PURDUE UNIVERSITY

PROFESSIONAL PRACTICE PROGRAMS

STUDENT WORK REPORT

Co-Op Student Information

Date: 05/06/2015

Student Name: Osama S. Alraddadi

Student Signature: [signature]

Student Email: OSA @ purdue.edu

School/Discipline: School of Engineering Technology /MET

Please circle your current work session:

- 3-session – 1 2 3
- 5-session – 1 2 3 4 5
- Master (1)

Co-Op Employer Information

Does the Work Report contain Proprietary Information? Y or (N) (please circle one)

May Purdue post the Work Report on the OPP website? (Y) or N (please circle one)

Co-op Employer: LENNOX INTERNITIONAL INC.

Supervisor Name: PRAVEEN VALLURUPALLI

Supervisor Signature: [signature]

Summary:

The first session of the co-op training for the trainee, Osama S. Alraddadi, began in Jan-12-2015 in the Residential Heating Platform at the Product Development and Research facility of Lennox International. The trainee was appointed as a Mechanical Engineering Co-op to mostly work on gas furnaces and their related components. The assignment had four goals to be accomplished by the end of the two sessions (i.e., August-2015) and they were defined by the manager of the heating platform. The goals contained two independent projects and several supporting tasks for other projects. For the first session, the independent project was setting up a test bench with a data acquisition system to perform an automated cyclic test on gas valves while collecting various measurements. The supporting tasks were also focused on the testing and reliability areas. The trainee performed various types of tests such as quantifying flow characteristics by using wind-tunnel and measuring leakage rates of certain components to investigate their compliance with the American National Standards. The trainee gained various skills during the co-op such as LabVIEW programming, hands-on experience and data analysis. The trainee believes that this experience is noteworthy and he has gained both knowledge and experience more that has exceeded his expectations.

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1- Introduction

Lennox International Inc. (LLI) is a provider of heating, cooling, ventilation and air conditioning (HVAC) products. LII's headquarter is located in Richardson, Texas, while its manufacturing facilities are located in both Marshalltown, Iowa and Saltillo, Mexico. In Carrollton, Texas, the Product Development and Research (PR&R) facility is located. PD&R serves both residential heating and cooling, and commercial heating and cooling. PD&R is responsible for all the product development stages from ideas and designs to prototypes and tests. Reliability, controls, and applied research are also a part of PD&R. The trainee was appointed in the residential heating platform at PD&R to join a team of 10 members of engineers, engineering aide, principal engineer, CAD designers and the manager, Praveen Vallurupalli.

Different resources were allocated to the trainee as well as a training plan was assigned. The trainee was given an equal space as everyone else with all necessary supplies to perform the required tasks. The trainee was also assigned for several trainings that were led by his team members. The training covered combustion theory and application, different types of heating products at LII, general development of engineering processes at LII, laboratory tours and introduction to the available resources at PD&R facility. The trainee was also assigned to a direct supervisor, Ray Wojcieson, a Sr. Principal Engineer at the residential heating platform. All the projects were supervised by Engineer Wojcieson except some of the supporting tasks for other projects.

The manager of the residential heating platform established a performance plan for the trainee. The plan included four different goals and objectives for the two sessions training (i.e., Spring-2015 and Summer-2015). The goals include projects and supporting tasks that the trainee has to complete during his training. The trainee was assigned to two independent projects that are two of the four goals. The first project, which is discussed in the following section, should be completed during the first session. The second project, which is discussed in the future projects at the end of this report, is expected to be completed during the second session. The supporting tasks, on the other hand, are continuous and they are based on the need and demand from other projects in the residential heating platform. The supporting tasks cover two of the other goals and objectives, and they are discussed in more details in the third section of this report.

2- Independent Project: The Gas Rig

One of the main components of gas furnaces is the gas valve (GV) that regulates the upstream pressure to a desired downstream pressure. Based on the furnace model, LLI uses three different types of GVs in their residential heating units: (i) modulating, (ii) two-stage, and (iii) single-stage. The modulating GV regulates pressure to provide any firing rate between 35% and 100% of the total heating capacity of the furnace. The demand of different firing comes from a signal pressure that a combustion air inducer supplies to a special port on the modulating GV. The two-stage GV has only two preset firing rates that are high firing rate or low firing rate. The change between high rate and low rate is controlled by an electrical signal from the control board of the gas furnace. The single stage GV has only one firing rate which provides the maximum firing rate of the furnace. As all the valves functions differently and

manufactured to LII by different suppliers, the GVs need to be tested in order to ensure that they meet with LLI's standards and specifications. Testing the GVs was assigned to the trainee as an independent project on his first session (i.e., Spring-2015), where the project timeline is shown in table-1. The trainee was asked to build a test rig for the GVs and develop a LabVIEW application that performs the test and collects data autonomously.

Table 1 - Gas Rig Project Timeline

	January	February	March	April	May
Software Development					
Building Gas Rig					
Data Acquisition Setup					
Documentation					
Testing, Analysis & Reports				*Ongoing until August*	

The gas rig's goal was to test the three different types of GVs according to the manufacturer's procedure. The approach was to perform a cyclic test in which the GVs are opened, pressure measurements are taken, and then GVs are closed as a one cycle. In the case of modulating and two-stage GVs, all stages are tested within one cycle and pressure readings are collected at each stage. The manifold pressure measurements are the main indicator of valve's functionality as manufacturers specifies the expected manifold pressure ranges of all valves, and at any stage. The manufacturer also specifies other testing standards such as the acceptable range of upstream pressure and the size of the downstream orifice, which were all implemented into the design of the test rig. Based on all the previously mentioned specifications, the gas rig was designed by the trainee and built by the model shop at PD&R. During the same time, the trainee was developing a data acquisition system (DAQ) to operate the GVs as well as to collect the different measurements. The DAQ uses National Instruments (NI) modules, solid-state relays and transformers. The methodology of the test and all the critical steps were defined and approved by the direct supervisor of the trainee.

In the beginning of April, the first test was performed and the results were analyzed. The trainee developed reports for the results that include different graphical and statistical analyses. The analyses helped the residential heating team to thoroughly understand how the GVs operate under different circumstances. The trainee completed his main task within the defined timeline. Testing GVs and analyzing data will continue until confidence in the results is achieved for each type of the GVs. The gas rig project was very beneficial for the trainee as he acquired various skills such as LabVIEW programming, hands-on experience (e.g., electrical wiring), testing skills and data analysis techniques.

3- Supporting Tasks:

The trainee was assigned to ongoing projects in the residential heating platform where he performed specific tasks based on the need of these projects. During the Spring-2015 session, the trainee participated into three different supporting tasks: NOx project, Leak Testing and Warranty Claims.

i- NO_x Project

Recently, air quality standards in different parts of the United States have new requirements for the acceptable amount of NO_x (nitrous oxide) that is produced from different heating equipment. Therefore, LII is upgrading their heating units to meet with these standards. A possible change due to the gas furnace upgrade is the burner, where the combustion process takes a place. Downstream the burner, there is a combustion air inducer that creates a vacuum pressure to pull both gas and air through the burner before ignition. Hence, the pressure drop across the burner becomes an important criterion in selecting the optimal burner. As a part of the first session of the co-op training, the trainee was assigned to the NO_x project to quantify the flow and pressure characteristics of different burners.

To evaluate the different burners, a small wind tunnel was used. A vacuum pressure was applied at one side of the tunnel while a burner was attached to the other side. The pressure drop across a known-size orifice-plate, which was placed inside the tunnel, was measured. By using Bernoulli's equation, the air flow rate across each burner at different vacuum pressure was calculated. The results of this test assisted in evaluating the required vacuum pressure at the downstream of each burner in order to achieve desirable flow rates. The flow rates are important because they are directly related to the rate of input energy to the heat-exchangers, which are different based on the size of the heat-exchanger. The burner with the least restriction would provide enough rate of energy (BTU/hour) to the heat-exchanger without overloading the combustion air inducer. In spite of that, the flow and pressure characteristics are not the only criteria in choosing the optimal burner. Inflammability, size and noise, for instance, are some of the other criteria.

ii- Leakage testing

Another task was assigned to the trainee during his first co-op session was leakage testing for different components such as heat-exchangers. Heat exchangers of the gas furnace have an allowable leakage rate that is defined by the American National Standards Institute (ANSI). The trainee was assigned to test clamshell heat-exchangers for its leakage rate after a changing its material. The test was carried by pressurizing each clamshell of the heat exchanger with air to a specified pressure that ANSI defined in its procedure for testing the leakage rate. The supply pressure to the inlet side of the heat exchanger passes through a flow meter, while the outlet side is connected to a manometer. The change in the reading of the flow meter after a known amount of time gives the leakage rate. Ambient temperature, relative humidity, and barometric pressure are

also taken into account when the test is performed. The trainee performed the test on several heat-exchangers as well as other components of the gas furnace.

iii- Warranty Analysis

As part of any consumer market, there are always warranty claims and returned parts. When a problem becomes prominent at LLI, the returned parts are sent directly to the reliability team at the PD&R to further investigate the problem. During the first session of the co-op training, the trainee was assigned a task work with one of the Mechanical Reliability Engineers. The task was to gather all available information of various returned components. Each returned component was also inspected by the trainee for any visible defects. Once data were collected and observations were noted, the trainee performed basic statistical analysis and data entry. The Reliability Engineer, on the other hand, performed more sophisticated failure analyses. The trainee did not apply any of the failure analyses himself nor did he use its tools but he was exposed to them by the Reliability Engineer.

4- Future project

In the next session, summer-2015, the trainee will continue to work on the same supporting tasks as well as he will be working on a new independent project. The project is an extended version of the gas rig. Instead of testing the gas valve as a single component, the gas valve will be installed in actual gas furnace and the whole system will be monitored. The trainee will develop a more complex LabVIEW software and data acquisition system to monitor all the electrical and mechanical variables. The goal is to understand how the introduction of a new component would affect the system normal operating conditions.

5- Conclusion

The first session of the co-op training at LII was a remarkable experience for the trainee. Applying the classroom knowledge into practical applications and filling the gap between theory and practice were certain advantages of this co-op training. Gaining new skills such as LabVIEW programming, hands-on experience, data analyses and setting up test benches were highly beneficial to the trainee. The trainee also aims to turn the wheel and apply his co-op experience towards his research work at Purdue University. The experience as a whole will definitely be a major factor in determining the trainee's future career goals.