DOCKETED	
Docket Number:	09-AFC-05C
Project Title:	Abengoa Mojave Compliance
TN #:	232687
Document Title:	COMP14-06-00 Carbon Adsorption System Improvement
Description:	COMP14-06-00 Carbon Adsorption System Improvement
Filer:	Jose Manuel Bravo Romero
Organization:	Mojave Solar Project
Submitter Role:	Applicant
Submission Date:	4/7/2020 11:52:20 AM
Docketed Date:	4/7/2020

Mojave Solar LLC

42134 Harper Lake Road	Phone: 760 308 0400
Hinkley, California 92347

Submitted Electronically

Subject: **09-AFC-5C**
Condition: **Compliance 14**
Description: **Petition to Amend**
Submittal Number: **COMP 14-06-00**

February 13, 2020

Keith Winstead
Compliance Project Manager
Siting, Transmission and Environmental Protection
California Energy Commission
1516 Ninth Street, MS-2000
Sacramento, CA 95814
keith.winstead@energy.ca.gov

Christian Anderson, Air Quality Engineer
Mojave Air Quality Management District
14306 Park Avenue
Victorville, California 92392
canderson@mdaqmd.ca.gov

Dear Mr. Winstead and Mr. Anderson,

As required by Condition of Certification COMPLIANCE-14, pursuant to Title 20 of the California Code of Regulations, section 1769 (a) of the California Energy Commission regulations, Mojave Solar Project (MSP) files this Petition to Amend with the California Energy Commission.

Should you have any questions or comments, please don't hesitate to contact me.

I look forward to receiving your approval to proceed.

Sincerely,

Jose Manuel Bravo Romero

Manager
Permitting, Compliance, Quality & Environmental Department
ASI Operations LLC
42134 Harper Lake Rd
Hinkley, CA 92347
Cell: (303) 378-7302
jmanuel.bravo@atlanticayield.com

Mojave Solar LLC

42134 Harper Lake Road
Hinkley, California 92347

Phone: 760 308 0400

Attachments: Petition To Amend (PTO). / Staff Approved Project Modification (SAPM) report.

Mojave Solar Project (09-AFC-5C)

Petition to Amend

COMPLIANCE 14-06-00 Carbon Adsorption System Improvement

Version:1

Review date: 02/12/2020

1 Introduction

1.1 Introduction to Petition

Pursuant to Title 20 of the California Code of Regulations, section 1769 (a) of the California Energy Commission (Commission) regulations, Mojave Solar Project (MSP) files this Petition to Amend (Petition) with the California Energy Commission (Commission) to modify the existing Mojave Solar Project (MSP) Final Decision. The Commission certified the License for the MSP on September 8, 2010 and MSP is currently under operation.

This petition requests the installation of new improved Carbon Beds on vertical position replacing the existing horizontal vessels. As discussed in this Petition, the new system will not result in any significant environmental impacts and no modifications to the Conditions of Certification are necessary.

1.2 Overview of Proposed Modifications

The project is a solar electric generating facility located on 1,765 acres in unincorporated San Bernardino County, CA.

The project site is accessed by Harper Lake Road, which is located approximately 20 miles west of Barstow along the Highway 58 corridor. The project site is approximately six miles North of where Harper Lake Road intersects with Highway 58.

1.2.1 Background

During normal startup and typical operating transient conditions (daily warm-up or restart from extended intraday outages), the ullage system and associated emission controls must function to accommodate expanding HTF that reduces freeboard volume in the expansion and overflow tanks. Nitrogen added to the freeboard of these tanks during contraction cycles must later be vented (e.g., at least once per day) during normal warm up and expansion cycles.

When the VP-1® HTF is heated to high temperatures, it begins to degrade and accumulates some lower boiling point products (e.g., Benzene, Toluene, Phenol…) that are key drivers of increased potential for volatile organic compound (VOC) emissions. More low boilers means more potential load on emission control systems. Some constituent compounds are also classified by the EPA as hazardous air pollutants (HAPs). However, it is well known that granular activated carbon is capable of quantitative VOCs capture to very low equilibrium concentrations, which are below practical detection limits when the activated carbon filters are properly designed and maintained.

The current carbon filter system is configured in parallel with no guard beds. The original design also involved horizontal cylindrical packed beds of activated carbon with no vapor plenum below the carbon bed. The original design did not anticipate having any moisture contamination. MSP consistently reported that the existing emission control system proved adequate performance in compliance testing until recently. On 15 March 2019, third-party testing reported 94.3% removal of VOCs after carbon filters MF-206C/D (expansion system), compared to 95% minimum efficiency required by the operating permit. Efficiency at this level suggests either break-through is occurring (saturated bed), or there is mal-distribution (channeling), or unintended bypassing (internal or external), or all of the above.

The California Energy Comission's CPM and the Mojave Desert Air Quality Management District's representatives were aware and actively participating on all process at all times either in person or through electronic communications. The District provided already a Temporary Permit To Operate (Annex 2) in order to keep the Compliance at all times. This Permit can turn into a permanent upon this Petition's approval.

1.3 Description and need for the modifications

The purpose of this petition is to improve quantitatively VOCs capture and qualitatively the Ullage System by installing the suggested and proven new Carbon Bed configuration.

Mojave Solar consider installing a carbon bed system that can provide vertical flow orientation. The proposed canisters will include a flat activated carbon bed support across the entire cross-sectional area as well as a plenum area below this support for effective air distribution across the bed (Annex 1). In order to handle a wide range of flows and VOC concentrations, the system will include three vessels (three units for the high-pressure side and three for the low-pressure side) that can be used one at a time, operated in parallel, or in series. The three canisters will be interconnected using a pipe rack system that allows the vessels to operate in series, lead lag, or single vessel.

This new modification is installed in Beta temporarily (after agencies approval) and was tested on September 2019 (please refer to AQ72-10-01 submission for further information). Also, as a proven efficiency, we are including the submittal for AQ70-05-00, PTO's C012015 and C012016 Annual emission report submittal (Annex 3), which attest the improvement between the existing system (Alpha) and the new modification proposed (Beta).

1.3.1 Modifications to Conditions of Certification

MSP believe that a modification to the conditions of certification contained in the Final Decision is not necessary and therefore this Petition do not propose any, the only Conditions of Certification that might be affected is AQ-12, that can be considered as Staff Approved Project Modification (SAPM) since the change itself will only affect the Mojave Desert Air Quality

Management District granted permits to operated numbers C012015 and C012016 (Refer to AQSC8-11-00 MDAQMD Renewed Permits to Operate) included in Annex 2.

2 IV Engineering Assessment

This section contains an evaluation of the modification proposed in this Petition to determine if it would result in modification of the findings, conclusions or conditions of certification for each technical discipline included within the Engineering Assessment section of the Final Decision.

2.1 Facility Design

The construction of the new staging area would not change any component of the design of the facility nor would result in any operational changes when compared to how the facility is currently operated.

3 V Public Health and Safety

This section contains an evaluation of the modifications proposed in this Petition to determine if they would result in modification to the findings, conclusions or conditions of certification for each technical discipline included within the Public Health and Safety section of the Final Decision.

3.1 Green House Gas Emissions, Air Quality and Public Health

This Petition will not affect the emissions from the MSP and therefore will not result in modification to the findings, conclusions or conditions of certification in the areas of Air Quality, of Greenhouse Gases, and Public Health. The three of them will be benefited from this proposed improvement.

3.2 Worker Safety and Fire Protection

This Petition does not affect any of the findings, conclusions, or conditions of certification in the Worker Safety and Fire Protection section of the Final Decision.

3.3 Hazardous Materials Management

This Petition does not affect any of the findings, conclusions, or conditions of certification in the Hazardous Materials Management section of the Final Decision. Nonetheless, the Hazardous Material Business Plan, the Spill Prevention, Control and Countermeasure Plan (SPCC) and the Process Safety Management Plan (PSMP) will be modified after the construction to properly address this new area, since some hazardous materials will be stored in this location.

3.4 Waste Management

This Petition does not affect any of the findings, conclusions, or conditions of certification in the Waste Management section of the Final Decision.

4 VI Environmental Assesment

This section contains an evaluation of the modification proposed in this Petition to determine if it would result in modification to any of the findings, conclusions or conditions of certification for each technical discipline included within the Environmental Assessment section of the Final Decision.

4.1 Biological Resources

This Petition does not affect any of the findings, conclusions, or conditions of certification in the Biological Resources section of the Final Decision because it does not propose any changes to operation of the MSP.

4.2 Soil and Water Resources

This Petition does not affect any of the findings, conclusions, or conditions of certification in the Soil and Water Resources section of the Final Decision because it does not modify any construction activity or planned operation of the MSP.

4.3 Cultural Resources

This Petition does not affect any of the findings, conclusions, or conditions of certification in the Cultural Resources section of the Final Decision because it does not modify any construction activity or planned operation of the MSP.

4.4 Geological and Paleontological Resources

This Petition does not affect any of the findings, conclusions, or conditions of certification in the Geological and Paleontological Resources section of the Final Decision because it does not propose any changes to operation of the MSP.

5 VII Local Impact Assesment

This section contains an evaluation of the modifications proposed in this Petition to determine if it would result in modification to any findings, conclusions or conditions of certification for each technical discipline included within the Local Impact Assessment section of the Final Decision.

5.1 Land Use

The modification proposed in this Petition will not affect the findings and conclusions contained in the Land Use section of the Final Decision.

5.2 Traffic and Transportation

This Petition does not affect any of the findings, conclusions, or conditions of certification in the Traffic and Transportation section of the Final Decision because it does not propose any changes to operation of the MSP.

5.3 Socioeconomics and Environmental Justice

The Petition will not affect the findings and conclusions, nor require any modifications to the existing conditions of certification, contained in the Socioeconomic Resources section of the Final Decision because the modification does not modify construction or operation of the MSP.

5.4 Noise and Vibration

This Petition does not affect any of the findings, conclusions, or conditions of certification in the Noise and Vibration section of the Final Decision because it does not propose any changes to operation of the MSP.

5.5 Visual Resources

This Petition does not affect any of the findings conclusions, or conditions of certification in the Visual Resources section of the Final Decision because the new staging area will not result in a significant visual impact.

6 Potential effects on Property Owners

The Commission's Power Plant Siting Regulations require a Petition for Amendment to include 1) a discussion of how the modification affects the public; 2) a list of property owners potentially affected by the modification; and 3) a discussion of the potential effect on nearby property owners, the public and the parties in the application proceedings.

As described in technical area evaluated in Sections 2 through 5 of this Petition, this Petition does not create any significant impacts, and it therefore would not affect the public differently than identified in the Final Decision.

7 Annexes:

7.1 Annex 1. MSP Modification Proposal

ABSTRACT
Basis design for improved vertical flow activated carbon emissions treatment system at the Mojave Solar Project.

January 2020

MOJAVE SOLAR / ULLAGE SYSTEM

Basis Of Design For Improved Carbon Bed System

CARBON SUPPLY INC
CSI
SALES, SERVICE AND MORE

January 21, 2020

Mojave Solar LLC
42134 Harper Lake Road
Hinkley, CA 92347

Subject: Ullage Site Emission Controls System Improvement

ENGINEERING EVALUATION AND CERTIFICATION

This report was prepared to provide a recommendation for improving the existing activated carbon emissions control system that is currently installed at the Mojave Solar power plant. It was prepared for the exclusive use of Mojave Solar for the express purpose stated above. Any reuse of this report for a different purpose or by others not identified above shall be at the uses sole risk without liability to Carbon Supply Inc. To the extent that this report is based on information provided to Carbon Supply Inc. by third parties. Carbon Supply Inc. may have efforts to verify this third part information, but Carbon Supply Inc. cannot guarantee the completeness or accuracy of this information. The opinions express and data collected are based on the conditions of the site existing at the time of the field investigation. No other warranties, express or implied are made by Carbon Supply Inc.

All information, conclusions, and recommendations provided by CSI in this document regarding the site have been prepared under the supervision of and reviewed by the licensed professional whose signature appears below.

Licensed Approver:

Name: Wael S. Ibrahin, P.E.

Date: 1/21/2020

REGISTERED PROFESSIONAL ENGINEER
WAEL S. IBRAHIM
48336
EXP. 6/30/2020
CIVIL
STATE OF CALIFORNIA

Table Of Contents

Observation

Mojave Solar's current carbon bed design consists of cylindrical vessels designed to treat a horizontal flow through a packed bed of activated carbon media. The existing design can potentially cause the flow of air to bypass across the top of horizontal bed leading to unintentional channeling. Activated carbon beds are currently set up for parallel flow operation.

Equipment Recommendation

Carbon supply Inc recommends carbon bed system that can provide vertical flow orientation. The proposed canisters will include a flat activated carbon bed support across the entire cross-sectional area as well as a plenum area below this support for effective air distribution across the bed. In order to handle a wide range of flows and VOC concentrations, the systems will include three vessels that can be used one at a time, operated in parallel, or in series. The three canisters will be interconnected using a pipe rack system that allows the vessels to operate in series, lead lag, or single vessel. For the high-pressure system, each carbon bed is designed to contain 3,000 lbs. of activated carbon media. The low-pressure system will also consist of three carbon beds and each will contain 1,000 lbs. of carbon media.

(High Pressure System Triplex Carbon Bed, Model 1106 Drawing 1106-B)

Operating Recommendations

The preferred method of operation should include (2) filters in series flow, while the third canister it to be held on standby. By having a tertiary canister on standby, this will allow the system to continue operating two vessels in series, while the spent carbon bed is serviced and replaced. Listed below are typical operational modes.

• Shutdown - Both filters completely off-line and isolated.

• Series Flow - Influent enters primary filter and exits through secondary filter.

• Isolation Flow - Only one filter is receiving influent.

• Parallel Flow - Both filters are receiving the influent as the primary. Flow is split equally between the filters. This mode is used when higher flow rates need to be achieved and contact times are not critical.

(Lead/Lag Piping System "Drawing No. 1106-D")

Carbon Bed Size Design

Activated carbon bed sizing for a particular application is governed primarily by bed surface loading rate. With a standard 4-foot carbon bed depth, a maximum gas-loading rate of 100 cfm per square foot of bed surface should be maintained. This ensures adequate gas contact and sufficient time to reach adsorption equilibrium. Higher gas flows are handled by increasing the carbon bed surface (larger adsorbers) or adding multiple beds in parallel.

The two main issues with sizing vapor phase carbon beds are the total carbon bed weight and the air flow. The ideal or logical carbon bed weight is usually determined once the expected carbon usage rates are calculated using our isotherm program and can therefore estimate when service will be required to replace spent activated carbon.

Beta High Pressure System Sizing Recommendation

Based on the historical data provided, the average flow rate for the Beta high pressure is roughly 438.96 CFM, the highest recorded flow rate was measured at 885 CFM, and the lowest was 210 CFM. CSI is recommending a lead lag system consisting of thee (54" inch) diameter vessels, each capable of holding 3,000 lbs. of activated carbon media.

Dimensions: 54" OD Bed x 114" side shell

Bed Area: (53.25" ID) = 15.466 square ft.

Nominal Flow Rate (cfm): 1,546.60 CFM

Carbon Capacity (pounds): 3,000 lbs.

Fittings: 8" inch – 150# RFSO Flange

Beta Low Pressure System Sizing Recommendation

Based on the historical data provided, the average flow rate for the Beta low pressure system is roughly 213.94 CFM, the highest recorded flow rate was measured at 1,062 CFM, and the lowest was 18 CFM. The low-pressure system appears to have the highest fluctuation in flow rates. In order to match the flowrate with the best possible operating range of the carbon vessels; the interconnecting pipe manifold will allow the operator to direct the flow distribution between a single, series, or parallel flow orientation. CSI is recommending a lead lag system consisting of thee (36” inch) diameter vessels, each capable of holding 1,500 lbs. of activated carbon media.

Dimensions: 36" OD bed x 108” side shell

Bed Area: (35.25” ID) = 6.73 square ft

Nominal Flow Rate (cfm): 673 CFM

Carbon Capacity (pounds): 1,500 lbs.

Fittings: 4” inch – 150# RFSO Flange

CSI filter vessels are designed and manufactured in the USA, in accordance with engineering standards set forth by the American Society of Mechanical Engineers (ASME). The materials used in construction are in accordance with standards established by AWWA and EPA.

History Of Recorded Flow Rates

	Alpha			Beta	
	Low Pressure	**High Pressure**		**Low Pressure**	**High Pressure**
6/5/2015	95.52	408.13	6/5/2015	200.44	602.37
6/5/2015	74.85	504.23	6/5/2015	53.59	885.05
6/28/2016	13	220	6/28/2016	375	492
6/28/2016	497	334	6/28/2016	18	301
7/7/2017	457	948	7/7/2017	1062	857
7/7/2017	593	885	7/7/2017	1040	487
9/12/2018	151	1199	9/12/2018	53	526
9/12/2018	256	626	9/12/2018	67	597
7/9/2018	15	317	7/9/2018	22	264
7/9/2018	12	309	7/9/2018	35	240
12/3/2018	N/A	N/A	12/3/2018	177	271
12/3/2018	N/A	N/A	12/3/2018	232	268
3/15/2019	43	602	3/15/2019	N/A	N/A
3/15/2019	31	467	3/15/2019	N/A	N/A
6/27/2019	71	268	6/27/2019	25	432
6/27/2019	81	265	6/27/2019	23	375
9/11/2019	N/A	N/A	9/11/2019	21	216
9/11/2019	N/A	N/A	9/11/2019	19	210
Average	170.74	525.17	**Average**	213.94	438.96

Theoretical Vapor Phase Isotherm Prediction
Beta Plant

High Pressure System

Flow: 210 CFM **Temperature** 20° C
Cubic Meters/Hour: 356.979231 **Pressure** 760 mm Hg

Tank No.	Compound	Mol. Wt.	Concentration	mg/m3/hr	Sorption % (w/w)	Carbon Saturated Pounds Per Hour
46 Inlet	**Hexane**	86.18	581 ppm	730736.49	18.00%	9.94443
46 Inlet	**Benzene**	78.10	640 ppm	729665.55	15.00%	11.91583
					Total	21.86026

High Pressure System Estimated Saturated Carbon Lbs. Per Hour: 21.86026

Low Pressure System

Flow: 21 CFM **Temperature** 20° C
Cubic Meters/Hour: 35.6979231 **Pressure** 760 mm Hg

Tank No.	Compound	Mol. Wt.	Concentration	mg/m3/hr	Sorption % (w/w)	Carbon Saturated Pounds Per Hour
31 Inlet	**Hexane**	86.18	18518 ppm	2330039.14	20.00%	28.53809
31 Inlet	**Benzene**	78.10	20918 ppm	23936706.87	18.00%	325.74941
40 Exhaust	**Hexane**	86.18	5.2 ppm	661.48	15.00%	0.01080
40 Exhaust	**Benzene**	78.10	0.49	54.62	12.00%	0.00111
					Total	354.29941

Low Pressure System Estimated Saturated Carbon Lbs. Per Hour: 354.29941

The above data is calculated based on carbon capacities to exhaustion. Other factors including temperature, humidity, and the presence of other contaminants in the air stream may affect the usage rate. These numbers are general guidelines for use in system design.

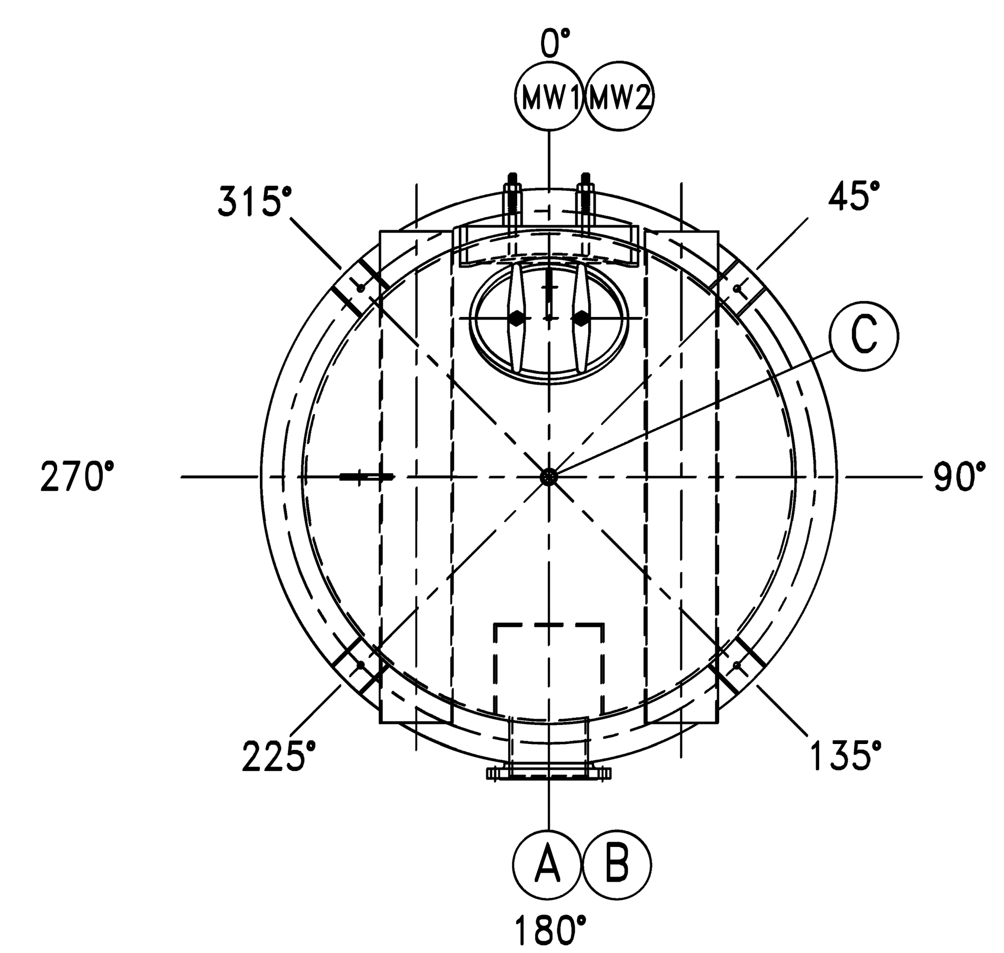
Frequency of unit exchange will depend on the types and loading of VOC’s being treated. Activated carbon media exchange should be scheduled before carbon breakthrough occurs. If the beds are used sequentially, the timing of the breakthrough from the second bed can be estimated by comparing it with the breakthrough time for the first bed (assuming that they operate under similar conditions).

NOZZLE SCHEDULE				
NOZ.	QTY.	SIZE/RATING	MATERIAL	SERVICE
A	1	8"-150# RFSO FLANGE	SA105	INLET
B	1	8"-150# RFSO FLANGE	SA105	OUTLET
C	1	1"-3000# COUPLING	SA105	VENT
D	1	2"-3000# COUPLING	SA105	DRAIN
E	2	1/4"-3000# COUPLING	SA105	SAMPLING PORT
F	2	1/4"-3000# COUPLING	SA105	PRESSURE GAUGE
MW1	1	12"X16"X 3/4"THK ELLIP.MANWAY	SA516 70	MANWAY
MW2	1	14"X18"X 3/4"THK ELLIP.MANWAY	SA516 70	MANWAY

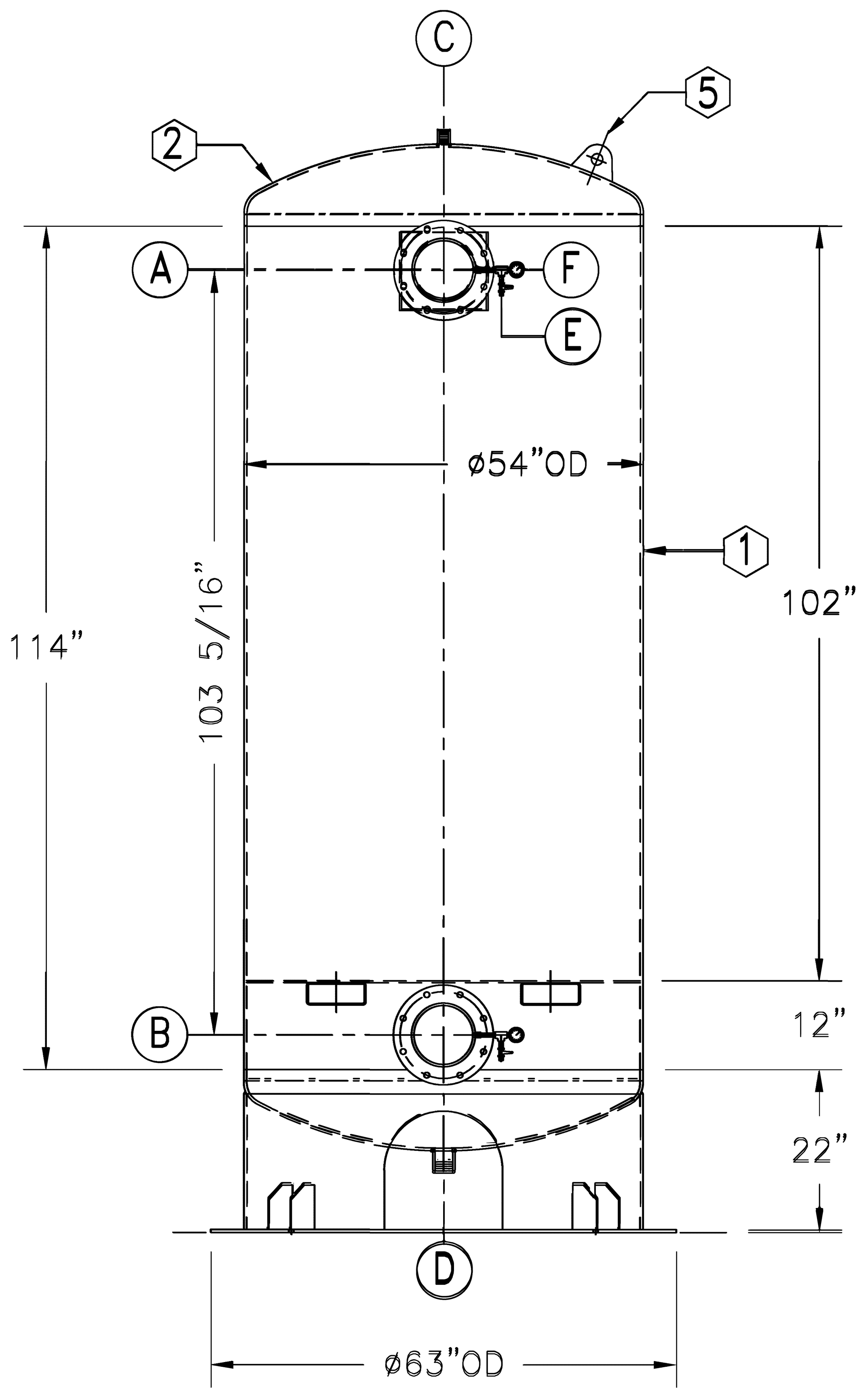
ITEM	QTY.	DIMENSIONS	MATERIAL	DESCRIPTION
1	1	3/8"-PLT X 102" X 168 1/2"LG	SA516 70	SHELL
2	1	ø54"OD, 1 1/2"SF, 3/8"-PLT, F&D HEAD	SA516 70	TOP & BTM. HEAD
3	1	ø53 1/4"OD, STEEL MESH ASSEMBLY	STEEL	STEEL MESH
4	2	4" X 8" X 3/16"-WALL X 54"LG	SA36	FORKLIFT SLOT
5	2	1/2"-PLT X 4" X 6"LG	SA36	LIFT LUG
6	1	1/4"-PLT X ø63"OD	SA516 70	BASE PLATE
7	8	1/4"-PLT X 4 1/2" X 6"	SA36	BASE PLATE GUSSET

COATINGS SCHEDULE		
SURFACE	SURFACE PREPERATION	PRODUCT SPECIFICATION
INTERNAL	SSPC-SP10	SW SHERPLATE PW EPOXY 20-30mls DFT
EXTERNAL	SSPC-SP6	SW ENVIROLASTIC 940 DTM

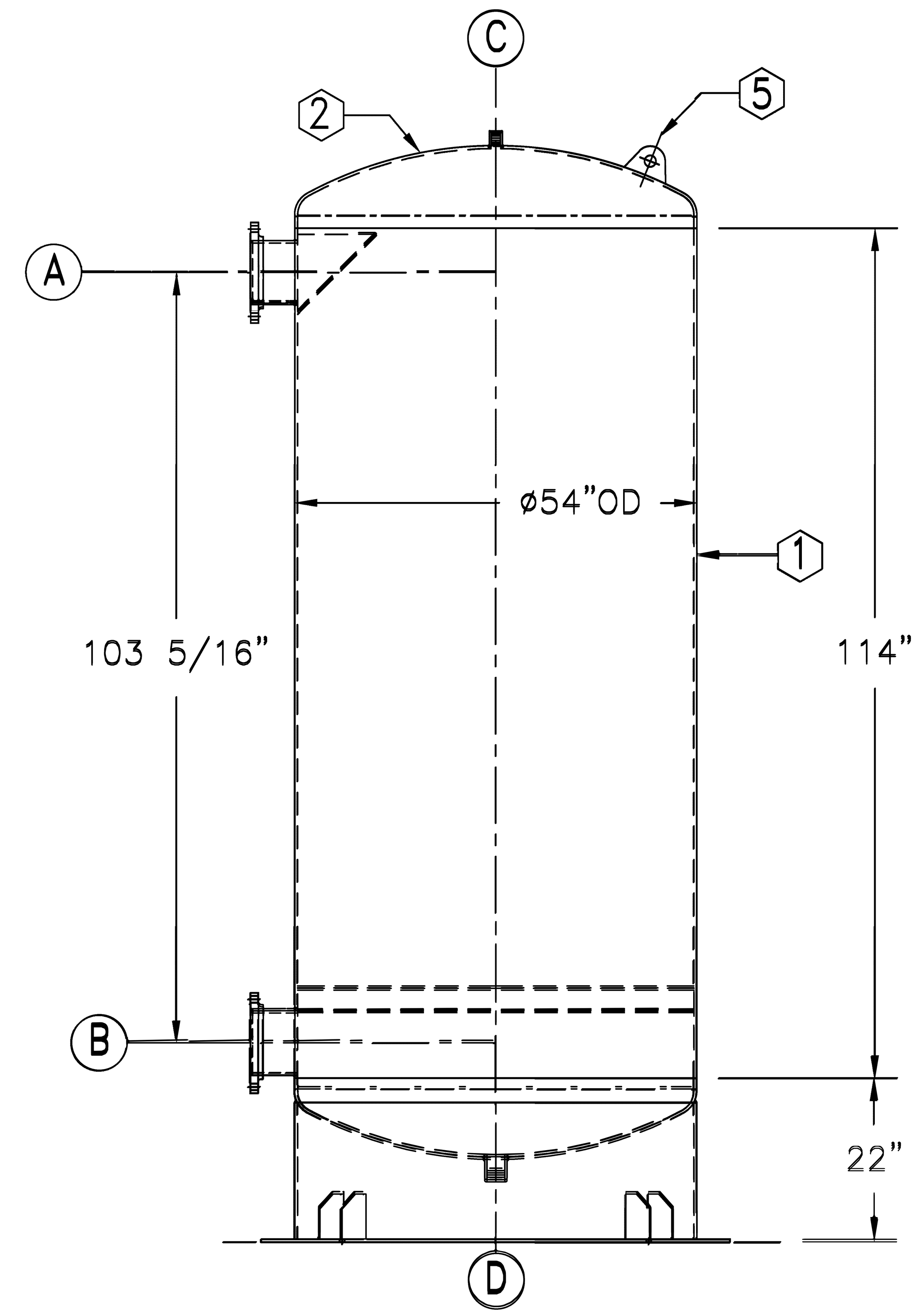
NOTES:
1. ALL MATERIALS & PARTS CALLED OUT ON THIS DRAWING SHALL BE AS SPECIFIED OR "APPROVED EQUAL".
2. DIMENSIONS, UNLESS OTHERWISE INDICATED, ARE NOMINAL. SHOP TOLERANCES ARE:
   FRACTIONS = ±1/16"
   DECIMALS: .XX = ±.010
   .XXX = ±.005
   ANGLES: = ±1/2°
3. DESIGNED IN ACCORDANCE WITH ASME CODE, SECTION VIII, DIVISION 1. VESSEL. NOT STAMPED.
4. INTERNAL PRESSURE: 5PSI.
5. TEMPERATURE: 120°F.
6. PARTIAL VACUUM: 2.94PSI.
7. APPROXIMATE SHIPPING WT.: 2,000#.
8. THESE MATERIALS ARE CONFIDENTIAL AND ARE THE PROPRIETARY INFORMATION OF CARBON SUPPLY, INC. AND MAY NOT BE USED OR REPRODUCED WITHOUT THE CONSENT OF CARBON SUPPLY, INC.



TOP VIEW



FRONT VIEW
(SEE TOP VIEW FOR NOZ. TRUE ORIENTATION)



SHT. 1

CARBON SUPPLY INC.
CSI
BELL GARDENS, CA

CSI V-3000FB
CARBON BED

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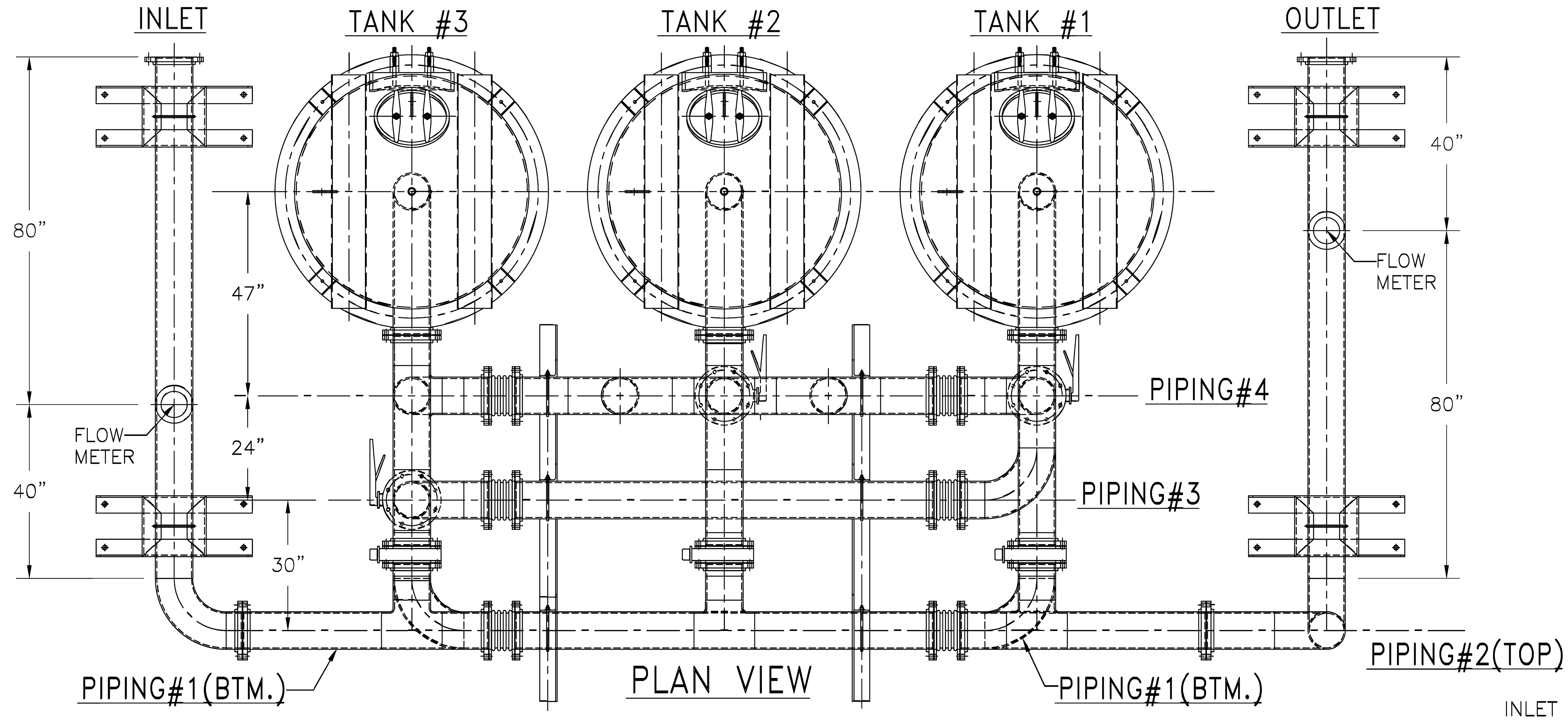
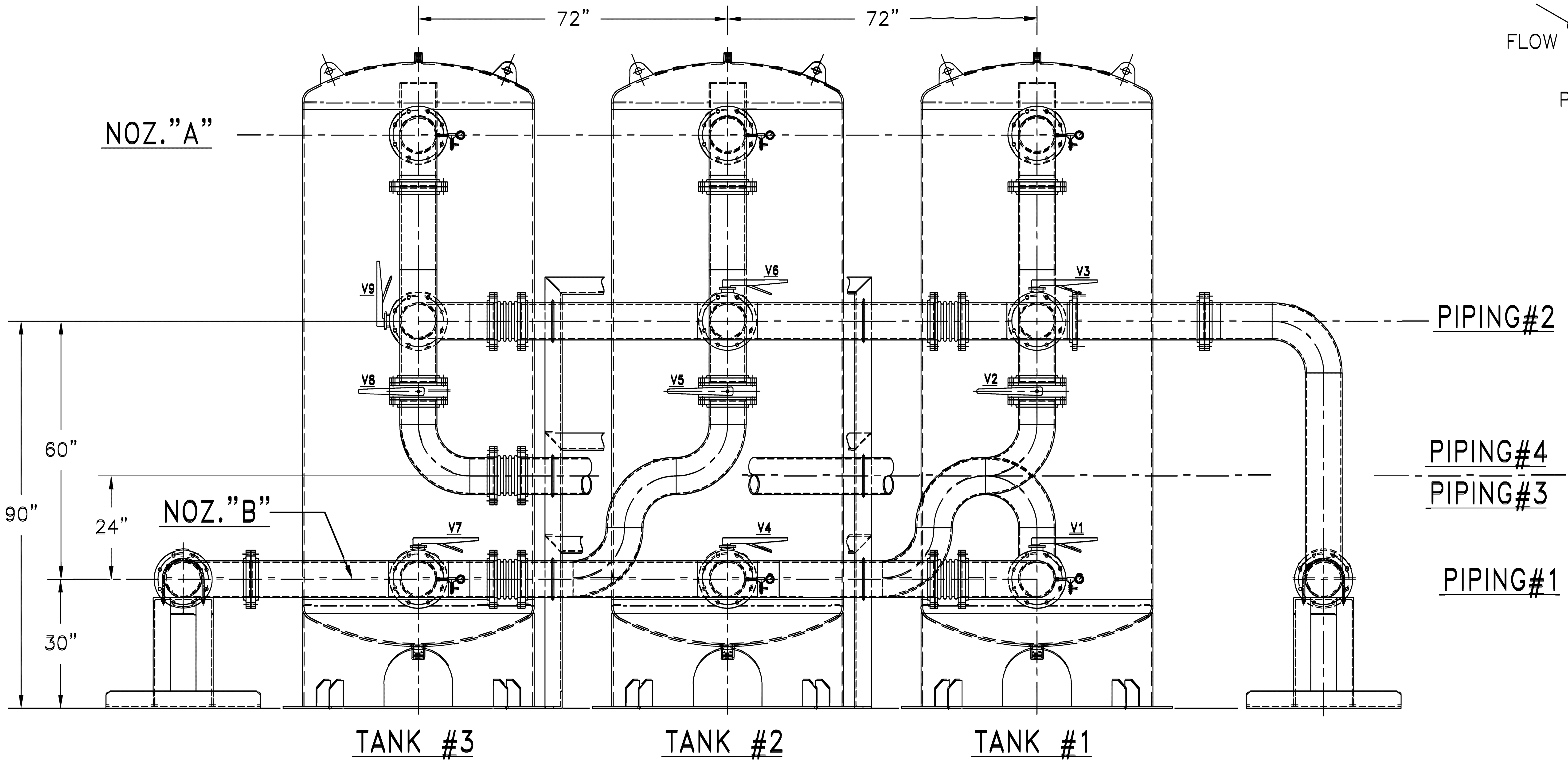
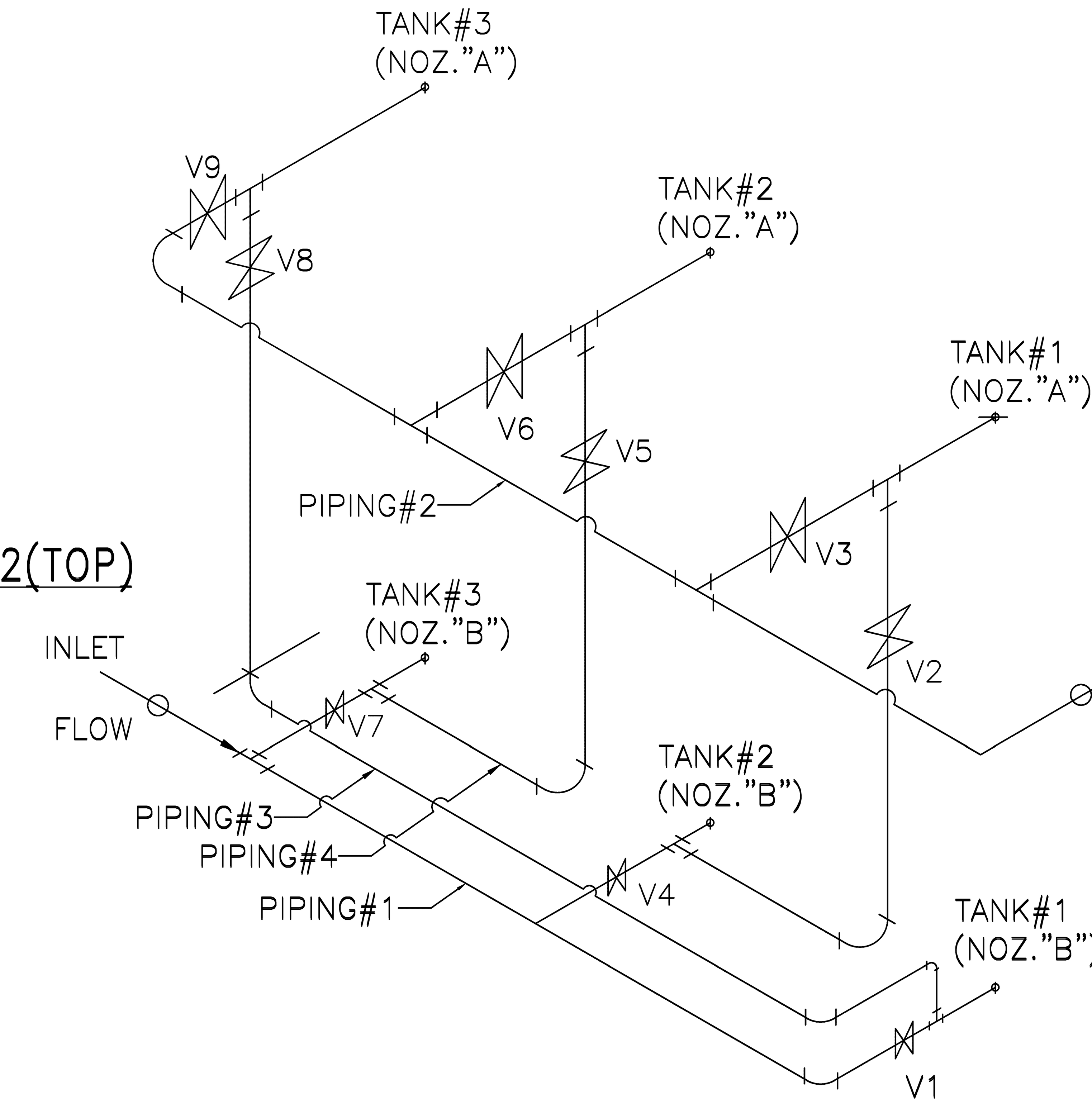
REV.	DESCRIPTION	DATE	BY	CHK.	APP.	ISSUE	CUSTOMER		JOB NO.	



PLAN VIEW



FRONT VIEW



TRIPLE TANK PIPING SCHEMATIC

SHT. 2

CARBON SUPPLY INC.

CSI

BELL GARDENS, CA

CSI V-3000-1106

TRIPLEX CARBON BED, MODEL 1106

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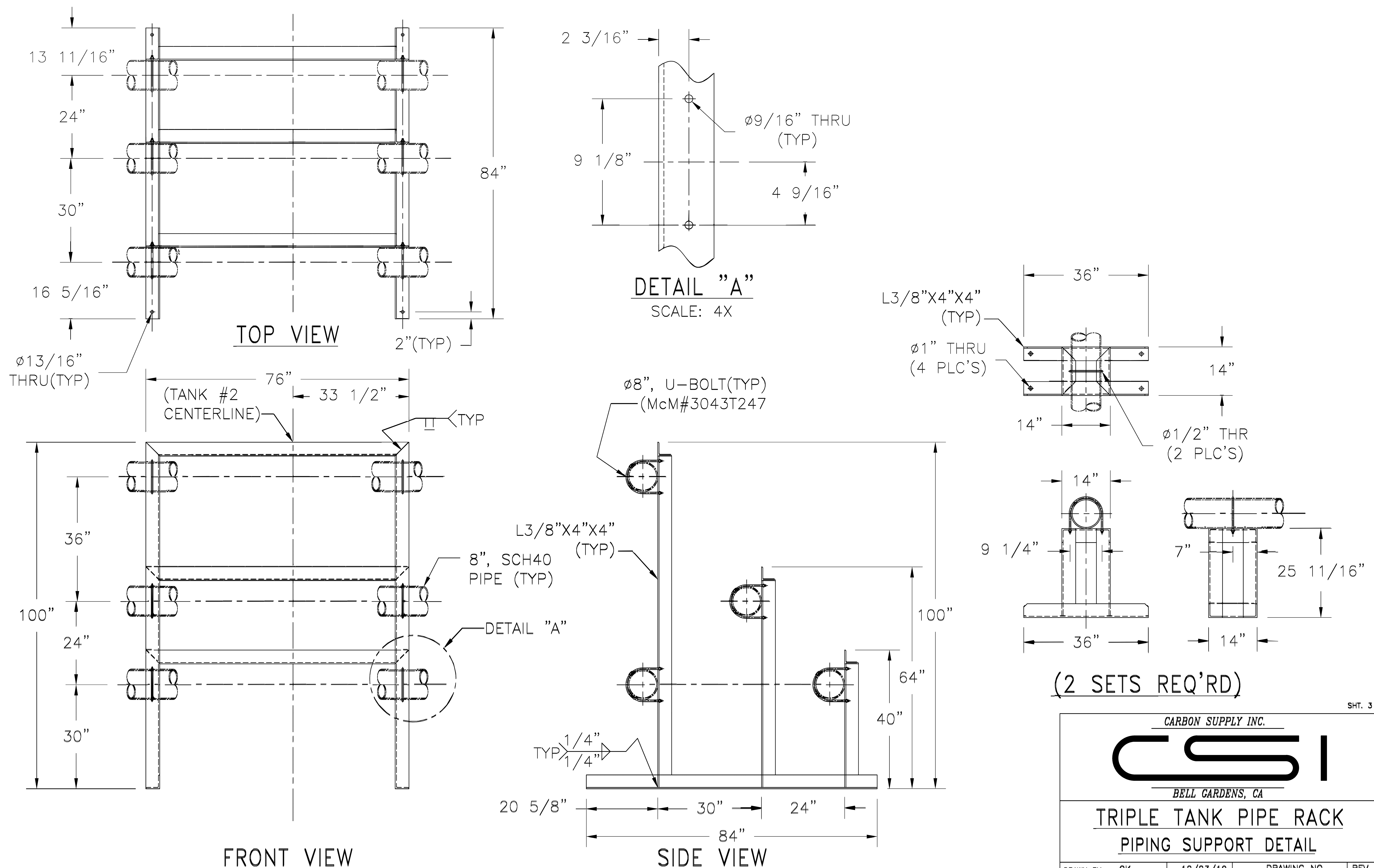

SHT. 3

CARBON SUPPLY INC.

CSI

BELL GARDENS, CA

TRIPLE TANK PIPE RACK

PIPING SUPPORT DETAIL

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CUSTOMER		JOB NO.	

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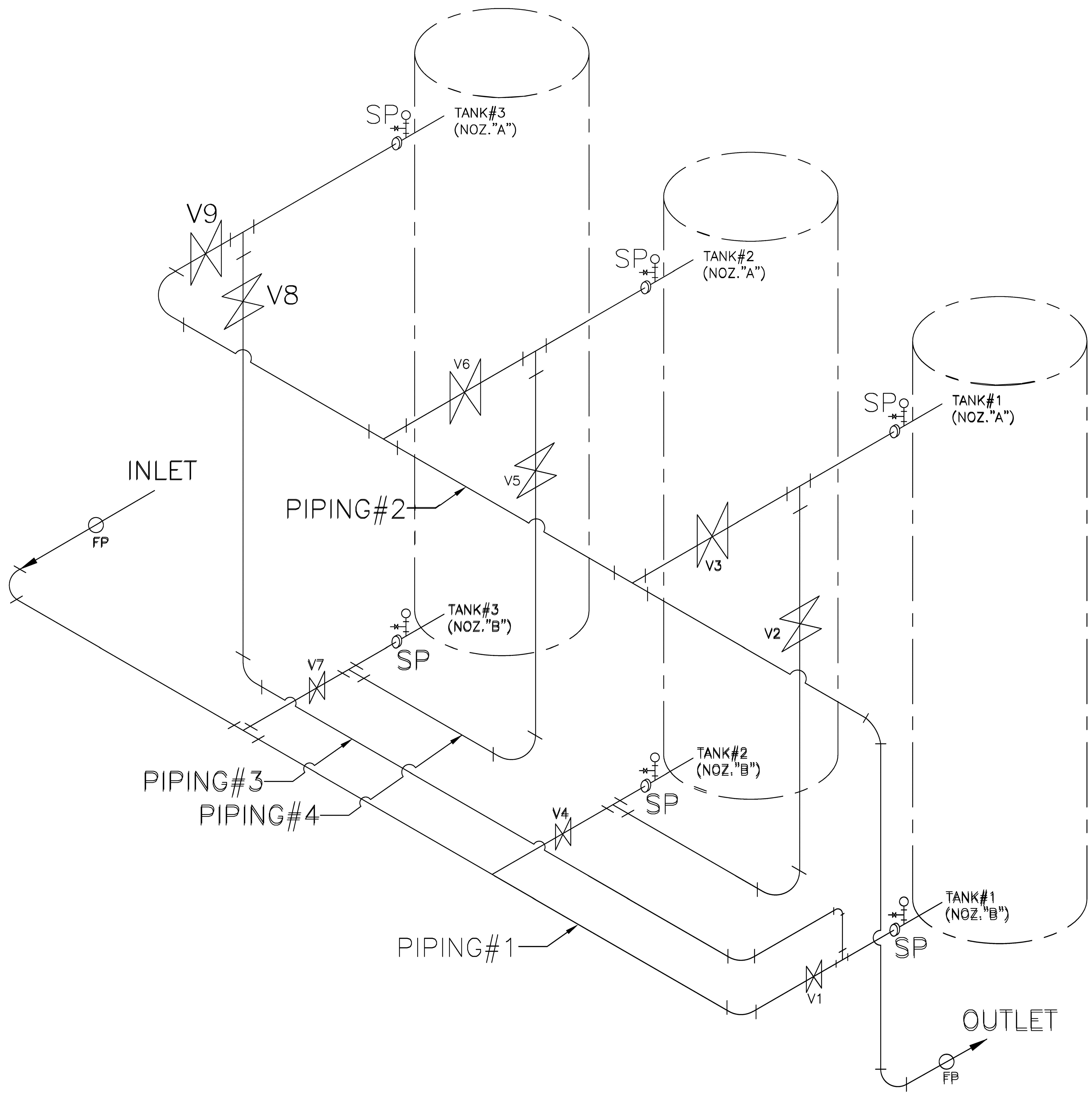

SHT. 4

CARBON SUPPLY INC.

CSI

BELL GARDENS, CA

LEAD/LAG PIPING SYSTEM

SCHEMATIC DIAGRAM

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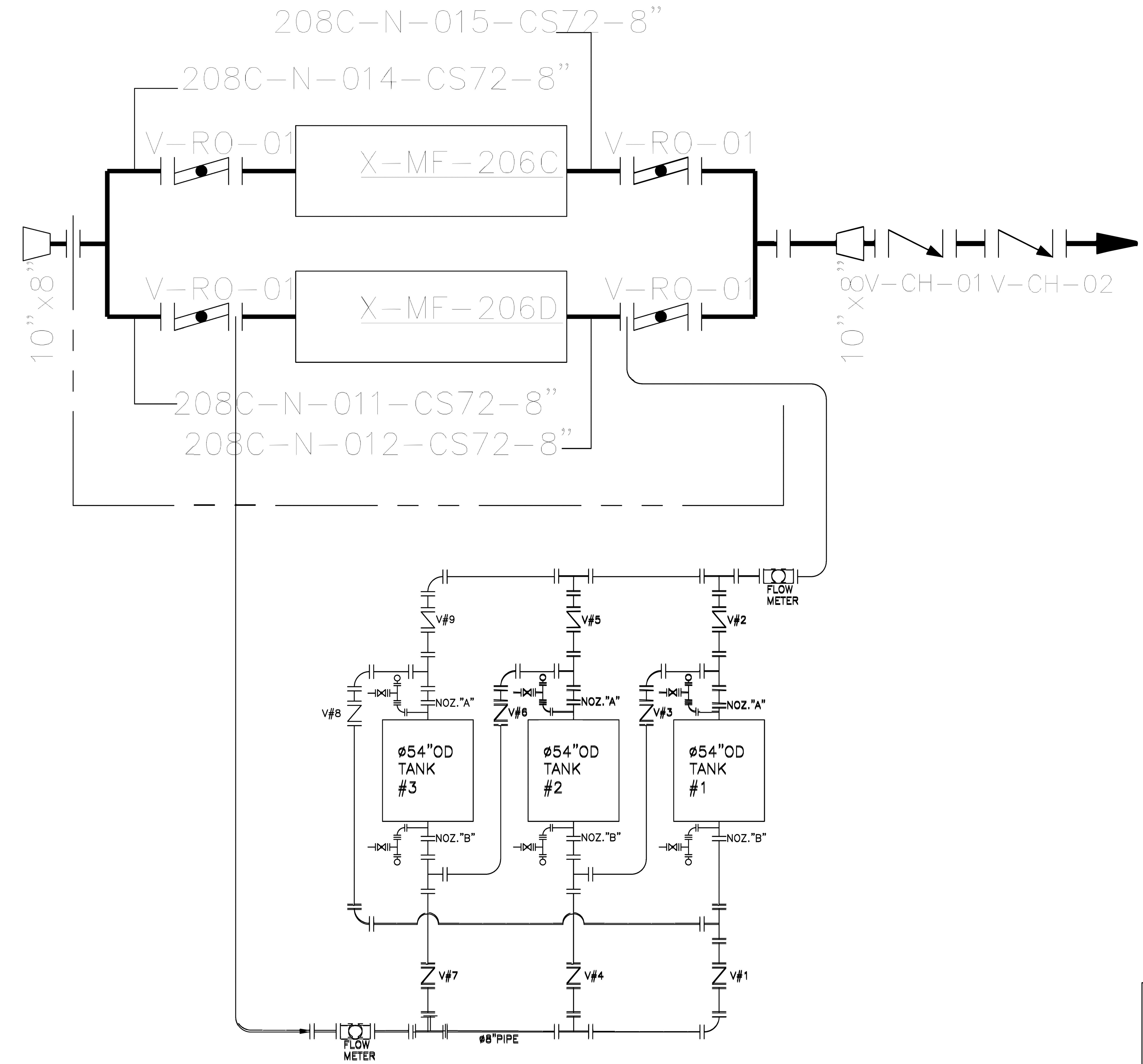

HIGH PRESSURE

SHT. 5

CARBON SUPPLY INC.

CSI

BELL GARDENS, CA

MOJAVE SOLAR

ø54"OD CARBON BED

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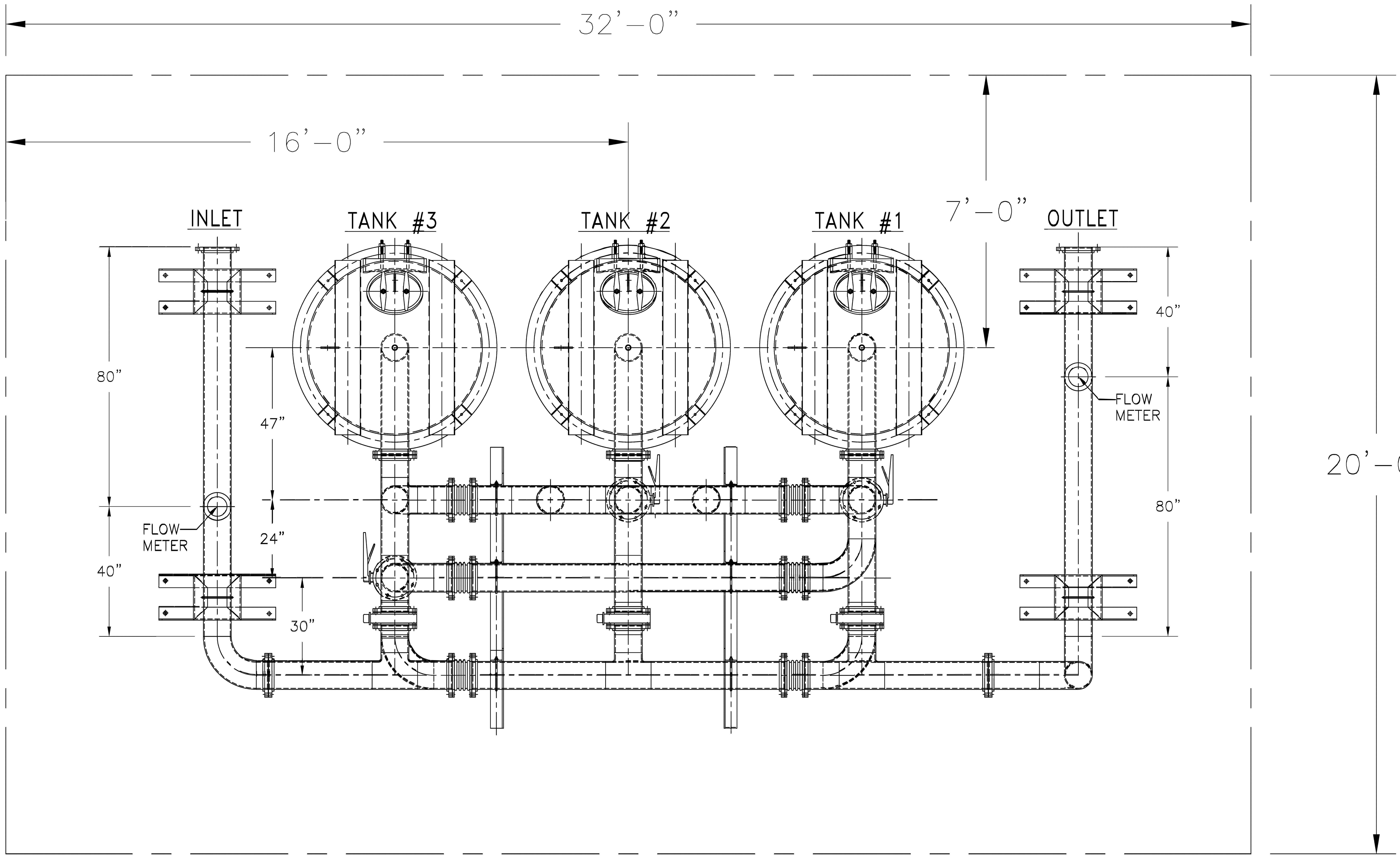
REV.	DESCRIPTION	DATE	BY	CHK.	APP.	ISSUE	CUSTOMER	

DRAWING NO. 1106-E

REV. 0

SCALE 9/16"=6"

JOB NO.



PLAN VIEW

SHT. 6

CARBON SUPPLY INC.

CSI

BELL GARDENS, CA

CSI V-3000-1106

APPROXIMATE CONCRETE PAD

DRAWN BY: CK	12/27/19	DRAWING NO. 1106-F	REV. 0
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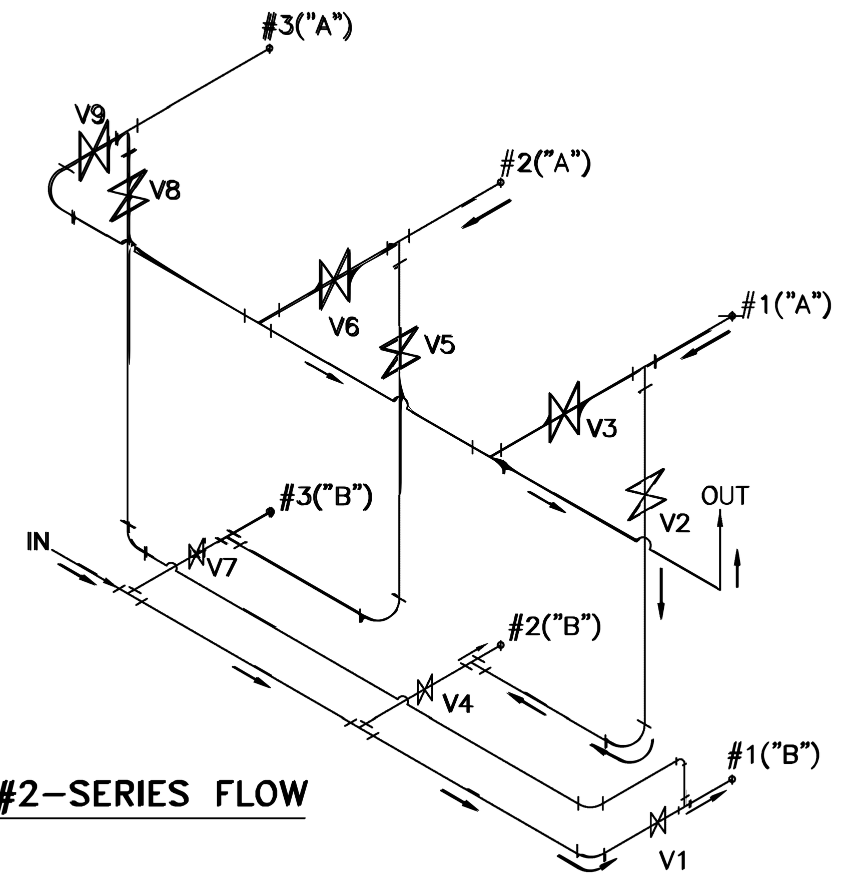
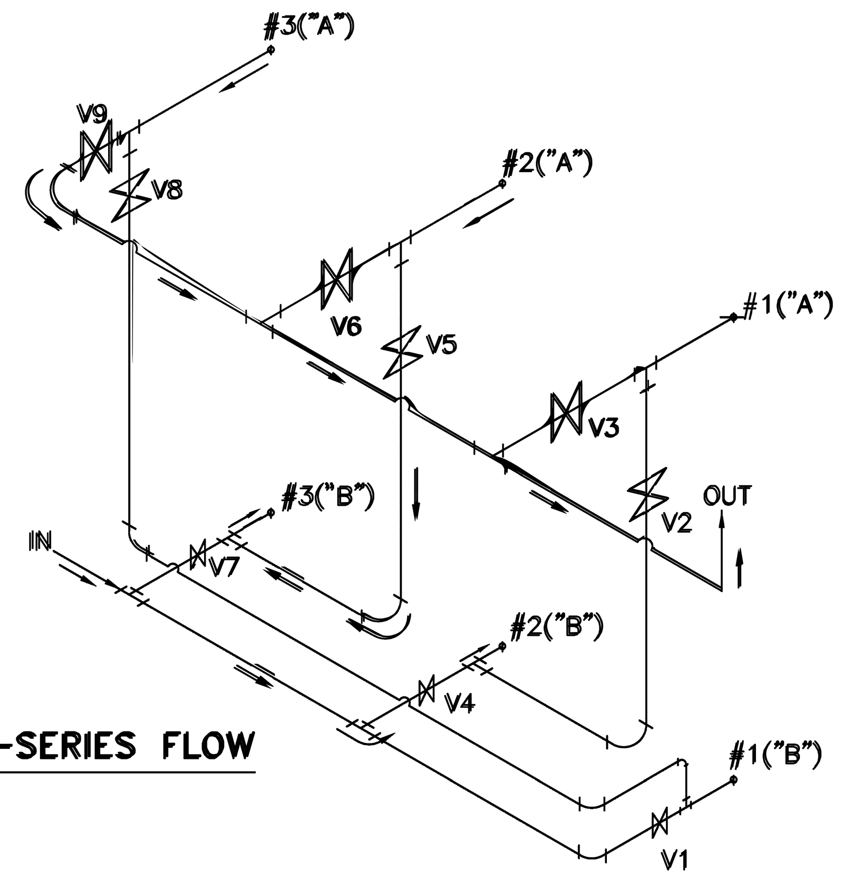
CUSTOMER		JOB NO.	

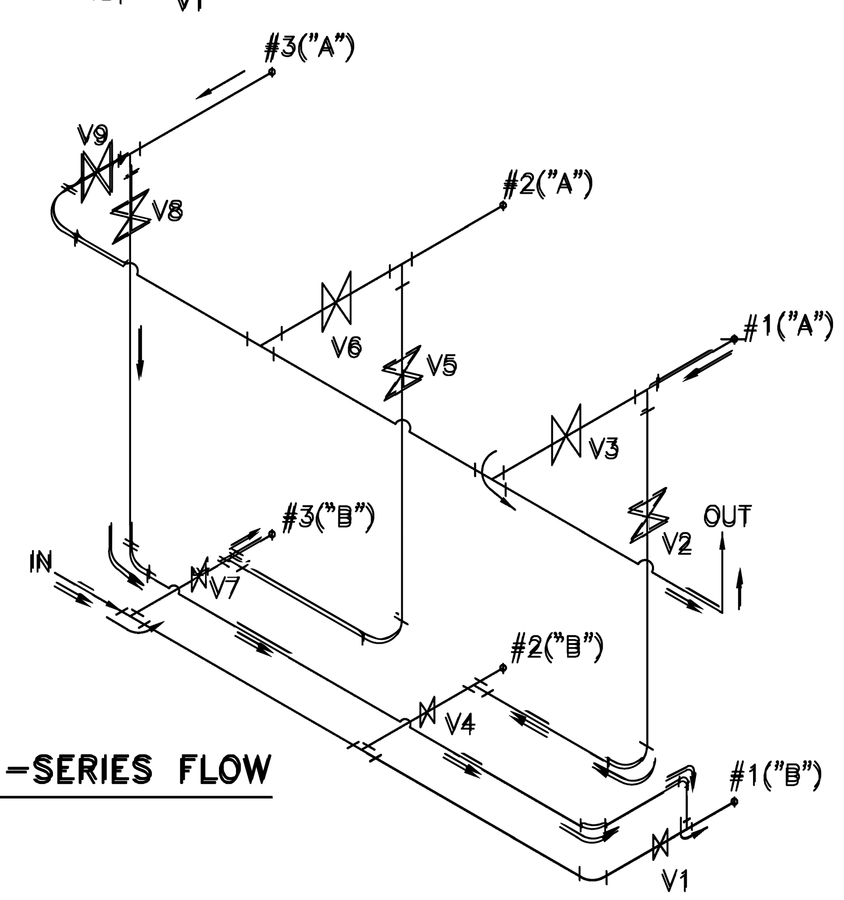
REV.	DESCRIPTION	DATE	BY	CHK.	APP.	ISSUE



TANK#1 TO TANK#2-SERIES FLOW



TANK#2 TO TANK#3-SERIES FLOW



TANK#3 TO TANK#1-SERIES FLOW

TANK#1 TO TANK #2 SERIES FLOW

	V1	V2	V3	V4	V5	V6	V7	V8	V9
TANK#1	OPEN	OPEN	CLOSE						
TANK#2				CLOSE	CLOSE	OPEN			
TANK#3							CLOSE	CLOSE	CLOSE

TANK#2 TO TANK #3 SERIES FLOW

	V1	V2	V3	V4	V5	V6	V7	V8	V9
TANK#1	CLOSE	CLOSE	CLOSE						
TANK#2				OPEN	OPEN	CLOSE			
TANK#3							CLOSE	CLOSE	OPEN

TANK#3 TO TANK #1 SERIES FLOW

	V1	V2	V3	V4	V5	V6	V7	V8	V9
TANK#1	CLOSE	CLOSE	OPEN						
TANK#2				CLOSE	CLOSE	CLOSE			
TANK#3							OPEN	OPEN	CLOSE

CARBON SUPPLY INC.

CSI

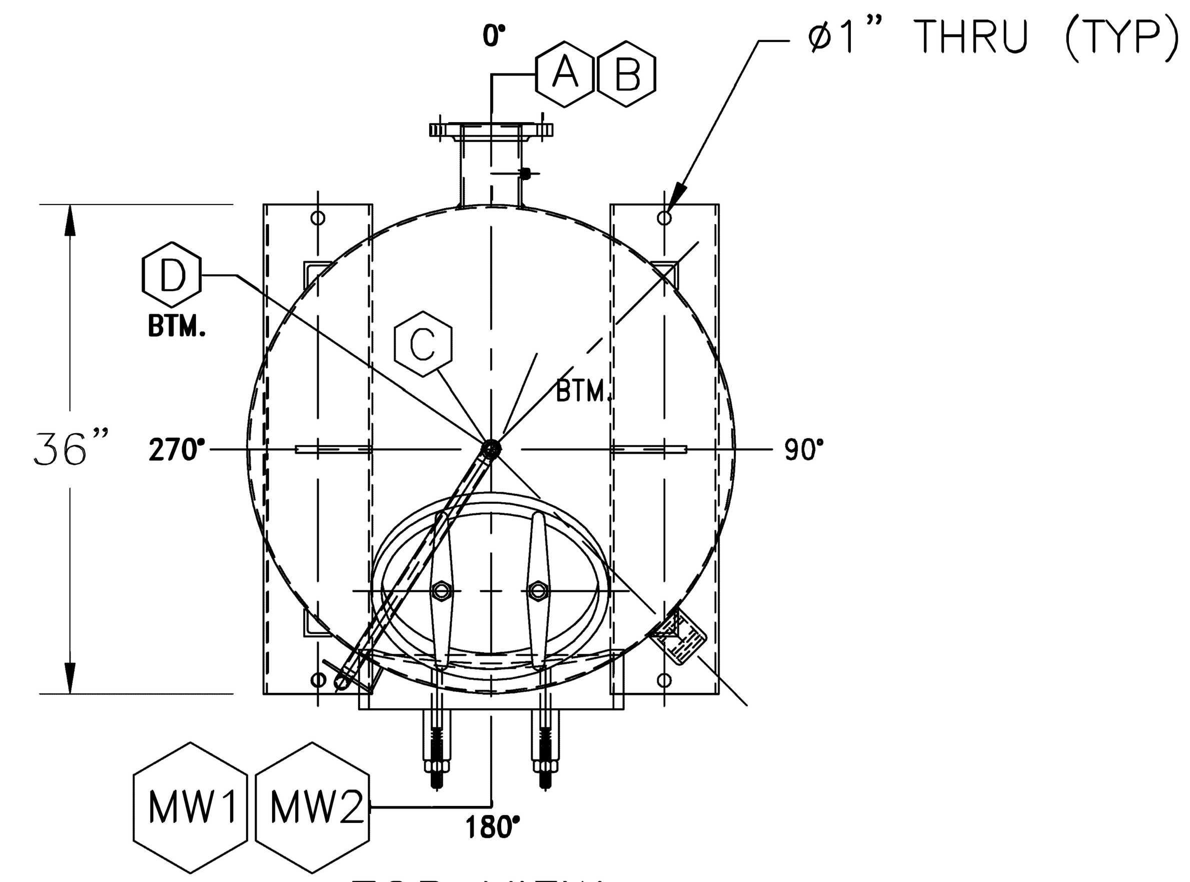
BELL GARDENS, CA

Ø54"OD X 114"-SHELL

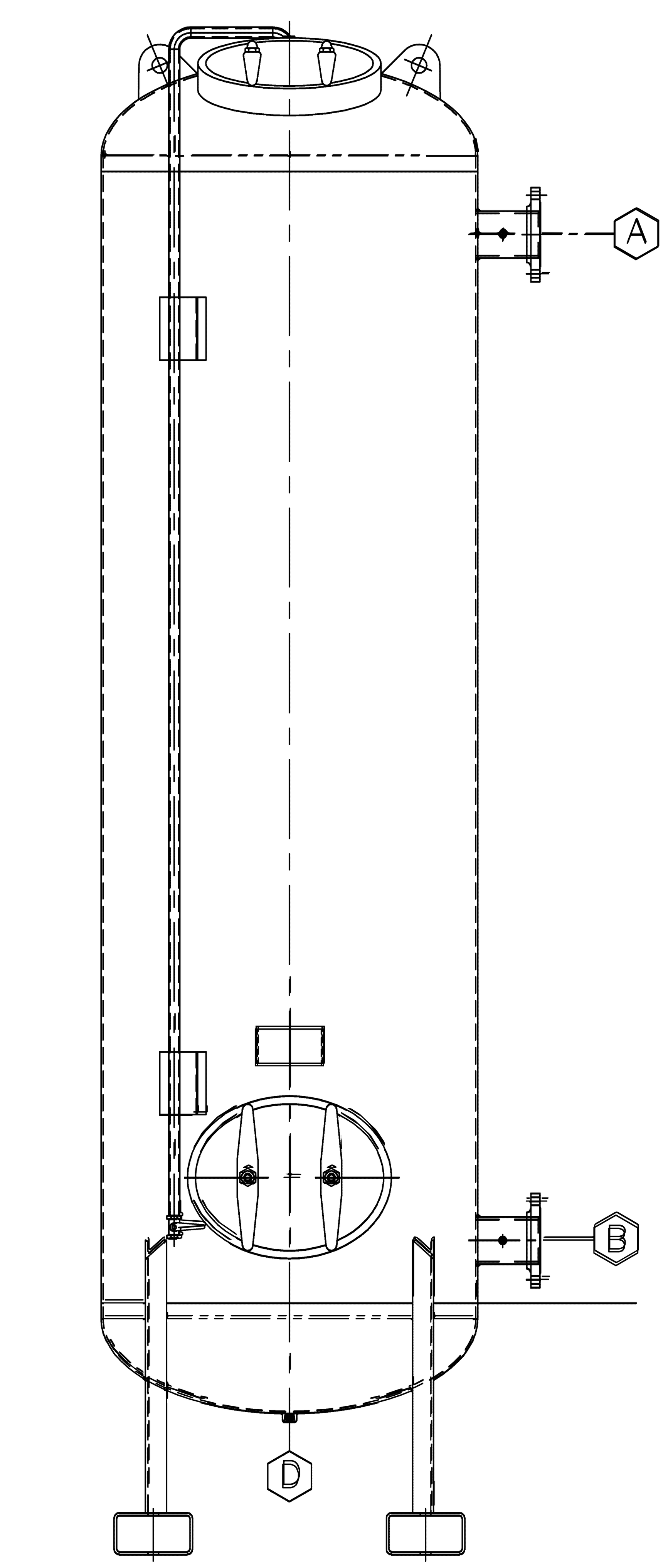
LEAD/LAG SERIES FLOW

DRAWN BY:	ck	12/20/19	DRAWING NO. 1106-G	REV. 0
CHECK:				
APPR'D:	J. ROBLES		SCALE 1"=12"	
CUSTOMER			JOB NO.	

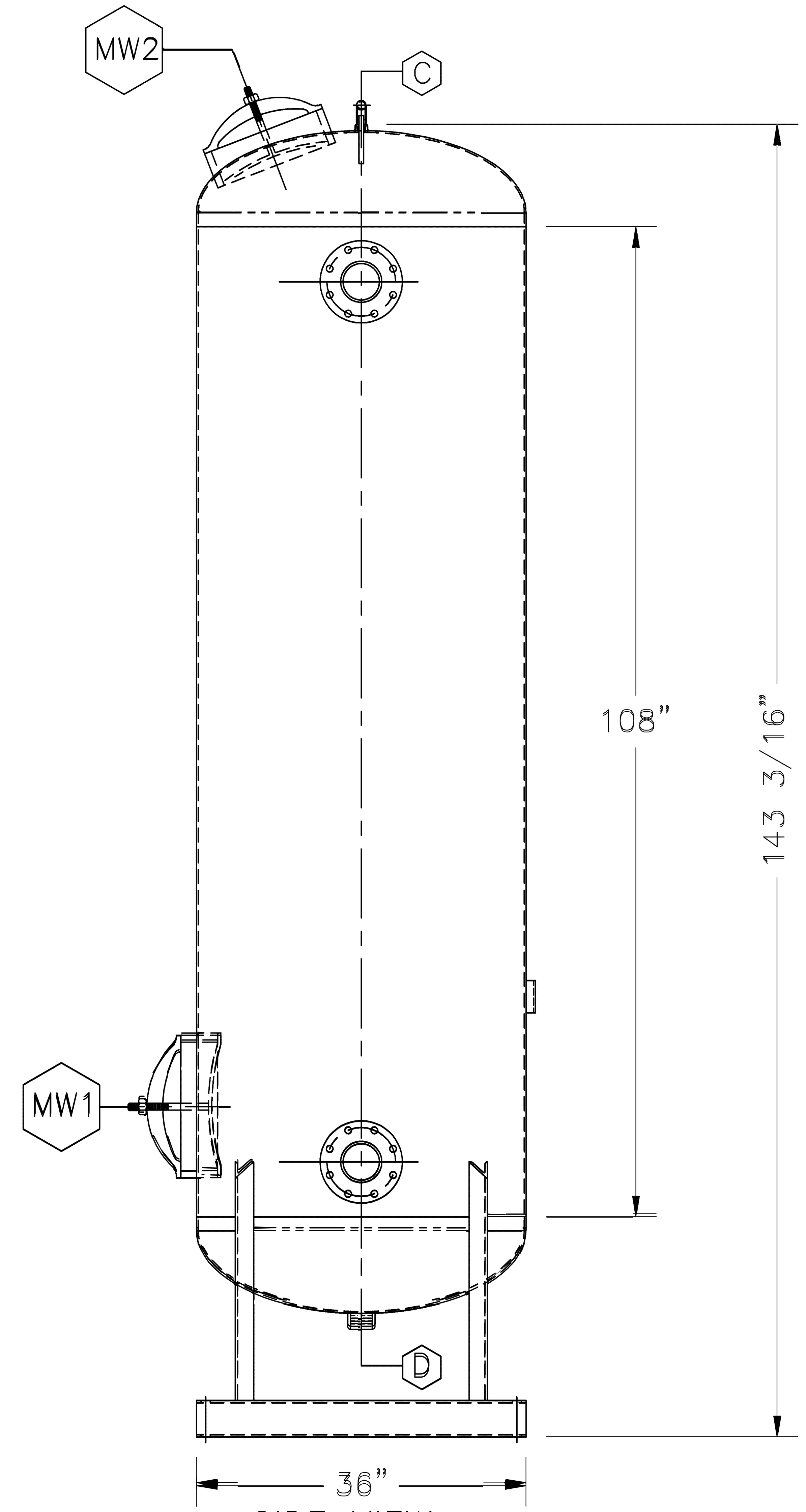
REV.	DESCRIPTION	DATE	BY	CHK.	APP.	ISSUE



TOP VIEW



FRONT VIEW



SIDE VIEW

NOZZLE SCHEDULE			
NOZ.	QTY.	SIZE/RATING	SERVICE
A	1	ø4",150# RFSO FLANGE	INLET
B	1	ø4",150# RFSO FLANGE	OUTLET
C	1	ø3/4"–COUPLING	VENT
D	1	ø3/4"–COUPLING	DRAIN
MW1	1	12" X 16"	ELLIPTICAL MANWAY W/COVER
MW2	1	14" X 18"	ELLIPTICAL MANWAY W/COVER

ITEM	QTY.	DIMENSIONS	MATERIAL	DESCRIPTION
1	1	3/8"–PLT X 102" X 168 1/2"LG	SA516 70	SHELL
2	1	ø54"OD, 1 1/2"SF, 3/8"–PLT, F&D HEAD	SA516 70	TOP & BTM. HEAD
3	1	ø53 1/4"OD, STEEL MESH ASSEMBLY	STEEL	STEEL MESH
4	2	4" X 8" X 3/16"–WALL X 54"LG	SA36	FORKLIFT SLOT
5	2	1/2"–PLT X 4" X 6"LG	SA36	LIFT LUG
6	1	1/4"–PLT X ø63"OD	SA516 70	BASE PLATE
7	8	1/4"–PLT X 4 1/2" X 6"	SA36	BASE PLATE GUSSET

COATINGS SCHEDULE		
SURFACE	SURFACE PREPERATION	PRODUCT SPECIFICATION
INTERNAL	SSPC–SP10	SW SHERPLATE PW EPOXY 20–30mls DFT
EXTERNAL	SSPC–SP6	SW ENVIROLASTIC 940 DTM

NOTES:

1. ALL MATERIALS & PARTS CALLED OUT ON THIS DRAWING SHALL BE AS SPECIFIED OR "APPROVED EQUAL".
2. DIMENSIONS, UNLESS OTHERWISE INDICATED, ARE NOMINAL. SHOP TOLERANCES ARE:
   FRACTIONS = $\pm\frac{1}{16}$"
   DECIMALS: .XX = ±.010
   .XXX = ±.005
   ANGLES: = $\pm\frac{1}{2}$°
3. DESIGNED IN ACCORDANCE WITH ASME CODE, SECTION VIII, DIVISION 1. VESSEL. NOT STAMPED.
4. INTERNAL PRESSURE: 75PSI.
5. TEMPERATURE: 100°F.
6. THESE MATERIALS ARE CONFIDENTIAL AND ARE THE PROPRIETARY INFORMATION OF CARBON SUPPLY, INC. AND MAY NOT BE USED OR REPRODUCED WITHOUT THE CONSENT OF CARBON SUPPLY, INC.

SHT. 1

CARBON SUPPLY INC.

CSI

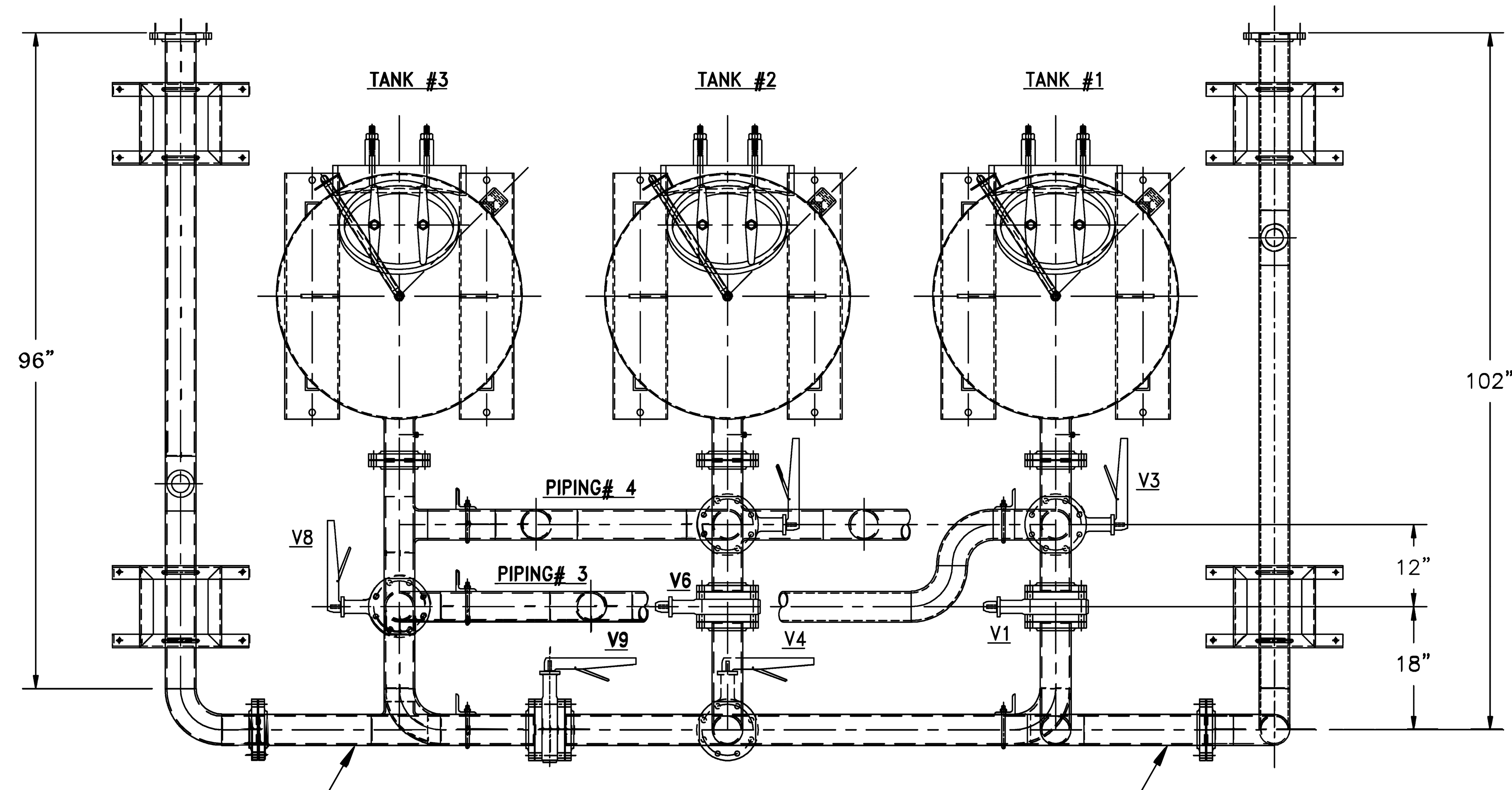
BELL GARDENS, CA

ø36"OD X 72" SHELL

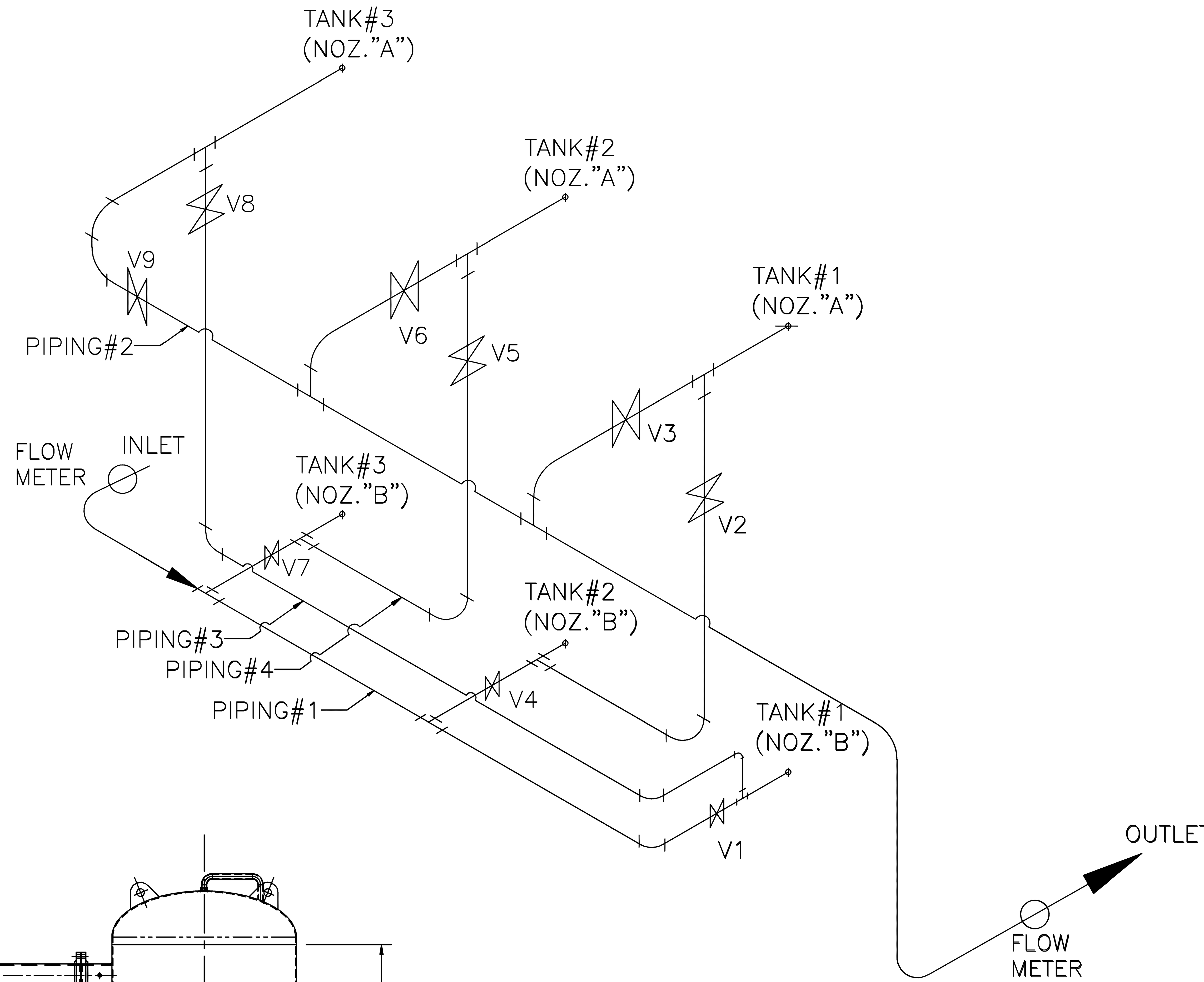
FILTER TANK

DRAWN BY:	CK	12/23/19	DRAWING NO. 1107–A	REV. 0
CHECK:				
APPR'D:			SCALE 1"=6"	
CUSTOMER			JOB NO.	

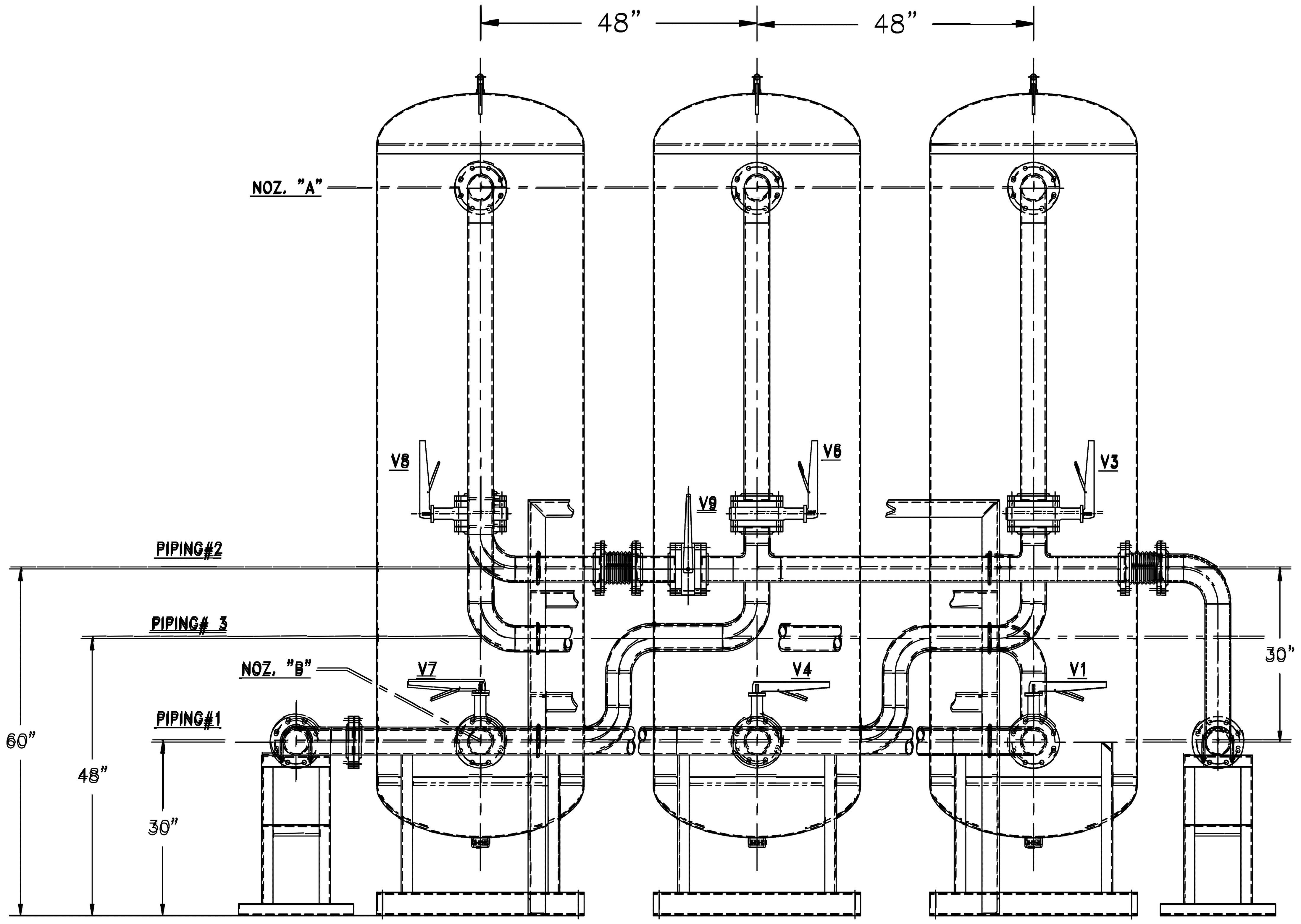
REV.	DESCRIPTION	DATE	BY	CHK.	APP.	ISSUE



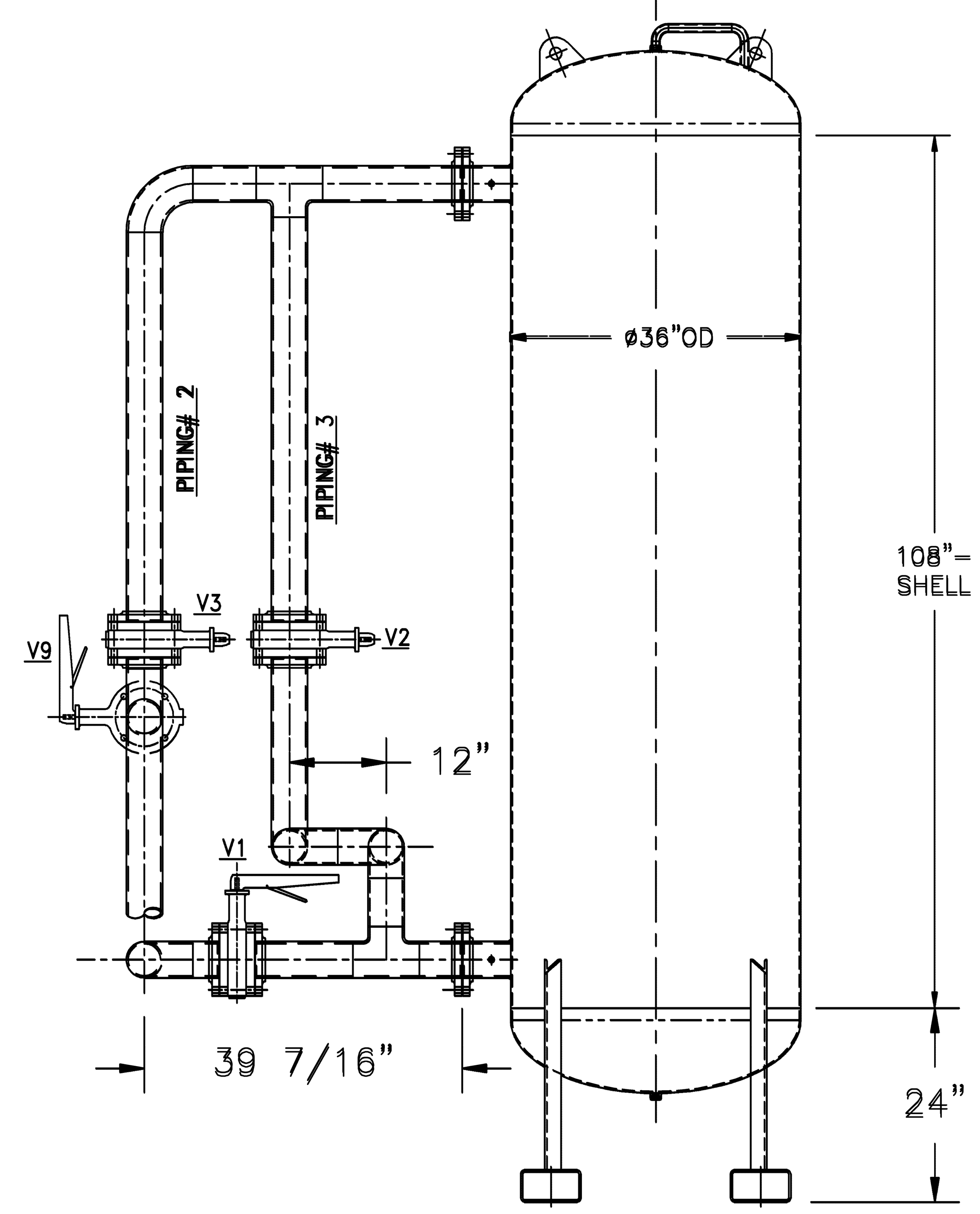
TOP VIEW



TRIPLE TANK PIPING SCHEMATIC



FRONT VIEW



SIDE VIEW

SHT. 2

CARBON SUPPLY INC.

CSI

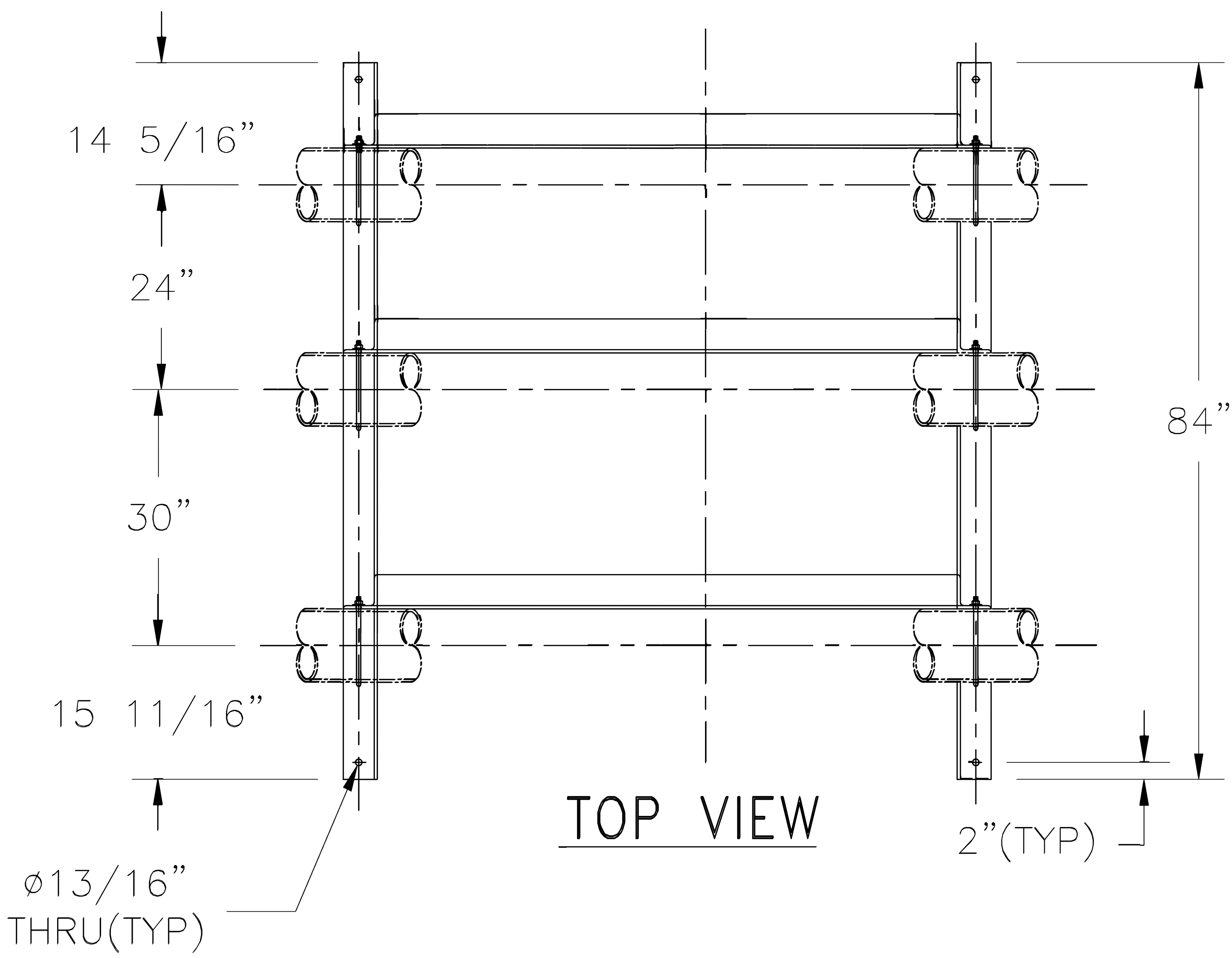
BELL GARDENS, CA

CSI V-1500-1107

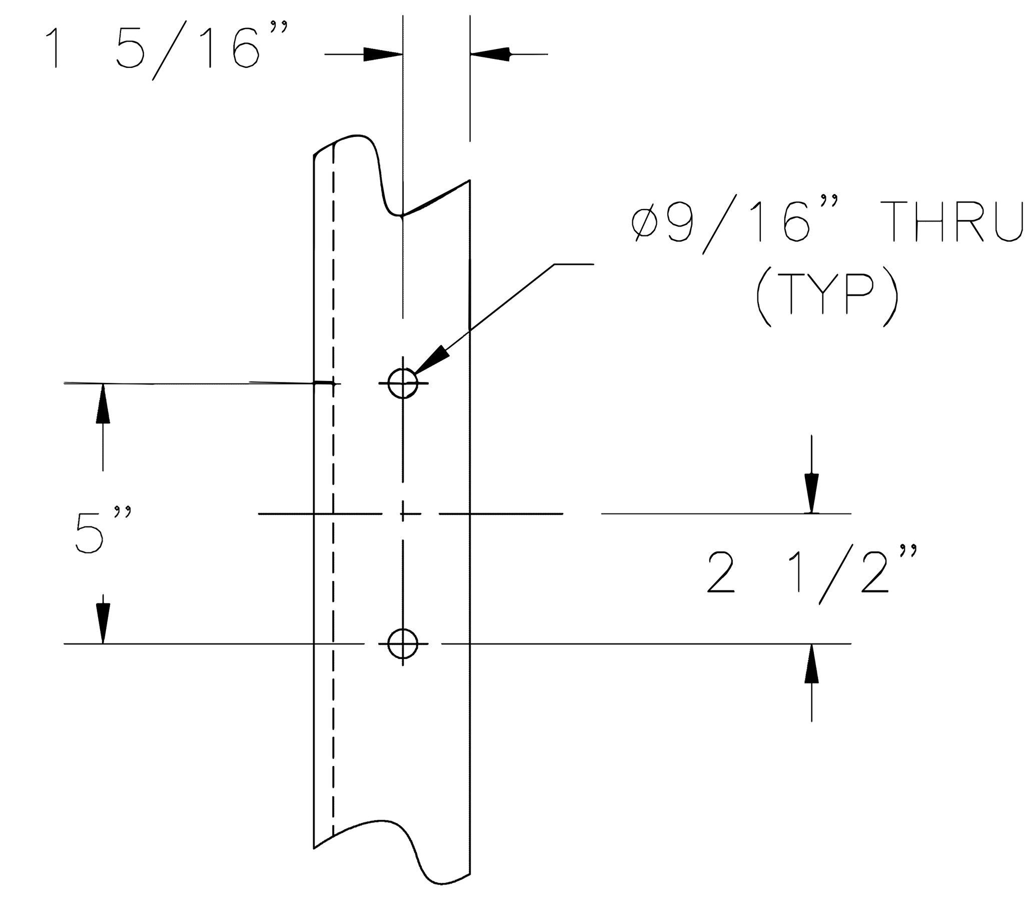
TRIPLEX CARBON BED, MODEL 1107

DRAWN BY: CK	12/30/19	DRAWING NO. 1107-B	REV. 0
CHECK:			
APPR'D:		SCALE 9/16"=6"	
CUSTOMER		JOB NO.	

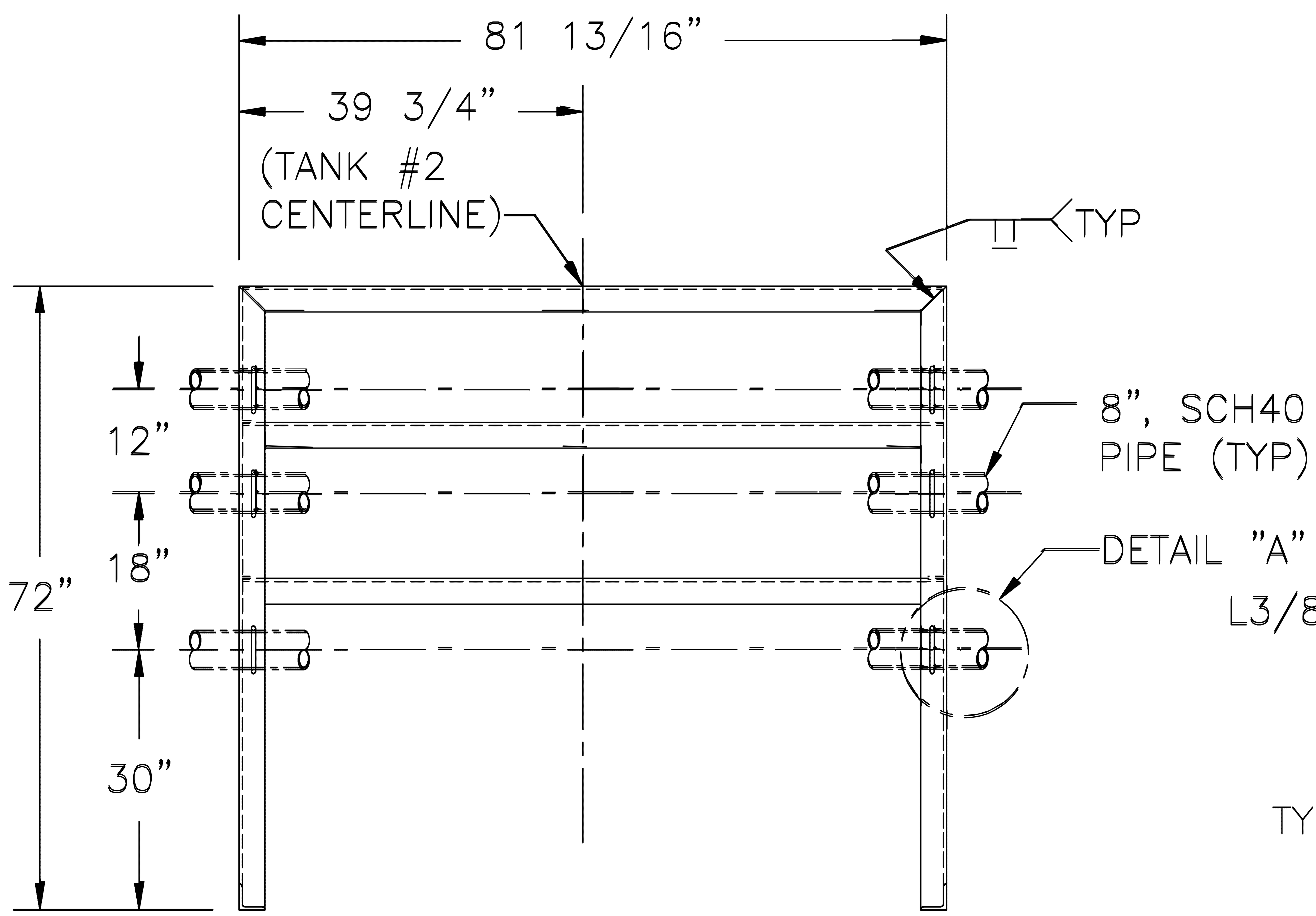
REV.	DESCRIPTION	DATE	BY	CHK.	APP.	ISSUE



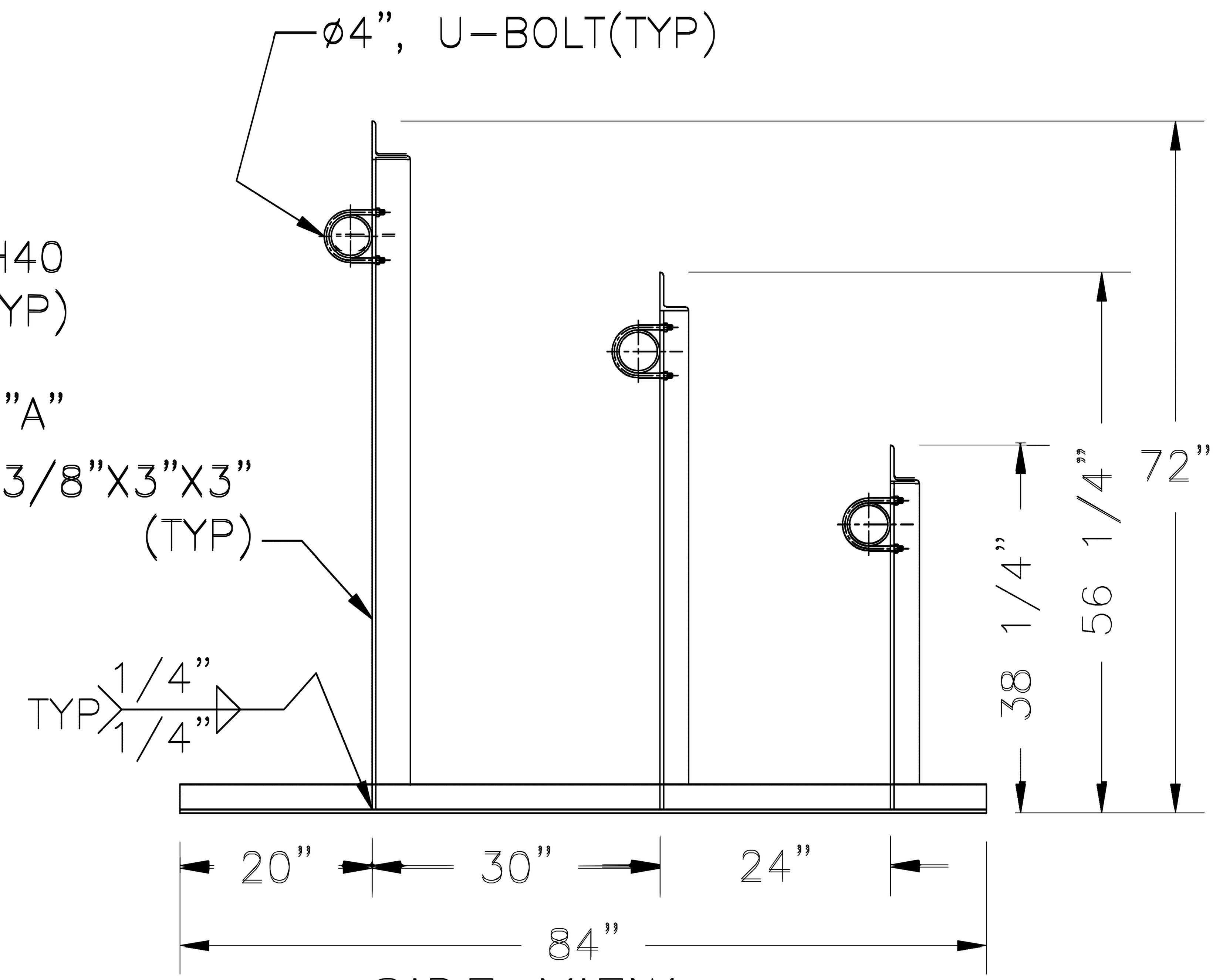
TOP VIEW



DETAIL "A"
SCALE: 4X



FRONT VIEW



SIDE VIEW

SHT. 3

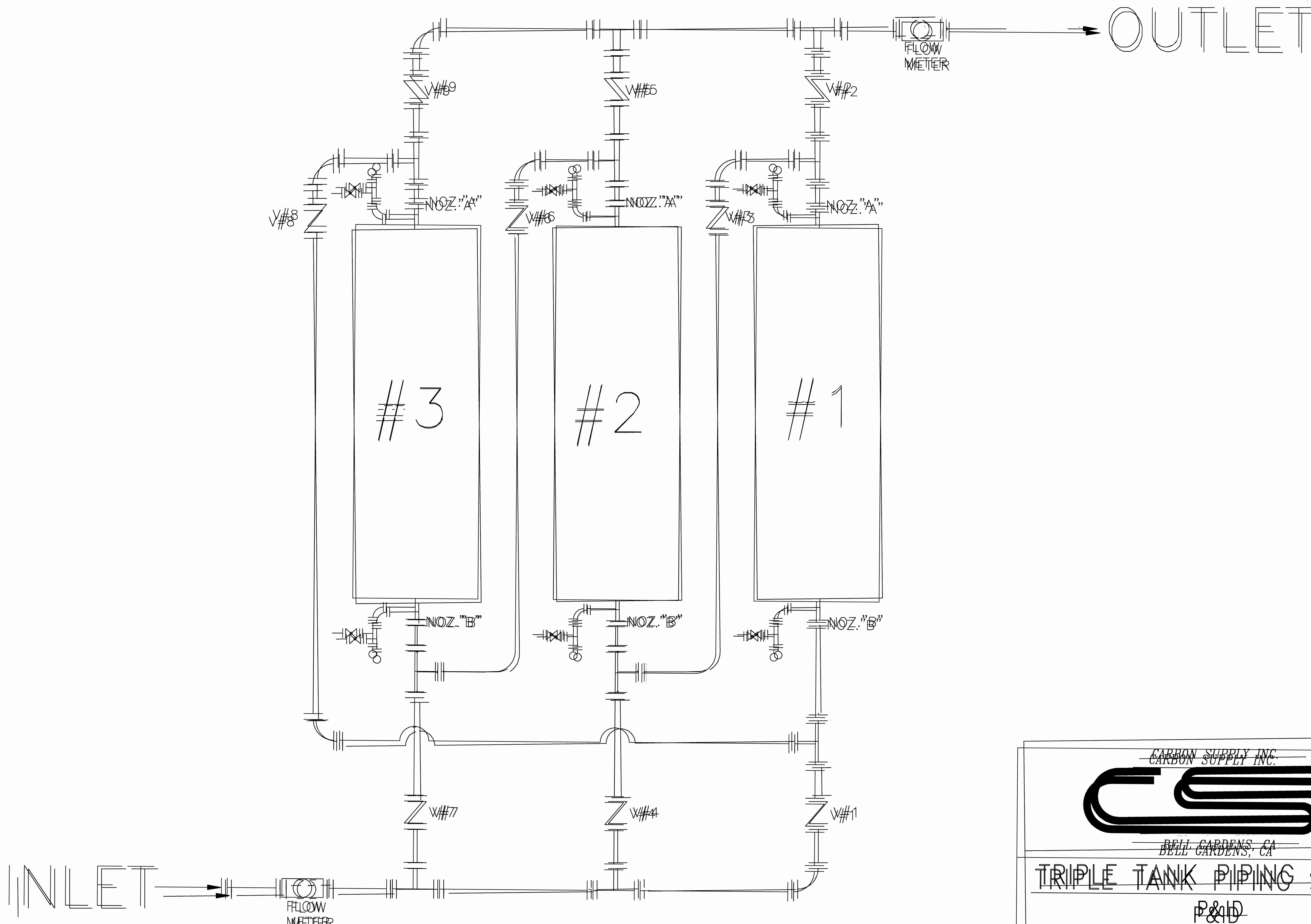
CARBON SUPPLY INC.
CSI
BELL GARDENS, CA

TRIPLE TANK PIPING SYSTEM

PIPING SUPPORT

DRAWN BY: CK	12/31/19	DRAWING NO. 1107-C	REV. 0
CHECK:			
APPR'D:		SCALE 9/16"=6"	
CUSTOMER		JOB NO.	

REV.	DESCRIPTION	DATE	BY	CHK.	APP. ISSUE



SHT. 4

CARBON SUPPLY INC.

CSI

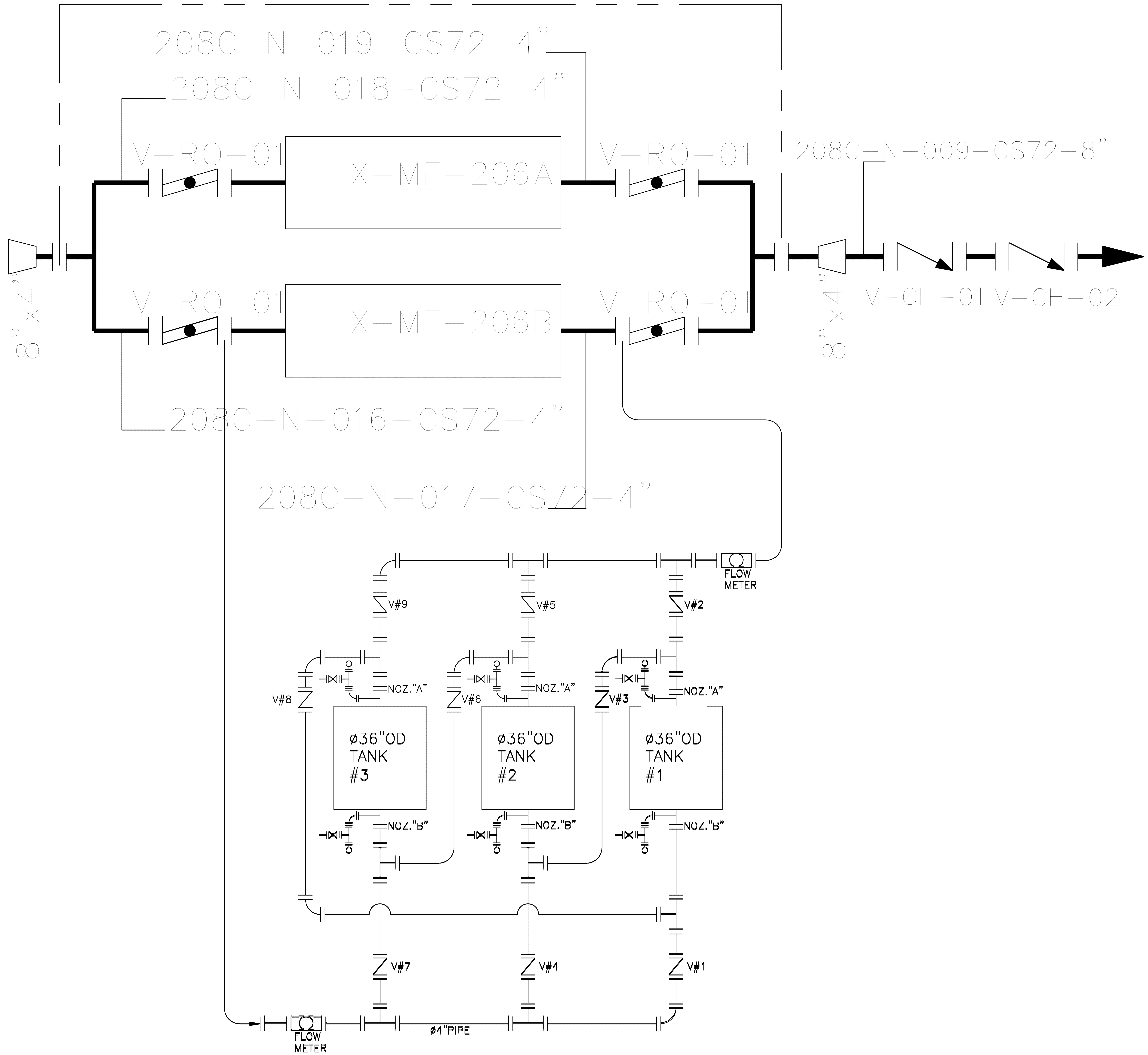
BELL GARDENS, CA

TRIPLE TANK PIPING SYSTEM

P&ID

DRAWN BY: CK	12/31/19	DRAWING NO. 1107-D	REV. 0
CHECK:		SCALE 9/16"=6"	
APPR'D:		JOB NO.	

REV.	DESCRIPTION	DATE	BY	CHK.	APP.	ISSUE	CUSTOMER



LOW PRESSURE

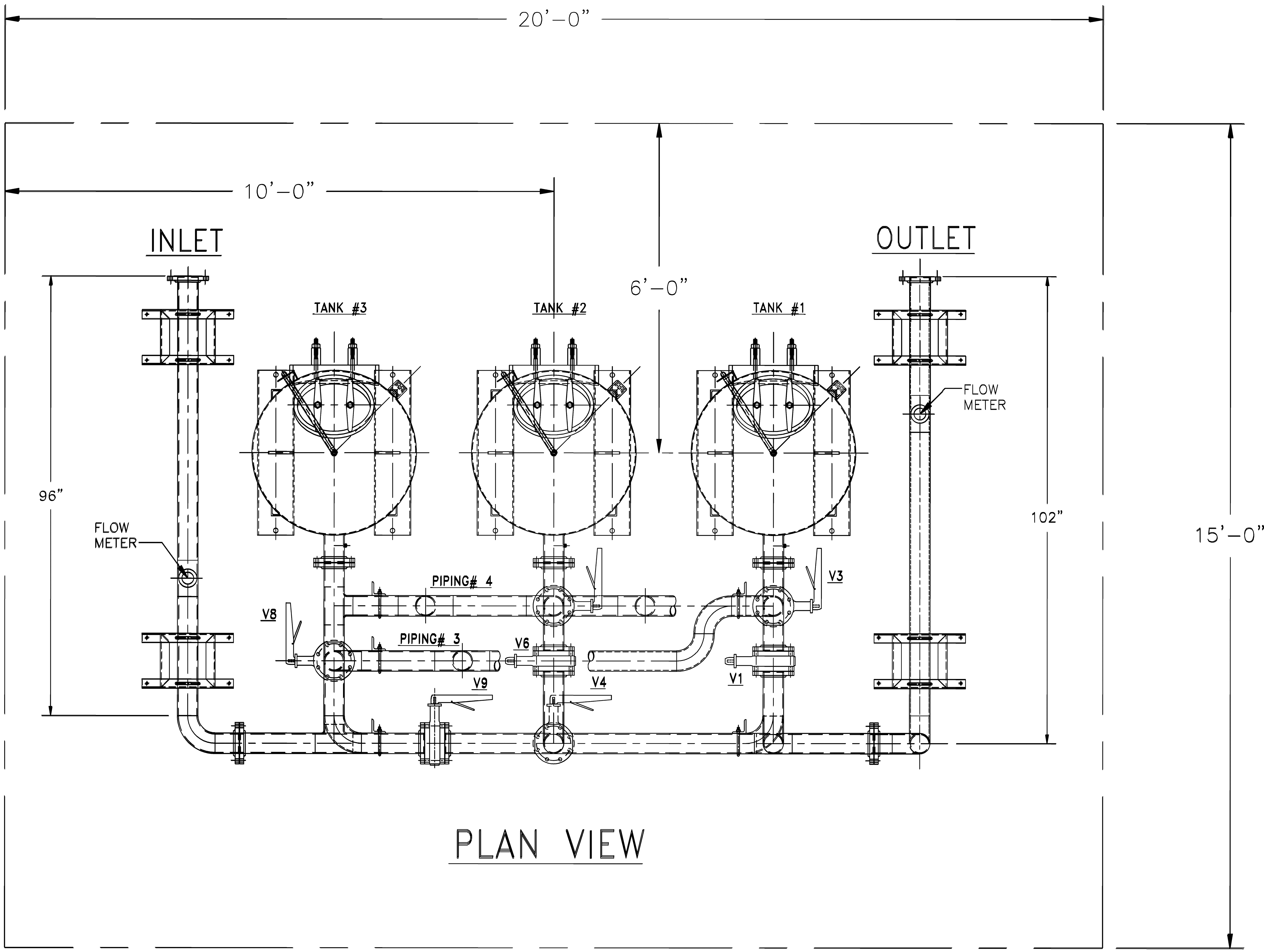
SHT. 5

CARBON SUPPLY INC.
CSI
BELL GARDENS, CA

MOJAVE SOLAR
ø36"OD CARBON BED

DRAWN BY: CK	12/31/19	DRAWING NO. 1107-E	REV. 0
CHECK:			
APPR'D:		SCALE 9/16"=6"	
CUSTOMER		JOB NO.	

REV.	DESCRIPTION	DATE	BY	CHK.	APP.	ISSUE



PLAN VIEW

SHT. 6

CARBON SUPPLY INC.

CSI

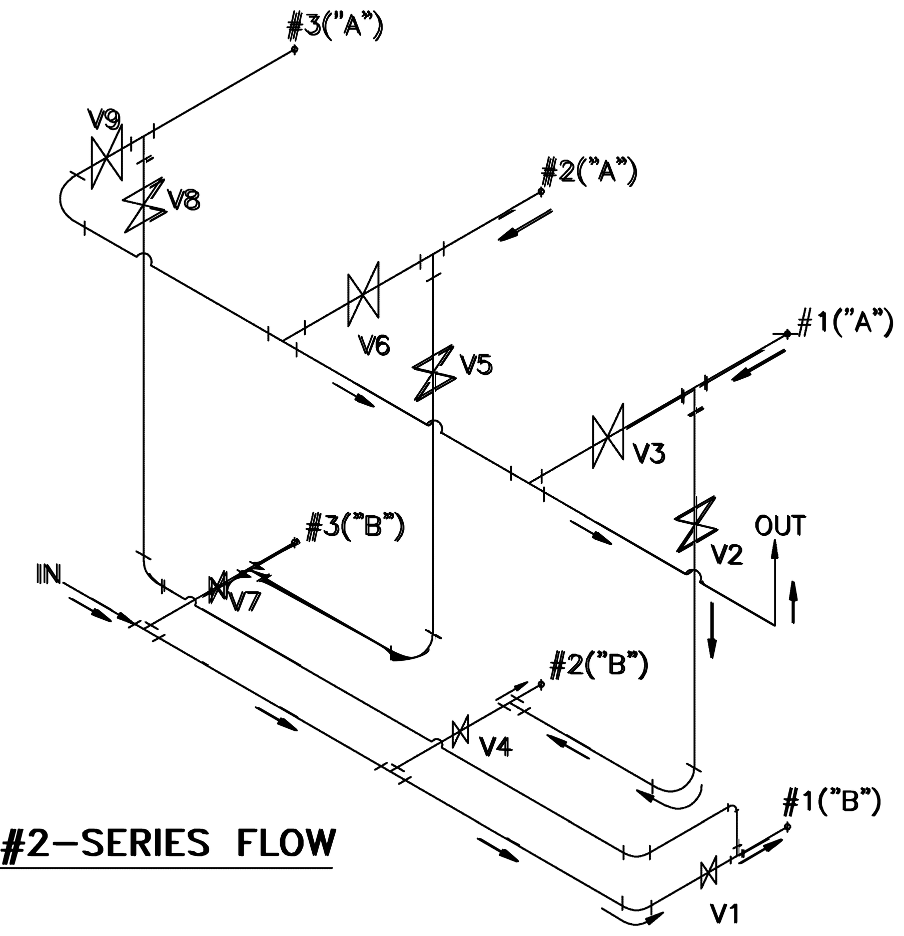
BELL GARDENS, CA

CSI V–1500–1107

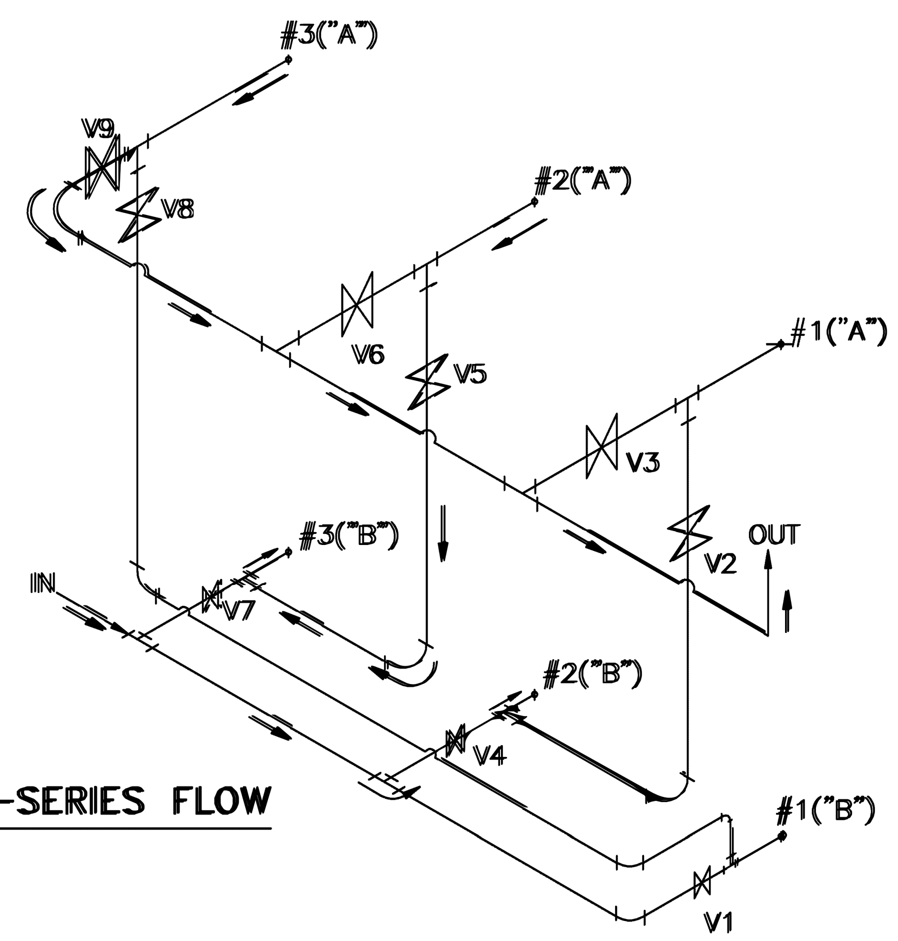
APPROXIMATE CONCRETE PAD

DRAWN BY:	CK	12/31/19	DRAWING NO. 1107–F	REV. 0
CHECK:				
APPR'D:			SCALE 9/16"=6"	
CUSTOMER			JOB NO.	

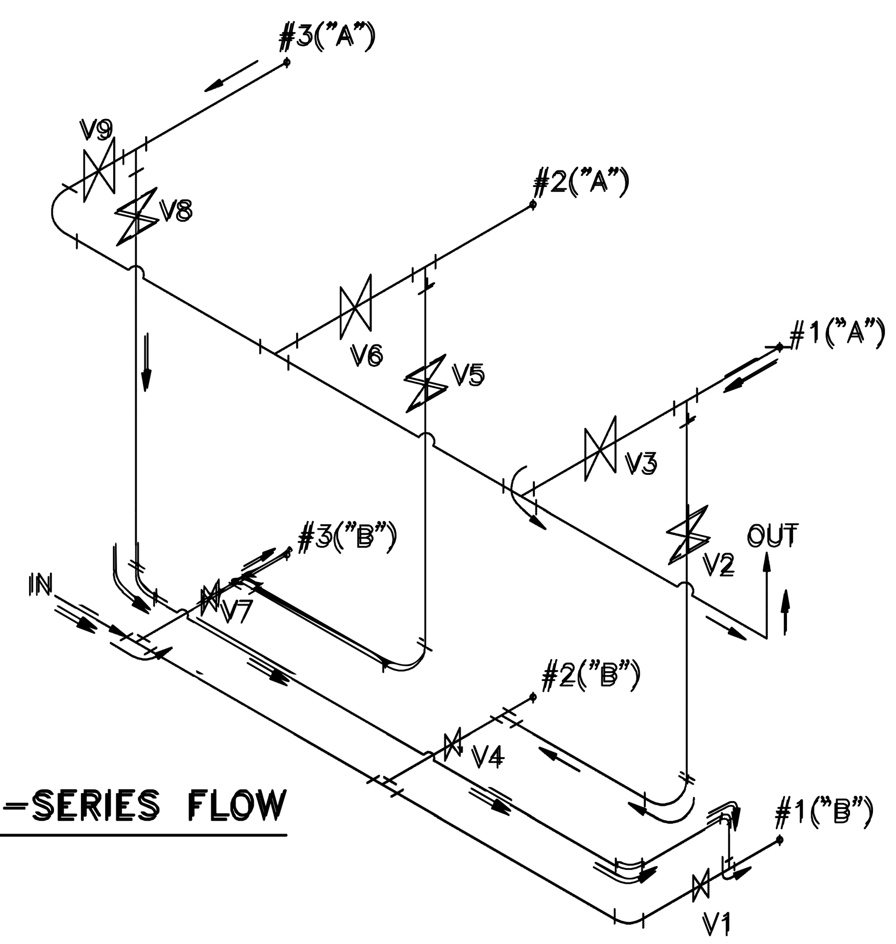
REV.	DESCRIPTION	DATE	BY	CHK.	APP.	ISSUE



TANK#1 TO TANK#2-SERIES FLOW



TANK#2 TO TANK#3-SERIES FLOW



TANK#3 TO TANK#1-SERIES FLOW

TANK#1 TO TANK #2 SERIES FLOW

	V1	V2	V3	V4	V5	V6	V7	V8	V9
TANK#1	OPEN	OPEN	CLOSE						
TANK#2				CLOSE	CLOSE	OPEN			
TANK#3							CLOSE	CLOSE	CLOSE

TANK#2 TO TANK #3 SERIES FLOW

	V1	V2	V3	V4	V5	V6	V7	V8	V9
TANK#1	CLOSE	CLOSE	CLOSE						
TANK#2				OPEN	OPEN	CLOSE			
TANK#3							CLOSE	CLOSE	OPEN

TANK#3 TO TANK #1 SERIES FLOW

	V1	V2	V3	V4	V5	V6	V7	V8	V9
TANK#1	CLOSE	CLOSE	OPEN						
TANK#2				CLOSE	CLOSE	CLOSE			
TANK#3							OPEN	OPEN	CLOSE

CARBON SUPPLY INC.

CSI

BELL GARDENS, CA

Ø36"OD X 102"-SHELL

AIR TANK SERIES FLOW

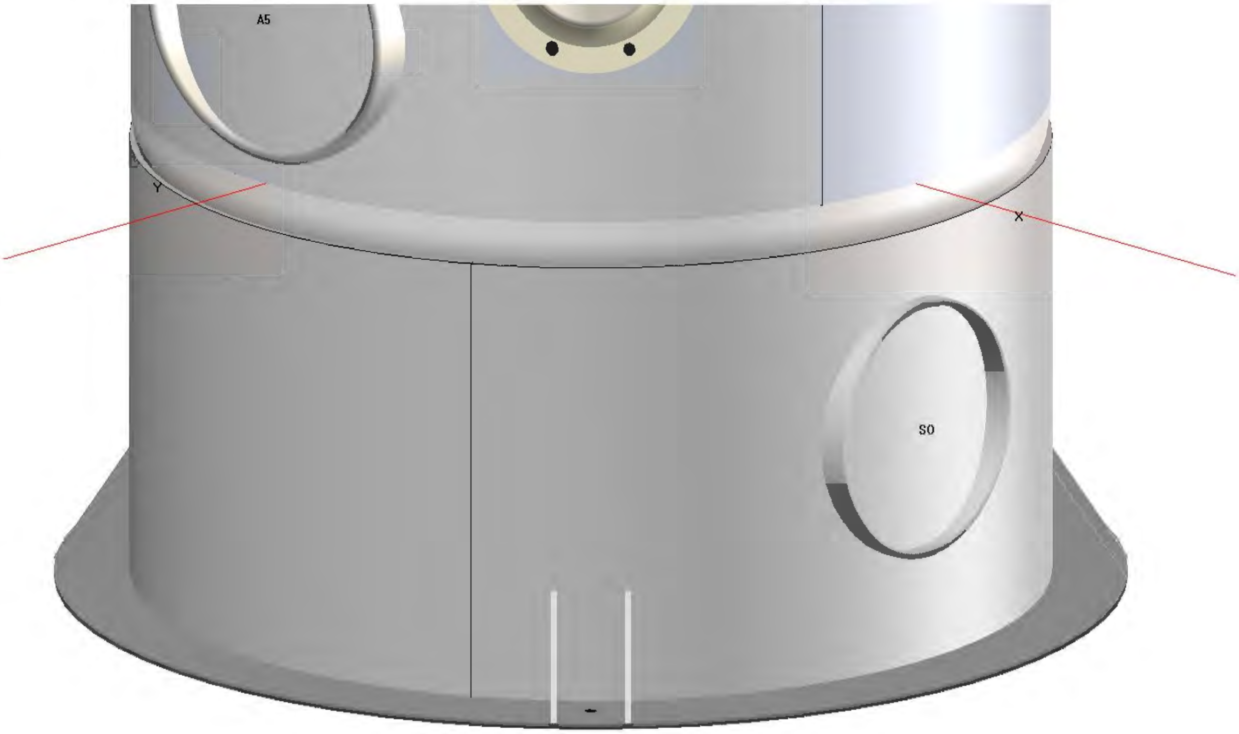
DRAWN BY: ck	12/31/19	DRAWING NO. 1107-G	REV. 0
CHECK:			
APPR'D: J. ROBLES		SCALE 1"=12"	
CUSTOMER		JOB NO.	

REV.	DESCRIPTION	DATE	BY	CHK.	APP.	ISSUE

Carbon Supply Inc

8429 Eastern Avenue

Bell Gardens, Ca 90201



Vessel Design Calculations

Item: 54"OD x 114" Shell Vertical Tank Support Skirt

Vessel No:

Customer:

Contract:

Designer: CK

Date: 1/13/20

Notes:

1. Seismic parameters:

a.) Per ASCE 7-10 Ground Supported.

b.) Site Class "D".

c.) Ss=18.8%; S1=6.40%

2. Wind Loads:

a.) Per ASCE 7-10

b.) Design Wind Speed: 115mph.

c.) Risk Category II

d.) Exposure Category "C"

Table of Contents

Weight Summary

Weight (lb) Contributed by Vessel Elements											
Component	Metal New*	Metal Corroded	Insulation	Insulation Supports	Lining	Piping + Liquid	Operating Liquid		Test Liquid		Surface Area ft2
							New	Corroded	New	Corroded	
54"OD Top F&D Head	292.6	292.6	0	0	0	0	0	0	562.9	562.9	20
54"OD Shell	2,000.6	2,000.6	0	0	0	0	9,178.7	9,178.7	9,178.7	9,178.7	131
54"OD Bottom F&D Head	303.1	303.1	0	0	0	0	524.9	524.9	524.9	524.9	21
Support Skirt	423.4	423.4	0	0	0	0	0	0	0	0	57
Base Ring	141	141	0	0	0	0	0	0	0	0	20
TOTAL:	**3,160.7**	**3,160.7**	**0**	**0**	**0**	**0**	**9,703.6**	**9,703.6**	**10,266.5**	**10,266.5**	**248**
*Shells with attached nozzles have weight reduced by material cut out for opening.											

Weight (lb) Contributed by Attachments											
Component	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays	Tray Supports	Rings & Clips	Vertical Loads	Surface Area ft2
	New	Corroded	New	Corroded							
54"OD Top F&D Head	0	0	38.7	38.7	0	0	0	0	0	0	0
54"OD Shell	0	0	123.7	123.7	0	0	0	0	0	0	3
54"OD Bottom F&D Head	0	0	2.5	2.5	0	0	0	0	0	0	0
Support Skirt	0	0	18.7	18.7	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**183.6**	**183.6**	**0**	**0**	**0**	**0**	**0**	**0**	**3**

Vessel Totals		
	New	Corroded
Operating Weight (lb)	13,048	13,048
Empty Weight (lb)	3,344	3,344
Test Weight (lb)	13,611	13,611
Surface Area (ft^2)	251	-
Capacity** (US gal)	1,229	1,229
**The vessel capacity does not include volume of nozzle, piping or other attachments.		

Vessel Lift Condition	
Vessel Lift Weight, New (lb)	3,344
Center of Gravity from Datum (in)	44.3549

Seismic Code

Building Code: ASCE 7-10 ground supported		
Site Class		D
Importance Factor, I_e		1.0000
Spectral Response Acceleration at short period (% g), S_s		18.80%
Spectral Response Acceleration at period of 1 sec (% g), S_1		6.40%
Response Modification Coeficient from Table 15.4-2, R		3.0000
Acceleration-based Site Coefficient, F_a		1.6000
Velocity-based Site Coefficient, F_v		2.4000
Long-period Transition Period, T_L		12.0000
Redundancy factor, ρ		1.0000
Risk Category (Table 1.5-1)		II
User Defined Vertical Accelerations Considered		No
Hazardous, toxic, or explosive contents		No
Vessel Characteristics		
Height		12.6132 ft
Weight	Operating, Corroded	13,048 lb
	Empty, Corroded	3,344 lb
Period of Vibration Calculation		
Fundamental Period, T	Operating, Corroded	0.024 sec (f = 42.2 Hz)
	Empty, Corroded	0.012 sec (f = 84.2 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.

12.4.2.3 Basic Load Combinations for Allowable Stress Design			
Load combinations considered in accordance with ASCE section 2.4.1:			
5.	$D + P + P_s + 0.7E$	$= (1.0 + 0.14S_{DS})D + P + P_s + 0.7\rho Q_E$	
8.	$0.6D + P + P_s + 0.7E$	$= (0.6 - 0.14S_{DS})D + P + P_s + 0.7\rho Q_E$	
Parameter description			
D	= Dead load		
P	= Internal or external pressure load		
P_s	= Static head load		
E	= Seismic load	$= E_h$ +/- E_v	$= \rho Q_E$ +/- $0.2S_{DS}D$

Seismic Shear Reports:

Operating, Corroded
Empty, Corroded
Base Shear Calculations

Seismic Shear Report: Operating, Corroded					
Component	**Elevation of Bottom above Base (in)**	**Elastic Modulus E (10^6 psi)**	**Inertia I (ft^4)**	**Seismic Shear at Bottom (lb_f)**	**Bending Moment at Bottom (lb_f-ft)**
54"OD Top F&D Head	140.4824	29.3	*	26	69
54"OD Shell	26.4824	29.3	1.0952	532	3,552
54"OD Bottom F&D Head (top)	24	29.3	*	536	3,662
Support Skirt	0	26.0	1.103	549	4,776
*Moment of Inertia I varies over the length of the component					

Seismic Shear Report: Empty, Corroded					
Component	**Elevation of Bottom above Base (in)**	**Elastic Modulus E (10^6 psi)**	**Inertia I (ft^4)**	**Seismic Shear at Bottom (lb_f)**	**Bending Moment at Bottom (lb_f-ft)**
54"OD Top F&D Head	140.4824	29.4	*	28	70
54"OD Shell	26.4824	29.4	1.0952	130	1,215
54"OD Bottom F&D Head (top)	24	29.4	*	131	1,242
Support Skirt	0	29.4	1.103	141	1,539
*Moment of Inertia I varies over the length of the component					

11.4.3: Maximum considered earthquake spectral response acceleration

The maximum considered earthquake spectral response acceleration at short period, S_{MS}
$S_{MS} = F_a * S_s$ = 1.6000 * 18.80 / 100 = 0.3008
The maximum considered earthquake spectral response acceleration at 1 s period, S_{M1}
$S_{M1} = F_v * S_1$ = 2.4000 * 6.40 / 100 = 0.1536

11.4.4: Design spectral response acceleration parameters

Design earthquake spectral response acceleration at short period, S_{DS}
S_{DS} = 2 / 3 * S_{MS} = 2 / 3 * 0.3008 = 0.2005
Design earthquake spectral response acceleration at 1 s period, S_{D1}
S_{D1} = 2 / 3 * S_{M1} = 2 / 3 * 0.1536 = 0.1024

11.6 Seismic Design Category

The Risk Category is II.
From Table 11.6-1, the Seismic Design Category based on S_{Ds} = 0.2005 is B.
From Table 11.6-2, the Seismic Design Category based on S_{D1} = 0.1024 is B.
This vessel is assigned to Seismic Design Category B.

12.4.2.3: Seismic Load Combinations: Vertical Term

Factor is applied to dead load.

Compressive Side: = 1.0 + 0.14 * S_{DS}
= 1.0 + 0.14 * 0.2005
= 1.0281
Tensile Side: = 0.6 - 0.14 * S_{DS}
= 0.6 - 0.14 * 0.2005
= 0.5719

Base Shear Calculations

Operating, Corroded
Empty, Corroded

Base Shear Calculations: Operating, Corroded

Paragraph 15.4.2: T < 0.06, so:

V = 0.30 * S_{DS} * W * I_e
= 0.30 * 0.2005 * 13,047.8359 * 1.0000
= 784.96 lb

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h

Q_E = V
E_h = 0.7 * ρ * Q_E (Only 70% of seismic load considered as per Section 2.4.1)
= 0.7 * 1.0000 * 784.96
= 549.47 lb

Base Shear Calculations: Empty, Corroded

Paragraph 15.4.2: T < 0.06, so:

$V = 0.30 * S_{DS} * W * I_e$

$= 0.30 * 0.2005 * 3{,}344.2463 * 1.0000$

$= 201.19$ lb

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h

$Q_E = V$

$E_h = 0.7 * \rho * Q_E$ (Only 70% of seismic load considered as per Section 2.4.1)

$= 0.7 * 1.0000 * 201.19$

$= 140.83$ lb

Building Code: ASCE 7-10		
Elevation of base above grade		0.00 ft
Increase effective outer diameter by		0.00 ft
Wind Force Coefficient, Cf		0.5300
Risk Category (Table 1.5-1)		II
Basic Wind Speed, V		115.00 mph
Exposure Category		C
Wind Directionality Factor, Kd		0.9500
Topographic Factor, Kzt		1.0000
Enforce min. loading of 16 psf		Yes
Hazardous, toxic, or explosive contents		No
Vessel Characteristics		
Height, h		12.6132 ft
Effective Width, b	Operating, Corroded	4.3563 ft
	Empty, Corroded	4.3563 ft
Fundamental Frequency, n_1	Operating, Corroded	42.1936 Hz
	Empty, Corroded	84.1517 Hz
Damping coefficient, β	Operating, Corroded	0.0240
	Empty, Corroded	0.0200

Table Lookup Values

2.4.1 Basic Load Combinations for Allowable Stress Design	
Load combinations considered in accordance with ASCE section 2.4.1:	
5.	$D + P + P_s + 0.6W$
7.	$0.6D + P + P_s + 0.6W$
Parameter Description	
D	= Dead load
P	= Internal or external pressure load
P_s	= Static head load
W	= Wind load

Wind Deflection Reports:

Operating, Corroded
Empty, Corroded
Wind Pressure Calculations

Wind Deflection Report: Operating, Corroded								
Component	**Elevation of Bottom above Base (in)**	**Effective OD (ft)**	**Elastic Modulus E (10^6 psi)**	**Inertia I (ft^4)**	**Platform Wind Shear at Bottom (lb_f)**	**Total Wind Shear at Bottom (lb_f)**	**Bending Moment at Bottom (lb_f-ft)**	**Deflection at Top (in)**
54"OD Top F&D Head	140.4824	4.50	29.3	*	0	31	68	0.0004
54"OD Shell	26.4824	4.50	29.3	1.095	0	441	2,589	0.0004
54"OD Bottom F&D Head (top)	24	4.50	29.3	*	0	450	2,681	0
Support Skirt	0	4.51	26.0	1.103	0	537	3,667	0
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Empty, Corroded								
Component	**Elevation of Bottom above Base (in)**	**Effective OD (ft)**	**Elastic Modulus E (10^6 psi)**	**Inertia I (ft^4)**	**Platform Wind Shear at Bottom (lb_f)**	**Total Wind Shear at Bottom (lb_f)**	**Bending Moment at Bottom (lb_f-ft)**	**Deflection at Top (in)**
54"OD Top F&D Head	140.4824	4.50	29.4	*	0	31	68	0.0004
54"OD Shell	26.4824	4.50	29.4	1.095	0	441	2,589	0.0003
54"OD Bottom F&D Head (top)	24	4.50	29.4	*	0	450	2,681	0
Support Skirt	0	4.51	29.4	1.103	0	537	3,667	0
*Moment of Inertia I varies over the length of the component								

Wind Pressure (WP) Calculations

Gust Factor ($\bar{G}$) Calculations

Kz $= 2.01 * (Z/Zg)^{2/\alpha}$
$= 2.01 * (Z/900.00)^{0.2105}$
qz $= 0.00256 * Kz * Kzt * Kd * V^2$
$= 0.00256 * Kz * 1.0000 * 0.9500 * 115.0000^2$
$= 32.1632 * Kz$
WP $= 0.6 * \max[qz * G * Cf, 16\ lb/ft^2]$
$= 0.6 * \max[qz * G * 0.5300, 16\ lb/ft^2]$

Design Wind Pressures							
Height Z (')	Kz	qz (psf)	WP (psf)				
			Operating	Empty	Hydrotest New	Hydrotest Corroded	Vacuum
15.0	0.8489	27.30	9.60	9.60	N.A.	N.A.	N.A.
Design Wind Force determined from: F = Pressure * Af , where Af is the projected area.							

Gust Factor Calculations

Operating, Corroded
Empty, Corroded

Gust Factor Calculations: Operating, Corroded

Vessel is considered a rigid structure as n_1 = 42.1936 Hz ≥ 1 Hz.

$\bar{z}$ = max[0.60 * h , z_{min}]
= max[0.60 * 12.6132 , 15.0000]
= 15.0000

$I_{\bar{z}}$ = c * $(33 / \bar{z})^{1/6}$
= 0.2000 * $(33 / 15.0000)^{1/6}$
= 0.2281

$L_{\bar{z}}$ = l * $(\bar{z} / 33)^{ep}$
= 500.0000 * $(15.0000 / 33)^{0.2000}$
= 427.0566

Q = Sqr(1 / (1 + 0.63 * $((b + h) / L_{\bar{z}})^{0.63}$))
= Sqr(1 / (1 + 0.63 * $((4.3563 + 12.6132) / 427.0566)^{0.63}$))
= 0.9611

G = 0.925 * (1 + 1.7 * g_Q * $I_{\bar{z}}$ * Q) / (1 + 1.7 * g_v * $I_{\bar{z}}$)
= 0.925 * (1 + 1.7 * 3.40* 0.2281 * 0.9611) / (1 + 1.7 * 3.40 * 0.2281)
= 0.9045

Gust Factor Calculations: Empty, Corroded

Vessel is considered a rigid structure as n_1 = 84.1517 Hz ≥ 1 Hz.

$\bar{z}$ = max[0.60 * h , z_{min}]
= max[0.60 * 12.6132 , 15.0000]
= 15.0000

$I_{\bar{z}}$ = c * $(33 / \bar{z})^{1/6}$
= 0.2000 * $(33 / 15.0000)^{1/6}$
= 0.2281

$L_{\bar{z}}$ = l * $(\bar{z} / 33)^{ep}$

$= 500.0000 * (15.0000 / 33)^{0.2000}$

$= 427.0566$

Q $= Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})^{0.63}))$

$= Sqr(1 / (1 + 0.63 * ((4.3563 + 12.6132) / 427.0566)^{0.63}))$

$= 0.9611$

G $= 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})$

$= 0.925 * (1 + 1.7 * 3.40 * 0.2281 * 0.9611) / (1 + 1.7 * 3.40 * 0.2281)$

$= 0.9045$

Table Lookup Values	
α = 9.5000, z_g = 900.00 ft	[Table 26.9-1, page 256]
c = 0.2000, l = 500.0000, ep = 0.2000	[Table 26.9-1, page 256]
$\bar{a}$ = 0.1538, $\bar{b}$ = 0.6500	[Table 26.9-1, page 256]
z_{min} = 15.0000 ft	[Table 26.9-1, page 256]
g_Q = 3.40	[26.9.4 page 254]
g_v = 3.40	[26.9.4 page 254]

<table>
<tr><th colspan="5">ASME Section VIII Division 1, 2017 Edition</th></tr>
<tr><td colspan="2">Component</td><td colspan="3">Support Skirt</td></tr>
<tr><td colspan="2">Skirt is Attached To</td><td colspan="3">54"OD Bottom F&D Head</td></tr>
<tr><td colspan="2">Skirt Attachment Offset</td><td colspan="3">2.4824" down from the top seam</td></tr>
<tr><td colspan="2" rowspan="3">Material</td><td colspan="3">SA-36 (II-D p. 10, ln. 18)</td></tr>
<tr><td>Impact Tested[1]</td><td>Normalized</td><td>Fine Grain Practice</td></tr>
<tr><td>No</td><td>No</td><td>No</td></tr>
<tr><th colspan="5">Design Temperature</th></tr>
<tr><td colspan="2">Internal</td><td colspan="3">650°F</td></tr>
<tr><th colspan="5">Dimensions</th></tr>
<tr><td rowspan="2">Inner Diameter</td><td>Top</td><td colspan="3">53.375"</td></tr>
<tr><td>Botttom</td><td colspan="3">53.375"</td></tr>
<tr><td colspan="2">Length (includes base ring thickness)</td><td colspan="3">24"</td></tr>
<tr><td colspan="2">Nominal Thickness</td><td colspan="3">0.375"</td></tr>
<tr><td rowspan="2">Corrosion</td><td>Inner</td><td colspan="3">0"</td></tr>
<tr><td>Outer</td><td colspan="3">0"</td></tr>
<tr><th colspan="5">Weight</th></tr>
<tr><td colspan="2">New</td><td colspan="3">423.37 lb</td></tr>
<tr><td colspan="2">Corroded</td><td colspan="3">423.37 lb</td></tr>
<tr><th colspan="5">Joint Efficiency</th></tr>
<tr><td colspan="2">Top</td><td colspan="3">0.55</td></tr>
<tr><td colspan="2">Bottom</td><td colspan="3">0.7</td></tr>
</table>

[1] Impact testing requirements are not checked for supports

Skirt design thickness, largest of the following + corrosion = 0.0109 in

The governing condition is due to seismic, compressive stress at the base, operating & corroded.

The skirt thickness of 0.375 in is adequate.

Results Summary							
Loading	**Condition**	**Tensile or Compressive Side**	**Governing Skirt Location**	**Temperature (°F)**	**Allowable Stress (psi)**	**Calculated Stress/E (psi)**	**Required thickness (in)**
Wind	operating, corroded	Tensile	top	650	9,487.44	-80.3	0.0032
		Compressive	bottom			255.54	0.0101
	empty, corroded	Tensile	bottom	70	16,600	30.52	0.0007
		Compressive			14,394.93	102.3	0.0027
Seismic	operating, corroded	Tensile	top	650	9,487.44	-60.97	0.0024
		Compressive	bottom			276.9	0.0109
	empty, corroded	Tensile	top	70	14,394.93	-7.44	0.0002
		Compressive	bottom			73.71	0.0019

Loading due to wind, operating & corroded

Windward side (tensile)

Required thickness, tensile stress at base:

$t = -0.6*W / (\pi*D*S_t*E) + 48*M / (\pi*D^2*S_t*E)$

$= -0.6*12,906.84 / (\pi*53.75*9,487*1) + 48*3,667.1 / (\pi*53.75^2*9,487*1)$

$= 0.0028$ in

Required thickness, tensile stress at the top:

$t = -0.6*W_t / (\pi*D_t*S_t*E) + 48*M_t / (\pi*D_t^2*S_t*E)$

$= -0.6*12,464.74 / (\pi*53.75*9,487*1) + 48*2,680.7 / (\pi*53.75^2*9,487*1)$

$=$ 0.0032 in

Leeward side (compressive)

Required thickness, compressive stress at base:

$t = W / (\pi*D*S_c*E_c) + 48*M / (\pi*D^2*S_c*E_c)$

$= 12,906.84 / (\pi*53.75*9,487*1) + 48*3,667.1 / (\pi*53.75^2*9,487*1)$

$=$ 0.0101 in

Required thickness, compressive stress at the top:

$t = W_t / (\pi*D_t*S_c*E_c) + 48*M_t / (\pi*D_t^2*S_c*E_c)$

$= 12,464.74 / (\pi*53.75*9,487*1) + 48*2,680.7 / (\pi*53.75^2*9,487*1)$

$= 0.0093$ in

Loading due to wind, empty & corroded

Windward side (tensile)

Required thickness, tensile stress at base:

t = $-0.6*W / (\pi*D*S_t*E) + 48*M / (\pi*D^2*S_t*E)$
= $-0.6*3{,}203.25 / (\pi*53.75*16{,}600*0.7) + 48*3{,}667.1 / (\pi*53.75^2*16{,}600*0.7)$
= 0.0007 in

Required thickness, tensile stress at the top:

t = $-0.6*W_t / (\pi*D_t*S_t*E) + 48*M_t / (\pi*D_t^2*S_t*E)$
= $-0.6*2{,}761.15 / (\pi*53.75*16{,}600*0.55) + 48*2{,}680.7 / (\pi*53.75^2*16{,}600*0.55)$
= 0.0005 in

Leeward side (compressive)

Required thickness, compressive stress at base:

t = $W / (\pi*D*S_c*E_c) + 48*M / (\pi*D^2*S_c*E_c)$
= $3{,}203.25 / (\pi*53.75*14{,}395*1) + 48*3{,}667.1 / (\pi*53.75^2*14{,}395*1)$
= 0.0027 in

Required thickness, compressive stress at the top:

t = $W_t / (\pi*D_t*S_c*E_c) + 48*M_t / (\pi*D_t^2*S_c*E_c)$
= $2{,}761.15 / (\pi*53.75*14{,}395*1) + 48*2{,}680.7 / (\pi*53.75^2*14{,}395*1)$
= 0.0021 in

Loading due to seismic, operating & corroded

Tensile side

Required thickness, tensile stress at base:

t = $-(0.6 - 0.14*S_{DS})*W / (\pi*D*S_t*E) + 48*M / (\pi*D^2*S_t*E)$
= $-(0.6 - 0.14*0.2005)*12{,}906.84 / (\pi*53.75*9{,}487*1) + 48*4{,}775.5 / (\pi*53.75^2*9{,}487*1)$
= 0.0019 in

Required thickness, tensile stress at the top:

$t = -(0.6 - 0.14*S_{DS})*W_t / (\pi*D_t*S_t*E) + 48*M_t / (\pi*D_t^2*S_t*E)$
$= -(0.6 - 0.14*0.2005)*12,464.74 / (\pi*53.75*9,487*1) + 48*3,659.8 / (\pi*53.75^2*9,487*1)$
$= 0.0024$ in

Compressive side

Required thickness, compressive stress at base:

$t = (1 + 0.14*S_{DS})*W / (\pi*D*S_c*E_c) + 48*M / (\pi*D^2*S_c*E_c)$
$= (1 + 0.14*0.2005)*12,906.84 / (\pi*53.75*9,487*1) + 48*4,775.5 / (\pi*53.75^2*9,487*1)$
$= 0.0109$ in

Required thickness, compressive stress at the top:

$t = (1 + 0.14*S_{DS})*W_t / (\pi*D_t*S_c*E_c) + 48*M_t / (\pi*D_t^2*S_c*E_c)$
$= (1 + 0.14*0.2005)*12,464.74 / (\pi*53.75*9,487*1) + 48*3,659.8 / (\pi*53.75^2*9,487*1)$
$= 0.01$ in

Loading due to seismic, empty & corroded

Tensile side

Required thickness, tensile stress at base:

$t = -(0.6 - 0.14*S_{DS})*W / (\pi*D*S_t*E) + 48*M / (\pi*D^2*S_t*E)$
$= -(0.6 - 0.14*0.2005)*3,203.25 / (\pi*53.75*14,395*1) + 48*1,539.3 / (\pi*53.75^2*14,395*1)$
$= 0.0002$ in

Required thickness, tensile stress at the top:

$t = -(0.6 - 0.14*S_{DS})*W_t / (\pi*D_t*S_t*E) + 48*M_t / (\pi*D_t^2*S_t*E)$
$= -(0.6 - 0.14*0.2005)*2,761.15 / (\pi*53.75*14,395*1) + 48*1,240.8 / (\pi*53.75^2*14,395*1)$
$= 0.0002$ in

Compressive side

Required thickness, compressive stress at base:

$t = (1 + 0.14*S_{DS})*W / (\pi*D*S_c*E_c) + 48*M / (\pi*D^2*S_c*E_c)$
$= (1 + 0.14*0.2005)*3,203.25 / (\pi*53.75*14,395*1) + 48*1,539.3 / (\pi*53.75^2*14,395*1)$
$= 0.0019$ in

Required thickness, compressive stress at the top:

$$t = (1 + 0.14*S_{DS})*W_t / (\pi*D_t*S_c*E_c) + 48*M_t / (\pi*D_t^2*S_c*E_c)$$
$$= (1 + 0.14*0.2005)*2{,}761.15 / (\pi*53.75*14{,}395*1) + 48*1{,}240.8 / (\pi*53.75^2*14{,}395*1)$$
$$= 0.0016 \text{ in}$$

Skirt Buckling Check per ASCE 15.7.10.5

4.4.12.2.b Allowable Axial Compressive Membrane Stress		
$M_x = L / (R_o*t)^{0.5}$		(4.4.124)
cbar = 2.64	for $M_x \le 1.5$	(4.4.69)
cbar = $3.13 / M_x^{0.42}$	for $1.5 < M_x < 15$	(4.4.70)
cbar = 1	for $M_x \ge 15$	(4.4.71)
C_x = min[409*cbar / (389 + D_o / t) , 0.9]	for $D_o / t < 1247$	(4.4.67)
C_x = 0.25*cbar	for $1247 \le D_o / t \le 2000$	(4.4.68)
$F_{xe} = C_x*E_y*t / D_o$		(4.4.66)
$F_{xa2} = F_{xe} / FS$		(4.4.65)
$F_{xa1} = S_y / FS$	for $D_o / t \le 135$	(4.4.62)
$F_{xa1} = 466*S_y / [FS*(331 + D_o / t)]$	for $135 < D_o / t < 600$	(4.4.63)
$F_{xa1} = 0.5*S_y / FS$	for $600 \le D_o / t \le 2000$	(4.4.64)
$F_{xa} = \min[F_{xa1} , F_{xa2}]$		(4.4.61)
$\lambda_c = K_u*L_u / (\pi*r_g)*(F_{xa}*FS / E_y)^{0.5}$		(4.4.125)
New / Corroded		
D_o / t = 54.125 / 0.375 =		144.3333
M_x = 24 / (27.0625*0.375)$^{0.5}$ =		7.5338
cbar = 3.13 / $M_x^{0.42}$ =		1.3403
C_x = min[409*1.3403 / (389 + 54.125 / 0.375) , 0.9] =		0.9
Operating Hot & Corroded		
F_{xe} = 0.9*26.0E+06*0.375 / 54.125 =		162,125 psi
F_{xa1} = 466*26,700 / [1*(331 + 54.125 / 0.375)] =		26,176 psi
F_{xa2} = 162,125 / 1 =		162,125 psi
F_{xa} = min[26,176 , 162,125] =		26,176 psi
λ_c = 2.1*151.359 / (π*19.004)*(26,176*1 / 26.0E+06)$^{0.5}$ =		0.1689
Operating Hot & New		
F_{xe} = 0.9*26.0E+06*0.375 / 54.125 =		162,125 psi
F_{xa1} = 466*26,700 / [1*(331 + 54.125 / 0.375)] =		26,176 psi
F_{xa2} = 162,125 / 1 =		162,125 psi
F_{xa} = min[26,176 , 162,125] =		26,176 psi

λ_c = 2.1*151.359 / (π*19.004)*(26,176*1 / 26.0E+06)$^{0.5}$ =	0.1689
Empty Cold & Corroded	
F_{xe} = 0.9*29.4E+06*0.375 / 54.125 =	183,326 psi
F_{xa1} = 466*36,000 / [1*(331 + 54.125 / 0.375)] =	35,293 psi
F_{xa2} = 183,326 / 1 =	183,326 psi
F_{xa} = min[35,293 , 183,326] =	35,293 psi
λ_c = 2.1*151.359 / (π*19.004)*(35,293*1 / 29.4E+06)$^{0.5}$ =	0.1845
Empty Cold & New	
F_{xe} = 0.9*29.4E+06*0.375 / 54.125 =	183,326 psi
F_{xa1} = 466*36,000 / [1*(331 + 54.125 / 0.375)] =	35,293 psi
F_{xa2} = 183,326 / 1 =	183,326 psi
F_{xa} = min[35,293 , 183,326] =	35,293 psi
λ_c = 2.1*151.359 / (π*19.004)*(35,293*1 / 29.4E+06)$^{0.5}$ =	0.1845

4.4.12.2.c Compressive Bending Stress		
$\gamma = S_y*D_o / (E_y*t)$		(4.4.78)
$F_{ba} = F_{xa}$	for $135 \le D_o / t \le 2000$	(4.4.74)
$F_{ba} = 466*S_y / [FS*(331 + D_o / t)]$	for $100 \le D_o / t < 135$	(4.4.75)
$F_{ba} = 1.081*S_y / FS$	for $D_o / t < 100$ and $\gamma \ge 0.11$	(4.4.76)
$F_{ba} = S_y*(1.4 - 2.9*\gamma) / FS$	for $D_o / t < 100$ and $\gamma < 0.11$	(4.4.77)
Operating Hot & Corroded		
$D_o / t = 54.125 / 0.375 =$		144.3333
$\gamma = 26{,}700*54.125 / (26.0E+06*0.375) =$		0.1482
$F_{ba} = F_{xa} =$		26,176 psi
Operating Hot & New		
$D_o / t = 54.125 / 0.375 =$		144.3333
$\gamma = 26{,}700*54.125 / (26.0E+06*0.375) =$		0.1482
$F_{ba} = F_{xa} =$		26,176 psi
Empty Cold & Corroded		
$D_o / t = 54.125 / 0.375 =$		144.3333
$\gamma = 36{,}000*54.125 / (29.4E+06*0.375) =$		0.1767
$F_{ba} = F_{xa} =$		35,293 psi
Empty Cold & New		
$D_o / t = 54.125 / 0.375 =$		144.3333
$\gamma = 36{,}000*54.125 / (29.4E+06*0.375) =$		0.1767
$F_{ba} = F_{xa} =$		35,293 psi

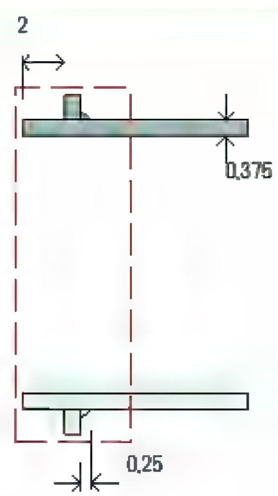
4.4.12.2.d Allowable Shear Stress		
$C_v = 4.454$	for $M_x \le 1.5$	(4.4.81)
$C_v = (9.64 / M_x^2)*(1 + 0.0239*M_x^3)^{0.5}$	for $1.5 < M_x < 26$	(4.4.82)
$C_v = 1.492 / M_x^{0.5}$	for $26 \le M_x < 4.347*(D_o / t)$	(4.4.83)
$C_v = 0.716*(t / D_o)^{0.5}$	for $M_x \ge 4.347*(D_o / t)$	(4.4.84)
$\alpha_v = 0.8$	for $D_o / t \le 500$	(4.4.85)
$\alpha_v = 1.389 - 0.218*\log_{10}(D_o / t)$	for $D_o / t > 500$	(4.4.86)
$\eta_v = 1$	for $F_{ve} / S_y \le 0.48$	(4.4.87)
$\eta_v = 0.43*(S_y / F_{ve}) + 0.1$	for $0.48 < F_{ve} / S_y < 1.7$	(4.4.88)
$\eta_v = 0.6*(S_y / F_{ve})$	for $F_{ve} / S_y \ge 1.7$	(4.4.89)
$F_{ve} = \alpha_v*C_v*E_y*(t / D_o)$		(4.4.80)
$F_{va} = \eta_v*F_{ve} / FS$		(4.4.79)
Operating Hot & Corroded		
$D_o / t = 54.125 / 0.375 =$		144.3333
$M_x = 24 / (27.0625*0.375)^{0.5} =$		7.5338
$F_{ve} / S_y = 81{,}986 / 26{,}700 =$		3.0706
$C_v = (9.64 / 7.5338^2)*(1 + 0.0239*7.5338^3)^{0.5} =$		0.5689
$\alpha_v = 0.8 =$		0.8
$\eta_v = 0.6*(26{,}700 / 81{,}986) =$		0.1954
$F_{ve} = 0.8*0.5689*26.0E+06*(0.375 / 54.125) =$		81,986 psi
$F_{va} = 0.1954*81{,}986 / 1 =$		16,020 psi
Operating Hot & New		
$D_o / t = 54.125 / 0.375 =$		144.3333
$M_x = 24 / (27.0625*0.375)^{0.5} =$		7.5338
$F_{ve} / S_y = 81{,}986 / 26{,}700 =$		3.0706
$C_v = (9.64 / 7.5338^2)*(1 + 0.0239*7.5338^3)^{0.5} =$		0.5689
$\alpha_v = 0.8 =$		0.8
$\eta_v = 0.6*(26{,}700 / 81{,}986) =$		0.1954
$F_{ve} = 0.8*0.5689*26.0E+06*(0.375 / 54.125) =$		81,986 psi
$F_{va} = 0.1954*81{,}986 / 1 =$		16,020 psi
Empty Cold & Corroded		
$D_o / t = 54.125 / 0.375 =$		144.3333

M_x = 24 / (27.0625*0.375)$^{0.5}$ =	7.5338
F_{ve} / S_y = 92,707 / 36,000 =	2.5752
C_v = (9.64 / 7.5338^2)*(1 + 0.0239*7.5338^3)$^{0.5}$ =	0.5689
α_v = 0.8 =	0.8
η_v = 0.6*(36,000 / 92,707) =	0.233
F_{ve} = 0.8*0.5689*29.4E+06*(0.375 / 54.125) =	92,707 psi
F_{va} = 0.233*92,707 / 1 =	21,600 psi
Empty Cold & New	
D_o / t = 54.125 / 0.375 =	144.3333
M_x = 24 / (27.0625*0.375)$^{0.5}$ =	7.5338
F_{ve} / S_y = 92,707 / 36,000 =	2.5752
C_v = (9.64 / 7.5338^2)*(1 + 0.0239*7.5338^3)$^{0.5}$ =	0.5689
α_v = 0.8 =	0.8
η_v = 0.6*(36,000 / 92,707) =	0.233
F_{ve} = 0.8*0.5689*29.4E+06*(0.375 / 54.125) =	92,707 psi
F_{va} = 0.233*92,707 / 1 =	21,600 psi

4.4.12.2.i Axial Compression, Bending Moment, and Shear		
$f_b = M / S$		(4.4.119)
$f_a = F / A$		(4.4.120)
$f_v = V*\sin[\phi] / A$		(4.4.122)
$K_s = 1 - (f_v / F_{va})^2$		(4.4.105)
$F_e = \pi^2*E_y / (K_u*L_u / r_g)^2$		(4.4.110)
$\Delta = C_m / (1 - f_a*FS / F_e)$		(4.4.109)
$F_{ca} = F_{xa}*[1 - 0.74*(\lambda_c - 0.15)]^{0.3}$	for $0.15 < \lambda_c < 1.2$	(4.4.72)
$f_a / (K_s*F_{ca}) + 8*\Delta*f_b / (9*K_s*F_{ba}) \le 1$	for $f_a / (K_s*F_{ca}) \ge 0.2$	(4.4.112)
$f_a / (2*K_s*F_{ca}) + \Delta*f_b / (K_s*F_{ba}) \le 1$	for $f_a / (K_s*F_{ca}) < 0.2$	(4.4.113)
New / Corroded		
$r_g = 0.25*(54.125^2 + 53.375^2)^{0.5} =$		19.004"
$A = \pi*(54.125^2 - 53.375^2) / 4 =$		63.32 in^2
$S = \pi*(54.125^4 - 53.375^4) / (32*54.125) =$		845.0449 in^3
Operating Hot & Corroded		
Seismic ASCE 15.7.10.5	$f_b = 80{,}033.2 / 845.0449 =$	95 psi
	$f_a = 12{,}906.84 / 63.32 =$	204 psi
	$f_v = 784.96*\sin[90] / 63.32 =$	12 psi
	$K_s = 1 - (12 / 16{,}020)^2 =$	1
	$F_e = \pi^2*26.0E+06 / (2.1*151.359 / 19.004)^2 =$	917,289 psi
	$\Delta = 1 / (1 - 204*1 / 917{,}289) =$	1.0002
	$F_{ca} = 26{,}176*[1 - 0.74*(0.1689 - 0.15)]^{0.3} =$	26,065 psi
	$f_a / (K_s*F_{ca}) = 204 / (1*26{,}065) =$	0.0078
	204 / (2*1*26,065) + 1.0002*95 / (1*26,176) =	0.0075
	Combined load check passes.	
Operating Hot & New		
Seismic ASCE 15.7.10.5	$f_b = 80{,}033.2 / 845.0449 =$	95 psi
	$f_a = 12{,}906.84 / 63.32 =$	204 psi
	$f_v = 784.96*\sin[90] / 63.32 =$	12 psi
	$K_s = 1 - (12 / 16{,}020)^2 =$	1
	$F_e = \pi^2*26.0E+06 / (2.1*151.359 / 19.004)^2 =$	917,289 psi
	$\Delta = 1 / (1 - 204*1 / 917{,}289) =$	1.0002

	F_{ca} = 26,176*[1 - 0.74*(0.1689 - 0.15)]$^{0.3}$ =	26,065 psi
	f_a / (K_s*F_{ca}) = 204 / (1*26,065) =	0.0078
	204 / (2*1*26,065) + 1.0002*95 / (1*26,176) =	0.0075
	Combined load check passes.	
Empty Cold & Corroded		
Seismic ASCE 15.7.10.5	f_b = 24,552.4 / 845.0449 =	29 psi
	f_a = 3,203.25 / 63.32 =	51 psi
	f_v = 201.19*sin[90] / 63.32 =	3 psi
	K_s = 1 - (3 / 21,600)^2 =	1
	F_e = π^2*29.4E+06 / (2.1*151.359 / 19.004)^2 =	1,037,242 psi
	Δ = 1 / (1 - 51*1 / 1,037,242) =	1
	F_{ca} = 35,293*[1 - 0.74*(0.1845 - 0.15)]$^{0.3}$ =	35,021 psi
	f_a / (K_s*F_{ca}) = 51 / (1*35,021) =	0.0014
	51 / (2*1*35,021) + 1*29 / (1*35,293) =	0.0015
	Combined load check passes.	
Empty Cold & New		
Seismic ASCE 15.7.10.5	f_b = 24,552.4 / 845.0449 =	29 psi
	f_a = 3,203.25 / 63.32 =	51 psi
	f_v = 201.19*sin[90] / 63.32 =	3 psi
	K_s = 1 - (3 / 21,600)^2 =	1
	F_e = π^2*29.4E+06 / (2.1*151.359 / 19.004)^2 =	1,037,242 psi
	Δ = 1 / (1 - 51*1 / 1,037,242) =	1
	F_{ca} = 35,293*[1 - 0.74*(0.1845 - 0.15)]$^{0.3}$ =	35,021 psi
	f_a / (K_s*F_{ca}) = 51 / (1*35,021) =	0.0014
	51 / (2*1*35,021) + 1*29 / (1*35,293) =	0.0015
	Combined load check passes.	

ASME Section VIII Division 1, 2017 Edition	
Component	Skirt Opening
Description	Skirt Opening
Drawing Mark	SO
Sleeve Material	SA-36 (II-D p. 10, ln. 18)
Location and Orientation	
Attached to	Support Skirt
Orientation	radial
Offset, L	13.25"
Angle, θ	0°
Distance, r	27.875"
Through a Category B Joint	No
Dimensions	
Inside Diameter	13.25"
Nominal Wall Thickness	0.375"
Skirt Thickness	0.375"
Leg_{41}	0.25"
Leg_{43}	0"
External Projection Available, L_{pr1}	0.8125"
Internal Projection, L_{pr2}	2"
Corrosion — Inner	0"
Corrosion — Outer	0"



Skirt Opening Reinforcement Summary			Required Thickness t_r (in)	A_T (in^2)	A_r (in^2)	Ratio	Status
Operating Hot & Corroded	Wind	Tensile	0	4.5079	0	N/A	OK
		Compressive	0.0096	4.4397	0.1278	34.7476	OK
	Seismic	Tensile	0	4.5079	0	N/A	OK
		Compressive	0.0104	4.434	0.1384	32.045	OK
Empty Cold & Corroded	Wind	Tensile	0.0004	4.5053	0.0048	939.399	OK
		Compressive	0.0024	4.4912	0.0313	143.4164	OK
	Seismic	Tensile	0	4.5079	0	N/A	OK
		Compressive	0.0018	4.4955	0.0233	193.2792	OK

Note: Skirt required thickness of zero on tensile side indicates load is compressive.

Skirt Opening Reinforcement Calculations	
$L_R = \min[(R_{eff}*t)^{0.5}, 2*R_n]$	(4.5.4)
$L_{H1} = \min[1.5*t , t_e] + (R_n*t_n)^{0.5}$	(4.5.11)
$L_{H2} = L_{pr1}$	(4.5.12)
$L_{H3} = 8*(t + t_e)$	(4.5.13)
$L_H = \min[L_{H1}, L_{H2}, L_{H3}] + t$	(4.5.14)
$L_{I1} = (R_n*t_n)^{0.5}$	(4.5.16)
$L_{I2} = L_{pr2}$	(4.5.17)
$L_{I3} = 8*(t + t_e)$	(4.5.18)
$L_I = \min[L_{I1}, L_{I2}, L_{I3}]$	(4.5.19)
$f_{r1} = \min[S_n / S , 1]$	
$f_{r2} = \min[S_n / S , 1]$	
$A_1 = 2*L_R*(E_1*t - t_r)$	
$A_2 = 2*(L_H - t_r)*t_n*f_{r2}$	
$A_3 = 2*L_I*t_i*f_{r2}$	
$A_{41} = L_{41}^2*f_{r2}$	
$A_{43} = L_{43}^2*f_{r2}$	
$A_T = A_1 + A_2 + A_3 + A_{41} + A_{43}$	
$A_r = d*t_r + 2*t_n*t_r*(1 - f_{r1})$	

Corroded	
L_R = min[$(26.6875*0.375)^{0.5}$, 2*6.625] =	3.1635"
L_{H1} = min[1.5*0.375 , 0] + $(6.625*0.375)^{0.5}$ =	1.5762"
L_{H2} = 0.8125 =	0.8125"
L_{H3} = 8*(0.375 + 0) =	3"
L_H = min[1.5762, 0.8125, 3] + 0.375 =	1.1875"
L_{I1} = $(6.625*0.375)^{0.5}$ =	1.5762"
L_{I2} = L_{pr2} =	2"
L_{I3} = 8*(0.375 + 0) =	3"
L_I = min[1.5762, 2, 3] =	1.5762"
Operating Hot & Corroded Wind Compressive	
f_{r1} = min[16,600 / 16,600 , 1] =	1
f_{r2} = min[16,600 / 16,600 , 1] =	1
A_1 = 2*3.1635*(1*0.375 - 0.0096) =	2.3116 in^2
A_2 = 2*(1.1875 - 0.0096)*0.375*1 =	0.8834 in^2
A_3 = 2*1.5762*0.375*1 =	1.1821 in^2
A_{41} = 0.25^2*1 =	0.0625 in^2
A_{43} = 0^2*1 =	0 in^2
A_T = 2.3116 + 0.8834 + 1.1821 + 0.0625 + 0 =	4.4397 in^2
A_r = 13.25*0.0096 + 2*0.375*0.0096*(1 - 1) =	0.1278 in^2
A_T = 4.4397 in^2 ≥ A_r = 0.1278 in^2	
Empty Cold & Corroded Wind Tensile	
f_{r1} = min[16,600 / 16,600 , 1] =	1
f_{r2} = min[16,600 / 16,600 , 1] =	1
A_1 = 2*3.1635*(1*0.375 - 0.0004) =	2.3703 in^2
A_2 = 2*(1.1875 - 0.0004)*0.375*1 =	0.8904 in^2
A_3 = 2*1.5762*0.375*1 =	1.1821 in^2
A_{41} = 0.25^2*1 =	0.0625 in^2
A_{43} = 0^2*1 =	0 in^2
A_T = 2.3703 + 0.8904 + 1.1821 + 0.0625 + 0 =	4.5053 in^2
A_r = 13.25*0.0004 + 2*0.375*0.0004*(1 - 1) =	0.0048 in^2
A_T = 4.5053 in^2 ≥ A_r = 0.0048 in^2	

Empty Cold & Corroded Wind Compressive	
f_{r1} = min[16,600 / 16,600 , 1] =	1
f_{r2} = min[16,600 / 16,600 , 1] =	1
A_1 = 2*3.1635*(1*0.375 - 0.0024) =	2.3577 in^2
A_2 = 2*(1.1875 - 0.0024)*0.375*1 =	0.8889 in^2
A_3 = 2*1.5762*0.375*1 =	1.1821 in^2
A_{41} = 0.25^2*1 =	0.0625 in^2
A_{43} = 0^2*1 =	0 in^2
A_T = 2.3577 + 0.8889 + 1.1821 + 0.0625 + 0 =	4.4912 in^2
A_r = 13.25*0.0024 + 2*0.375*0.0024*(1 - 1) =	0.0313 in^2
A_T = 4.4912 in^2 ≥ A_r = 0.0313 in^2	
Operating Hot & Corroded Seismic Compressive	
f_{r1} = min[16,600 / 16,600 , 1] =	1
f_{r2} = min[16,600 / 16,600 , 1] =	1
A_1 = 2*3.1635*(1*0.375 - 0.0104) =	2.3066 in^2
A_2 = 2*(1.1875 - 0.0104)*0.375*1 =	0.8828 in^2
A_3 = 2*1.5762*0.375*1 =	1.1821 in^2
A_{41} = 0.25^2*1 =	0.0625 in^2
A_{43} = 0^2*1 =	0 in^2
A_T = 2.3066 + 0.8828 + 1.1821 + 0.0625 + 0 =	4.434 in^2
A_r = 13.25*0.0104 + 2*0.375*0.0104*(1 - 1) =	0.1384 in^2
A_T = 4.434 in^2 ≥ A_r = 0.1384 in^2	
Empty Cold & Corroded Seismic Compressive	
f_{r1} = min[16,600 / 16,600 , 1] =	1
f_{r2} = min[16,600 / 16,600 , 1] =	1
A_1 = 2*3.1635*(1*0.375 - 0.0018) =	2.3615 in^2
A_2 = 2*(1.1875 - 0.0018)*0.375*1 =	0.8893 in^2
A_3 = 2*1.5762*0.375*1 =	1.1821 in^2
A_{41} = 0.25^2*1 =	0.0625 in^2
A_{43} = 0^2*1 =	0 in^2
A_T = 2.3615 + 0.8893 + 1.1821 + 0.0625 + 0 =	4.4955 in^2
A_r = 13.25*0.0018 + 2*0.375*0.0018*(1 - 1) =	0.0233 in^2

$$A_T = 4.4955 \text{ in}^2 \geq A_r = 0.0233 \text{ in}^2$$

Base Ring

Inputs	
Base configuration	single base plate
Base plate material	SA36
Base plate allowable stress, S_p	20,000 psi
Foundation compressive strength	1,658 psi
Concrete ultimate 28-day strength	3,000 psi
Bolt circle, BC	58.25"
Base plate inner diameter, D_i	49.125"
Base plate outer diameter, D_o	63"
Base plate thickness, t_b	0.375"
Gusset separation, w	4"
Gusset height, h	6"
Gusset thickness, t_g	0.375"
Anchor Bolts	
Material	Bolt Material
Allowable stress, S_b	20,000 psi
Bolt size and type	0.625" coarse threaded
Number of bolts, N	4
Corrosion allowance (applied to root radius)	0"
Anchor bolt clearance	0.125"
Bolt root area (corroded), A_b	0.2 in^2
Diameter of anchor bolt holes, d_b	0.75"
Initial bolt preload	0% (0 psi)
Bolt at 0°	No

Results Summary							
Load	Vessel condition	Base V (lb_f)	Base M (lb_f-ft)	W (lb)	Required bolt area (in^2)	t_r Base (in)	Foundation bearing stress (psi)
Wind	operating, corroded	536.5	3,667.1	13,047.8	0	0.1952	13.54
Wind	operating, new	536.5	3,667.1	13,047.8	0	0.1952	13.54
Wind	empty, corroded	536.5	3,667.1	3,344.2	0.0127	0.1254	5.59
Wind	empty, new	536.5	3,667.1	3,344.2	0.0127	0.1254	5.59
Seismic	operating, corroded	549.5	4,775.5	13,047.8	0	0.2034	14.7
Seismic	operating, new	549.5	4,775.5	13,047.8	0	0.2034	14.7
Seismic	empty, corroded	140.8	1,539.3	3,344.2	0	0.1063	4.01
Seismic	empty, new	140.8	1,539.3	3,344.2	0	0.1063	4.01

Anchor bolt load (operating, corroded + Wind)

P = -0.6*W / N + 48 * M / (N*BC)
= -0.6*13,047.84 / 4 + 48 * 3,667.1 / (4*58.25)
= -1,201.72 lb_f

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (operating, corroded + Wind)

$A_c = \pi*(D_o^2 - D_i^2) / 4 - N*\pi*d_b^2 / 4$
$= \pi*(63^2 - 49.125^2) / 4 - 4*\pi*0.75^2 / 4$
= 1,220.1038 in^2

$I_c = \pi*(D_o^4 - D_i^4) / 64$
$= \pi*(63^4 - 49.125^4) / 64$
= 487,394 in^4

$f_c = N*A_b*Preload / A_c + W / A_c + 6*M*D_o / I_c$
= 4*0.202*0 / 1,220.1038 + 13,047.84 / 1,220.1038 + 6*3,667.1*63 / 487,394
= 14 psi

As f_c <= 1,658 psi the base plate width is satisfactory.

Base plate required thickness (operating, corroded + Wind)

From Brownell & Young, Table 10.3:, l / b = 0.1082

$M_x = 0.0025*14*40.9994^2 = 57.6$ lb_f

$M_y = -0.4766*14*4.4375^2 = -127.1$ lb_f

$t_r = (6*M_{max} / S_p)^{0.5}$

$= (6*127.06 / 20{,}000)^{0.5}$
= [0.1952] in

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, operating, corroded + Wind)

Bolt load = A_b*f_s =0.202*0 = 0 lb_f

$t_r = (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))^{0.5}$
$= (3.91*0 / (36{,}000*(2*4.4375 / 4+4 / (2*2.0625)-0.75*(2 / 4+1 / (2*2.0625)))))^{0.5}$
= 0 in

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$S_r = 1.5*F*b / (gussets*\pi*t_{sk}^2*h)$
$= 1.5*0*4.4375 / (2*\pi*0.375^2*6)$
= 0 psi

As S_r <= 24,900 psi the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (operating, new + Wind)

P = -0.6*W / N + 48 * M / (N*BC)
= -0.6*13,047.84 / 4 + 48 * 3,667.1 / (4*58.25)
= -1,201.72 lb_f

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (operating, new + Wind)

$A_c = \pi*(D_o^2 - D_i^2) / 4 - N*\pi*d_b^2 / 4$
$= \pi*(63^2 - 49.125^2) / 4 - 4*\pi*0.75^2 / 4$
= 1,220.1038 in^2

$I_c = \pi*(D_o^4 - D_i^4) / 64$
$= \pi*(63^4 - 49.125^4) / 64$
= 487,394 in^4

$f_c = N*A_b*Preload / A_c + W / A_c + 6*M*D_o / I_c$
= 4*0.202*0 / 1,220.1038 + 13,047.84 / 1,220.1038 + 6*3,667.1*63 / 487,394
= [14] psi

As f_c <= 1,658 psi the base plate width is satisfactory.

Base plate required thickness (operating, new + Wind)

From Brownell & Young, Table 10.3:, l / b = 0.1082

$M_x = 0.0025*14*40.9994^2 = 57.6$ lb_f

M_y = -0.4766*14*4.4375^2 = -127.1 lb_f

t_r = (6*M_{max} / S_p)$^{0.5}$
= (6*127.06 / 20,000)$^{0.5}$
= 0.1952 in

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, operating, new + Wind)

Bolt load = A_b*f_s =0.202*0 = 0 lb_f

t_r= (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))$^{0.5}$
= (3.91*0 / (36,000*(2*4.4375 / 4+4 / (2*2.0625)-0.75*(2 / 4+1 / (2*2.0625)))))$^{0.5}$
= 0 in

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

S_r = 1.5*F*b / (gussets*π*t_{sk}^2*h)
= 1.5*0*4.4375 / (2*π*0.375^2*6)
= 0 psi

As S_r <= 24,900 psi the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (empty, corroded + Wind)

P = -0.6*W / N + 48 * M / (N*BC)
= -0.6*3,344.25 / 4 + 48 * 3,667.1 / (4*58.25)
= 253.82 lb_f

Required area per bolt = P / S_b = 0.0127 in^2

The area provided (0.202 in^2) by the specified anchor bolt is adequate.

Foundation bearing stress (empty, corroded + Wind)

A_c = π*(D_o^2 - D_i^2) / 4 - N*π*d_b^2 / 4
= π*(63^2 - 49.125^2) / 4 - 4*π*0.75^2 / 4
= 1,220.1038 in^2

I_c = π*(D_o^4 - D_i^4) / 64
= π*(63^4 - 49.125^4) / 64
= 487,394 in^4

f_c = N*A_b*Preload / A_c + W / A_c + 6*M*D_o / I_c
= 4*0.202*0 / 1,220.1038 + 3,344.25 / 1,220.1038 + 6*3,667.1*63 / 487,394
= 6 psi

As f_c <= 1,658 psi the base plate width is satisfactory.

Base plate required thickness (empty, corroded + Wind)

From Brownell & Young, Table 10.3:, l / b = 0.1082

M_x = 0.0025*6*40.9994^2 = 23.8 lb_f

M_y = -0.4766*6*4.4375^2 = -52.4 lb_f

$t_r = (6*M_{max} / S_p)^{0.5}$
= (6*52.42 / 20,000)$^{0.5}$
= 0.1254 in

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, empty, corroded + Wind)

Bolt load = A_b*f_s =0.202*1,257 = 253.82 lb_f

$t_r = (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))^{0.5}$
= (3.91*253.82 / (36,000*(2*4.4375 / 4+4 / (2*2.0625)-0.75*(2 / 4+1 / (2*2.0625)))))$^{0.5}$
= 0.1024 in

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$S_r = 1.5*F*b / (gussets*\pi*t_{sk}^2*h)$
= 1.5*253.82*4.4375 / (2*π*0.375^2*6)
= 318.68 psi

As S_r <= 24,900 psi the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (empty, new + Wind)

P = -0.6*W / N + 48 * M / (N*BC)
= -0.6*3,344.25 / 4 + 48 * 3,667.1 / (4*58.25)
= 253.82 lb_f

Required area per bolt = P / S_b = 0.0127 in^2

The area provided (0.202 in^2) by the specified anchor bolt is adequate.

Foundation bearing stress (empty, new + Wind)

$A_c = \pi*(D_o^2 - D_i^2) / 4 - N*\pi*d_b^2 / 4$
= π*(63^2 - 49.125^2) / 4 - 4*π*0.75^2 / 4
= 1,220.1038 in^2

$I_c = \pi*(D_o^4 - D_i^4) / 64$
= π*(63^4 - 49.125^4) / 64
= 487,394 in^4

$f_c = N*A_b*Preload / A_c + W / A_c + 6*M*D_o / I_c$
= 4*0.202*0 / 1,220.1038 + 3,344.25 / 1,220.1038 + 6*3,667.1*63 / 487,394
= 6 psi

As f_c <= 1,658 psi the base plate width is satisfactory.

Base plate required thickness (empty, new + Wind)

From Brownell & Young, Table 10.3:, l / b = 0.1082

$M_x = 0.0025*6*40.9994^2 = 23.8\ lb_f$

$M_y = -0.4766*6*4.4375^2 = -52.4\ lb_f$

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*52.42 / 20,000)^{0.5}$
= 0.1254 in

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, empty, new + Wind)

Bolt load = A_b*f_s =0.202*1,257 = 253.82 lb_f

$t_r = (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))^{0.5}$
$= (3.91*253.82 / (36,000*(2*4.4375 / 4+4 / (2*2.0625)-0.75*(2 / 4+1 / (2*2.0625)))))^{0.5}$
= 0.1024 in

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$S_r = 1.5*F*b / (gussets*\pi*t_{sk}^2*h)$
$= 1.5*253.82*4.4375 / (2*\pi*0.375^2*6)$
= 318.68 psi

As S_r <= 24,900 psi the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (operating, corroded + Seismic)

$P = -(0.6 - 0.14*S_{DS})*W / N + 48 * M / (N*BC)$
= -(0.6 - 0.14*0.2005)*13,047.84 / 4 + 48 * 4,775.5 / (4*58.25)
= -881.8 lb_f

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (operating, corroded + Seismic)

$A_c = \pi*(D_o^2 - D_i^2) / 4 - N*\pi*d_b^2 / 4$
$= \pi*(63^2 - 49.125^2) / 4 - 4*\pi*0.75^2 / 4$
= 1,220.1038 in^2

$I_c = \pi*(D_o^4 - D_i^4) / 64$
$= \pi*(63^4 - 49.125^4) / 64$
$= 487,394$ in^4

$f_c = N*A_b*Preload / A_c + (1 + 0.14*S_{DS})*W / A_c + 6*M*D_o / I_c$
= 4*0.202*0 / 1,220.1038 + (1 + 0.14*0.2005)*13,047.84 / 1,220.1038 + 6*4,775.5*63 / 487,394
= 15 psi

As f_c <= 1,658 psi the base plate width is satisfactory.

Base plate required thickness (operating, corroded + Seismic)

From Brownell & Young, Table 10.3:, l / b = 0.1108

$M_x = 0.0025*15*40.9994^2 = 62.5$ lb_f

$M_y = -0.4766*15*4.4375^2 = -137.9$ lb_f

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*137.94 / 20,000)^{0.5}$
= 0.2034 in

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, operating, corroded + Seismic)

Bolt load = A_b*f_s =0.202*0 = 0 lb_f

$t_r = (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))^{0.5}$
$= (3.91*0 / (36,000*(2*4.4375 / 4+4 / (2*2.0625)-0.75*(2 / 4+1 / (2*2.0625)))))^{0.5}$
= 0 in

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$S_r = 1.5*F*b / (gussets*\pi*t_{sk}^2*h)$
$= 1.5*0*4.4375 / (2*\pi*0.375^2*6)$
= 0 psi

As S_r <= 24,900 psi the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (operating, new + Seismic)

$P = -(0.6 - 0.14*S_{DS})*W / N + 48 * M / (N*BC)$
= -(0.6 - 0.14*0.2005)*13,047.84 / 4 + 48 * 4,775.5 / (4*58.25)
= -881.8 lb_f

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (operating, new + Seismic)

$A_c = \pi*(D_o^2 - D_i^2) / 4 - N*\pi*d_b^2 / 4$
$= \pi*(63^2 - 49.125^2) / 4 - 4*\pi*0.75^2 / 4$
$= 1,220.1038$ in^2

$I_c = \pi*(D_o^4 - D_i^4) / 64$
$= \pi*(63^4 - 49.125^4) / 64$
$= 487,394$ in^4

$f_c = N*A_b*Preload / A_c + (1 + 0.14*S_{DS})*W / A_c + 6*M*D_o / I_c$
= 4*0.202*0 / 1,220.1038 + (1 + 0.14*0.2005)*13,047.84 / 1,220.1038 + 6*4,775.5*63 / 487,394
= 15 psi

As f_c <= 1,658 psi the base plate width is satisfactory.

Base plate required thickness (operating, new + Seismic)

From Brownell & Young, Table 10.3:, l / b = 0.1082

$M_x = 0.0025*15*40.9994^2 = 62.5$ lb_f

$M_y = -0.4766*15*4.4375^2 = -137.9$ lb_f

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*137.94 / 20,000)^{0.5}$
= 0.2034 in

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, operating, new + Seismic)

Bolt load = A_b*f_s =0.202*0 = 0 lb_f

$t_r= (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))^{0.5}$
$= (3.91*0 / (36,000*(2*4.4375 / 4+4 / (2*2.0625)-0.75*(2 / 4+1 / (2*2.0625)))))^{0.5}$
= 0 in

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$S_r = 1.5*F*b / (gussets*\pi*t_{sk}^2*h)$
$= 1.5*0*4.4375 / (2*\pi*0.375^2*6)$
= 0 psi

As S_r <= 24,900 psi the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (empty, corroded + Seismic)

$P = -(0.6 - 0.14*S_{DS})*W / N + 48 * M / (N*BC)$
= -(0.6 - 0.14*0.2005)*3,344.25 / 4 + 48 * 1,539.3 / (4*58.25)
= -161.06 lb_f

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (empty, corroded + Seismic)

$A_c = \pi*(D_o^2 - D_i^2) / 4 - N*\pi*d_b^2 / 4$
$= \pi*(63^2 - 49.125^2) / 4 - 4*\pi*0.75^2 / 4$
$= 1,220.1038 \text{ in}^2$

$I_c = \pi*(D_o^4 - D_i^4) / 64$
$= \pi*(63^4 - 49.125^4) / 64$
$= 487,394 \text{ in}^4$

$f_c = N*A_b*Preload / A_c + (1 + 0.14*S_{DS})*W / A_c + 6*M*D_o / I_c$
$= 4*0.202*0 / 1,220.1038 + (1 + 0.14*0.2005)*3,344.25 / 1,220.1038 + 6*1,539.3*63 / 487,394$
= 4 psi

As f_c <= 1,658 psi the base plate width is satisfactory.

Base plate required thickness (empty, corroded + Seismic)

From Brownell & Young, Table 10.3:, l / b = 0.1082

$M_x = 0.0025*4*40.9994^2 = 17.1 \text{ lb}_f$

$M_y = -0.4766*4*4.4375^2 = -37.7 \text{ lb}_f$

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*37.65 / 20,000)^{0.5}$
= 0.1063 in

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, empty, corroded + Seismic)

Bolt load = A_b*f_s =0.202*0 = 0 lb_f

$t_r = (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))^{0.5}$
$= (3.91*0 / (36,000*(2*4.4375 / 4+4 / (2*2.0625)-0.75*(2 / 4+1 / (2*2.0625)))))^{0.5}$
= 0 in

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$S_r = 1.5*F*b / (gussets*\pi*t_{sk}^2*h)$
$= 1.5*0*4.4375 / (2*\pi*0.375^2*6)$
= 0 psi

As S_r <= 24,900 psi the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (empty, new + Seismic)

$P = -(0.6 - 0.14*S_{DS})*W / N + 48 * M / (N*BC)$
$= -(0.6 - 0.14*0.2005)*3,344.25 / 4 + 48 * 1,539.3 / (4*58.25)$
$= -161.06\ lb_f$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (empty, new + Seismic)

$A_c = \pi*(D_o^2 - D_i^2) / 4 - N*\pi*d_b^2 / 4$
$= \pi*(63^2 - 49.125^2) / 4 - 4*\pi*0.75^2 / 4$
$= 1,220.1038\ in^2$

$I_c = \pi*(D_o^4 - D_i^4) / 64$
$= \pi*(63^4 - 49.125^4) / 64$
$= 487,394\ in^4$

$f_c = N*A_b*Preload / A_c + (1 + 0.14*S_{DS})*W / A_c + 6*M*D_o / I_c$
$= 4*0.202*0 / 1,220.1038 + (1 + 0.14*0.2005)*3,344.25 / 1,220.1038 + 6*1,539.3*63 / 487,394$
= 4 psi

As f_c <= 1,658 psi the base plate width is satisfactory.

Base plate required thickness (empty, new + Seismic)

From Brownell & Young, Table 10.3:, l / b = 0.1082

$M_x = 0.0025*4*40.9994^2 = 17.1\ lb_f$

$M_y = -0.4766*4*4.4375^2 = -37.7\ lb_f$

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*37.65 / 20,000)^{0.5}$
= 0.1063 in

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, empty, new + Seismic)

Bolt load = A_b*f_s =0.202*0 = 0 lb_f

$t_r= (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))^{0.5}$
$= (3.91*0 / (36,000*(2*4.4375 / 4+4 / (2*2.0625)-0.75*(2 / 4+1 / (2*2.0625)))))^{0.5}$
= 0 in

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$S_r = 1.5*F*b / (gussets*\pi*t_{sk}^2*h)$
$= 1.5*0*4.4375 / (2*\pi*0.375^2*6)$
= 0 psi

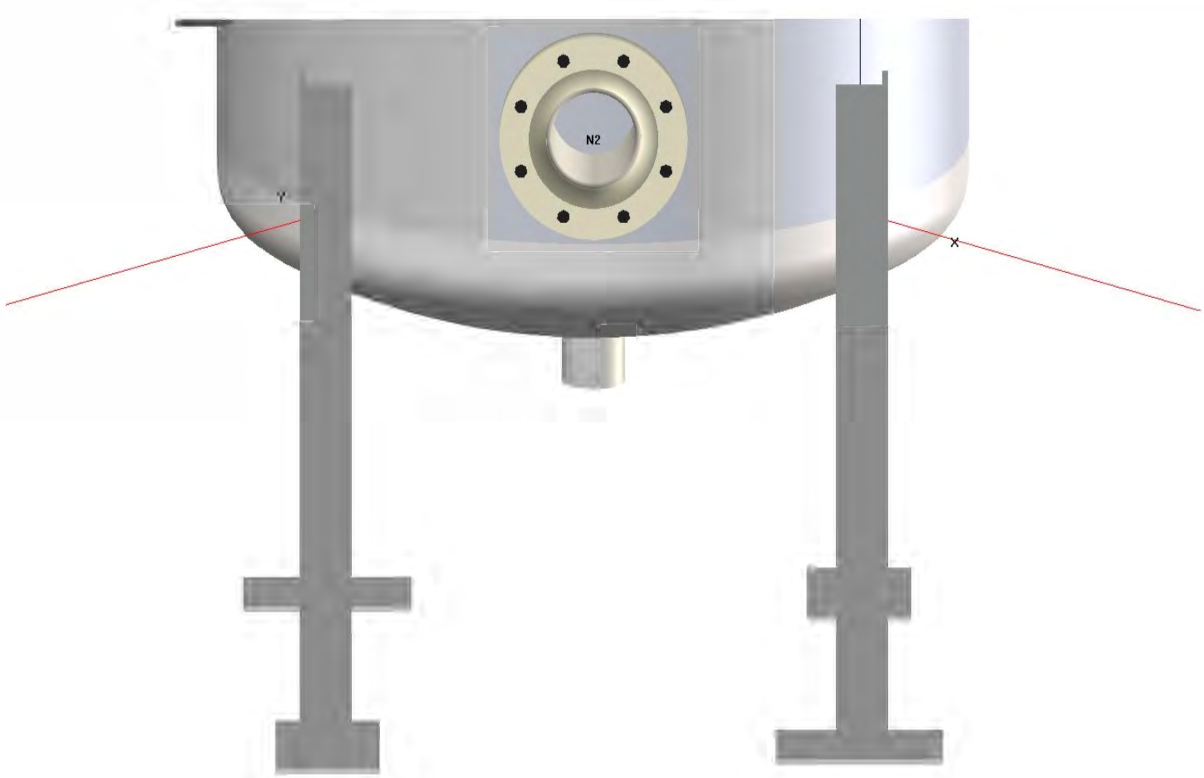
As S_r <= 24,900 psi the skirt thickness is adequate to resist the gusset reaction.

Carbon Supply Inc

8429 Eastern Ave.,

Bell Gardens, Ca

90201



Vessel Design Calculations

Item: 36"OD X 102" Shell Vertical Tank

Vessel No:

Customer:

Contract:

Designer: CK

Date: 1/13/20

NOTE:
1.) Seismic Parameters:
a.) Per ASCE 7-10 Ground Supported
b.) Site Class "D"
c.) Ss=18.80%; S1=6.40%

2.) Wind Loads:
a.) Per ASCE 7-10
b.) Design Wind Speed: 115 mph
c.) Risk Category II
d.) Exposure Categoty "C"

Table of Contents

Weight Summary

Weight (lb) Contributed by Vessel Elements											
Component	Metal New*	Metal Corroded	Insulation	Insulation Supports	Lining	Piping + Liquid	Operating Liquid		Test Liquid		Surface Area ft^2
							New	Corroded	New	Corroded	
36"OD Top F&D Head	51.7	51.7	0	0	0	0	0	0	196.2	196.2	8
36"OD Shell	597.4	597.4	0	0	0	0	3,657.4	3,657.4	3,685.3	3,685.3	78
36"OD Bottom F&D Head	78.9	78.9	0	0	0	0	187.2	187.2	187.2	187.2	10
Angle Legs	51.7	51.7	0	0	0	0	0	0	0	0	9
TOTAL:	**779.8**	**779.8**	**0**	**0**	**0**	**0**	**3,844.7**	**3,844.7**	**4,068.7**	**4,068.7**	**105**

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

Weight (lb) Contributed by Attachments											
Component	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays	Tray Supports	Rings & Clips	Vertical Loads	Surface Area ft^2
	New	Corroded	New	Corroded							
36"OD Top F&D Head	0	0	42	42	0	0	0	0	0	0	0
36"OD Shell	0	0	73.1	73.1	0	0	0	0	0	0	2
36"OD Bottom F&D Head	0	0	2.5	2.5	0	0	0	0	0	0	0
Angle Legs	0	0	0	0	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**117.7**	**117.7**	**0**	**0**	**0**	**0**	**0**	**0**	**3**

Vessel Totals		
	New	Corroded
Operating Weight (lb)	4,742	4,742
Empty Weight (lb)	897	897
Test Weight (lb)	4,966	4,966
Surface Area (ft^2)	108	-
Capacity** (US gal)	485	485

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

Vessel Lift Condition	
Vessel Lift Weight, New (lb)	897
Center of Gravity from Datum (in)	47.0559

Building Code: ASCE 7-10 ground supported		
Site Class		D
Importance Factor, I_e		1.0000
Spectral Response Acceleration at short period (% g), S_s		18.80%
Spectral Response Acceleration at period of 1 sec (% g), S_1		6.40%
Response Modification Coeficient from Table 15.4-2, R		3.0000
Acceleration-based Site Coefficient, F_a		1.6000
Velocity-based Site Coefficient, F_v		2.4000
Long-period Transition Period, T_L		12.0000
Redundancy factor, ρ		1.0000
Risk Category (Table 1.5-1)		II
User Defined Vertical Accelerations Considered		No
Hazardous, toxic, or explosive contents		No
Vessel Characteristics		
Height		11.1446 ft
Weight	Operating, Corroded	4,742 lb
	Empty, Corroded	897 lb
Period of Vibration Calculation		
Fundamental Period, T	Operating, Corroded	0.165 sec (f = 6.0 Hz)
	Empty, Corroded	0.070 sec (f = 14.2 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.

12.4.2.3 Basic Load Combinations for Allowable Stress Design			
Load combinations considered in accordance with ASCE section 2.4.1:			
5.	$D + P + P_s + 0.7E$	$= (1.0 + 0.14S_{DS})D + P + P_s + 0.7\rho Q_E$	
8.	$0.6D + P + P_s + 0.7E$	$= (0.6 - 0.14S_{DS})D + P + P_s + 0.7\rho Q_E$	
Parameter description			
D	= Dead load		
P	= Internal or external pressure load		
P_s	= Static head load		
E	= Seismic load	$= E_h$ +/- E_v	$= \rho Q_E$ +/- $0.2S_{DS}D$

Seismic Shear Reports:

Operating, Corroded
Empty, Corroded
Base Shear Calculations

Seismic Shear Report: Operating, Corroded					
Component	**Elevation of Bottom above Base (in)**	**Elastic Modulus E (10^6 psi)**	**Inertia I (ft^4)**	**Seismic Shear at Bottom (lb_f)**	**Bending Moment at Bottom (lb_f-ft)**
36"OD Top F&D Head	126	29.3	*	8	31
36"OD Shell (top)	24	29.3	0.1631	214	1,215
Angle Legs	0	29.0	0.0001	222	1,656
36"OD Shell (bottom)	24	29.3	0.1631	6	2
36"OD Bottom F&D Head	24	29.3	*	5	1
*Moment of Inertia I varies over the length of the component					

Seismic Shear Report: Empty, Corroded					
Component	Elevation of Bottom above Base (in)	Elastic Modulus E (10^6 psi)	Inertia I (ft^4)	Seismic Shear at Bottom (lb_f)	Bending Moment at Bottom (lb_f-ft)
36"OD Top F&D Head	126	29.4	*	8	31
36"OD Shell (top)	24	29.4	0.1631	38	315
Angle Legs	0	29.0	0.0001	42	398
36"OD Shell (bottom)	24	29.4	0.1631	2	1
36"OD Bottom F&D Head	24	29.4	*	2	1
*Moment of Inertia I varies over the length of the component					

11.4.3: Maximum considered earthquake spectral response acceleration

The maximum considered earthquake spectral response acceleration at short period, S_{MS}
$S_{MS} = F_a * S_s$ = 1.6000 * 18.80 / 100 = 0.3008
The maximum considered earthquake spectral response acceleration at 1 s period, S_{M1}
$S_{M1} = F_v * S_1$ = 2.4000 * 6.40 / 100 = 0.1536

11.4.4: Design spectral response acceleration parameters

Design earthquake spectral response acceleration at short period, S_{DS}
$S_{DS} = 2 / 3 * S_{MS}$ = 2 / 3 * 0.3008 = 0.2005
Design earthquake spectral response acceleration at 1 s period, S_{D1}
$S_{D1} = 2 / 3 * S_{M1}$ = 2 / 3 * 0.1536 = 0.1024

11.6 Seismic Design Category

The Risk Category is II.
From Table 11.6-1, the Seismic Design Category based on S_{Ds} = 0.2005 is B.
From Table 11.6-2, the Seismic Design Category based on S_{D1} = 0.1024 is B.
This vessel is assigned to Seismic Design Category B.

12.4.2.3: Seismic Load Combinations: Vertical Term

Factor is applied to dead load.

Compressive Side: $= 1.0 + 0.14 * S_{DS}$
$= 1.0 + 0.14 * 0.2005$
$= 1.0281$
Tensile Side: $= 0.6 - 0.14 * S_{DS}$
$= 0.6 - 0.14 * 0.2005$
$= 0.5719$

Base Shear Calculations

Operating, Corroded
Empty, Corroded

Base Shear Calculations: Operating, Corroded

Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.

T = 0.1654 sec.

12.8.1: Calculation of Seismic Response Coefficient

C_s is the value computed below, bounded by C_sMin and C_sMax:
C_sMin is calculated with equation 15.4-1 and shall not be less than 0.03; in addition, if S_1 >= 0.6g, C_sMin shall not be less than eqn 15.4-2.
C_sMax calculated with 12.8-3 because (T = 0.1654) <= (T_L = 12.0000)

C_s = S_{DS} / (R / I_e) = 0.2005 / (3.0000 / 1.0000) = 0.0668
C_sMin = max[0.044 * S_{DS} * I_e , 0.03] = max[0.044 * 0.2005 * 1.0000 , 0.03] = 0.0300
C_sMax = S_{D1} / (T * (R / I_e)) = 0.1024 / (0.1654 * (3.0000 / 1.0000)) = 0.2064
C_s = 0.0668

12.8.1: Calculation of Base Shear

V = C_s * W
= 0.0668 * 4,742.0996
= 316.98 lb

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h

Q_E = V
E_h = 0.7 * ρ * Q_E (Only 70% of seismic load considered as per Section 2.4.1)
= 0.7 * 1.0000 * 316.98
= 221.89 lb

Base Shear Calculations: Empty, Corroded

Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.

T = 0.0704 sec.

12.8.1: Calculation of Seismic Response Coefficient

C_s is the value computed below, bounded by C_sMin and C_sMax:
C_sMin is calculated with equation 15.4-1 and shall not be less than 0.03; in addition, if S_1 >= 0.6g, C_sMin shall not be less than eqn 15.4-2.
C_sMax calculated with 12.8-3 because (T = 0.0704) <= (T_L = 12.0000)

C_s = S_{DS} / (R / I_e) = 0.2005 / (3.0000 / 1.0000) = 0.0668
C_sMin = max[0.044 * S_{DS} * I_e , 0.03] = max[0.044 * 0.2005 * 1.0000 , 0.03] = 0.0300
C_sMax = S_{D1} / (T * (R / I_e)) = 0.1024 / (0.0704 * (3.0000 / 1.0000)) = 0.4849
C_s = 0.0668

12.8.1: Calculation of Base Shear

V = C_s * W
= 0.0668 * 897.4465
= 59.99 lb

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h
Q_E = V
E_h = 0.7 * ρ * Q_E (Only 70% of seismic load considered as per Section 2.4.1)
= 0.7 * 1.0000 * 59.99
= 41.99 lb

Wind Code

Building Code: ASCE 7-10		
Elevation of base above grade		0.00 ft
Increase effective outer diameter by		0.00 ft
Wind Force Coefficient, Cf		0.5500
Risk Category (Table 1.5-1)		II
Basic Wind Speed, V		115.00 mph
Exposure Category		C
Wind Directionality Factor, Kd		0.9500
Topographic Factor, Kzt		1.0000
Enforce min. loading of 16 psf		Yes
Hazardous, toxic, or explosive contents		No
Vessel Characteristics		
Height, h		11.1446 ft
Effective Width, b	Operating, Corroded	2.9081 ft
	Empty, Corroded	2.9081 ft
Fundamental Frequency, n_1	Operating, Corroded	6.0473 Hz
	Empty, Corroded	14.2055 Hz
Damping coefficient, β	Operating, Corroded	0.0250
	Empty, Corroded	0.0200

Table Lookup Values

2.4.1 Basic Load Combinations for Allowable Stress Design	
Load combinations considered in accordance with ASCE section 2.4.1:	
5.	$D + P + P_s + 0.6W$
7.	$0.6D + P + P_s + 0.6W$
Parameter Description	
D	= Dead load
P	= Internal or external pressure load
P_s	= Static head load
W	= Wind load

Wind Deflection Reports:

Operating, Corroded
Empty, Corroded
Wind Pressure Calculations

Wind Deflection Report: Operating, Corroded								
Component	**Elevation of Bottom above Base (in)**	**Effective OD (ft)**	**Elastic Modulus E (10^6 psi)**	**Inertia I (ft^4)**	**Platform Wind Shear at Bottom (lb_f)**	**Total Wind Shear at Bottom (lb_f)**	**Bending Moment at Bottom (lb_f-ft)**	**Deflection at Top (in)**
36"OD Top F&D Head	126	3.00	29.3	*	0	15	32	0.0159
36"OD Shell (top)	24	3.00	29.3	0.1631	0	257	1,237	0.0159
Angle Legs	0	0	29.0	0.0001356	0	274	1,780	0.0155
36"OD Shell (bottom)	24	3.00	29.3	0.1631	0	17	5	0.0155
36"OD Bottom F&D Head	24	3.00	29.3	*	0	15	4	0.0155
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Empty, Corroded								
Component	**Elevation of Bottom above Base (in)**	**Effective OD (ft)**	**Elastic Modulus E (10^6 psi)**	**Inertia I (ft^4)**	**Platform Wind Shear at Bottom (lb_f)**	**Total Wind Shear at Bottom (lb_f)**	**Bending Moment at Bottom (lb_f-ft)**	**Deflection at Top (in)**
36"OD Top F&D Head	126	3.00	29.4	*	0	15	32	0.0159
36"OD Shell (top)	24	3.00	29.4	0.1631	0	257	1,237	0.0159
Angle Legs	0	0	29.0	0.0001356	0	274	1,780	0.0155
36"OD Shell (bottom)	24	3.00	29.4	0.1631	0	17	5	0.0155
36"OD Bottom F&D Head	24	3.00	29.4	*	0	15	4	0.0155
*Moment of Inertia I varies over the length of the component								

Wind Pressure (WP) Calculations

Gust Factor ($\bar{G}$) Calculations

Kz $= 2.01 * (Z/Zg)^{2/\alpha}$

$= 2.01 * (Z/900.00)^{0.2105}$

qz $= 0.00256 * Kz * Kzt * Kd * V^2$

$= 0.00256 * Kz * 1.0000 * 0.9500 * 115.0000^2$

$= 32.1632 * Kz$

WP $= 0.6 * \max[\ qz * G * Cf, 16\ lb/ft^2\ ]$

$= 0.6 * \max[\ qz * G * 0.5500, 16\ lb/ft^2\ ]$

Design Wind Pressures							
Height Z (')	Kz	qz (psf)	WP (psf)				
			Operating	Empty	Hydrotest New	Hydrotest Corroded	Vacuum
15.0	0.8489	27.30	9.60	9.60	N.A.	N.A.	N.A.
Design Wind Force determined from: F = Pressure * Af , where Af is the projected area.							

Gust Factor Calculations

Operating, Corroded
Empty, Corroded

Gust Factor Calculations: Operating, Corroded

Vessel is considered a rigid structure as n_1 = 6.0473 Hz ≥ 1 Hz.

$\bar{z}$ = max[0.60 * h , z_{min}]
= max[0.60 * 11.1446 , 15.0000]
= 15.0000

$I_{\bar{z}}$ = c * (33 / $\bar{z}$)$^{1/6}$
= 0.2000 * (33 / 15.0000)$^{1/6}$
= 0.2281

$L_{\bar{z}}$ = l * ($\bar{z}$ / 33)^{ep}
= 500.0000 * (15.0000 / 33)$^{0.2000}$
= 427.0566

Q = Sqr(1 / (1 + 0.63 * ((b + h) / $L_{\bar{z}}$)$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((2.9081 + 11.1446) / 427.0566)$^{0.63}$))
= 0.9652

G = 0.925 * (1 + 1.7 * g_Q * $I_{\bar{z}}$ * Q) / (1 + 1.7 * g_v * $I_{\bar{z}}$)
= 0.925 * (1 + 1.7 * 3.40* 0.2281 * 0.9652) / (1 + 1.7 * 3.40 * 0.2281)
= 0.9067

Gust Factor Calculations: Empty, Corroded

Vessel is considered a rigid structure as n_1 = 14.2055 Hz ≥ 1 Hz.

$\bar{z}$ = max[0.60 * h , z_{min}]
= max[0.60 * 11.1446 , 15.0000]
= 15.0000

$I_{\bar{z}}$ = c * (33 / $\bar{z}$)$^{1/6}$

$= 0.2000 * (33 / 15.0000)^{1/6}$

$= 0.2281$

$L_{\bar{z}} = l * (\bar{z} / 33)^{ep}$

$= 500.0000 * (15.0000 / 33)^{0.2000}$

$= 427.0566$

$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{\bar{z}})^{0.63}))$

$= Sqr(1 / (1 + 0.63 * ((2.9081 + 11.1446) / 427.0566)^{0.63}))$

$= 0.9652$

$G = 0.925 * (1 + 1.7 * g_Q * I_{\bar{z}} * Q) / (1 + 1.7 * g_v * I_{\bar{z}})$

$= 0.925 * (1 + 1.7 * 3.40 * 0.2281 * 0.9652) / (1 + 1.7 * 3.40 * 0.2281)$

$= 0.9067$

Table Lookup Values	
$\alpha = 9.5000$, $z_g = 900.00$ ft	[Table 26.9-1, page 256]
c = 0.2000, l = 500.0000, ep = 0.2000	[Table 26.9-1, page 256]
$\bar{a} = 0.1538$, $\bar{b} = 0.6500$	[Table 26.9-1, page 256]
$z_{min} = 15.0000$ ft	[Table 26.9-1, page 256]
$g_Q = 3.40$	[26.9.4 page 254]
$g_v = 3.40$	[26.9.4 page 254]

Angle Legs

Inputs	
Leg material	SA36
Leg description	2.5x2.5x1/4 Equal Angle (Leg in)
Number of legs, N	4
Overall length	30"
Base to girth seam length	24"
Effective length coefficient, K	1.5
Coefficient, C_m	0.85
Leg yield stress, F_y	36,000 psi
Leg elastic modulus, E	29,000,000 psi
Anchor Bolts	
Anchor bolt size	0.5" coarse threaded
Anchor bolt material	
Bolt circle, BC	38"
Anchor bolts/leg, n	1
Anchor bolt allowable stress, S_b	20,000 psi
Anchor bolt corrosion allowance	0"
Anchor bolt hole clearance	0.0625"
Base Plate	
Base plate length	5"
Base plate width	8"
Base plate thickness	0.25" (0.2312" required)
Base plate allowable stress	24,000 psi
Foundation allowable bearing stress	1,658 psi
Welds	
Leg to shell fillet weld	0.1875" (0.0154" required)
Legs braced	No

Note: The support attachment point is assumed to be 1 in up from the cylinder circumferential seam.

Governing Condition : Wind operating corroded, Moment = 1,231.7 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	293.0	28.0	246	2,235	0	0.0960	0.1055
	90	1,172.6	109.2	985	2,324	3,881	0.2885	0.3068
	180	1,583.2	28.0	1,330	4,793	0	0.2661	0.2633
	270	1,172.6	109.2	985	2,324	3,881	0.2885	0.3068
45	0	293.0	68.6	246	3,450	1,723	0.2019	0.2291
	90	293.0	68.6	246	3,450	1,723	0.2019	0.2291
	180	1,583.2	68.6	1,330	6,007	1,723	0.3760	0.3870
	270	1,583.2	68.6	1,330	6,007	1,723	0.3760	0.3870

Wind empty corroded, Moment = 1,231.7 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	-283.7	28.0	-238	2,217	0	0.0638	0.0823
	90	211.4	109.2	178	419	3,881	0.1651	0.1892
	180	622.0	28.0	523	2,888	0	0.1381	0.1457
	270	211.4	109.2	178	419	3,881	0.1651	0.1892
45	0	-283.7	68.6	-238	3,432	1,723	0.1681	0.2059
	90	-283.7	68.6	-238	3,432	1,723	0.1681	0.2059
	180	622.0	68.6	523	4,102	1,723	0.2450	0.2694
	270	622.0	68.6	523	4,102	1,723	0.2450	0.2694

Seismic operating corroded, Moment = 1,212.9 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	266.3	22.6	224	1,866	0	0.0812	0.0889
	90	1,205.5	88.3	1,013	2,389	3,139	0.2660	0.2796
	180	1,609.8	22.6	1,353	4,529	0	0.2574	0.2532
	270	1,205.5	88.3	1,013	2,389	3,139	0.2660	0.2796
45	0	266.3	55.5	224	2,848	1,394	0.1668	0.1889
	90	266.3	55.5	224	2,848	1,394	0.1668	0.1889
	180	1,609.8	55.5	1,353	5,511	1,394	0.3464	0.3532
	270	1,609.8	55.5	1,353	5,511	1,394	0.3464	0.3532

Seismic empty corroded, Moment = 314.2 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	16.2	4.3	14	285	0	0.0110	0.0126
	90	217.4	16.7	183	431	594	0.0479	0.0516
	180	322.1	4.3	271	892	0	0.0488	0.0501
	270	217.4	16.7	183	431	594	0.0479	0.0516
45	0	16.2	10.5	14	471	264	0.0271	0.0316
	90	16.2	10.5	14	471	264	0.0271	0.0316
	180	322.1	10.5	271	1,078	264	0.0650	0.0690
	270	322.1	10.5	271	1,078	264	0.0650	0.0690

Leg Calculations (AISC manual ninth edition)

Axial end load, P_1 (Based on vessel total bending moment acting at leg attachment elevation)

$P_1 = W_t / N + 48*M_t / (N*D)$
= 4,690.37 / 4 + 48*1,231.7 / (4*36)
= 1,583.17 lb_f

Allowable axial compressive stress, F_a (AISC chapter E)

Local buckling check (AISC 5-99)

b / t = (2.5 / 0.25) < (76 / Sqr(36)) so Q_s = 1

Flexural-torsional buckling (AISC 5-317)

Shear center distance w_o = 0.8372
$r_o^2 = w_o^2 + (I_z + I_w) / A$
= 0.8372^2 + (0.29 + 1.12) / 1.19
= 1.88 in^2

Torsional constant J = 0.02 in^4
Shear modulus G = 11,165 ksi

$F_{ej} = G*J / (A*r_o^2)$
= 11.17E+06*0.02 / (1.19*1.8824)
= 124 ksi

$K*l / r_w$ = 1.5*22.5 / 0.9698 = 34.7994

$F_{ew} = \pi^2*E / (K*l / r_w)^2$
= π^2*29,000 / $(34.7994)^2$
= 236 ksi

$H = 1 - (w_o^2 / r_o^2)$
= 1 - (0.8372^2 / 1.8824)
= 0.6276

$F_e = ((F_{ew} + F_{ej}) / (2*H))*(1 - Sqr(1 - (4*F_{ew}*F_{ej}*H) / (F_{ew} + F_{ej})^2))$
= ((236 + 124) / (2*0.6276))*(1 - Sqr(1 - (4*236*124*0.6276) / $(236 + 124)^2$))
= 98 ksi

Equivalent slenderness ratio

$K*l / r = \pi*Sqr(E / F_e)$
= π*Sqr(29,000 / 98)
= 54.0879

$C_c = Sqr(2*\pi^2*E / (F_y*Q_s))$
= Sqr(2*π^2*29,000,000 / (36,000*1))

$= 126.0993$

$K*l / r = 1.5*22.5 / 0.4908 = 68.7641$

$F_a = 1 * (1 - (K*l / r)^2 / (2*C_c^2))*F_y / (5 / 3 + 3*(K*l / r) / (8*C_c)-(K*l / r)^3 / (8*C_c^3))$
$= 1 * (1 - (68.7641)^2 / (2*126.0993^2))*36{,}000 / (5 / 3 + 3*(68.7641) / (8*126.0993)-(68.7641)^3 / (8*126.0993^3))$
$= 16{,}558$ psi

Allowable axial compression and bending (AISC chapter H)

Note: r is divided by 1.35 - See AISC 6.1.4, pg. 5-314

$F'_{ex} = 1*12*\pi^2*E / (23*(K*l / r)^2)$
$= 1*12*\pi^2*29{,}000{,}000 / (23*(92.8315)^2)$
$= 17{,}328$ psi

$F'_{ey} = 1*12*\pi^2*E / (23*(K*l / r)^2)$
$= 1*12*\pi^2*29{,}000{,}000 / (23*(46.9792)^2)$
$= 67{,}661$ psi

$F_b = 1*0.66*F_y$
$= 1*0.66*36{,}000$
$= 23{,}760$ psi

Compressive axial stress

$f_a = P_1 / A$
$= 1{,}583.17 / 1.19$
= 1,330 psi

Bending stresses

$f_{bx} = F*\cos(\alpha)*L / (I_x / C_x) + P_1*E_{cc} / (I_x / C_x)$
$= 68.59*\cos(45)*22.5 / (0.2867 / 0.7538) + 1{,}583.17*0.7538 / (0.2867 / 0.7538)$
= 6,007 psi

$f_{by} = F*\sin(\alpha)*L / (I_y / C_y)$
$= 68.59*\sin(45)*22.5 / (1.12 / 1.77)$
= 1,723 psi

AISC equation H_{1-1}

$H_{1-1} = f_a / F_a + C_{mx}*f_{bx} / ((1 - f_a / F'_{ex})*F_{bx}) + C_{my}*f_{by} / ((1 - f_a / F'_{ey})*F_{by})$
$= 1{,}330 / 16{,}558 + 0.85*6{,}007 / ((1 - 1{,}330 / 17{,}328)*23{,}760) + 0.85*1{,}723 / ((1 - 1{,}330 / 67{,}661)*23{,}760)$
= 0.376

AISC equation H_{1-2}

$H_{1-2} = f_a / (0.6*1*F_y) + f_{bx} / F_{bx} + f_{by} / F_{by}$
= 1,330 / (0.6*1*36,000) + 6,007 / 23,760 + 1,723 / 23,760
= 0.387

4, 2.5x2.5x1/4 Equal Angle legs are adequate.

Anchor bolts - Wind empty corroded condition governs

Tensile loading per leg (1 bolt per leg)

R = 48*M / (N*BC) - 0.6*W / N
= 48*1,780.4 / (4*38) - 0.6*897.45 / 4
= 427.63 lb_f

Required area per bolt

$A_b = R / (S_b*n)$
= 427.63 / (20,000*1)
= 0.0214 in^2

Area of a 0.5" coarse threaded bolt (corroded) = 0.126 in^2

0.5" coarse threaded bolts are satisfactory.

Check the leg to vessel fillet weld, Bednar 10.3, Wind operating corroded 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).

$Z_w = (2*b*d + d^2) / 3$
= $(2*3.5355*7.5 + 7.5^2) / 3$
= 36.4275 in^2

$J_w = (b + 2*d)^3 / 12 - d^2*(b + d)^2 / (b + 2*d)$
= $(3.5355 + 2*7.5)^3 / 12 - 7.5^2*(3.5355 + 7.5)^2 / (3.5355 + 2*7.5)$
= 161.104 in^3

$E = d^2 / (b + 2*d)$
= $7.5^2 / (3.5355 + 2*7.5)$
= 3.034717 in

Governing weld load f_x = Cos(45)*68.59 = 48.5 lb_f
Governing weld load f_y = Sin(45)*68.59 = 48.5 lb_f

$f_1 = P_1 / L_{weld}$
= 1,583.17 / 18.5355
= 85.41 lb_f/in (V$_L$ direct shear)

$f_2 = f_y*L_{leg}*0.5*b / J_w$
= 48.5*22.5*0.5*3.5355 / 161.104
= 11.97 lb_f/in (V$_L$ torsion shear)

$f_3 = f_y / L_{weld}$
= 48.5 / 18.5355
= 2.62 lb_f/in (V$_c$ direct shear)

$f_4 = f_y*L_{leg}*E / J_w$
= 48.5*22.5*3.0347 / 161.104
= 20.56 lb_f/in (V$_c$ torsion shear)

$f_5 = (f_x*L_{leg} + P_1*E_{cc}) / Z_w$
= (48.5*22.5 + 1,583.17*0.7538) / 36.4275
= 62.72 lb_f/in (M$_L$ bending)

$f_6 = f_x / L_{weld}$
= 48.5 / 18.5355
= 2.62 lb_f/in (Direct outward radial shear)

$f = Sqr((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
= $Sqr((85.41 + 11.97)^2 + (2.62 + 20.56)^2 + (62.72 + 2.62)^2)$
= 119.54 lb_f/in (Resultant shear load)

Required leg to vessel fillet weld leg size (welded both sides + top)

$t_w = f / (0.707*0.55*S_a)$
= 119.54 / (0.707*0.55*20,000)
= 0.0154 in

The 0.1875 in leg to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$f_p = P / (B*N)$
= 1,747.77 / (8*5)
= 44 psi

Required base plate thickness is the largest of the following: (0.2312 in)

$t_b = Sqr(0.5*P / S_b)$
= Sqr(0.5*1,747.77 / 24,000)
= 0.1908 in

t_b = 0.5*(B - d)*Sqr(3*f_p / S_b)
= 0.5*(8 - 2.5)*Sqr(3*44 / 24,000)
= 0.2032 in

t_b = Sqr(3*P_t*0.5*Abs(OD - BC) / S_b)
= Sqr(3*427.63*0.5*Abs(36 - 38) / 24,000)
= 0.2312 in

The base plate thickness is adequate.

Check the leg to vessel attachment stresses, WRC 537 (Wind operating corroded governs)

Applied Loads	
Radial load, P_r	-48.5 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	2,284.6 lb_f-in
Longitudinal shear, V_L	1,583.17 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	78.65 psi
Mean shell radius, R_m	17.9063"
Local shell thickness, T	0.1875"
Design factor	3

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

$\gamma = R_m / T = 17.9063 / 0.1875 = 95.5$

$C_1 = 1.7678$, $C_2 = 5.9528$ in

Local circumferential pressure stress = $P*R_i / T$ =7,472 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =3,736 psi

Maximum combined stress (P_L+P_b+Q) = 10,361 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±60,000 psi

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

Maximum local primary membrane stress (P_L) = 8,285 psi
Allowable local primary membrane stress (P_L) = ±1.5*S = ±30,000 psi

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

Stresses at the leg edge per WRC Bulletin 537										
Figure	**Y**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	3.4224	0.2627	0	0	0	0	49	49	49	49
4C*	10.7041	0.2151	155	155	155	155	0	0	0	0
1C	0.0554	0.1608	0	0	0	0	458	-458	458	-458
2C-1	0.0273	0.1608	226	-226	226	-226	0	0	0	0
3A*	4.0384	0.148	0	0	0	0	0	0	0	0
1A	0.0644	0.1693	0	0	0	0	0	0	0	0
3B*	6.276	0.2218	-658	-658	658	658	0	0	0	0
1B-1	0.0158	0.1861	-1,850	1,850	1,850	-1,850	0	0	0	0
Pressure stress*			7,472	7,472	7,472	7,472	7,472	7,472	7,472	7,472
Total circumferential stress			5,345	8,593	10,361	6,209	7,979	7,063	7,979	7,063
Primary membrane circumferential stress*			6,969	6,969	8,285	8,285	7,521	7,521	7,521	7,521
3C*	4.7067	0.2151	68	68	68	68	0	0	0	0
4C*	9.1212	0.2627	0	0	0	0	132	132	132	132
1C-1	0.0371	0.2236	307	-307	307	-307	0	0	0	0
2C	0.03	0.2236	0	0	0	0	248	-248	248	-248
4A*	8.4124	0.148	0	0	0	0	0	0	0	0
2A	0.0238	0.2112	0	0	0	0	0	0	0	0
4B*	3.1848	0.2218	-587	-587	587	587	0	0	0	0
2B-1	0.0167	0.246	-1,477	1,477	1,477	-1,477	0	0	0	0
Pressure stress*			3,736	3,736	3,736	3,736	3,736	3,736	3,736	3,736
Total longitudinal stress			2,047	4,387	6,175	2,607	4,116	3,620	4,116	3,620
Primary membrane longitudinal stress*			3,217	3,217	4,391	4,391	3,868	3,868	3,868	3,868
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	-355	-355	355	355
Total Shear stress			0	0	0	0	-355	-355	355	355
Combined stress (P_L+P_b+Q)			5,345	8,593	10,361	6,209	8,011	7,099	8,011	7,099

* denotes primary stress.

7.2 Annex 2. Beta's Temporary Permit To Operate and Alpha's PTO.

MOJAVE DESERT AIR QUALITY MANAGEMENT DISTRICT
14306 Park Avenue, Victorville, CA 92392-2310
760.245.1661 -- 800.635.4617 -- FAX 760.245.2022

PERMIT TO OPERATE

C012015

Operation under this permit must be conducted in compliance with all information included with the initial application, initial permit condition, and conditions contained herein. The equipment must be maintained and kept in good operating condition at all times. This Permit to Operate or copy must be posted on or within 8 meters of equipment. If a copy is posted, the original must be maintained on site, available for inspection at all times.

EXPIRES LAST DAY OF: SEPTEMBER 2020

OWNER OR OPERATOR (Co.#1876)

Mojave Solar LLC
42134 Harper Lake Road
Hinkley, CA 92347

EQUIPMENT LOCATION (Fac.#3130)

Mojave Solar - Harper Lake
Harper Lake Road, adjacent to SEGS VIII & IX
Hinkley, CA 92347

Description:
CARBON ADSORPTION SYSTEM, HTF ULLAGE/EXPANSION SYSTEM (ALPHA) consisting of: Carbon adsorption system having two (2) multi-bed carbon filter sets capturing ullage/expansion system emissions. Ullage vent scrubber and overflow tank vent scrubber will each vent only to their own carbon filter set. Both sets will vented to atmosphere through one common stack.

CONDITIONS:

1. Operation of this equipment shall be conducted in compliance with all data and specifications submitted with the application under which this permit is issued unless otherwise noted below.

2. This equipment must be in use and operating properly at all times the HTF ullage/expansion system with valid District Permit B011046 is venting.

3. This carbon adsorption system shall provide at a minimum 95% control efficiency of VOC emissions vented from the HTF ullage/expansion system under valid District Permit B011046. Control efficiency shall be demonstrated by sampling VOC emissions per US EPA Method 25 at the inlet and outlet of the carbon beds during initial and annual compliance tests.

4. The owner/operator shall prepare and submit a monitoring and change-out plan for the carbon adsorption system which ensures that the system is operating at optimal control efficiency at all times for District approval 60 days prior to commercial

Fee Schedule: 7 (h)	Rating: 1 device	SIC: 4911	SCC: 30688801	Location/UTM(Km): 470E/3877N

This permit does not authorize the emission of air contaminants in excess of those allowed by law, including Division 26 of the Health and Safety Code of the State of California and the Rules and Regulations of the District. This permit cannot be construed as permission to violate existing laws, ordinances, statutes or regulations of this or other governmental agencies. This permit must be renewed by the expiration date above. If billing for renewal fee required by Rule 301(c) is not received by expiration date above, please contact the District.

Mojave Solar LLC
42134 Harper Lake Road

Hinkley, CA 92347

By: [signature]
Brad Poiriez
Air Pollution Control Officer

operation date (COD). Once approved, any subsequent changes to the monitoring and change-out plan must be submitted in writing to the District for approval prior to implementation.

5. Total emissions of VOC to the atmosphere shall not exceed 792.1 lbs/year, calculated based on the most recent test results.

6. Total emissions of benzene to the atmosphere shall not exceed 507.4 lbs/year, calculated based on the most recent test results.

7. During operation, o/o shall monitor VOC (as hexane) measured at outlet from the carbon beds. Sampling is to be performed at a minimum on a weekly basis. Samples shall be analyzed using a District approved photo ionization detector (PID).

8. PID shall be considered invalid if not calibrated in accordance with the manufactures recommended calibration procedures.

9. The o/o shall maintain an operations log (in electronic or hardcopy format) current and on-site for a period of five (5) years. The log shall contain at a minimum the following information and shall be provided to District personnel upon request.
a. Date and time of VOC monitoring;
b. Results of VOC monitoring; and
c. Date and description of all maintenance, malfunctions, repairs, and carbon change out(s).

10. The o/o shall provide stack sampling ports and platforms necessary to perform source tests required to verify compliance with District rules, regulations and permit conditions. The location of these ports and platforms shall be subject to District approval.

11. Prior to January 31 of each new year, the o/o of this unit shall submit to the District a summary report of all VOC emissions (based on annual source test results).

12. The o/o shall conduct all required compliance/certification tests in accordance with a District-approved test plan. Thirty (30) days prior to the compliance/certification tests the operator shall provide a written test plan for District review and approval. Written notice of the compliance/certification test shall be provided to the District ten (10) days prior to the tests so that an observer may be present. A written report with the results of such compliance/certification tests shall be submitted to the District within forty-five (45) days after testing is completed.All compliance/certification test notifications, protocols, and results may be submitted electronically to reporting@mdaqmd.ca.gov

13. The o/o shall perform the following initial compliance tests on this equipment in accordance with the MDAQMD Compliance Test Procedural Manual. The test report shall be submitted to the District within 180 days of COD. The following compliance tests are required:
a. VOC as hexane in ppmvd and lb/hr (measured per USEPA Reference Methods 25 and 18 or equivalent).
b. Benzene in ppmvd and lb/hr (measured per CARB method 410 or equivalent).

14. The o/o shall perform the following compliance tests on this equipment at least once every twelve (12) months in accordance with the MDAQMD Compliance Test Procedural Manual. The following compliance tests are required:
a. VOC as hexane in ppmvd and lb/hr (measured per USEPA Reference Methods 25A and 18 or equivalent).
b. Benzene in ppmvd and lb/hr (measured per CARB method 410 or equivalent).

Additionally, records of all compliance tests shall be maintained on site for a period of five (5) years and presented to District personnel upon request.

MOJAVE DESERT AIR QUALITY MANAGEMENT DISTRICT
14306 Park Avenue, Victorville, CA 92392-2310
760.245.1661 -- 800.635.4617 -- FAX 760.245.2022

PERMIT TO OPERATE

C012016

Operation under this permit must be conducted in compliance with all information included with the initial application, initial permit condition, and conditions contained herein. The equipment must be maintained and kept in good operating condition at all times. This Permit to Operate or copy must be posted on or within 8 meters of equipment. If a copy is posted, the original must be maintained on site, available for inspection at all times.

EXPIRES LAST DAY OF: SEPTEMBER 2020

OWNER OR OPERATOR (Co.#1876)

Mojave Solar LLC
42134 Harper Lake Road
Hinkley, CA 92347

EQUIPMENT LOCATION (Fac.#3130)

Mojave Solar - Harper Lake
Harper Lake Road, adjacent to SEGS VIII & IX
Hinkley, CA 92347

Description:
CARBON ADSORPTION SYSTEM, HTF ULLAGE/EXPANSION SYSTEM (BETA) consisting of: Carbon adsorption system having two (2) multi-bed carbon filter sets capturing ullage/expansion system emissions. Ullage vent scrubber and overflow tank vent scrubber will each vent only to their own carbon filter set. Both sets will vented to atmosphere through one common stack. ***As of 8/27/19 this facility has proposed to temporarily install two vertical, carbon vessels to bypass the existing horizontal carbon filter set in attempt to test solutions for improving compliance with the control efficiency, source testing, and emission requirements of this permit. Upon successful completion of the source testing, control efficiency and emission limits specified herein, this description shall be made permanent.***

CONDITIONS:

1. Operation of this equipment shall be conducted in compliance with all data and specifications submitted with the application under which this permit is issued unless otherwise noted below.

2. This equipment must be in use and operating properly at all times the HTF ullage/expansion system with valid District Permit B011047 is venting.

3. This carbon adsorption system shall provide at a minimum 95% control efficiency of VOC emissions vented from the HTF ullage/expansion system under valid District Permit B011047. Control efficiency shall be demonstrated by sampling VOC

Fee Schedule: 7 (h)	Rating: 1 device	SIC: 4911	SCC: 30688801	Location/UTM(Km): 470E/3877N

This permit does not authorize the emission of air contaminants in excess of those allowed by law, including Division 26 of the Health and Safety Code of the State of California and the Rules and Regulations of the District. This permit cannot be construed as permission to violate existing laws, ordinances, statutes or regulations of this or other governmental agencies. This permit must be renewed by the expiration date above. If billing for renewal fee required by Rule 301(c) is not received by expiration date above, please contact the District.

Mojave Solar LLC
42134 Harper Lake Road

Hinkley, CA 92347

By:
Brad Poiriez
Air Pollution Control Officer

emissions per US EPA Method 25 at the inlet and outlet of the carbon beds during initial and annual compliance tests.

4. The owner/operator shall prepare and submit a monitoring and change-out plan for the carbon adsorption system which ensures that the system is operating at optimal control efficiency at all times for District approval 60 days prior to commercial operation date (COD). Once approved, any subsequent changes to the monitoring and change-out plan must be submitted in writing to the District for approval prior to implementation.

5. Total emissions of VOC to the atmosphere shall not exceed 792.1 lbs/year, calculated based on the most recent test results.

6. Total emissions of benzene to the atmosphere shall not exceed 507.4 lbs/year, calculated based on the most recent test results.

7. During operation, o/o shall monitor VOC (as hexane) measured at outlet from the carbon beds. Sampling is to be performed at a minimum on a weekly basis. Samples shall be analyzed using a District approved photo ionization detector (PID).

8. PID shall be considered invalid if not calibrated in accordance with the manufactures recommended calibration procedures.

9. The o/o shall maintain an operations log (in electronic or hardcopy format) current and on-site for a period of five (5) years. The log shall contain at a minimum the following information and shall be provided to District personnel upon request.
a. Date and time of VOC monitoring;
b. Results of VOC monitoring; and
c. Date and description of all maintenance, malfunctions, repairs, and carbon change out(s).

10. The o/o shall provide stack sampling ports and platforms necessary to perform source tests required to verify compliance with District rules, regulations and permit conditions. The location of these ports and platforms shall be subject to District approval.

11. Prior to January 31 of each new year, the o/o of this unit shall submit to the District a summary report of all VOC emissions (based on annual source test results).

12. The o/o shall conduct all required compliance/certification tests in accordance with a District-approved test plan. Thirty (30) days prior to the compliance/certification tests the operator shall provide a written test plan for District review and approval. Written notice of the compliance/certification test shall be provided to the District ten (10) days prior to the tests so that an observer may be present. A written report with the results of such compliance/certification tests shall be submitted to the District within forty-five (45) days after testing is completed.

13. The o/o shall perform the following initial compliance tests on this equipment in accordance with the MDAQMD Compliance Test Procedural Manual. The test report shall be submitted to the District within 180 days of COD. The following compliance tests are required:
a. VOC as hexane in ppmvd and lb/hr (measured per USEPA Reference Methods 25 and 18 or equivalent).
b. Benzene in ppmvd and lb/hr (measured per CARB method 410 or equivalent).

All compliance/certification test notifications, protocols, and results may be submitted electronically to reporting@mdaqmd.ca.gov

14. The o/o shall perform the following compliance tests on this equipment at least once every twelve (12) months in accordance with the MDAQMD Compliance Test Procedural Manual. The following compliance tests are required:
a. VOC as hexane in ppmvd and lb/hr (measured per USEPA Reference Methods 25A and 18 or equivalent).
b. Benzene in ppmvd and lb/hr (measured per CARB method 410 or equivalent).

Additionally, records of all compliance tests shall be maintained on site for a period of five (5) years and presented to District personnel upon request.

7.3 Annex 3. AQ70-05-00, PTO's C012015 and C012016 Annual emission report submittal

Mojave Solar LLC

42134 Harper Lake Road
Hinkley, California 92347
Phone: 760 308 0400

Submitted Electronically

Subject: **09-AFC-5C**
Condition: **AQ-70**
Description: **Summary report of all VOC emissions based on annual test results. Year 2019.**
Submittal Number: **AQ70-05-00**

January 6, 2020

Keith Winstead
Compliance Project Manager
Siting, Transmission and Environmental Protection
California Energy Commission
1516 Ninth Street, MS-2000
Sacramento, CA 95814
keith.winstead@energy.ca.gov

Christian Anderson, Air Quality Engineer
Mojave Air Quality Management District
14306 Park Avenue
Victorville, California 92392
canderson@mdaqmd.ca.gov

Dear Mr. Winstead and Mr. Anderson,

Pursuant to Condition of Certification AQ-70, following Condition 11 of the Permits to operate numbers C012015 and C012016 attached is the annual summary report of all Mojave Solar LLC, VOC emissions.

Should you have any questions or comments, please don't hesitate to contact me.

Sincerely,

Jose Manuel Bravo Romero

Manager
Permitting, Compliance, Quality & Environmental Department
ASI Operations LLC
42134 Harper Lake Rd
Hinkley, CA 92347
Cell: (303) 378-7302
jmanuel.bravo@atlanticayield.com

Attachments: Summary report of all VOC emissions based on annual test results.

2019 Ullage emission - based on 7/21/2019 and 9/11/2019 tests data

Mojave Solar LLC

Hours venting

	Alpha		Beta	
	Expansion	Overflow	Expansion	Overflow
Jan	37.5	51.5	31.625	47
Feb	50.25	61.5	13.25	45.25
Mar	57.875	74	64.25	45.5
Apr	81.875	62	65.375	193.75
May	63.875	68	68.75	104.25
Jun	73.625	182.75	75.625	453.5
Jul	42.25	138	68.875	473
Aug	35.625	169.5	61	464.5
Sep	43.125	62	84	276.5
Oct	63.75	58.75	62.5	42
Nov	45.25	105.25	46	45
Dec	45.25	105.25	46	45
Annual Total	640	1139	687	2235

VOCs as C6, lb

Alpha		Beta	
Expansion	Overflow	Expansion	Overflow
6.28125	3.056525	0.1012	0.05875
8.416875	3.650025	0.0424	0.0565625
9.6940625	4.3919	0.2056	0.056875
13.714063	3.6797	0.2092	0.2421875
10.699063	4.0358	0.22	0.1303125
12.332188	10.846213	0.242	0.566875
7.076875	8.1903	0.2204	0.59125
5.9671875	10.059825	0.1952	0.580625
7.2234375	3.6797	0.2688	0.345625
10.678125	3.4868125	0.2	0.0525
7.579375	6.2465875	0.1472	0.05625
7.579375	6.2465875	0.1472	0.05625
107.2	67.6	2.2	2.8

benzene, lb

Alpha		Beta	
Expansion	Overflow	Expansion	Overflow
2.925	2.3072	0.00411125	0.00564
3.9195	2.7552	0.0017225	0.00543
4.51425	3.3152	0.0083525	0.00546
6.38625	2.7776	0.00849875	0.02325
4.98225	3.0464	0.0089375	0.01251
5.74275	8.1872	0.00983125	0.05442
3.2955	6.1824	0.00895375	0.05676
2.77875	7.5936	0.00793	0.05574
3.36375	2.7776	0.01092	0.03318
4.9725	2.632	0.008125	0.00504
3.5295	4.7152	0.00598	0.0054
3.5295	4.7152	0.00598	0.0054
49.94	51.00	0.09	0.27

Calculation notes:
- Vent valves are considered close if it is <2% open.
- 15 min average valve positions are used to determine whether each vent valve is open or close.
- In case of bad PI data, the valve position In the previous period is automatically used.

- Alpha expansion vessel vent VOCs emission rate is deteremined by performance test as 0.1675 lb/hr
- Alpha overflow vent VOCs emission rate is deteremined by performance test as 0.05935 lb/hr
- Beta expansion vessel vent VOCs emission rate is deteremined by performance test as 0.0032 lb/hr
- Beta overflow vessel vent VOCs emission rate is deteremined by performance test as 0.00125 lb/hr

- Alpha expansion vessel vent benzene emission rate is deteremined by performance test as 0.078 lb/hr
- Alpha overflow vent benzene emission rate is deteremined by performance test as 0.0448 lb/hr
- Beta expansion vessel vent benzene emission rate is deteremined by performance test as 0.00013 lb/hr
- Beta overflow vessel vent benzene emission rate is deteremined by performance test as 0.00012 lb/hr

Annual totals

Project last run 7/21/2019 & 09/11/2019

Alpha projected annual VOC	524.4	lb/yr
Beta projected annual VOC	15.0	lb/yr
Alpha projected annual benzene	302.8	lb/yr
Beta projected annual benzene	1.1	lb/yr

Annual VOC limit per plant 792.1 lb/yr
Annual benzene limit per plant 507.4 lb/yr

2019 Source Test results

		Run 1	Run 2	Average		Run 1	Run 2	Average
Alpha	Exp Ves VOC as C6, lb/hr	0.143	0.192	0.1675	Exp Ves Benzene, lb/hr	0.069	0.087	0.078
Alpha	Overflow VOC as C6, lb/hr	0.0686	0.0501	0.05935	Overflow Benzene, lb/hr	5.19E-02	3.77E-02	0.0448
Beta	Exp Ves VOC as C6, lb/hr	0.0032	0.0032	0.0032	Exp Ves Benzene, lb/hr	0.00013	0.00013	0.00013
Beta	Overflow VOC as C6, lb/hr	0.0015	0.001	0.00125	Overflow Benzene, lb/hr	1.30E-04	1.10E-04	0.00012