Spring Final Paper

Team 14
Noise Mitigation in an Organic Rankine Cycle (ORC) Turbine Bypass Line

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ABSTRACT

Reducing and eliminating waste heat has become a primary concern for industry over the past few decades. With more research being done on the subject, industries are making the push to clean up and improve efficiencies. Though there are many solutions implemented into cleaner energy, many sources generate byproducts (disturbs wildlife, generates further waste, etc...) which left unchecked limits the development and implementation of environmental waste heat management. The byproduct of Verdicorp's Organic Rankine Cycle systems (ORC) is an excess noise production during the system's start up and shutdown. During these phases of the system's operation gases are rerouted to the bypass line rather than through the turbine which results in an unacceptably loud noise. The deadening of the bypass line will require extensive analysis of the existing hardware and acoustic research to locate the exact location(s) where the noise is being generated. After the problem area(s) are located, various solutions will be designed, prototyped, and tested to determine the best noise reducing method. An overall reduction in the noise produced by this ORC in bypass will result in quieter operation enabling further distribution of these systems in noise sensitive environments.

ACKNOWLEDGMENTS

Team 14 would like to extend our deep appreciation to the FAMU-FSU College of engineering and the Mechanical engineering department for their time and devotion to organizing this year's senior design projects. We also want to personally thank Verdicorp, our sponsor Corey Nelson, and our advisor Dr. Cattafesta for their time, consideration, and experience in their fields.

1. Introduction

Over the past few decades there has been a significant drive for renewable energy and increased efficiency in industry. One company that wants to improve efficiency and reduce thermal waste is Verdicorp. Their ORC system begins by taking waste heat such as bio-gas, solar thermal, geothermal, bio-mass, heat streams, or any other source of excess heat and using it to run a turbine to produce grid level electricity. The integration of these systems would make use of the thermal waste produced and improve the overall efficiency of most systems. Currently their ORC systems are installed in over 40 countries worldwide [1]. After observing the noise generated on site, the first task for mitigation of the noise will involve determining the origin of the noise. Verdicorp only provided the general location of the noise as the bypass line, but did not include any specific locations on the line. With the future objective of the company to keep the ORCs in shipping containers for easier transportation and setup, this makes the noise testing more challenging and will be discussed later in the paper. In order to make this system more viable in sound sensitive environments the noise that is generated through the bypass line must be mitigated.

2. Project Definition

2.1 Need Statement

When operating in bypass, the ORC system generates an unacceptably loud amount of noise. A solution needs to be found to mitigate the bypass line noise while not impeding the performance of the system or requiring significant modifications of existing components.

2.1.1 Goal Statement, Objectives, and Constraints

The optimal goal of our sponsor is for the startup and shutoff of the ORC to be as close to nominal steady-state operating noise levels as viably possible. Within the range of steady-state operating condition the noise generated from the ORC should abide by OSHA standards.

Objectives

- Create a reasonably cost effective solution to dampen the noise
- Generate prototype(s) for onsite testing on Verdicorp's test bed
- Mitigate startup and shutdown noise to steady-state operational levels
- Create a solution that is replicable across their ORC product line

Constraints

- No significant modification of existing components that would hinder performance
- Designs must be manufactured onsite by Verdicorp personnel

2.2 Background Research

2.2.1 Organic Rankine Cycle (ORC)

The organic rankine cycle is a thermodynamic process where heat is transferred to a fluid at a constant pressure. The fluid is evaporated and then expanded through a vapor turbine which drives a generator, producing electricity which is then stepped up to grid level [2].

Figure 1. Verdicorp Cutaway Turbo Expander [1]

As explained by Verdicorp, the system is described as a chiller running backwards, instead of using electrical energy to produce cooling, the organic rankine cycle takes heat from different sources and turn it into economical electrical energy [1]. This system is often used by companies who have significant waste heat and want to increase the efficiency of their systems. The heat sources vary from solar concentrators, waste engine heat, manufacturing processes, or even waste steam [2]. Compared to various other forms of waste heat electrical generation, Verdicorp's ORCs are unique in the fact that they do not depend on a stand-alone heat sources to power them, but are only fed with byproduct heat of another process. In this way the ORC is self-sufficient and only adds efficiency and a reduction in thermal waste for a company. Although not implemented widely in the United States where energy costs are lower than other parts of the world, at around 12 cents per kWh, overseas the cost of electricity is around 18 to 20 cents per kWh [3]. With this system installed the monetary return on electricity alone can pay for the system in a few years.

2.2.2 Noise Level Measurement

As previously mentioned and indicated by the sponsor, the noise generated from the bypass line does not have a clear source or location. Whether the noise is the result of purely fluid in pipe flow or vibration or another unknown source, the first action that needs to be taken by the team is a detailed analysis of the noise source. Without the proper equipment to measure the noise available at Verdicorp, further research was conducted to choose a proper array of testing equipment. The first aspect that needs to be taken into consideration is the room in which the ORC is operating. Verdicorp's long time goal is to have the ORC shipped and operated within shipping containers, the same conditions as the test rig which our team has access to. Due to the steel walls and confined space of the shipping container, determining the location of the sound proves difficult due to the noise reflection and reverberation conditions that the container creates. To determine the noise levels created by the bypass line a selection of recording devices are available. While adhering to federal standards of safety and testing from the occupational safety and health administration (OSHA), one potential device is a sound level meter or SLM.

Figure 2. 3M Type 2 SLM [4]

As shown in figure 2, a type 2 SLM is qualified for noise surveys for OSHA and is capable of measurements of ±2 dBA. OSHA also qualifies a type 1 SLM for measurement, but is not required and is more suited for laboratory testing with a smaller measuring tolerance of ±1 dBA. With the proper measurement devices, the next issue as mentioned previously is dealing with the environment in which the measurements will be taken. Due to the small space within the steel shipping container, additional steps will be required to conduct accurate sound measurements. After more on site visits and research, the preferred microphone for our testing purposed will be a Pom3535l-r-3, the characteristics of which can be seen in appendix()

When choosing a location to measure the noise level of a system, there are three principle zones to account for.

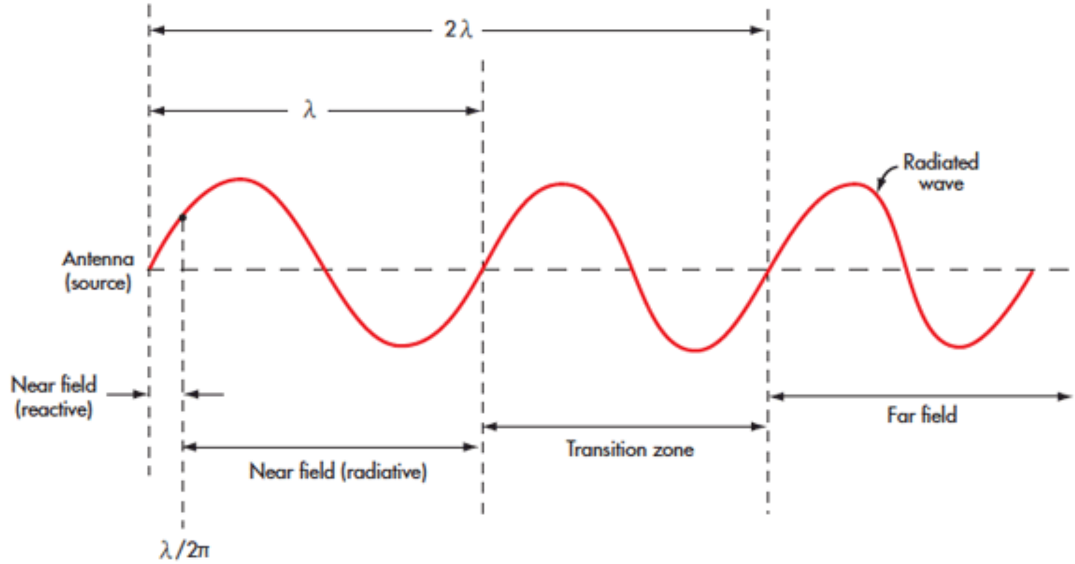


Figure 3. Graphical depiction of practical room with measurement zones

Figure 3 above shows the three regions where sound can be measured. These are the near field, the transition (or free) field, and the far field. The near field is measured at either two times the length of the machine or device creating the noise, or the lowest frequency wavelength emanating from the machine. Setting up a SLM in this range can result in a large variance in the recorded readings based on the location in the zone, and is not recommended. On the opposite end of the spectrum, measurements taken in the far field (in this case near the walls of the container) can also lead to misreading due to the reverberating of the sound waves on the walls. The preferred location to measure the noise is between the far and near fields in the free field.

An addition made with recent research is that a SLM is the generally accepted tool for measuring sound pressure waves, but in the absence of substantial funding for the expensive equipment and the difficulty in procuring these tools, a SLM may be substituted with a microphone and some additional software. Using a high quality microphone with a logging software such as LabVIEW, the SLM may be replaces using the sound and vibration software package that is provided by National Instruments. In effect this turns a microphone into a SLM and would be a satisfactory and cost effective solution to recording the noise levels. Further communication with local academic resources will also provide an DAQ card, which for the case of our testing is simple enough to plug into any software and hardware compatible laptop and serve to sample the data at an appropriate rate. As mentioned about measurement zones, the selection of a microphone is essential to credible measurements. This divides microphones into two major areas with different environments that they can measure within. A free field microphone is omnidirectional and used in areas where there are no sound waves reflected at the microphone or in an anechoic chamber. The second is a pressure field microphone, which has the same magnitude of sound pressure at any point in the field and is direction oriented.

2.2.3 Vibration Effects on Noise Levels

As mentioned before, the source of the noise generated by the bypass line is unclear. Many suggestions have been stated in order to find the possible source of noise and one of them could be due to vibration. In its simplest form, vibration can be considered as the oscillating motion of a body around an equilibrium position, which is the position of the body when the sum of the forces acting on the body is equal to zero [5]. These oscillations are carried out by using small mechanical transducers called accelerometers, which are connected to the vibrating object. The accelerometer is then connected to a pre-amplifier which allow the device to measure the vibration velocity, displacement and acceleration [6]. A frequency analysis of the vibration signal is often needed in order to determine the most appropriate means of mitigating the vibrations. In terms of piping, vibration is a serious issue that needs to be attended to in order to prevent fatigue failure. The two types of piping vibration are steady-state and transient.

Steady-state vibration is forced, repetitive, and happens over a relatively long period of time. Rotating equipment, pressure pulsations, or even fluid flow are within the issues that lead to a steady-state vibration [7]. This type of vibration can cause a fatigue failure due to a large number of high stress cycles. On the other hand, transient vibrations occur for a relatively short period of time and are usually generated by larger forces than the ones involved in steady-state [7]. The most common cause of this type of vibration is related to the pressure pulses traveling through the fluid. These pulses produce dynamic forces on the pipe that are proportional to the straight length of the pipe between bends and are usually related to water hammer. Water hammering is usually caused by rapid pump stops or starts or by a quick valve opening or closing.

2.2.4Noise Types and Dampening Materials

The objective of this project is to mitigate the noise produced by the ORC. There are many different types of noise and corresponding dampening techniques. It is important to identify the type of noise being produced in order to select the correct mitigation procedure. Types of noise are displayed in Table 1.

Table 1. Noise Types and Examples [8]

Type of Noise	Characteristics	Example
Continuous	Noise produced without interruption	Air Conditioning hum
Intermittent*	Noise that increases and decreases in level rapidly	Train passing a station
Impulsive	Sudden burst of high level noise	Construction/Demolition work
Low Frequency	Low background humming	Large Diesel Engine
**When in bypass mode, the ORC issues continuous noise with intermittent swells.*		

Noted in Table 1, the ORC emits a continuous noise in bypass mode with swells of intermittent noise until the pump reaches 40 Hz. This information will be used to select an appropriate mitigation method. Noise levels can be reduced in a large number of ways including: distance, dampening, absorption, reflection, diffusion, noise cancellation and vibration cancellation. Dampening material could be placed on the bypass line itself as long as the material could withstand the temperature and vibrational parameters of the line.

The Verdicorp ORC's in commission today are housed in a variety of ways based on user preference. It is desired in the future to house the ORC units inside large commercial shipping containers. These containers will be located as close to the warehouse or place of business as possible in order to run the system and perform maintenance. This eliminates distance as a viable mitigation technique. One option that is currently employed in industry is active noise cancellation, which involves the process of using a microphone to collect sound that is analyzed by a computer. Applications of this type of technology are seen with Bose headphones and many of today's automobile manufacturers. Sound waves of opposite polarity (180° out of phase) are emitted from a speaker causing destructive interference and canceling the noise produced by the source. This method is feasible but may lack practicality if a simpler solution exists. There is a high possibility that the bypass line in question experiences strong vibrational forces from the turbulent 245fa refrigerant passing through it. These vibrations can lead to resonation of larger pieces of equipment which could be the main source of the noise. If this is the case, metal braces could be introduced between the bypass line and either the ORC system itself or the wall of the container. This method would reduce the vibration experienced by the bypass line as well as the corresponding resonation. Noise absorbing materials function by making use of friction inside the materials cellular structure to dampen oscillation [9]. These materials are used in noise cancelling panels, foam, fiberglass, and cotton. Typically these materials are hung from walls and ceilings to catch a large number of reflecting sound waves.

2.2.5 Fluid Noise inside Pipes

While there are a number of possibilities that can lead to the noise in the turbine bypass line, a likely cause or at the very least contributor to the noise is from the fluid flow passing through the bypass line. This is a common issue that can be found in many industrial settings that use piping systems during operation [10]. There are a number of reasons that noise is generated from this process, with the most common reason having to do with the flow transmitting across a high pressure drops due to complex piping systems. These pressure changes can be created from bends in the pipes, expansion valves, contractions, and even control valves and regulators. When the fluid passes through these devices it can disrupt the fluid flow and cause the flow to become turbulent.

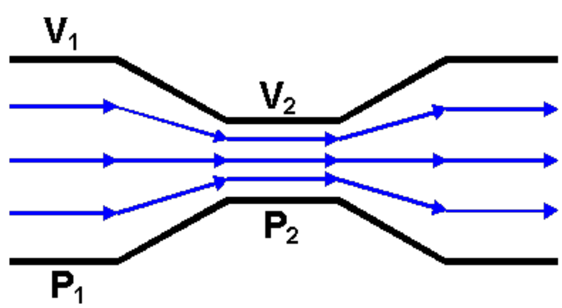


Figure 4. Flow going through a contraction value

The flow becomes turbulent by the vast amount of pressure differences in the pipe, giving off energy that can be perceived as sound. This means there is a direct relation between the amount of pressure differences and the amount of noise given off by the flow. Figure 4 above shows how the flow changes as the diameter of the pipe changes. When the diameter of the pipe decreases its velocity increases, and its pressure decreases. This is further explained by Bernoulli's equation that shows the relation between the flows in two different pipe diameters [11].

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 \qquad [Eq\ 1.]$$

More issues can arise once this noise from the flow is created, as it can also then be amplified by propagating through the pipes and can travel through the pipe walls by way of acoustic transmission.

The superheated flow that runs through the turbine is switched to the bypass line by a control valve, which is also a very well documented source of noise in other industrial pipelines[]. The control valve is an essential component of piping systems, but vary greatly in how much turbulence and noise they create depending on the manufacturer.

3. Methodology

In order to better understand how the customer's requirements relate to the product's capabilities, a house of quality matrix was created. Since the design has not yet been completed and there are currently no competitors, a scaled down version of the HOQ was used. A house of quality takes the customer's requirements and compares them with the engineering characteristics of the product in a rankings system to better understand which properties and requirements outweigh others. The HOQ can been seen below in Figure 5.

	ENGINEERING CHARACTERISTICS						
CR	**CI**	**Meets OSHA standards**	**Material Choice**	**Fasteners and Fixtures**	**Temperature Resistance**	**Acoustic Transmission**	**Vibration Transmission**
Adaptable	7			6		7	7
Low Cost	8		10	6			
In-house Manufacturing	8	10	10	4			
Non-Intrusive to Performance	10		8	5			
Steady-State Noise Levels	10	10	10			10	8
Compact	2		6	8	5	6	
Ease of Installation	5			10		8	
Maintenance	3		10	8	10		8
Score		180	382	262	40	201	153
Relative weight		14.78	31.36	21.51	3.28	16.50	12.56
Rank		4	1	2	6	3	5

Figure 5. Bypass Line Noise Mitigation HOQ

On the left side of the HOQ is the customer's requirements; these were compiled after both speaking to the sponsor and from the problem statement. There are 8 customer requirements, and each of these 8 requirements are given a value between 0 – 10 depending on their importance to the customer. The customer requirements are:

- Adaptable – The product can fit on many different sizes of their system.
- Low cost – Ensures Verdicorp can retrofit existing systems affordably.
- In-house Manufacturing – Verdicorp would like to be able to manufacture the product in their own machine shop.
- Non-Intrusive to Performance – The ORC system requires closely monitored flow rates and velocities that can easily be disrupted with the addition of complex components.

- Steady-State Noise Levels – Verdicorp would like the sound of the bypass line to sound similar to the ORC at steady-state, which is when the turbine is active.
- Compact – The ORC pipelines often have small clearances around them and the product needs to be able to fit within these spaces.
- Maintenance – As the product becomes worn the customer would like it to be easily replaceable without requiring extensive modifications.

After compiling a list of the customer requirements, the engineering characteristics of the product needed to be examined and then determine what effects the customer requirements the most. There were 6 engineering characteristics used to help determine this relationship, which are seen at the top of the HOQ and are listed below:

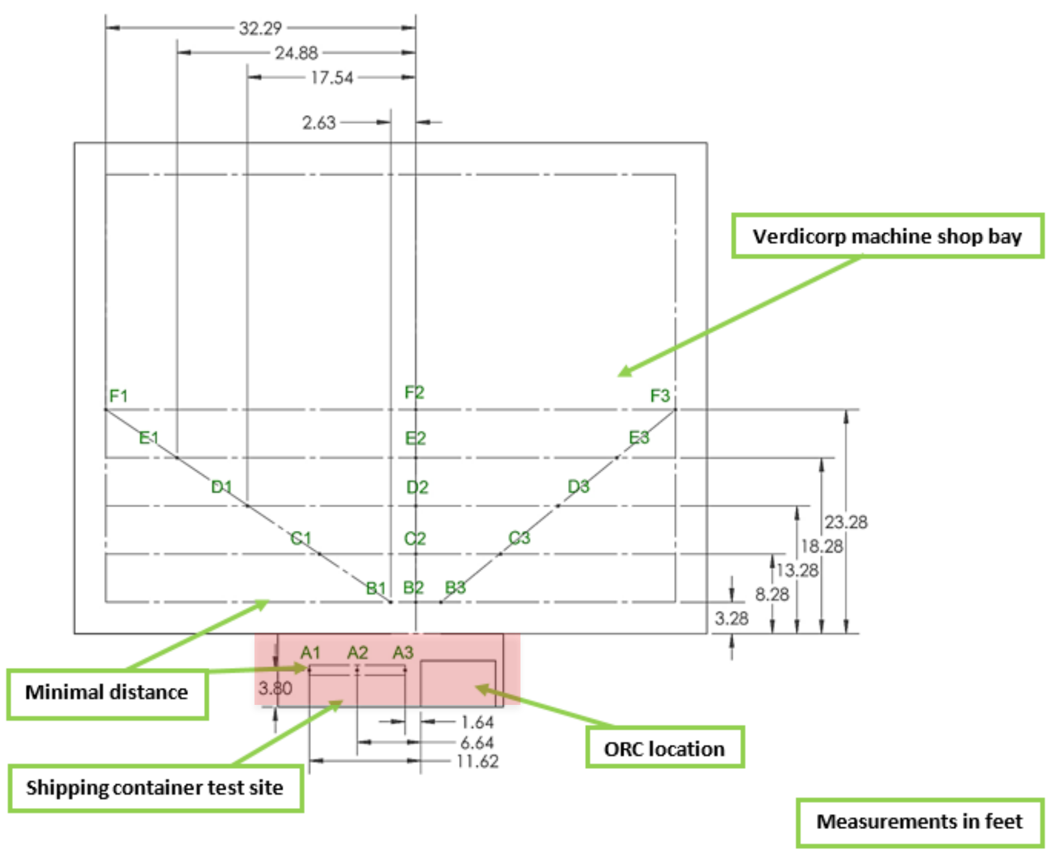
- Meets OSHA standards – The Occupational Safety and Health Administration has very stringent and specific standards that equipment used in the workplace must adhere to. This means the product must adhere to these same standards or risk steep fines and the inability to be used.
- Material Choice – The material choice is especially important in making sure the customer's specific requirements are best met.
- Fasteners and Fixtures – How the product is connected to the ORC system plays a major role in fulfilling the customer requirements.
- Temperature Resistance – The product will see significant temperatures on a consistent basis and will need to be able to withstand said temperatures without causing damage to the product that would hurt its performance.
- Acoustic Transmission – The overall goal of the product is to mitigate the noise from the turbine bypass line which means that the product needs to limit the amount of acoustics that will pass through it.
- Vibration Transmission – The possibility of vibrations being a leading factor in the cause of the noise means that the product should also limit the amount of vibrations that can pass through it.

After compiling both the customer requirements and the engineering characteristics, and adding them to the HOQ, both topics can be related to one another. This process looks at what engineering characteristics effect customer requirements, and if applicable rank that value between 0 – 10. Once complete, the value is then multiplied by the customer importance and that engineering characteristic's values are totaled. Once all of the engineering characteristics have their values totaled, it is possible to rank them from 1 to 6 and see which the most important engineering characteristic is.

For this product it was determined that the most important characteristic is what material is used, followed by how the product is fastened to the ORC system. Its acoustic transmission was the next most important characteristic, followed by it meeting OSHA standards, its ability to limit vibrations, and finally its temperature resistance.

3.1 Measurement Methodology

To properly characterize the noise given off by the ORC system, proper measurement procedures need to be followed to provide accurate and reliable data for concept generation. The locations within a closed body chosen for measurements must be further than one meter from any wall or surface that can cause noise to rebound back to the testing equipment, changing the pressure levels and frequency of the original sound. The same hold for the ground, where the microphone used for measurements should be supported 1.2 meters off the floor.



To abide by these measurement methods, a measurement template was created. From figure () the measurement layout was developed with the safety of the Verdicorp employees both inside and outside of the steel shipping container as shown in the red highlighted zone. The measurements are taken at six different zones with three measurements taken along each zone to provide enough measurements to generate an acoustic contour plot when enough data is collected from measurements. At each measurement point, the startup transient and steady state noise levels will be recorded three times each to get a more accurate idea of the average dB level.

4. Data Collection and Processing

5. Project Planning

Proper planning and organization are required to ensure that work is done both on time and of the highest possible quality for the sponsors. To achieve this a few methods for planning were employed, the first is the critical path method or CPM.

Table 2. CPM table of tasks and durations

Activity	Duration (Days)	Predecessor	Description
A	1	-	Contact Sponsor
B	14	A	Background Research
C	18	A	Equipment Gathering
D	2	B & C	Test Site Schematics
E	14	D	On-Site Noise Measurements
F	7	E	Measurement Analysis
G	7	F	Concept Design
H	7	F	CAD Modeling
I	14	G & H	Prototype Manufacturing
J	14	I	Prototype Testing

Table 2 shows the overall task list for the research, design, and testing of solutions to mitigate the turbine bypass noise levels. For the purpose of generating an overview of the project these tasks are simplified as singular items, not including the multiple aspects that may go into each. From table 2 a CPM network diagram may be formed to generate a visual depiction of the progression of tasks throughout the problem solving process. By processing the tasks using the critical path method the total time for the completion of the project can be determined, and setbacks due to unforeseen circumstances can result in certain tasks being prioritized to finish the project on time.

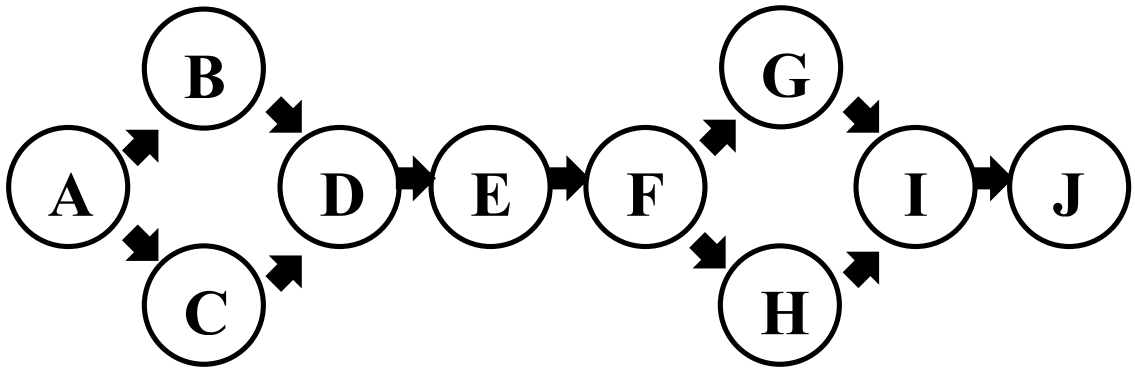


Figure 6. Network diagram of ORC noise mitigation

From table 2 and using figure 6, the longest course of action uses the path {A,C,D,E,F,(G/H),I,J}. This longest time to completion dictates the prioritized tasks that must be completed according to their assigned time. The only slack that occurs throughout the process is with stage B, which is background research. Although important, obtaining the equipment for the project is projected to take a significantly longer period of time than the research, resulting in more play for the total length of the research task.

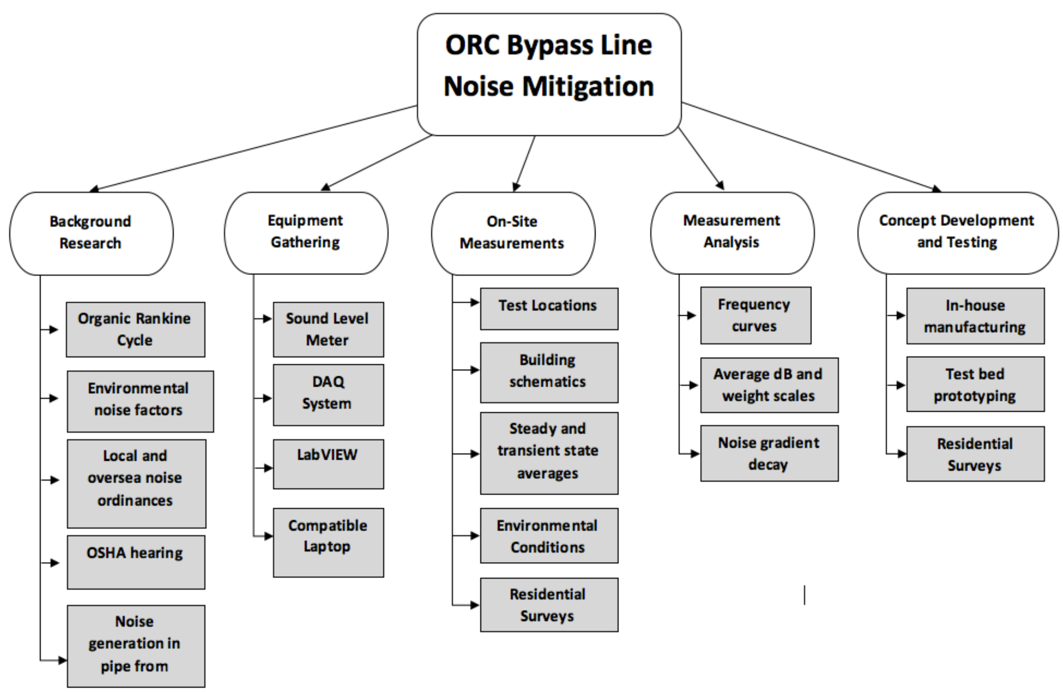


Figure 7. Work breakdown structure of design process

Following the CPM the work breakdown structure (WBS) was used to provide more definition to some select tasks from the CPM. Where the WBS excels is to better show in detail the steps that are required in order for each task to be completed. This is a power tool due to the ability of spreading the workload of each task over its pre-described working dates and completion time. Together both of these project planning methods develop hard due dates, with progressive steps for achieving each of the dates. Due to the nature of the project, the majority of the time for this project as shown in figure 7 is in the beginning phases of the project with research and proper measurement procedures. The additional time is required due to the lack of information in regards to the exact location, type, and loudness of the noise generated by the bypass line. With this knowledge the best approach and breakdown of each task can be assigned throughout the team and achieved with the optimal efficiency. The task and their durations can be seen in more detail in the appendix where a full Gantt chart has been provided, this serves as a rough and setback assumed guide that can assist in guiding the project to its completion.

6. Resource Management

Table 3: Personnel task list

Task	Team Member Responsible
Acquire DAQ card	Luis Figueroa
Acquire LabVIEW data processor	William Mauch
Acquire microphone	Austin Houser
Develop measurement plan	All members
Schedule visit to Verdicorp for measurements	Chad Adams
Take measurements at Verdicorp	All members

The most important step that needs to be taken is finding the source of the noise. In order to find the source, we must take very detailed measurements of the area surrounding the ORC. A measurement plan must be developed and a measurement device must be acquired. The measurement plan will involve analyzing the blueprints of the Verdicorp facility (obtainable upon request) and finding the best areas to test; best meaning the areas where we can test waves that experience the least amount of interference. We will also need to plan for testing outside of the facility. The available measurement areas are limited by an RV park, a pond, and a busy highway. The selected testing areas must also be located a distance from the outside boiler. The boiler is stored in a shipping container in the southwest corner of the grounds. The noise from the boiler could interfere with the measurements being taken of the bypass line noise. This measurement device will be a “virtual” sound level meter. This virtual SLM will be composed of a battery powered microphone connected to a laptop with a DAQ card running LabVIEW along with National Instruments Virtual SLM software. This virtual SLM is being chosen over a conventional SLM because of the availability of the components and the conventional SLM would require some form of training. In order to measure the noise, multiple team members will need to hold the microphone, battery pack, and laptop. Once measurements are taken, the data will be analyzed and a noise mitigation solution will be selected. The frequency, decibel level and noise type will dictate what mitigation solution is chosen.

7. Conclusion

From the initially provided problem statement and communication with the sponsor, it has been indicated that further research and on-site testing is required to begin the evaluation of noise mitigation. Until a more accurate measurement of the system during startup, steady-state, and shutoff can be taken, the original problem statement issued to the group needed a revision. As indicated to our team from our sponsor, the peak bypass noise generation and steady-state noise levels are not well known and defined, thus the initial statement of 80 dBA as the reference point will most likely need alteration. The test bed location in the city of Tallahassee must abide by local noise ordinances, which for commercial and residential areas are 55dBA and 70 dBA respectively. Due to this the need statement of the problem has been modified to account for these unknowns and as such became the following: when operating in bypass, the ORC system generates an unacceptably loud amount of noise. A solution needs to be found to mitigate the bypass line noise while not impeding the performance of the system or requiring significant modifications of existing components. Once the steady-state noise levels have been recorded a common reference point will have been created and a solution set can be designed to solve the sponsor's problem.

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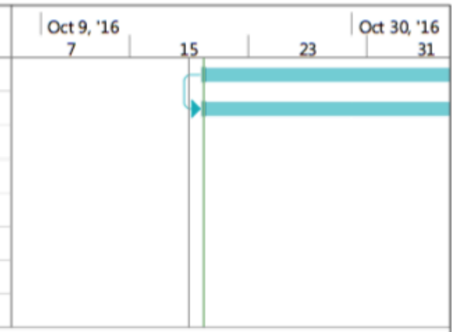
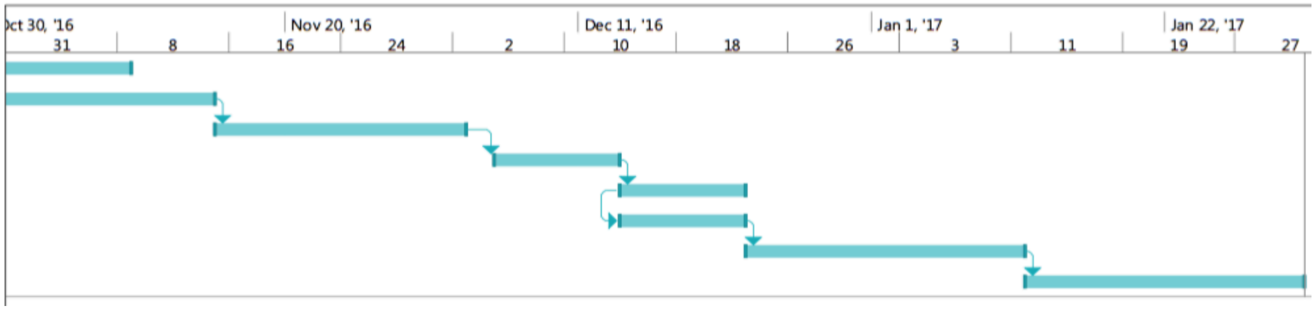
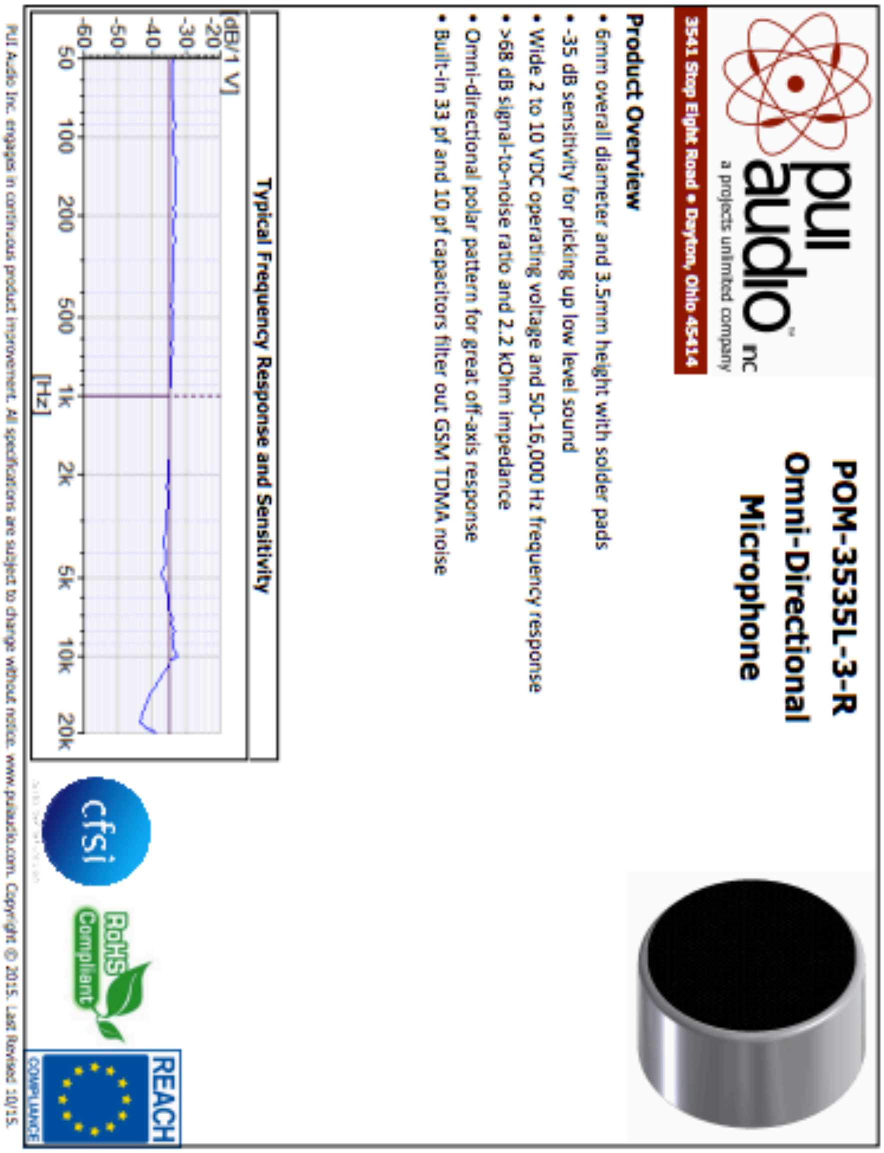
Appendix A

Task Name	Duration	Start	Finish
Background Research	14 days	Thu 10/20/16	Tue 11/8/16
Equipment Gathering	18 days	Thu 10/20/16	Mon 11/14/16
On-site Noise Measurements	14 days	Tue 11/15/16	Fri 12/2/16
Measurement Analysis	7 days	Mon 12/5/16	Tue 12/13/16
Concept Design	7 days	Wed 12/14/16	Thu 12/22/16
CAD Modeling	7 days	Wed 12/14/16	Thu 12/22/16
Prototype Manfacturing	14 days	Fri 12/23/16	Wed 1/11/17
Prototype Testing & Analysis	14 days	Thu 1/12/17	Tue 1/31/17






pui audio inc

a projects unlimited company

3541 Stop Eight Road • Dayton, Ohio 45414

POM-3535L-3-R Omni-Directional Microphone

Product Overview

- 6mm overall diameter and 3.5mm height with solder pads
- -35 dB sensitivity for picking up low level sound
- Wide 2 to 10 VDC operating voltage and 50-16,000 Hz frequency response
- >68 dB signal-to-noise ratio and 2.2 kOhm impedance
- Omni-directional polar pattern for great off-axis response
- Built-in 33 pf and 10 pf capacitors filter out GSM TDMA noise

Typical Frequency Response and Sensitivity

PUI Audio Inc. engages in continuous product improvement. All specifications are subject to change without notice. www.puiaudio.com. Copyright © 2015. Last Revised: 10/15.

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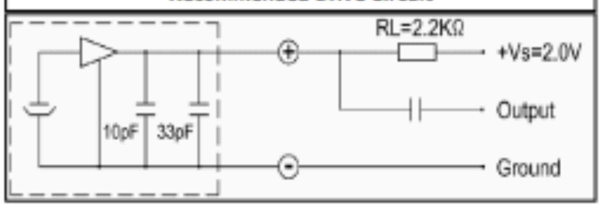
a projects unlimited company

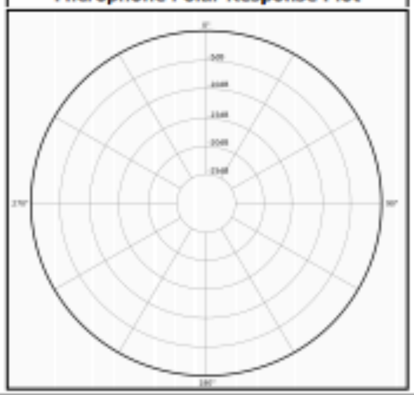
POM-3535L-3-R Omni-Directional Microphone

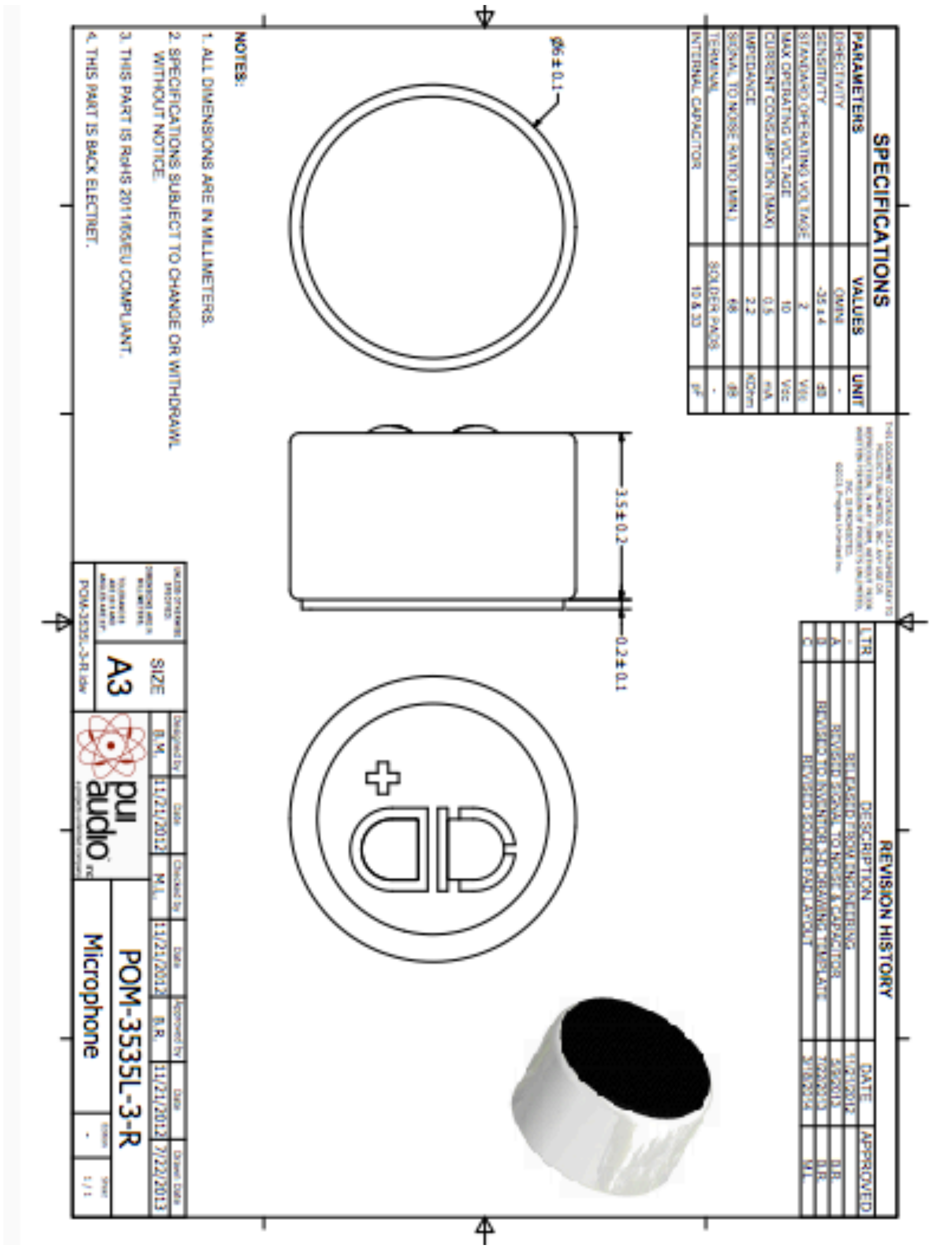
Mechanical and Environment Testing	
Test Description	**Test Condition**
High Temperature	70°C with random humidity for 200 hours
Low Temperature	-25°C with random humidity for 200 hours
Humidity	40°C with 90% relative humidity for 200 hours
Vibration	3 mm movement for 3 minutes in each of 3 axis
Drop Test	70 cm free fall onto 20 mm thick board, two directions
Temperature Cycle Test	-10°C to 50°C, 5 cycles

Recommended Drive Circuit

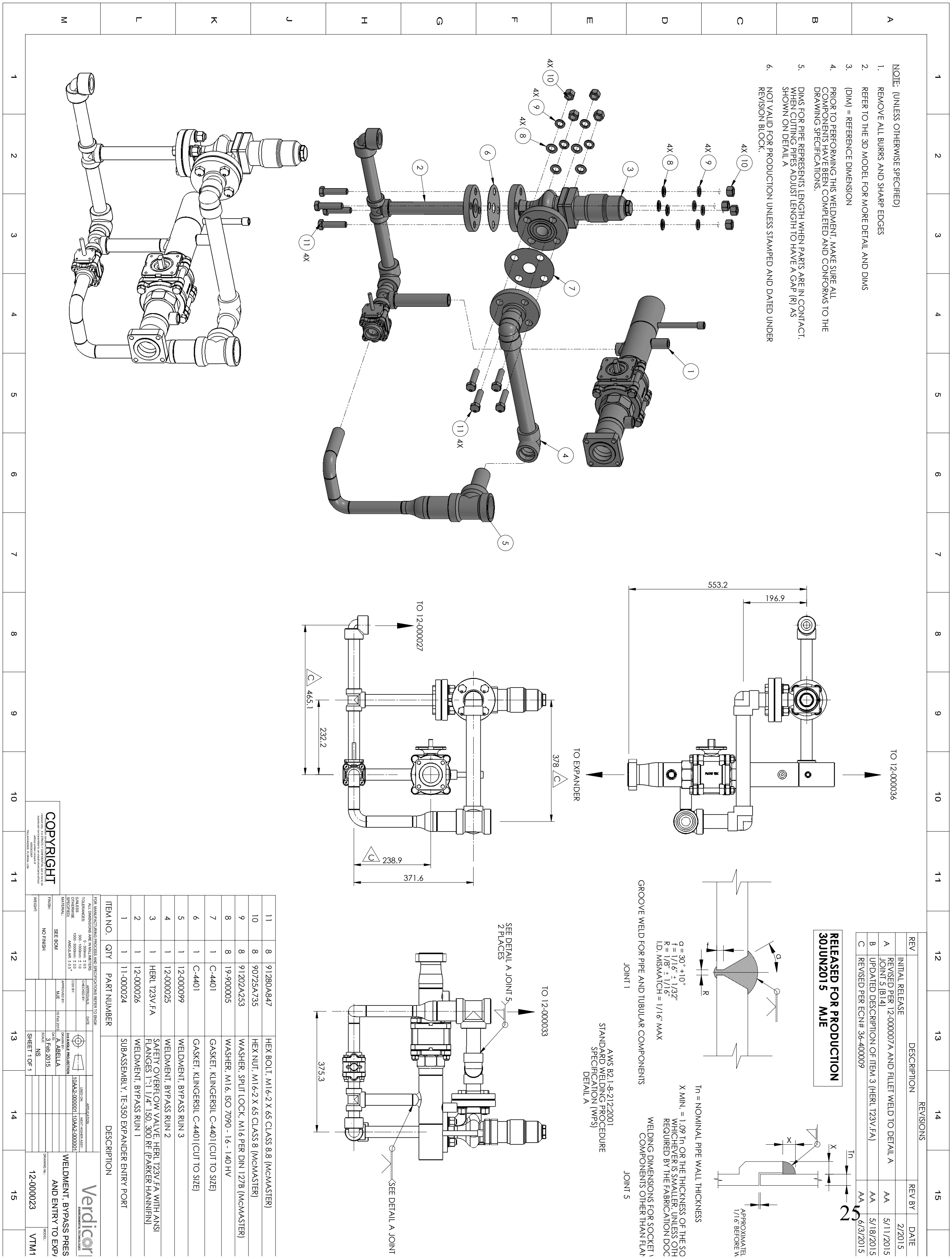


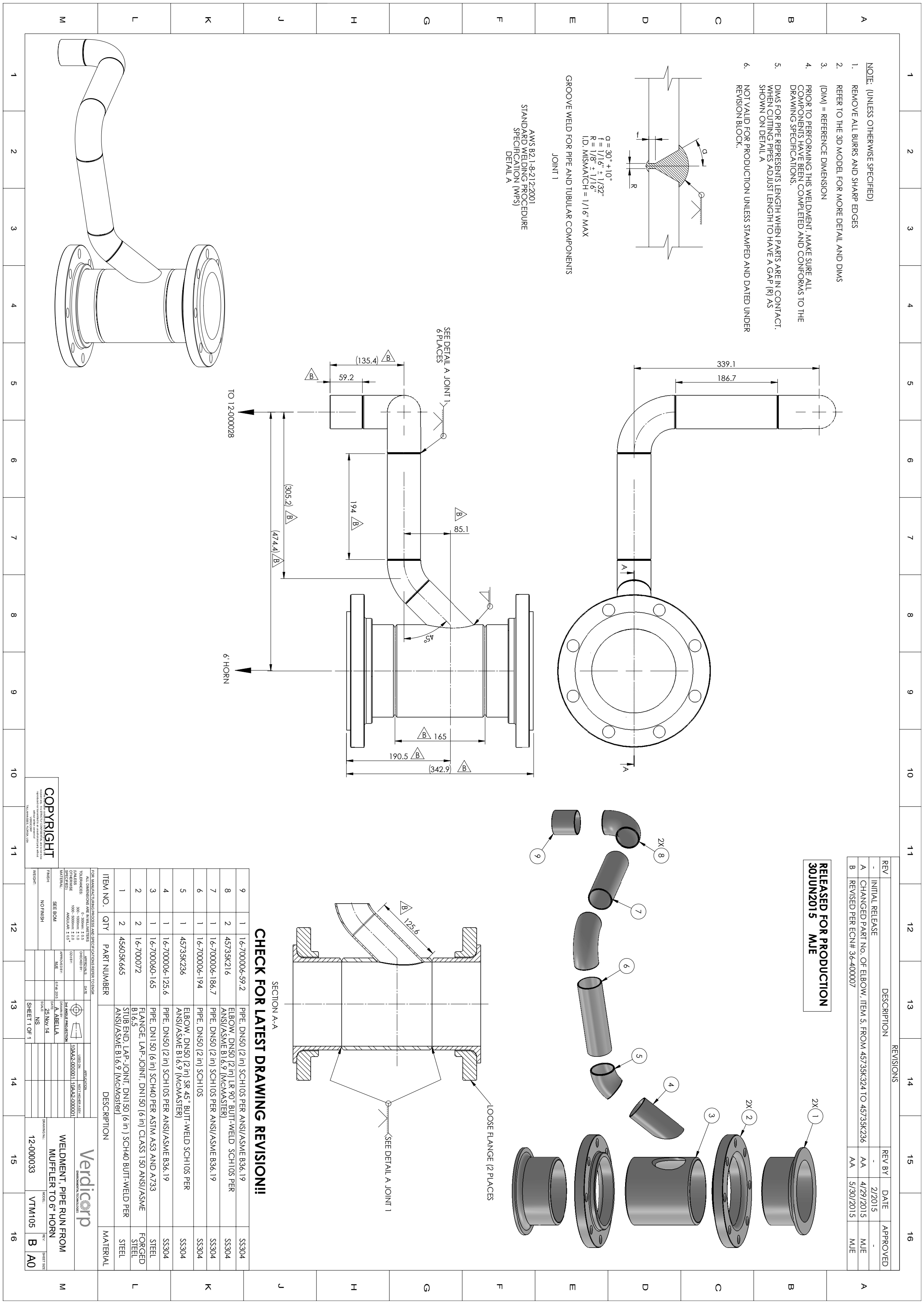
Microphone Polar Response Plot





https://www.ehp.qld.gov.au/licences-permits/pdf/noise-measurement-manual-em1107.pdf
http://www.ni.com/white-paper/14349/en/


NOTE: (UNLESS OTHERWISE SPECIFIED)
1. REMOVE ALL BURRS AND SHARP EDGES
2. REFER TO THE 3D MODEL FOR MORE DETAIL AND DIMS
3. (DIM) = REFERENCE DIMENSION
4. PRIOR TO PERFORMING THIS WELDMENT, MAKE SURE ALL COMPONENTS HAVE BEEN COMPLETED AND CONFORMS TO THE DRAWING SPECIFICATIONS.
5. DIMS FOR PIPE REPRESENTS LENGTH WHEN PARTS ARE IN CONTACT. WHEN CUTTING PIPES ADJUST LENGTH TO HAVE A GAP (R) AS SHOWN ON DETAIL A
6. NOT VALID FOR PRODUCTION UNLESS STAMPED AND DATED UNDER REVISION BLOCK.
REVISIONS
REV | DESCRIPTION | REV BY | DATE
INITIAL RELEASE | 2/2015
A | REVISED PER 12-000007A AND FILLET WELD TO DETAIL A JOINT 5 (B14) | AA | 5/11/2015
B | UPDATED DESCRIPTION OF ITEM 3 (HERL T23V.FA) | AA | 5/18/2015
C | REVISED PER ECN# 36-400009 | AA | 6/3/2015
RELEASED FOR PRODUCTION 30JUN2015 MJE
TO 12-000036
TO 12-000027
TO 12-000033
TO EXPANDER
553.2
196.9
465.1
232.2
378
238.9
371.6
375.3
SEE DETAIL A JOINT 5 2 PLACES
SEE DETAIL A JOINT
GROOVE WELD FOR PIPE AND TUBULAR COMPONENTS
JOINT 1
AWS B2.1-8-212:2001 STANDARD WELDING PROCEDURE SPECIFICATION (WPS) DETAIL A
Tn = NOMINAL PIPE WALL THICKNESS
JOINT 5
ITEM NO. | QTY | PART NUMBER | DESCRIPTION
11 | 8 | 91280A847 | HEX BOLT, M16-2 X 65 CLASS 8.8 (McMASTER)
10 | 8 | 90725A735 | HEX NUT, M16-2 X 65 CLASS 8 (McMASTER)
9 | 8 | 91202A253 | WASHER, SPLIT LOCK, M16 PER DIN 127B (McMASTER)
8 | 8 | 19-900005 | WASHER, M16, ISO 7090 - 16 - 140 HV
7 | 1 | C-4401 | GASKET, KLINGERSIL C-4401(CUT TO SIZE)
6 | 1 | C-4401 | GASKET, KLINGERSIL C-4401(CUT TO SIZE)
5 | 1 | 12-000099 | WELDMENT, BYPASS RUN 3
4 | 1 | 12-000025 | WELDMENT, BYPASS RUN 2
3 | 1 | HERL T23V.FA | SAFETY OVERFLOW VALVE, HERL T23V.FA WITH ANSI FLANGES 1"/1 1/4" 150, 300 RF (PARKER HANNIFIN)
2 | 1 | 12-000026 | WELDMENT, BYPASS RUN 1
1 | 1 | 11-000024 | SUBASSEMBLY, TE-350 EXPANDER ENTRY PORT
COPYRIGHT
NO FINISH
SEE BOM
Verdicorp
WELDMENT, BYPASS PRES AND ENTRY TO EXP
12-000023
SHEET 1 OF 1


REVISIONS
REV | DESCRIPTION | REV BY | DATE | APPROVED
- | INITIAL RELEASE | - | 2/2015 | -
A | CHANGED PART No. OF ELBOW, ITEM 5, FROM 45735K324 TO 45735K236 | AA | 4/29/2015 | MJE
B | REVISED PER ECN# 36-400007 | AA | 5/30/2015 | MJE
RELEASED FOR PRODUCTION 30JUN2015 MJE
NOTE: (UNLESS OTHERWISE SPECIFIED)
1. REMOVE ALL BURRS AND SHARP EDGES
2. REFER TO THE 3D MODEL FOR MORE DETAIL AND DIMS
3. (DIM) = REFERENCE DIMENSION
4. PRIOR TO PERFORMING THIS WELDMENT, MAKE SURE ALL COMPONENTS HAVE BEEN COMPLETED AND CONFORMS TO THE DRAWING SPECIFICATIONS.
5. DIMS FOR PIPE REPRESENTS LENGTH WHEN PARTS ARE IN CONTACT. WHEN CUTTING PIPES ADJUST LENGTH TO HAVE A GAP (R) AS SHOWN ON DETAIL A
6. NOT VALID FOR PRODUCTION UNLESS STAMPED AND DATED UNDER REVISION BLOCK.
α = 30° +10°
f = 1/16" ± 1/32"
R = 1/8" ± 1/16"
I.D. MISMATCH = 1/16" MAX
GROOVE WELD FOR PIPE AND TUBULAR COMPONENTS
JOINT 1
AWS B2.1-8-212:2001
STANDARD WELDING PROCEDURE
SPECIFICATION (WPS)
DETAIL A
339.1
186.7
SEE DETAIL A JOINT 1
6 PLACES
85.1
45°
165
190.5
(342.9)
(135.4)
59.2
194
(305.2)
(474.4)
TO 12-000028
6" HORN
LOOSE FLANGE (2 PLACES
125.6
SEE DETAIL A JOINT 1
SECTION A-A
CHECK FOR LATEST DRAWING REVISION!!
ITEM NO. | QTY | PART NUMBER | DESCRIPTION | MATERIAL
9 | 1 | 16-700006-59.2 | PIPE, DN50 (2 in) SCH10S PER ANSI/ASME B36.19 | SS304
8 | 2 | 45735K216 | ELBOW, DN50 (2 in) LR 90° BUTT-WELD SCH10S PER ANSI/ASME B16.9 (McMASTER) | SS304
7 | 1 | 16-700006-186.7 | PIPE, DN50 (2 in) SCH10S PER ANSI/ASME B36.19 | SS304
6 | 1 | 16-700006-194 | PIPE, DN50 (2 in) SCH10S | SS304
5 | 1 | 45735K236 | ELBOW, DN50 (2 in) SR 45° BUTT-WELD SCH10S PER ANSI/ASME B16.9 (McMASTER) | SS304
4 | 1 | 16-700006-125.6 | PIPE, DN50 (2 in) SCH10S PER ANSI/ASME B36.19 | SS304
3 | 1 | 16-700060-165 | PIPE, DN150 (6 in) SCH40 PER ASTM A53 AND A733 | STEEL
2 | 2 | 16-700072 | FLANGE, LAP-JOINT, DN150 (6 in) CLASS 150 ANSI/ASME B16.5 | FORGED STEEL
1 | 2 | 45605K665 | STUB END, LAP-JOINT, DN150 (6 in) SCH40 BUTT-WELD PER ANSI/ASME B16.9 (McMaster) | STEEL
COPYRIGHT
MATERIAL: SEE BOM
FINISH: NO FINISH
A. ABELLA
25 Nov 14
NS
SHEET 1 OF 1
10AA2-000001
Verdicorp
WELDMENT, PIPE RUN FROM MUFFLER TO 6" HORN
12-000033
VTM105
B
A0