Risk Assessment
Safety Plan

Project information:

Danfoss Turbocor Compressor Inlet Sting Apparatus		Date of submission
Dynamic real-time monitoring and recording of compressor inlet guide vane operations		March 2, 2018

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Faculty mentor	Phone Number	e-mail
William Bilbow	N/A	william.bilbow@danfoss.com
Shayne McConomy	N/A	smcconomy@eng.famu.fsu.edu
Kunihiko Taira	N/A	ktaira@fsu.edu
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I. Project description:

Our project provides Danfoss Turbocor with a method of real time monitoring and recording of the Inlet Guide Vanes (IGVs) at the front of the compressor to help determine the failure modes for the IGVs. It achieves this through a camera placed in front of the inlet in an aerodynamic housing spanning the diameter of the pipe. This housing acts as a sealed chamber that the camera sits in which protects it from the refrigerant flowing through the inlet pipe. The lighting for the vanes is provided by integrated lights in the video scope which shine through the sight glass at the front of the housing. To determine the angle of the IGVs, April Tag codes placed on the IGVs will be read in by the camera. These codes will either be placed on the vanes using stickers or painted directly onto the vanes using refrigerant resistant paint. With these codes on the vanes, computer software with access to the camera feed will be able to approximate the angle of the IGVs.

II. Describe the steps for your project:

When installing the system into the testing loop, the first step is to attach the tags to the IGVs at the front of the compressor. Then the front flange is connected to the front of the compressor, and the rear of the system is connected to the rest of the refrigerant loop with a brazing process. Once the system is integrated into the testing loop, the camera can be inserted into the top of the camera housing until it is resting in front of the sight glass. Then the camera is connected to the computer at the Danfoss testing facilities where the video feed is processed to output the angle of the vanes. Once testing is complete, the camera will be disconnected from the computer and removed from the housing. The pipe section can then be removed from the testing loop by disconnecting the flange connection and breaking the brazed connection at the rear. Finally, the tags can be removed now that the inlet of the compressor is exposed.

III. Given that many accidents result from an unexpected reaction or event, go back through the steps of the project and imagine what could go wrong to make what seems to be a safe and well-regulated process turn into one that could result in an accident. (See examples)

There are limited risks while installing and removing the device in the test lab that could cause significant damage, more of the risks occur while the compressor is running and the camera is recording a video feed while inside the housing where none of the previous steps are taking place and where no action is required. However, some of the risks associated with the installation include: the flange or braze seal at the front and rear of the compressor not being sealed correctly, the camera being damaged while being inserted to the housing, and incorrectly attaching the tags to the inlet guide vanes.

IV. Perform online research to identify any accidents that have occurred using your materials, equipment or process. State how you could avoid having this hazardous situation arise in your project.

There are quite a few accidents that could occur while the system is running that we have identified from some online research and extensive discussions with Danfoss. The largest risk associated with our project is that the sight glass of the camera housing fails. This can happen in a few different ways. The first is where the sight glass breaks and shatters due to the pressure differences on either side of the sight glass. A shattered sight glass could expose the compressor to small glass particles entering the inlet flow and damaging the IGVs or the impellers. The other failure mode of the sight glass occurs if the epoxy holding the sight glass in place fails causing the entire sight glass to enter the front of the compressor. This would cause more damage than the shattered sight glass since a larger particle is entering the compressor. In both of these scenarios, the camera could be damaged due refrigerant exposure in the pipe. This risk could be mitigated by modifying the design so that there is a mechanical constraint to keep the sight glass from popping out as a single piece. Additionally, the thickness of the glass could be increased to have a larger safety factor with respect to the pressures. Another risk associated with our project is if our tags on the IGVs fail. With both stickers or paint the risk of damaging the compressor is minimal since none of the materials used will be strong enough to damage the impellers. Instead, there is the risk of contaminating the refrigerant in the loop and the associated time required to reapply the tags to the IGVs. This risk could be mitigated by etching the required patters directly into the vanes which would add some time to the installation and could impact the fluid dynamics of the vanes in operation.

V. For each identified hazard or "what if" situation noted above, describe one or more measures that will be taken to mitigate the hazard. (See examples of engineering controls, administrative controls, special work practices and PPE).

For the risks associated with the sight glass, we will conduct testing with sample sight glasses in an effort to provide Danfoss with estimates in the lifespan of the glass and the epoxy. Additionally, we will include inspection steps in our installation procedure to make sure that there are no cracks in the sight glass or gaps in the epoxy before being installed to the refrigerant loop. We will also suggest that the compressor loop should be turned on and allowed to run for a few minutes before inserting the camera so that any problems identified with the housing can be fixed before the camera is inserted and potentially damaged. Waiting to insert the camera will also allow the testing facility to validate the flange connection and braze connection at the front and back of the device. For the IGV tags, we will make sure to use materials that do not contaminate the refrigerant and test our final tag materials in refrigerant to provide Danfoss with an estimate for the frequency at which the tags need to be replaced.

VI. Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").

When installing the system into the testing loop, the first step is to visually inspect the sight glass to determine that there are no cracks in the glass and no gaps in the epoxy between the glass and the brass. Then attach the tags to the IGVs at the front of the compressor. After inspecting the glass and attaching the tags, the front flange is connected to the front of the compressor, and the rear of the system is connected to the rest of the refrigerant loop with a brazing process. Once the system is integrated into the testing loop, the compressor should be turned on and allowed run for a few minutes to make sure that the sight glass stays in place and that the connections to the rest of the loop at the front and rear have been sealed properly. The camera can then be inserted into the top of the camera housing until it is resting in front of the sight glass. Then the camera is connected to the computer at the Danfoss testing facilities where the video feed is processed to output the angle of the vanes. If the system is installed for extended periods of time, the tags or sight glass may need to be replaced to mitigate any risk of failure. Once testing is complete, the camera will be disconnected from the computer and removed from the housing. The pipe section can then be removed from the testing loop by disconnecting the flange connection and breaking the brazed connection at the rear. Finally, the tags can be removed now that the inlet of the compressor is exposed.

VII. Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.

The emergency response procedure is the same for failure of the April tags and for failure of the sight glass. If one of these failures occur, the compressor should be shut down immediately and the camera needs to be removed from the housing. Once the compressor has come to rest, the refrigerant loop needs to be drained. Once everything is off and the loop is drained, the device can be disconnected from the loop and the April tags or the sight glass can be inspected and fixed. If the camera fails and the sight glass and the April tags have not failed, then the compressor does not need to be shutdown. Instead, the camera can just be removed from the housing and inspected to see if it can be fixed or if it needs to be replaced.

VIII. List emergency response contact information:

- Call 911 for injuries, fires or other emergency situations
- Call your department representative to report a facility concern

Name	Phone Number	Faculty or other COE emergency contact	Phone Number
Arnold Schaefer	(561) 578-7771	William Bilbow	N/A
Brandon Klenck	(321) 544-0026	Shayne McConomy	N/A
Travis Carter	(407) 414-9447	Kunihiko Taira	N/A
Peter House	(850) 566-3098	Obiechina Abakporo	N/A

IX. Safety review signatures

- Faculty Review update (required for project changes and as specified by faculty mentor)
- Updated safety reviews should occur for the following reasons:
  1. Faculty requires second review by this date:
  2. Faculty requires discussion and possibly a new safety review BEFORE proceeding with step(s)
  3. An accident or unexpected event has occurred (these must be reported to the faculty, who will decide if a new safety review should be performed.
  4. Changes have been made to the project.

Team Member	Date	Faculty mentor	Date
Arnold Schaefer	March 1, 2018		
Brandon Klenck	March 1, 2018		
Travis Carter	March 1, 2018		
Peter House	March 1, 2018		

Report all accidents and near misses to faculty mentor.