T503 Environmental Test Chamber

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Abstract—**Our project goal is to design an air control system that attaches to a plastic chamber to test compressors at different temperatures and humidity levels. Compressors are parts of air-conditioners that compress a liquid to cool down and draw moisture from the air. Each one must work in the weather where it will be used. The main issues when testing them are air leaks and heat loss through the testing cell. Our design addresses this problem by putting the air control unit right next to the chamber. This reduces the needed amount of duct, which lessens air leaks and heat transfer. All cracks and holes seal tightly to create a closed volume of air, as well. These choices allow for accurate control of inner conditions within 15 minutes. The design also stops condensed water from building up by collecting and returning it to the humidifier. Our design improves an existing design by increasing the range of cooling, humidity, and mobility, and by lowering the heat lost to the surrounding air. It features a more powerful air chiller, humidifier, and two more heaters. Ducts from these pieces attach to the chamber's sidewalls and are easily removable. Putting the unit on the floor rather than a wall simplifies the previous design greatly. Sensors check the inner temperature and humidity levels to adjust to the user's wanted values. This achieves hands-free testing in harsh and mild settings. Testing the compressor's performance in each condition allows the user to find out its abilities before selling or using it. Since the system is mobile, it can attach to any large box for testing devices in common weather. In this way, our project has wide application and can help many industries.**

I. Nomenclature

Notation	***Definition***
AHU	Air Handling Unit
A/C	Air Conditioning
C	Celcius
COE	College of Engineering
F	Fahrenheit
$FAMU$	Florida Agricultural & Mechanical University
FSU	Florida State University
$HVAC$	Heating, Ventilation, and Air Conditioning
RGB	Red Green Blue
RH	Relative Humidity

II. Introduction

A. Project Objective

This project aims to validate the existing design of an environmental testing chamber and deliver an assembly that monitors and regulates its internal temperature and humidity for use in a laboratory environment.

B. Key Goals

The goals of this project are to validate, finalize, and implement the chamber design. These include conducting a thorough heat balance analysis, modifying and finalizing the hardware and software, and overseeing the construction of the final product. The chamber is desired to be capable of fluctuating from conditions ranging from 10°C to 50°C and 0-95% relative humidity within 15 minutes. Other goals are that the compressor can be seen during testing and can be easily accessed. The final goal is to deliver a system capable of long-term testing of Danfoss Turbocor compressors.

C. Assumptions

Some assumptions were made about this project to limit its scope and maintain focus on achieving the key goals. It is assumed that the design will rest on a flat test rig that rests on a level surface. There will be access to machining services and multiple power sources, including a 110V power outlet. Another presumption is that the compressor's conductive heat is small enough to be considered negligible and hence unaccounted for. It is also assumed that the user has access to a crane capable of lifting and lowering the compressor into the test chamber. The existing support for the test chamber is assumed to have sufficient load capacity for the compressor, and the compressor's size remains the same. These assumptions allow for concentration on the content and challenges of this project's scope.

III. Targets and Metrics

A. Support

The sole targets for this system were for the walls to support all equipment (10 lbs) and air ducts (5 lbs). These targets were validated by attaching all duct flanges, screws, wing nuts, and ducts, and observing the short term and long term effects of the attachments.

B. Control

The first control targets were to monitor the temperature and humidity within 1°C and 1% of the true values. These were validated using a thermometer and hygrometer respectively. The system must also be capable of adding and removing heat from the control volume (to reach 10°C to 50°C) and increasing and decreasing humidity (to reach 0% to 95%).

These were also validated using a thermometer and hygrometer. Another control target was to regulate the circulation of air in the chamber to ensure adequate air is provided to the control volume to produce desired conditions. The air flow needed to be at least 1 ft^3/m. To validate the flow rate, a pitot tube was placed at each outlet of the A/C unit, and the flow rate was calculated using this velocity readings and the known cross-sectional area of the ducts. The system also needed to be able to achieve its designated targets within 15 minutes. The time response target was validated using a stopwatch.

C. Accessibility

The first target for accessibility was to make sure that the inside of the chamber is visible at all times and from at least 3 sides, which was validated through observation of the system at all humidity settings. The other accessibility target was to achieve no direct human interaction with the system other than to input desired temperature and humidity values. The method of validation was observing the system in use. Additionally, the system could not be intrusive to the parts already in place. To achieve an unobtrusive system, another target is to allow the system to be fully install-able and removable within a 15 minute time frame. This target will be validated once the system is installed at the Danfoss lab facility.

IV. Results and Discussion

Fig. 1. Assembled system prototype.

The following sections outline the targets and their respective results for each system, along with percent error.

A. Support

Function	**Target**	**Result**
Support Equipment	10 lbs	Success
Support Ducts	5 lbs	Success

B. Control

Function	**Target**	**Result**
Monitor Temperature	Within 1°C	Success
Monitor Relative Humidity	Within 1%	Failure Error: 1%
Add Heat	50°C	Success
Provide Cooling	10°C	Failure Error: 2%
Increase Relative Humidity	95% RH	Success
Decrease Relative Humidity	0% RH	Failure 15%
Regulate Air Circulation	1 ft^3/m	Success

C. Accessibility

Function	**Target**	**Result**
Provide Clear View	3 sides	Success
Adjust Conditions	No human Interaction	Success

As shown by the results above, the system (Fig. 1) was mostly successful, with small errors in monitoring the humidity and providing cooling. The 1% error in monitoring humidity was due to the failure of one of the humidity sensors to work, while the other was limited to 2% accuracy. The cooling error was also due to component limitations, since the A/C unit only output air at 12°C, contradictory to its listed capability of 0°C. The largest error, decreasing humidity, was due to physical and budget limitations. In order to reach 0% relative humidity at 10°C, the refrigerant in the coils of the cooling unit must be cooled to extremely low temperatures to extract all moisture from the air, which a unit within our given budget is incapable of. However, the system would be able to reach lower relative humidities at temperatures higher than 50°C.

D. Observations

One noteworthy observation made during testing was that there is little condensation buildup on the bottom of the chamber, even when the air was fully saturated. However, when the system is run for long periods of time, the condensation collection system will drain this water and refill the humidifier. At 95% humidity, dark objects can still be seen from all three sides, meaning the compressor will remain visible throughout testing at test rig 12. It is also worth noting that the servo controlling the A/C power occasionally fails to press the button hard enough, causing a system error. To account for this problem, a pitot tube should be placed in the duct work to determine when air is being supplied, and adjust accordingly. Finally, the system was able to achieve up to 55°C in the 15-minute time constraint, allowing for testing at the hottest temperatures recorded on Earth.

V. Conclusion

The targets of this project were within 2% of intended values overall. The environmental test chamber successfully met 8 out of the 11 total targets and is completely autonomous following user input. While not all values were achieved, the system still performed quickly while within the ranges that it was capable of, reaching its extremes in 15 minutes or less. Overall, the project delivered a system that can regulate the internal humidity and temperature of a chamber to a range of desired values. The simple control panel (Fig. 2) allows for straightforward operation, and the system can be scaled to larger control volumes with minor modifications.

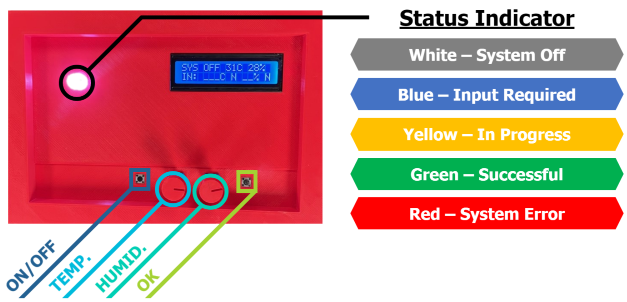

Fig. 2. System control panel and its components.

A. Errors

The prototype created by the team is a model of part of the existing test rig at the Danfoss Turbocor lab facility where the system will be implemented. There are air leaks due to the nature of the plastic tote, differences in materials and structure from the test rig itself, and a lack of a condensation collection system that would be installed in the lab facility. Due to these variances, there are disparities in the demonstration and validation of the prototype. To decrease current errors further, more accurate temperature and humidity sensors should be installed and the control volume should be sealed as tightly as possible. Other errors are due to discrepancies between the listed capabilities of the current A/C unit and its true capabilities. The system is capable of maintaining the temperature and humidity within 2°C and 2% RH of the desired values, which is reasonable considering the wide range of potential conditions. These slight fluctuations also reflect what compressors encounter in real-world environments.

B. Future Work

In the future, the system would ideally be relocated to the Danfoss Turbocor lab and implemented into test rig 12. It would then be tested to determine any further improvements to the design, and tuned to account for the difference in volume and air leaks. In order to make the move as swift and easy as possible, a plexiglass wall the same size as the one at the lab will be drilled for use with our system. This includes three holes of 5” diameters surrounded by six 1/4” holes, and one 3” hole for the humidifier. To do this, the dimensions for the plexiglass wall of the chamber have been requested from Danfoss and will be necessary to determine what size to cut the plexiglass down to. Additionally, the condensation collection system would need to be implemented by measuring the location of the compressor stand and creating a sloped funnel made out of clear vinyl. At the bottom of the funnel, our tubing would attach and be routed to the humidifier tank.

In following stages of this project, sensors with higher accuracy should be implemented to optimize system performance. The control of the A/C unit could also be improved by adding a permanent solution to pressing and holding its power button which is more easily removable. The next design iteration should also aim to group all system components into one mobile system. This is essential in developing a system which can be applied to any test rig or control volume for purposes of testing a wide range of materials and equipment at the listed conditions.

To improve the system’s scalability, other design aspects should also be modified. For instance, wireless communication between sensors, servos, and the microprocessor should be considered to improve portability and reduce obstruction with existing equipment. All 3D-printed parts could be switched to fabricated parts of higher quality. Other solutions could also be implemented to further decrease the cooling and dehumidifying capabilities. Such changes would allow for a more useful and versatile design.

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