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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

ECODYNE Limited
4475 Corporate Drive
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PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
REFERENCE: PO P-5675-02

MANUFACTURER'S DATA BOOK

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ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
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B56 - Traffic & Logistics

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ECODYNE Limited

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	AMABRASIVE	FERROUS
AMASTEEL GRIT	(SHOT / GRIT MIX)	

SECTION II — COMPOSITION / INGREDIENTS

Chemical Name	CAS Registry No	% Weight	ACGIH - TLV (mg/m^3)	OSHA - PEL (mg/m^3)
Iron - Fe	7439-89-6	>96		
Oxide fume as Fe			5	10
Carbon - C	7440-44-0	<1.2	none estab.	none estab.
Manganese - Mn	7439-96-5	<1.3		
Elemental, Inorganic Compounds as Mn			0.2	5 (ceiling)
Fume as Mn			none estab.	5 (ceiling)
Silicon - Si	7440-21-3	<1.2		
as total dust			10	15
Respirable fraction			none estab.	5
Chromium - Cr	7440-47-3	<0.25		
Elemental, Inorganic Compounds as Cr metal			0.5	1
Cr II compounds - as Cr			none estab.	0.5
Cr III compounds - as Cr			0.5	0.5
Cr VI compounds - water soluble			0.05	5 ug
Cr VI compounds - insoluble			0.01	5 ug
Chromic Acid and Chromates as CrO_3			none estab.	0.1 (ceiling)
Cr VI (hexavalent chromium) in product as shipped		Not detected	0.05 & 0.01	5 ug /2.5 action
Copper – Cu	7440-50-8	<0.25		
Fume			0.2	0.1
Dust & mists			1	1
Nickel - Ni	7440-02-0	<0.20		
Elemental metal			1.5	
Insoluble as Ni			0.1	1
Soluble compounds as Ni			0.2	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	Melting Point - 1371-1483 Degrees C
Specific Gravity (at 60 Degrees F) >7.6	Vapor Pressure - Not Applicable
% Volatile by Volume - Not Applicable	pH - Not Applicable
Appearance and Odor - Spherical - no odor	Percent Solid by Weight - 100%

SECTION IV — REACTIVITY DATA

Stability – Stable   Hazardous decomposition products – None   Hazardous Polymerization - will not occur

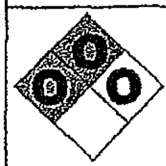
Shot will break down into progressively smaller particles and dust during normal use.

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.



NFPA Hazard Rating: 0 = Insignificant 1 = Slight 2 = Moderate 3 = High 4 = Extreme

Health (blue) = 0 Flammability (red) = 0 Reactivity (yellow) = 0 Special (colorless)

SECTION VI HEALTH HAZARD DATA

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.

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

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.

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.

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.

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

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Updated: Thursday, 04 October, 2001 03:28:38 PM

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 Miksic, President/CEO

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

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2

ECODYNE Limited

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:

TITLE

RUST PREVENTIVE SPEC, AFTER FILTERS

CUSTOMER

MEG Energy Corporation
c/o SNC-Lavalin
Christina Lake Phase 3A

PO No. P-5675-02

SCALE – N/A

ECODYNE Limited
A Marmon Water/Berkshire Hathaway Company

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REV	DATE	REMARKS	BY	CHKD
B	13 June 2013	ADDED CAT SHEETS	AV	[illegible]
A	APR 26 2013	FIRST ISSUE	AV	

	BY	DATE
DRN	AV	APR 26 2013
CHKD	[illegible]	13 June 2013
APPD	[illegible]	13 June 2013

DWG. NO. 32125-A-1023

REV. B

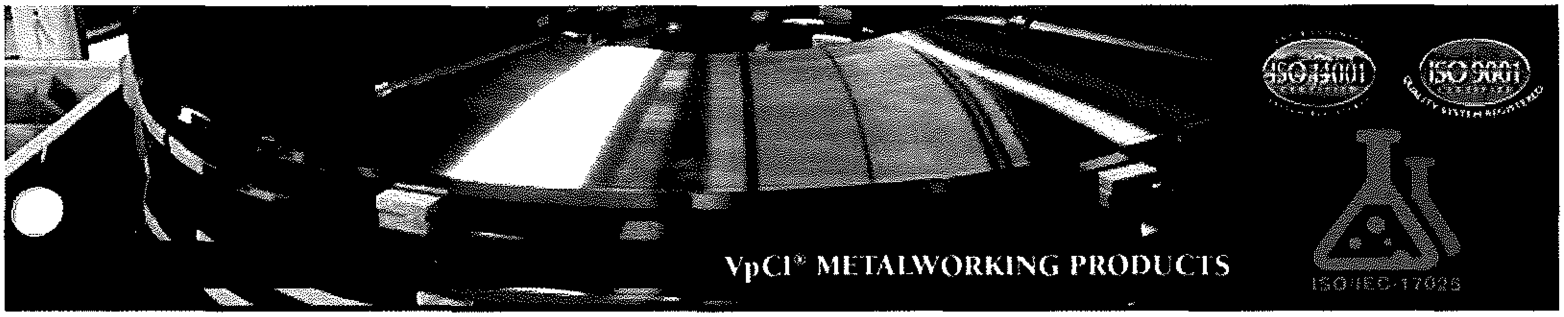
Rust Preventive Treatment

Vapour Phase Corrosion Inhibitors (VpCI):

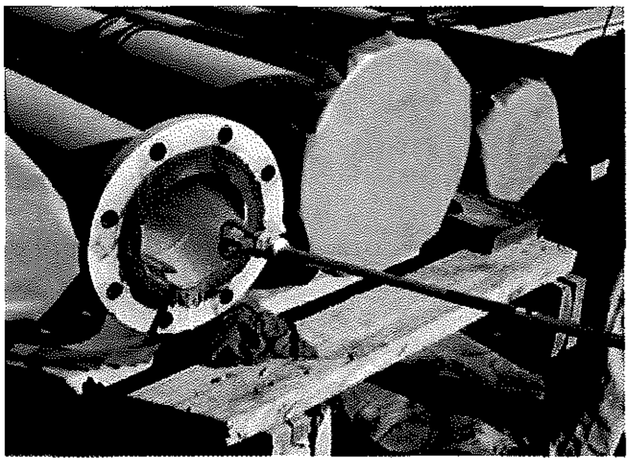
NOTE: Vapour Phase Corrosion Inhibitors (sometimes called Volatile Corrosion Inhibitors) protect metals against corrosion by chemically preventing the corrosion reaction from taking place. (Compared to barriers like paint, which prevent the corrosion causing chemicals from reaching the metal). Because 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®-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

<u>VpCI-337</u>

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)

<u>VpCI-337 Winterized</u>

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.

CORTEC CORPORATION

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./ft^3 (1 L/m^3) 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, 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.

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CORTEC CORPORATION
Environmentally Safe VpCI® MCI® Technologies

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ISO accreditation applies to Cortec's processes only.

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 ft²/gal @ 3 mils (7-8 m²/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.

CORTEC CORPORATION

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 ¼" 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.

CORTEC CORPORATION
Environmentally Safe VpCI®/MCI® Technologies

4119 White Bear Parkway, St. Paul, MN 55110 USA
Phone (651) 429-1100, Fax (651) 429-1122
Toll Free (800) 4-CORTEC, E-mail info@cortecvci.com
Internet http://www.cortecvci.com

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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	CUSTOMER
STORAGE & INSTALLATION INSTRUCTIONS ~~For~~ AFTER FILTERS AND WAC ~~VESSELS~~	MEG Energy Corporation c/o SNC Lavalin Christina Lake Phase 3A

REV	DATE	REMARKS	BY	CHKD		BY	DATE
					SCALE -		
					DRN	ELG	2014 Nov 18
A	2014 Nov 18	FIRST ISSUE	ELG	WKR	CHKD	WKR	2014 Nov 18
					APPD	ELG	2014 Nov 18

ECODYNE Limited

A Marmon Water/Berkshire Hathaway Company

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DWG. NO.	REV.
32125-A-5002	A

ECODYNE JOB NO. 12-32125
TABLE OF CONTENTS

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.

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).

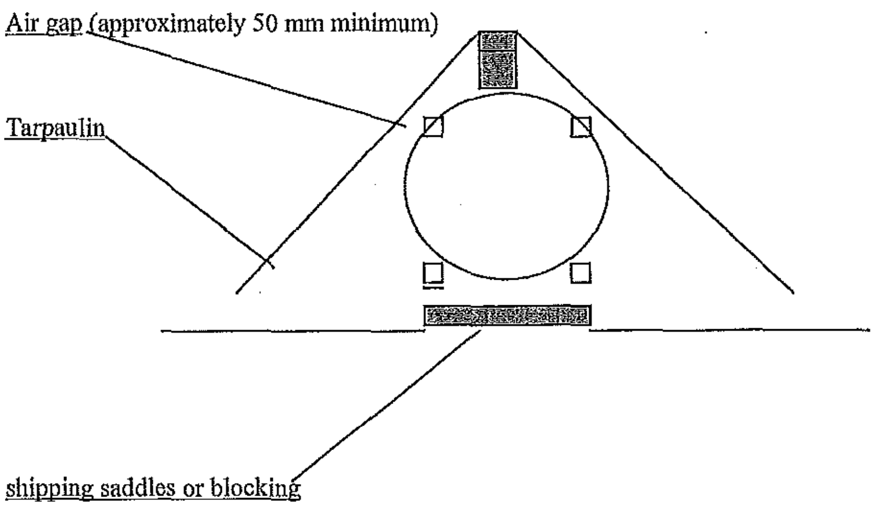
> Note: When lifting pressure vessels, tailing lug must be used to prevent any loading on the vessel legs until the vessel is in the vertical position. Also use spreader bar or long slings to avoid damage to lifting lugs. Refer to lifting diagrams, 32125-D-2201 and 32125-D-2202.

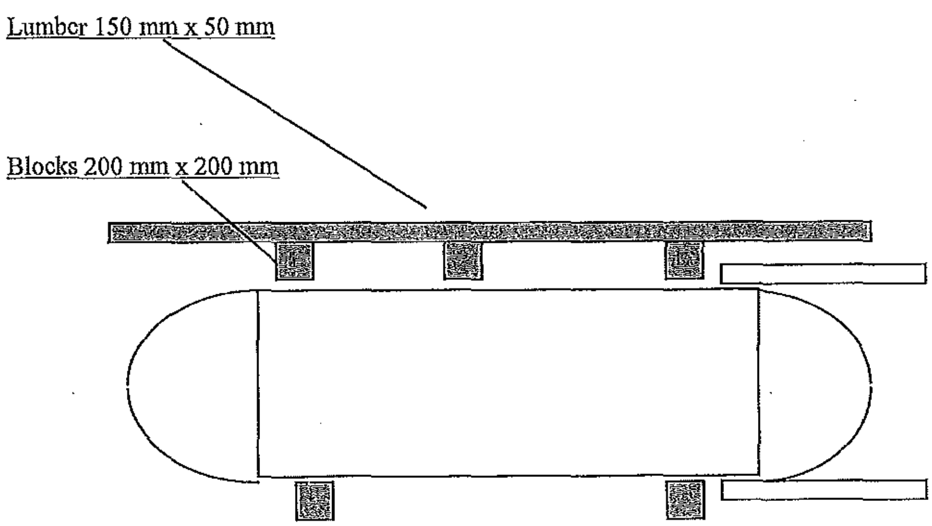
Long-Term Storage: Pressure Vessels

- 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 spacrk 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
½	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
¾	6	50	40	70	50
¾	8	80	60	90	70
7/8	10	80	60	90	70
7/8	12	110	80	130	100
¾	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 ¼	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.

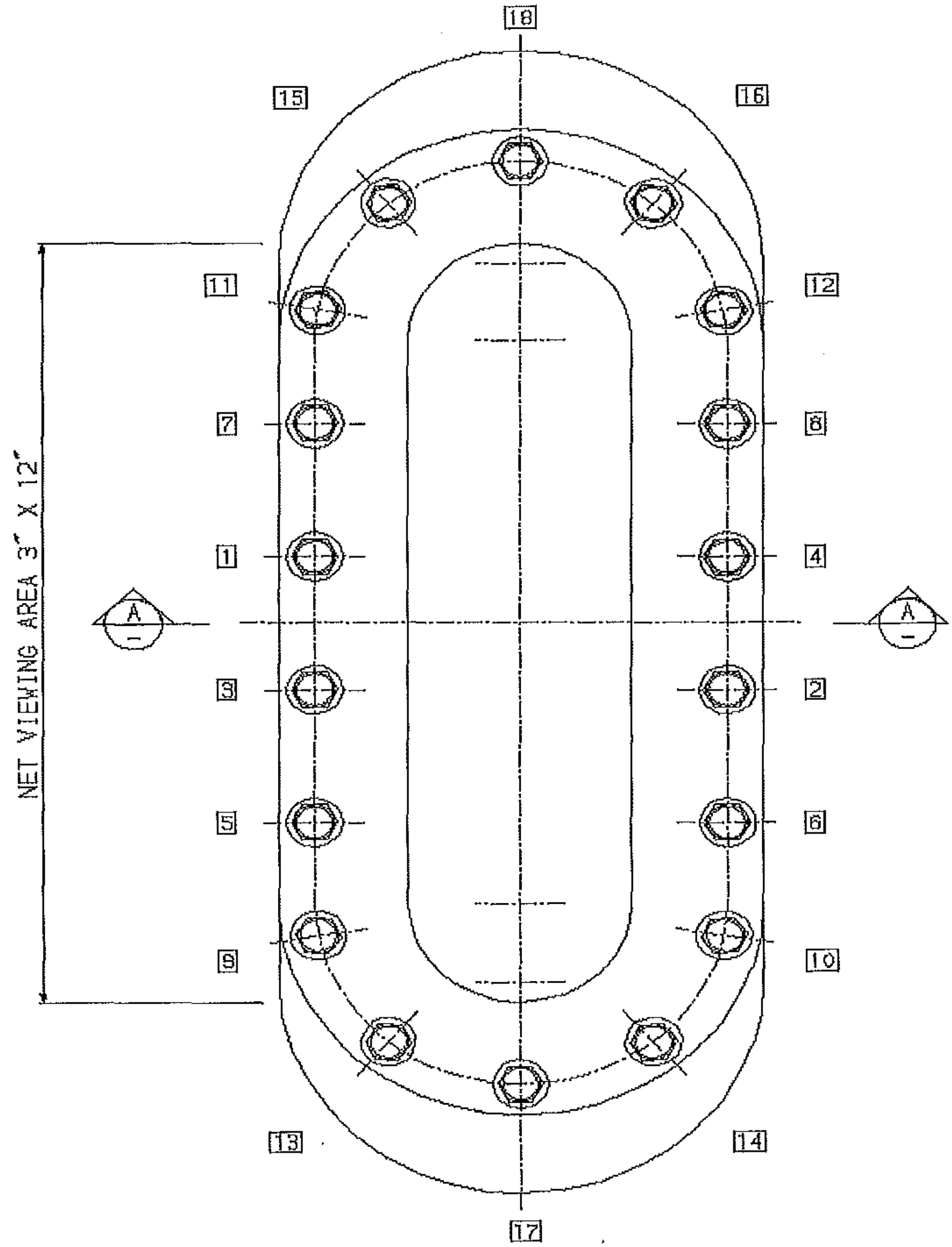
(b) Bolt torque shall not exceed the maximum allowable values (otherwise the rubber lining on the flange face may crack or delaminate). Bolt torque shall be uniformly applied such that the gasket is uniformly but moderately pre-compressed, and just starts to extrude from the flanged joint. Bring the 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
THIGHTENING 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 is 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 then 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

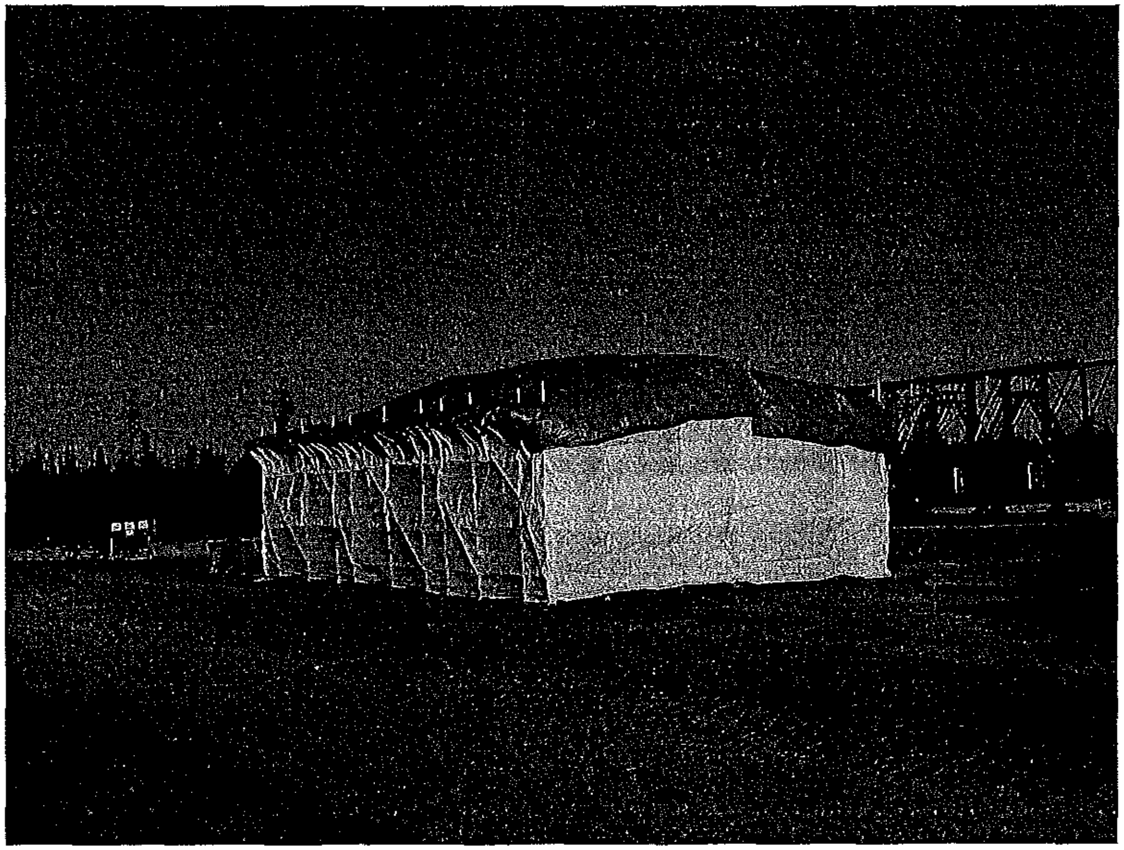
Nitrile rubber (Polymeric 2048).
The manufacturer of this rubbers has recommended that vessels lined with this rubber are not handled at temperature below -17C. Ecodyne has successfully shipped pressure vessels lined with other semi-hard rubber at lower temperature than that, but has no experience with 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).



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

Q56 – Quality Management

ECODYNE Limited

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	Customer:
INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 A	**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 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.
						BY	DATE	
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-4351 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 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 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 W W	05-09-13 05-09-13 05-09-13	R R W	5-17-13	 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 W	05-09-13 05-09-13	R R	5-12-13	R R	5/9/13 5/9/13			yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
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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}	Welder Symbol Welder Qualification / welder qualification continuity log	W	5.13.13	R	5.17.13	R	5/9/13			yes
			* confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records		R	5.13.13	R		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	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 -45⁰ C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W W	05-10-13 05-14-13	R R	 5-17-13	R R R		5/9/13 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 W	05-10-13 05-10-13	R R	5-17-13	R R		5/9/13 5/9/13		- yes

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PROJECT: MEG Energy - Christina Lake Phase 3A
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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 * the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33 * full penetration welding is required for the two piece strainer plate	ASME Section VIII									-
a	* Strainer plate has been welded & drilled in accordance with drawing				W	05-10-13	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	05-10-13	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												
d	* Fit and weld the shell course to the head				W	05-10-13	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
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NO.	ACTIVITY	REFERENCE DOCUMENT	CHARACTERISTIC VERIFIED	ACCEPTANCE CRITERIA	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	ASME Section VIII	W	05-15-13	M		M/V	5/9/13			-
			* all weld defects and spatter has been removed		W	05-15-13	M		M/V	17/5/13			
			* all pressure component edges have a minimum radius of 3 mm		W	05-15-13	M		M/V	17/5/13			
			* all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted)		W	05-15-13	M	5.17.13	M/V	17/5/13			
			* leg attachment weld is carried around to the inside of the flanges		W	05-15-13	M		M/V	17/5/13			

INSPECTION & TEST PLAN

ECODYNE Limited

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ECODYNE JOB: 32125
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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	5-17-13	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 A
Drawing Number: 32125-A-4351
REVISION: B

TC: Test Certificate Required

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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	ASME Section VIII ASME Section V	W	05.15.13	V/R		M/R			12/5/13	yes
			* 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	Production Hardness testing is not required	V	05-16-13	R	5-17-13	M/R			12/5/13	
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	05.23.13	V/R		W			10/6/13	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" - ¼" diameter nipples in weep holes		W	05.23.13	V/R	5-23-13	W			10/16/13	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 *(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)	Quality Requirements 32125-A-4200	W	6-27-13	V		W(R)		W(R)	10/6/13	
			* vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification	Nameplate in SI units	W	6-27-13	V	5-27/13	W		W	10/6/13	
			* 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		W	6-27-13	V		W(R)		W(R)	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 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	05-23-13	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	05-23-13	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:

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD. JOB No: 12-32 A

VESSEL TYPE: AFTER FILTER SERIAL No: 0411

APPROVED BY QA: Arie Willemsen CRN: W1159.2

	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	[signature] 3/5/13	R [signature] MAR 07.13	[signature] (SNC MEG)	24/4/13
Welding Procedures	[signature] 3/5/13	R [signature] MAR 07.13	[signature]	24/4/13
CRN		R [signature] MAY 28.13	[signature]	24/4/13
Welder Qualifications	[signature] 3/5/13	R [signature] MAY 28.13	[signature]	24/4/13
Out of Roundness (UG - 80)	[signature] 05.10.13	V [signature] MAY 10, 2013	[signature]	17/5/13
Materials	[signature] 05/10/13	R [signature] MAY 10.2013	[signature]	17/5/13
Internal	[signature] 05.10.13	H [signature] MAY 10.2013	[signature]	17/5/13
Dimensional	[signature] 05/17/13	V [signature]	[signature]	17/5/13
Other:				
Repair-by-weld-procedure				
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	[signature] 05/17/13	R [signature] MAY 28.13	[signature]	17/5/13
Arc Strikes, Gouges	[signature] 05/17/13			
Supports	[signature] 05/17/13			
Heat Treatment	---	---		
Final	[signature] 05/23/13	H [signature] MAY 28.13	[signature]	5/9/13
Hydrostatic Test	[signature] 05/23/13	H [signature] MAY 23.13	[signature]	5/9/13
Name Plate Stamping	[signature] 05/23/13	H [signature] MAY 23.13	[signature]	5/9/13
Data Reports		H [signature] MAY 28.13	[signature]	5/9/13
Paint	---	---	[signature]	5/9/13
Preparation for Shipment				

Remarks:

[signature] (PREPED) FOR STORAGE

LESENA STEEL LTD

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD. JOB No: 12-32 A

VESSEL TYPE: AFTER FILTER SERIAL No: 0411

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. [signature] MAR 07, 2013 DATE: FEB/4/2013

APPROVED BY QC: AW
ARIE WILLEMSEN

	DIMENSIONS	FIT UP & WELD PREP.	WELD (dbl., sinl, lap, butt)	Cust. Insp.
TOP HEAD	41'-6"	J 05.15.13	DBL., BUTT	
BOTTOM HEAD	41'-6"	J 05.15.13	DBL., BUTT	
SHELL LONG SEAM	94' Lg	J 05.15.13	DBL., BUTT	
FLANGES NOZZELS OPENINGS				

CONN. I.D.	SIZE	MATERIAL	FIT UP & WELD PREP.	WELD DIMENSION OS	REPAD	IS	Cust. Insp.
N1	12"	SA-105N/SA-106B/SA-516-70N	J 05.17.13	3/8"	1/2"	3/8"	
N2	12"	SA-105N/SA-234-WPB/ SA-106B/SA-516-70N	J 05.17.13	3/8"	1/2"		
N3A, N3B	4"	SA-105N	J 05.17.13	7/8"			
N4	3"	SA-105N/SA-106B/SA-516-70N	J 05.17.13	3/8"	3/8"		
SG1A, SG1B	6"	SA-516-70N	J 05.17.13	3/8"		3/8"	
M1	24"	SA-105N/SA-106B/SA-516-70N	J 05.17.13	3/8"	1/2"		
M2	24"	SA-105N/SA-106B/SA-516-70N	J 05 17 "	3/8"	1/2"		

INSPECTION & TEST PLAN
AFTER FILTER VESSEL
3A-F-208 B

TITLE	Customer:
INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 B	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 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.	
						BY	DATE		
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; Material clarifications	TM	AV	DRN	TM	11/12 2012	DWG. NO.	REV.
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012	32125-A-4352	B
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	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	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	05.9.13	R					5/9/13	-
			* Calculations have been provided for approval		W	05.09.13	R			5-9-13			
		△	* Pre-fabrication meeting - *SNC / MEG Surveillance Level 3*		W	05.09.13	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	Approval records / stamp for the procedures	W	05.09.13	R		R			5/9/13	yes
			* randomly check that the approved weld procedures are being applied - check amperage and voltage during operation		W	05.09.13	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}	Welder Symbol	W	05/6/13	R	5-15-13	R	5/9/13			yes
			* confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records	Welder Qualification / welder qualification continuity log	R	05-16-13	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 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	* 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 -45^0 C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W W	05-10-13 05-10-13	R R	5-15-13	R R R	5/9/13 5/9/13 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 W	05-10-13 05-10-13	R R	5-15-13	R R	5/9/13 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 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
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 * the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33 * full penetration welding is required for the two piece strainer plate	ASME Section VIII Nozzles are to be located clear of vessel long & circ seams									-
a	* Strainer plate has been welded & drilled in accordance with drawing				W	05-10-13	M		M/V	5/9/13			
b	* Top & Bottom heads laid out and nozzles fit & welded				W	05-10-13	M	5-15-13	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	05-10-13	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 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	ASME Section VIII	W	05-15-13	M		M/V		17/5/13		-
			* all weld defects and spatter has been removed		W	05-15-13	M		M/V		17/5/13		
			* all pressure component edges have a minimum radius of 3 mm		W	05-15-13	M		M/V		17/5/13		
			* all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted)		W	05-15-13	M	5-17-13	M/V		17/5/13		
			* leg attachment weld is carried around to the inside of the flanges		W	05-15-13	M		M/V		17/5/13		

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
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	05/17/13	W	5.17.13	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
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	ASME Section VIII ASME Section V	W	05/17/13	V/R		M/R			17/5/13	yes
			* 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	Production Hardness testing is not required	V	05/17/13	R	5-17-13	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	05/17/13	V/R		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" - ¼" diameter nipples in weep holes		W	05-17-13	V/R	5-17-13	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 *(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 W W	05/21/13 05/21/13 05/21/13	V V V	 5/21/13 	W (R) W W (R)		W (R) W W (R)	10/6/13 10/6/13 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 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	05-17-13	R	5-21/13	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	05-17-13	H	5-21/13	H			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:

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 MAR07.13	[illegible]	24/4/13
Welding Procedures	AW 3/5/13	R MAR07.13	[illegible]	24/4/13
CRN		R	[illegible]	24/4/13
Welder Qualifications	AW 3/5/13	R	[illegible]	24/4/13
Out of Roundness (UG - 80)	05.10/13	V MAY10.2013	[illegible]	17/5/13
Materials	05/10.13	R MAY10.2013	[illegible]	17/5/13
Internal	05/10.13	H MAY10.2013	[illegible]	17/5/13
Dimensional	05/17/13	V 05/17/2013	[illegible]	17/5/13
Other:				
Repair-by-weld-procedure	—			
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	05/17/2013	R 05/17/2013	[illegible]	17/5/13
Arc Strikes, Gouges	05/17/2013			
Supports	05/17/2013			
Heat Treatment	---	---		
Final	05/17/2013	H 05/17/2013	[illegible]	17/5/13
Hydrostatic Test	05/17/2013	H	[illegible]	17/5/13
Name Plate Stamping	05/17/2013	H	[illegible]	17/5/13
Data Reports	05/17/2013	H	[illegible]	17/5/13
Paint	---	---		
Preparation for Shipment				

Remarks:

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. MAR 07, 2013 DATE: FEB/4/2013

APPROVED BY QC:
ARIE WILLEMSEN

		DIMENSIONS	FIT UP & WELD PREP.	WELD (dbl., sinl, lap, butt)			Cust. Insp.
TOP HEAD		41'-6"	05.15.13	DBL., BUTT			
BOTTOM HEAD		41'-6"	05.15.13	DBL., BUTT			
SHELL LONG SEAM		94.1 Lg	05.15.13	DBL., BUTT			
FLANGES NOZZELS OPENINGS							
CONN. I.D.	SIZE	MATERIAL	FIT UP & WELD PREP.	WELD DIMENSION OS	REPAD	IS	
N1	12"	SA-105N/SA-106B/SA-516-70N	05.17.13	3/8"	1/2"	3/8"	
N2	12"	SA-105N/SA-234-WPB/ SA-106B/SA-516-70N	05.17.13	3/8"	1/2"		
N3A, N3B	4"	SA-105N	05.17.13	7/8"			
N4	3"	SA-105N/SA-106B/SA-516-70N	05.17.13	3/8"	3/8"		
SG1A, SG1B	6"	SA-516-70N	05.17.13	3/8"		3/8"	
M1	24"	SA-105N/SA-106B/SA-516-70N	05.17.13	3/8"	1/2"		
M2	24"	SA-105N/SA-106B/SA-516-70N	05.17.13	3/8"	1/2"		

INSPECTION & TEST PLAN

AFTER FILTER VESSEL

3A-F-208 C

TITLE	Customer:
INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 C	**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 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.	
						BY	DATE		
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; Material clarifications	TM	AV	DRN	TM	11/12 2012	DWG. NO.	REV.
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012	32125-A-4353	B
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	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	05-09-13	R						-
			* Calculations have been provided for approval		W	05-09-13	R	5-27-13					
		△	* Pre-fabrication meeting *- SNC / MEG* *Surveillance Level 3*		W	05-09-13	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	Approval records / stamp for the procedures	W	05-09-13	R		R	5/9/13			yes
			* randomly check that the approved weld procedures are being applied - check amperage and voltage during operation		W	05-09-13	R	5-27-13	R	5/9/17			

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}	Welder Symbol Welder Qualification / welder qualification continuity log	W	05-10-13	R	5-27-13	R		5/9/13		yes
			* confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records		R	05-10-13	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
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 -45⁰ C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W W	05-10-13 05-10-13	R R	5-27-13	R R R	5/9/13 5/9/13 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 W	05-10-13 05-10-13	R	5.27.13	R R	5/9/13 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 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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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 * the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33 * full penetration welding is required for the two piece strainer plate	ASME Section VIII Nozzles are to be located clear of vessel long & circ seams									
a	* Strainer plate has been welded & drilled in accordance with drawing				W	05/27/13	M		M/V			5/9/13	-
b	* Top & Bottom heads laid out and nozzles fit & welded				W	05/27/13	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	05/27/13	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

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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	ASME Section VIII	W	5.27.13	M		M/V			10/6/13	-
			* all weld defects and spatter has been removed		W	5/27/13	M		M/V			10/6/13	
			* all pressure component edges have a minimum radius of 3 mm		W	5/27/13	M	5.27.13	M/V			10/6/13	
			* all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted)		W	5/21/13	M		M/V			10/6/13	
			* leg attachment weld is carried around to the inside of the flanges		W	5/27/13	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 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	
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	5/27/13	W	5-27/13	W			10/8/13	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 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
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	ASME Section VIII ASME Section V	W	05/27/13	V/R	5-27-13	M/R			10/6/13	yes
			* 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	Production Hardness testing is not required	V	05/27/13	R		M/R			10/6/13	
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	05/24/13	V/R		W			10/6/13	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" - ¼" diameter nipples in weep holes		W	05-28-13	V/R	5-28-13	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 C
Drawing Number: 32125-A-4353
REVISION: B

TC: Test Certificate Required

H: Hold Point (do not fab past this point until accepted)
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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
11.	Preparation for Shipment to the Coating Shop	Drawings	* all interior hardware has been supplied as detailed on the drawings (including resin removal blind flange & hardware)	Quality Requirements 32125-A-4200	W	5.28.13	V		W R		W R	10/6/13	
	(note that coating, installation of internals and insulation are to be completed at the coating shop)		* vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification	Nameplate in SI units	W	5.28.13	V	5.28/13	W		W	10/6/13	
			* 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		W	05.28	V		W R		W R	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 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	05-28-13	R	5-28/13	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	05-28-13	H	5.28/13	H			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:

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD. JOB No: 12-32 C

VESSEL TYPE: AFTER FILTER SERIAL No: 0413

APPROVED BY QA: Arie Willemsen CRN: W1159.2

	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	AW 3/5/13	R MAR 20.13		
Welding Procedures	AW 3/5/13	R MAR 20.13		
CRN		R MAY 28.13		
Welder Qualifications	AW 3/5/13	R MAY 28.13		
Out of Roundness (UG - 80)	05/22/13	V 05/22/2013		
Materials	05/22/13	R 05/22/2013		
Internal	05/22/13	H 05/22/2013		
Dimensional	05/22/13	V MAY 28.13		
Other:				
Repair-by-weld-procedure				
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	05.28.13	R MAY 28.13		
Arc Strikes, Gouges	05-28.13			
Supports	05.28.13			
Heat Treatment	---	---		
Final	05.28.13	H MAY 28.13		
Hydrostatic Test	05.28.13	H MAY 28.13		
Name Plate Stamping	05.28.13	H MAY 28.13		
Data Reports	05.28.13	H MAY 28.13		
Paint	---	---		
Preparation for Shipment				

Remarks:

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.: 1041 kPa (g) T.P.: 1354 kPa (g) C.R.N. No: W1159.2

PRE-REVIEWED BY A. I. MAR 07. 13 DATE: FEB/4/2013

APPROVED BY QC:
ARIE WILLEMSEN

	DIMENSIONS	FIT UP & WELD PREP.	WELD (dbl., sinl, lap, butt)	Cust. Insp.
TOP HEAD	41'-6"	05/27/13	DBL., BUTT	
		05/27/13		
BOTTOM HEAD	41'-6"	05/27/13	DBL., BUTT	
SHELL LONG SEAM	94' Lg	05/27/13	DBL., BUTT	
FLANGES NOZZELS OPENINGS				

CONN. I.D.	SIZE	MATERIAL	FIT UP & WELD PREP.	WELD DIMENSION OS	REPAD	IS	
N1	12"	SA-105N/SA-106B/SA-516-70N	05/27/13	3/8"	1/2"	3/8"	
N2	12"	SA-105N/SA-234-WPB/ SA-106B/SA-516-70N	05/27/13	3/8"	1/2"		
N3A, N3B	4"	SA-105N	05/27/13	7/8"			
N4	3"	SA-105N/SA-106B/SA-516-70N	05/27/13	3/8"	3/8"		
SG1A, SG1B	6"	SA-516-70N	05/27/13	3/8"		3/8"	
M1	24"	SA-105N/SA-106B/SA-516-70N	05/27/13	3/8"	1/2"		
M2	24"	SA-105N/SA-106B/SA-516-70N	05/27/13	3/8"	1/2"		

INSPECTION & TEST PLAN
AFTER FILTER VESSEL
3A-F-208 D

TITLE	Customer:
INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 D	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 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.	
						BY	DATE		
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; Material clarifications	TM	AV	DRN	TM	11/12 2012	DWG. NO.	REV.
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012	32125-A-4354	B
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 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* *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 W W	05-09-13 05-09-13 05-09-13	R R W	SS SS SS	 W	 RT 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 W	05-09-13 05-09-13	R R	SS SS	R R	RT 5/9/13 RT 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 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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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}	Welder Symbol	W	05-10-13	R		R	5/9/13			yes
			* confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records	Welder Qualification / welder qualification continuity log	R	05-10-13	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

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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 -45⁰ C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W W	05-28-13 05-28-13	R R	SS SS	R R R	RT 5/9/13 RT 5/9/13 RT 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 W	05-28-13 05-28-13	R R	SS SS	R R	RT 5/9/13 RT 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 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
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	SS	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	Nozzles are to be located clear of vessel long & circ seams	W	8-28-13	M	SS	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	8-28-13	V	SS	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

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7.	Weld Profile	ASME	* confirm that the weld profile and reinforcement are in accordance with UW 35	ASME Section VIII	W	8-28-13	M	SS	M/V			10/6/13	
			* all weld defects and spatter has been removed		W	8-28-13	M	SS	M/V			10/6/13	
			* all pressure component edges have a minimum radius of 3 mm		W		M	SS	M/V			10/6/13	
			* all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted)		W	8-28-13	M	SS	M/V			10/6/13	
			* leg attachment weld is carried around to the inside of the flanges		W	8-28-13	M	SS	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 D
Drawing Number: 32125-A-4354
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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	05/30/13	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

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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
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	ASME Section VIII ASME Section V	W	05-30-13	V/R		M/R			10/6/13	yes
			* 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	Production Hardness testing is not required	V	05-30-13	R	May 30/13	M/R			10/6/13	
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	06-03-13	V/R		W			10/6/13	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" - ¼" diameter nipples in weep holes		W	06-03-13	V/R	5-30/13	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 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
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)	Quality Requirements 32125-A-4200	W	06.03.13	V		W R		R W	10/6/13	
			* vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification	Nameplate in SI units	W	06.03.13	V	5/31/13	W		W	10/6/13	
			* 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		W	06.03.13	V		W R		W R	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 D
Drawing Number: 32125-A-4354
REVISION: B

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<tr><th>FAB</th><th>Sign/ Date</th><th>ECO</th><th>Sign/ Date</th><th>SNC</th><th>Sign/ Date</th><th>MEG</th><th>Sign/ Date</th><th>TC</th></tr>
<tr><td>12.</td><td>Documents</td><td>Purchase Req</td><td>* 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</td><td>Drawings & Code

Ecodyne is responsible for assembly of documentation in accordance with project requirements</td><td>W</td><td>06-03-13</td><td>R</td><td>5.31/13</td><td>M/R</td><td></td><td></td><td>10/6/13</td><td>yes</td></tr>
<tr><td>13.</td><td>Inspection Release to the Coating Shop (for coating & installation of inlet & strainers)</td><td>Purchase Order</td><td>* confirm that all work has been done per the purchase order and all referenced drawings and specifications
- ITP signed off</td><td>Drawings & Code</td><td>H</td><td>06-03-13</td><td>H</td><td>5.31/13</td><td>H</td><td></td><td></td><td>10/6/13</td><td>yes</td></tr>
</table>

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:

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD. JOB No: 12-32 D

VESSEL TYPE: AFTER FILTER SERIAL No: 0414

APPROVED BY QA: Arie Willemsen CRN: W 1159.2

	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	AW 3/5/13	MAR07.13		
Welding Procedures	AW 3/5/13	MAR07.13		
CRN		JUN03.13		
Welder Qualifications	AW 3/5/13	JUN03.13		
Out of Roundness (UG - 80)	05.28/13	MAY28.13		
Materials	05.28/13	MAY28.13		
Internal	05.28/13	MAY28.13		
Dimensional	05/30/13	JUNE03.13		
Other:				
Repair-by-weld-procedure				
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	06.03.13	JUN03.13		
Arc Strikes, Gouges	06-03/13			
Supports	06.03/13			
Heat Treatment	---	---		
Final	06-03-13	JUN03.13		
Hydrostatic Test	06.03.13	JUN03.13		
Name Plate Stamping	06.03.13	JUN03.13		
Data Reports	06.03.13	JUN03.13		
Paint	---	---		
Preparation for Shipment				

Remarks:

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. MAR 07.13 DATE: FEB/4/2013

APPROVED BY QC: AW
ARIE WILLEMSEN

	DIMENSIONS	FIT UP & WELD PREP.	WELD (dbl., sinl, lap, butt)	Cust. Insp.
TOP HEAD	41'-6"	05/30/13	DBL., BUTT	
		05/30/13		
BOTTOM HEAD	41'-6"	05/30/13	DBL., BUTT	
SHELL LONG SEAM	94' lg	05/30/13	DBL., BUTT	
FLANGES NOZZELS OPENINGS				

CONN. I.D.	SIZE	MATERIAL	FIT UP & WELD PREP.	WELD DIMENSION OS	REPAD	IS	
N1	12"	SA-105N/SA-106B/SA-516-70N	05 30/13	3/8"	1/2"	3/8"	
N2	12"	SA-105N/SA-234-WPB/ SA-106B/SA-516-70N	05/30/13	3/8"	1/2"		
N3A, N3B	4"	SA-105N	05.30.13	7/8"			
N4	3"	SA-105N/SA-106B/SA-516-70N	05.30/13	3/8"	3/8"		
SG1A, SG1B	6"	SA-516-70N	05.13.13	3/8"		3/8"	
M1	24"	SA-105N/SA-106B/SA-516-70N	05 10/13	3/8"	1/2"		
M2	24"	SA-105N/SA-106B/SA-516-70N	05/13	3/8"	1/2"		

INSPECTION & TEST PLAN
AFTER FILTER VESSEL
3A-F-208 E

TITLE	Customer:
INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 E	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 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.
						BY	DATE	
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	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
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 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 W W	05.09.13 05.09.13 05.09.13	R R W	5-09/13	 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 W		R R	5-29/13	R R	5/9/13 5/9/13			yes

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
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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 R	5.15.13 5.13.13	R R	5-9/13	R R	5/9/13 5/9/13			yes

INSPECTION & TEST PLAN

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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 W	06-02-13 06-02-13	R R	6-02-13	R R R	5/9/13 5/9/13 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 W	06-02-13 06-02-13	R R	6-02-13	R R	5/9/13 5/9/13			- yes

INSPECTION & TEST PLAN

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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 * the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33 * full penetration welding is required for the two piece strainer plate	ASME Section VIII Nozzles are to be located clear of vessel long & circ seams									-
a	* Strainer plate has been welded & drilled in accordance with drawing				W	06.03.13	M		M/V	5/9/13			
b	* Top & Bottom heads laid out and nozzles fit & welded				W	06.03.13	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				W	06.03.13	M		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.												

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7.	Weld Profile	ASME	* confirm that the weld profile and reinforcement are in accordance with UW 35	ASME Section VIII	W	06-03-13	M		M/V			10/6/13	-
			* all weld defects and spatter has been removed		W	06-03-13	M		M/V			10/6/13	
			* all pressure component edges have a minimum radius of 3 mm		W	06-03-13	M		M/V			10/6/13	
			* all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted)		W	06-03-13	M	6-10-13	M/V			10/6/13	
			* leg attachment weld is carried around to the inside of the flanges		W	06-03-13	M		M/V			10/6/13	

INSPECTION & TEST PLAN

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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	06.07.13	W	6-10/13	W			10/6/13	yes

INSPECTION & TEST PLAN

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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 V	06-07-13 06-07-13	V/R R	6-10-13	M/R M/R			10/6/13 10/6/13	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	06-12-13	V/R		W			10/6/13	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" - ¼" diameter nipples in weep holes		W	06-12-13	V/R		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
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)	Quality Requirements 32125-A-4200	W	06-12-13	V		W R		W R	10/6/13	
			* vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification	Nameplate in SI units	W	06-12-13	V		W		W	10/6/13	
			* 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		W	06-12-13	V		W R		W R	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
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	06-12-13	R		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		H *		H			10/6/13	yes

* SIGNED IN ERROR 6-10/13

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:

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	AW 3/5/13	RK MAR07.13		
Welding Procedures	AW 3/5/13	RK MAR07.13		
CRN		RK JUN12.13		
Welder Qualifications	AW 3/5/13	RK JUN12.13		
Out of Roundness (UG - 80)	06.07.13	VK JUN07.13		
Materials	06.07.13	RK JUN07.13		
Internal	06.07.13	HK JUN07.13		
Dimensional	06.12.13	VK JUN12.13		
Other:	–			
Repair-by-weld-procedure	–			
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	06.12.13	RK JUN12.13		
Arc Strikes, Gouges	06.12.13			
Supports	06.12.13			
Heat Treatment	---	---		
Final	06.12.13	HK JUN12.13		
Hydrostatic Test	06.12.13	HK JUN12.13		
Name Plate Stamping	06.12.13	HK JUN12.13		
Data Reports	06.12.13	HK JUN12.13		
Paint	---	---		
Preparation for Shipment	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.: 1041 kPa (g) T.P.: 1354 kPa (g) C.R.N. No: W1159.2

PRE-REVIEWED BY A. I. MAR 07.13 DATE: FEB/4/2013

APPROVED BY QC: AW
ARIE WILLEMSEN

	DIMENSIONS	FIT UP & WELD PREP.	WELD (dbl., sinl, lap, butt)	Cust. Insp.
TOP HEAD	41'-6"	06.07.13	DBL., BUTT	
BOTTOM HEAD	41'-6"	06.07.13	DBL., BUTT	
SHELL LONG SEAM	94' (g	06.07.13	DBL., BUTT	

FLANGES NOZZELS OPENINGS							
CONN. I.D.	SIZE	MATERIAL	FIT UP & WELD PREP.	WELD DIMENSION OS	REPAD	IS	
N1	12"	SA-105N/SA-106B/SA-516-70N	06.07.13	3/8"	1/2"	3/8"	
N2	12"	SA-105N/SA-234-WPB/ SA-106B/SA-516-70N	06.07.13	3/8"	1/2"		
N3A, N3B	4"	SA-105N	06.07.13	7/8"			
N4	3"	SA-105N/SA-106B/SA-516-70N	06.07.13	3/8"	3/8"		
SG1A, SG1B	6"	SA-516-70N	06.07.13	3/8"		3/8"	
M1	24"	SA-105N/SA-106B/SA-516-70N	06.07.13	3/8"	1/2"		
M2	24"	SA-105N/SA-106B/SA-516-70N	06.07.13	3/8"	1/2"		

INSPECTION & TEST PLAN
AFTER FILTER VESSEL
3A-F-208 F

TITLE	Customer:
INSPECTION & TEST PLAN AFTER FILTER VESSEL 3A-F-208 F	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 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.	
						BY	DATE	DWG. NO.	REV.
B	Dec 19 2012	Client inspection points; SNC/MEG Surveillance Level 3; Material clarifications	TM	AV	DRN	TM	11/12 2012	32125-A-4356	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 △	* 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 W W	05-09-13 05-09-13 05-09-13	R R W	5-9-13	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 W	05-09-13 05-09-13	R R	5-9/13	R R	5/9/13 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
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}	Welder Symbol	W	05.10.13	R	5/9/13	R	5/9/13			yes
			* confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records	Welder Qualification / welder qualification continuity log	R	05.10.13	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 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 -45⁰ C Internal & external attachments, welded directly to vessel pressure components, to be same grade of material	W W	06-17-13 06-17-13	R R	5-9-13	R R R			5/9/13 5/9/13 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 W	06-17-13 06-17-13	R R	5-9-13	R R			5/9/13 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 * the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33 * full penetration welding is required for the two piece strainer plate	ASME Section VIII Nozzles are to be located clear of vessel long & circ seams									-
a	* Strainer plate has been welded & drilled in accordance with drawing				W	06-17-13	M		M/V	5/9/13			
b	* Top & Bottom heads laid out and nozzles fit & welded				W	06-17-13	M	5-9-13	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	06-17-13	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 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	ASME Section VIII	W	06.17.13	M		M/V			6/17/13	-
			* all weld defects and spatter has been removed		W	06.17.13	M		M/V			6/17/13	
			* all pressure component edges have a minimum radius of 3 mm		W	06.17.13	M		M/V			6/17/13	
			* all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted)		W	06.17.13	M	6.24.13	M/V			6/17/13	
			* leg attachment weld is carried around to the inside of the flanges		W	06.17.13	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	0624.13	W	6-24-13	W			6/24/13	yes

NOT ON ON AT TIME OF THIS INSP. . 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 V	06-25-13	V/R R	6-24/13	M/R 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	06-27-13	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" - ¼" diameter nipples in weep holes		W	06-27-13	V/R		W			6/12/13	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 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	* all interior hardware has been supplied as detailed on the drawings (including resin removal blind flange & hardware)	Quality Requirements 32125-A-4200	W	06-27-13	V		W		W	6/26/13	
			* vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification	Nameplate in SI units	W	06-27-13	V		W		W		
			* 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		W	06-27-13	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:

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	AW 3/5/13	R MAR 07.13		
Welding Procedures	AW 3/5/13	R MAR 07.13		
CRN	06/27/13	R JUN 27.13		
Welder Qualifications	AW 3/5/13	R JUN 27.13		
Out of Roundness (UG - 80)	06.18.13	✓ JUN 18.13		
Materials	06.18.13	R JUN 18.13		
Internal	06.18.13	H JUN 18.13		
Dimensional	06.19.13	✓ JUN 27.13		
Other:				
Repair-by-weld-procedure				
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	06.27.13	R JUN 27.13		
Arc Strikes, Gouges	06.27.13			
Supports	06.27.13			
Heat Treatment	---	---		
Final	06.27.13	H JUN 27.13		
Hydrostatic Test	06.27.13	H JUN 27.13		
Name Plate Stamping	06.27.13	H JUN 27.13		
Data Reports	06.27.13	H JUN 27.13		
Paint	---	---		
Preparation for Shipment	06.27.13			

Remarks:

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 revE

W. P.: 1041 kPa (g) T.P.: 1354 kPa (g) C.R.N. No: W1159.2

PRE-REVIEWED BY A. I. MAR07.13 DATE: FEB/4/2013

APPROVED BY QC:
ARIE WILLEMSEN

	DIMENSIONS	FIT UP & WELD PREP.	WELD (dbl., sinl, lap, butt)	Cust. Insp.
TOP HEAD	41'-6"	06.11.13	DBL., BUTT	
BOTTOM HEAD	41'-6"	06.11.13	DBL., BUTT	
SHELL LONG SEAM	94' lg	06.11.13	DBL., BUTT	

FLANGES NOZZELS OPENINGS							
CONN. I.D.	SIZE	MATERIAL	FIT UP & WELD PREP.	WELD DIMENSION OS	REPAD	IS	
N1	12"	SA-105N/SA-106B/SA-516-70N	06.12.13	3/8"	1/2"	3/8"	
N2	12"	SA-105N/SA-234-WPB/ SA-106B/SA-516-70N	06.12.13	3/8"	1/2"		
N3A, N3B	4"	SA-105N	06.12.13	7/8"			
N4	3"	SA-105N/SA-106B/SA-516-70N	06.12.13	3/8"	3/8"		
SG1A, SG1B	6"	SA-516-70N		3/8"		3/8"	
			06.12.13				
M1	24"	SA-105N/SA-106B/SA-516-70N		3/8"	1/2"		
M2	24"	SA-105N/SA-106B/SA-516-70N	06.12.13	3/8"	1/2"		

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			ECODYNE Limited A Marmon Water/Berkshire Hathaway Company 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.
						BY	DATE	
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-4357 — 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 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 △	* 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 W W	05-09-13 05-09-13 05-09-13	R R W	5-9-13	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 W	05-09-13 05-09-13	R R	5-9-13	R R	5/9/13 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

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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}	Welder Symbol Welder Qualification / welder qualification continuity log	W	05.13.13	R	5-9/13	R			5/9/13	yes
			* confirm that all welders used on the project have current qualifications for the fabrication facility by reviewing the welder qualification records		R	05.13.13	R		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	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*	W	06-14-13	R		R	5/9/13			yes
				ASME Section II Lift lug materials to be suitable for -45⁰ C	W	06-14-13	R	5-9-13	R	5/9/13			
				Internal & external attachments, welded directly to vessel pressure components, to be same grade of material					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	ASME Section VIII	W	06-14-13	R	5-9-13	R	5/9/13			-
			* the head manufacturer has provided certification and Data Report	Certificate of Conformance U-2A (2-piece heads)	W	06-14-13	R		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 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
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 * the maximum allowable misalignment of the fit-up is to be in accordance with section UW 33 * full penetration welding is required for the two piece strainer plate	ASME Section VIII Nozzles are to be located clear of vessel long & circ seams									-
a	* Strainer plate has been welded & drilled in accordance with drawing				W	06.14.13	M		M/V	5/9/13			
b	* Top & Bottom heads laid out and nozzles fit & welded				W	06.14.13	M	5-9-13	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	06.14.13	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

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ECODYNE JOB: 32125
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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	ASME Section VIII	W	08.18.13	M		M/V			5/9/13	-
			* all weld defects and spatter has been removed		W	08.18.13	M		M/V			5/9/13	
			* all pressure component edges have a minimum radius of 3 mm		W		M		M/V			5/9/13	
			* all exterior & internal attachment welds are seal welds except as noted and around vessel seams (unless otherwise noted)		W	08.18.13	M	6-9-13	M/V			5/9/13 5/9/13	
			* leg attachment weld is carried around to the inside of the flanges		W	08.18.13	M		M/V			6/20/13	

INSPECTION & TEST PLAN

ECODYNE Limited

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ECODYNE JOB: 32125
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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	6/18/13	W	6-19/13	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

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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	ASME Section VIII ASME Section V	W	6.19.13	V/R		M/R	6/20/13			yes
			* 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	Production Hardness testing is not required	V	6.19.13	R	6/19/13	M/R	6/20/13			
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	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" - ¼" 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)
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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
11.	Preparation for Shipment to the Coating Shop	Drawings	* all interior hardware has been supplied as detailed on the drawings (including resin removal blind flange & hardware)	Quality Requirements 32125-A-4200	W	06-20-13	V		W		W	6/21/13	
	(note that coating, installation of internals and insulation are to be completed at the coating shop)		* vessel nameplate, etc. have been checked for accuracy - nameplate to include all information detailed in vessel specification	Nameplate in SI units	W	06-20-13	V		W		W		
			* 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		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	06-20-13	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	06-20-13	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

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	06-20-13	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	06-20-13	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:

TRAVELER / QUALITY CONTROL CHECK LIST

CUSTOMER: ECODYNE LTD. JOB No: 12-32 G

VESSEL TYPE: AFTER FILTER SERIAL No: 0417

APPROVED BY QA: Arie Willemsen CRN: W1159.2

	QC Inspector	Authorized Inspector	Customer Inspector	Date
INITIAL :				
Design Calculations & Drawings	AW 3/5/13	RK MAR07.13		
Welding Procedures	AW 3/5/13	RK MAR07.13		
CRN	06.20.13	RK JUN20.13		
Welder Qualifications	AW 3/5/13	RK JUN20.13		
Out of Roundness (UG - 80)	06.18.13	JUN 18.13		
Materials	06.18.13	RK JUN18.13		
Internal	06.18.13	HK JUN 18.13		
Dimensional	06.19.13	JUN20.13		
Other:				
Repair-by-weld-procedure				
TESTS & INSPECTIONS:				
Review of Radiography Film & Report	06.19.13	RK JUN 20.13		
Arc Strikes, Gouges	06.19.13			
Supports	06.19.13			
Heat Treatment	---	---		
Final	06.20.13	HK JUN20.13		
Hydrostatic Test	06.20.13	HK JUN20.13		
Name Plate Stamping	06.20.13	HK JUN20.13		
Data Reports	06.20.13	HK JUN20.13		
Paint	---	---		
Preparation for Shipment	06.20.13			

Remarks:

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.E

W. P.: 1041 kPa (g) T.P.: 1354 kPa (g) C.R.N. No: W1159.2

PRE-REVIEWED BY A. I. 19MAR07.13 DATE: FEB/4/2013

APPROVED BY QC:
ARIE WILLEMSEN

		DIMENSIONS	FIT UP & WELD PREP.	WELD (dbl., sinl, lap, butt)			Cust. Insp.
TOP HEAD		41'-6"	Jb 12.13	DBL., BUTT			
BOTTOM HEAD		41'-6"	Jb 12.13	DBL., BUTT			
SHELL LONG SEAM		94' 6	Jb 12.13	DBL., BUTT			
FLANGES NOZZELS OPENINGS							
CONN. I.D.	SIZE	MATERIAL	FIT UP & WELD PREP.	WELD DIMENSION OS	REPAD	IS	
N1	12"	SA-105N/SA-106B/SA-516-70N	Jb 12.13	3/8"	1/2"	3/8"	
N2	12"	SA-105N/SA-234-WPB/ SA-106B/SA-516-70N	Jb 12.13	3/8"	1/2"		
N3A, N3B	4"	SA-105N	Jb 12.13	7/8"			
N4	3"	SA-105N/SA-106B/SA-516-70N	Jb 12.13	3/8"	3/8"		
SG1A, SG1B	6"	SA-516-70N	Jb 12.13	3/8"		3/8"	
M1	24"	SA-105N/SA-106B/SA-516-70N	Jb 12.13	3/8"	1/2"		
M2	24"	SA-105N/SA-106B/SA-516-70N	Jb 12.1	3/8"	1/2"		

INSPECTION & TEST PLAN
LINING & COATING
Filter ~~& WAC Vessels~~

TITLE	Customer:
INSPECTION & TEST PLAN LINING & COATING Filter ~~& WAC Vessels~~	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 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.	
						BY	DATE		
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.	REV.
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012	32125-A-4501	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

LINING & COATING Filter & ~~WAC~~ Vessels DRAW~~ING 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
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/Sept/13			-
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 W		R R		R R	5/Sept/13 5/Sept/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
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	SSPC SP-5	W		R		M/R	5/9/13			yes
			* Daily log has been maintained to record all pertinent information		W		R		M/R	5/9/13			

INSPECTION & TEST PLAN

ECODYNE Limited

PROJECT: MEG Energy - Christina Lake Phase 3A
ECODYNE JOB: 32125
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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	* Confirm the material by checking documentation and batch numbers	Rubber Data Sheets	V/R		R		M/R	5/9/13			
			* lining thickness has been confirmed - ¼ inch	N/A	W		V		M/R				
			* Visual inspection of the lined surfaces with all detrimental defects (blisters, voids, etc.) corrected - lining has completely covered all interior surfaces that are not alloy		W		W		W				
			* Continuity of the entire lining checked with a High Voltage Spark Tester (voltage per data sheet) - Pin Hole Free		W		W		W				yes
			* Check the hardness of the lining is in conformance with the data sheet		W		V/R		V/W				
			* Record critical information in daily log		W		R		R				

INSPECTION & TEST PLAN

ECODYNE Limited

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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 Paint Manufacturer Data Sheets	W W W W		V R R R		R/V R/V R/V R/V				
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 SSPC PA-2 Drawings/ Specification	W W W		W V R		W M/V R/V				yes

Sept. 4/13 (7) 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
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 W	9/24/13 9/24/13	W W		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	9/04/13	V/R		W				-

9/04/13 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
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	9/04/13 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	9/04/13 After Filter	H		H				-

INSPECTION & TEST PLAN

INSULATION - Filter & ~~WAC~~ Vessels

100% JULY 26 2013

VESSEL 208A

TITLE	Customer:
INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels	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 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.	
						BY	DATE		
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.	REV.
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012	32125-A-4502	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 Δ	* 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 Jun 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 Jun 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	SG July 18 2013	R	9-29/13	M/V			30/7/13	
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W	SG July 26 2013	V/R	9/29/13	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	SG July 26 2013	V/R	9/29/13	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	SG July 26 2013	R	9/29/13	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 July 26 2013	H	9/29/13	H				

INSPECTION & TEST PLAN

INSULATION – Filter & WAC Vessels

100% JULY 26 2013
VESSEL 208 B

TITLE	Customer:
INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels	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 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.
						BY	DATE	
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	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 July 15 2013	R	6-19/13	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 July 18, 2013	R	8-29/13	M/V			30/7/13	
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W	SB July 26 2013	V/R	9/29/13	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 July 26 2013	V/R	9/29/13	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 July 26 2013	R	9/29/13	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 July 26 2013	H	9/29/13	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
A Marmon Water/Berkshire Hathaway Company

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.

						BY	DATE
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 15 2013	R	8-18-13	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 July 15 2013	R	8-18-13	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	July 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* 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 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.
						BY	DATE		
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.	REV.
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012	32125-A-4502	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 July 18 2013	R	7-18/13	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 July 15 2013	R	7-18/13	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	AUG 6 2013 SB	R	8-6/13	M/V				
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W	AUG 8 2013 SB	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 SB	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 SB	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 SB	H	8-6/13	H				

INSPECTION & TEST PLAN
INSULATION – Filter & WAC Vessels

VESSEL 208E.

TITLE	Customer:
INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels	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 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.	
						BY	DATE		
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.	REV.
A	Nov 12 2012	FIRST ISSUE	TM	AV	CHKD	AV	11/12 2012	32125-A-4502	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 Jun 18 2013	R	7-15-13	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 Jun 15 2013	R	7-15-13	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	AUG 8 2013	R	8-8-13	M/V				
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W	AUG 28 2013	V/R	8-23-13	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 28 2013	V/R	8-23-13	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 28 2013	R	8-23-13	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 28 2013	H	8-23-13	H				

INSPECTION & TEST PLAN

INSULATION – Filter & WAC Vessels

VESSEL 208 F

TITLE	Customer:
INSPECTION & TEST PLAN INSULATION Filter & WAC Vessels	MEG Energy Corporation Christina Lake Phase 3A c/o SNC-Lavalin PO No. P-5675-02

REV	DATE	REMARKS	BY	CHKD				
					SCALE - N/A			ECODYNE Limited A Marmon Water/Berkshire Hathaway Company 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.
						BY	DATE	
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 Jun 18 2013	R	7-18-13	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 Jul 15 2013	R	7-18-13	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 28 2013	V/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* Δ *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 A Marmon Water/Berkshire Hathaway Company 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.
						BY	DATE	
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	June 18 2013	R	8-15-13	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	July 15 2013	R	8-15-13	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 19 2013	R	8-21-13	M/V				
4.	Cladding	Drawings	* insulation is clad as detailed in specification	specification	W SB	AUG 21 2013	V/R	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 SB	AUG 21 2013	V/R	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	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	8-21-13	H				

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

D51 – Data Sheets

ECODYNE Limited

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 A Marmon Water/Berkshire Hathaway Company
C	2013 Mar 12	PAGE 3 PER SNC MARKUP PAGE 4 - MEDIA	[signature]	AV		BY	DATE	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.
B	2013 FEB 07	FIRSTREVISION	IA	AV	DRAWN	IA	2012 Nov 22	DRAWING NO. 32125-A-2053 REV C
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

Equipment Name	After Filter Vessel	Data Sheet No.:	DS-CL03A-Y-200-F208
		Requisition No.:	508298-200-45-MR-5675-0002

DESIGN DATA

Service	HLS effluent water filtration		
Operating Temperature	80.0 / 105. °C	Pressure	755.0 kPag
Design Temp. Min.:	5.0 °C	Max.:	120.0 °C
Design Pressure @ Minimum Temperature:	1034 / FV kPag		
@ Maximum Temperature:	1034 / FV kPag		
Sour Service	N/A	Lethal Service	N/A
New Vessel MAWP Limited by -	Top Head	@	1037.0 kPag
Corrosion Allowance - Shell / Heads	3.2 / 3.2 mm		
Wall Thickness - Shell / Heads	19.1 / 18.22/19.05 mm		
Joint Efficiency - Shell / Heads	1.0 / 1.0		
Registration	Alberta	Design Code	ASME Sec VIII Div 1
Code Stamp	Yes, U Stamp	Orientation	Vertical
Post Weld Heat Treatment	per Code		
Head Type	2:1 Semi-elliptical		
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

PAINTING & INSULATION

External Surface Preparation	Per spec 085354-3010-PC-50 (D2)
Internal Surface Preparation	N/A
Structural Surface Preparation	Per spec 085354-3010-PC-50 (S3) (Note 10)
Vessel External Prime	per spec 085354-3010-PC-50 (D2)
Vessel Internal Prime	N/A
Structural Prime	Per spec 085354-3010-PC-50 (S3) (Note 10)
Vessel External Finish	N/A
Vessel Internal Finish	N/A
Structural Finish	Per spec 085354-3010-PC-50 (S3) (Note 10)
External Insulation - Shell	Per spec 085354-3010-IN-00 (Note 8)
External Insulation - Heads	Per spec 085354-3010-IN-00 (Note 8)
Internal Insulation	N/A
External Cladding	Per spec 085354-3010-IN-00
Insulation - Bottom Head	Per spec 085354-3010-IN-00
Insulation - Skirt	N/A
Fireproofing - Skirt	N/A
Fireproofing - Saddles	N/A

MATERIALS

Shell	SA516 - 70N	Repads	SA516 - 70N
Heads	SA516 - 70N	Fittings	SA105N/SA234 WPB
Trays	N/A	Supports	SA516 -70N(R-Pads)
Bolts/Nuts	SA193 B7/A194 2H	Flanges	SA105 N
Nozzle-Necks	A106 - B	Gaskets	SPW SS 316
Internal Lining	N/A	Pipe	SA106 - B
Internals	SS 316L (Note 7)	Mist Eliminator	N/A
Structural Attachments - External	SA516 - 70N (Poison pads only)		
Structural Attachments - Internal	SA516 - 70N (Poison pads only)		
Material Impact Test Required	Per Code		
Certified Elevated Temp Tests Req'd	No		

QUALITY CONTROL / INSPECTION / TESTING

Hydrotest Pressure	Per Code kPag
Hydrotest Medium	Water
Hydrotest Duration	1 hr. minimum hrs
Radiographic Inspection	RT2
Ultrasonic Inspection	per spec 085354-3010-EW-20
Magnetic Particle Inspection	per spec 085354-3010-EW-20
Dye Penetrant Inspection	per spec 085354-3010-EW-20
Material Mill Test Reports	100% Traceability
Post Weld Heat Treatment Records	Per MR Section III
Hydrotest Reports	Per MR Section III
Radiographic Inspection Reports	Per MR Section III
Ultrasonic Inspection Reports	Per MR Section III
Magnetic Particle Inspection Reports	Per MR Section III
Dye Penetrant Inspection Reports	Per MR Section III
Fabricator Quality Control Manual	Per MR Section III
Shop Inspection by Owner	Yes
Welding Procedure Review/Approval	Per MR Section III

DIMENSIONAL/SHIPPING DATA

Vessel Size	3962 mm OD	x	2540 mm T/T
Boot/Gas Dome	mm ID	x	mm S/S
Capacity	46.74 m³		
Centerline/Bottom Seam Elevation	0.95 m		
Weight - Empty	26100 kg	Weight - Hydrotest	71630 kg
Weight - Operat'g	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

* To be specified / confirmed by Seller.
1. All nozzles shall be flush with vessel inside surface.
2. Seller shall design and install all the internals.
3. National Board registration req'd for vessels fabricated outside Canada.
4. ABSA registration is required to obtain CRN for all vessels.
5. Structural attachments are defined as any non-pressure part welded directly to the shell or head of the filter vessel.
6. Ambient temperatures are for filter package indoor building location.
7. Removable internals shall be fabricated from SS 316L.
8. 38 mm (hot) mineral fiber c/w 0.8 mm corrugated aluminum cladding shall be provided and installed by Seller.
9. Seller shall provide a minimum of two (2) grounding lugs
10. Uninsulated surfaces including vessel legs, davits, lugs and clips

ACCESSORIES BY FABRICATOR

Manway Davits	Y	Ladders	N
Ladder and Platform Clips	N	Platforms	N
Pipe Support and Guide Clips	Y	Lifting Lugs	Y
Insulation Supports	Y	Pipe Coil	N
Insulation Supports Bottom Head	Y	Anodes	N
Fireproofing Supports	N	Nameplate	Y
Legs	Y	Mist Eliminator	N
Tray/Packing Supports	N	Vortex Breaker	N
Manway Internal Grab Rungs	N	Grounding Lugs	Y
Siphon Drains on Nozzles			

MEG Energy Corp. SNC·LAVALIN

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	22/Nov/12	IA	AV		Rev'd by Ecodyne

PROJECT	Christina Lake Regional Project Phase 3A		
JOB NO.	508298	TAG NO.	3A-F-208 A-G
LOCATION	Conklin, Alberta	PAGE	1 of 4

PRESSURE VESSEL DATA SHEET

Data Sheet No.: DS-CL03A-Y-200-F208

Equipment Name: After Filter Vessel

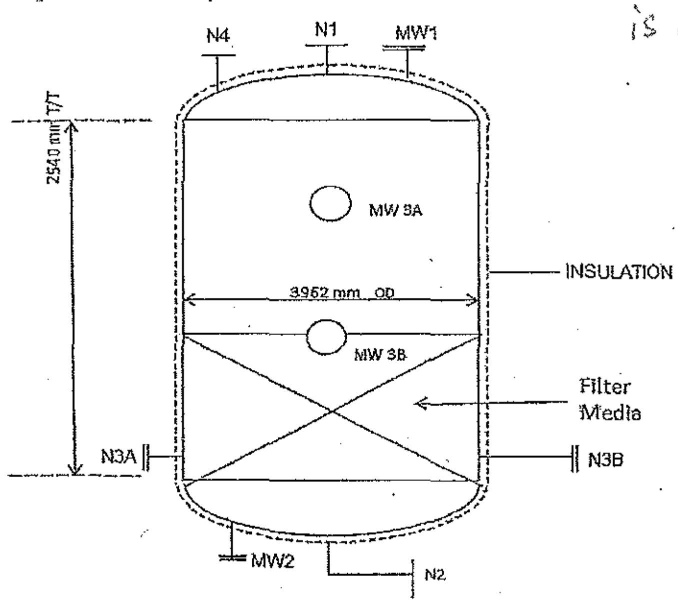
Requisition No.: 508298-200-45-MR-5675-0002

CONNECTION SCHEDULE

Mark	Nominal Size (In.)	Qty.	Flange ASME Class	Flange Type	Service	Projection (mm)
N1	12	1	150#	RFWN	Filter Inlet (HLS Effluent)	
N2	12	1	150#	RFWN	Filtered Water Outlet (elbow nozzle)	
N3 A/B	4	2	150#	RFWN	Media Outlet c/w gaskets, blind flange, bolts and nuts	
N4	3 0	1	150#	RFWN	PSV (Note 15)	
1 M1	24	1	150#	RFWN	Manway c/w davit, blind flange, gasket, bolts and nuts	
M2	24	1	150#	RFWN	Manway c/w davit, blind flange, gasket, bolts and nuts	
SG1A/SG1B	6	2	150#	Pad	Sight Glass - Single pane 2" thickness	
1					1	

VESSEL SKETCH

Size to be confirmed when PSV Calculation by vendor is done.



REVISIONS

NO.	DATE	BY	CHK	APP	DESCRIPTION
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B	25/May/12	SM	RA	SP	Issued for Quote
0	14/Sep/12	CS	RA	SP	Issued for Purchase
1	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	2 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 0	21 1	25 0	
Across filter - dirty @ max. flow, kPa		1 45	1 50	
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. 1
13) Turndown depends on system design (by others). Unit turndown expected is 3 to 1 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. 0
16) All sight glasses shall be single glass and shall be supplied by Seller. 1
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. 0
20) Control valves : One FCV per vessel to control equal flow to each vessel. To be supplied by others. 0
21) Maximum pressure drop across filter; one unit in backwash, remaining vessels at package design flow.
22) Vessels located indoors 2

REVISIONS

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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

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

After Filter Details

After Filter Media Specification(Note 18):

1. **Filter media support base:** 65 cm (total depth)
   Material: graduated anthracite coal
   Density: 0.8 g/cm^3 2

Layer #	Sieve size	Depth (cm)	Volume / filter (m^3)	Package Volume (m^3)
1.	~~1" x 3/4"~~	15	1.85	13
2.	~~3/4" x 1/2"~~	10	1.25	8.75
3.	~~1/2" x 1/4"~~	10	1.25	8.75
4.	~~1/4" x 1/8"~~	15	1.85	13
5.	~~1/8" x 1/16"~~	15	1.85	13

Support base shall be installed over Johnson screen strainers with 2.5 mm slots.

2. **Filter media:** 100 cm (depth)
   Material: anthracite coal
   Density: 1.4 g/cm^3
   Effective Size: 0.6 - 0.8 mm
   Uniformity coefficient: <= 1.5
   Moh's Hardness >3
   Acid Solubility < 2.5% by weight
   Media Volume: 12.5 m^3 per filter (87.5 m^3 total package)

Notes: 1

1. Normal temperature of backwash water is expected to be 80 degrees C, however during start-up the temperature may be as low as 10 degrees C.
2. Filter Media support base is: 2

Layer #	Sieve size
1	1-5/8" x 13/16"
2	9/16" x 13/16"
3	5/16" x 9/16"
4	3/16" x 5/16"
5	3/16" x 3/32"

move to table

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	SC	AV	AV	Ecodyne note
2	12/Mar/13	SC	AV	AV	Ecodyne note

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	4 of 4

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

H51 – General Arrangement/Outline Drawings

1

ECODYNE Limited

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

Dimensional Outline Drawing & BOM

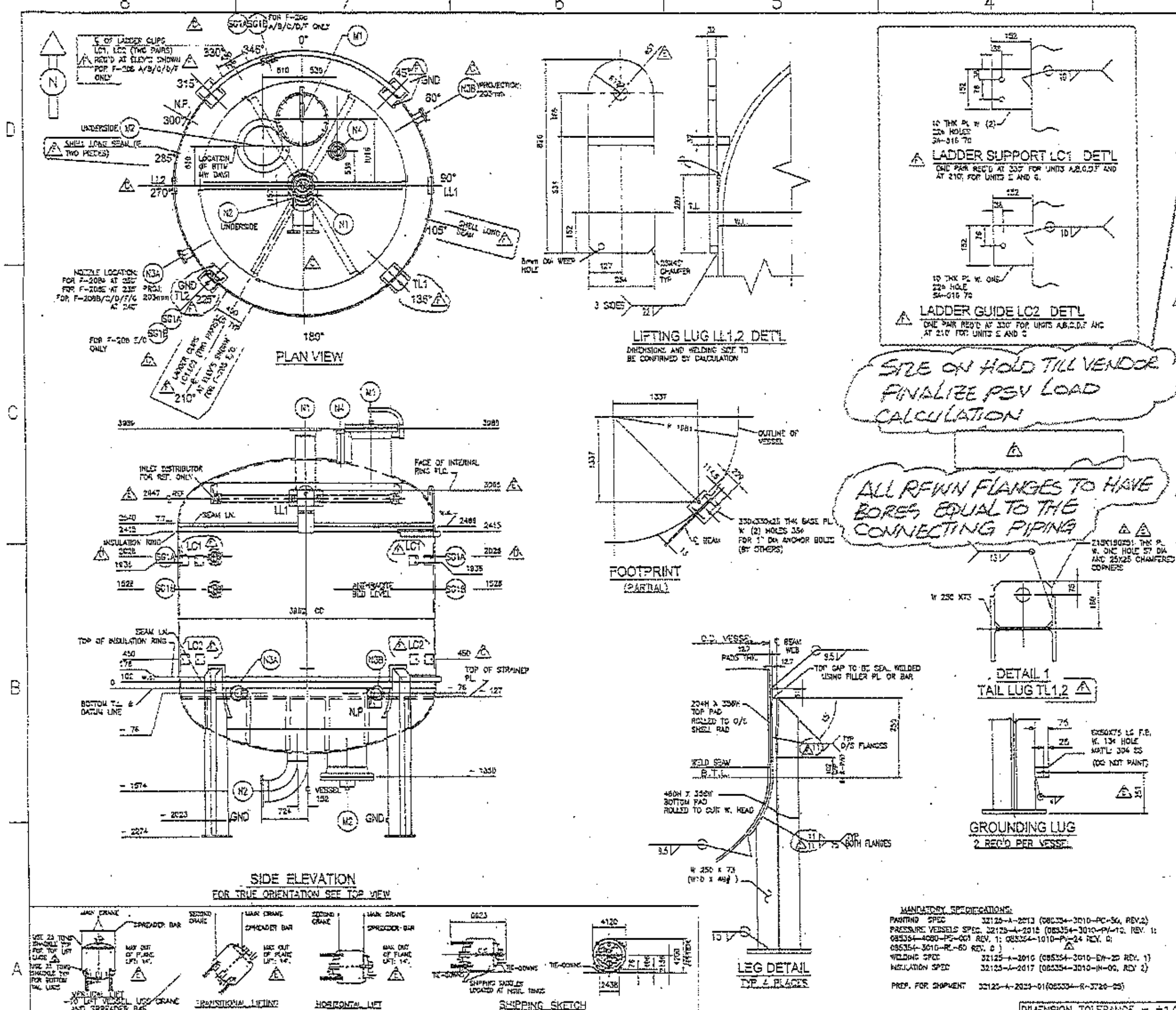

TABLE OF CONNECTIONS

ITEM	QTY	DESCRIPTION	MATERIAL	SERVICE
N1	1	12"- 150#, RF, WN, FLG./ SCH.80 (0.562"THK) PIPE NECK/ R-PAD (432 OD x 22.2THK)/CS INSIDE RING FL. CONN.	SA-105N/SA-106B/SA-516 70N/ SA-516 70	WATER INLET/BACKWASH OUT C/W INSIDE RING FLANGE
N2	1	12"- 150#, SR, WN, FLG./ SCH.80 (0.562"THK) PIPE NECK/ R-PAD (445 OD X22.2THK) / LR ELBOW 45	SA-105N/SA-106B /SA-516 70N/ SA-234 WPB	WATER OUTLET/BACKWASH INLET C/W INSIDE BAFFLE
N3A,N3B	2	6"- 150#, RF, LWN, FLG.	SA-105N	MEDIA REMOVAL C/W BLIND
N4	1	3"- 150#, RF, WN, FLG. /SCH.160 PIPE NECK (138 OD X 12.7 THK)	SA-105N/SA-106B /SA-516 70N	PSV
SG1A, SG1B	2	6"X RECESSED, STUDDED PAD (255 OD X 54.5 THK) / COVER PL.	SA-516 70 N/SA-516 70	SIGHTGLASS
M1	1	24"-150# RF WN FLG./XS PIPE NECK/R-PAD (932 OD X 22.2 THK) / COVER	SA-105N/SA-106 B/SA-516 70N/ SA-105N	TOP MANWAY C/W DAVIT
M2	1	24"-150# RF, WN FLG./XS PIPE NECK/R-PAD (948 OD X 22.2 THK) / COVER	SA-105N/SA-106 B/SA-516 70N SA-105N	BOTTOM MANWAY C/W DAVIT

BILL OF MATERIALS

ITEM	QTY	DESCRIPTION	MATERIAL	SERVICE
		ACCESSORIES		
LL1,LL2	2	LIFTING LUG - SEE DETAIL	SA-516 70N	
TL1,TL2	2	TAILING LUG SEE DETAIL	SA-516 70N	
NP	1	NAME PLATE BRACKET	SA-516 70N / SA-240 TP304/304L	
GND	2	GROUNDING LUG	SA-240 TP304/304L	
LEG	4	SUPPORT - VESSEL LEG	CSA-G40.21 350W	
LEG R-PAD	4 SET	LEG R-PAD	SA-516 70N	
M1	20	STUD BOLT 1 1/4" DIA X 7" LG. C/W (2)HEAVY HEX NUTS AND (2)SAE WASHERS	SA-193 B7/SA-194 2H/CS	BOLTING BY FABRICATOR
M2	20	STUD BOLT 1 1/4"DIA X 7" LG C/W (2)HEAVY HEX NUTS AND (2)SAE WASHERS.	SA-193 B7/SA-194 2H/CS	BOLTING BY FABRICATOR
N3A,N3B	16	STUD BOLT 5/8" DIA X 3 3/4"LG. C/W (2) HEX NUTS AND (2) SAE WASHERS.	SA-193 B7/SA-194 2H/CS	BOLTING BY FABRICATOR
N3A,N3B	16	STUD BOLT 1/2" DIA X 3 1/2"LG. C/W HEAVY HEX NUT AND SAE WASHER	SA-193 B7/SA-194 2H/CS	BOLTING BY FABRICATOR
~~1~~		~~PIPE SUPPORT (SEE DETAIL A)~~		

DESIGN DATA

CODE: ASME SECTION VIII, DIVISION 1, 2010 EDITION + A11 ADDENDUM
REGISTRATION, CRN FOR PROV. OF ALBERTA, U-STAMP REQ'D
INSPECTION: AUTHORIZED INSP., ECODYNE, CUSTOMER
DESIGN LOADS: PER NBC 2005 ED AND ALBERTA BUILDING CODE 2006 ED FOR CHRISTINA LAKE, ALBERTA
EARTHQUAKE : w/ 2 SITE CLASS "D"
WIND : INSTALLED INDOOR (CALC. NOT REQ'D)
INITIAL DESIGN PRESS. INTERNAL: 1034 kPa (g) @ 120 °C
INITIAL DESIGN PRESS. EXTERNAL: FULL VACUUM [MIN 84 kPa(d)] @ 120 °C
INTERNAL PRESSURE (MAWP) = 1041 kPa (g) @ 120 °C
EXTERNAL PRESSURE (MAEP) = 221.4 kPa (g) @ 120 °C
MDMT: -29°C @ 1037 kPa(g), EXCEPT LIFTING LUGS
MDMT FOR LIFTING LUGS : -45°C
MAP = 1037 kPa (g) @ 10 °C
SHOP HYDRO TEST PRESSURE: 1348 kPa (g) @ 10 °C
FIELD HYDRO TEST PRESSURE: 1348 kPa (g) @ 10 °C
CORROSION ALLOWANCE: 2.2 mm , INTERNAL
P.W.H.T.: NOT REQ'D
IMPACT TEST: NOT REQUIRED PER UCS-66, UG-20(f)
RADIOGRAPHY: SHELL LONG SEAM- FULL PER UW-11(a)(5)
HEAD-SHELL SEAM- SPOT PER UW-11(a)(5)(b)
JOINT EFFICIENCY: SHELL-1.00, TOP HEAD-1.00 WITH 100 % RT; BOTTOM HEAD- 1.00 WITH 100 % RT.

TOP HEAD: ASME CODE 2:1 ELLIPTICAL 3962 OD X 51 STR. FL. X 15.22 mm MAF, 22.2 mm NOM.
BOTTOM HEAD: ASME CODE 2:1 ELLIPTICAL 3962 OD X 102 STR. FL. X 19.05mm MAF, 25.4 mm NOM.
SHELL: 19.05 mm THK PLATE

MATERIALS: (AS APPLICABLE IF NOT OTHERWISE SPECIFIED.)
SHELL, HEADS, RE-PADS: SA-516 70 N
STRAINER PLATE INSIDE: SA-516 70 N
CLIPS ,GUSSETS WELDED TO PRESSURE ENCLOSURE: SA-516 70 N
LIFTING LUGS PLATES: SA-516 70 N, CHCA IMPACT TEST CERTIFIED
LEG BEAMS: SA/CSA-G40.21 350W; LEG BASE PLATES: A-36 OR G40.21 300W EXTERNAL INSULATION RINGS: SA/CSA-G40.21 300W
64mm DIA STAYRODS: SA/CSA-G40.21 300W
EXTERNAL STUD BOLTS (FULLY THREADED) SA-193 B7
EXTERNAL NUTS (HEAVY HEX) SA-194 2H
WASHERS: TYPE "A" PLAIN (ANSI B18.22.1- TABLE 1A) ZINC PLATED
REMOVABLE INTERNALS: 316 SS
GASKETS: EXTERNAL: 3.2mm THK SPW 316 SS WINDING, GRAPHITE FILLED, CS CENTERING RING
SIGHTWINDOWS: 1.6mm & 3.2mm THK FLUOROELASTOMER (GARLOCK 9780)
SIGHTGLASS: TEMPERED POLYCARBONATE
INTERIOR LINING: BARE
EXTERIOR COATING: (BY PAINTING SHOP) PER SPEC. 32125-A-2013
INSULATION: 38mm THICK MINERAL WOOL W. CORRUGATED ALUMINUM CLADDING

GENERAL NOTES :

1) NOZZLES TO HAVE PROJECTION INDICATED ON DWG. N2, N3A, N3B, N4, M1, M2 TO BE FLUSH WITH INSIDE SURFACE OF THE VESSEL
2) ALL BOLT HOLES ARE TO STRADDLE VESSEL CENTRE LINES UNLESS OTHERWISE NOTED
3) ALL CATEGORY A,B,D WELDS TO BE FULL PENETRATION WELDS.
4) MINIMUM 1/4"CONTINUOUS FILLET WELD ON ALL CLIPS AND ATTACHMENTS UNLESS OTHERWISE NOTED.
5) ALL OPENINGS SHALL BE REINFORCED TO SATISFY THE REQUIREMENTS OF THE ASME CODE
6) ALL REINFORCING PADS TO HAVE 1/4" NPT TELLTALE HOLE AND SHOP AIR-SOAP TESTED TO 25 PSIG
NOZZLE ≥ 12" SHALL HAVE 2 TELL TALE HOLES
FABRICATOR TO PROVIDE 1/4 NPT NIPPLES X 3"LG THREADED BOTH ENDS FOR ALL TELLTALE HOLES.
7) INTERIOR SURFACE PREP. BY FABRICATOR: BARE SURFACE INSIDE TO BE CLEAN WITH NO SHARP EDGES
8) EXTERIOR SURFACE PREP. BY FABRICATOR INCLUDES:
- ALL WELDS ARE CONTINUOUS UNLESS OTHERWISE NOTED.
- ALL SLAG AND WELD SPLATTER REMOVED.
- NO SHARP EDGES
9) PRIOR TO SHIPMENT ALL CONNECTIONS WITHOUT BLIND FLANGES ARE TO BE COVERED WITH 1/2" THK. PLYWOOD OR 1/8" THK. STEEL PLATE NO SMALLER THAN THE O.D. OF THE FLANGE AND SECURED WITH AT LEAST (4) BOLTS - BY FAB. SHOP
10) LINING SHOP SHALL SUPPLY ONE SET OF GASKETS FOR MANWAYS AND BLINDED CONNECTIONS.

MANDATORY SPECIFICATIONS:

PAINTING SPEC 32125-A-2013 (085354-3010-PC-56, REV.2)
PRESSURE VESSELS SPEC. 32125-A-2015 (085354-3010-PV-10, REV. 1; 085354-4080-PS-001 REV. 1; 085354-1010-PV-24 REV. 0; 085354-3010-RL-60 REV. 0)
WELDING SPEC 32125-A-2016 (085354-3010-EW-20 REV. 1)
INSULATION SPEC 32125-A-2017 (085354-3010-IN-02, REV 2)

PREP. FOR SHIPMENT 32125-A-2023-01(085354-R-3720-05)

VESSEL WEIGHT (Kg)		
SHIPPING	HYDROTEST	OPERATING
26100	71530	63100

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

REV	DATE	REMARKS	BY	CHKD
F	2013APR16	LADDER SUPPORT CLIPS DET'S ADDED AS NOTED		
E	2013MAR07	REVISION AS INDICATED BY	LP	IA
D	2013FEB05	REV'D AS NOTED	IA	FH
C	2013JAN17	REV'D AS NOTED	IA	FH
B	2012DEC13	SIGHTWINDOW ELEVATION REV'D.	IA	FH
A	2012DEC03	FIRST ISSUE	IA	FH

SCALE	N.T.S.	
	BY	DATE
DRAWN	IA	2012NOV10
CHECKED	FH	
APPROVED	AV	

TITLE
VESSEL ASS'Y
AFTER FILTER
3962mm OD X 2540mm T/T
TAG 3A-F-208 A TO G

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

ECODYNE Limited
A Marmon Water / Berkshire Hathaway Company

DWG. NO. 32125-D-2202-01 REV F

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SHEET 1 OF 1

TITLE	CUSTOMER
PROJECT BILL OF MATERIAL Tags: 3A-F-208 A to G 3A-V-211 A to F	MEG Energy Corporation c/o SNC-Lavalin Christina Lake Phase 3A PO No. P-5675-02

					SCALE:	N/A		ECODYNE Limited A Marmon Water/Berkshire Hathaway Company
						BY	DATE	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.
					DRAWN	AV	2013 07 June	DRAWING NO. 32125-A-1010 — REV A
A	2013 07 June	FIRST ISSUE	AV	IL	CHECKED	IL	2013 17 June	
REV	DATE	REMARKS	BY	CHKD	APPROVED	AV	2013 10 June	

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

2

ECODYNE Limited

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

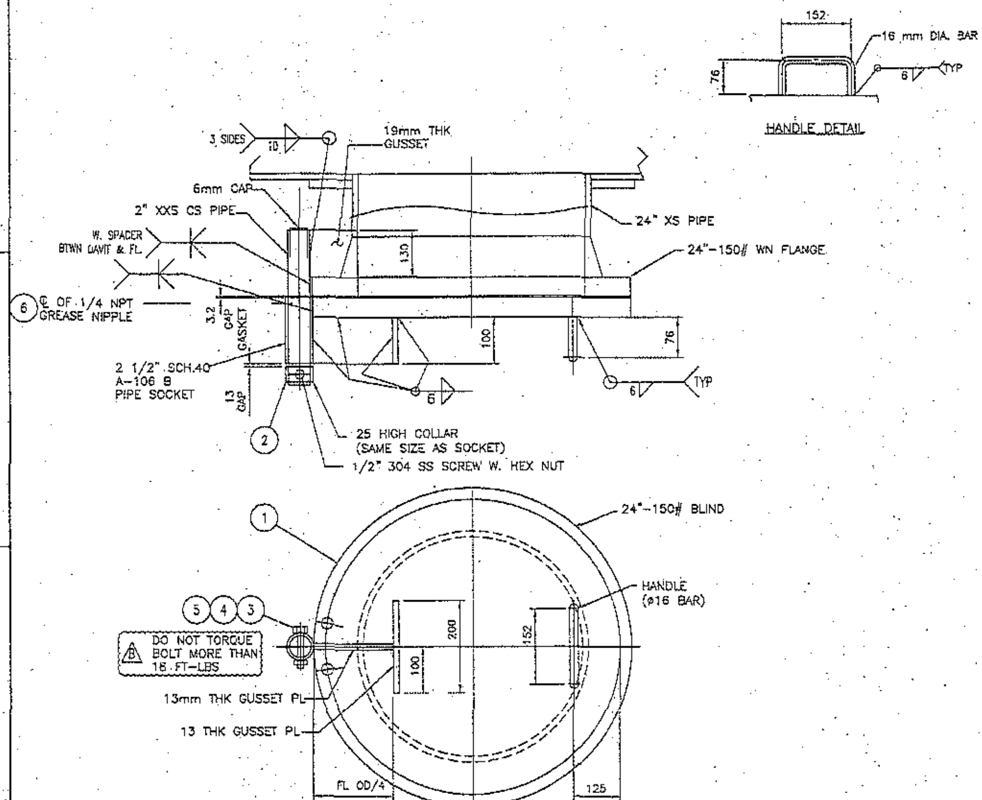
1

ECODYNE Limited

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

Equipment Detail Drawings c/w BOM

BILL OF MATERIAL			
ITEM	QTY	DESCRIPTION	MATERIAL
1		MANWAY COVER ASSEMBLY	
2		DAVIT COLLAR	A-106 B
3	1	1/2-13 X 4" HEX HD BOLT	18.8 S.S.
4	1	1/2-13 HEX NUT	18.8 S.S.
5	1	1/2"DIA LOCK WASHER	18.8 S.S.
6	1	1/4 NPT. GREASE FITTING	CS GALVANIZED



NOTES:

1. SEE VESSEL DWG. FOR: MANHOLE SIZE, RATING & FLANGES TYPE.
CHECK MANHOLE HEIGHT FOR DAVIT TO CLEAR VESSEL/INSULATION, HINGE OR DAVIT ORIENTATION, MATERIALS OF PRESSURE PARTS AND ATTACHMENTS WELDED TO THEM, LINING/PAINTING.
2. ALL DAVITS SHALL BE SCH.80 PIPE
3. PACK DAVIT SOCKET WITH GREASE BEFORE ASSEMBLY.
4. SOCKET PIPE: A-106 B.

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

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

REV	DATE	REMARKS	BY	CHKD
B	2013MAR11	REVISION AS INDICATED BY B	IA	FH
A	2012DEC13	FIRST ISSUE	IA	FH

SCALE	N.T.S.	
	BY	DATE
DRAWN	IA	2012NOV12
CHECKED	FH	2012DEC13
APPROVED	AV	2012DEC13

TITLE
ASS'Y & DETAILS
24" BOTTOM MANWAY
FOR AFTER FILTER

ECODYNE Limited
A Marmon Water / Berkshire Hathaway Company

DWG. NO. 32125-C-2221-01 DWG. NO. B

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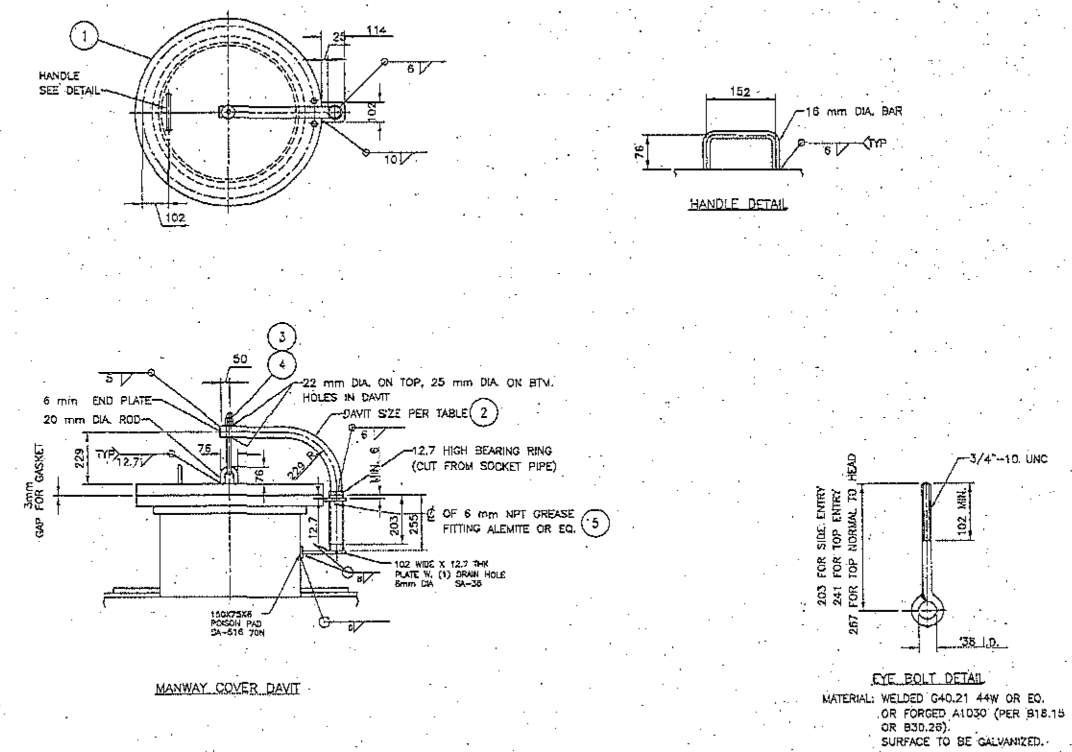
SHEET 1 OF 1

BILL OF MATERIAL			
ITEM	QTY	DESCRIPTION	MATERIAL
1	1	MANWAY COVER ASSEMBLY	SA-105
2	1	DAVIT ARM	SA-106B
3	2	HEX NUT, 3/4"-10 NC	A-307 GALV.
4	1	FLAT WASHER, ANSI TYPE 'A' PLAIN 2" O.D.	C.S. GALV.
5	1	1/4 NPT GREASE FITTING	C.S. GALV.

DAVIT SIZE	1 1/2" DIA.[2)]	2" DIA.[2)]
SOCKET SIZE	2" SCH.80	2 1/2" SCH.40
MANWAY (FLG & COVER) SIZE & RATING	18"-150#	24"- 150#
	20"-150#	30"- 150#
		18"- 300#
		20"- 300#



NOTES:

1. SEE VESSEL DWG. FOR:
   MANHOLE SIZE, RATING & FLANGES TYPE.
   CHECK MANHOLE HEIGHT FOR DAVIT TO CLEAR VESSEL/INSULATION.
   HINGE OR DAVIT ORIENTATION.
   MATERIALS OF PRESSURE PARTS AND ATTACHMENTS WELDED TO THEM.
   LINING/PAINTING.
2. ALL DAVITS SHALL BE SCH.80 PIPE
3. PACK DAVIT SOCKET WITH GREASE BEFORE ASSEMBLY.
4. SOCKET PIPE: A-106 B.

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

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

SCALE	1/1	
	BY	DATE
DRAWN	[signature]	2012NOV12
CHECKED	[signature]	2013 MAR 11
APPROVED	AY	2013 MAR 12

TITLE
ASS'Y
24" TOP MANWAY
FOR
AFTER FILTERS

ECODYNE Limited
A member of The Marmon Group of companies

DWG. NO. 32125-C-2220-01 REV A

REV	DATE	REMARKS	BY	CHKD
A	2013 MAR 11	FIRST ISSUE	[signature]	[signature]

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2

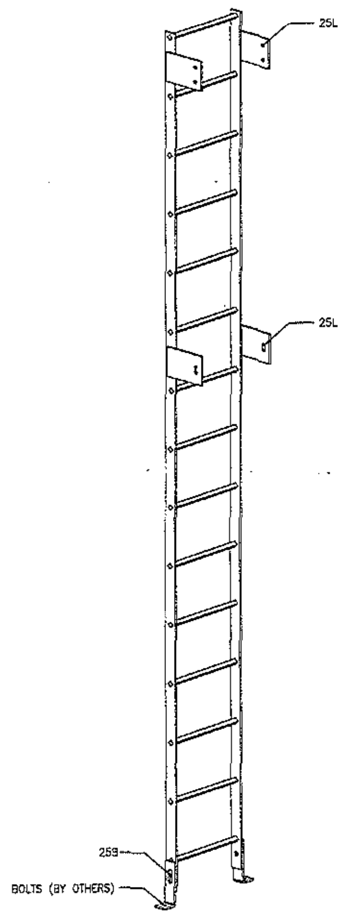
ECODYNE Limited

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 ±3.2 (±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 > ½"
   A307 ZINC PLATED IF ≤½"
   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

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

	BY	DATE
SCALE		
DRAWN		2013APR17
CHECKED		2013 MAY 15
APPROVED	AV	2013 MAY 17

TITLE
DETAIL & ASS'Y
LADDER
AFTER FILTER

ECODYNE Limited
A Marmon Water / Berkshire Hathaway Company

DWG. NO. 32125-D-2252-01 REV A

REV	DATE	REMARKS	BY	CHKD	REV	DATE	REMARKS	BY	CHKD	REV	DATE	REMARKS	BY	CHKD
										A	2013 MAY 17	FIRST ISSUE		

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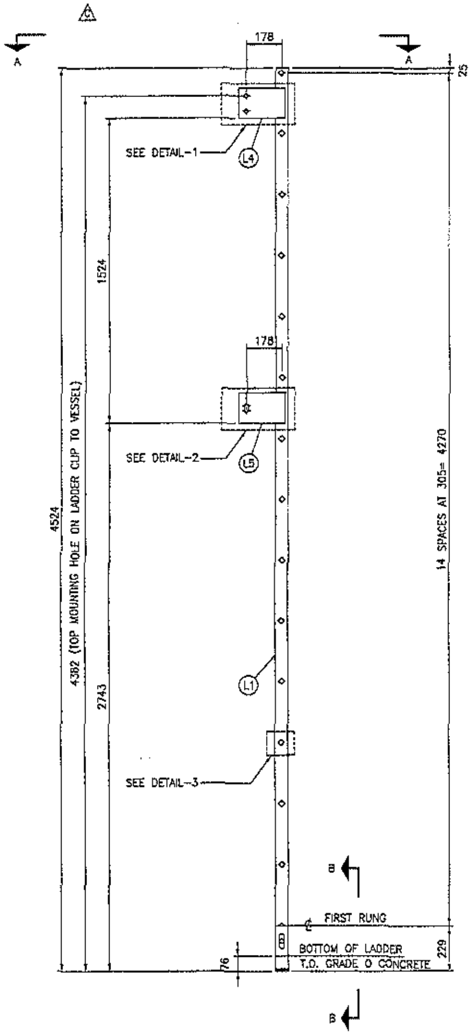
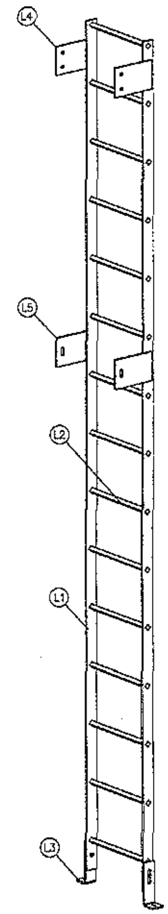
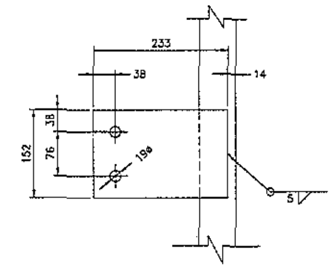


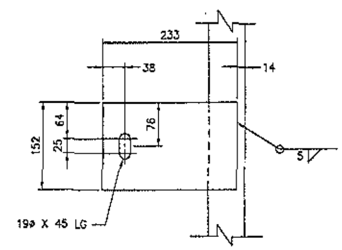
ELEVATION
SCALE NTS



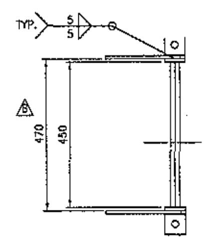
ISOVIEW



DETAIL 1
SCALE NTS



DETAIL 2
SCALE NTS



SECTION A / 02
SCALE NTS

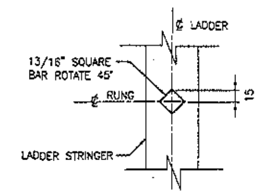
MATERIAL LIST

QTY	MARK	DESCRIPTION
2	L1	2 1/2" X 3/8" FLATBAR (LADDER STRINGER)
12	L2	3/4" SQUARE BAR (LADDER RUNGS)
2	L3	2 1/2" X 3/8" BENT PLATE (LADDER ANCHOR)
2	L4	3/8" THK PLATE (LADDER CLIPS ON LADDER)
2	L5	3/8" THK PLATE (LADDER CLIPS ON LADDER)
		QTY SHOWN FOR ONE LADDER

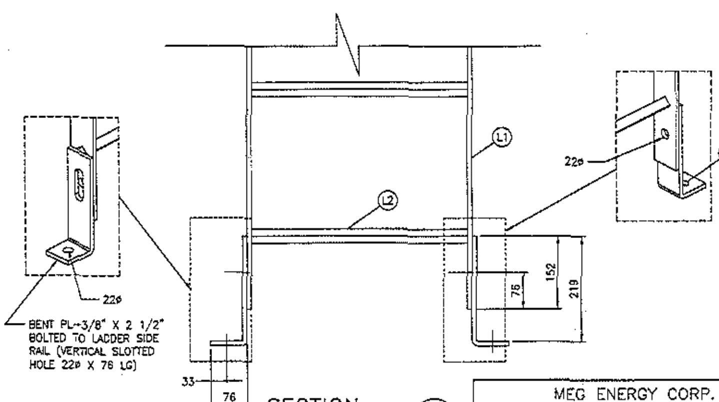
SHIPPING LIST

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)



DETAIL 3
SCALE NTS
LADDER RUNG



SECTION B / 02
SCALE NTS

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

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

REV	DATE	REMARKS	BY	CHKD
C	2014APR25	DIMENSION WAS IMPERIAL		
B	2014APR11	REVISED AS NOTED	LP	FH
A	2013MAY10	FIRST ISSUE	LP	FH

SCALE	BY	DATE
DRAWN	LP	2013APR17
CHECKED	FH	2013MAY10
APPROVED	AV	2013MAY10

TITLE
DETAIL & ASS'Y
LADDER
AFTER FILTER

ECODYNE Limited
A Marmon Water / Berkshire Hathaway Company

DWG. NO. 32125-D-2252-02 REV C

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3

ECODYNE Limited

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

Weld Location Plan

ECODYNE Limited

AFTER FILTERS
3A-F-208 A to G

Weld Map

ASME Vessels

Contents:

Title	Customer
Weld 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

REV	DATE	REMARKS	BY	CHKD		BY	DATE
					SCALE -		
					DRN	VEN	FEB 20 2013
A	FEB 20 2013	FIRST ISSUE	VEN	TB	CHKD	TB	FEB 20 2013
					APPD	AV	FEB 20 2013

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DWG. NO. 32125-A-2904

REV. A

LESENA STEEL LTD.

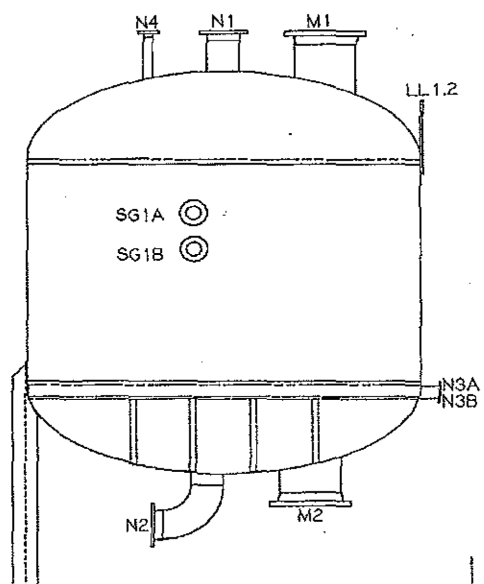
WELD MAP

Rev. 1 Date: FEB. 12/2013 Prepared By: Arie Willemsen

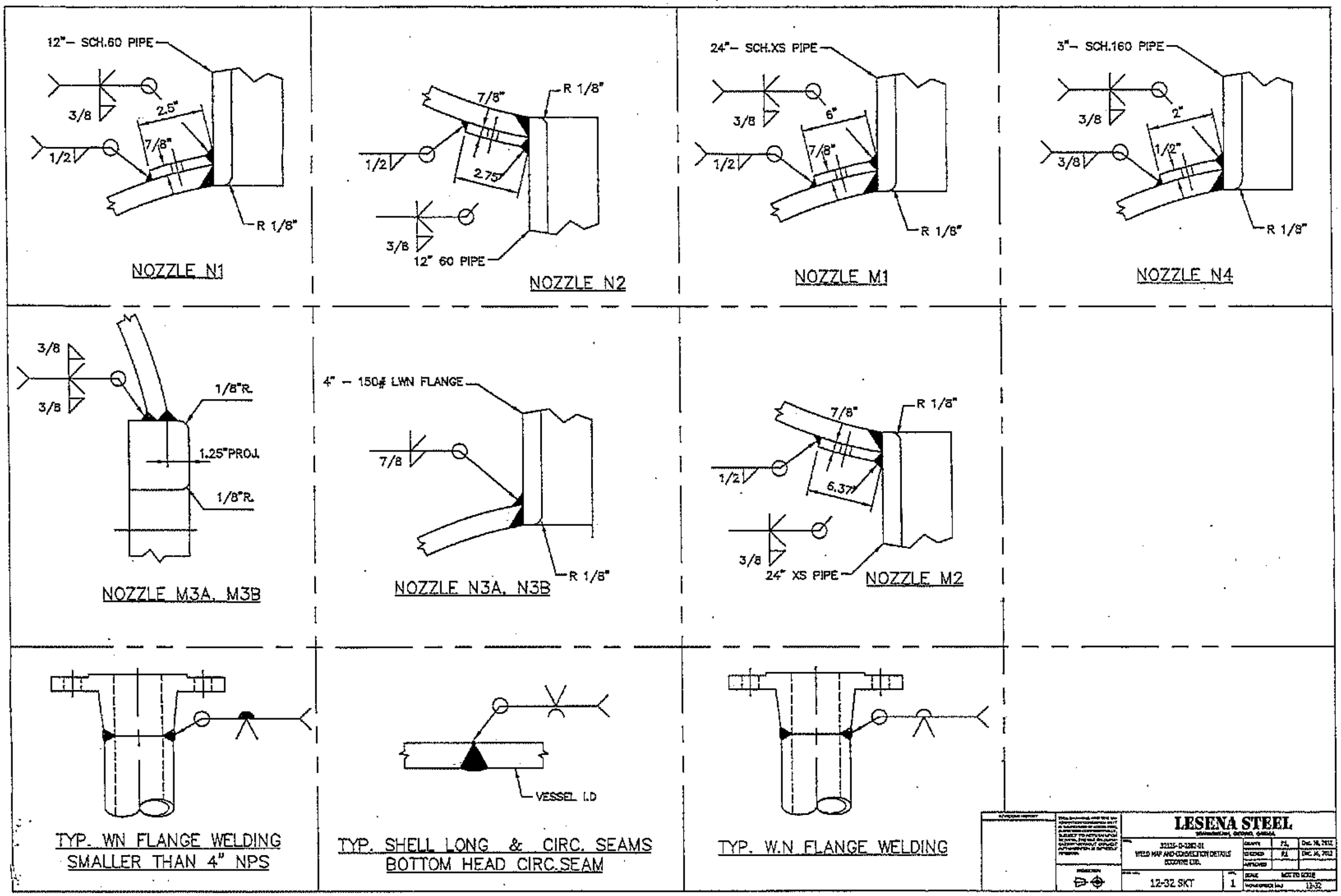
Job No.: 12-32 A - G Drawing No.:-32125-D--2202-01, Rev D Pages: 1 of 1

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



12"– SCH.60 PIPE
3/8
1/2
2.5"
7/8"
R 1/8"
NOZZLE N1
7/8"
R 1/8"
1/2
2.75
3/8
12" 60 PIPE
NOZZLE N2
24"– SCH.XS PIPE
3/8
6"
1/2
7/8"
R 1/8"
NOZZLE M1
3"– SCH.160 PIPE
3/8
2"
3/8
1/2"
R 1/8"
NOZZLE N4
3/8
3/8
1/8"R.
1.25"PROJ.
1/8"R.
NOZZLE M3A, M3B
4" – 150# LWN FLANGE
7/8
R 1/8"
NOZZLE N3A, N3B
7/8"
R 1/8"
1/2
6.37
3/8
24" XS PIPE
NOZZLE M2
TYP. WN FLANGE WELDING
SMALLER THAN 4" NPS
VESSEL I.D
TYP. SHELL LONG & CIRC. SEAMS
BOTTOM HEAD CIRC.SEAM
TYP. W.N FLANGE WELDING
LESENA STEEL
WELD MAP AND CONNECTION DETAILS
12-32 SKT
1
12-32

4

ECODYNE Limited

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

Non-Destructive Examination Location Plan

ECODYNE Limited

AFTER FILTERS
3A-F-208 A to G

NDE Map

ASME Vessels

Contents:

Title NDE 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

REV	DATE	REMARKS	BY	CHKD
A	FEB 20 2013	FIRST ISSUE	VEN	TB

SCALE -

	BY	DATE
DRN	VEN	FEB 20 2013
CHKD	TB	FEB 20 2013
APPD	AV	FEB 20 2013

ECODYNE Limited

A Marmon Water/Berkshire Hathaway Company

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DWG. NO.	REV.
32125-A-2906	A

LESENA STEEL LTD

NDE MAP

CRN No: V2929.2

CUSTOMER: ECODYNE Ltd.

JOB No : 12-32 A - G

VESSEL TYPE: AFTER FILTER VESSEL

SERIAL No: 0411-0417

HEAD THK.: TOP.-18.22 mm MIN.* BTM.-19.05 mm MIN.* SHELLTHK.: 19.05 mm NOM.*

DATE: Dec. 18, 2012

CODE ACCEPTANCE LEVEL: RT –2

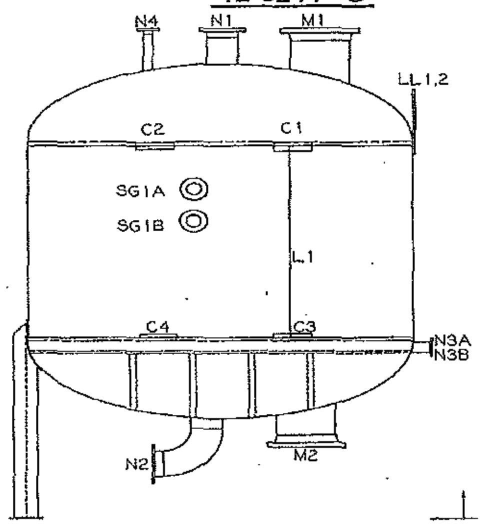
CIRCUMFERENTIAL SEAMS: SPOT

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 - G



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

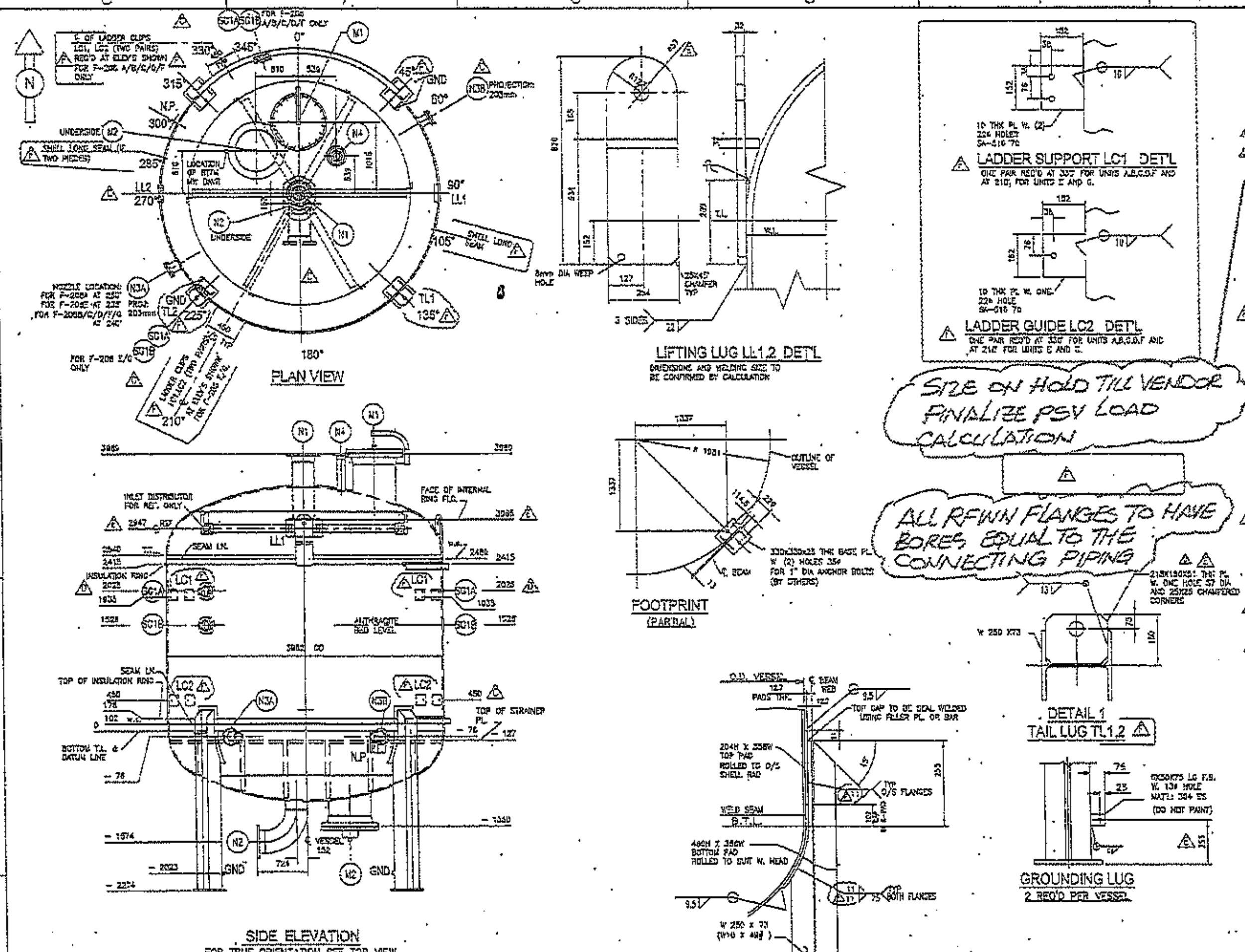
MPI : LIFTING LUGS

5

ECODYNE Limited

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

Lifting, Tailing Lug Drawings



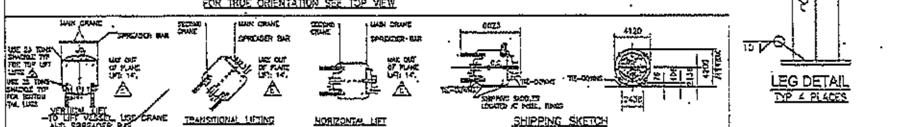


TABLE OF CONNECTIONS

ITEM	QTY	DESCRIPTION	MATERIAL	SERVICE
N1	1	12"-150#, RF, WN, FLG./ SCH.40 (0.562"THK) PIPE NECK/ R-PAD (432 OD x 22.2THK)/C/W INSIDE RING FL. CONN.	SA-105N/SA-106B/SA-516-70N/ SA-516 70	WATER INLET/BACKWASH OUT C/W INSIDE RING FLANGE
N2	1	12"-150#, RF, WN, FLG./ SCH.40 (0.562"THK) PIPE NECK/ R-PAD (465 OD 22.2THK) / LR ELBOW 90	SA-105N/SA-106B /SA-516 70N/ SA-234 WPB	WATER OUTLET/BACKWASH INLET C/W INSIDE BAFFLE
N3A,N3B	2	4"-150#, RF, LWN, FLG.	SA-105N	MEDIA REMOVAL C/W BLIND
N4	1	3"-150#, RF, WN, FLG. /SCH.160 PIPE NECK (193 OD X 12.7 THK)	SA-105N/SA-106B /SA-516 70N	PSV
SG1A, SG1B	2	6"Ø RECESSED, STUDDED PAD (285 OD X 54.6 THK) / COVER FL.	SA-516 70 N/SA-516 70	SIGHTGLASS
M1	1	24"-150# RF WN FLG./XS PIPE NECK/R-PAD (938 OD X 22.2 THK) / COVER	SA-105N/SA-106 B/SA-516 70N/ SA-105N	TOP MANWAY C/W DAVIT
M2	1	24"-150# RF, WN FLG./XS PIPE NECK/R-PAD (948 OD X 22.2 THK) / COVER	SA-105N/SA-106 B/SA-516 70N SA-105N	BOTTOM MANWAY C/W DAVIT

BILL OF MATERIALS

ITEM	QTY	DESCRIPTION	MATERIAL	SERVICE
		ACCESSORIES		
LL1,LL2	2	LIFTING LUG - SEE DETAIL	SA-516 70N	
TL1,TL2	2	TAILING LUG SEE DETAIL	SA-516 70N	
NP	1	NAME PLATE BRACKET	SA-516 70N / SA-240 TP304/304L	
GND	2	GROUNDING LUG	SA-240 TP304/304L	
LEG	4	SUPPORT - VESSEL LEG	CSA-G40.21 350W	
LEG R-PAD	4 SET	LEG R-PAD	SA-516 70N	
M1	20	STUD BOLT 1 1/4" DIA X 7" LG. C/W (2)HEAVY HEX NUTS AND (2)SAE WASHERS	SA-193 B7/SA-194 2H/CS	BOLTING BY FABRICATOR
M2	20	STUD BOLT 1 1/4"DIA X 7" LG C/W (2)HEAVY HEX NUTS AND (2)SAE WASHERS,	SA-193 B7/SA-194 2H/CS	BOLTING BY FABRICATOR
N3A,N3B	16	STUD BOLT 5/8" DIA X 3 3/4"LG. C/W (2) HEX NUTS AND (2) SAE WASHERS.	SA-193 B7/SA-194 2H/CS	BOLTING BY FABRICATOR
N1A,N1B	16	STUD BOLT 1/2" DIA X 3 1/2"LG. C/W HEAVY HEX NUT AND SAE WASHER	SA-193 B7/SA-194 2H/CS	BOLTING BY FABRICATOR
~~—~~	~~1~~	~~PIPE SUPPORT (SEE DETAIL 3)~~		

DESIGN DATA
CODE: ASME SECTION VIII, DIVISION 1, 2010 EDITION + A11 ADDENDUM.
REGISTRATION, CRN FOR PROV. OF ALBERTA. U-STAMP REQ'D
INSPECTION: AUTHORIZED INSP., ECODYNE, CUSTOMER.
DESIGN LOADS: PER NBC 2005 ED AND ALBERTA BUILDING CODE 2006 ED FOR CHRISTINA LAKE, ALBERTA
EARTHQUAKE I = 1.3; SITE CLASS 'D'
WIND : INSTALLED INDOOR (CALC. NOT REQ'D)
INITIAL DESIGN PRESS. INTERNAL: 1034 kPa (g) @ 120 °C
INITIAL DESIGN PRESS. EXTERNAL: FULL VACUUM [MIN 94 kPa(a)] @ 120 °C
INTERNAL PRESSURE (MAWP) = 1041 kPa (g) @ 120 °C
EXTERNAL PRESSURE (MAEP) = 221.4 kPa (g) @ 120 °C
MDMT: -29°C @ 1037 kPa(g), EXCEPT LIFTING LUGS
MDMT FOR LIFTING LUGS : -45°C
MAP = 1037 kPa (g) @ 10 °C
SHOP HYDRO TEST PRESSURE: 1348 kPa (g) @ 10 °C
FIELD HYDRO TEST PRESSURE: 1348 kPa (g) @ 10 °C
CORROSION ALLOWANCE: 3.2 mm , INTERNAL
P.W.H.T.: NOT REQ'D
IMPACT TEST: NOT REQUIRED PER UCS-66, UG-20(f)
RADIOGRAPHY. SHELL LONG SEAM- FULL PER UW-11(a)(5)
HEAD-SHELL SEAM- SPOT PER UW-11(a)(5)(b)
JOINT EFFICIENCY SHELL-1.00, TOP HEAD-1.00 WITH 100 % RT; BOTTOM HEAD- 1.00 WITH 100 % RT.

TOP HEAD. ASME CODE 2:1 ELLIPTICAL 3962 OD X 51 STR. FL. X 16.32 mm MAF, 22.2 mm NOM.
BOTTOM HEAD: ASME CODE 2:1 ELLIPTICAL 3962 OD X 102 STR. FL. X 19.03mm MAF, 25.4 mm NOM.
SHELL 18.05 mm THK. PLATE.

MATERIALS: (AS APPLICABLE IF NOT OTHERWISE SPECIFIED.)
SHELL, HEADS, RE-PADS: SA-516 70 N
STRAINER PLATE INSIDE: SA-516 70 N
CLIPS ,GUSSETS WELDED TO PRESSURE ENCLOSURE: SA-516 70 N
LIFTING LUGS PLATES: SA-516 70 N, CHARPY IMPACT TEST CERTIFIED
LEG BEAMS: SA/CSA-G40.21 350W; LEG BASE PLATES: A-36 OR G40.21 300W EXTERNAL INSULATION RINGS: SA/CSA-G40.21 300W
8mm. DIA. STAYRODS: SA/CSA-G40.21 300W
EXTERNAL STUD BOLTS (FULLY THREADED) SA-193 B7
EXTERNAL NUTS (HEAVY HEX) SA-194 2H
WASHERS: TYPE "A" PLAIN (ANSI B18.22.1- TABLE 1A) ZINC PLATED
REMOVABLE INTERNALS: 316 SS
GASKETS: EXTERNAL: 3.2mm THK SPW 316 SS WINDING, GRAPHITE FILLED, CS CENTERING RING
SIGHTWINDOWS: 1.6mm & 3.2mm THK FLUOROELASTOMER (GARLOCK 9780)
SIGHTGLASS: TEMPERED POLYCARBONATE
INTERIOR LINING, BARE
EXTERIOR COATING: (BY PAINTING SHOP) PER SPEC. 32125-A-2013
INSULATION: 38mm THICK MINERAL WOOL W. CORRUGATED ALUMINUM CLADDING

GENERAL NOTES:
1) NOZZLES TO HAVE PROJECTION INDICATED ON DWG. N2, N3A, N3B, N4, M1, M2 TO BE FLUSH WITH INSIDE SURFACE OF THE VESSEL.
2) ALL BOLT HOLES ARE TO STRADDLE VESSEL CENTRE LINES UNLESS OTHERWISE NOTED
3) ALL CATEGORY A,B,D WELDS TO BE FULL PENETRATION WELDS.
4) MINIMUM 1/4"CONTINUOUS FILLET WELD ON ALL CLIPS AND ATTACHMENTS UNLESS OTHERWISE NOTED.
5) ALL OPENINGS SHALL BE REINFORCED TO SATISFY THE REQUIREMENTS OF THE ASME CODE
6) ALL REINFORCING PADS TO HAVE 1/4" NPT TELLTALE HOLE AND SHOP AIR-SOAP TESTED TO 25 PSIG
NOZZLE ≥ 12" SHALL HAVE 2 TELL TALE HOLES
FABRICATOR TO PROVIDE 1/4 NPT NIPPLES X 3"LG THREADED BOTH ENDS FOR ALL TELLTALE HOLES
7) INTERIOR SURFACE PREP. BY FABRICATOR:
BARE SURFACE INSIDE TO BE CLEAN WITH NO SHARP EDGES
8) EXTERIOR SURFACE PREP. BY FABRICATOR INCLUDES:
- ALL WELDS ARE CONTINUOUS UNLESS OTHERWISE NOTED.
- ALL SLAG AND WELD SPLATTER REMOVED.
- NO SHARP EDGES.
9) PRIOR TO SHIPMENT ALL CONNECTIONS WITHOUT BLIND FLANGES ARE TO BE COVERED WITH 1/2" THK. PLYWOOD OR 1/8" THK. STEEL PLATE NO SMALLER THAN THE O.D. OF THE FLANGE AND SECURED WITH AT LEAST (4) BOLTS - BY FAB. SHOP.
10) LINING SHOP SHALL SUPPLY ONE SET OF GASKETS FOR MANWAYS AND BLINDED CONNECTIONS.

MANDATORY SPECIFICATIONS:

PAINTING SPEC	32125-A-2013 (085354-3010-PC-30, REV.2)
PRESSURE VESSELS SPEC.	32125-A-2015 (085354-3010-PV-10, REV. 1; 085354-4080-PS-001 REV. 1; 085354-1010-PV-24 REV. 0; 085354-3010-RL-60 REV. 0)
WELDING SPEC	32125-A-2016 (085354-3010-EW-20 REV. 1)
INSULATION SPEC	32125-A-2017 (085354-3010-IN-00, REV 2)
PREP. FOR SHIPMENT	32125-A-2020-01(085354-R-3720-05)

VESSEL WEIGHT (Kg)		
SHIPPING	HYDROTEST	OPERATING
26100	71830	63100

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

REV	DATE	REMARKS	BY	CHKD
F	2013APR16	LADDER SUPPORT CLIPS DET'S ADDED AS NOTED		
E	2013MAR07	REVISION AS INDICATED BY △	LP	IA
D	2013FEB05	REV'D AS NOTED	IA	FH
C	2013JAN17	REV'D AS NOTED	IA	FH
B	2012DEC13	SIGHTWINDOW ELEVATION REV'D.	IA	FH
A	2012DEC03	FIRST ISSUE	IA	FH

SCALE	N.T.S.	
	BY	DATE
DRAWN	IA	2012NOV10
CHECKED	FH	
APPROVED	AV	

TITLE
VESSEL ASS'Y
AFTER FILTER
3962mm OD X 2540mm T/T
TAG 3A-F-208 A TO G

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

ECODYNE Limited
A Marmon Water / Berkshire Hathaway Company

DWG. NO. 32125-D-2202-01 REV F

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

K51 – System Diagrams & Schedules

								VALVES OPEN: AFTER FILTER 3A-F-208A (NOTE 6)							PUMPS RUNNING	GENERAL NOTES
							VALVES DESCRIPTION	SERVICE INLET	SERVICE OUTLET	BACKWASH INLET	BACKWASH OUTLET	RINSE VALVE (BY OTHERS)	BACKWASH FLOW CONTROL (BY OTHERS)	INLET FLOW CONTROL	AFTER FILTER BW PUMP (BY OTHERS)	
OPERATION	ACCUM TIME (MIN)	STEP No.	STEP TIME (MIN)	FLOW m3/h	FLOW gpm or scfm	DESCRIPTION	SOURCE / TAG	3A-KV-20811	3A-KV-20815	3A-KV-20813	3A-KV-20812	3A-KV-20814	3A-FIC-20602	3A-FIC-20811	3A-P-208A/B/C	REMARKS
BACKWASH SEQUENCE	-	1	1.0	-	-	CLOSURE	—							SC		
	-	2	10.0	430	1883	BACKWASH	HEATED CLEARWATER WATER			X	X		SO/M		X	NOTE 4
	-	3	2.0	-	-	BED SETTLE	—						SC			
	-	4	5.0	142	625	BED RINSE	TREATED WATER	X				X		SO/M		NOTE 5
SERVICE STATUS				-	-	OFF	—									
				142	625	SERVICE	TREATED WATER	X	X					M		
				-	-	BACKWASH (SEE ABOVE)	—									

LEGEND

X - OPEN VALVE OR PUMP ON
CLOSE - BLANK SPACE
M - MODULATING VALVE
Z - VALVE WITH RATE SET
SO - SLOW OPENING VALVE
SC - SLOW CLOSING VALVE

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: 166 m^3/h PER VESSEL.
NORMAL: 7 FILTERS ON LINE: 142 m^3/h PER VESSEL.

4) BACKWASH SYSTEM DESIGN FLOW IS 540 m^3/h (2378 gpm). EXPECTED BACKWASH FLOW IS 430 m^3/h AT 60 °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.

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

6) SEQUENCE SHOWN IS FOR 3A-F-208A (TYPICAL OF SEVEN). ONLY ONE FILTER IS IN BACKWASH AT A TIME.

MEG ENERGY CORP.
CHRISTINA LAKE FACILITY
CHRISTINA REGIONAL PROJ.
PHASE 3A
ENG.: SNC- LAVALIN

P.O.: P-5675-02

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

SCALE	NTS	
	BY	DATE
DRAWN	SA	NOV.22/12
CHECKED	SS	NOV.22/12
APPROVED	AV	NOV.22/12

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

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DWG. NO. 32125-B-3052-01 REV C

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MAR 13 2013

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

L51 – Calculations, Simulations & Analyses

1

ECODYNE Limited

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								CUSTOMER
After Filter Pressure Vessel And Nozzle Load Calculations								MEG Energy Corporation c/o SNC Lavalin Christina Lake Phase 3A PO No. P-5675-02
					SCALE -			ECODYNE Limited A Marmon Water/Berkshire Hathaway Company
						BY	DATE	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.
B	2013 Mar 28	PER CLIENT MARK-UP AND UPDATED VESSEL DRAWING	VEN	RJ	DRN	VEN	2013 Jan 15	DWG. NO. / REV.
A	2013 Jan 15	FIRST ISSUE	AV	RJ	CHKD	RJ	2013 Mar 28	32125-A-2902 / B
REV	DATE	REMARKS	BY	CHKD	APPD	AAV	2013 Mar 28	

Table Of Contents

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 <= 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

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
TOP HEAD	1,034	120	1,041.57	1,279.83	224.31	120	-42.1	Note 1		No
Straight Flange on TOP HEAD	1,034	120	1,313.95	1,553.46	354.46	120	-48	Note 2		No
3962 mm O.D. SHELL	1,034	120	1,069.57	1,332.18	221.4	120	-42.46	Note 3		No
Straight Flange on BOTTOM HEAD	1,034	120	1,289.56	1,553.46	354.46	120	-48	Note 5		No
BOTTOM HEAD	1,034	120	1,065.8	1,338.64	250.06	120	-42.26	Note 4		No
SUPPORT LEG	1,034	120	1,041.57	N/A	N/A	N/A	N/A	N/A		N/A
TOP MANWAY (M1)	1,034	120	1,041.57	1,041.57	224.31	120	-47.9	Nozzle	Note 6	No
								Pad	Note 7	No
BOTTOM MANWAY (M2)	1,034	120	1,041.57	1,041.57	250.06	120	-47.36	Nozzle	Note 8	No
								Pad	Note 9	No
WATER INLET (N1)	1,034	120	1,041.57	1,041.57	224.31	120	-47.9	Nozzle	Note 10	No
								Pad	Note 11	No
WATER OUTLET (N2)	1,034	120	1,041.57	1,041.57	250.06	120	-47.26	Nozzle	Note 12	No
								Pad	Note 13	No
MEDIA REMOVAL (N3A)	1,034	120	1,041.57	1,041.57	250.06	120	-29	Note 14		No
MEDIA REMOVAL (N3B)	1,034	120	1,041.57	1,041.57	250.06	120	-29	Note 14		No
PSV/VENT (N4)	1,034	120	1,041.57	1,041.57	224.31	120	-48	Nozzle	Note 15	No
								Pad	Note 16	No
SIGHT GLASS (SG1A)	1,034	120	1,041.57	1,041.57	221.4	120	-43.36	Note 17		No
SIGHT GLASS (SG1B)	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) $1.5*0.9*S_y$ 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) $1.5*0.9*S_y$ 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
M1	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		
M2	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		
N1	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		
N2	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		
N3A	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
N3B	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
N4	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		
SG1A	SIGHT GLASS	255 OD x 54.5	Nozzle	SA-516 70	No	Yes	Yes	N/A	No
SG1B	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/A_r (%)
						Nom t (mm)	Design t (mm)	User t (mm)	Width (mm)	t_{pad} (mm)		
M1	609.6	12.7	6.88	Yes	Yes	18.22*	16.67		152.4	22.2	3.2	100.4
M2	609.6	12.7	6.8	Yes	Yes	19.05*	17.26		161.92	22.2	3.2	104.3
N1	323.85	14.27	13.18	Yes	Yes	18.22*	16.65		63.5	22.2	3.2	107.7
N2	323.85	14.27	13.18	Yes	Yes	19.05*	17.29		69.85	22.2	3.2	105.1
N3A	139.7	19.05	8.93	Yes	Yes	19.05*	18.59		N/A	N/A	3.2	104.6
N3B	139.7	19.05	8.93	Yes	Yes	19.05*	18.59		N/A	N/A	3.2	104.6
N4	88.9	11.13	9.14	Yes	Yes	18.22*	16.66		50.8	12.7	3.2	128.7
SG1A	255	54.5	11.31	Yes	Yes	19.05	18.39		N/A	N/A	3.2	127.9
SG1B	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
TOP HEAD	SA-516 70	3,962 OD	999.61	18.22*	18.12	3.2	1.00	Internal
Straight Flange on TOP HEAD	SA-516 70	3,962 OD	51	22.2	18.21	3.2	1.00	Internal
3962 mm O.D. SHELL	SA-516 70	3,962 OD	2,387	19.05	18.54	3.2	1.00	Internal
Straight Flange on BOTTOM HEAD	SA-516 70	3,962 OD	102	22.2	18.56	3.2	1.00	Internal
BOTTOM HEAD	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							
TOP HEAD	0	0	659.1	608.6	39.5	0	0	0	0	0	2.98
3962 mm O.D. SHELL	0	0	33.4	29.4	1,848.7	0	0	0	102.5	10,474*	0.52
BOTTOM HEAD	0	0	656.7	621.6	79	0	0	0	20.6	10,409*	3.1
SUPPORT LEG	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 m^2

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 kPa @ 120 °C
External design pressure: P_e = 103.42 kPa @ 120 °C

Static liquid head:

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

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

Design MDMT = -28.89°C
Rated MDMT = -42.1°C

No impact test performed
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)	=	<u>18.12</u> mm
Design thickness due to external pressure (t_e)	=	<u>13.41</u> mm
Maximum allowable working pressure (MAWP)	=	<u>1,041.57</u> kPa
Maximum allowable pressure (MAP)	=	<u>1,279.83</u> 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 Metric: B = 35.7978 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 mm + Corrosion = 10.21 mm + 3.2 mm = 13.41 mm

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

t = $1.67*P_e*D_o*K / (2*S*E + 2*1.67*P_e*(K - 0.1))$ + Corrosion
= 1.67*103.42*3,962*0.997835 / (2*138,000*1 + 2*1.67*103.42*(0.997835 - 0.1)) + 3.2
= 5.67 mm

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

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

Equivalent outside spherical radius (R_o)
R_o = K_o*D_o
= 0.8918*3,962
= 3,533.3 mm

A = $0.125 / (R_o / t)$
= 0.125 / (3,533.3 / 15.02)
= 0.000531

From Table CS-2 Metric: B = 52.768 MPa

P_a = $B / (R_o / t)$
= 52,767.98 / (3,533.3 / 15.02)
= 224.3097 kPa

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

P = $2*S*E*t / ((K*D_o - 2*t*(K - 0.1))*1.67) - P_{s2}$
= 2*138,000*1*15.02 / ((0.997835*3,962 - 2*15.02*(0.997835 - 0.1))*1.67) - 0
= 632.19 kPa

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

% Extreme fiber elongation - UCS-79(d)

EFE = $(75*t / R_f)*(1 - R_f / R_o)$
= $(75*22.2 / 678.45)*(1 - 678.45 / \infty)$
= 2.4541%

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, ln. 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 kPa @ 120 °C
External design pressure: P_e = 103.42 kPa @ 120 °C

Static liquid head:

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

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

Design MDMT = -28.89 °C
Rated MDMT = -42.46 °C

No impact test performed
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 L_c = 2,387 mm
t = 19.05 mm

Insulation thk:	38 mm	density:	256.3 kg/m³	Weight:	292.1 kg
Insulation Support Spacing:	2,438.4 mm	Individual Support Weight:	9.1 kg	Total Support Weight:	9.1 kg
Lining/Refractory thickness:	6.35 mm	density:	1,922.21 kg/m³	Weight:	358.6 kg

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

t = $P*R_o$ / (S*E + 0.40*P) + Corrosion
= 1,072.09*1,981 / (138,000*1.00 + 0.40*1,072.09) + 3.2
= 18.54 mm

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

P = S*E*t / (R_o - 0.40*t) - P_s
= 138,000*1.00*15.85 / (1,981 - 0.40*15.85) - 38.09
= 1,069.57 kPa

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

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

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

L / D_o = 3,196.26 / 3,962 = 0.8067
D_o / t = 3,962 / 11.54 = 343.4494
From table G: A = 0.000269
From table CS-2 Metric: B = 26.64 MPa

$$P_a = 4*B / (3*(D_o / t))$$
$$= 4*26{,}640 / (3*(3{,}962 / 11.54))$$
$$= 103.42 \text{ kPa}$$

Design thickness for external pressure P_a = 103.42 kPa

t_a = t + Corrosion = 11.54 + 3.2 = 14.74 mm

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

L / D_o = 3,196.26 / 3,962 = 0.8067
D_o / t = 3,962 / 15.85 = 249.9748
From table G: A = 0.000418
From table CS-2 Metric: B = 41.508 MPa

$$P_a = 4*B / (3*(D_o / t))$$
$$= 4*41{,}508.05 / (3*(3{,}962 / 15.85))$$
$$= 221.4 \text{ kPa}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = (50*t / R_f)*(1 - R_f / R_o)$$
$$= (50*19.05 / 1{,}971.48)*(1 - 1{,}971.48 / \infty)$$
$$= 0.4831\%$$

The extreme fiber elongation does not exceed 5%.

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

$$P_v = W / (2*\pi*R_m) + M / (\pi*R_m^2)$$
$$= 98.03*17{,}381.9 / (2*\pi*1{,}973.08) + 10000*34{,}208.7 / (\pi*1{,}973.08^2)$$
$$= 165.4676 \text{ N/cm}$$

$$\alpha = P_v / (P_e*D_o)$$
$$= 100*165.4676 / (103.42*3{,}962)$$
$$= 0.0404$$

$$n = 7$$

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

$= 1.23 / (3{,}196.26 / 3{,}962)^2$
$= 1.8900$

Ratio P_e $= (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (7^2 - 1 + 1.8900 + 1.8900*0.0404) / (7^2 - 1 + 1.8900)$
$= 1.0015$

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

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

P_v $= W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 98.03*-62{,}474.3 / (2*\pi*1{,}973.08) + 10000*5{,}638.6 / (\pi*1{,}973.08^2)$
$= -489.5850$ N/cm

α $= P_v / (P_e*D_o)$
$= 100*-489.5850 / (103.42*3{,}962)$
$= -0.1195$

n $= 7$

m $= 1.23 / (L / D_o)^2$
$= 1.23 / (3{,}196.26 / 3{,}962)^2$
$= 1.8900$

Ratio P_e $= (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (7^2 - 1 + 1.8900 + 1.8900*-0.1195) / (7^2 - 1 + 1.8900)$
$= 1.0000$

Ratio $P_e * P_e \leq$ 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, ln. 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 kPa @ 120 °C
External design pressure: P_e = 103.42 kPa @ 120 °C

Static liquid head:

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

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

The head internal pressure design thickness is 18.6 mm.

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

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

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

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

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

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)

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

$$A = 0.125 / (R_o / t)$$
$$= 0.125 / (3{,}531.84 / 10.2)$$
$$= 0.000361$$

From Table CS-2 Metric: B = 35.7978 MPa

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

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

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

t = $1.67*P_e*D_o*K / (2*S*E + 2*1.67*P_e*(K - 0.1))$ + Corrosion
= 1.67*103.42*3,962*0.997834 / (2*138,000*1 + 2*1.67*103.42*(0.997834 - 0.1)) + 3.2
= 5.67 mm

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)
R_o = K_o*D_o
= 0.8914*3,962
= 3,531.84 mm

A = $0.125 / (R_o / t)$
= 0.125 / (3,531.84 / 15.85)
= 0.000561

From Table CS-2 Metric: B = 55.7213 MPa

P_a = $B / (R_o / t)$
= 55,721.34 / (3,531.84 / 15.85)
= 250.0571 kPa

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

P = $2*S*E*t / ((K*D_o - 2*t*(K - 0.1))*1.67) - P_{s2}$
= 2*138,000*1*15.85 / ((0.997834*3,962 - 2*15.85*(0.997834 - 0.1))*1.67) - 0
= 667.38 kPa

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

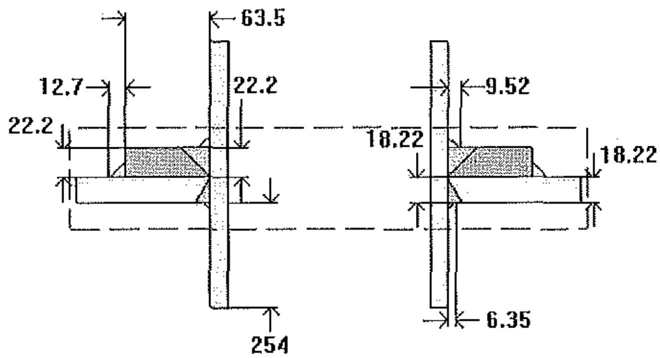
% Extreme fiber elongation - UCS-79(d)

EFE = $(75*t / R_f)*(1 - R_f / R_o)$
= $(75*22.2 / 678.16)*(1 - 678.16 / \infty)$
= 2.4552%

The extreme fiber elongation does not exceed 5%.

WATER INLET (N1)

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



$t_{w(lower)}$ = 18.22 mm
Leg_{41} = 9.53 mm
$t_{w(upper)}$ = 22.2 mm
Leg_{42} = 12.7 mm
Leg_{43} = 6.35 mm
h_{new} = 254 mm
D_p = 450.85 mm
t_e = 22.2 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:	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, 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
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, ln. 19) (normalized)
Diameter:	450.85 mm
Is split:	No

ASME B16.5-2009 Flange

Description:	NPS 12 Class 150 WN A105

Bolt Material:	SA-193 B7 Bolt <= 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

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2) For P = 1,046.15 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}
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

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(301.7, 150.85 + (14.27 - 3.2) + (18.22 - 3.2))
= 301.7 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(18.22 - 3.2), 2.5*(14.27 - 3.2) + 22.2)
= 37.55 mm

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(2.5*(18.22 - 3.2), 2.5*(14.27 - 3.2 - 3.2))
= 19.69 mm

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 1,046.1486*150.85 / (118,000*1 - 0.6*1,046.1486)
= 1.34 mm

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

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 mm

Area required per UG-37(c)

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

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

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

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

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

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
= <u>41.0175</u> cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>4.6781</u> cm^2

= 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 cm^2

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

A_2 = smaller of the following= $\underline{6.249}$ cm^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= (5*(11.07 - 1.34)*0.8551*15.02) / 100$
$= 6.249\ cm^2$

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= (2*(11.07 - 1.34)*(2.5*11.07 + 22.2)*0.8551) / 100$
$= 8.3026\ cm^2$

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

$= 5*t*t_i*f_{r2}$
$= (5*15.02*7.87*0.8551) / 100$
$= \underline{5.0566}\ cm^2$

$= 5*t_i*t_i*f_{r2}$
$= (5*7.87*7.87*0.8551) / 100$
$= \underline{2.6511}\ cm^2$

$= 2*h*t_i*f_{r2}$
$= (2*250.8*7.87*0.8551) / 100$
$= \underline{33.7747}\ cm^2$

$A_{41} = Leg^2*f_{r3}$
$= (9.53^2*0.8551) / 100$
$= \underline{0.7755}\ cm^2$

$A_{42} = Leg^2*f_{r4}$
$= (12.7^2*1) / 100$
$= \underline{1.6129}\ cm^2$

$A_{43} = Leg^2*f_{r2}$
$= (1.78^2*0.8551) / 100$
$= \underline{0.0271}\ cm^2$

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

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
$= 4.6781 + 6.249 + 2.6511 + 0.7755 + 1.6129 + 0.0271 + 28.194$

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

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

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

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

UG-45 Nozzle Neck Thickness Check

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

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

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

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

t_{b1} = 18.08 mm

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[18.08 , 4.7]
= 18.08 mm

t_b = min[t_{b3} , t_{b1}]
= min[11.53 , 18.08]
= 11.53 mm

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

Available nozzle wall thickness new, t_n = 0.875*14.27 = 12.49 mm

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*138 =	102.12 MPa
Nozzle wall in shear:	0.7*118 =	82.6 MPa
Inner fillet weld in shear:	0.49*118 =	57.82 MPa
Outer fillet weld in shear:	0.49*138 =	67.62 MPa
Upper groove weld in tension:	0.74*138 =	102.12 MPa
Lower fillet weld in shear:	0.49*118 =	57.82 MPa

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*S_i = $(\pi / 2)$*323.85*9.53*57.82 = 280,160.5 N

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*S_o = $(\pi / 2)$*450.85*12.7*67.62 = 608,178.28 N

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*t_n*S_n = $(\pi / 2)$*312.78*11.07*82.6 = 449,436.31 N

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*323.85*15.02*102.12 = 780,248.65 N

(5) Lower fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*S_l = $(\pi / 2)$*323.85*1.78*57.82 = 52,296.63 N

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*323.85*22.2*102.12 = 1,153,261.07 N

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

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

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

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

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

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

Path 1-1 through (2) & (3) = 608,178.28 + 449,436.31 = 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 = 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 = 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	N
Circumferential moment:	M_1 =	12,390	N-m
Circumferential shear:	V_2 =	12,100	N
Longitudinal moment:	M_2 =	12,390	N-m
Longitudinal shear:	V_1 =	12,100	N
Torsion moment:	M_t =	17,520	N-m
Internal pressure:	P =	1,046.15	kPa
Head yield stress:	S_y =	236	MPa

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

Mean dish radius R_m = 3,554.18 mm

U = r_o / Sqr(R_m*t) = 0.976
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =123.52 MPa

Maximum combined stress (P_L+P_b+Q) = 266.86 MPa
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-414 MPa

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

Maximum local primary membrane stress (P_L) = 145.62 MPa
Allowable local primary membrane stress (P_L) = +-1.5*S = +-207 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 / Sqr(R_m*t) = 0.445
Pressure stress intensity factor, I = 0.47135 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =58.219 MPa

Maximum combined stress (P_L+P_b+Q) = 109.39 MPa
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-414 MPa

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

Maximum local primary membrane stress (P_L) = 63 MPa
Allowable local primary membrane stress (P_L) = +-1.5*S = +-207 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*	0.1465	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
Total σ_x stress		17.478	93.596	109.041	16.954	17.478	93.596	109.041	16.954
Membrane σ_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
Total σ_y stress		45.74	69.044	73.746	45.588	45.74	69.044	73.746	45.588
Membrane σ_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
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

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

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 (≤ S = 118 MPa)

Shear stress in the nozzle wall due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi{*}R_i{*}t_n)$
$= (12{,}100^2 + 12{,}100^2)^{0.5} / (\pi{*}150.85{*}11.07)$
= 3.26 MPa

$\sigma_{torsion} = M_t / (2{*}\pi{*}R_i^2{*}t_n)$
$= 17{,}520 / (2{*}\pi{*}150.85^2{*}11.07)$

= 11.064 MPa

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 3.26 + 11.064
= 14.325 MPa

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

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm^2) For Pe = 224.31 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}
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

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

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-28 t_{rn} = 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} = lesser of 1 or S_n / S_v = 0.8551

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

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

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

A = 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}))
= (0.5*(301.7*15.02*1 + 2*11.07*15.02*1*(1 - 0.8551))) / 100
= <u>22.898</u> cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>0</u> cm^2

= 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*15.02) - 2*11.07*(1*15.02 - 1*15.02)*(1 - 0.8551)) / 100
= 0 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 + 11.07)*(1*15.02 - 1*15.02) - 2*11.07*(1*15.02 - 1*15.02)*(1 - 0.8551)) / 100
= 0 cm^2

A_2 = smaller of the following= <u>6.0626</u> cm^2

= 5*(t_n - t_m)*f_{r2}*t
= (5*(11.07 - 1.63)*0.8551*15.02) / 100
= 6.0626 cm^2

= 2*(t_n - t_m)*(2.5*t_n + t_e)*f_{r2}
= (2*(11.07 - 1.63)*(2.5*11.07 + 22.2)*0.8551) / 100
= 8.0548 cm^2

A_3 = smaller of the following= <u>2.6511</u> cm^2

= 5*t*t_i*f_{r2}
= (5*15.02*7.87*0.8551) / 100
= <u>5.0566</u> cm^2

= 5*t_i*t_i*f_{r2}
= (5*7.87*7.87*0.8551) / 100
= <u>2.6511</u> cm^2

$= 2*h*t_i*f_{r2}$
$= (2*250.8*7.87*0.8551) / 100$
$= \underline{33.7747}\ cm^2$

$A_{41} = Leg^2*f_{r3}$
$= (9.53^2*0.8551) / 100$
$= \underline{0.7755}\ cm^2$

$A_{42} = Leg^2*f_{r4}$
$= (12.7^2*1) / 100$
$= \underline{1.6129}\ cm^2$

$A_{43} = Leg^2*f_{r2}$
$= (1.78^2*0.8551) / 100$
$= \underline{0.0271}\ cm^2$

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

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

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

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

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

UG-45 Nozzle Neck Thickness Check

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

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

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

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

t_{b2}	=	6.41 mm

t_{b2}	=	max[t_{b2} , $t_{b\ UG16}$]
	=	max[6.41 , 4.7]
	=	6.41 mm

t_b	=	min[t_{b3} , t_{b2}]
	=	min[11.53 , 6.41]
	=	6.41 mm

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

Available nozzle wall thickness new, t_n = 0.875*14.27 = 12.49 mm

The nozzle neck thickness is adequate.

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

L / D_o	= 452.73 / 323.85		=	1.3980
D_o / t	= 323.85 / 1.63		=	198.2439
From table G:		A	=	0.000337
From table CS-2 Metric:		B	=	33.3504 MPa

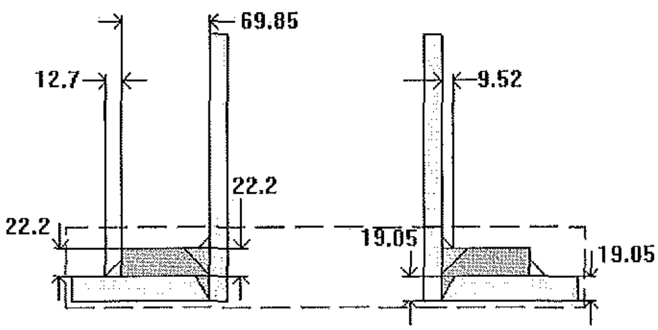
P_a	=	4*B / (3*(D_o / t))
	=	4*33,350.43 / (3*(323.85 / 1.63))
	=	224.31 kPa

Design thickness for external pressure P_a = 224.31 kPa

t_a = t + Corrosion = 1.63 + 3.2 = 4.83 mm

WATER OUTLET (N2)

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



$t_{w(lower)}$ = 19.05 mm
Leg_{41} = 9.53 mm
$t_{w(upper)}$ = 22.2 mm
Leg_{42} = 12.7 mm
D_p = 463.79 mm
t_e = 22.2 mm

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, Lpr:	459.69 mm
Projection available outside vessel to flange face, Lf:	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

Bolt Material:	SA-193 B7 Bolt <= 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

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2) For P = 1,095.89 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}
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

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

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(19.05 - 3.2), 2.5*(14.27 - 3.2) + 22.2)
= 39.62 mm

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 1,095.8895*150.85 / (118,000*1 - 0.6*1,095.8895)
= 1.41 mm

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

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 mm

Area required per UG-37(c)

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

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

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

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

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

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
= 42.9946 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 5.2561 cm^2

= 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 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*14.09) - 2*11.07*(1*15.85 - 1*14.09)*(1 - 0.8551)) / 100
= 0.891 cm^2

A_2 = smaller of the following= 6.5497 cm^2

$= 5*(t_n - t_m)*f_{r2}*t$
$= (5*(11.07 - 1.41)*0.8551*15.85) / 100$
$= 6.5497\ cm^2$

$= 2*(t_n - t_m)*(2.5*t_n + t_e)*f_{r2}$
$= (2*(11.07 - 1.41)*(2.5*11.07 + 22.2)*0.8551) / 100$
$= 8.2458\ cm^2$

$A_{41} = Leg^2*f_{r3}$
$= (9.53^2*0.8551) / 100$
$= \underline{0.7755}\ cm^2$

$A_{42} = Leg^2*f_{r4}$
$= (12.7^2*1) / 100$
$= \underline{1.6129}\ cm^2$

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= ((463.79 - 324.09)*22.2*1) / 100$
$= \underline{31.0134}\ cm^2$

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

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

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

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

UG-45 Nozzle Neck Thickness Check

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

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

$t_{a\ UG\text{-}22}$ = 5.37 mm

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[4.61 , 5.37]
= 5.37 mm

t_{b1} = 18.79 mm

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[18.79 , 4.7]
= 18.79 mm

t_b = min[t_{b3} , t_{b1}]
= min[11.53 , 18.79]
= 11.53 mm

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

Available nozzle wall thickness new, t_n = 0.875*14.27 = 12.49 mm

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*138 = 102.12 MPa
Nozzle wall in shear:	0.7*118 = 82.6 MPa
Inner fillet weld in shear:	0.49*118 = 57.82 MPa
Outer fillet weld in shear:	0.49*138 = 67.62 MPa
Upper groove weld in tension:	0.74*138 = 102.12 MPa

Strength of welded joints:

(1) Inner fillet weld in shear
(π / 2)*Nozzle OD*Leg*S_i = (π / 2)*323.85*9.53*57.82 = 280,160.5 N

(2) Outer fillet weld in shear
(π / 2)*Pad OD*Leg*S_o = (π / 2)*463.79*12.7*67.62 = 625,635.56 N

(3) Nozzle wall in shear
(π / 2)*Mean nozzle dia*t_n*S_n = (π / 2)*312.78*11.07*82.6 = 449,436.31 N

(4) Groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*323.85*15.85*102.12 = 823,366.07 N

(6) Upper groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*323.85*22.2*102.12 = 1,153,261.07 N

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

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

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

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

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

Load for path 1-1 lesser of W or W_{1-1} = 525,389.29 N
Path 1-1 through (2) & (3) = 625,635.56 + 449,436.31 = $\underline{1{,}075{,}071.87}$ 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} = 142,513.73 N
Path 2-2 through (1), (4), (6) = 280,160.5 + 823,366.07 + 1,153,261.07 = $\underline{2{,}256{,}787.63}$ 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 N
Path 3-3 through (2), (4) = 625,635.56 + 823,366.07 = $\underline{1{,}449{,}001.62}$ 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	N
Circumferential moment:	M_1 =	12,390	N-m
Circumferential shear:	V_2 =	12,100	N
Longitudinal moment:	M_2 =	12,390	N-m
Longitudinal shear:	V_1 =	12,100	N
Torsion moment:	M_t =	17,520	N-m
Internal pressure:	P =	1,095.89	kPa
Head yield stress:	S_y =	236	MPa

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

Mean dish radius R_m = 3,554.59 mm

U = r_o / Sqr(R_m*t) = 0.976
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =122.616 MPa

Maximum combined stress (P_L+P_b+Q) = 248.24 MPa
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-414 MPa

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

Maximum local primary membrane stress (P_L) = 142.01 MPa
Allowable local primary membrane stress (P_L) = +-1.5*S = +-207 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 / Sqr(R_m*t) = 0.44
Pressure stress intensity factor, I = 0.51997 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =63.756 MPa

Maximum combined stress (P_L+P_b+Q) = 113.02 MPa
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-414 MPa

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

Maximum local primary membrane stress (P_L) = 68.31 MPa
Allowable local primary membrane stress (P_L) = +-1.5*S = +-207 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
Total σ_x stress		24.594	97.83	112.681	23.945	24.594	97.83	112.681	23.945
Membrane σ_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
Total σ_y stress		51.814	74.139	78.662	51.621	51.814	74.139	78.662	51.621
Membrane σ_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
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

$\sigma_{n\,(Pm)} = P^*R_i / (2^*t_n) - P_r / (\pi^*(R_o^2 - R_i^2)) + M^*R_o / I$
$= 1{,}095.89 / 1000^*150.85 / (2^*9.29) - -9{,}880 / (\pi^*(161.93^2 - 150.85^2)) + 1.7522E{+}07^*161.93 / 1.3324E{+}08$
$= 31.099$ MPa

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 (≤ S = 118 MPa)

Shear stress in the nozzle wall due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi^*R_i^*t_n)$
$= (12{,}100^2 + 12{,}100^2)^{0.5} / (\pi^*150.85^*11.07)$
$= 3.26$ MPa

$\sigma_{torsion} = M_t / (2^*\pi^*R_i^{2*}t_n)$
$= 17{,}520 / (2^*\pi^*150.85^{2*}11.07)$

= 11.064 MPa

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 3.26 + 11.064
= 14.325 MPa

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

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm^2) For Pe = 250.06 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}
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

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(301.93, 150.96 + (14.27 - 3.2) + (19.05 - 3.2))
= 301.93 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(19.05 - 3.2), 2.5*(14.27 - 3.2) + 22.2)
= 39.62 mm

Nozzle required thickness per UG-28 t_{rn} = 1.88 mm

From UG-37(d)(1) required thickness t_r = 15.85 mm

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

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

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

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

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

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

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
= <u>24.1817</u> cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>0</u> cm^2

= 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 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 cm^2

A_2 = smaller of the following= <u>6.2322</u> cm^2

= 5*(t_n - t_{rn})*f_{r2}*t
= (5*(11.07 - 1.88)*0.8551*15.85) / 100
= 6.2322 cm^2

= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}
= (2*(11.07 - 1.88)*(2.5*11.07 + 22.2)*0.8551) / 100
= 7.8471 cm^2

A_{41} = Leg^2*f_{r3}
= (9.53^2*0.8551) / 100
= <u>0.7755</u> cm^2

A_{42} = Leg^2*f_{r4}
= (12.7^2*1) / 100
= <u>1.6129</u> cm^2

A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}
= ((463.79 - 324.09)*22.2*1) / 100
= <u>31.0134</u> cm^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= 0 + 6.2322 + 0.7755 + 1.6129 + 31.0134
= 39.634 cm^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 19 mm or t_n or t_e = 11.07 mm
$t_{c(min)}$ = lesser of 6 mm or 0.7*t_{min} = 6 mm
$t_{c(actual)}$ = 0.7*Leg = 0.7*9.53 = 6.67 mm

Outer fillet: t_{min} = lesser of 19 mm or t_e or t = 15.85 mm
$t_{w(min)}$ = 0.5*t_{min} = 7.92 mm
$t_{w(actual)}$ = 0.7*Leg = 0.7*12.7 = 8.89 mm

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-28}$ = 5.08 mm

$t_{a\ UG-22}$ = 4.55 mm

t_a = max[$t_{a\ UG-28}$, $t_{a\ UG-22}$]
= max[5.08 , 4.55]
= 5.08 mm

t_{b2} = 6.78 mm

t_{b2} = max[t_{b2} , $t_{b\ UG16}$]
= max[6.78 , 4.7]
= 6.78 mm

t_b = min[t_{b3} , t_{b2}]
= min[11.53 , 6.78]
= 6.78 mm

t_{UG-45} = max[t_a , t_b]
= max[5.08 , 6.78]
= 6.78 mm

Available nozzle wall thickness new, t_n = 0.875*14.27 = 12.49 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
From table G: A = 0.000326
From table CS-2 Metric: B = 32.3485 MPa

P_a = 4*B / (3*(D_o / t))
= 4*32,348.52 / (3*(323.85 / 1.88))
= 250.06 kPa

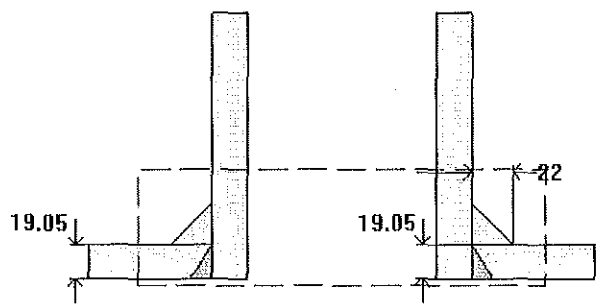
Design thickness for external pressure P_a = 250.06 kPa

t_a = t + Corrosion = 1.88 + 3.2 = 5.08 mm

MEDIA REMOVAL (N3A)

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

$t_{w(lower)}$ = 19.05 mm
Leg_{41} = 22 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, 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

Hydrotest rating:	3,000 kPa @ 10°C
PWHT performed:	No

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

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(109.19, 54.59 + (19.05 - 3.2) + (19.05 - 3.2))$$
$$= 109.19 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$$
$$= MIN(2.5*(19.05 - 3.2), 2.5*(19.05 - 3.2) + 0)$$
$$= 39.62 \text{ mm}$$

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

$$t_{rn} = P*R_n / (S_n*E - 0.6*P)$$
$$= 1,081.8959*54 / (138,000*1 - 0.6*1,081.8959)$$
$$= 0.42 \text{ mm}$$

Required thickness t_r from UG-37(a)

t_r = $P*D_o*K / (2*S*E + 2*P*(K - 0.1))$
= 1,081.9*3,962*0.997834 / (2*138,000*1 + 2*1,081.9*(0.997834 - 0.1))
= 15.39 mm

Area required per UG-37(c)

Allowable stresses: S_n = 138, S_v = 138 MPa

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= (109.19*15.39*1 + 2*15.85*15.39*1*(1 - 1)) / 100
= 16.803 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.5032 cm^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= (109.19*(1*15.85 - 1*15.39) - 2*15.85*(1*15.85 - 1*15.39)*(1 - 1)) / 100
= 0.5032 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*15.85 - 1*15.39) - 2*15.85*(1*15.85 - 1*15.39)*(1 - 1)) / 100
= 0.2923 cm^2

A_2 = smaller of the following= 12.2245 cm^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= (5*(15.85 - 0.42)*1*15.85) / 100
= 12.2245 cm^2

= $5*(t_n - t_{rn})*f_{r2}*t_n$
= (5*(15.85 - 0.42)*1*15.85) / 100
= 12.2251 cm^2

A_{41} = Leg^2*f_{r2}
= $(22^2*1) / 100$
= 4.84 cm^2

Area = $A_1 + A_2 + A_{41}$

$= 0.5032 + 12.2245 + 4.84$
$= \underline{17.5677}\ cm^2$

As Area >= 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
$t_{c(actual)} = 0.7*Leg = 0.7*22 = 15.4$ 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.

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 1,081.8959*54 / (138,000*1 - 0.6*1,081.8959) + 3.2
= 3.62 mm

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[3.62 , 0]
= 3.62 mm

t_{b1} = 18.59 mm

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[18.59 , 4.7]
= 18.59 mm

t_b = min[t_{b3} , t_{b1}]
= min[8.93 , 18.59]
= 8.93 mm

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[3.62 , 8.93]
= 8.93 mm

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 Pe = 250.06 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}
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

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(109.19, 54.59 + (19.05 - 3.2) + (19.05 - 3.2))$$
$$= 109.19 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$$
$$= MIN(2.5*(19.05 - 3.2), 2.5*(19.05 - 3.2) + 0)$$
$$= 39.62 \text{ mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0.77 mm

From UG-37(d)(1) required thickness t_r = 15.85 mm

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

Allowable stresses: S_n = 138, S_v = 138 MPa

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

$A = 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}))$
$= (0.5*(109.19*15.85*1 + 2*15.85*15.85*1*(1 - 1))) / 100$
$= \underline{8.653}$ cm²

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{0}$ cm²

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= (109.19*(1*15.85 - 1*15.85) - 2*15.85*(1*15.85 - 1*15.85)*(1 - 1)) / 100$
$= 0$ cm²

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= (2*(15.85 + 15.85)*(1*15.85 - 1*15.85) - 2*15.85*(1*15.85 - 1*15.85)*(1 - 1)) / 100$
$= 0$ cm²

A_2 = smaller of the following= $\underline{11.9503}$ cm²

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= (5*(15.85 - 0.77)*1*15.85) / 100$
$= 11.9503$ cm²

$= 5*(t_n - t_{rn})*f_{r2}*t_n$
$= (5*(15.85 - 0.77)*1*15.85) / 100$
$= 11.9509$ cm²

$A_{41} = Leg^2*f_{r2}$
$= (22^2*1) / 100$
$= \underline{4.84}$ cm²

Area $= A_1 + A_2 + A_{41}$
$= 0 + 11.9503 + 4.84$
$= \underline{16.7903}$ cm²

As Area >= 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
$t_{c(actual)} = 0.7*Leg = 0.7*22 = 15.4$ 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.

$t_{a\ UG\text{-}28}$ = 3.97 mm

t_a = max[$t_{a\ UG\text{-}28}$, $t_{a\ UG\text{-}22}$]
= max[3.97 , 0]
= 3.97 mm

t_{b2} = 6.78 mm

t_{b2} = max[t_{b2} , $t_{b\ UG16}$]
= max[6.78 , 4.7]
= 6.78 mm

t_b = min[t_{b3} , t_{b2}]
= min[8.93 , 6.78]
= 6.78 mm

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[3.97 , 6.78]
= 6.78 mm

Available nozzle wall thickness new, t_n = 19.05 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 Metric: B = 34.0228 MPa

P_a = 4*B / (3*(D_o / t))
= 4*34,022.83 / (3*(139.7 / 0.77))
= 250.05 kPa

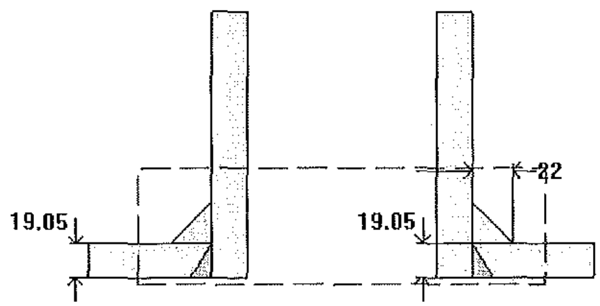
Design thickness for external pressure P_a = 250.05 kPa

t_a = t + Corrosion = 0.77 + 3.2 = 3.97 mm

MEDIA REMOVAL (N3B)

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

$t_{w(lower)}$ = 19.05 mm
Leg_{41} = 22 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

Hydrotest rating:	3,000 kPa @ 10°C
PWHT performed:	No

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

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(109.19, 54.59 + (19.05 - 3.2) + (19.05 - 3.2))
= 109.19 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(19.05 - 3.2), 2.5*(19.05 - 3.2) + 0)
= 39.62 mm

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 1,081.8959*54 / (138,000*1 - 0.6*1,081.8959)
= 0.42 mm

Required thickness t_r from UG-37(a)

$$
\begin{aligned}
t_r &= P*D_o*K / (2*S*E + 2*P*(K - 0.1)) \\
&= 1{,}081.9*3{,}962*0.997834 / (2*138{,}000*1 + 2*1{,}081.9*(0.997834 - 0.1)) \\
&= 15.39 \text{ mm}
\end{aligned}
$$

Area required per UG-37(c)

Allowable stresses: S_n = 138, S_v = 138 MPa

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

$$
\begin{aligned}
A &= d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}) \\
&= (109.19*15.39*1 + 2*15.85*15.39*1*(1 - 1)) / 100 \\
&= \underline{16.803} \text{ cm}^2
\end{aligned}
$$

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{0.5032}$ cm^2

$$
\begin{aligned}
&= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\
&= (109.19*(1*15.85 - 1*15.39) - 2*15.85*(1*15.85 - 1*15.39)*(1 - 1)) / 100 \\
&= 0.5032 \text{ cm}^2
\end{aligned}
$$

$$
\begin{aligned}
&= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\
&= (2*(15.85 + 15.85)*(1*15.85 - 1*15.39) - 2*15.85*(1*15.85 - 1*15.39)*(1 - 1)) / 100 \\
&= 0.2923 \text{ cm}^2
\end{aligned}
$$

A_2 = smaller of the following= $\underline{12.2245}$ cm^2

$$
\begin{aligned}
&= 5*(t_n - t_{rn})*f_{r2}*t \\
&= (5*(15.85 - 0.42)*1*15.85) / 100 \\
&= 12.2245 \text{ cm}^2
\end{aligned}
$$

$$
\begin{aligned}
&= 5*(t_n - t_{rn})*f_{r2}*t_n \\
&= (5*(15.85 - 0.42)*1*15.85) / 100 \\
&= 12.2251 \text{ cm}^2
\end{aligned}
$$

$$
\begin{aligned}
A_{41} &= Leg^2*f_{r2} \\
&= (22^2*1) / 100 \\
&= \underline{4.84} \text{ cm}^2
\end{aligned}
$$

Area = $A_1 + A_2 + A_{41}$

$= 0.5032 + 12.2245 + 4.84$

$= \underline{17.5677}\ cm^2$

As Area >= 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
$t_{c(actual)}$ = 0.7*Leg = 0.7*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.

$t_{a\ UG-27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 1,081.8959*54 / (138,000*1 - 0.6*1,081.8959) + 3.2
= 3.62 mm

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[3.62 , 0]
= 3.62 mm

t_{b1} = 18.59 mm

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[18.59 , 4.7]
= 18.59 mm

t_b = min[t_{b3} , t_{b1}]
= min[8.93 , 18.59]
= 8.93 mm

t_{UG-45} = max[t_a , t_b]
= max[3.62 , 8.93]
= 8.93 mm

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 Pe = 250.06 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}
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

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(109.19, 54.59 + (19.05 - 3.2) + (19.05 - 3.2))
= 109.19 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(19.05 - 3.2), 2.5*(19.05 - 3.2) + 0)
= 39.62 mm

Nozzle required thickness per UG-28 t_{rn} = 0.77 mm

From UG-37(d)(1) required thickness t_r = 15.85 mm

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

Allowable stresses: S_n = 138, S_v = 138 MPa

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

$A = 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}))$
$= (0.5*(109.19*15.85*1 + 2*15.85*15.85*1*(1 - 1))) / 100$
$= \underline{8.653}\ cm^2$

Area available from FIG. UG-37.1

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

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= (109.19*(1*15.85 - 1*15.85) - 2*15.85*(1*15.85 - 1*15.85)*(1 - 1)) / 100$
$= 0\ cm^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= (2*(15.85 + 15.85)*(1*15.85 - 1*15.85) - 2*15.85*(1*15.85 - 1*15.85)*(1 - 1)) / 100$
$= 0\ cm^2$

A_2 = smaller of the following= $\underline{11.9503}$ cm^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= (5*(15.85 - 0.77)*1*15.85) / 100$
$= 11.9503\ cm^2$

$= 5*(t_n - t_{rn})*f_{r2}*t_n$
$= (5*(15.85 - 0.77)*1*15.85) / 100$
$= 11.9509\ cm^2$

$A_{41} = Leg^2*f_{r2}$
$= (22^2*1) / 100$
$= \underline{4.84}\ cm^2$

$Area = A_1 + A_2 + A_{41}$
$= 0 + 11.9503 + 4.84$
$= \underline{16.7903}\ cm^2$

As Area >= 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
$t_{c(actual)}$ = 0.7*Leg = 0.7*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.

$t_{a\ UG\text{-}28}$ = 3.97 mm

t_a = max[$t_{a\ UG\text{-}28}$, $t_{a\ UG\text{-}22}$]
= max[3.97 , 0]
= 3.97 mm

t_{b2} = 6.78 mm

t_{b2} = max[t_{b2} , $t_{b\ UG16}$]
= max[6.78 , 4.7]
= 6.78 mm

t_b = min[t_{b3} , t_{b2}]
= min[8.93 , 6.78]
= 6.78 mm

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[3.97 , 6.78]
= 6.78 mm

Available nozzle wall thickness new, t_n = 19.05 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 Metric: B = 34.0228 MPa

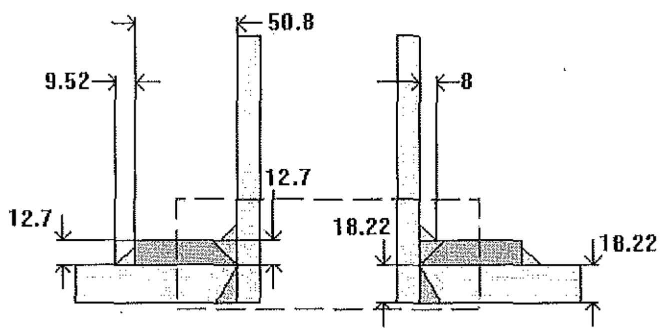
P_a = 4*B / (3*(D_o / t))
= 4*34,022.83 / (3*(139.7 / 0.77))
= 250.05 kPa

Design thickness for external pressure P_a = 250.05 kPa

t_a = t + Corrosion = 0.77 + 3.2 = 3.97 mm

PSV/VENT (N4)

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



$t_{w(lower)}$ = 18.22 mm
Leg_{41} = 8 mm
$t_{w(upper)}$ = 12.7 mm
Leg_{42} = 9.53 mm
D_p = 192.42 mm
t_e = 12.7 mm

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

Bolt Material:	SA-193 B7 Bolt <= 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

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2) For P = 1,046.9 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}
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 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 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

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(74.66, 37.33 + (11.13 - 3.2) + (18.22 - 3.2))$$
$$= 74.66 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(18.22 - 3.2), 2.5*(11.13 - 3.2) + 12.7)
= 32.51 mm

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 1,046.9022*36.52 / (118,000*1 - 0.6*1,046.9022)
= 0.33 mm

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

t_r = P*K_1*D_o / (2*S*E + 0.8*P)
= 1,046.9022*0.8985*3,962 / (2*138,000*1 + 0.8*1,046.9022)
= 13.46 mm

Area required per UG-37(c)

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

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

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

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

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

A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})
= (74.66*13.46*1 + 2*7.93*13.46*1*(1 - 0.8551)) / 100
= 10.3595 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 1.1271 cm^2

= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})
= (74.66*(1*15.02 - 1*13.46) - 2*7.93*(1*15.02 - 1*13.46)*(1 - 0.8551)) / 100
= 1.1271 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 + 7.93)*(1*15.02 - 1*13.46) - 2*7.93*(1*15.02 - 1*13.46)*(1 - 0.8551)) / 100
= 0.6787 cm^2

A_2 = smaller of the following= 4.2258 cm^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= (5*(7.93 - 0.33)*0.8551*15.02) / 100$
$= 4.8806\ cm^2$

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= (2*(7.93 - 0.33)*(2.5*7.93 + 12.7)*0.8551) / 100$
$= 4.2258\ cm^2$

$A_{41} = Leg^2*f_{r3}$
$= (8^2*0.8551) / 100$
$= \underline{0.5471}\ cm^2$

$A_{42} = Leg^2*f_{r4}$
$= (0^2*1) / 100$
$= \underline{0}\ cm^2$

(Part of the weld is outside of the limits)

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= ((149.31 - 90.82)*12.7*1) / 100$
$= \underline{7.4284}\ cm^2$

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 1.1271 + 4.2258 + 0.5471 + 0 + 7.4284$
$= \underline{13.3284}\ cm^2$

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 19 mm or t_n or t_e = 7.93 mm
$t_{c(min)}$ = lesser of 6 mm or $0.7*t_{min}$ = $\underline{5.55}$ mm
$t_{c(actual)}$ = 0.7*Leg = 0.7*8 = 5.6 mm

Outer fillet: t_{min} = lesser of 19 mm or t_e or t = 12.7 mm
$t_{w(min)}$ = $0.5*t_{min}$ = $\underline{6.35}$ mm
$t_{w(actual)}$ = 0.7*Leg = 0.7*9.53 = 6.67 mm

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}27} = P*R / (S*E - 0.6*P) + Corrosion$

= 1,046.9022*36.52 / (118,000*1 - 0.6*1,046.9022) + 3.2
= 3.53 mm

$t_{a\ UG\text{-}22}$ = 4.15 mm

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[3.53 , 4.15]
= 4.15 mm

t_{b1} = 18.1 mm

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[18.1 , 4.7]
= 18.1 mm

t_b = min[t_{b3} , t_{b1}]
= min[8 , 18.1]
= 8 mm

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[4.15 , 8]
= 8 mm

Available nozzle wall thickness new, t_n = 0.875*11.13 = 9.73 mm

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*138 =	102.12 MPa
Nozzle wall in shear:	0.7*118 =	82.6 MPa
Inner fillet weld in shear:	0.49*118 =	57.82 MPa
Outer fillet weld in shear:	0.49*138 =	67.62 MPa
Upper groove weld in tension:	0.74*138 =	102.12 MPa

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*S_i = $(\pi / 2)$*88.9*8*57.82 = 64,593.64 N

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*S_o = $(\pi / 2)$*192.42*9.53*67.62 = 194,675.29 N

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*t_n*S_n = $(\pi / 2)$*80.97*7.93*82.6 = 83,264.54 N

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*88.9*15.02*102.12 = 214,185.9 N

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*88.9*12.7*102.12 = 181,107.42 N

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

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (1,035.9528 - 112.7095 + 2*7.93*0.8551*(1*15.02 - 1*13.46))*138$
$= \underline{130,320.47}$ N

$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$
$= (422.5798 + 742.8372 + 54.7096 + 0)*138$
$= \underline{168,377.49}$ N

$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (422.5798 + 0 + 54.7096 + 0 + 2*7.93*15.02*0.8551)*138$
$= \underline{93,958.72}$ N

$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (422.5798 + 0 + 742.8372 + 54.7096 + 0 + 0 + 2*7.93*15.02*0.8551)*138$
$= \underline{196,470.27}$ N

Load for path 1-1 lesser of W or W_{1-1} = 130,320.47 N
Path 1-1 through (2) & (3) = 194,675.29 + 83,264.54 = $\underline{277,939.83}$ 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 N
Path 2-2 through (1), (4), (6) = 64,593.64 + 214,185.9 + 181,107.42 = $\underline{459,886.96}$ 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 N
Path 3-3 through (2), (4) = 194,675.29 + 214,185.9 = $\underline{408,861.2}$ 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	N
Circumferential moment:	M_1 =	585	N-m
Circumferential shear:	V_2 =	1,850	N
Longitudinal moment:	M_2 =	585	N-m
Longitudinal shear:	V_1 =	1,850	N
Torsion moment:	M_t =	825	N-m
Internal pressure:	P =	1,046.9	kPa
Head yield stress:	S_y =	236	MPa

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

Mean dish radius R_m = 3,554.18 mm

U = r_o / Sqr(R_m*t) = 0.412
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =123.602 MPa

Maximum combined stress (P_L+P_b+Q) = 152.02 MPa
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-414 MPa

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

Maximum local primary membrane stress (P_L) = 126.42 MPa
Allowable local primary membrane stress (P_L) = +-1.5*S = +-207 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
Shear from V_1		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
Total Shear stress		1.379	1.379	0.552	0.552	0.552	0.552	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 / Sqr(R_m*t) = 0.142
Pressure stress intensity factor, I = 0.42229 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =52.2 MPa

Maximum combined stress (P_L+P_b+Q) = 72.53 MPa
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-414 MPa

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

Maximum local primary membrane stress (P_L) = 53.04 MPa
Allowable local primary membrane stress (P_L) = +-1.5*S = +-207 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*	0.254	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
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
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_t		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

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o{}^2 - R_i{}^2)) + M*R_o / I$
$= 1{,}046.9 / 1000*36.52 / (2*6.53) - -1{,}510 / (\pi*(44.45^2 - 36.52^2)) + 827{,}314.7*44.45 / 1{,}668{,}246$
$= 25.718$ MPa

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 ($\leq S = 118$ MPa)

Shear stress in the nozzle wall due to external loads

$\sigma_{shear} = (V_L{}^2 + V_c{}^2)^{0.5} / (\pi*R_i*t_n)$
$= (1{,}850^2 + 1{,}850^2)^{0.5} / (\pi*36.52*7.93)$
$= 2.877$ MPa

$\sigma_{torsion} = M_t / (2*\pi*R_i{}^2*t_n)$
$= 825 / (2*\pi*36.52^2*7.93)$

= 12.419 MPa

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 2.877 + 12.419
= 15.296 MPa

UG-45: The total combined shear stress (15.296 MPa) is below than the allowable ($0.7*S_n = 0.7*118 = 82.6$ MPa)

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm^2) For Pe = 224.31 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}
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

L_R = MAX(d, $R_n + (t_n - C_n) + (t - C)$)
= MAX(74.66, 37.33 + (11.13 - 3.2) + (18.22 - 3.2))
= 74.66 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*($t_n - C_n$) + t_e)
= MIN(2.5*(18.22 - 3.2), 2.5*(11.13 - 3.2) + 12.7)
= 32.51 mm

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} = lesser of 1 or S_n / S_v = 0.8551

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

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

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

A = $0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}))$
= (0.5*(74.66*15.02*1 + 2*7.93*15.02*1*(1 - 0.8551))) / 100
= 5.7789 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0 cm^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= (74.66*(1*15.02 - 1*15.02) - 2*7.93*(1*15.02 - 1*15.02)*(1 - 0.8551)) / 100
= 0 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 + 7.93)*(1*15.02 - 1*15.02) - 2*7.93*(1*15.02 - 1*15.02)*(1 - 0.8551)) / 100
= 0 cm^2

A_2 = smaller of the following= 3.9413 cm^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= (5*(7.93 - 0.84)*0.8551*15.02) / 100
= 4.5516 cm^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= (2*(7.93 - 0.84)*(2.5*7.93 + 12.7)*0.8551) / 100
= 3.9413 cm^2

A_{41} = Leg^2*f_{r3}
= (8^2*0.8551) / 100
= 0.5471 cm^2

A_{42} = Leg^2*f_{r4}
= (0^2*1) / 100
= 0 cm^2

(Part of the weld is outside of the limits)

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= ((149.31 - 90.82)*12.7*1) / 100
= 7.4284 cm^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= $0 + 3.9413 + 0.5471 + 0 + 7.4284$
= $\underline{11.9168}$ cm^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 19 mm or t_n or t_e = 7.93 mm
$t_{c(min)}$ = lesser of 6 mm or $0.7*t_{min}$ = $\underline{5.55}$ mm
$t_{c(actual)}$ = 0.7*Leg = 0.7*8 = 5.6 mm

Outer fillet: t_{min} = lesser of 19 mm or t_e or t = 12.7 mm
$t_{w(min)}$ = $0.5*t_{min}$ = $\underline{6.35}$ mm
$t_{w(actual)}$ = 0.7*Leg = 0.7*9.53 = 6.67 mm

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}28}$ = 4.04 mm

$t_{a\ UG\text{-}22}$ = 3.87 mm

t_a = max[$t_{a\ UG\text{-}28}$, $t_{a\ UG\text{-}22}$]
= max[4.04 , 3.87]
= 4.04 mm

t_{b2} = 6.41 mm

t_{b2} = max[t_{b2} , $t_{b\ UG16}$]
= max[6.41 , 4.7]
= 6.41 mm

t_b = min[t_{b3} , t_{b2}]
= min[8 , 6.41]
= 6.41 mm

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[4.04 , 6.41]
= 6.41 mm

Available nozzle wall thickness new, t_n = 0.875*11.13 = 9.73 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 Metric: B = 17.8584 MPa

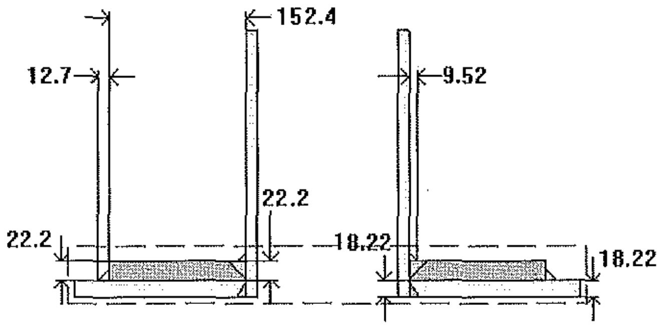
P_a = 4*B / (3*(D_o / t))
= 4*17,858.37 / (3*(88.9 / 0.84))
= 224.3 kPa

Design thickness for external pressure P_a = 224.3 kPa

t_a = t + Corrosion = 0.84 + 3.2 = 4.04 mm

TOP MANWAY (M1)

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



$t_{w(lower)}$ = 18.22 mm
Leg_{41} = 9.53 mm
$t_{w(upper)}$ = 22.2 mm
Leg_{42} = 12.7 mm
D_p = 942.38 mm
t_e = 22.2 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, ln. 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, ln. 19) (normalized)
Diameter:	942.38 mm
Is split:	No

ASME B16.5-2009 Flange

Description:	NPS 24 Class 150 WN 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:	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

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2) For P = 1,047.54 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}
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

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(618.14, 309.07 + (12.7 - 3.2) + (18.22 - 3.2))
= 618.14 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(18.22 - 3.2), 2.5*(12.7 - 3.2) + 22.2)

$= \quad 37.55$ mm

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

$t_{rn} = P*R_n / (S_n*E - 0.6*P)$
$= 1,047.5351*295.3 / (118,000*1 - 0.6*1,047.5351)$
$= 2.64$ mm

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

$t_r = P*K_1*D_o / (2*S*E + 0.8*P)$
$= 1,047.5351*0.8985*3,962 / (2*138,000*1 + 0.8*1,047.5351)$
$= 13.47$ mm

Area required per UG-37(c)

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

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

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

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

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

$A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
$= (618.14*13.47*1 + 2*9.5*13.47*1*(1 - 0.8551)) / 100$
$= \underline{83.6347}\ cm^2$

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{9.5355}$ cm^2

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= (618.14*(1*15.02 - 1*13.47) - 2*9.5*(1*15.02 - 1*13.47)*(1 - 0.8551)) / 100$
$= 9.5355\ cm^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= (2*(15.02 + 9.5)*(1*15.02 - 1*13.47) - 2*9.5*(1*15.02 - 1*13.47)*(1 - 0.8551)) / 100$
$= 0.7174\ cm^2$

A_2 = smaller of the following= $\underline{4.4077}$ cm^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= (5*(9.5 - 2.64)*0.8551*15.02) / 100$
$= 4.4077\ cm^2$

$= 2*(t_n - t_m)*(2.5*t_n + t_e)*f_{r2}$
$= (2*(9.5 - 2.64)*(2.5*9.5 + 22.2)*0.8551) / 100$
$= 5.3935\ cm^2$

$A_{41} = Leg^2*f_{r3}$
$= (9.53^2*0.8551) / 100$
$= \underline{0.7755}\ cm^2$

$A_{42} = Leg^2*f_{r4}$
$= (12.7^2*1) / 100$
$= \underline{1.6129}\ cm^2$

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= ((942.38 - 637.58)*22.2*1) / 100$
$= \underline{67.6656}\ cm^2$

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 9.5355 + 4.4077 + 0.7755 + 1.6129 + 67.6656$
$= \underline{83.9972}\ cm^2$

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 19 mm or t_n or t_e = 9.5 mm
$t_{c(min)}$ = lesser of 6 mm or $0.7*t_{min}$ = $\underline{6}$ mm
$t_{c(actual)}$ = 0.7*Leg = 0.7*9.53 = 6.67 mm

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

UG-45 Nozzle Neck Thickness Check (Access Opening)

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

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 1,047.5351*295.3 / (118,000*1 - 0.6*1,047.5351) + 3.2
= 5.84 mm

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[5.84 , 0]

= 5.84 mm

Available nozzle wall thickness new, t_n = 0.875*12.7 = 11.11 mm

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*138 = 102.12 MPa
Nozzle wall in shear:	0.7*118 = 82.6 MPa
Inner fillet weld in shear:	0.49*118 = 57.82 MPa
Outer fillet weld in shear:	0.49*138 = 67.62 MPa
Upper groove weld in tension:	0.74*138 = 102.12 MPa

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*S_i = $(\pi / 2)$*609.6*9.53*57.82 = 527,360.92 N

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*S_o = $(\pi / 2)$*942.38*12.7*67.62 = 1,271,226.21 N

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*t_n*S_n = $(\pi / 2)$*600.1*9.5*82.6 = 739,685.65 N

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*609.6*15.02*102.12 = 1,468,703.3 N

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*609.6*22.2*102.12 = 2,170,844.31 N

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

$$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$$
$$= (8{,}363.4683 - 953.5465 + 2*9.5*0.8551*(1*15.02 - 1*13.47))*138$$
$$= \underline{1{,}026{,}043.39}\ N$$

$$W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$$
$$= (440.7733 + 6{,}766.56 + 77.5482 + 161.29)*138$$
$$= \underline{1{,}027{,}571.82}\ N$$

$$W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (440.7733 + 0 + 77.5482 + 0 + 2*9.5*15.02*0.8551)*138$$
$$= \underline{105{,}203.42}\ N$$

$$W_{3\text{-}3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (440.7733 + 0 + 6{,}766.56 + 77.5482 + 161.29 + 0 + 2*9.5*15.02*0.8551)*138$$
$$= \underline{1{,}061{,}246.85}\ N$$

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 = <u>2,010,911.87</u> 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 = <u>4,166,908.53</u> 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 = <u>2,739,929.51</u> 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 Pe = 224.31 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}
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

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(618.12, 309.06 + (12.7 - 3.2) + (18.22 - 3.2))
= 618.12 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(18.22 - 3.2), 2.5*(12.7 - 3.2) + 22.2)
= 37.55 mm

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

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

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

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

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

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
= 46.6259 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0006 cm^2

= 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 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 cm^2

A_2 = smaller of the following= 4.2884 cm^2

= 5*(t_n - t_{rn})*f_{r2}*t
= (5*(9.5 - 2.82)*0.8551*15.02) / 100
= 4.2884 cm^2

= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}
= (2*(9.5 - 2.82)*(2.5*9.5 + 22.2)*0.8551) / 100
= 5.2477 cm^2

A_{41} = Leg^2*f_{r3}
= (9.53^2*0.8551) / 100
= 0.7755 cm^2

A_{42} = Leg^2*f_{r4}
= (12.7^2*1) / 100
= 1.6129 cm^2

A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}
= ((942.38 - 637.58)*22.2*1) / 100
= 67.6656 cm^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= 0.0006 + 4.2884 + 0.7755 + 1.6129 + 67.6656
= 74.343 cm^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 19 mm or t_n or t_e = 9.5 mm
$t_{c(min)}$ = lesser of 6 mm or 0.7*t_{min} = 6 mm
$t_{c(actual)}$ = 0.7*Leg = 0.7*9.53 = 6.67 mm

Outer fillet: t_{min} = lesser of 19 mm or t_e or t = 15.02 mm
$t_{w(min)}$ = 0.5*t_{min} = 7.51 mm
$t_{w(actual)}$ = 0.7*Leg = 0.7*12.7 = 8.89 mm

UG-45 Nozzle Neck Thickness Check (Access Opening)

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

$t_{a\ UG\text{-}28}$ = 6.02 mm

t_a = max[$t_{a\ UG\text{-}28}$, $t_{a\ UG\text{-}22}$]
= max[6.02 , 0]
= 6.02 mm

Available nozzle wall thickness new, t_n = 0.875*12.7 = 11.11 mm

The nozzle neck thickness is adequate.

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

L / D_o	= 703.99 / 609.6	=	1.1548
D_o / t	= 609.6 / 2.82	=	216.0111
From table G:	A	=	0.000367
From table CS-2 Metric:	B	=	36.3403 MPa

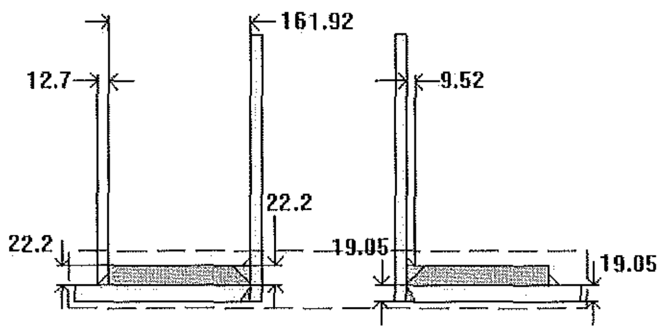
P_a = 4*B / (3*(D_o / t))
= 4*36,340.3 / (3*(609.6 / 2.82))
= 224.31 kPa

Design thickness for external pressure P_a = 224.31 kPa

t_a = t + Corrosion = 2.82 + 3.2 = 6.02 mm

BOTTOM MANWAY (M2)

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



$t_{w(lower)}$ = 19.05 mm
Leg_{41} = 9.53 mm
$t_{w(upper)}$ = 22.2 mm
Leg_{42} = 12.7 mm
D_p = 951.77 mm
t_e = 22.2 mm

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, ln. 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, ln. 19) (normalized)
Diameter:	951.77 mm
Is split:	No

ASME B16.5-2009 Flange

Description:	NPS 24 Class 150 WN 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:	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

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2) For P = 1,093.69 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}
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

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(608.66, 304.33 + (12.7 - 3.2) + (19.05 - 3.2))$$
$$= 608.66 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$$
$$= MIN(2.5*(19.05 - 3.2), 2.5*(12.7 - 3.2) + 22.2)$$

= 39.62 mm

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

t_m = $P*R_n / (S_n*E - 0.6*P)$
= 1,093.6942*295.3 / (118,000*1 - 0.6*1,093.6942)
= 2.75 mm

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

t_r = $P*K_1*D_o / (2*S*E + 0.8*P)$
= 1,093.6942*0.8985*3,962 / (2*138,000*1 + 0.8*1,093.6942)
= 14.06 mm

Area required per UG-37(c)

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

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

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

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

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

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= (608.66*14.06*1 + 2*9.5*14.06*1*(1 - 0.8551)) / 100
= <u>85.9763</u> cm²

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>10.8316</u> cm²

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= (608.66*(1*15.85 - 1*14.06) - 2*9.5*(1*15.85 - 1*14.06)*(1 - 0.8551)) / 100
= 10.8316 cm²

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= (2*(15.85 + 9.5)*(1*15.85 - 1*14.06) - 2*9.5*(1*15.85 - 1*14.06)*(1 - 0.8551)) / 100
= 0.8574 cm²

A_2 = smaller of the following= <u>4.5716</u> cm²

= $5*(t_n - t_m)*f_{r2}*t$
= (5*(9.5 - 2.75)*0.8551*15.85) / 100
= 4.5716 cm²

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= (2*(9.5 - 2.75)*(2.5*9.5 + 22.2)*0.8551) / 100$
$= 5.3019\ cm^2$

$A_{41} = Leg^2*f_{r3}$
$= (9.53^2*0.8551) / 100$
$= \underline{0.7755}\ cm^2$

$A_{42} = Leg^2*f_{r4}$
$= (12.7^2*1) / 100$
$= \underline{1.6129}\ cm^2$

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= ((951.77 - 627.92)*22.2*1) / 100$
$= \underline{71.8947}\ cm^2$

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 10.8316 + 4.5716 + 0.7755 + 1.6129 + 71.8947$
$= \underline{89.6863}\ cm^2$

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 19 mm or t_n or t_e = 9.5 mm
$t_{c(min)}$ = lesser of 6 mm or $0.7*t_{min}$ = $\underline{6}$ mm
$t_{c(actual)}$ = 0.7*Leg = 0.7*9.53 = 6.67 mm

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

UG-45 Nozzle Neck Thickness Check (Access Opening)

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

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 1,093.881*295.3 / (118,000*1 - 0.6*1,093.881) + 3.2
= 5.95 mm

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[5.95 , 0]

= 5.95 mm

Available nozzle wall thickness new, t_n = 0.875*12.7 = 11.11 mm

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*138 =	102.12 MPa
Nozzle wall in shear:	0.7*118 =	82.6 MPa
Inner fillet weld in shear:	0.49*118 =	57.82 MPa
Outer fillet weld in shear:	0.49*138 =	67.62 MPa
Upper groove weld in tension:	0.74*138 =	102.12 MPa

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*S_i = $(\pi / 2)$*609.6*9.53*57.82 = 527,360.92 N

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*S_o = $(\pi / 2)$*951.77*12.7*67.62 = 1,283,900.31 N

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*t_n*S_n = $(\pi / 2)$*600.1*9.5*82.6 = 739,685.65 N

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*609.6*15.85*102.12 = 1,549,865.49 N

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*609.6*22.2*102.12 = 2,170,844.31 N

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

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
= 1,041,004.67 N

W_{1-1} = $(A_2 + A_5 + A_{41} + A_{42})*S_v$
= (457.1604 + 7,189.47 + 77.5482 + 161.29)*138
= 1,088,194.83 N

W_{2-2} = $(A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
= (457.1604 + 0 + 77.5482 + 0 + 2*9.5*15.85*0.8551)*138
= 109,325.75 N

W_{3-3} = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
= (457.1604 + 0 + 7,189.47 + 77.5482 + 161.29 + 0 + 2*9.5*15.85*0.8551)*138
= 1,123,730.78 N

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 = 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 = 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 = 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 Pe = 250.06 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}
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

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(608.65, 304.32 + (12.7 - 3.2) + (19.05 - 3.2))
= 608.65 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(19.05 - 3.2), 2.5*(12.7 - 3.2) + 22.2)
= 39.62 mm

Nozzle required thickness per UG-28 t_{rn} = 2.64 mm

From UG-37(d)(1) required thickness t_r = 15.85 mm

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

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

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

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

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

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

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
= <u>48.4523</u> cm²

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>0</u> cm²

= 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 cm²

= 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 cm²

A_2 = smaller of the following= <u>4.6484</u> cm²

= 5*(t_n - t_{rn})*f_{r2}*t
= (5*(9.5 - 2.64)*0.8551*15.85) / 100
= 4.6484 cm²

= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}
= (2*(9.5 - 2.64)*(2.5*9.5 + 22.2)*0.8551) / 100
= 5.3903 cm²

A_{41} = Leg^2*f_{r3}
= (9.53^2*0.8551) / 100
= <u>0.7755</u> cm²

A_{42} = Leg^2*f_{r4}
= (12.7^2*1) / 100
= <u>1.6129</u> cm²

A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}
= ((951.77 - 627.92)*22.2*1) / 100
= <u>71.8947</u> cm²

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= $0 + 4.6484 + 0.7755 + 1.6129 + 71.8947$
= $\underline{78.9315}$ cm^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 19 mm or t_n or t_e = 9.5 mm
$t_{c(min)}$ = lesser of 6 mm or 0.7*t_{min} = $\underline{6}$ mm
$t_{c(actual)}$ = 0.7*Leg = 0.7*9.53 = 6.67 mm

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

UG-45 Nozzle Neck Thickness Check (Access Opening)

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

$t_{a\ UG\text{-}28}$ = 5.84 mm

t_a = max[$t_{a\ UG\text{-}28}$, $t_{a\ UG\text{-}22}$]
= max[5.84 , 0]
= 5.84 mm

Available nozzle wall thickness new, t_n = 0.875*12.7 = 11.11 mm

The nozzle neck thickness is adequate.

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

L / D_o = 542.21 / 609.6 = 0.8895
D_o / t = 609.6 / 2.64 = 230.8405
From table G: A = 0.000436
From table CS-2 Metric: B = 43.2924 MPa

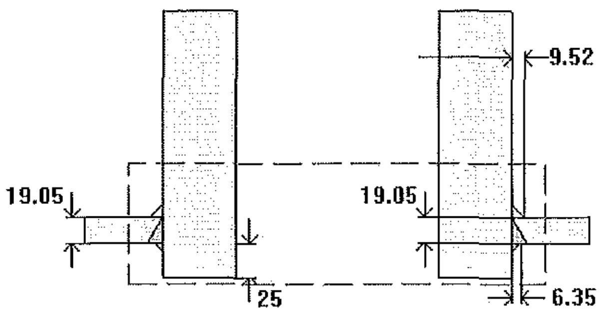
P_a = 4*B / (3*(D_o / t))
= 4*43,292.45 / (3*(609.6 / 2.64))
= 250.06 kPa

Design thickness for external pressure P_a = 250.06 kPa

t_a = t + Corrosion = 2.64 + 3.2 = 5.84 mm

SIGHT GLASS (SG1A)

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



$t_{w(lower)}$ = 19.05 mm
Leg_{41} = 9.52 mm
Leg_{43} = 6.35 mm
h_{new} = 25 mm

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

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(152.4, 76.2 + (54.5 - 3.2) + (19.05 - 3.2))$$
$$= 152.4 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$$
$$= MIN(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2) + 0)$$
$$= 39.62 \text{ mm}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = MIN(2.5*(t - C), 2.5*(t_i - C_n - C))$$
$$= MIN(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2 - 3.2))$$
$$= 39.62 \text{ mm}$$

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

t_{rn} = $P*R_n / (S_n*E - 0.6*P)$
= 1,061.5949*76.2 / (138,000*1 - 0.6*1,061.5949)
= 0.59 mm

Required thickness t_r from UG-37(a)

t_r = $P*R_o / (S*E + 0.4*P)$
= 1,061.5949*1,981 / (138,000*1 + 0.4*1,061.5949)
= 15.19 mm

Area required per UG-37(c)

Allowable stresses: S_n = 138, S_v = 138 MPa

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$ + Tapped hole area loss
= (152.4*15.19*1 + 2*51.3*15.19*1*(1 - 1)) / 100 + 4.8387
= 27.9921 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 1.0013 cm^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= (152.4*(1*15.85 - 1*15.19) - 2*51.3*(1*15.85 - 1*15.19)*(1 - 1)) / 100
= 1.0013 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 + 51.3)*(1*15.85 - 1*15.19) - 2*51.3*(1*15.85 - 1*15.19)*(1 - 1)) / 100
= 0.8826 cm^2

A_2 = smaller of the following= 12.8806 cm^2

= $2*(t_n - t_{rn})*f_{r2}*L_{pr}$
= (2*(51.3 - 0.59)*1*12.7) / 100
= 12.8806 cm^2

= $2*(t_n - t_{rn})*f_{r2}*L_{pr}$
= (2*(51.3 - 0.59)*1*12.7) / 100
= 12.8806 cm^2

A_3 = smaller of the following= 20.971 cm^2

$= 5*t*t_i*f_{r2}$
$= (5*15.85*48.1*1) / 100$
$= \underline{38.118}\ cm^2$

$= 5*t_i*t_i*f_{r2}$
$= (5*48.1*48.1*1) / 100$
$= \underline{115.6786}\ cm^2$

$= 2*h*t_i*f_{r2}$
$= (2*21.8*48.1*1) / 100$
$= \underline{20.971}\ cm^2$

$A_{41} = Leg^2*f_{r2}$
$= (9.52^2*1) / 100$
$= \underline{0.9065}\ cm^2$

$A_{43} = Leg^2*f_{r2}$
$= (1.78^2*1) / 100$
$= \underline{0.0316}\ cm^2$

Area $= A_1 + A_2 + A_3 + A_{41} + A_{43}$
$= 1.0013 + 12.8806 + 20.971 + 0.9065 + 0.0316$
$= \underline{35.791}\ cm^2$

As Area >= 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} = 6 mm
$t_{c(actual)}$ = 0.7*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

$t_{a\ UG\text{-}27} = P*R / (S*E - 0.6*P) + Corrosion$
$= 1{,}061.5949*76.2 / (138{,}000*1 - 0.6*1{,}061.5949) + 3.2$
$= 3.79$ mm

$t_a = \max[\ t_{a\ UG\text{-}27}\ ,\ t_{a\ UG\text{-}22}\ ]$

$= \max[\, 3.79 , 0 \,]$
$= 3.79$ mm

$t_{b1} = P*R_o / (S*E + 0.4*P) + \text{Corrosion}$
$= 1{,}061.5949*1{,}981 / (138{,}000*1 + 0.4*1{,}061.5949) + 3.2$
$= 18.39$ mm

$t_{b1} = \max[\, t_{b1} , t_{b\ UG16} \,]$
$= \max[\, 18.39 , 4.7 \,]$
$= 18.39$ mm

$t_b = \min[\, t_{b3} , t_{b1} \,]$
$= \min[\, 11.31 , 18.39 \,]$
$= 11.31$ mm

$t_{UG\text{-}45} = \max[\, t_a , t_b \,]$
$= \max[\, 3.79 , 11.31 \,]$
$= 11.31$ mm

Available nozzle wall thickness new, $t_n = 54.5$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm^2) For Pe = 221.4 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}
16.9161	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

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(152.4, 76.2 + (54.5 - 3.2) + (19.05 - 3.2))
= 152.4 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2) + 0)
= 39.62 mm

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2 - 3.2))
= 39.62 mm

Nozzle required thickness per UG-28 t_{rn} = 0.42 mm

From UG-37(d)(1) required thickness t_r = 15.85 mm

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

Allowable stresses: S_n = 138, S_v = 138 MPa

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

A = 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})) + Tapped hole area loss
= (0.5*(152.4*15.85*1 + 2*51.3*15.85*1*(1 - 1))) / 100 + 4.8387
= <u>16.9161</u> cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>0</u> cm^2

= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})
= (152.4*(1*15.85 - 1*15.85) - 2*51.3*(1*15.85 - 1*15.85)*(1 - 1)) / 100
= 0 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 + 51.3)*(1*15.85 - 1*15.85) - 2*51.3*(1*15.85 - 1*15.85)*(1 - 1)) / 100
= 0 cm^2

A_2 = smaller of the following= <u>12.9232</u> cm^2

= 2*(t_n - t_{rn})*f_{r2}*L_{pr}
= (2*(51.3 - 0.42)*1*12.7) / 100
= 12.9232 cm^2

= 2*(t_n - t_{rn})*f_{r2}*L_{pr}
= (2*(51.3 - 0.42)*1*12.7) / 100
= 12.9232 cm^2

A_3 = smaller of the following= <u>20.971</u> cm^2

= 5*t*t_i*f_{r2}
= (5*15.85*48.1*1) / 100
= <u>38.118</u> cm^2

= 5*t_i*t_i*f_{r2}
= (5*48.1*48.1*1) / 100
= <u>115.6786</u> cm^2

= 2*h*t_i*f_{r2}
= (2*21.8*48.1*1) / 100
= <u>20.971</u> cm^2

A_{41} = Leg^2*f_{r2}
= $(9.52^2*1) / 100$
= $\underline{0.9065}$ cm^2

A_{43} = Leg^2*f_{r2}
= $(1.78^2*1) / 100$
= $\underline{0.0316}$ cm^2

Area = $A_1 + A_2 + A_3 + A_{41} + A_{43}$
= $0 + 12.9232 + 20.971 + 0.9065 + 0.0316$
= $\underline{34.8323}$ cm^2

As Area >= 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
$t_{c(actual)}$ = 0.7*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

$t_{a\ UG\text{-}28}$ = 3.62 mm

t_a = max[$t_{a\ UG\text{-}28}$, $t_{a\ UG\text{-}22}$]
= max[3.62 , 0]
= 3.62 mm

t_{b2} = $P*R_o / (S*E + 0.4*P)$ + Corrosion
= 221.3986*1,981 / (138,000*1 + 0.4*221.3986) + 3.2
= 6.38 mm

t_{b2} = max[t_{b2} , $t_{b\ UG16}$]
= max[6.38 , 4.7]
= 6.38 mm

t_b = min[t_{b3} , t_{b2}]
= min[11.31 , 6.38]
= 6.38 mm

t_{UG-45} = max[t_a , t_b]
= max[3.62 , 6.38]
= 6.38 mm

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)

L / D_o = 16.81 / 255 = 0.0659
D_o / t = 255 / 0.42 = 604.2399
From table G: A = 0.001822
From table CS-2 Metric: B = 100.3343 MPa

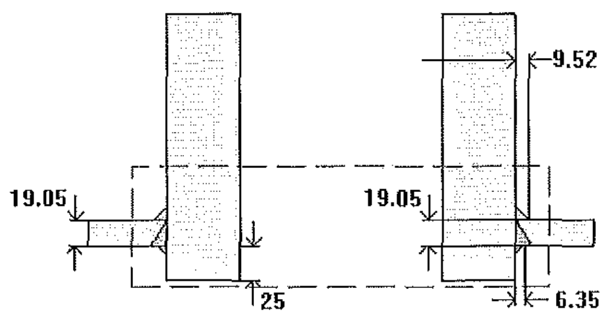
P_a = 4*B / (3*(D_o / t))
= 4*100,334.25 / (3*(255 / 0.42))
= 221.4 kPa

Design thickness for external pressure P_a = 221.4 kPa

t_a = t + Corrosion = 0.42 + 3.2 = 3.62 mm

SIGHT GLASS (SG1B)

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



$t_{w(lower)}$ = 19.05 mm
Leg_{41} = 9.52 mm
Leg_{43} = 6.35 mm
h_{new} = 25 mm

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, 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:	24.8294 kPa
Longitudinal joint efficiency:	1

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2) For P = 1,066.4 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}
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

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(152.4, 76.2 + (54.5 - 3.2) + (19.05 - 3.2))
= 152.4 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2) + 0)
= 39.62 mm

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2 - 3.2))
= 39.62 mm

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

t_{rn} = $P*R_n / (S_n*E - 0.6*P)$
= 1,066.3964*76.2 / (138,000*1 - 0.6*1,066.3964)
= 0.59 mm

Required thickness t_r from UG-37(a)

t_r = $P*R_o / (S*E + 0.4*P)$
= 1,066.3964*1,981 / (138,000*1 + 0.4*1,066.3964)
= 15.26 mm

Area required per UG-37(c)

Allowable stresses: S_n = 138, S_v = 138 MPa

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$ + Tapped hole area loss
= (152.4*15.26*1 + 2*51.3*15.26*1*(1 - 1)) / 100 + 4.8387
= <u>28.0966</u> cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>0.8968</u> cm^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= (152.4*(1*15.85 - 1*15.26) - 2*51.3*(1*15.85 - 1*15.26)*(1 - 1)) / 100
= 0.8968 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 + 51.3)*(1*15.85 - 1*15.26) - 2*51.3*(1*15.85 - 1*15.26)*(1 - 1)) / 100
= 0.7903 cm^2

A_2 = smaller of the following= <u>12.88</u> cm^2

= $2*(t_n - t_{rn})*f_{r2}*L_{pr}$
= (2*(51.3 - 0.59)*1*12.7) / 100
= 12.88 cm^2

= $2*(t_n - t_{rn})*f_{r2}*L_{pr}$
= (2*(51.3 - 0.59)*1*12.7) / 100
= 12.88 cm^2

A_3 = smaller of the following= 20.971 cm^2

$$= 5*t*t_i*f_{r2}$$
$$= (5*15.85*48.1*1) / 100$$
$$= \underline{38.118}\ cm^2$$

$$= 5*t_i*t_i*f_{r2}$$
$$= (5*48.1*48.1*1) / 100$$
$$= \underline{115.6786}\ cm^2$$

$$= 2*h*t_i*f_{r2}$$
$$= (2*21.8*48.1*1) / 100$$
$$= \underline{20.971}\ cm^2$$

$$A_{41} = Leg^2*f_{r2}$$
$$= (9.52^2*1) / 100$$
$$= \underline{0.9065}\ cm^2$$

$$A_{43} = Leg^2*f_{r2}$$
$$= (1.78^2*1) / 100$$
$$= \underline{0.0316}\ cm^2$$

$$\text{Area} = A_1 + A_2 + A_3 + A_{41} + A_{43}$$
$$= 0.8968 + 12.88 + 20.971 + 0.9065 + 0.0316$$
$$= \underline{35.6859}\ cm^2$$

As Area >= 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} = 6 mm
$t_{c(actual)}$ = 0.7*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

$$t_{a\ UG\text{-}27} = P*R / (S*E - 0.6*P) + Corrosion$$
$$= 1{,}066.3964*76.2 / (138{,}000*1 - 0.6*1{,}066.3964) + 3.2$$
$$= 3.79\ mm$$

$$t_a = \max[\ t_{a\ UG\text{-}27}\ ,\ t_{a\ UG\text{-}22}\ ]$$

$$= \max[\,3.79\ ,\ 0\,]$$
$$= 3.79 \text{ mm}$$

$$t_{b1} = P*R_o / (S*E + 0.4*P) + \text{Corrosion}$$
$$= 1{,}066.3964*1{,}981 / (138{,}000*1 + 0.4*1{,}066.3964) + 3.2$$
$$= 18.46 \text{ mm}$$

$$t_{b1} = \max[\,t_{b1}\ ,\ t_{b\ UG16}\,]$$
$$= \max[\,18.46\ ,\ 4.7\,]$$
$$= 18.46 \text{ mm}$$

$$t_b = \min[\,t_{b3}\ ,\ t_{b1}\,]$$
$$= \min[\,11.31\ ,\ 18.46\,]$$
$$= 11.31 \text{ mm}$$

$$t_{UG\text{-}45} = \max[\,t_a\ ,\ t_b\,]$$
$$= \max[\,3.79\ ,\ 11.31\,]$$
$$= 11.31 \text{ mm}$$

Available nozzle wall thickness new, $t_n = 54.5$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (cm^2) For Pe = 221.4 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}
16.9161	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

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(152.4, 76.2 + (54.5 - 3.2) + (19.05 - 3.2))
= 152.4 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2) + 0)
= 39.62 mm

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(2.5*(19.05 - 3.2), 2.5*(54.5 - 3.2 - 3.2))
= 39.62 mm

Nozzle required thickness per UG-28 t_{rn} = 0.42 mm

From UG-37(d)(1) required thickness t_r = 15.85 mm

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

Allowable stresses: S_n = 138, S_v = 138 MPa

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

A = 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})) + Tapped hole area loss
= (0.5*(152.4*15.85*1 + 2*51.3*15.85*1*(1 - 1))) / 100 + 4.8387
= <u>16.9161</u> cm²

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>0</u> cm²

= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})
= (152.4*(1*15.85 - 1*15.85) - 2*51.3*(1*15.85 - 1*15.85)*(1 - 1)) / 100
= 0 cm²

= 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 + 51.3)*(1*15.85 - 1*15.85) - 2*51.3*(1*15.85 - 1*15.85)*(1 - 1)) / 100
= 0 cm²

A_2 = smaller of the following= <u>12.9232</u> cm²

= 2*(t_n - t_{rn})*f_{r2}*L_{pr}
= (2*(51.3 - 0.42)*1*12.7) / 100
= 12.9232 cm²

= 2*(t_n - t_{rn})*f_{r2}*L_{pr}
= (2*(51.3 - 0.42)*1*12.7) / 100
= 12.9232 cm²

A_3 = smaller of the following= <u>20.971</u> cm²

= 5*t*t_i*f_{r2}
= (5*15.85*48.1*1) / 100
= <u>38.118</u> cm²

= 5*t_i*t_i*f_{r2}
= (5*48.1*48.1*1) / 100
= <u>115.6786</u> cm²

= 2*h*t_i*f_{r2}
= (2*21.8*48.1*1) / 100
= <u>20.971</u> cm²

A_{41} = $Leg^2 * f_{r2}$
= $(9.52^{2} * 1) / 100$
= <u>0.9065</u> cm^2

A_{43} = $Leg^2 * f_{r2}$
= $(1.78^{2} * 1) / 100$
= <u>0.0316</u> cm^2

Area = $A_1 + A_2 + A_3 + A_{41} + A_{43}$
= $0 + 12.9232 + 20.971 + 0.9065 + 0.0316$
= <u>34.8323</u> cm^2

As Area >= 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 $0.7*t_{min}$ = <u>6</u> mm
$t_{c(actual)}$ = 0.7*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

$t_{a\ UG\text{-}28}$ = 3.62 mm

t_a = max[$t_{a\ UG\text{-}28}$, $t_{a\ UG\text{-}22}$]
= max[3.62 , 0]
= 3.62 mm

t_{b2} = $P*R_o / (S*E + 0.4*P)$ + Corrosion
= 221.3986*1,981 / (138,000*1 + 0.4*221.3986) + 3.2
= 6.38 mm

t_{b2} = max[t_{b2} , $t_{b\ UG16}$]
= max[6.38 , 4.7]
= 6.38 mm

t_b = min[t_{b3} , t_{b2}]
= min[11.31 , 6.38]
= 6.38 mm

t_{UG-45} = max[t_a , t_b]
= max[3.62 , 6.38]
= 6.38 mm

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)

L / D_o	= 16.81 / 255		=	0.0659
D_o / t	= 255 / 0.42		=	604.2399
From table G:		A	=	0.001822
From table CS-2 Metric:		B	=	100.3343 MPa

P_a = 4*B / (3*(D_o / t))
= 4*100,334.25 / (3*(255 / 0.42))
= 221.4 kPa

Design thickness for external pressure P_a = 221.4 kPa

t_a = t + Corrosion = 0.42 + 3.2 = 3.62 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:

$T = 2 * PI * Sqr(\{Sum(W_i * y_i^2)\} / \{g * Sum(W_i * y_i)\})$, 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

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

$V = 2/3 * S(T_a) * M_v * \underline{I_E} * \underline{W} / (R_d * R_o)$
$= 2/3 * 0.0826 * 1.0000 * 1.3000 * 179{,}796.4375 / (2.5000 * 1.0000)$
$= 5{,}147.9604$ lb (2,335.08 kg)

Per 4.1.8.11.(2), the minimum lateral earthquake force, V, shall be no less than V_{min}:

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 lb (237.49 kg)

When R_d is greater than or equal to 1.5, V shall be no more than V_{max}:

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 lb (2,940.30 kg)

V = 5,147.96 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

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 lb (1,249.18 kg)

Per 4.1.8.11.(2), the minimum lateral earthquake force, V, shall be no less than V_{min}:

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 lb (76.32 kg)

When R_d is greater than or equal to 1.5, V shall be no more than V_{max}:

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 lb (944.96 kg)

V = 2,083.28 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

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 lb (2,335.08 kg)

Per 4.1.8.11.(2), the minimum lateral earthquake force, V, shall be no less than V_{min}:

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)

= 523.5673 lb (237.49 kg)

When R_d is greater than or equal to 1.5, V shall be no more than V_{max}:

V_{max} = 2/3 * 2/3 * S(0.2) * $\underline{I_E}$ * $\underline{W}$ / (R_d * R_o)
= 2/3 * 2/3 * 0.1560 * 1.3000 * 179,796.4375 / (2.5000 * 1.0000)
= 6,482.2607 lb (2,940.30 kg)

V = 5,147.96 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)**

$P_1 = W_t / N + 4*M_t / (N*D)$
$= 804{,}948.88 / 4 + 4*1e3*36{,}442.7 / (4*3{,}987.4)$
$= \underline{210{,}376.67}$ N

Allowable axial compressive stress, F_a (AISC chapter E)

$C_c = Sqr(2*\pi^2*E / F_y)$
$= Sqr(2*\pi^2*199{,}948 / 350)$
$= 106.1914$

$K*l / r = 1.2*2{,}410.9 / 64.69 = 44.7234$

$F_a = 1 * (1 - (K*l / r)^2 / (2*C_c^2))*F_y / (5 / 3 + 3*(K*l / r) / (8*C_c)-(K*l / r)^3 / (8*C_c^3))$
$= 1 * (1 - (44.7234)^2 / (2*106.1914^2))*350 / (5 / 3 + 3*(44.7234) / (8*106.1914)-(44.7234)^3 / (8*106.1914^3))$
$= 175.71$ MPa

Allowable axial compression and bending (AISC chapter H)

$F'_{ex} = 1*12*\pi^2*E / (23*(K*l / r)^2)$
$= 1*12*\pi^2*199{,}948 / (23*(44.7234)^2)$
$= 514.756$ MPa

$F'_{ey} = 1*12*\pi^2*E / (23*(K*l / r)^2)$
$= 1*12*\pi^2*199{,}948 / (23*(26.2074)^2)$
$= 1{,}499.074$ MPa

$F_b = 1*0.66*F_y$
$= 1*0.66*350$
$= 231$ MPa

Compressive axial stress

$f_a = P_1 / A$
$= 210{,}376.67 / 9{,}290.3038$
$= \underline{22.645}$ MPa

Bending stresses

$f_{bx} = F*\cos(\alpha)*L / (I_x / C_x) + P_1*E_{cc} / (I_x / C_x)$
$= 6{,}791.73*\cos(56)*2{,}410.9 / (1e4*3{,}887.6013 / 127) + 210{,}376.67*12.7 / (1e4*3{,}887.6013 / 127)$
$= \underline{38.64}$ MPa

$f_{by} = F*\sin(\alpha)*L / (I_y / C_y)$
$= 6{,}791.73*\sin(56)*2{,}410.9 / (1e4*11{,}321.49 / 126.75)$
$= \underline{15.197}$ MPa

AISC equation $H_{1\text{-}1}$

$H_{1\text{-}1} = f_a / F_a + C_{mx}*f_{bx} / ((1 - f_a / F'_{ex})*F_{bx}) + C_{my}*f_{by} / ((1 - f_a / F'_{ey})*F_{by})$
$= 22.645 / 175.71 + 0.85*38.64 / ((1 - 22.645 / 514.756)*231) + 0.85*15.197 / ((1 - 22.645 / 1{,}499.074)*231)$
$= \underline{0.3344}$

AISC equation $H_{1\text{-}2}$

$H_{1\text{-}2} = f_a / (0.6*1*F_y) + f_{bx} / F_{bx} + f_{by} / F_{by}$
$= 22.645 / (0.6*1*350) + 38.64 / 231 + 15.197 / 231$
$= \underline{0.3409}$

4, W 10x49 legs are adequate.

Anchor bolts - Seismic empty corroded condition governs

Tensile loading per leg (2 bolts per leg)

R = 4*M / (N*BC) - W / N
= 4*37,983.3 / (4*3.7816) - 257,033 / 4
= -54,214 N
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).

$Z_w = (2*b*d + d^2) / 3$
$= (2*25.3492*11.81 + 11.81^2) / 3$
$= 246.0747 \text{ cm}^2$

$J_w = (b + 2*d)^3 / 12 - d^2*(b + d)^2 / (b + 2*d)$
$= (25.3492 + 2*11.81)^3 / 12 - 11.81^2*(25.3492 + 11.81)^2 / (25.3492 + 2*11.81)$
$= 5{,}852.7376 \text{ cm}^3$

$E = d^2 / (b + 2*d)$
$= 118.1^2 / (253.49 + 2*118.1)$
$= 28.48$ mm

Governing weld load $f_x = Cos(56)*6,791.73 = 3,797.89$ N
Governing weld load $f_y = Sin(56)*6,791.73 = 5,630.6$ N

$f_1 = P_1 / L_{weld}$
$= 210,376.67 / 48.9692$
$= 4,296.1$ N/cm (V_L direct shear)

$f_2 = f_y*L_{leg}*0.5*b / J_w$
$= 5,630.6*241.09*0.5*25.3492 / 5,852.7376$
$= 2,939.74$ N/cm (V_L torsion shear)

$f_3 = f_y / L_{weld}$
$= 5,630.6 / 48.9692$
$= 114.98$ N/cm (V_c direct shear)

$f_4 = f_y*L_{leg}*E / J_w$
$= 5,630.6*241.09*2.8482 / 5,852.7376$
$= 660.62$ N/cm (V_c torsion shear)

$f_5 = (f_x*L_{leg} + P_1*E_{cc}) / Z_w$
$= (3,797.89*241.09 + 210,376.67*1.27) / 246.0747$
$= 4,806.71$ N/cm (M_L bending)

$f_6 = f_x / L_{weld}$
$= 3,797.89 / 48.9692$
$= 77.56$ N/cm (Direct outward radial shear)

$f = Sqr((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
$= Sqr((4,296.1 + 2,939.74)^2 + (114.98 + 660.62)^2 + (4,806.71 + 77.56)^2)$
$= 8,764.42$ N/cm (Resultant shear load)

Required leg to pad fillet weld leg size (welded both sides + top)

$t_w = f / (0.707*0.55*S_a)$
$= 876.44 / (0.707*0.55*138)$
$= \underline{16.33}$ mm

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

$Z_w = b*d + d^2 / 3$
$= 356*460 + 460^2 / 3$
$= 234,293.3$ cm^2

$J_w = (b + d)^3 / 6$
$= (35.6 + 46)^3 / 6$
$= 90,556.42$ cm^3

$f_1 = P_1 / L_{weld}$
$= 210,376.67 / 163.2$

= 1,289.07 N/cm (V_L direct shear)

$f_2 = f_y * L_{leg} * 0.5 * b / J_w$
= 5,630.6*2,410.9*0.5*356 / 9,055,641.6
= 266.83 N/cm (V_L torsion shear)

$f_3 = f_y / L_{weld}$
= 5,630.6 / 163.2
= 34.5 N/cm (V_c direct shear)

$f_4 = f_y * L_{leg} * 0.5 * d / J_w$
= 5,630.6*2,410.9*0.5*460 / 9,055,641.6
= 344.78 N/cm (V_c torsion shear)

$f_5 = (f_x * L_{leg} + P_1 * E_{cc}) / Z_w$
= (3,797.89*241.09 + 210,376.67*12.7) / 2,342.9333
= 504.84 N/cm (M_L bending)

$f_6 = f_x / L_{weld}$
= 3,797.89 / 163.2
= 23.27 N/cm (Direct outward radial shear)

$f = Sqr((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
= $Sqr((1,289.07 + 266.83)^2 + (34.5 + 344.78)^2 + (504.84 + 23.27)^2)$
= 1,686.29 N/cm (Resultant shear load)

Required pad to vessel fillet weld leg size (welded all around the pad edge)

$t_w = f / (0.707*0.55*S_a)$
= 168.63 / (0.707*0.55*138)
= <u>3.14</u> mm

9.5 mm pad to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$f_p = P / (B*N)$
= 227,452.37 / (330*330)
= 2.089 MPa

m = (N - 0.95*d) / 2
= (330 - 0.95*253.49) / 2
= 44.59 mm

n = (B - 0.8*b) / 2
= (330 - 0.8*254) / 2
= 63.4 mm

$L = 0.5*(d + b) / 2 - Sqr((0.5*(d + b))^2 / 4 - P / (4*F_p))$
= $0.5*(253.49 + 254) / 2 - Sqr((0.5*(253.49 + 254))^2 / 4 - 227,452.37 / (4*5.171))$
= 55.46 mm

$t_b = Largest(m, n, L)*Sqr(3*f_p / S_b)$
= 63.4*Sqr(3*2.089 / 165.474)
= <u>12.34</u> mm

The base plate thickness is adequate.

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 mm

Local circumferential pressure stress = P*R_i / t =133.972 MPa

Local longitudinal pressure stress = P*R_i / (2*t) =66.989 MPa

Maximum combined stress (P_L+P_b+Q) = 179.38 MPa
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-414 MPa

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

Maximum local primary membrane stress (P_L) = 148.04 MPa
Allowable local primary membrane stress (P_L) = +-1.5*S = +-207 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 mm

Local circumferential pressure stress = P*R_l / t =133.972 MPa

Local longitudinal pressure stress = P*R_l / (2*t) =66.989 MPa

Maximum combined stress (P_L+P_b+Q) = 194.79 MPa
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-414 MPa

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

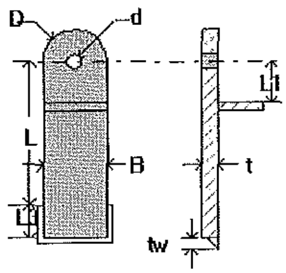
Maximum local primary membrane stress (P_L) = 145.24 MPa
Allowable local primary membrane stress (P_L) = +-1.5*S = +-207 MPa

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_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	-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, Dp	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}	39.35 mm
Required Lug Thickness, t_{reqd}	21.28 mm
Lug Stress Ratio, σ_{ratio}	0.91
Weld Shear Stress Ratio, τ_{ratio}	0.95
Lug Design	Acceptable
Local Stresses	Acceptable
Maximum Out of Plane Lift Angle - Weak Axis Bending	10.11°

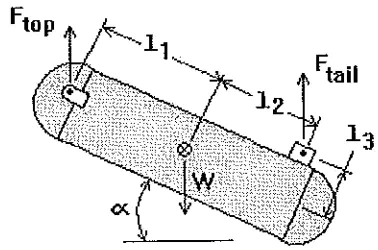
COMPRESS recommends a spreader beam be used to prevent weak axis bending of the top lugs.
No consideration is given for any bracing plate from the lug to the vessel.

Lift Forces

Lift force on lugs during rotational lift ($0° \leq \alpha \leq 90°$):

$2{*}F_{top} = W{*}(l_2{*}\cos(\alpha) + l_3{*}\sin(\alpha)) / (l_1{*}\cos(\alpha) + l_2{*}\cos(\alpha) + l_3{*}\sin(\alpha))$

$F_{tail} = W - (2{*}F)$



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} = $(2^*F_v / (\pi^*\sigma_s))^{0.5}$
= $(2^*254,846.6 / (\pi^*104.8))^{0.5}$ = <u>39.35 mm</u>

d_{reqd} / D_p = 39.35 / 50.8 = 0.77 Acceptable

σ = F_v / A
= $F_v / (2^*(0.25^*\pi^*D_p^2))$
= $254,846.6 / (2^*(0.25^*\pi^*50.8^2))$ = 62.87 MPa

σ / σ_s = 62.87 / 104.8 = 0.6 Acceptable

Lug Thickness - Tensile stress

t_{reqd} = $F_v / ((D - d)^*\sigma_t)$
= 254,846.6 / ((254 - 57)*157.2) = 8.23 mm

t_{reqd} / t = 8.23 / 32 = 0.26 Acceptable

σ = F_v / A

$= F_v / ((D - d)*t)$
$= 254,846.6 / ((254 - 57)*32) = 40.43$ MPa

$\sigma / \sigma_t = 40.43 / 157.2 = 0.26$ Acceptable

Lug Thickness - Bearing stress

$t_{reqd} = F_v / (D_p*\sigma_p)$
$= 254,846.6 / (50.8*235.8) = \underline{21.28 \text{ mm}}$

$t_{reqd} / t = 21.28 / 32 = 0.66$ Acceptable

$\sigma = F_v / A_{bearing}$
$= F_v / (D_p*(t))$
$= 254,846.6 / (50.8*(32)) = 156.77$ MPa

$\sigma / \sigma_p = 156.77 / 235.8 = 0.66$ Acceptable

Lug Thickness - Shear stress

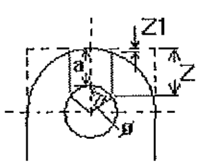
$t_{reqd} = [F_v / \sigma_s] / (2*L_{shear})$
$= (254,846.6 / 104.8) / (2*105.79) = \underline{11.49 \text{ mm}}$

$t_{reqd} / t = 11.49 / 32 = 0.36$ Acceptable

$\tau = F_v / A_{shear}$
$= F_v / (2*t*L_{shear})$
$= 254,846.6 / (2*32*105.79) = 37.64$ MPa

$\tau / \sigma_s = 37.64 / 104.8 = 0.36$ Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



$\phi = 55*D_p / d$
$= 55*50.8 / 57$
$= 49.0175°$
$Z = 0.5*(D - d) + 0.5*D_p*(1 - \cos(\phi))$
$= 0.5*(254 - 57) + 0.5*50.8*(1 - \cos(49.0175))$
$= 107.24$ mm
$Z1 = 0.5*D - \text{sqr}(0.25*D*D - (0.5*D_p*\sin(\phi))^2)$

$= 0.5*254 - sqr(0.25*254*254 - (0.5*50.8*\sin(49.0175))^2)$

$= 1.46$ mm

$L_{shear} = Z - Z1$

$= 105.79$ mm

Lug Plate Stress

Lug stress, tensile + bending, during rotational lift:

$\sigma_{ratio} = [F_{ten} / (A_{ten}*\sigma_t)] + [M_{bend} / (Z_{bend}*\sigma_b)] \leq 1$

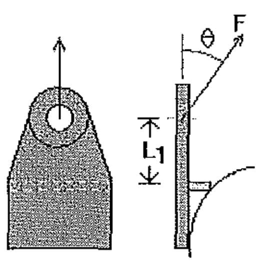
$= [(F_{top}(\alpha)*\sin(\alpha)) / (t*B*\sigma_t)] + [(6*F_{top}(\alpha) *L*\cos(\alpha)) / (t*B^2 * \sigma_b)] \leq 1$

$= 117,771.7*\sin(38.0) / (32*254*157.2) + 6*(117,771.7)*547*\cos(38.0) / (32*254^2*172.92)$

$= \underline{0.91}$ Acceptable

Weak Axis Bending Stress

Maximum lift cable angle from vertical $\theta = 10.11°$



$\sigma_b = M / Z = (F*\sin(\theta)* L_1) / Z$

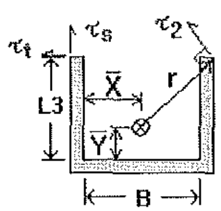
$F*\cos(\theta) = 0.5*W \Rightarrow F = 0.5*W / \cos(\theta)$

$\theta = \arctan((2*\sigma_b*Z) / (W* L_1))$

$\theta = \arctan((2*172.92*(254*32^2/6)) / (509,693.3*165)) = 10.11°$

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_{weld} = $0.707 * t_w * (2 * L_3 + B)$
= $0.707*22*(2*152 + 254)$ = $8,679.13\ mm^2$

τ_t = $F_r * \cos(\alpha) / A_{weld}$
= $117,771.7*\cos(38.0) / 8,679.13$ = 10.69 MPa

τ_s = $F_r * \sin(\alpha) / A_{weld}$
= $117,771.7*\sin(38.0) / 8,679.13$ = 8.35 MPa

Torsional shear:

Weld centroid:

Y_{bar} = $L_3^2 / (2*L_3 + B)$
= $152^2 / (2*152 + 254)$ = 41.41 mm

Second polar moment of area:

J = $0.707*t_w*((8*L_3^3 + 6*L_3*B^2 + B^3) / 12 - L_3^4 / (2*L_3 + B))$
= $0.707*22* ((8*152^3 + 6*152*254^2 + 254^3) / 12 - 152^4 / (2*152 + 254))$ = $119040808\ mm^4$

Radial distance from centroid to weld:

r = $sqr((X_{bar})^2 + (L_3 - Y_{bar})^2)$
= $sqr((0.5*254)^2 + (152 - 41.41)^2)$ = 168.41 mm

θ_r = $\arctan((L_3 - Y_{bar}) / (X_{bar}))$
= $\arctan(110.59 / 127)$ = 41.05°

τ_2 = M * r / J
= $[F(\alpha)*\cos(\alpha)*(L + L_3 - Y_{bar})] * r / J$
= $(117,771.7*\cos(38.0)*657.59)*168.41 / 119040804.1994$
= 86.34 MPa

τ_{ratio} = $sqr((\tau_t + \tau_2*\sin(\theta_r))^2 + (\tau_s + \tau_2*\cos(\theta_r))^2) / \tau_{allowable} \le 1$
= $sqr ((10.69 + 86.34*\sin(41.05))^2 + (8.35 + 86.34*\cos(41.05))^2) / 104.8$
= 0.95 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 mm

Local circumferential pressure stress = P*R_i / t =0 MPa

Local longitudinal pressure stress = P*R_i / (2*t) =0 MPa

Maximum combined stress (P_L+P_b+Q) = 68.26 MPa
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-414 MPa

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

Maximum local primary membrane stress (P_L) = -8.73 MPa
Allowable local primary membrane stress (P_L) = +-1.5*S = +-207 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_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	-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.

2

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

Stress Analysis due to Nozzle Loads

Not Applicable

3

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

Foundation Load Calculations

Not Applicable

4

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

Lifting Device

See ASME Design Calculation

5

ECODYNE Limited

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	CUSTOMER
Pressure Relief Valve Sizing Basis	**MEG Energy Corporation** **c/o SNC Lavalin** **Christina Lake Phase 3A** **PO No. P-5675-02**

REV	DATE	REMARKS	BY	CHKD
D	2013 June 24	REVISED PAGE 3	[illegible]	AV
C	2013 Apr 26	ADDED PAGE 3	SC	AV
B	2013 Mar 5	ADDED A FIRE CASE CONSIDERATION	AV	SC
A	2013 Jan 17	FIRST ISSUE	AV	SC

SCALE -

	BY	DATE
DRN	AV	2013 Jan 17
CHKD	SC	2013 Jan 17
APPD	AV	2013 Jan 17

ECODYNE Limited

A Marmon Water/Berkshire Hathaway Company

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DWG. NO.	REV.
32125-A-5021	**D**

Cover page

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
53																			
54																			
55		MEG Energy, Christina Lake- After Filters PSVs										22 Jul'2010sc							
56		Thermal relief Valve –			PSV-	for seven After Filters													
57																			
58		Basis: Relief of water from shut-in vessel due to liquid volume expansion when heat is absorbed from ambient-																	
59		Outdoor installation absorbing solar heat at 500 btu/h/ft2									<— Not applicable for this case								
60		Approx calculation																	
61																			
62																			
63		Dia ft, mm	13	3962															
64																			
65		S.side ft, mm	8	2438		Vol, ft3, L	1637.0	46349	incl elliptical hds										
66																			
67																			
68		Heat absorbed fr ambient	20.0	kW		=> btu/hr	68288			Temp increase rate F/h, C/h =		0.67	0.37						
69		based on heat transfer fr ambient to uninsulated					=C67*3414.4			Assuming all heat go to water for time calculation									
70		vessel at air velocity 8.8 ft/s. Conservative since vessels are insulated								Time to hot temp, h=>		59.74							
71																			
72					Initial temp, F, C		Hot temp, F, C			Time of heating, h									
73					40	4.4	80	26.7											
74																			
75		Water sp Vol, ft3/lb			0.016019		0.016072												
76		Water vol, ft3			1637.0		1642.462												
77																			
78		CS vessel vol, ft3,			1637.0		1638.262												
79																			
80		Water vol exp - vessel vol exp , ft3, L					4.100	116.1		59.74	h								
81																			
82		Water relief flow, ft3/h					0.069												
83		Water relief flow, gph					0.51												
84		Water relief flow, gpm, m3/h					0.0086	0.00194											
85																			
86		Water relief capacity specified, gpm m3/h					2.00	0.45	==> This illustrates that a PSV with nominal capacity of 2 gpm (0.45 m3/h) is more than										
87									sufficient.										
88							Actual relief capacity with 0.068 in2												
89							Ref:												
90							Farris 2700 Series PSV												
91							0.0.068 in inlet size 3/4x1" threaded												
92							Relief capacity 22.4 gpm, Pset 100#												
93																			
94																			
95																			
96																			
97																			
98																			
99																			
100																			
101																			
102																			

	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					This job does not include PSV . This is estimated in case client want to put in PSV assuming there is										
5					sustainable and prolonged fire. Calc is approximate. No basis was stated by client. Use this for allowance										
6					of nozzle.										
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 vesssel 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 defination of A.												
24												*2:1 ellip head factor=*	*1.38*		
25		**Calculation:**										*F + D head factor=*	*1.17*		
26			*input*						Area, ft2			*Flat head factor =*	*1*		
27			Vessel dia, ft:				13		366.3	head surface		*Head factor used=*	*1.38*		
28			Vessel length or straight side, ft:				8.33		340.2	vessel side surface					
29			Total surface area, ft2						706.5						
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, Consodidated 1900 ser						
42															
43										Actual selection has to be done by valve supplier					
44										based on specific valve charactoerics and piping config					
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		163.6	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, consodidated 1900 ser						