EML4551 – Senior Design Project 1
Designation: Group 1 – Danfoss-Turbocor Labyrinth Seal Test Rig
Fall 2008

December 1st, 2008
Subject: Proposed Work for Spring

The labyrinth seal test rig project is expected to span the time period from last August 2008 to early April of 2009. The project has been divided into a design phase and a physical phase, with the first taking place up to early December 2008. The second half of the allotted time, from early January to early April of 2009, will be spent acquiring the physical components of the design, assembling the test rig, running the test rig, gathering data, analyzing data, and presenting conclusions to the project sponsor.

The first half of the allotted time ended early December with completed engineering drawings of all of the parts and a list of the required raw materials and corresponding raw material providers. In addition to those raw material needs, certain vendor products also have been listed for purchase such as pressure and flow sensors, bearings, O-rings, brass piping connectors (such as T-connectors), screws, bolts, washers, nuts, and Teflon pipe tape. The raw materials and vendor products will be ordered during mid-to-late December. The raw materials will need to be machined to meet the project's design needs, though some of this machine work may be outsourced (more research required). In particular, a provider of welding services may be sought. It would be ideal that the parts arrive in early January.

Machining
Once the parts have arrived, the raw materials will need to be machined to meet the design specifications. This will require space in a machine shop's time budget. Most of the machining will take place in the sponsor's machine shop. Most parts are cylindrical in shape and will be lathed to proper dimensions. There are also several threaded screw holes that must be created on either a lathe or a milling machine. There are a few parts that require toleranced, straight grooves, and this will also be machined on a milling machine. Once the parts have been machined they will be test-fitted and tolerances will be checked. The machining of the raw materials is expected to be completed by early-to-mid February, 2009.
Once it has been verified that the machined dimensions for the labyrinth-seal's standardized connection are true, a labyrinth-seal billet design (un-machined with standardized bolt holes) should be given to Danfoss-Turbocor so that they can machine labyrinth seals for the rig to test once the rig is assembled. The rig can be assembled independent of the machining of the labyrinth seals to be tested, and so this task should be held-off until the assembly parts have been machined.

Assembly
With all of the parts machined the test rig can be assembled. The design completed in December included assembly considerations that are now critical. The bearings and shaft, and the differential threaded mechanism, have particularly complex assembly instructions. The particulars of critical assembly are as follows: for the shaft and bearings, the thrust bearing will be mounted to the reference, the shaft will be mounted to the thrust bearing, then the low-pressure enclosure will be placed over the shaft and the radial bearings placed over the shaft and pressed into the low-pressure bearing mount. For the differential threaded mechanism, the dual-threaded screw will be screwed into its respective flange and then the smaller screw will be screwed into the dual-threaded screw. The smaller screw will then be permanently attached to a push plate that will indirectly attach to the labyrinth seal. The dual-threaded screw flange is a sliding component that will be freely attached to the reference.

O-rings will be lightly greased with a compatible sealing lubricant and will be placed in their respective glands (grooves). The surfaces that will be sliding against each other, for the alignment to achieve concentricity, will be lightly lubricated.
All of the threaded attachments for the pressure components will be lightly wrapped in Teflon tape to ensure an air-tight seal. This practice is common in plumbing applications and can be applied for air applications as well. The threaded attachments will be screwed into their respective locations, being careful not to over-tighten, but still be tight enough to create an air-tight seal. A raw labyrinth seal billet (un-machined billet with adaptor holes to attach to the test rig) will be put in place; it will not allow a leak because it is solid metal. The test rig will then be pressurized and a light, soapy solution will be lightly applied to check for leaks on the screwed-in, Teflon-taped parts. The Teflon-taped parts have been found to be more likely to leak than o-rings (due to initial under-tightening of screws or inadequate application of Teflon tape). The o-rings and corresponding glands have been designed so that the o-ring deforms as the parts are connected with bolting. With the o-rings deforming into the glands, and vacuum grease filling microscopic imperfections in the metal, the seal is air-tight up to pressures that extrude the o-ring through out of the gland. If the Teflon-taped parts are found to be leaking, they will be tightened slightly and re-checked. If they still leak they will be marked for re-tape after they have all been checked. The rig will then be decompressed by turning off the supply and slightly loosening the low-pressure side of the regulator so that a leak occurs. Any threaded parts marked for re-tape will then be disassembled, re-wrapped with Teflon tape, and reassembled. The leak check will be repeated until all leaks have been fixed (bubble solution no longer creates bubbles). If the screwed parts are found to be without leak, the seal of the o-rings can be checked by pressurizing the chamber, cutting off supply, and then watching for a decrease in chamber pressure over a period of time.
With the rig checked for leaks and found to be air-tight at design pressure it can be assumed that flow moves only though the labyrinth-seal to be tested.

Data Collection
In addition to the physical aspects of the system, there will also be data collection. The data will be collected electronically from sensors applied to system components. The sensors will communicate a pressure, temperature, or flow state, depending upon the type of sensor. The communication will be in the form of varying electrical voltage or current (but not both). The type of system, either voltage or current variance, is decided upon by the project sponsor Danfoss-Turbocor as they will be supplying some of the sensors, and all of the sensors should be compatible. The sensors will connect to an electrical hub designed specifically to provide a data conveyance to a computer. This hub will be purchased from a vendor. The hub will connect to a computer through a USB or parallel-port connection. The raw data being fed into the computer through the connection must be interpreted by software. The software that the project group has decided to use is “LabView.” A student copy or a copy provided from Danfoss-Turbocor will be used. The group will need to acquire knowledge in order to use the software. The software requires the user to have mild computer programming experience. Once the group has created the interface with Labview, data should be able to be collected. The data will be collected with LabView and exported into a text-based, comma-delimited data file. This data file is expected to be able to be imported into Microsoft Excel for further analysis.
The entire process of developing the data collection system can and will be conducted in parallel to the machining operations’ time frame. This will allow the data collection system to be ready at the same time as the system is assembled and leak-proofed.

Conclusions Drawn from Data Analysis

The data analysis may yield many conclusions. Some of the expected conclusions pertain to numerical values for maximum flow rate through a particular design of labyrinth seal. Other conclusions will be drawn from the ability of found flow-predicting equations to accurately and precisely predict the experimental, statistical flow values. Conclusions will be made to the project sponsor and are top secret. People die over this kind of information. The Death Star is fully operational, despite what information the rebels may have!

Special Concerns

Due to uncertainties in predicted flow, the purchase of a flow meter may be held off until an accurate measurement of the flow from a mass-change calculation can be performed. This particularity of circumstance has occurred out of concern for the cost and applicable flow range of flow meters: if the flow is outside of the flow range of the meter, the meter could be rendered ineffective at measuring the flow and the funding for purchasing a new flow meter may be unavailable. This issue may be exacerbated if time-frame limitations do not allow for purchase and delivery of the flow meter by a to-be-defined deadline.