ECF-HANFORD-19-0133
Revision 0

Mathematical Engineering Analysis for Increasing the Flows at the Reduction-Oxidation (REDOX) Facility

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
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By Janis D. Aardal at 2:47 pm, Feb 06, 2020

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ENVIRONMENTAL CALCULATION COVER PAGE

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Date: 1-16-20

Calculation Title and Description:
Mathematical Engineering Analysis for Increasing the Flows at the Reduction-Oxidation (REDOX) Facility

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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SECTION 5 - Applicable if Calculation is a Risk Assessment or Uses an Environmental Model

Prior to Initiating Modeling:

Required training for modelers completed:
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Integration Lead:

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Calculation Approved:
Risk/Modeling Integration Manager:

Print First and Last Name	Signature	Date

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1 Purpose

The purpose of this environmental calculation is to provide the methodology, assumptions and calculations used for the mathematical engineering analysis of the Reduction-Oxidation (REDOX) Facility in order to show sampling defensibility after increasing the effluent and sampling flows at the 291-S-1 stack.

2 Background

A historical document review indicates that the REDOX facility had three canyon exhaust fans, per HW-32319, *Ventilation for Radiation Protection at REDOX*. Two electrically driven fans, capable of 20,000 cfm each, and one steam powered turbine, capable of 40,000 cfm, was available for use from the 291-S fan house. The turbine fan only powered on when the differential pressures upstream hit a predetermined emergency level.

In 1966 and 1967, ISO-1108, *REDOX Deactivation Manual*, delineated the process of putting the REDOX facility into a stand-by mode. The documentation indicates that the exhaust systems relating to the 291-S-1 stack had remained the same at that time.

Engineering drawing, H-2-95383, *291-S-1 Probe Assembly Stack Sample/Monitor*, indicates the specifications of the rake probe and the effluent and sampling speeds that are necessary for the system to be at a near-isokinetic state.

A 1995 memorandum, *REDOX Facility Surveillance and Maintenance S/RIDS and N&SCP Transmittal*, from ERC Team to Bechtel Hanford Incorporated, summarized the necessary and sufficient standards for the REDOX surveillance and maintenance program. That document confirmed that each of the two electrically driven fans were capable of 20,000 cfm each. At that time, the standby electrical fan was available to be powered up via diesel engine that was on standby in the event of a power outage. The turbine powered fan was identified as a backup fan that had been isolated in previous years.

Currently, the steam turbine is isolated. Both of the electrically powered fans are used interchangeably and neither fan has a separate diesel engine on stand-by to supply power to them.

Given the age of the REDOX facility and the fact that it was built previous to any of the American National Standards Institute (ANSI) documents, specifically those relating to representative and defensible sampling, the reasonable assumption is that this facility was built to Department of Energy (DOE) standards. The calculation to follow is a mathematical engineering analysis used to show the same near-isokinetic state after increasing the effluent flows to the original DOE standard.

3 Methodology

With the current sampling flows of the 291-S-1 stack documented to be near-isokinetic the following methodology implements a mathematical engineering analysis process to determine what the sample flows will need to be, after an increase in effluent flows, to ensure that the system remains near-isokinetic.

The mathematical engineering analysis is determined as follows:

1. Determine the current design effluent flows and sample flows and calculate the isokinetic ratio.
   a. Calculate the effluent duct “Stack Area” using design parameters.
   b. Calculate the effluent duct “Stack Velocity” with 1 electrically driven fan running.

c. Calculate the individual "Nozzle Area" for each of the sample rake nozzles using design parameters.

d. Calculate the "Total Nozzle Area" of the current sample rake.

e. Calculate the total "Sample Velocity" of the rake probe.

f. Calculate the "Flow Ratio" of the effluent and sample design velocities to determine the isokinetics of the current system. *NOTE: Isokinetic = 1.0*

2. Assuming use of both electrically driven fans, at capacity, determine the "Sample Flow Rate" needed for the sampling system to remain isokinetic.

a. Calculate the "Design Stack Flow Velocity" assuming both fans running at capacity and previous inputs, as needed.

b. Calculate the "Sample Flow Rate" assuming an isokinetic sample profile and previous inputs, as needed.

4 Assumptions and Inputs

All of the assumptions and inputs are delineated as laid out in the methodology:

1. For determining the current design effluent flows and sample flows in order to calculate the isokinetic ratio.

a. Inputs:

i. Based on historical documentation, HW-32319, *Ventilation for Radiation Protection at REDOX*, each of the two electrically driven fans is capable of 20,000 cfm. The current system only runs one fan at a time, thus, 20,000 cfm is used.

ii. Drawing, H-2-95383, *291-S-1 Probe Assembly Stack Sampler/Monitor* (Sheet 1), states the following design parameters:

1. The stack inner diameter is 47.75 inches.

2. The stack is said to be near-isokinetic at stack flow velocities of 1610 feet/minute. This lines up with the calculated assumption below.

3. Nozzles are sized to provide near-isokinetic sampling at 2.2 cfm sample extraction rate.

4. Nozzle tip specifications show a 0.375 inch tube with wall thickness of 0.065 inches on each side.

iii. The remainder of the inputs are calculated based on constants and previously calculated values.

b. Assumptions:

iv. Drawing, H-2-95383, *291-S-1 Probe Assembly Stack Sampler/Monitor* (Sheet 1), shows two rake probes. It is assumed that one of these probes was for the historical purpose of pulling a sample for a continuous air monitor (CAM), much like U-Plant did.

2. Assuming use of both electrically driven fans, at capacity, determine the "Sample Flow Rate" needed for the sampling system to remain isokinetic.

a. Inputs:

i. Based on historical documentation, HW-32319, *Ventilation for Radiation Protection at REDOX*, each of the two electrically driven fans is capable of 20,000 cfm. Assuming that both fans are running at a time a value of 40,000 cfm is used.

ii. Drawing, H-2-95383, *291-S-1 Probe Assembly Stack Sampler/Monitor* (Sheet 1), states the following design parameters that are carried over:

1. The stack inner diameter is 47.75 inches.
2. Nozzle tip specifications show a 0.375 inch tube with wall thickness of 0.065 inches on each side.

iii. The remainder of the inputs are calculated based on constants and previously calculated values.

b. Assumptions:

i. i. Drawing, H-2-95383, *291-S-1 Probe Assembly Stack Sampler/Monitor* (Sheet 1), shows two rake probes. It is assumed that one of these probes was for the historical purpose of pulling a sample for a continuous air monitor (CAM), much like U-Plant did.

ii. The "Stack Flow Velocity" is assumed to be double with both fans running (a linear relationship). It is recognized that due to system losses that this value will actually be less but 40,000 CFM is used as a conservative highest possible value. The components/system is assumed to be able to handle the increase in velocity.

iii. The "Desired Flow Ratio" is 1.00 as the increased flows are to remain isokinetic.

3. Overall

a. The basis of this calculation assumes a linear relationship between the effluent flow rates and the sample flow rates.

5 Software Applications

A Microsoft EXCEL®[1] spreadsheet was used to complete the mathematical engineering analysis.

6 Calculation

The calculation is presented in Tables 1 and 2 using the steps defined in the Methodology.

[1] Microsoft and Excel are registered trademarks of the Microsoft Corporation.

Table 1 - Mathematical Engineering Analysis for Current Effluent/Sample Flows at REDOX

A	B	C	D	E	F
Stack Effluent Flow Analysis					
	Calculated Value Designation	**Units**	**Reference / Assumption Number**	**Current Flow Calculations**	**Calculation**
1	Max Design Stack Volumetric Flow	ft^3/min	1	20000.00	Input
2	Design Stack Inner Diameter	in	2	47.75	Input
3	Design Stack Area	in^2	---	1789.85	PI*((E2/2)^2)
4	Design Stack Area	ft^2	---	12.43	E3/144
5	Design Stack Flow Velocity	ft/min	---	1609.07	E1/E4
Sample Effluent Flow Analysis					
	Calculated Value Designation	**Units**	**Reference / Assumption Number**	**Current Flow Calculations**	**Calculation**
6	Design Sample Flow Rate	ft^3/min	2	2.20	Input
7	Individual Nozzle Diameter	in	5	0.25	0.375 - (2* 0.065)
8	Individual Nozzle Area	in^2	---	0.05	PI()*(E7/2)^2
9	Individual Nozzle Area	ft^2	---	3.27E-04	E8/144
10	Number of Nozzles	N/A	2,3	5.00	Input
11	Total Nozzle Area	ft^2	---	1.64E-03	E9*E10
12	Design Sample Velocity	ft/min	---	1343.98	E6/E11

Table 1 - Mathematical Engineering Analysis for Current Effluent/Sample Flows at REDOX

Isokinetic Flow Ratio for Effluent and Sample Velocity					
	Calculated Value Designation	**Units**	**Reference / Assumption Number**	**Current Flow Calculations**	**Calculation**
13	Flow Ratio	N/A	4	0.84	E12/E5

NOTES:

1. Value obtained from HW-32319, Page 3. The REDOX facility has 2 electrically driven fans designed for 20,000 cfm each.
2. Value taken from H-2-95383, 291-S-1 Probe Assembly Stack Sampler/Monitor, Sheet 1, 10/28/85
3. Drawing indicates there are two parallel rakes with 5 nozzles each and an extra nozzle each to measure stack flow. Only one of these rakes are currently utilized for stack sampling.
4. The flow ratio is a comparison of the Design Stack Flow Velocity and the Design Sample Velocity to show how isokinetic the sampling system is.
5. Value taken from H-2-95383, 291-S-1 Probe Assembly Stack Sampler/Monitor, Sheet 2, 10/28/85

Table 2 - Mathematical Engineering Analysis for Doubling Effluent/Sample Flows at REDOX

A	B	C	D	E	F
Stack Effluent Flow Analysis					
	Calculated Value Designation	**Units**	**Reference / Assumption Number**	**Current Flow Calculations**	**Calculation**
1	Max Design Stack Volumetric Flow	ft^3/min	1	40000.00	Input
2	Design Stack Inner Diameter	in	2	47.75	Input
3	Design Stack Area	in^2	---	1789.85	PI*((E2/2)^2)
4	Design Stack Area	ft^2	---	12.43	E3/144
5	Design Stack Flow Velocity	ft/min	---	3218.15	E1/E4
Isokinetic Flow Ratio for Effluent and Sample Velocity					
	Calculated Value Designation	**Units**	**Reference / Assumption Number**	**Current Flow Calculations**	**Calculation**
6	Desired Flow Ratio	N/A	4	1.00	Desired Input
Sample Effluent Flow Analysis					
	Calculated Value Designation	**Units**	**Reference / Assumption Number**	**Current Flow Calculations**	**Calculation**
7	Individual Nozzle Diameter	in	2	0.25	0.375 - (2* 0.065)
8	Individual Nozzle Area	in^2	---	0.05	PI()*(E7/2)^2
9	Individual Nozzle Area	ft^2	---	3.27E-04	E8/144
10	Number of Nozzles	N/A	2,5	5.00	Input
11	Total Nozzle Area	ft^2	---	1.64E-03	E9*E10

Table 2 - Mathematical Engineering Analysis for Doubling Effluent/Sample Flows at REDOX

12	Design Sample Velocity	ft/min	---	3218.15	=E5
13	Sample Flow Rate	ft^3/min	6	5.27	E12/E11

NOTES:

1. Value obtained from HW-32319. The REDOX facility has 2 electrically driven fans designed for 20,000 cfm each.
2. Value taken from H-2-95383, 291-S-1 Probe Assembly Stack Sampler/Monitor, Sheet 1, 10/28/85
3. Although the Design Stack Flow Velocity is calculated the same as the current flows, it is double the current Design Stack Flow Velocity.
4. The flow ratio is a comparison of the "Design Stack Flow Velocity" and the "Design Sample Velocity" to show how isokinetic the sampling system is. In the case of using both electrically driven fans a fully isokinetic system is desired. (Isokinetic = 1.00)
5. Drawing indicates there are two parallel rakes with 5 nozzles each and an extra nozzle each to measure stack flow. Only one of these rakes are currently utilized for stack sampling.
6. "Design Sample Flow Rate" was calculated based on a desired velocity profile to maintain an isokinetic relationship as discussed in Note 4. The original "Total Nozzle Area" remains the same.

7 Results/Conclusions

The mathematical analysis effectively backs the historical documentation and allows the facility to employ higher effluent rates and still maintain sampling defensibility. The calculation shows that running both electrically driven fans concurrently and doubling the effluent flows at the REDOX facility can create the same near-isokinetic sampling scenario that currently exists while running one fan.

8 References

H-2-95383, *291-S-1 Probe Assembly Stack Sample/Monitor*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

HW-32319, *Ventilation for Radiation Protection at REDOX*. General Electric Company. U.S. Government, Richland, Washington.

ISO-1108, *REDOX Deactivation Manual*, Atomic Energy Commission – Richland, Richland, Washington.

025277, *REDOX Facility Surveillance and Maintenance S/RIDS and N&SCP Transmittal*, Bechtel Hanford Incorporated. Richland, Washington.

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Appendix A

H-2-95383, *291-S-1 Probe Assembly Stack Sample/Monitor*

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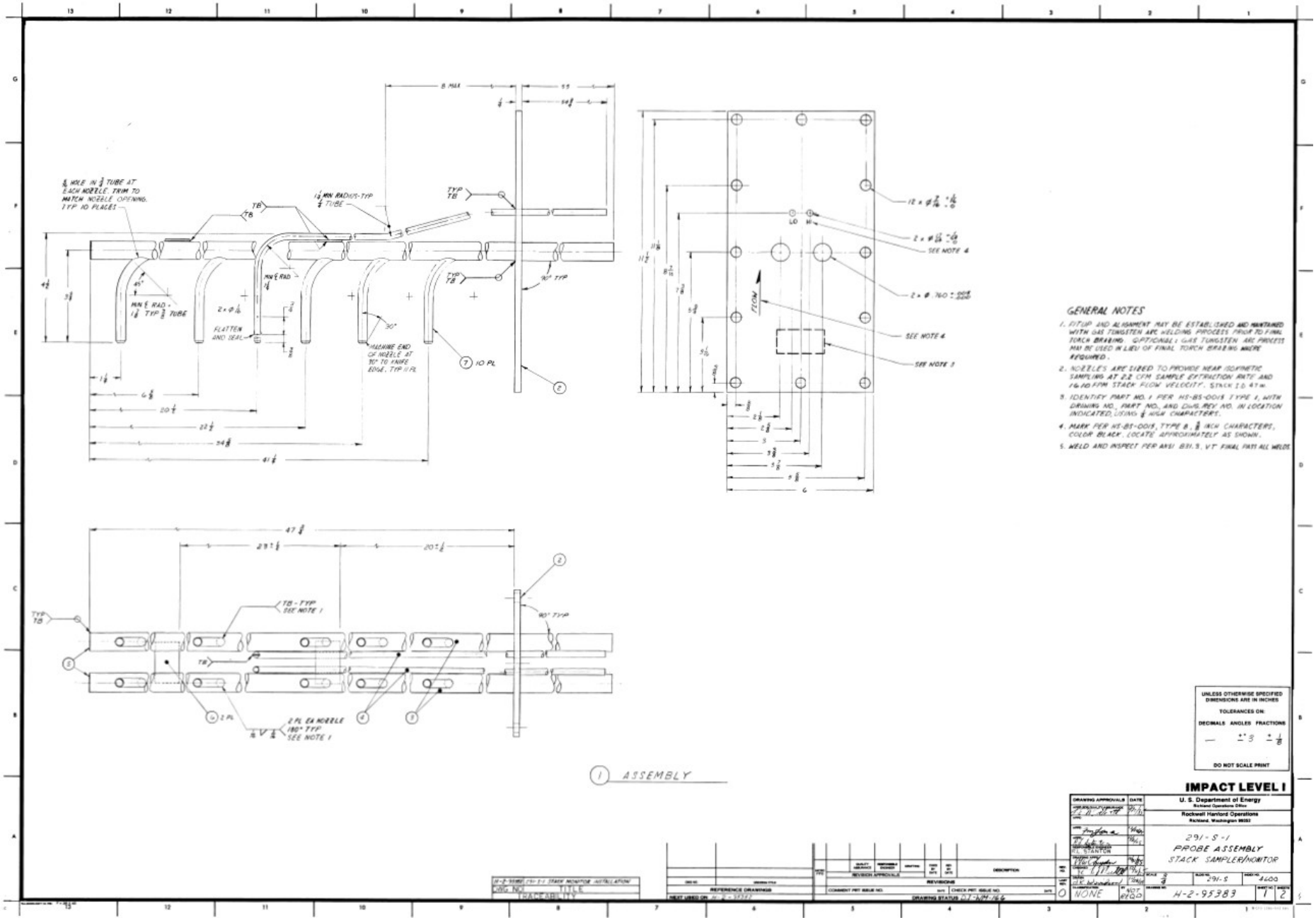
GENERAL NOTES
1. FITUP AND ALIGNMENT MAY BE ESTABLISHED AND MAINTAINED WITH GAS TUNGSTEN ARC WELDING PROCESS PRIOR TO FINAL TORCH BRAZING. OPTIONAL: GAS TUNGSTEN ARC PROCESS MAY BE USED IN LIEU OF FINAL TORCH BRAZING WHERE REQUIRED.
2. NOZZLES ARE SIZED TO PROVIDE NEAR ISOKINETIC SAMPLING AT 2.2 CFM SAMPLE EXTRACTION RATE AND 16.10 FPM STACK FLOW VELOCITY. STACK I.D. 47 in.
3. IDENTIFY PART NO. 1 PER HS-BS-0015 TYPE 1, WITH DRAWING NO., PART NO., AND DWG. REV NO. IN LOCATION INDICATED, USING 1/4 HIGH CHARACTERS.
4. MARK PER HS-BS-0015, TYPE B, 3/8 INCH CHARACTERS, COLOR BLACK. LOCATE APPROXIMATELY AS SHOWN.
5. WELD AND INSPECT PER ANSI B31.3, VT FINAL PASS ALL WELDS.
1 ASSEMBLY
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON:
DECIMALS ANGLES FRACTIONS
DO NOT SCALE PRINT
IMPACT LEVEL I
U. S. Department of Energy
Richland Operations Office
Rockwell Hanford Operations
Richland, Washington 99352
291-S-1
PROBE ASSEMBLY
STACK SAMPLER/MONITOR
H-2-95383
NONE
TRACEABILITY

SEPARATE PARTS LIST

DRAWING NO.	SHEET NO.	SHEETS	TITLE	JOB	MAT'L. WO. NO.	QCRN.
H-2-95383	SPL. 2	2	291-S-1 PROBE ASSEMBLY STACK SAMPLER MONITOR	DATE	FCN. OR EO. NO.	FABR. WO. NO.

APPROVALS - DATE 12-31-85
RES. ENG. R.L. Stark DFT. APPD. [signature]
DRAWN B.K. Davidson ENG. APPD. [signature]
CHECKED BY J.L. Elkin QA. APPD. [signature] 12/31/85

APPROVALS - DATE
RES. ENG. DFT. APPD.
DRAWN ENG. APPD.
CHECKED BY QA. APPD.

S M

REV. NO. 0
BLDG NO. 291-S
INDEX NO. 4600

PREPARED BY
TRAVELER NO.

QUANTITY REQ'D.	PT. NO.	DESCRIPTION	MAT'L./REF.	IMP LVL.	REQ./STORE NO. / BUYER/ST. ORDER	QTY. / UNIT	B. QTY. / COST	TOTAL COST	ORD. / REC.	MATERIAL STATUS	CQ. OR AR. NUMBER	M/COOD DATE	QC. APCT
X	1	ASSEMBLY		I									
1	2	PLATE, $\frac{1}{4}$ THK	ASTM A 240 304L SST	III									
AR	3	TUBING, $\frac{3}{4}$ O.D. x .065 WALL, SEAMLESS	ASTM A 269 304L SST										
AR	4	TUBING, $\frac{1}{4}$ O.D. x .035 WALL, SEAMLESS	ASTM A 269 304L SST										
2	5	END CAP, 16 GA (.060), $\frac{3}{4}$ DIA	ASTM A 240 304L SST										
2	6	SHEET, 16 GA (.060), 1W x $1\frac{3}{4}$ L	ASTM A 240 304L SST										
AR	7	TUBING, $\frac{3}{8}$ O.D. x .065 WALL, SEAMLESS	ASTM A 269 304L SST										

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