A multidisciplinary learning experience: control valves noise testing and modeling

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ABSTRACT

Control valves are generally present whenever fluid flow regulation is required therefore found in a wide variety of industrial applications. Control valves regulate flow by increasing or decreasing the fluid pressure drop across the element. These pressure drop adjustments are usually accompanied by noise generation. This paper describes the work done to test and model the level of noise generated by specialty valves manufactured by one of Rowan's industrial partners, DFT Inc. This project involved students from three engineering disciplines, employees from the Rowan University Cogeneration Plant and the valve manufacturer. This multidisciplinary engineering team provided DFT Inc. with a means of predicting the noise generated by their unique control valve design as a result of various flow conditions. As outcomes of this project a computer model to predict noise production for aerodynamic and hydrodynamic flows was developed and a hydrodynamic flow testing apparatus was designed and installed at the cogeneration plant. This flow-testing loop provided the empirical data required by the computer model. In an effort to further validate the results of the computer models, an anechoic chamber was built and used for both, aero- and hydrodynamic testing.

ROWAN UNIVERSITY'S ENGINEERING CLINIC

Rowan University is a comprehensive regional state university with six colleges: Business Administration, Communications, Education, Fine and Performing Arts, Liberal Arts and Sciences and Engineering. The College of Engineering was founded using a major gift in 1992 from Henry Rowan. Rowan University is pioneering a progressive engineering program that uses innovative methods of teaching and learning to prepare students for a rapidly changing and highly competitive marketplace, as recommended by ASEE [1]. To best meet these needs, the four engineering programs of chemical, civil/environmental, electrical/computer, and mechanical engineering include an interdisciplinary engineering clinic every semester. Sharing many features in common with the model for medical training, the clinic provides an atmosphere of faculty mentoring hands-on, laboratory setting. At the freshman level, students conduct engineering measurements and reverse engineer a process or product. The sophomore engineering clinic is communications-intensive and also introduces students to the design process of each discipline. The junior and senior clinics provide an opportunity for the most ambitious part of our project-intensive curriculum in which students work on a real engineering problem usually sponsored and mentored by local industry.

BACKGROUND

Noise in an industrial setting is commonly defined as unwanted or annoying sound and sound is defined as the auditory sensation produced by oscillatory pressure fluctuations in the ambient atmospheric pressure. Because of its vague definition, noise is usually described or specified by the physical characteristics of sound. The properties of sound are the magnitude of sound pressure and the frequency of its fluctuations as shown in Figure 1. The loudness of a sound is measured by the amplitude of the sound pressure (p_s) which is mathematically defined by:

$$\text{Sound Pressure Level (SPL)} = 20 \cdot \log_{10}\left(\frac{p_s}{0.0002}\right), \; decibels(dB) \qquad (1)$$

where (p_s) is the amplitude of the sound pressure in microbars. The arbitrary selected reference sound pressure of 0.0002 μbars is defined as the "threshold of audibility" or the minimum pressure fluctuation detected by the ear at 1000 Hz. Because of the wide range, the sound pressure measurements are made in a logarithmic scale with decibels as units. The apparent loudness of a sound is a function not only of the sound pressure but also of the frequency. Figure 2 shows the determination of the threshold of audibility and the threshold of feeling. Curves 1 to 6 represent attempts to determine the absolute threshold of hearing at various frequencies by the authors listed. MAP = minimum audible pressure at the eardrum; MAF = minimum audible pressure in a free sound field, measured at the place where the listener's head had been. Curves 7 to 12 represent attempts to determine the upper boundary of the auditory realm, beyond which sounds are too intense for comfort, and give rise to nonauditory sensations of tickle and pain. While the loudness of a sound is primarily determined by the amplitude of pressure fluctuations, the apparent or perceived loudness of a sound is a function of frequency. For example, the normal ear is most sensitive to sounds in the area of 3,000Hz. Consequently, sounds near this

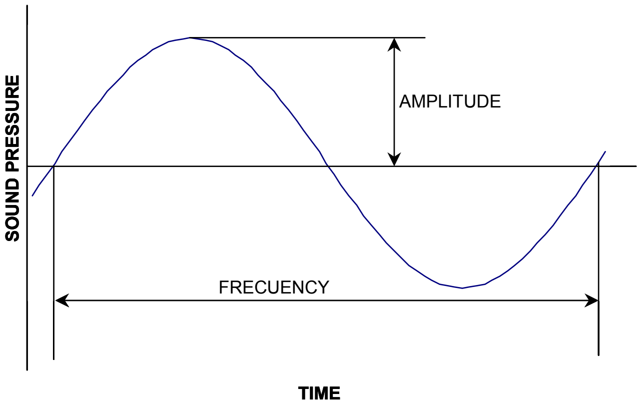


Figure 1. Properties of sound. Adapted from Hutchison[2]

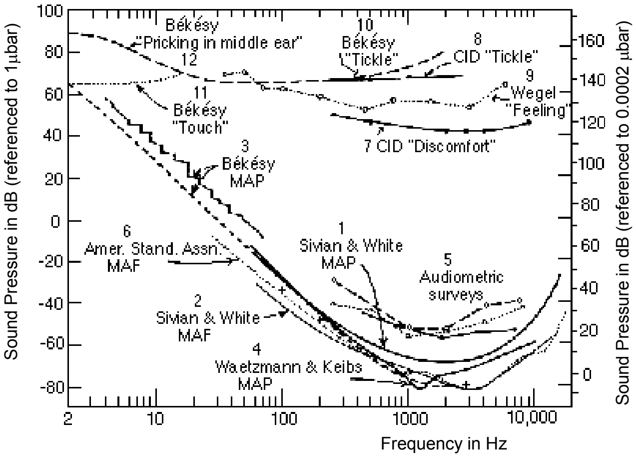


Figure 2. Determination of the threshold of audibility and the threshold of feeling. Adapted from Licklider[3]

frequency are perceived as being louder. Sound pressure measurements are often weighted to adjust the frequency response. The human ear is not as effective hearing at low frequencies as it is hearing higher frequency sounds. This means that high frequency sounds are perceived as being louder than low frequency ones. To replicate the human ear perception of sounds, the sound pressure level measurements are usually filtered using what it is referred to as an "A" filter and the units denoted as dB(A). These measurements give a better indication of the subjective loudness of a noise.

Sound intensity (I) is another common way of quantifying sound. The sound intensity is a measure of acoustic energy and is defined as the acoustic power transmitted through a unit area which is perpendicular to the source. The sound intensity is mathematically defined as:

$$\text{Sound Intensity Level} = 10 \cdot \log_{10}\left(\frac{I}{10^{-16}}\right), \textit{decibels} \qquad (2)$$

where the reference is arbitrarily selected as 10^{-16} watts/cm^2.

Fluid flow is a major source of industrial noise. Fluid transmission noise can be a result of the fluid dynamics that occur within pumps, compressors, sudden expansions/contractions and control valves.

SOURCES OF VALVE NOISE

The noise is typically due to both, the mechanical vibration of valve components due to flow and the flow itself, both aerodynamic and hydrodynamic.

Mechanical noise produced by control valves is a result of random pressure fluctuations within the valve body and/or the fluid impingement of valve internals that come into mechanical contact with the fluid flow. The sound that is produced by this type of vibration is normally in the frequency rang of 1500 Hz and perceived as metallic rattling. Though the physical damage that is typically associated with this type of vibration is generally more of a concern than the noise that is emitted. Noise as a result of such vibrations is in general not predictable and can only be eliminated by improving the valve or fluid network design.

Control valves handling liquid flows can cause significant amounts of noise as a result of the flow of the liquid. The noise resulting from hydrodynamic flows can be generally classified into three distinct classifications:

1) Non-cavitating
2) Cavitating
3) Flashing

Noise resulting from non-cavitating flow is not typically of sufficient intensity to be problematic. The generally accepted mechanism for noise production as a result of non-cavitating flow is turbulent velocity fluctuations in the fluid stream which are usually referred to as "Reynolds stresses". Such velocity fluctuations are present in control valves as a result of the large decrease in the magnitude of the linear velocity downstream of the vena contracta shown in. Noise resulting from cavitation is more likely to be significant. Cavitation is a two-stage process. First bubbles of vapor form as the liquid pressure drops below its vapor pressure. When the pressure recovers and rises above the vapor pressure, these bubbles collapse, or implode. Cavitation affects the capacity of a valve, causes noise, vibration and erosion of valve components. The onset of such collapsing produces a characteristic increase in noise. Control valves tend to promote cavitation due to the close tolerances for which fluids are forced to travel. The minimal cross-sectional area, the vena contracta, is the location were fluid pressure is at the minimum, a favorable location for cavitation to occur as shown in Figure 3. Noise produced by cavitation has a broad frequency range and produces a rattling that would be anticipated if gravel were contained and traveling with the fluid. While cavitation produces noticeable noise, in many applications concern over noise problems come second to fears of physical damage. Cavitation may cause severe damage to metal valve components due to mechanical stress.

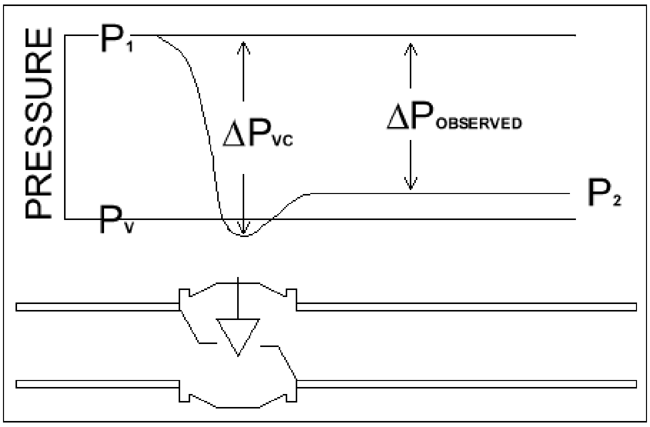


Figure 3. Pressure differential across the valve.

Flashing is a condition that occurs when the downstream pressure of a control valve is lower than the upstream vapor pressure, causing a partial liquid vaporization with the vapor remaining in the flow. The flow is then chocked and therefore independent of the downstream pressure. Noise as a result of a valve that is handling such a flow is due to the deceleration and expansion of the two-phase flow.

Finally, aerodynamic noise, another major contributor of valve noise, is due to the direct conversion of the energy of a turbulent gas stream. The principle source of aerodynamic noise from control valves is the recovery region, which is downstream of the vena contracta. The shear forces in this location create flow patterns that are discontinuous and chaotic.

The ability to predict control valve noise has become a critical task for manufacturers of valves. The demand for such information stems partly from increased government regulations, requiring sound levels to be within acceptable limits. According to the Occupational Safety and Health Administration (OSHA)[4], 15 percent of workers exposed to noise levels of 85 dBA or higher will develop material hearing impairment. Persons should not be exposed to noise above 115 dBA. The National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental (ACGIH) both believed that 85 dBA is the recommended exposure limit.

PROJECT DESCRIPTION

This project was sponsored by DFT Inc., a check valve and control valve manufacturing company, located in Exton, Pennsylvania. DFT partnered with the Engineering department at Rowan University to solve the problem of predicting the noise generated by their control valves. Although extensive literature information can be found on how to predict and model such noise; the methods are limited to those valves configurations that are more commonly used for control purposes that is, globe valves, butterfly valves, and needle valves. DFT's unique design called for a new approach for predicting and modeling hydrodynamic and aerodynamic noise. Figure 4 shows one of the DFT commercially available valves.

Due to the multidisciplinary nature and complexity of this problem a clinic team was formed. This clinic team included of six students, three faculty members and personnel from Rowan Cogeneration plant. The one main objective of this project was to correctly predict the noise that a DFT control valve produces.

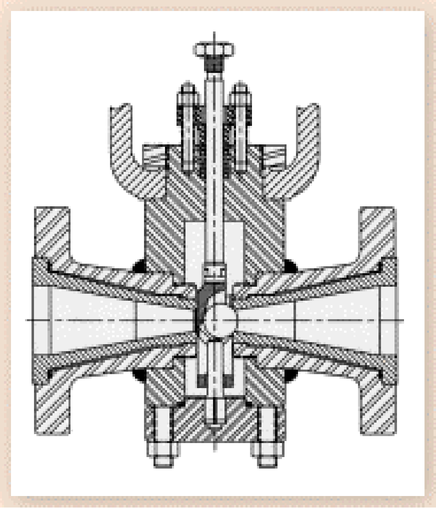


Figure 4. ULTRA-TROL by DFT Inc

Objectives

Given the main goal for this team, three distinctive objectives were identified, these are:

1. Aerodynamic and hydrodynamic data generation in anechoic chamber.
2. Hydrodynamic data validation in flow loop at Rowan Cogeneration plant.
3. Development of a computer program that model

Objective 1: The first step towards completion of this objective was the construction of an anechoic chamber in the mechanical engineering high bay laboratory. Two mechanical engineering students along with a mechanical engineering faculty designed and built this chamber. The anechoic chamber is an 8x8x12 foot insulated room with a floor hatch and a 3-foot balcony as shown in Figure 5. These sizes were arrived at after much consideration about where to place a "room" of this size in the high bay lab. The sizes allow for the anechoic chamber to be placed directly on top of an existing structure (hence the floor access) thereby saving space and further isolating the test fixture. The design for the anechoic chamber was drawn using AutoCAD. The inside of the chamber is lined with Medium Density Fiberboard (MDF) and 4 inch thick acoustical foam. These two materials coupled together absorb both high (4 inch acoustical foam) and low (MDF) frequency vibration. Combined with the R-22 insulation in the wooden frame structure makes it truly anechoic and allows for precise sound pressure level measurements of any test fixtures that are placed inside.

Figure 5. Rowan anechoic chamber

There are two ICU can lights and a smoke detector in the ceiling, and two 110 Volt outlets and microphone connections in the floor. All measurement equipment other than the microphone was placed outside of the anechoic chamber. The test setup inside of the chamber consist of a valve connected, on both sides, to at least 40 inches of continuous piping running horizontally before intersecting a chamber wall.

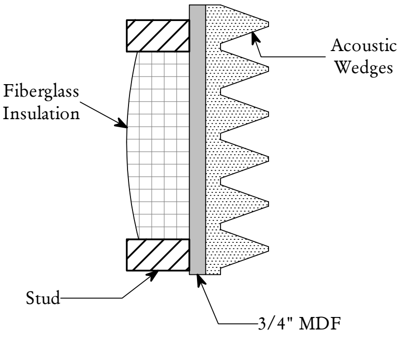


Figure 6. Wall Section in Anechoic Chamber

There is also at least 20 inches of space between the valve and every wall. All the internal dimensions of the chamber were chosen following the guidelines given in the International Electrotechnical Commission (IEC) standards IEC 60534-8[5].

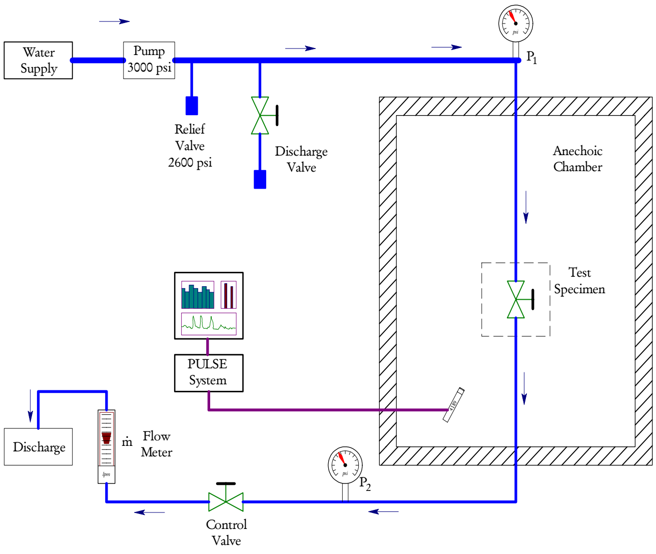


Figure 7. Hydrodynamic loop.

In addition the chamber was designed to fully comply with the appropriate dimensions and specifications for constructing a commercial room according to the BOCA Building Code[6].

Once the chamber was completed the Chemical Engineering process technician helped the mechanical engineering students with the plumbing so that both aerodynamic (air) and hydrodynamic (water) testing could be done through the system without major hardware changes. The hydrodynamic loop is shown in Figure 7 and the aerodynamic is depicted in Figure 9.

For the aerodynamic noise prediction, the IEC Standard 60534-8-3[7] was used. The equations were reviewed as given by the standards and then applied to use in the model.

Aerodynamic flow in a pipe undergoes different types of regimes. According to the IEC standard[7], the various regimes are results of differing sonic phenomena or reactions between molecules in the gas and sonic shock cells. Five different regimes are identified. In regime I, flow is subsonic and gas is partially recompressed. Regime II is characterized by the existence of sonic flow. This is due to interaction between shock cells and turbulent flow mixing. In regime III, the flow becomes supersonic. No isentropic recompression exists. The flow is in regime IV when the shock cell structure diminishes. Further decrease in outlet pressure will result in no increase in noise. Finally, the flow is in regime V when there is a constant acoustical efficiency. Regimes are determined by calculating the valve outlet absolute pressure at critical flow conditions, the absolute *vena contracta* (the narrowest central flow region of a jet), pressure at critical flow conditions, the valve outlet absolute pressure at break point, and the valve outlet absolute pressure where region of constant acoustical efficiency begins. Once these pressures are calculated, the regime of the flow can be determined. Each of the five regimes has different governing equations that are used to calculate the noise levels produced by a control valve. These equations are outlined in. the IEC standard[7] as well.

For hydrodynamic flow, the noise prediction was based on the IEC Standard 60534-8-4[8]. Unlike aerodynamic flows, hydrodynamic flows do not go through regimes. Instead, flows are categorized either as cavitating or non-cavitating as shown in Figure 8. To determine the flow type, certain pressure ratios must be evaluated. There are two different kinds of pressure ratios: the differential pressure ratio, x_F, which can be calculated by

$$x_F = \frac{\Delta P}{P_1 - P_v} \tag{3}$$

where ΔP is the differential pressure between upstream and downstream $\left(P_1 - P_2\right)$ and P_v is the absolute vapor pressure of the liquid at inlet temperature; and the characteristic pressure ratio, x_{F_z}, that must be obtained experimentally. The IEC standard also outline a procedure used for measuring the characteristic pressure ratio. Before the actual characteristic pressure ratio was obtained, knowledge of hydrodynamic flow theory was applied to predict a value for the constant. This value was first used for preliminary predictions of the control valve noise. After both pressure ratios were determined, the IEC standard equations were applied to obtain the sound pressure. These predicted values were then to be compared with the experimentally obtained data, and the model adjusted accordingly.

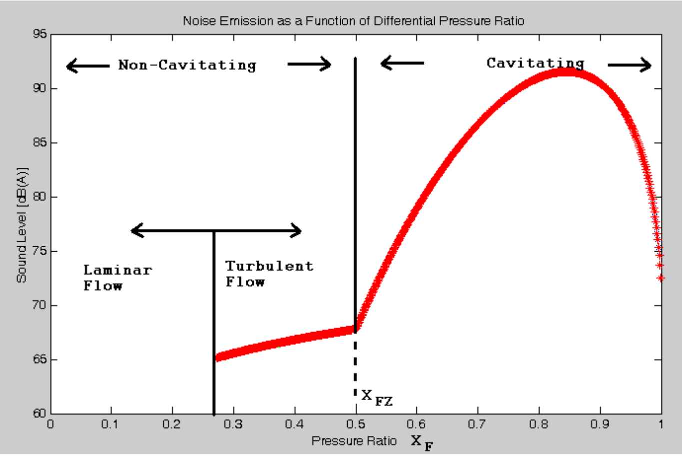


Figure 8. The characteristic pressure ratio, x_{F_z} marks the transition from non-cavitating to cavitating flow.

Instrumentation

The flow loop was fully instrumented to capture pressure and flow values at critical points. An electronic pressure transducer (Omega model PX202-3KGV) was located upstream of the test valve directly outside the anechoic chamber. The transducer was connected to the pipe through a snubber (Omega model PS-4E) to dampen out pressure fluctuations. A strain gauge display (Omega model DP25-s) was used to read pressures measured by the transducer. A second pressure gauge (McDaniel Controls, Inc. 0-3000 psi for hydrodynamic, USG Model 18941 for aerodynamic) was installed downstream of the test chamber to measure pressure drop across the test valve. A flow meter (Omege 0-15 gpm for hydrodynamic, King Instrument 0-56 SCFM for aerodynamic) was installed at the end of the flow loop, near the discharge. The noise from the test valve was measured using a Brüel & Kjær model 4189 microphone with a Brüel & Kjær model 2671 preamplifier. The microphone was calibrated using a Brüel & Kjær model 4231 94 dB Microphone Calibrator. Data acquisition and analysis was performed using the Brüel & Kjær PULSE system (type 7700).

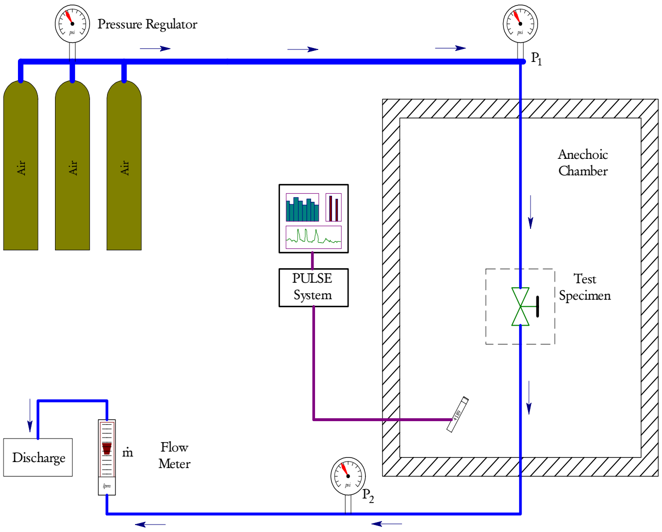


Figure 9. Aerodynamic loop

Hydrodynamic testing required a high-pressure water source. The water was pressurized using a piston pump (HYDRO model # 2359B-P) rated at 3000 psi. Attached to the pump was a dampening device (a fluid capacitor) to reduce pressure pulsations from the piston. The capacitor was a steel cylinder 3 inches in diameter and 18 inches tall. It was tapped at both ends to allow for a pipe connection. A pressure relief valve was installed downstream of the pump and set at 2600 psi (17.9 MPa). This effectively limited the maximum pressure available to the system. The piston pump produced a positive displacement; that is, it maintained a constant flow rate of 3.5 gpm (13.25 lpm) regardless of downstream pressure. To allow variations in flow rate through the test valve a discharge valve was added directly downstream from the pump. The discharge valve released a portion of the 3.5 gpm directly to the atmosphere; the remaining flow was sent through the test valve. A control valve (Swagelock model SS-3NBS-4G) was located downstream of the test chamber. By opening or closing the control valve, backpressure on the test valve could be increased and decreased.

Sound levels were taken for a 0.25 inch (6.35 mm) control valve and both aero- and hydrodynamic noise was measured.

The data were later used to adjust the computer prediction model.

Objective 2: To further validate the computer-modeling program for larger scale valve trims; a DFT control valve was installed at Rowan University Cogeneration plant.

It had been recognized in the early stages of the project that the Rowan University Cogeneration plant would be a particularly useful resource for the purposes of field-testing control valves. The Rowan University Cogeneration Plant is an on-campus facility that provides the school with power and steam.

Two students and a faculty member of the Chemical Engineering program worked in cooperation with personnel from Rowan Facilities, Public Safety and an outside contractor. Rowan Facilities was instrumental in defining the best location for the installation and in the operation of the testing loop. After careful considerations of all possible locations for this loop, an auxiliary 3" O.D boiler feed line was chosen. Under normal operating conditions, 40 GPM of treated boiler feed water at a pressure of 260 PSIG and a temperature of 210°F flows through this pipe segment. The chemical engineering students designed the loop and produced the drawings required by Public Safety and the outside contractor. Rowan Public safety was included to guarantee that the old asbestos-made insulation would be safely removed from the segment of pipe chosen. An outside contractor was responsible for manufacturing all the spool pieces needed and for the final installation of the valve and the flow meter. All distances between the test specimen and the instrumentation closely followed the guidelines given by the standard IEC 60534-8-2[9]

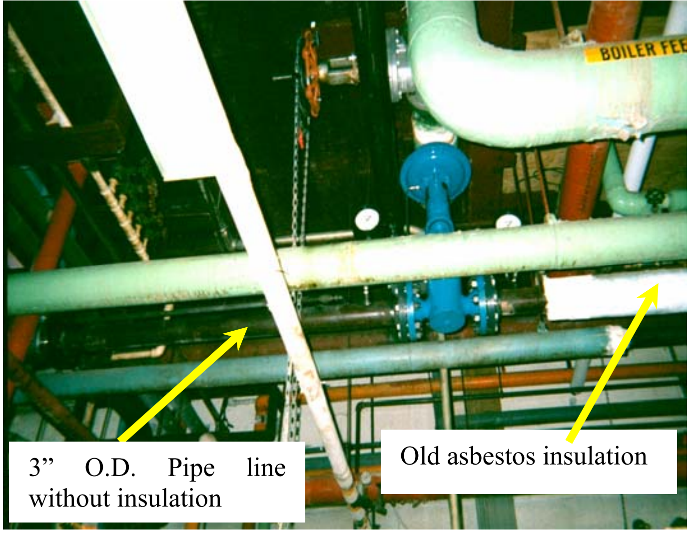
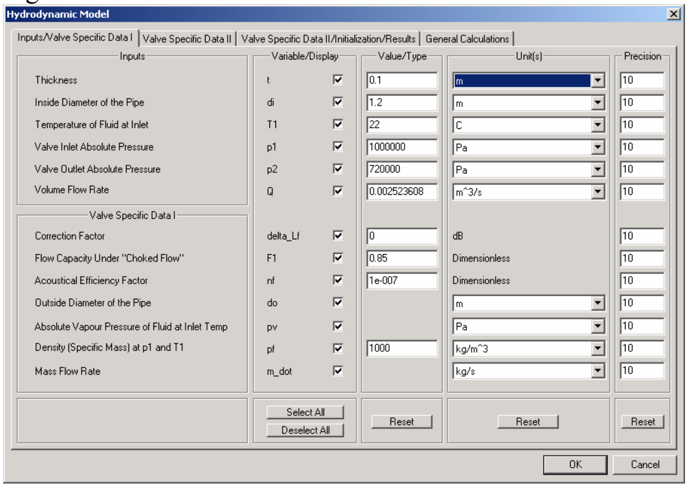


Figure 10. The DFT control valve is shown in blue.

In addition to the DFT control valve shown in Figure 10, the test section also contains pressure gauges manufactured by Trerice, with a 0-160 psi range and installed before and after the valve in order to measure the pressure drop across it. The ports for the pressure gauges were specified in accordance with IEC 60534-2-3[10]. In addition, an electromagnetic flowmeter, OMEGA FMG400, was installed in order to measure the flowrate through the test section. One reason a magnetic flow meter was chosen over other technologies was the absence of constrictions or other flow impinging internals, which could create additional noise.

Objective 3: As experimental data was been collected by the mechanical and chemical engineering clinic students, a group of students and faculty from the Electrical/Computer Engineering department was designing a computer program that could model both aero- and hydrodynamic noise. The computer models are SDI's (Single Document Interface). The SDI model was a sound choice that represents the true scope of the computer model: it provided the user with both working space and standard menu-driven functionality. The computer model allows for two types of analysis. The first analysis style is an absolute noise prediction. In this analysis mode the user is required to input both inlet and outlet valve pressure. The model will then make a noise prediction based specifically on these parameters. The second type of modeling that can take place is a pressure sweep. Here the user is required to enter only the inlet valve pressure. The downstream valve pressure is then varied internally in the model. A maximum valve noise prediction from the pressure sweep is then obtained. The user is also able to specify what outputs are truncated to the report. If the user wishes to see the intermediate variables involved in the calculations he or she is capable of doing so. If only the final output is desired that too can be printed.

One of the most important aspects in computer program design is to ensure the user-interface is as friendly as possible. Other portions of the interface are the toolbar and the menu systems. Buttons clearly define their nature and are available immediately to the user. In the case where the user may feel that the toolbar may be an unfortunate obstruction, an option in the menu system (under the view section) can toggle the visibility of the toolbar. A status bar is also in place as a forum for briefly describing what each button does in sentence form. A snapshot of a hydrodynamic example problem is shown in Figure 11.

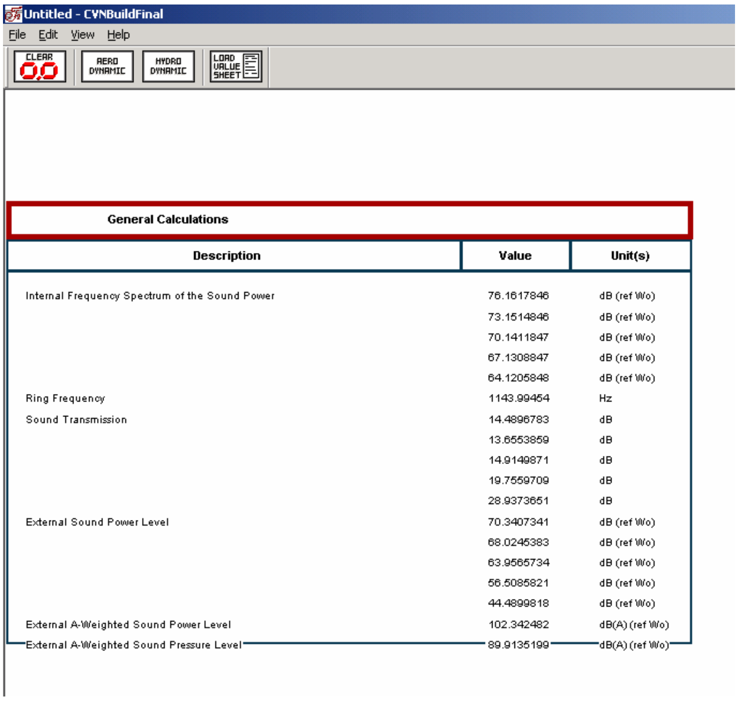


Inputs	Variable/Display		Value/Type	Unit(s)	Precision
Thickness	t	☑	0.1	m	10
Inside Diameter of the Pipe	di	☑	1.2	m	10
Temperature of Fluid at Inlet	T1	☑	22	C	10
Valve Inlet Absolute Pressure	p1	☑	1000000	Pa	10
Valve Outlet Absolute Pressure	p2	☑	720000	Pa	10
Volume Flow Rate	Q	☑	0.002523608	m^3/s	10
Valve Specific Data I					
Correction Factor	delta_Lf	☑	0	dB	10
Flow Capacity Under "Choked Flow"	F1	☑	0.85	Dimensionless	10
Acoustical Efficiency Factor	nf	☑	1e-007	Dimensionless	10
Outside Diameter of the Pipe	do	☑		m	10
Absolute Vapour Pressure of Fluid at Inlet Temp	pv	☑		Pa	10
Density (Specific Mass) at p1 and T1	pf	☑	1000	kg/m^3	10
Mass Flow Rate	m_dot	☑		kg/s	10

Figure 11. Input page for hydrodynamic model.

Results Obtained from the Computer Model

The IEC Standard for aerodynamic noise prediction[7] provides examples for each regime. The examples were used as default values for the input to the computer program. When input values were implemented, the results of the computer program matched the examples in the standards. It can then be concluded that the computer program properly predicts valve noise. Unlike aerodynamic flow, there are no examples available for the hydrodynamic noise prediction. The results obtained from field-testing needed to be compared with those that were obtained from the computer model. Certain values within the code needed to be adjusted so that the valve noise prediction was correctly calibrated. Extensive testing was performed to ensure accurate prediction of valve noise for differing valve types. Figure 12 shows the "General Calculations" output screen of the hydrodynamic model.



General Calculations

Description	Value	Unit(s)
Internal Frequency Spectrum of the Sound Power	76.1617846	dB (ref Wo)
	73.1514846	dB (ref Wo)
	70.1411847	dB (ref Wo)
	67.1308847	dB (ref Wo)
	64.1205848	dB (ref Wo)
Ring Frequency	1143.99454	Hz
Sound Transmission	14.4896783	dB
	13.6553859	dB
	14.9149871	dB
	19.7559709	dB
	28.9373651	dB
External Sound Power Level	70.3407341	dB (ref Wo)
	68.0245383	dB (ref Wo)
	63.9565734	dB (ref Wo)
	56.5085821	dB (ref Wo)
	44.4899818	dB (ref Wo)
External A-Weighted Sound Power Level	102.342482	dB(A) (ref Wo)
External A-Weighted Sound Pressure Level	89.9135199	dB(A) (ref Wo)

Figure 12. The program reports A- weighted sound pressure and sound power levels.

LEARNING OUTCOMES

The Junior/Senior Clinic model has proven to be very successful is providing students with a variety of skills that no typical lecture or lab course can provide. In this project-based course, the students have the opportunity to work in multidisciplinary teams. These multidisciplinary teams usually include engineering students but may also incorporate business, computer science, marketing, and other sciences majors. The multidisciplinary team environment provides the students with a unique working experience highly praised by industry and rarely found in new hires educated in traditional engineering programs. In the Control Valves project, the team included engineering students, utility-plant workers and managers, Rowan's public safety employees, and external contractors.

Although many of the projects are sponsored by industry, some are also funded through research grants from federal or state agencies such and the National Science Foundation, the Department of Energy, and the Environmental Protection Agency.

The engineering clinics learning objectives are quite broad, besides the exposure to working in multidisciplinary teams; the students learn how to perform professional literature searches, how to design and conduct experiments, learn about safety and environmental issues, analyze and interpret data, communicate through oral and written reports, and use modern engineering tools.

With industry project, students are provided with a budget to buy supplies and equipment. They have to specify the required equipment, obtained at least three quotes and produce the purchase requisition. They are also responsible to follow up on their orders and there is pressure to begin obtaining this equipment so that work can progressively move. This experience helps them develop managerial skills and gives them a flavor of the "working pressure" they will face in corporate life. The students have informal meetings with the sponsor at a frequency usually mandated by the nature of the project and the level of involvement desired by the company representatives. The students also meet once a week with the faculty advisors to analyze the progress made in the project and any issues that could be delaying it. Students are also required to submit an individual weekly journal, and also weekly memos and agendas for the following meeting. The purpose of the journal is to informally communicate with the advisors, and express any concern the students may have with the dynamics of the team. These journals help the faculty realize team-dynamics issues and to establish a course of action to solve any problems before the progress of project is jeopardized.

The Control Valves project received funding from the industrial sponsor and the university. In this projects the students activities included: developing a detailed literature review, designing of the flow loops for the co-generation plant and for the anechoic chamber, specifying, quoting and purchasing all parts required for both flow loops, designing an experimental plan for the co-generation data gathering and one for the anechoic chamber, collecting, processing and analyzing data, working with Rowan's Public Safety to ensure the removal of all asbestos insulation before any other work started.

The students from the three disciplines involved in the project had the opportunity to acquire certain technical knowledge not typically covered in their programs. For instance, the chemical engineering students learned about acoustics, noise measuring, noise generation in hydrodynamic and aerodynamic flow regimes, and cogeneration. They also had a hands-on learning experience in how to operate a boiler in a utility plant. The electrical and computer engineering students learned fluid mechanics topics such as fluid flow in pipes, compressible and incompressible flow, cavitation, flashing and chocked flow, design and operations of control valves and power generation in a steam plant.

All students gained experience in producing specific deliverables for an external industrial sponsor. They were also given the opportunity to present their work internally and externally [11].

CONCLUSIONS

A multidisciplinary engineering team provided DFT Inc. with a means of predicting the noise generated by their unique control valve design as a result of various flow conditions. As outcomes of this project a computer model to predict noise production for aerodynamic and hydrodynamic flows was developed, and a hydrodynamic flow testing apparatus was designed and installed at Rowan University Cogeneration Plant. This flow-testing loop provided the empirical data required by the computer model. In an effort to further validate the results of the computer models, an anechoic chamber was built in the high bay of Rowan Hall. This chamber allowed the testing of various smaller diameter valves for aerodynamic and hydrodynamic flow conditions.

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