot 48.1 \cdot 1) / 100 \\
 &= \underline{38.118} \text{ cm}^2 \\
 &= 5 \cdot t_i \cdot f_{r2} \\
 &= (5 \cdot 48.1 \cdot 48.1 \cdot 1) / 100 \\
 &= \underline{115.6786} \text{ cm}^2 \\
 &= 2 \cdot h \cdot t_i \cdot f_{r2} \\
 &= (2 \cdot 21.8 \cdot 48.1 \cdot 1) / 100 \\
 &= \underline{20.971} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= (9.52^2 \cdot 1) / 100 \\
 &= \underline{0.9065} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 \cdot f_{r2} \\
 &= (1.78^2 \cdot 1) / 100 \\
 &= \underline{0.0316} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
 &= 1.0013 + 12.8806 + 20.971 + 0.9065 + 0.0316 \\
 &= \underline{35.791} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 15.85 \text{ mm}$

$t_{c(\min)} = \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = \underline{6} \text{ mm}$

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 9.52 = 6.66 \text{ mm}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned}
 t_{a \text{ UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\
 &= 1,061.5949 \cdot 76.2 / (138,000 \cdot 1 - 0.6 \cdot 1,061.5949) + 3.2 \\
 &= 3.79 \text{ mm}
 \end{aligned}$$

$$t_a = \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}]$$

R2

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$$= \max[3.79, 0]$$
$$= 3.79 \text{ mm}$$

$$t_{b1} = P \cdot R_o / (S \cdot E + 0.4 \cdot P) + \text{Corrosion}$$
$$= 1,061.5949 \cdot 1,981 / (138,000 \cdot 1 + 0.4 \cdot 1,061.5949) + 3.2$$
$$= 18.39 \text{ mm}$$

$$t_{b1} = \max[t_{b1}, t_{b \text{ UG16}}]$$
$$= \max[18.39, 4.7]$$
$$= 18.39 \text{ mm}$$

$$t_b = \min[t_{b3}, t_{b1}]$$
$$= \min[11.31, 18.39]$$
$$= 11.31 \text{ mm}$$

$$t_{UG-45} = \max[t_a, t_b]$$
$$= \max[3.79, 11.31]$$
$$= 11.31 \text{ mm}$$

Available nozzle wall thickness new, $t_n = 54.5 \text{ mm}$

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For $P_e = 221.4 \text{ kPa @ } 120^\circ \text{C}$ The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
16.9161	34.8323	--	12.9232	20.971	--	0.9381	6.38	54.5

UG-41 Weld Failure Path Analysis Summary

Weld strength calculations are not required for
external pressure

UW-16 Weld Sizing Summary

Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	6	6.66	weld size is adequate

Calculations for external pressure 221.4 kPa @ 120 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(152.4, 76.2 + (54.5 - 3.2) + (19.05 - 3.2)) \\
 &= 152.4 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5 \cdot (19.05 - 3.2), 2.5 \cdot (54.5 - 3.2) + 0) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5 \cdot (t - C), 2.5 \cdot (t_i - C_n - C)) \\
 &= \text{MIN}(2.5 \cdot (19.05 - 3.2), 2.5 \cdot (54.5 - 3.2 - 3.2)) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 0.42 \text{ mm}$

From UG-37(d)(1) required thickness $t_r = 15.85 \text{ mm}$

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 138$, $S_v = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned} A &= 0.5(d_t F + 2t_n t_f F(1 - f_{r1})) + \text{Tapped hole area loss} \\ &= (0.5(152.4 \cdot 15.85 \cdot 1 + 2 \cdot 51.3 \cdot 15.85 \cdot 1(1 - 1))) / 100 + 4.8387 \\ &= \underline{16.9161} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = 0 \text{ cm}^2$

$$\begin{aligned} &= d(E_1 t - F t_f) - 2t_n (E_1 t - F t_f)(1 - f_{r1}) \\ &= (152.4(1 \cdot 15.85 - 1 \cdot 15.85) - 2 \cdot 51.3(1 \cdot 15.85 - 1 \cdot 15.85)(1 - 1)) / 100 \\ &= 0 \text{ cm}^2 \\ &= 2(t + t_n)(E_1 t - F t_f) - 2t_n (E_1 t - F t_f)(1 - f_{r1}) \\ &= (2(15.85 + 51.3)(1 \cdot 15.85 - 1 \cdot 15.85) - 2 \cdot 51.3(1 \cdot 15.85 - 1 \cdot 15.85)(1 - 1)) / 100 \\ &= 0 \text{ cm}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{12.9232} \text{ cm}^2$

$$\begin{aligned} &= 2(t_n - t_m) f_{r2} L_{pr} \\ &= (2(51.3 - 0.42) \cdot 1 \cdot 12.7) / 100 \\ &= 12.9232 \text{ cm}^2 \\ &= 2(t_n - t_m) f_{r2} L_{pr} \\ &= (2(51.3 - 0.42) \cdot 1 \cdot 12.7) / 100 \\ &= 12.9232 \text{ cm}^2 \end{aligned}$$

$A_3 = \text{smaller of the following} = \underline{20.971} \text{ cm}^2$

$$\begin{aligned} &= 5t_i t_f f_{r2} \\ &= (5 \cdot 15.85 \cdot 48.1 \cdot 1) / 100 \\ &= \underline{38.118} \text{ cm}^2 \\ &= 5t_i t_f f_{r2} \\ &= (5 \cdot 48.1 \cdot 48.1 \cdot 1) / 100 \\ &= \underline{115.6786} \text{ cm}^2 \\ &= 2h t_i f_{r2} \\ &= (2 \cdot 21.8 \cdot 48.1 \cdot 1) / 100 \\ &= \underline{20.971} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= (9.52^2 \cdot 1) / 100 \\
 &= \underline{0.9065} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 \cdot f_{r2} \\
 &= (1.78^2 \cdot 1) / 100 \\
 &= \underline{0.0316} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
 &= 0 + 12.9232 + 20.971 + 0.9065 + 0.0316 \\
 &= \underline{34.8323} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 19 mm or t_n or $t = 15.85$ mm

$t_{c(\min)}$ = lesser of 6 mm or $0.7 \cdot t_{\min} = \underline{6}$ mm

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 9.52 = 6.66$ mm

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$t_{a \text{ UG-28}} = 3.62 \text{ mm}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-28}}, t_{a \text{ UG-22}}] \\
 &= \max[3.62, 0] \\
 &= 3.62 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_{b2} &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) + \text{Corrosion} \\
 &= 221.3986 \cdot 1,981 / (138,000 \cdot 1 + 0.4 \cdot 221.3986) + 3.2 \\
 &= 6.38 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_{b2} &= \max[t_{b2}, t_{b \text{ UG16}}] \\
 &= \max[6.38, 4.7] \\
 &= 6.38 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_b &= \min[t_{b3}, t_{b2}] \\
 &= \min[11.31, 6.38] \\
 &= 6.38 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}t_{UG-45} &= \max[t_a, t_b] \\&= \max[3.62, 6.38] \\&= 6.38 \text{ mm}\end{aligned}$$

Available nozzle wall thickness new, $t_n = 54.5 \text{ mm}$

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 120 °C) UG-28(c)

$$\begin{aligned}L / D_o &= 16.81 / 255 = 0.0659 \\D_o / t &= 255 / 0.42 = 604.2399 \\ \text{From table G:} \quad A &= 0.001822 \\ \text{From table CS-2} \quad B &= 100.3343 \text{ MPa} \\ \text{Metric:}\end{aligned}$$

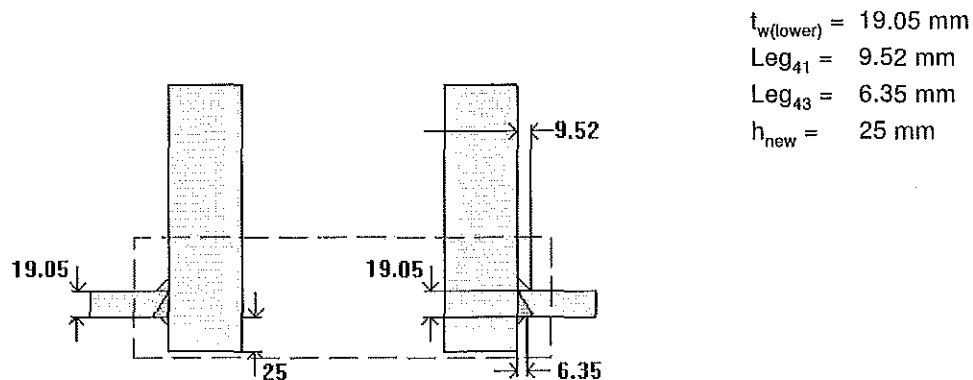
$$\begin{aligned}P_a &= 4*B / (3*(D_o / t)) \\&= 4*100,334.25 / (3*(255 / 0.42)) \\&= 221.4 \text{ kPa}\end{aligned}$$

Design thickness for external pressure $P_a = 221.4 \text{ kPa}$

$$t_a = t + \text{Corrosion} = 0.42 + 3.2 = 3.62 \text{ mm}$$

SIGHT GLASS (SG1B)

ASME Section VIII Division 1, 2010 Edition, A11 Addenda Metric



Note: round inside edges per UG-76(c)

Location and Orientation

Located on: 3962 mm O.D. SHELL
 Orientation: 225°
 Nozzle center line offset to datum line: 1,528 mm
 End of nozzle to shell center: 1,993.7 mm
 Passes through a Category A joint: No

Nozzle

Material specification: SA-516 70 (II-D Metric p. 18, In. 19) (normalized)
 Inside diameter, new: 146 mm
 Nominal wall thickness: 54.5 mm
 Corrosion allowance: 3.2 mm
 Projection available outside vessel, L_{pr}: 12.7 mm
 Internal projection, h_{new} : 25 mm
 Local vessel minimum thickness: 19.05 mm
 Liquid static head included: 24.8294 kPa
 Longitudinal joint efficiency: 1

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 1,066.4 kPa @ 120 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
28.0966	35.6859	0.8968	12.88	20.971	--	0.9381	11.31	54.5

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	6	6.66	weld size is adequate

Calculations for internal pressure 1,066.4 kPa @ 120 °C

Nozzle impact test exemption temperature from Fig UCS-66M Curve D = -41.06 °C
Fig UCS-66.1M MDMT reduction = 2.1 °C, (coincident ratio = 0.9629).

Nozzle UCS-66 governing thk: 19.05 mm

Nozzle rated MDMT: -43.16 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(152.4, 76.2 + (54.5 - 3.2) + (19.05 - 3.2)) \\
 &= 152.4 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2) + 0) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2 - 3.2)) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,066.3964 \cdot 76.2 / (138,000 \cdot 1 - 0.6 \cdot 1,066.3964) \\
 &= 0.59 \text{ mm}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 1,066.3964 \cdot 1,981 / (138,000 \cdot 1 + 0.4 \cdot 1,066.3964) \\
 &= 15.26 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 138$, $S_v = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) + \text{Tapped hole area loss} \\
 &= (152.4 \cdot 15.26 \cdot 1 + 2 \cdot 51.3 \cdot 15.26 \cdot 1 \cdot (1 - 1)) / 100 + 4.8387 \\
 &= \underline{28.0966} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.8968} \text{ cm}^2$$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= (152.4 \cdot (1 \cdot 15.85 - 1 \cdot 15.26) - 2 \cdot 51.3 \cdot (1 \cdot 15.85 - 1 \cdot 15.26) \cdot (1 - 1)) / 100 \\
 &= 0.8968 \text{ cm}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= (2 \cdot (15.85 + 51.3) \cdot (1 \cdot 15.85 - 1 \cdot 15.26) - 2 \cdot 51.3 \cdot (1 \cdot 15.85 - 1 \cdot 15.26) \cdot (1 - 1)) / 100 \\
 &= 0.7903 \text{ cm}^2
 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{12.88} \text{ cm}^2$$

$$\begin{aligned}
 &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\
 &= (2 \cdot (51.3 - 0.59) \cdot 1 \cdot 12.7) / 100 \\
 &= 12.88 \text{ cm}^2 \\
 &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\
 &= (2 \cdot (51.3 - 0.59) \cdot 1 \cdot 12.7) / 100 \\
 &= 12.88 \text{ cm}^2
 \end{aligned}$$

$A_3 = \text{smaller of the following} = \underline{20.971} \text{ cm}^2$

$$\begin{aligned}
 &= 5 * t_l * f_{r2} \\
 &= (5 * 15.85 * 48.1 * 1) / 100 \\
 &= \underline{38.118} \text{ cm}^2 \\
 &= 5 * t_l * f_{r2} \\
 &= (5 * 48.1 * 48.1 * 1) / 100 \\
 &= \underline{115.6786} \text{ cm}^2 \\
 &= 2 * h * t_l * f_{r2} \\
 &= (2 * 21.8 * 48.1 * 1) / 100 \\
 &= \underline{20.971} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 * f_{r2} \\
 &= (9.52^2 * 1) / 100 \\
 &= \underline{0.9065} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 * f_{r2} \\
 &= (1.78^2 * 1) / 100 \\
 &= \underline{0.0316} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
 &= 0.8968 + 12.88 + 20.971 + 0.9065 + 0.0316 \\
 &= \underline{35.6859} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 19 mm or t_n or $t = 15.85$ mm

$t_{c(\min)}$ = lesser of 6 mm or $0.7 * t_{\min} = \underline{6}$ mm

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 9.52 = 6.66$ mm

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned}
 t_{a \text{ UG-27}} &= P * R / (S * E - 0.6 * P) + \text{Corrosion} \\
 &= 1,066.3964 * 76.2 / (138,000 * 1 - 0.6 * 1,066.3964) + 3.2 \\
 &= 3.79 \text{ mm}
 \end{aligned}$$

$$t_a = \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}]$$

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$$\begin{aligned} &= \max[3.79 , 0] \\ &= 3.79 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_{b1} &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) + \text{Corrosion} \\ &= 1,066.3964 \cdot 1,981 / (138,000 \cdot 1 + 0.4 \cdot 1,066.3964) + 3.2 \\ &= 18.46 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_{b1} &= \max[t_{b1} , t_{b \text{ UG16}}] \\ &= \max[18.46 , 4.7] \\ &= 18.46 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3} , t_{b1}] \\ &= \min[11.31 , 18.46] \\ &= 11.31 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a , t_b] \\ &= \max[3.79 , 11.31] \\ &= 11.31 \text{ mm} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 54.5 \text{ mm}$

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For $P_e = 221.4 \text{ kPa @ } 120^\circ \text{C}$ The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
16.9161	34.8323	--	12.9232	20.971	--	0.9381	6.38	54.5

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	6	6.66	weld size is adequate

Calculations for external pressure 221.4 kPa @ 120 °C

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(152.4, 76.2 + (54.5 - 3.2) + (19.05 - 3.2)) \\
 &= 152.4 \text{ mm}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_a) \\
 &= \text{MIN}(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2) + 0) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2 - 3.2)) \\
 &= 39.62 \text{ mm}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_m = 0.42 \text{ mm}$

From UG-37(d)(1) required thickness $t_r = 15.85 \text{ mm}$

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 138$, $S_v = 138$ MPa

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned} A &= 0.5(d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) + \text{Tapped hole area loss} \\ &= (0.5(152.4 \cdot 15.85 \cdot 1 + 2 \cdot 51.3 \cdot 15.85 \cdot 1 \cdot (1 - 1))) / 100 + 4.8387 \\ &= \underline{16.9161} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 0 cm²

$$\begin{aligned} &= d(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= (152.4(1 \cdot 15.85 - 1 \cdot 15.85) - 2 \cdot 51.3(1 \cdot 15.85 - 1 \cdot 15.85)(1 - 1)) / 100 \\ &= 0 \text{ cm}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= (2(15.85 + 51.3)(1 \cdot 15.85 - 1 \cdot 15.85) - 2 \cdot 51.3(1 \cdot 15.85 - 1 \cdot 15.85)(1 - 1)) / 100 \\ &= 0 \text{ cm}^2 \end{aligned}$$

A_2 = smaller of the following = 12.9232 cm²

$$\begin{aligned} &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= (2(51.3 - 0.42) \cdot 1 \cdot 12.7) / 100 \\ &= 12.9232 \text{ cm}^2 \\ &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= (2(51.3 - 0.42) \cdot 1 \cdot 12.7) / 100 \\ &= 12.9232 \text{ cm}^2 \end{aligned}$$

A_3 = smaller of the following = 20.971 cm²

$$\begin{aligned} &= 5 \cdot t \cdot t_i \cdot f_{r2} \\ &= (5 \cdot 15.85 \cdot 48.1 \cdot 1) / 100 \\ &= \underline{38.118} \text{ cm}^2 \\ &= 5 \cdot t_i \cdot t_i \cdot f_{r2} \\ &= (5 \cdot 48.1 \cdot 48.1 \cdot 1) / 100 \\ &= \underline{115.6786} \text{ cm}^2 \\ &= 2 \cdot h \cdot t_i \cdot f_{r2} \\ &= (2 \cdot 21.8 \cdot 48.1 \cdot 1) / 100 \\ &= \underline{20.971} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot t_{r2} \\
 &= (9.52^2 \cdot 1) / 100 \\
 &= \underline{0.9065} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 \cdot t_{r2} \\
 &= (1.78^2 \cdot 1) / 100 \\
 &= \underline{0.0316} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
 &= 0 + 12.9232 + 20.971 + 0.9065 + 0.0316 \\
 &= \underline{34.8323} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 19 mm or t_n or $t = 15.85$ mm

$t_{c(\min)}$ = lesser of 6 mm or $0.7 \cdot t_{\min} = \underline{6}$ mm

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 9.52 = 6.66$ mm

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$t_{a \text{ UG-28}} = 3.62 \text{ mm}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-28}}, t_{a \text{ UG-22}}] \\
 &= \max[3.62, 0] \\
 &= 3.62 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_{b2} &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) + \text{Corrosion} \\
 &= 221.3986 \cdot 1,981 / (138,000 \cdot 1 + 0.4 \cdot 221.3986) + 3.2 \\
 &= 6.38 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_{b2} &= \max[t_{b2}, t_{b \text{ UG16}}] \\
 &= \max[6.38, 4.7] \\
 &= 6.38 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 t_b &= \min[t_{b3}, t_{b2}] \\
 &= \min[11.31, 6.38] \\
 &= 6.38 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}t_{UG-45} &= \max[t_a, t_b] \\&= \max[3.62, 6.38] \\&= 6.38 \text{ mm}\end{aligned}$$

Available nozzle wall thickness new, $t_n = 54.5$ mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 120 °C) UG-28(c)

$$\begin{aligned}L / D_o &= 16.81 / 255 = 0.0659 \\D_o / t &= 255 / 0.42 = 604.2399 \\ \text{From table G:} \quad A &= 0.001822 \\ \text{From table CS-2} \quad B &= 100.3343 \text{ MPa} \\ \text{Metric:}\end{aligned}$$

$$\begin{aligned}P_a &= 4*B / (3*(D_o / t)) \\&= 4*100,334.25 / (3*(255 / 0.42)) \\&= 221.4 \text{ kPa}\end{aligned}$$

Design thickness for external pressure $P_a = 221.4$ kPa

$$t_a = t + \text{Corrosion} = 0.42 + 3.2 = 3.62 \text{ mm}$$

Seismic Code

Method of seismic analysis:	NBC Canada 2005
Importance Factor:	$I_E = 1.3000$
Location:	Fort McMurray, Alberta
5% Damped Spectral Response Accel. at $T = 0.2s$	$S_a(0.2) = 0.1200$
5% Damped Spectral Response Accel. at $T = 0.5s$	$S_a(0.5) = 0.0560$
5% Damped Spectral Response Accel. at $T = 1.0s$	$S_a(1.0) = 0.0230$
5% Damped Spectral Response Accel. at $T = 2.0s$	$S_a(2.0) = 0.0060$
Site Class:	D
Acceleration-based Site Coefficient:	$F_a = 1.3000$
Velocity-based Site Coefficient:	$F_v = 1.4000$
Ductility-related force modification factor:	$R_d = 2.5000$
Overstrength-related force modification factor:	$R_o = 1.0000$
Vertical Accelerations Considered:	No

Vessel Characteristics

Vessel height: 19.0735 ft (5.81 m)

Vessel Weight:

Operating, Corroded: 179,796 lb (81,554 kg)

Empty, Corroded: 57,783 lb (26,210 kg)

Vacuum, Corroded: 179,796 lb (81,554 kg)

Period of Vibration Calculation

Fundamental Period, T :

Operating, Corroded: 0.484 sec ($f = 2.1$ Hz)

Empty, Corroded: 0.272 sec ($f = 3.7$ Hz)

Vacuum, Corroded: 0.484 sec ($f = 2.1$ Hz)

The fundamental period of vibration T (above) is calculated using the Rayleigh method of approximation:

$$T = 2 * \pi * \sqrt{(\text{Sum}(W_i * y_i^2)) / (g * \text{Sum}(W_i * y_i))}, \text{ where}$$

W_i is the weight of the i^{th} lumped mass, and
 y_i is its deflection when the system is treated as a cantilever beam.

Seismic Shear Reports:

Operating, Corroded

Empty, Corroded

Vacuum, Corroded

Base Shear Calculations

Seismic Shear Report: Operating, Corroded

Component	Elevation of bottom above base (mm)	Elastic modulus E (MPa)	Inertia I (m ⁴)	Seismic shear at Bottom (N)	Bending Moment at Bottom (N-m)
TOP HEAD	4,763	196,800.0	*	4,973.2	7,175.1
3962 mm O.D. SHELL (top)	2,376	196,800.0	0.3825	17,682.1	34,208.7
SUPPORT LEG	0	199,948.0	0.0352	22,865.5	90,036.9
3962 mm O.D. SHELL (bottom)	2,376	196,800.0	0.3825	5,098.3	5,638.6
BOTTOM HEAD	2,376	196,800.0	*	5,026.7	5,510

*Moment of Inertia I varies over the length of the component

Seismic Shear Report: Empty, Corroded

Component	Elevation of bottom above base (mm)	Elastic modulus E (MPa)	Inertia I (m ⁴)	Seismic shear at Bottom (N)	Bending Moment at Bottom (N-m)
TOP HEAD	4,763	202,272.2	*	1,981.1	6,083.8
3962 mm O.D. SHELL (top)	2,376	202,272.2	0.3825	5,030.2	13,794.3
SUPPORT LEG	0	199,948.0	0.0352	9,266.9	37,983.3
3962 mm O.D. SHELL (bottom)	2,376	202,272.2	0.3825	4,092.8	4,926.9
BOTTOM HEAD	2,376	202,272.2	*	4,075	4,823.2

*Moment of Inertia I varies over the length of the component

Seismic Shear Report: Vacuum, Corroded

Component	Elevation of bottom above base (mm)	Elastic modulus E (MPa)	Inertia I (m ⁴)	Seismic shear at Bottom (N)	Bending Moment at Bottom (N-m)
TOP HEAD	4,763	196,800.0	*	4,973.2	7,175.1
3962 mm O.D. SHELL (top)	2,376	196,800.0	0.3825	17,682.1	34,208.7
SUPPORT LEG	0	199,948.0	0.0352	22,865.5	90,036.9
3962 mm O.D. SHELL (bottom)	2,376	196,800.0	0.3825	5,098.3	5,638.6
BOTTOM HEAD	2,376	196,800.0	*	5,026.7	5,510

*Moment of Inertia I varies over the length of the component

Base Shear Calculations

Operating, Corroded

Empty, Corroded

Vacuum, Corroded

Base Shear Calculations: Operating, Corroded

Fundamental Period computed by Rayleigh approximation: 0.484

The design spectral response acceleration, $S(T_a)$ per 4.1.8.4.(6): 0.0826

Higher mode factor, M_v per 4.1.8.11.(5): 1.0000

$$\begin{aligned}
 V &= 2/3 * S(T_a) * M_v * I_E * W / (R_d * R_o) \\
 &= 2/3 * 0.0826 * 1.0000 * 1.3000 * 179,796.4375 / (2.5000 * 1.0000) \\
 &= 5,147.9604 \text{ lb (2,335.08 kg)}
 \end{aligned}$$

Per 4.1.8.11.(2), the minimum lateral earthquake force, V, shall be no less than V_{min} :

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$$\begin{aligned}
 V_{\min} &= 2/3 * S(2.0) * M_v * I_E * W / (R_d * R_o) \\
 &= 2/3 * 0.0084 * 1.0000 * 1.3000 * 179,796.4375 / (2.5000 * 1.0000) \\
 &= 523.57 \text{ lb (237.49 kg)}
 \end{aligned}$$

When R_d is greater than or equal to 1.5, V shall be no more than V_{\max} :

$$\begin{aligned}
 V_{\max} &= 2/3 * 2/3 * S(0.2) * I_E * W / (R_d * R_o) \\
 &= 2/3 * 2/3 * 0.1560 * 1.3000 * 179,796.4375 / (2.5000 * 1.0000) \\
 &= 6,482.26 \text{ lb (2,940.30 kg)}
 \end{aligned}$$

$$V = 5,147.96 \text{ lb (2,335.08 kg)}$$

Base Shear Calculations: Empty, Corroded

Fundamental Period computed by Rayleigh approximation: 0.272

The design spectral response acceleration, $S(T_a)$ per 4.1.8.4.(6): 0.1375

Higher mode factor, M_v per 4.1.8.11.(5): 1.0000

$$\begin{aligned}
 V &= 2/3 * S(T_a) * M_v * I_E * W / (R_d * R_o) \\
 &= 2/3 * 0.1375 * 1.0000 * 1.3000 * 57,783.3125 / (2.5000 * 1.0000) \\
 &= 2,753.9648 \text{ lb (1,249.18 kg)}
 \end{aligned}$$

Per 4.1.8.11.(2), the minimum lateral earthquake force, V , shall be no less than V_{\min} :

$$\begin{aligned}
 V_{\min} &= 2/3 * S(2.0) * M_v * I_E * W / (R_d * R_o) \\
 &= 2/3 * 0.0084 * 1.0000 * 1.3000 * 57,783.3125 / (2.5000 * 1.0000) \\
 &= 168.2650 \text{ lb (76.32 kg)}
 \end{aligned}$$

When R_d is greater than or equal to 1.5, V shall be no more than V_{\max} :

$$\begin{aligned}
 V_{\max} &= 2/3 * 2/3 * S(0.2) * I_E * W / (R_d * R_o) \\
 &= 2/3 * 2/3 * 0.1560 * 1.3000 * 57,783.3125 / (2.5000 * 1.0000) \\
 &= 2,083.2810 \text{ lb (944.96 kg)}
 \end{aligned}$$

$$V = 2,083.28 \text{ lb (944.96 kg)}$$

Base Shear Calculations: Vacuum, Corroded

Fundamental Period computed by Rayleigh approximation: 0.484

The design spectral response acceleration, $S(T_a)$ per 4.1.8.4.(6): 0.0826

Higher mode factor, M_v per 4.1.8.11.(5): 1.0000

$$\begin{aligned}
 V &= 2/3 * S(T_a) * M_v * I_E * W / (R_d * R_o) \\
 &= 2/3 * 0.0826 * 1.0000 * 1.3000 * 179,796.4375 / (2.5000 * 1.0000) \\
 &= 5,147.9604 \text{ lb (2,335.08 kg)}
 \end{aligned}$$

Per 4.1.8.11.(2), the minimum lateral earthquake force, V , shall be no less than V_{\min} :

$$\begin{aligned}
 V_{\min} &= 2/3 * S(2.0) * M_v * I_E * W / (R_d * R_o) \\
 &= 2/3 * 0.0084 * 1.0000 * 1.3000 * 179,796.4375 / (2.5000 * 1.0000)
 \end{aligned}$$

$$= 523.5673 \text{ lb (237.49 kg)}$$

When R_d is greater than or equal to 1.5, V shall be no more than V_{\max} :

$$\begin{aligned} V_{\max} &= 2/3 * 2/3 * S(0.2) * I_E * W / (R_d * R_o) \\ &= 2/3 * 2/3 * 0.1560 * 1.3000 * 179,796.4375 / (2.5000 * 1.0000) \\ &= 6,482.2607 \text{ lb (2,940.30 kg)} \end{aligned}$$

$$V = 5,147.96 \text{ lb (2,335.08 kg)}$$

SUPPORT LEG

Leg material:		CSA G40.21-350W
Leg description:		W 10x49 (Flange in)
Number of legs:	N = 4	
Overall length:	2,529	mm
Base to girth seam length:	2,376	mm
Pad length:	460	mm
Pad width:	356	mm
Pad thickness:	12.7	mm
Bolt circle:	3,781.6	mm
Anchor bolt size:	1	inch coarse threaded
Anchor bolt material:		SA 36
Anchor bolts/leg:	2	
Anchor bolt allowable stress:	$S_b = 103.42$	MPa
Anchor bolt corrosion allowance:	0	mm
Anchor bolt hole clearance:	10	mm
Base plate width:	330	mm
Base plate length:	330	mm
Base plate thickness:	25.4	mm (<u>12.34</u> mm required)
Base plate allowable stress:	165.474	MPa
Foundation allowable bearing stress:	5.171	MPa
User defined leg eccentricity:	12.7	mm
Effective length coefficient:	K = 1.2	
Coefficient:	$C_m = 0.85$	
Leg yield stress:	$F_y = 350$	MPa
Leg elastic modulus:	$E = 199,947.953$	MPa
Leg to pad fillet weld:	17	mm (<u>16.33</u> mm required)
Pad to shell fillet weld:	9.5	mm (<u>3.14</u> mm required)
Legs braced:	No	

Note: The support attachment point is assumed to be 25.4 mm up from the cylinder circumferential seam.

Conditions Investigated (Only Governing Condition Reported)

Weight operating corroded
 Weight operating new
 Weight empty corroded
 Weight empty new
 Weight test new
 Weight vacuum corroded
 Seismic operating corroded
 Seismic operating new
 Seismic empty corroded
 Seismic empty new
 Seismic vacuum corroded

Loading	Force attack angle °	Leg position °	Axial end load N	Shear resisted N	Axial f_a MPa	Bending f_{bx} MPa	Bending f_{by} MPa	Ratio H_{1-1}	Ratio H_{1-2}
Governing Condition Seismic operating new Moment = 36,442.7 N-m	0	0	192,097.8	2,934.7	20.677	31.083	0	0.2368	0.2330
		90	201,237.2	8,546.5	21.661	8.349	23.067	0.2415	0.2391
		180	210,376.7	2,934.7	22.645	31.842	0	0.2514	0.2457
		270	201,237.2	8,546.5	21.661	8.349	23.067	0.2415	0.2391
	45	0	192,097.8	5,740.6	20.677	39.94	10.956	0.3117	0.3188
		90	192,097.8	5,740.6	20.677	39.94	10.956	0.3117	0.3188
		180	210,376.7	5,740.6	22.645	40.698	10.956	0.3265	0.3314
		270	210,376.7	5,740.6	22.645	40.698	10.956	0.3265	0.3314
	56	0	192,097.8	6,791.7	20.677	37.882	15.197	0.3196	0.3282
		90	192,097.8	4,689.5	20.677	38.59	7.078	0.2920	0.2962
		180	210,376.7	6,791.7	22.645	38.64	15.197	0.3344	0.3409
		270	210,376.7	4,689.5	22.645	39.348	7.078	0.3068	0.3088

Leg Calculations (AISC manual ninth edition)

Axial end load, P_1 (Based on vessel total bending moment acting at leg attachment elevation)

$$\begin{aligned}
 P_1 &= W_1 / N + 4 * M_1 / (N * D) \\
 &= 804,948.88 / 4 + 4 * 1e3 * 36,442.7 / (4 * 3,987.4) \\
 &= \underline{210,376.67 \text{ N}}
 \end{aligned}$$

Allowable axial compressive stress, F_a (AISC chapter E)

$$\begin{aligned}
 C_c &= \text{Sqr}(2 * \pi^2 * E / F_y) \\
 &= \text{Sqr}(2 * \pi^2 * 199,948 / 350) \\
 &= 106.1914
 \end{aligned}$$

$$K * l / r = 1.2 * 2,410.9 / 64.69 = 44.7234$$

$$\begin{aligned}
 F_a &= 1 * (1 - (K * l / r)^2 / (2 * C_c^2)) * F_y / (5 / 3 + 3 * (K * l / r) / (8 * C_c) - (K * l / r)^3 / (8 * C_c^3)) \\
 &= 1 * (1 - (44.7234)^2 / (2 * 106.1914^2)) * 350 / (5 / 3 + 3 * (44.7234) / (8 * 106.1914) - (44.7234)^3 / (8 * 106.1914^3)) \\
 &= 175.71 \text{ MPa}
 \end{aligned}$$

Allowable axial compression and bending (AISC chapter H)

$$\begin{aligned}
 F'_{ox} &= 1 * 12 * \pi^2 * E / (23 * (K * l / r)^2) \\
 &= 1 * 12 * \pi^2 * 199,948 / (23 * (44.7234)^2) \\
 &= 514.756 \text{ MPa}
 \end{aligned}$$

$$\begin{aligned}
 F'_{oy} &= 1 * 12 * \pi^2 * E / (23 * (K * l / r)^2) \\
 &= 1 * 12 * \pi^2 * 199,948 / (23 * (26.2074)^2) \\
 &= 1,499.074 \text{ MPa}
 \end{aligned}$$

$$\begin{aligned}
 F_b &= 1 * 0.66 * F_y \\
 &= 1 * 0.66 * 350 \\
 &= 231 \text{ MPa}
 \end{aligned}$$

Compressive axial stress

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$$\begin{aligned}
 f_a &= P_1 / A \\
 &= 210,376.67 / 9,290.3038 \\
 &= \underline{22.645 \text{ MPa}}
 \end{aligned}$$

Bending stresses

$$\begin{aligned}
 f_{bx} &= F \cos(\alpha) * L / (I_x / C_x) + P_1 * E_{cc} / (I_x / C_x) \\
 &= 6,791.73 * \cos(56) * 2,410.9 / (1e4 * 3,887.6013 / 127) + 210,376.67 * 12.7 / (1e4 * 3,887.6013 / 127) \\
 &= \underline{38.64 \text{ MPa}}
 \end{aligned}$$

$$\begin{aligned}
 f_{by} &= F \sin(\alpha) * L / (I_y / C_y) \\
 &= 6,791.73 * \sin(56) * 2,410.9 / (1e4 * 11,321.49 / 126.75) \\
 &= \underline{15.197 \text{ MPa}}
 \end{aligned}$$

AISC equation H₁₋₁

$$\begin{aligned}
 H_{1-1} &= f_a / F_a + C_{mx} * f_{bx} / ((1 - f_a / F'_{ex}) * F_{bx}) + C_{my} * f_{by} / ((1 - f_a / F'_{ey}) * F_{by}) \\
 &= 22.645 / 175.71 + 0.85 * 38.64 / ((1 - 22.645 / 514.756) * 231) + 0.85 * 15.197 / ((1 - 22.645 / 1,499.074) * 231) \\
 &= \underline{0.3344}
 \end{aligned}$$

AISC equation H₁₋₂

$$\begin{aligned}
 H_{1-2} &= f_a / (0.6 * F_y) + f_{bx} / F_{bx} + f_{by} / F_{by} \\
 &= 22.645 / (0.6 * 350) + 38.64 / 231 + 15.197 / 231 \\
 &= \underline{0.3409}
 \end{aligned}$$

4, W 10x49 legs are adequate.

Anchor bolts - Seismic empty corroded condition governs

Tensile loading per leg (2 bolts per leg)

$$\begin{aligned}
 R &= 4 * M / (N * BC) - W / N \\
 &= 4 * 37,983.3 / (4 * 3,7816) - 257,033 / 4 \\
 &= -54,214 \text{ N}
 \end{aligned}$$

There is no net uplift (R is negative).

1 inch coarse threaded bolts are satisfactory.

Check the leg to pad fillet weld, Bednar 10.3, Seismic operating new governs

Note: continuous welding is assumed for all support leg fillet welds.

The following leg attachment weld analysis assumes the fillet weld is present on three sides (leg top closure plate is used).

$$\begin{aligned}
 Z_w &= (2 * b * d + d^2) / 3 \\
 &= (2 * 25.3492 * 11.81 + 11.81^2) / 3 \\
 &= 246.0747 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 J_w &= (b + 2 * d)^3 / 12 - d^2 * (b + d)^2 / (b + 2 * d) \\
 &= (25.3492 + 2 * 11.81)^3 / 12 - 11.81^2 * (25.3492 + 11.81)^2 / (25.3492 + 2 * 11.81) \\
 &= 5,852.7376 \text{ cm}^3
 \end{aligned}$$

$$\begin{aligned}
 E &= d^2 / (b + 2*d) \\
 &= 118.1^2 / (253.49 + 2*118.1) \\
 &= 28.48 \text{ mm}
 \end{aligned}$$

$$\text{Governing weld load } f_x = \cos(56) * 6,791.73 = 3,797.89 \text{ N}$$

$$\text{Governing weld load } f_y = \sin(56) * 6,791.73 = 5,630.6 \text{ N}$$

$$\begin{aligned}
 f_1 &= P_1 / L_{\text{weld}} \\
 &= 210,376.67 / 48.9692 \\
 &= 4,296.1 \text{ N/cm } (V_L \text{ direct shear})
 \end{aligned}$$

$$\begin{aligned}
 f_2 &= f_y * L_{\text{leg}} * 0.5 * b / J_w \\
 &= 5,630.6 * 241.09 * 0.5 * 25.3492 / 5,852.7376 \\
 &= 2,939.74 \text{ N/cm } (V_L \text{ torsion shear})
 \end{aligned}$$

$$\begin{aligned}
 f_3 &= f_y / L_{\text{weld}} \\
 &= 5,630.6 / 48.9692 \\
 &= 114.98 \text{ N/cm } (V_e \text{ direct shear})
 \end{aligned}$$

$$\begin{aligned}
 f_4 &= f_y * L_{\text{leg}} * E / J_w \\
 &= 5,630.6 * 241.09 * 2.8482 / 5,852.7376 \\
 &= 660.62 \text{ N/cm } (V_e \text{ torsion shear})
 \end{aligned}$$

$$\begin{aligned}
 f_5 &= (f_x * L_{\text{leg}} + P_1 * E_{cc}) / Z_w \\
 &= (3,797.89 * 241.09 + 210,376.67 * 1.27) / 246.0747 \\
 &= 4,806.71 \text{ N/cm } (M_L \text{ bending})
 \end{aligned}$$

$$\begin{aligned}
 f_6 &= f_x / L_{\text{weld}} \\
 &= 3,797.89 / 48.9692 \\
 &= 77.56 \text{ N/cm } (\text{Direct outward radial shear})
 \end{aligned}$$

$$\begin{aligned}
 f &= \text{Sqr}((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2) \\
 &= \text{Sqr}((4,296.1 + 2,939.74)^2 + (114.98 + 660.62)^2 + (4,806.71 + 77.56)^2) \\
 &= 8,764.42 \text{ N/cm } (\text{Resultant shear load})
 \end{aligned}$$

Required leg to pad fillet weld leg size (welded both sides + top)

$$\begin{aligned}
 t_w &= f / (0.707 * 0.55 * S_a) \\
 &= 876.44 / (0.707 * 0.55 * 138) \\
 &= \underline{16.33} \text{ mm}
 \end{aligned}$$

The 17 mm leg to pad attachment fillet weld size is adequate.

Check the pad to vessel fillet weld, Bednar 10.3, Seismic operating new governs

$$\begin{aligned}
 Z_w &= b*d + d^2 / 3 \\
 &= 356 * 460 + 460^2 / 3 \\
 &= 234,293.3 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 J_w &= (b + d)^3 / 6 \\
 &= (35.6 + 46)^3 / 6 \\
 &= 90,556.42 \text{ cm}^3
 \end{aligned}$$

$$\begin{aligned}
 f_1 &= P_1 / L_{\text{weld}} \\
 &= 210,376.67 / 163.2
 \end{aligned}$$

$$= 1,289.07 \text{ N/cm } (V_L \text{ direct shear})$$

$$\begin{aligned} f_2 &= f_y * L_{leg} * 0.5 * b / J_w \\ &= 5,630.6 * 2,410.9 * 0.5 * 356 / 9,055,641.6 \\ &= 266.83 \text{ N/cm } (V_L \text{ torsion shear}) \end{aligned}$$

$$\begin{aligned} f_3 &= f_y / L_{weld} \\ &= 5,630.6 / 163.2 \\ &= 34.5 \text{ N/cm } (V_o \text{ direct shear}) \end{aligned}$$

$$\begin{aligned} f_4 &= f_y * L_{leg} * 0.5 * d / J_w \\ &= 5,630.6 * 2,410.9 * 0.5 * 460 / 9,055,641.6 \\ &= 344.78 \text{ N/cm } (V_o \text{ torsion shear}) \end{aligned}$$

$$\begin{aligned} f_5 &= (f_x * L_{leg} + P_1 * E_{cc}) / Z_w \\ &= (3,797.89 * 241.09 + 210,376.67 * 12.7) / 2,342.9333 \\ &= 504.84 \text{ N/cm } (M_L \text{ bending}) \end{aligned}$$

$$\begin{aligned} f_6 &= f_x / L_{weld} \\ &= 3,797.89 / 163.2 \\ &= 23.27 \text{ N/cm } (\text{Direct outward radial shear}) \end{aligned}$$

$$\begin{aligned} f &= \text{Sqr}((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2) \\ &= \text{Sqr}((1,289.07 + 266.83)^2 + (34.5 + 344.78)^2 + (504.84 + 23.27)^2) \\ &= 1,686.29 \text{ N/cm } (\text{Resultant shear load}) \end{aligned}$$

Required pad to vessel fillet weld leg size (welded all around the pad edge)

$$\begin{aligned} t_w &= f / (0.707 * 0.55 * S_a) \\ &= 168.63 / (0.707 * 0.55 * 138) \\ &= \underline{3.14} \text{ mm} \end{aligned}$$

9.5 mm pad to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$$\begin{aligned} f_p &= P / (B * N) \\ &= 227,452.37 / (330 * 330) \\ &= 2.089 \text{ MPa} \end{aligned}$$

$$\begin{aligned} m &= (N - 0.95 * d) / 2 \\ &= (330 - 0.95 * 253.49) / 2 \\ &= 44.59 \text{ mm} \end{aligned}$$

$$\begin{aligned} n &= (B - 0.8 * b) / 2 \\ &= (330 - 0.8 * 254) / 2 \\ &= 63.4 \text{ mm} \end{aligned}$$

$$\begin{aligned} L &= 0.5 * (d + b) / 2 - \text{Sqr}((0.5 * (d + b))^2 / 4 - P / (4 * F_p)) \\ &= 0.5 * (253.49 + 254) / 2 - \text{Sqr}((0.5 * (253.49 + 254))^2 / 4 - 227,452.37 / (4 * 5.171)) \\ &= 55.46 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_b &= \text{Largest}(m, n, L) * \text{Sqr}(3 * f_p / S_b) \\ &= 63.4 * \text{Sqr}(3 * 2.089 / 165.474) \\ &= \underline{12.34} \text{ mm} \end{aligned}$$

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The base plate thickness is adequate.

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Check the leg to vessel attachment stresses, WRC-107 (Seismic operating corroded governs)

Applied Loads

Radial load: $P_r = -4,042.08$ N
 Circumferential moment: $M_c = 0$ N-m
 Circumferential shear: $V_c = 0$ N
 Longitudinal moment: $M_L = 12,367$ N-m
 Longitudinal shear: $V_L = 206,452.07$ N
 Torsion moment: $M_t = 0$ N-m
 Internal pressure: $P = 1,079.65$ kPa
 Mean shell radius: $R_m = 1,974.68$ mm
 Local shell thickness: $t = 15.85$ mm
 Shell yield stress: $S_y = 236$ MPa

Maximum stresses due to the applied loads at the pad edge (includes pressure)

$$R_m / t = 1,974.68 / 15.85 = 124.5883$$

$$C_1 = 178, C_2 = 365.1 \text{ mm}$$

$$\text{Local circumferential pressure stress} = P \cdot R_i / t = 133.972 \text{ MPa}$$

$$\text{Local longitudinal pressure stress} = P \cdot R_i / (2 \cdot t) = 66.989 \text{ MPa}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 179.38 \text{ MPa}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = \pm 3 \cdot S = \pm 414 \text{ MPa}$$

The maximum combined stress ($P_L + P_b + Q$) is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 148.04 \text{ MPa}$$

$$\text{Allowable local primary membrane stress } (P_L) = \pm 1.5 \cdot S = \pm 207 \text{ MPa}$$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the pad edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	6.923	0.1714	0	0	0	0	0.896	0.896	0.896	0.896
4C*	15.3881	0.1467	1.986	1.986	1.986	1.986	0	0	0	0
1C	0.0733	0.1185	0	0	0	0	7.074	-7.074	7.074	-7.074
2C-1	0.04	0.1185	3.861	-3.861	3.861	-3.861	0	0	0	0
3A*	4.8662	0.1145	0	0	0	0	0	0	0	0
1A	0.0749	0.1192	0	0	0	0	0	0	0	0
3B*	10.9883	0.1455	-12.087	-12.087	12.087	12.087	0	0	0	0
1B-1	0.0234	0.1274	-27.476	27.476	27.476	-27.476	0	0	0	0
Pressure stress*			133.972	133.972	133.972	133.972	133.972	133.972	133.972	133.972
Total circumferential stress			100.257	147.486	179.381	116.708	141.942	127.794	141.942	127.794
Primary membrane circumferential stress*			123.871	123.871	148.044	148.044	134.868	134.868	134.868	134.868
3C*	8.4277	0.1467	1.089	1.089	1.089	1.089	0	0	0	0
4C*	14.0988	0.1714	0	0	0	0	1.82	1.82	1.82	1.82
1C-1	0.0544	0.1512	5.254	-5.254	5.254	-5.254	0	0	0	0
2C	0.036	0.1512	0	0	0	0	3.475	-3.475	3.475	-3.475
4A*	9.331	0.1145	0	0	0	0	0	0	0	0
2A	0.0319	0.1436	0	0	0	0	0	0	0	0
4B*	4.5615	0.1455	-7.467	-7.467	7.467	7.467	0	0	0	0
2B-1	0.0231	0.153	-22.587	22.587	22.587	-22.587	0	0	0	0
Pressure stress*			66.989	66.989	66.989	66.989	66.989	66.989	66.989	66.989
Total longitudinal stress			43.278	77.945	103.387	47.705	72.285	65.335	72.285	65.335
Primary membrane longitudinal stress*			60.612	60.612	75.546	75.546	68.81	68.81	68.81	68.81
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	-8.922	-8.922	8.922	8.922
Total Shear stress			0	0	0	0	-8.922	-8.922	8.922	8.922
Combined stress (P_L+P_b+Q)			100.257	147.486	179.381	116.708	143.066	129.042	143.066	129.042

Note: * denotes primary stress.

Maximum stresses due to the applied loads at the leg edge (includes pressure)

$$R_m / t = 1,974.68 / 28.55 = 69.1665$$

$$C_1 = 126.75, C_2 = 93.74 \text{ mm}$$

$$\text{Local circumferential pressure stress} = P \cdot R_i / t = 133.972 \text{ MPa}$$

$$\text{Local longitudinal pressure stress} = P \cdot R_i / (2 \cdot t) = 66.989 \text{ MPa}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 194.79 \text{ MPa}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = +3 \cdot S = +414 \text{ MPa}$$

The maximum combined stress ($P_L + P_b + Q$) is within allowable limits.

Maximum local primary membrane stress (P_L) = 145.24 MPa

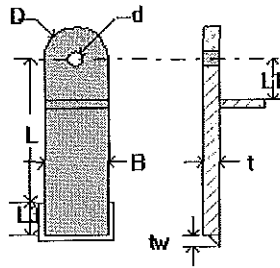
Allowable local primary membrane stress (P_L) = $\pm 1.5 \cdot S = \pm 207$ MPa

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the leg edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	12.2189	0.0546	0	0	0	0	0.876	0.876	0.876	0.876
4C*	12.278	0.0596	0.883	0.883	0.883	0.883	0	0	0	0
1C	0.1509	0.0601	0	0	0	0	4.488	-4.488	4.488	-4.488
2C-1	0.1133	0.0601	3.372	-3.372	3.372	-3.372	0	0	0	0
3A*	1.6404	0.058	0	0	0	0	0	0	0	0
1A	0.0988	0.0646	0	0	0	0	0	0	0	0
3B*	5.3396	0.0525	-10.384	-10.384	10.384	10.384	0	0	0	0
1B-1	0.0542	0.0541	-46.181	46.181	46.181	-46.181	0	0	0	0
Pressure stress*			133.972	133.972	133.972	133.972	133.972	133.972	133.972	133.972
Total circumferential stress			81.662	167.281	194.791	95.685	139.336	130.359	139.336	130.359
Primary membrane circumferential stress*			124.471	124.471	145.238	145.238	134.848	134.848	134.848	134.848
3C*	11.8358	0.0596	0.848	0.848	0.848	0.848	0	0	0	0
4C*	12.3682	0.0546	0	0	0	0	0.889	0.889	0.889	0.889
1C-1	0.1565	0.0565	4.654	-4.654	4.654	-4.654	0	0	0	0
2C	0.118	0.0565	0	0	0	0	3.509	-3.509	3.509	-3.509
4A*	2.2612	0.058	0	0	0	0	0	0	0	0
2A	0.0576	0.0618	0	0	0	0	0	0	0	0
4B*	1.4808	0.0525	-2.579	-2.579	2.579	2.579	0	0	0	0
2B-1	0.09	0.0548	-75.746	75.746	75.746	-75.746	0	0	0	0
Pressure stress*			66.989	66.989	66.989	66.989	66.989	66.989	66.989	66.989
Total longitudinal stress			-5.833	136.351	150.816	-9.984	71.388	64.369	71.388	64.369
Primary membrane longitudinal stress*			65.259	65.259	70.416	70.416	67.879	67.879	67.879	67.879
Shear from M_l			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	-19.285	-19.285	19.285	19.285
Total Shear stress			0	0	0	0	-19.285	-19.285	19.285	19.285
Combined stress (P_L+P_b+Q)			-87.494	167.281	194.791	-105.669	144.424	135.579	144.424	135.579

Note: * denotes primary stress.

LIFTING LUG



Geometry Inputs

Attached To	3962 mm O.D. SHELL
Material	A516-70
Distance of Lift Point From Datum	3,036 mm
Angular Position	90.00° and 270.00°
Length of Lug, L	547 mm
Width of Lug, B	254 mm
Thickness of Lug, t	32 mm
Hole Diameter, d	57 mm
Pin Diameter, D_p	50.8 mm
Lug Diameter at Pin, D	254 mm
Weld Size, t_w	22 mm
Weld Length, L_3	152 mm
Length to Brace Plate, L_1	165 mm
Load Angle from Vertical, ϕ	0.0000 °
Has Brace Plate	Yes

Intermediate Values

Load Factor	2.0000
Vessel Weight (new, incl. Load Factor), W	51974 kg
Lug Weight (new), W_{lug}	103 kg (Qty=2)
Distance from Center of Gravity to Top Lug, l_1	2,399.53 mm
Distance from Center of Gravity to Tail Lug, l_2	830.41 mm
Distance from Vessel Center Line to Tail Lug, l_3	1,575.76 mm
Allowable Stress, Tensile, σ_t	157.200 MPa
Allowable Stress, Shear, σ_s	104.800 MPa
Allowable Stress, Bearing, σ_p	235.801 MPa
Allowable Stress, Bending, σ_b	172.921 MPa
Allowable Stress, Weld Shear, $\tau_{allowable}$	104.800 MPa
Allowable Stress set to 1/3 Sy per ASME B30.20	No

Summary Values

Required Lift Pin Diameter, d_{reqd}	<u>39.35 mm</u>
Required Lug Thickness, t_{reqd}	<u>21.28 mm</u>
Lug Stress Ratio, σ_{ratio}	<u>0.91</u>
Weld Shear Stress Ratio, τ_{ratio}	<u>0.95</u>
Lug Design	Acceptable
Local Stresses	Acceptable
Maximum Out of Plane Lift Angle - Weak Axis Bending	10.11°

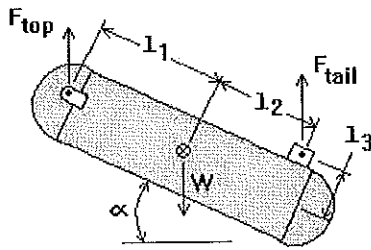
COMPRESS recommends a spreader beam be used to prevent weak axis bending of the top lugs. No consideration is given for any bracing plate from the lug to the vessel.

Lift Forces

Lift force on lugs during rotational lift ($0^\circ \leq \alpha \leq 90^\circ$):

$$2 * F_{top} = W * (l_2 * \cos(\alpha) + l_3 * \sin(\alpha)) / (l_1 * \cos(\alpha) + l_2 * \cos(\alpha) + l_3 * \sin(\alpha))$$

$$F_{tail} = W - (2 * F)$$



α [°]	F_{top} [N]	F_{tail} [N]
0	65,520.3	378,652.7
15	87,407.3	334,878.7
30	107,128.8	295,435.7
45	127,599.3	254,494.6
60	152,229.4	205,234.5
75	187,728.9	134,235.5
90	254,846.6	0
38 ¹	117,771.7	274,149.9
38 ²	117,771.7	274,149.9
¹ Lift angle at maximum lug stress.		
² Lift angle at maximum weld stress.		
Shell angle at lift lug	0.00°	

Lug Pin Diameter - Shear stress

$$d_{reqd} = (2 \cdot F_v / (\pi \cdot \sigma_s))^{0.5}$$

$$= (2 \cdot 254,846.6 / (\pi \cdot 104.8))^{0.5} = \underline{39.35 \text{ mm}}$$

$$d_{reqd} / D_p = 39.35 / 50.8 = 0.77 \quad \text{Acceptable}$$

$$\sigma = F_v / A$$

$$= F_v / (2 \cdot (0.25 \cdot \pi \cdot D_p^2))$$

$$= 254,846.6 / (2 \cdot (0.25 \cdot \pi \cdot 50.8^2)) = 62.87 \text{ MPa}$$

$$\sigma / \sigma_s = 62.87 / 104.8 = 0.6 \quad \text{Acceptable}$$

Lug Thickness - Tensile stress

$$t_{reqd} = F_v / ((D - d) \cdot \sigma_t)$$

$$= 254,846.6 / ((254 - 57) \cdot 157.2) = 8.23 \text{ mm}$$

$$t_{reqd} / t = 8.23 / 32 = 0.26 \quad \text{Acceptable}$$

$$\sigma = F_v / A$$

$$\begin{aligned}
 &= F_v / ((D - d) * t) \\
 &= 254,846.6 / ((254 - 57) * 32) = 40.43 \text{ MPa}
 \end{aligned}$$

$$\sigma / \sigma_t = 40.43 / 157.2 = 0.26 \quad \text{Acceptable}$$

Lug Thickness - Bearing stress

$$\begin{aligned}
 t_{\text{reqd}} &= F_v / (D_p * \sigma_p) \\
 &= 254,846.6 / (50.8 * 235.8) = \underline{21.28 \text{ mm}}
 \end{aligned}$$

$$t_{\text{reqd}} / t = 21.28 / 32 = 0.66 \quad \text{Acceptable}$$

$$\begin{aligned}
 \sigma &= F_v / A_{\text{bearing}} \\
 &= F_v / (D_p * t) \\
 &= 254,846.6 / (50.8 * (32)) = 156.77 \text{ MPa}
 \end{aligned}$$

$$\sigma / \sigma_p = 156.77 / 235.8 = 0.66 \quad \text{Acceptable}$$

Lug Thickness - Shear stress

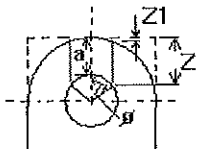
$$\begin{aligned}
 t_{\text{reqd}} &= [F_v / \sigma_s] / (2 * L_{\text{shear}}) \\
 &= (254,846.6 / 104.8) / (2 * 105.79) = \underline{11.49 \text{ mm}}
 \end{aligned}$$

$$t_{\text{reqd}} / t = 11.49 / 32 = 0.36 \quad \text{Acceptable}$$

$$\begin{aligned}
 \tau &= F_v / A_{\text{shear}} \\
 &= F_v / (2 * t * L_{\text{shear}}) \\
 &= 254,846.6 / (2 * 32 * 105.79) = 37.64 \text{ MPa}
 \end{aligned}$$

$$\tau / \sigma_s = 37.64 / 104.8 = 0.36 \quad \text{Acceptable}$$

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



$$\begin{aligned}
 \phi &= 55 * D_p / d \\
 &= 55 * 50.8 / 57 \\
 &= 49.0175^\circ \\
 Z &= 0.5 * (D - d) + 0.5 * D_p * (1 - \cos(\phi)) \\
 &= 0.5 * (254 - 57) + 0.5 * 50.8 * (1 - \cos(49.0175)) \\
 &= 107.24 \text{ mm} \\
 Z1 &= 0.5 * D - \text{sqr}(0.25 * D * D - (0.5 * D_p * \sin(\phi))^2)
 \end{aligned}$$

$$\begin{aligned}
 &= 0.5 \cdot 254 - \sqrt{(0.25 \cdot 254 \cdot 254 - (0.5 \cdot 50.8 \cdot \sin(49.0175))^2)} \\
 &= 1.46 \text{ mm} \\
 L_{\text{shear}} &= Z - Z_1 \\
 &= 105.79 \text{ mm}
 \end{aligned}$$

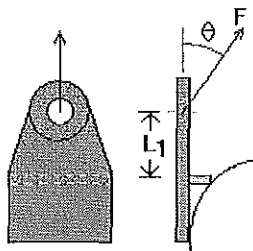
Lug Plate Stress

Lug stress, tensile + bending, during rotational lift:

$$\begin{aligned}
 \sigma_{\text{ratio}} &= [F_{\text{ten}} / (A_{\text{ten}} \cdot \sigma_t)] + [M_{\text{bend}} / (Z_{\text{bend}} \cdot \sigma_b)] \leq 1 \\
 &= [(F_{\text{top}}(\alpha) \cdot \sin(\alpha)) / (t \cdot B \cdot \sigma_t)] + [(6 \cdot F_{\text{top}}(\alpha) \cdot L \cdot \cos(\alpha)) / (t \cdot B^2 \cdot \sigma_b)] \leq 1 \\
 &= 117,771.7 \cdot \sin(38.0) / (32 \cdot 254 \cdot 157.2) + 6 \cdot (117,771.7) \cdot 547 \cdot \cos(38.0) / (32 \cdot 254^2 \cdot 172.92) \\
 &= \underline{0.91} \quad \text{Acceptable}
 \end{aligned}$$

Weak Axis Bending Stress

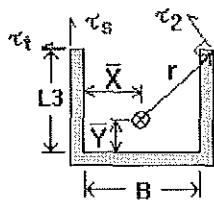
Maximum lift cable angle from vertical $\theta = 10.11^\circ$



$$\begin{aligned}
 \sigma_b &= M / Z &= (F \cdot \sin(\theta) \cdot L_1) / Z \\
 F \cdot \cos(\theta) &= 0.5 \cdot W &\Rightarrow F = 0.5 \cdot W / \cos(\theta) \\
 \theta &= \arctan((2 \cdot \sigma_b \cdot Z) / (W \cdot L_1)) \\
 \theta &= \arctan((2 \cdot 172.92 \cdot (254 \cdot 32^2 / 6)) / (509,693.3 \cdot 165)) &= 10.11^\circ
 \end{aligned}$$

Loading on brace plate and head are not considered.

Weld Stress



Weld stress, direct and torsional shear, during rotational lift:

Direct shear:

Maximum weld shear stress occurs at lift angle 38.00° ; lift force = 117,771.7 N

$$A_{\text{weld}} = 0.707 \cdot t_w \cdot (2 \cdot L_3 + B) \\ = 0.707 \cdot 22 \cdot (2 \cdot 152 + 254) = 8,679.13 \text{ mm}^2$$

$$\tau_t = F_r \cdot \cos(\alpha) / A_{\text{weld}} \\ = 117,771.7 \cdot \cos(38.0) / 8,679.13 = 10.69 \text{ MPa}$$

$$\tau_s = F_r \cdot \sin(\alpha) / A_{\text{weld}} \\ = 117,771.7 \cdot \sin(38.0) / 8,679.13 = 8.35 \text{ MPa}$$

Torsional shear:

Weld centroid:

$$Y_{\text{bar}} = L_3^2 / (2 \cdot L_3 + B) \\ = 152^2 / (2 \cdot 152 + 254) = 41.41 \text{ mm}$$

Second polar moment of area:

$$J = 0.707 \cdot t_w \cdot ((8 \cdot L_3^3 + 6 \cdot L_3 \cdot B^2 + B^3) / 12 - L_3^4 / (2 \cdot L_3 + B)) \\ = 0.707 \cdot 22 \cdot ((8 \cdot 152^3 + 6 \cdot 152 \cdot 254^2 + 254^3) / 12 - 152^4 / (2 \cdot 152 + 254)) = 119040808 \text{ mm}^4$$

Radial distance from centroid to weld:

$$r = \text{sqr}((X_{\text{bar}})^2 + (L_3 - Y_{\text{bar}})^2) \\ = \text{sqr}((0.5 \cdot 254)^2 + (152 - 41.41)^2) = 168.41 \text{ mm}$$

$$\theta_r = \arctan((L_3 - Y_{\text{bar}}) / (X_{\text{bar}})) \\ = \arctan(110.59 / 127) = 41.05^\circ$$

$$\tau_2 = M \cdot r / J \\ = [F(\alpha) \cdot \cos(\alpha) \cdot (L + L_3 - Y_{\text{bar}})] \cdot r / J \\ = (117,771.7 \cdot \cos(38.0) \cdot 657.59) \cdot 168.41 / 119040804.1994 \\ = 86.34 \text{ MPa}$$

$$\tau_{\text{ratio}} = \text{sqr}((\tau_t + \tau_2 \cdot \sin(\theta_r))^2 + (\tau_s + \tau_2 \cdot \cos(\theta_r))^2) / \tau_{\text{allowable}} \leq 1 \\ = \text{sqr}((10.69 + 86.34 \cdot \sin(41.05))^2 + (8.35 + 86.34 \cdot \cos(41.05))^2) / 104.8 \\ = \underline{0.95} \quad \text{Acceptable}$$

WRC 107 Analysis

Geometry

Height(radial):	32 mm
Width (circumferential):	254 mm
Length	152 mm
Fillet Weld Size:	22 mm
Located on:	3962 mm O.D. SHELL (152 mm from top end)
Location Angle:	90.00° and 270.00°

Applied Loads

Maximum stress ratio occurs at lift angle = 90.00° with lift force = 254,846.6 N

Radial load:	$P_r = 0$	N
Circumferential moment:	$M_c = 0$	N-m
Circumferential shear:	$V_c = 0$	N
Longitudinal moment:	$M_L = 4,077.55$	N-m
Longitudinal shear:	$V_L = 254,846.63$	N
Torsion moment:	$M_t = 0$	N-m
Internal pressure:	$P = 0$	kPa
Mean shell radius:	$R_m = 1,971.48$	mm
Shell yield stress:	$S_y = 262$	MPa

Maximum stresses due to the applied loads at the lug edge (includes pressure)

$$R_m / t = 1,971.48 / 19.05 = 103.4895$$

$$C_1 = 149, C_2 = 98 \text{ mm}$$

$$\text{Local circumferential pressure stress} = P \cdot R_i / t = 0 \text{ MPa}$$

$$\text{Local longitudinal pressure stress} = P \cdot R_i / (2 \cdot t) = 0 \text{ MPa}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 68.26 \text{ MPa}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = \pm 3 \cdot S = \pm 414 \text{ MPa}$$

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = -8.73 \text{ MPa}$$

$$\text{Allowable local primary membrane stress } (P_L) = \pm 1.5 \cdot S = \pm 207 \text{ MPa}$$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	16.8522	0.0603	0	0	0	0	0	0	0	0
4C*	17.4561	0.0685	0	0	0	0	0	0	0	0
1C	0.117	0.0694	0	0	0	0	0	0	0	0
2C-1	0.0801	0.0694	0	0	0	0	0	0	0	0
3A*	3.2011	0.0657	0	0	0	0	0	0	0	0
1A	0.0913	0.0713	0	0	0	0	0	0	0	0
3B*	9.5855	0.0572	-8.729	-8.729	8.729	8.729	0	0	0	0
1B-1	0.0476	0.0591	-27.531	27.531	27.531	-27.531	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			-36.26	18.802	36.26	-18.802	0	0	0	0
Primary membrane circumferential stress*			-8.729	-8.729	8.729	8.729	0	0	0	0
3C*	15.6668	0.0685	0	0	0	0	0	0	0	0
4C*	17.8502	0.0603	0	0	0	0	0	0	0	0
1C-1	0.1291	0.0634	0	0	0	0	0	0	0	0
2C	0.089	0.0634	0	0	0	0	0	0	0	0
4A*	4.652	0.0657	0	0	0	0	0	0	0	0
2A	0.0535	0.0671	0	0	0	0	0	0	0	0
4B*	2.831	0.0572	-2.062	-2.062	2.062	2.062	0	0	0	0
2B-1	0.0763	0.0588	-44.361	44.361	44.361	-44.361	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			-46.422	42.299	46.422	-42.299	0	0	0	0
Primary membrane longitudinal stress*			-2.062	-2.062	2.062	2.062	0	0	0	0
Shear from M_l			0	0	0	0	0	0	0	0
Circ shear from V_o			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	-34.129	-34.129	34.129	34.129
Total Shear stress			0	0	0	0	-34.129	-34.129	34.129	34.129
Combined stress (P_L+P_b+Q)			-46.422	42.299	46.422	-42.299	68.258	68.258	68.258	68.258

Note: * denotes primary stress.

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Stress Analysis due to Nozzle Loads

Not Applicable

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Foundation Load Calculations

Not Applicable

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

Lifting Device


See ASME Design Calculation

5

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

PSV/PRV Sizing Calculation

Note: PRV is not within Ecodyne scope of supply.

				TITLE Pressure Relief Valve Sizing Basis			CUSTOMER MEG Energy Corporation c/o SNC Lavalin Christina Lake Phase 3A PO No. P-5675-02		
					SCALE -			ECODYNE Limited  A Maxmon Water/Berkshire Hathaway Company <small>THIS DRAWING IS THE PROPERTY OF ECODYNE LIMITED. IT IS NOT TO BE USED FOR ANY PURPOSES DETRIMENTAL TO THE INTEREST OF THIS COMPANY AND IS SUBJECT TO RETURN UPON REQUEST.</small>	
D	2013 June 24	REVISED PAGE 3	<i>SA</i>	AV					
C	2013 Apr 26	ADDED PAGE 3	SC	AV		BY	DATE		
B	2013 Mar 5	ADDED A FIRE CASE CONSIDERATION	AV	SC	DRN	AV	2013 Jan 17	DWG. NO.	REV.
A	2013 Jan 17	FIRST ISSUE	AV	SC	CHKD	SC	2013 Jan 17	32125-A-5021	D
REV	DATE	REMARKS	BY	CHKD	APPD	AV	2013 Jan 17		

Cover page

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64																			
65		MERB Energy, Chubb Lake - After PSV																	
66		Thermal relief Valve -				PSV													
67																			
68		Design Relief of water from shut-in vessel due to high volume emergency when relief is provided from enabling																	
69		Customer installation not including solar heat at 550 bar/300°C																	
70		Approx calculation																	
71																			
72		Q _{rel} , m ³ /min																	
73																			
74		Q _{rel} , m ³ /min																	
75		Water sp. Vol. m ³ /min																	
76		Water vol. m ³																	
77		Q _{rel} vessel vol. m ³																	
78		Water vol. exp. vessel vol. m ³																	
79		Water relief flow, m ³ /h																	
80		Water relief flow, m ³ /h																	
81		Water relief flow, m ³ /h																	
82		Water relief flow, m ³ /h																	
83		Water relief capacity specified, m ³ /h																	
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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	file 32125\	32125 PSVgas		5Mar-2013sc											
2															
3															
4															
5															
6															
7															
8															
9	Relief valve Tag.	:		By client											
10	Vessel name and Tag:			3A-F--208 A to G After Filters											
11				3A-V-211 A to F Primary and Pol WAC vessels					(identical dia and T/T)						
12															
13	Pressure relief for gas due to vessel engulfed in sustained fire per API 521, 2007, 5.15. 2.2.1														
14															
15		Q =		21,000 * F * A^0.82											
16															
17		Q=		Total heat absorbed to wetted surface, Btu/h											
18		A=		total wetted area, ft2											
19				Recognizing large vessels are less likely to be completely exposed to flame											
20		F=		Environmental factor. Bare vessel F=1. Insulation not fire proofed F= 1											
21															
22	Other basis: vessel location has good drainage fr point of view of fire protection.														
23				This is slightly less conservative than OHSA due to definition of A.											
24															
25	Calculation:														
26		input							Area, ft2						
27		Vessel dia, ft:					13		368.3	head surface					
28		Vessel length or straight side, ft:					8.33		340.2	vessel side surface					
29		Total surface area, ft2							708.5						
30															
31		Q=====		21000* A^0.82 =					4555273	btu/h					
32		PSV set P, psig							150		163.6	psia		856	btu/lb, latent heat
33		Relief press at 121% of Pset for fire, psig							181.5		195.1	psia		845	btu/lb, latent heat
34		Latent heat at relief press, btu/lb							845	btu/lb	380	F			
35															
36		Steam relief rate, lb/h							5390.9	lb/h					
37															
38		Estimated orifice, in2							H, 0.9127	in2, ASME calc					
39		Relief rate, lb/h								7220	lb/h at 10 % over P				
40										7900	lb/h at 21% over P				
41		Estimated size							1.5" x 3"	150# flg Inlet, Consolidated 1900 ser					
42															
43															
44															
45															
46															
47															
48															

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
49			If adequate drainage for fire fighting do not exist										25 Jun-2013sc updated to			
50			input						Area, ft2			add this basis				
51			Vessel dia, ft:				13		366.3	head -approx 1.25 * flat surface						
52			Vessel length or straight side, ft:				8.33		340.2	vessel side surface						
53			Total surface area, ft2						706.5							
54																
55			Q===== 34,500* A^0.82 =								7483662	btu/h				
56			PSV set P, psig						150		163.8	psia	856 btu/lb, latent heat			
57			Relief press at 121% of Pset for fire, psig						181.5		195.1	psia	845 btu/lb, latent heat			
58			Latent heat at relief press, btu/lb						845	btu/lb						
59																
60			Steam relief rate, lb/h						8856.4	lb/h						
61																
62			Estimated orifice, in2						J 1.496 in2	ASME calc						
63			Relief rate, lb/h							11800 lb/h at 10 % over P						
64										13000 lb/h at 21 % over P						
65			Estimated size						2" x 3" 150# flg inlet, consolidated 1900 ser							