T: ____/100Marks Due: End of class the day after the date at the bottom of this page

Process Design: Introduction to Control Systems

CONTENTS

1 Expectations: The Student will:

1. Information Processing:
   - Describe concepts that are relevant to control of systems and processes in general
   - Categorize or group certain concepts together in order to focus in on conventional applications of control systems
   - Distinguish between a general descriptor / general term and specific examples of that general case
2. Planning
   - Apply the research portion of the design process to develop a conceptual solution for a particular product sub-system (refer to the pressurized air system example below).
3. Inquiring / Investigating / Problem-Solving
   - Hypothesize on a product solution, filter through a mass of valid yet unordered input information and apply the most relevant new concepts to the solution idea in an orderly written and in visual formats.
   - Consider the shear volume of control-related concepts in the table below... which concepts really apply to your problem situation?
   - For example: Consider a solar heat-treatment kiln with supplementary heating for overnight use. Which concepts do you really need to explore more deeply in order to…
     i. Get the kiln temperature "up to" the required value in the worst-case locations.
     ii. Prevent over-heating -- where the concern is safety
     iii. Prevent over-heating – where the concern is to not waste money
     iv. Turn on supplementary heat if the temperature drops below a certain level
     v. Minimize heat loss during non-solar-gain periods
     vi. And otherwise control temperature and air-flow in order to distribute heat energy throughout the kiln as uniformly as possible
   - Or… consider some problem that you would like to solve or an opportunity you would like to realize
     i. You could conceptualize a solution around this issue and do a mock up prototype in the shop for your culminating ISU

2 This Sub-Module is Important Because:

- People can die if there is insufficient attention to safety controls. In fact, some systems are designed to have "redundant" safety controls – several controls in series with one another. Not so long ago, designers and safety regulators insisted that computers / "chips" could not be trusted as safety controls – safety controls had to be "hard wired" and "failsafe".

3 Key Words / Phrases -- Concepts, Principles and Modelling

3.1 Control System Terminology

Please note that control systems is a huge area of engineering and systems design. The following list of terms may seem long, but in reality a great deal is missing. However, the essence of control systems is relatively straightforward – at least if we are willing to accept a particular definition of a control system. A complete control system of the basic types only includes a handful of important components. In some cases in the table below, two or three terms are actually "all about" pretty much the same thing – with some distinctions depending on the system application.

In the table below the following terms are in alphabetical order – which may or may not help your learning. To enhance your learning, use the "Sort" column to sort the rows according to some criteria that you feel are important to your own career goals or in the context of your application project, such as type of control system, specific application or whether the term relates to a physical component or is conceptual in nature. You could also consider the ISU that you have in mind for the last 3 weeks of the course.

Any key word or phrase below may be addressed in a summative test during or at the end of any unit or in an exam. The "definitions" in the "Initial Definition" column are typically generic and rather out-of-context. Information Processing is a key component of the Thinking Achievement Category in the Ontario Curriculum for Technological Design. Good project planning depends on how well you can process information. So, students are encouraged to synthesize (write or output) their own contextualized meaning of some of the most important keywords in the right hand column. Use your Translate, Interpret and Analysis thinking skills in particular to put these definitions into a more precise context for the assignment or some application that you want to investigate. **Note:** Use your Recall Thinking Skill first -- write down what you already know about each most relevant concept in some application with which you are familiar.

The **blue font** text in column 4 is from the teacher and is in relation to a device that could be used to automatically control the air pressure in a pneumatic piping / process system. Refer to section 5 below. Study the blue font text and then delete it.

Your assignment (see Section 5) is to use the same information processing strategy to conceptualize a control system for a solar lumber heat-treatment kiln with overnight electric-assist OR a system of your choice. Delete the teacher`s blue font text and insert your own ideas for the kiln control system **(or the system of interest to you)**. Choose the six most significant concepts.

The System of interest to me is: _____

1 Sort Group	2 Term / Concept	3 Initial Definition	4 Student Translation / Application in the Context of an Assignment or Problem to Solve **Blue font: Air Pressure Regulator idea below**
	Automatic Controller	A device or combination of devices, which measures the value of a variable, quantity, or condition and operates to correct or limit deviation of this measured value from a selected ("set point") reference	
	Automation	The act or method of making a processing or manufacturing system perform without the necessity of a human operator's intervention or supervision. The common word designating the state of being "automatic".	
	Closed Loop (Feedback Loop)	Several automatic control units and the process connected so as to provide a signal path that includes a forward path, a feedback path and a summing point. The controlled variable is consistently measured, and if it deviates from that which has been prescribed, corrective action is applied to the final element in such direction as to return the controlled variable to the desired value.	
	Control Accuracy	The degree of correspondence between the controlled variable and the desired value after stability has been achieved.	
	Control, General Types of	There are two broad types of controls: -Safety controls (eg high temperature limit switch) -Operational control (eg thermostat)	
	Control Loop	Starts at the process in the form of a measurement or variable, is monitored, and returns to the process in the form of a manipulated variable or "valve position" being controlled by some means.	
	Control Point	The value at which the controlled system or process settles out or stabilizes. It may or may not agree with the set point (instruction) applied to the controller.	
	Control System	A system in which deliberate guidance or manipulation is used to achieve a prescribed value of a variable.	*The control system is made up of an input load-bearing element (diaphragm), response element (adjustable spring), final control element (valve).*
	Controlling Means	The elements in a control system that contribute to the required corrective action.	
	Equilibrium	The condition of a system when all inputs and outputs (eg supply and demand) have steadied down and are in balance.	
	Feedback	Information about the status of the controlled variable that may be compared with information that is desired in the interest of making them coincide.	*Feedback or a "response" is essentially provided by the compression spring, rigidly fixed at one end and fastened to the diaphragm at the other. See Setpoint.*
	Final Control Element	Component of a control system (such as a valve) which directly regulates the flow of energy or material to the process.	*This is the valve which is directly connected to the flexible diaphragm membrane.*
	Input Signal	Incoming signal to measuring instrument, control	

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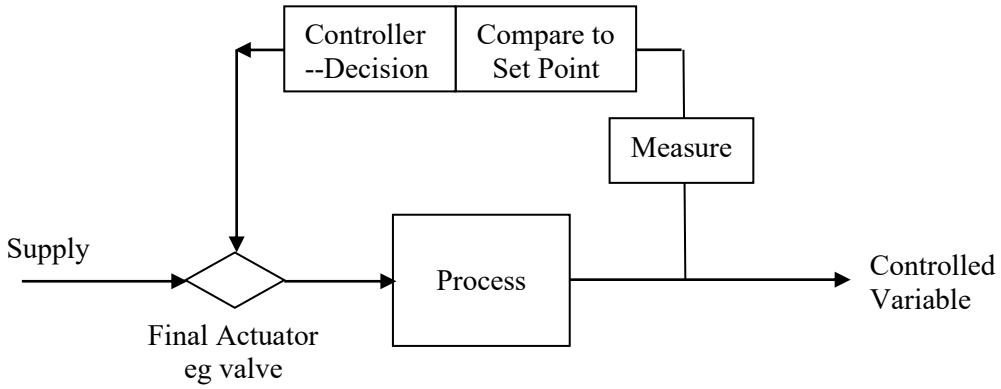
		units or system	
	Manipulated Variable	That which is altered by the automatic control equipment so as to change the variable under control and make it conform with the desired value.	
	Measuring Element	An element or component that converts any system activity or condition into a form or language that the controller can understand.	
	Open Loop	Control without feedback (e.g. an automatic washer operates and is controlled in pre-determined ways)	
	Output Signal	The signal provided by an instrument, for example, the signal that the controller delivers to the valve operator is the controller output.	
	Process	The equipment or "set of steps" for which supply and demand must be balanced – the system under control, excluding the equipment that does the controlling. More simply put, a process is a set of steps to be performed. This set of steps may or may not be characterized as a "white box" or a "black box". The steps may be performed in sequence or may include "Yes / No" paths or may include looping paths.	
	Self-regulation	The ability of an open-loop process or other device to settle out (stabilize) at some new operating value after a load change has taken place.	*This device basically provides self-regulation – but it is still considered automatic.*
	Servomechanism	An automatic control system that takes necessary corrective action as the result of feedback. The output may be mechanical position or something related to it as a function of time.	
	Set Point	The instruction given the automatic controller determining the point at which the controlled variable hopefully will stabilize.	*The set point is established manually when a person adjusts the compression force of the spring that is connected to the diaphragm. This is typically done with a threaded device.*
	Signal	Information in the form of a pneumatic pressure, an electric current, or mechanical position that carries information from one control loop component to another.	*A very important signal in this device is the pressure of the incoming fluid at a certain flow rate. When the pressure increases and pushes more on the diaphragm, the diaphragm will move against the force of the spring. Thus the new mechanical position of the diaphragm is a signal which then carries information with it to the next stage of the device. (See "Final Control Element")*
	System	Generally refers to all control components, including process, measurement, controller, operator, and valves, along with any other additional	

1 Sort Group	2 Term / Concept	3 Initial Definition	4 Student Translation / Application in the Context of an Assignment or Problem to Solve **Blue font: Air Pressure Regulator idea below**
		equipment that may contribute to its operation.	
	Value	The level of the signal being measured or controlled.	
	Variable	A level, quantity, or other condition that is subject to change. This may be regulated (the controlled variable) or simply measured (e.g. a barometer measuring atmospheric pressure)	

3.2 Visual Representation of a Control System



4 Sample Application Assignment – Study This Sample Carefully!

1. Using the most relevant of the terms above as your input, write a 100 (to 200) word version 1 Theory of Operation for a device that will be used to automatically control the air pressure in a pneumatic piping / process system. Be sure to explain which parts in your conceptual control device perform which control role(s) as defined above. This is individual work, but you may brainstorm with one partner. NOTE: This Theory of Operation is more detailed than a design brief. The Theory of Operation will require some research whereas a Design Brief is a fairly simple statement of your goal.

Teacher's Response – This would be a Version 1 Theory of Operation

I think the following six terms from the above table are the most relevant in this particular situation: Feedback, Control System, Signal, Self-Regulation, Final

Control Element and Setpoint. I will design a device that uses an adjustable spring force to set a desired output pressure for the air. If the demand for air increases, output pressure in the device drops and the spring will push open a valve allowing more flow. If the incoming pressure increases, a diaphragm which responds to that input pressure will push against the spring, thus partially closing the valve. This will result in a self-regulation of the flow rate and the output pressure. See my entries in the right hand column above for the role that each part will play in my conceptual device.

5 Assignment – Control System for Solar Heat-Treatment Kiln or Your Choice (100 Marks– Thinking)

1. Using the most relevant of the terms in the table above as your input (say the eight most important control-related concepts above), write a 200 to 400 word version 1 control system theory of operation for a _____ (SEE TWO OPTIONS BELOW). Be sure to explain which parts in your conceptual control system perform which control role(s) as defined in the table above. Draw a neat electronic flow chart to represent the flow of "information" within this control system -- include measurement and decision-making that the system continuously performs. This assignment is individual work, but you may brainstorm with one partner. NOTE: This Theory of Operation is more detailed than a design brief. The Theory of Operation will require some additional research whereas a Design Brief is a fairly simple statement of your goal. This Theory portion must make the connections among the 8 most important concepts you identify in the table above and must also explain the big picture – how the various components work together as a system.

Choose one of the following two options:

1. **A solar-powered lumber heat-treatment kiln with overnight electric-assist**
2. **Something that you would like to conceptually design in your culminating ISU**

6 Checking Understanding – The Fundamentals

Now do the Control System Moodle quiz on ThinkProblemSolving.org.

Peer Assessor's Name and Feedback: