Universiti Tun Hussein Onn Malaysia

# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## SEMESTER I
## SESSION 2022/2023

| | | |
|---|---|---|
| COURSE NAME | : | PROCESS CONTROL AND INSTRUMENTATION |
| COURSE CODE | : | BNL 31103 |
| PROGRAMME CODE | : | BNL |
| EXAMINATION DATE | : | FEBRUARY 2023 |
| DURATION | : | 3 HOURS |
| INSTRUCTION | : | 1. ANSWER **ALL** QUESTIONS |
| | | 2.THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.** |
| | | 3.STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK |

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

**Q1** (a) A pressure gauge with a range between 0 - 10 bar is found to have an error of ± 0.15 bar when calibrated by the manufacturer. Calculate,

(i) The error percentage of the gauge.

(ii) The error percentage when the reading obtained is 2.0 bar.

(iii) Comment the answer in (ii)

(3 marks)

(b) Describe the symbols/letters of process control and instrument drawing shown in **Figure Q1(b).**

(4 marks)

**(c)** **Figure Q1(c)** below shows an indirect level measurement. Determine the Upper Range Value (URV), the Lower Range Value (LRV), the range AND the span.

(6 marks)

(d) Describe the basic construction of a thermocouple including:

(i) Major component arrangement

(ii) Materials used

(4 marks)

(e) Describe the operation of the following types of actuators:

(i) Pneumatic

(ii) Hydraulic

(iii) Solenoid

(3 marks)

**Q2** (a) (i) State the difference of Absolute pressure, Gauge pressure and Differential pressure.

(2 marks)

(ii) Convert 200 inches water to kPa and PSI.

(1 mark)

(b) A controller output is a 4 to 20 mA signal that drives a valve to control flow. The relation between current and flow is $Q=45\sqrt{(I-2\ mA)}$ gal/min.

(i) Determine the flow for 12 mA. (1 mark)

(ii) Calculate the current produces a flow of 162 gal/min. (1 mark)

(c) Give **FIVE (5)** basic elements comprised in DCS and explain each elements.

(5 marks)

(d) Explain the definition SIS control system. Answer include how SIS perform, operate, standard used, structure and sketches of block diagram.

(6 marks)

(e) List Fire and gas detection system requirement AND explain the components involve.

(4 marks)

**Q3** (a) Explain the definition of controller. Answer include error/deviation, input signal and output signal.

(4 marks)

(b) Explain the difference between Reverse and Direct action controller.

(4 marks)

(c) List **THREE (3)** classification of controller modes and give **THREE (3)** examples each.

(6 marks)

(d) The choice of operating mode for any given process control system is a complicated decision. Explain what is involved in this operating mode selection process.

(3 marks)

(e) Using a standard measured indication range like 4 to 20 mA. Suppose we have a setpoint of 10.5 mA and a measurement of 13.7 mA. Determine the error and comment the +ve and -ve error.

(3 marks)

**Q4** (a) (i) Explain the definition of an automatic control system.

(4 marks)

(ii) Name the **TWO (2)** process variable of automatic control system.

(1 mark)

(iii) Explain the definition of the **TWO (2)** process variables in Q4(a)(ii).

(2 marks)

(b) (i) List the **FOUR (4)** basic functions that occurs in any automatic control system.
(2 marks)

(ii) Give **ONE (1)** example of control system that comprise the basic function in Q4(b)(i).

(2 marks)

(c) (i) List the **THREE (3)** functional elements needed to perform the functions of an automatic control system.

(2 marks)

(ii) With the help of block diagram, explain the performing of the **THREE (3)** functional elements in Q4(c)(i).

(3 marks)

(d) A liquid-level control system linearly converts a displacement of 2 to 3 m into a 4- to 20-mA control signal. A relay serves as the two-position controller to open or close an inlet valve. The relay closes at 12 mA and opens at 10 mA. Find,

(i) the relation between displacement level and current.

(1 mark)

(ii) the neutral zone or displacement gap in meters.

(2 marks)

**Q5** (a) **Figure Q5(a)** shows the Bode diagram with a gain plotted of a control system. Used this Bode diagram to detemine whether the system is in the stabilitity criteria according to Rule 1 and Rule 2. Hand-in the Bode diagram answer shows clearly the phase margin line, unity gain and the angular frequency.

(7 marks)

(b) **Figure Q5(b)** shows a graph result of error and output where overshoot and cycling often results when PI mode control is used in start-up of batch processes. The dashed line show the proportional band. **Figure Q5(b)** - top, also shows that around 3 sec, results are fully stable.

Given, $K_p = 5$ , $K_I = 1.0$ s-1 and $p_I(0) = 20\%$

Using the expression of controller output for the combination of the proportional mode and the integral mode (PI) as,

$$p = K_p e_p + K_p K_I \int_0^t e_p \, dt + p_I(0)$$

where $p_I(0)$ = integral term value at t = 0 (initial value)

(i) Determine the error and plot the linear graph of error (error versus time).
(3 marks)

(ii) Refering to Q5(b)(i) and **THREE (3)** time region, plot the graph of a proportional-integral controller output as a function of time.
(4 marks)

(c) **Figure Q5(c)** illustrates a process system using a proportional temperature controller for providing hot water. Steam is admitted to the heat exchanger to raise the temperature of the cold-water supply. The temperature detector monitors the hot water outlet and produces a 3 to 15 psi output signal that represents a controlled variable range of 100°F to 300°F.

The controller compares the measured variable signal with the setpoint 150 °F and sends a 3 to 15 psi output to the final control element, which is a 3-inches control valve. The controller has been set for a proportional band (PB) of 50%. The proportional controller is reverse-acting so that the control valve throttles down to reduce steam flow as the hot water outlet temperature increases. The control valve will open further to increase steam flow as the water temperature decreases.

(i) Explain in term of time (t), the measured variable increase and decrease corresponds to a full open and fully shut control valve position.
(3 marks)

(ii) Plot the graph of controller output (PSI, y-axis) versus measured variable (°F, x-axis), showing the controller is set up (set point 150 °F) such that the system functions. Also showing the setpoint, error and span at the graph.
(3 marks)

**-END OF QUESTIONS-**

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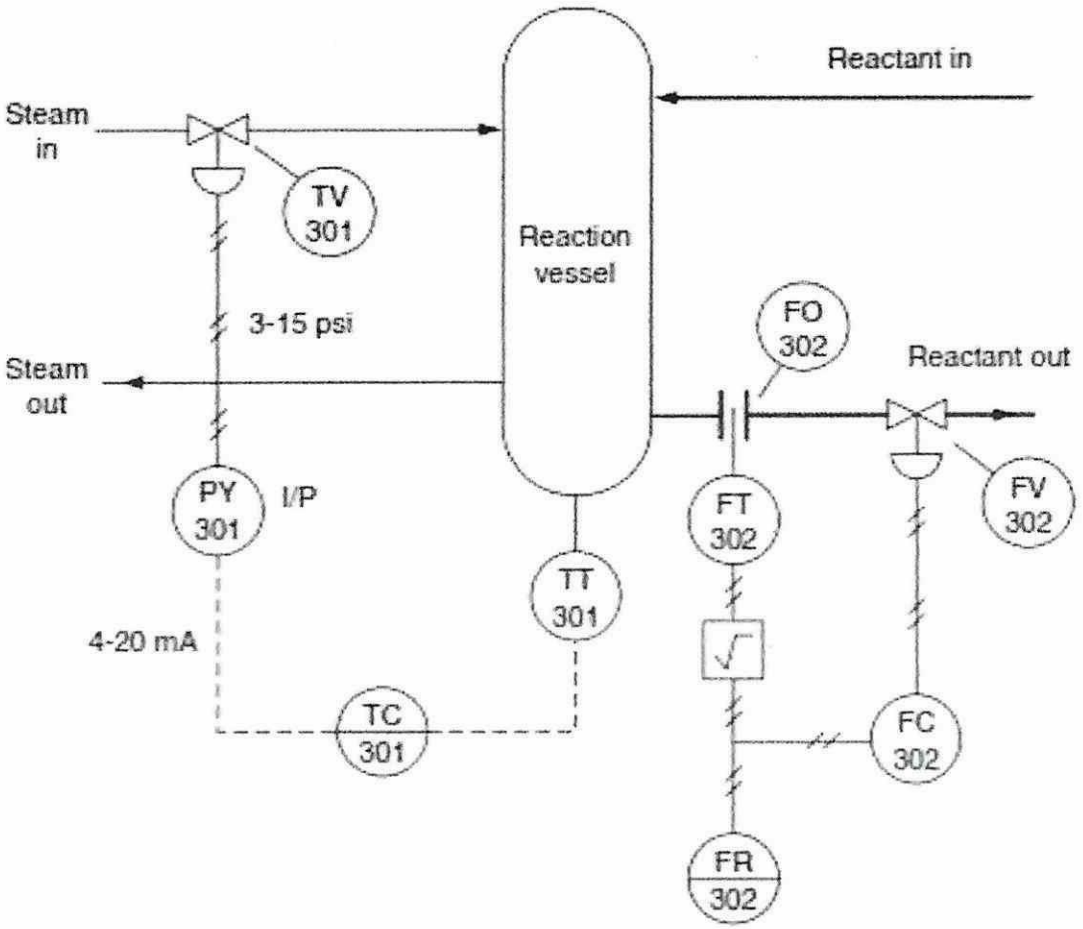


**Figure Q1(b)**

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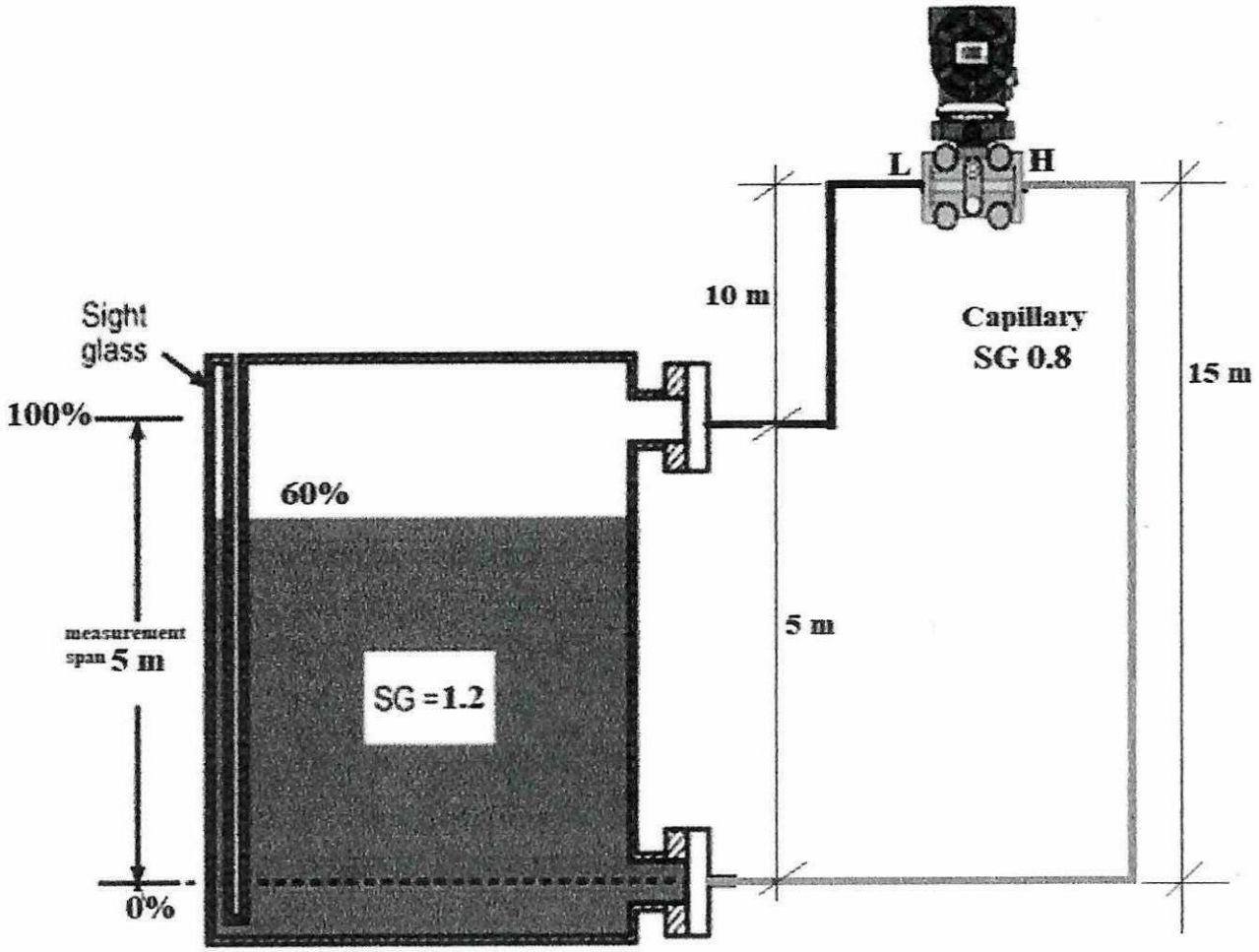


**Figure Q1(c)**

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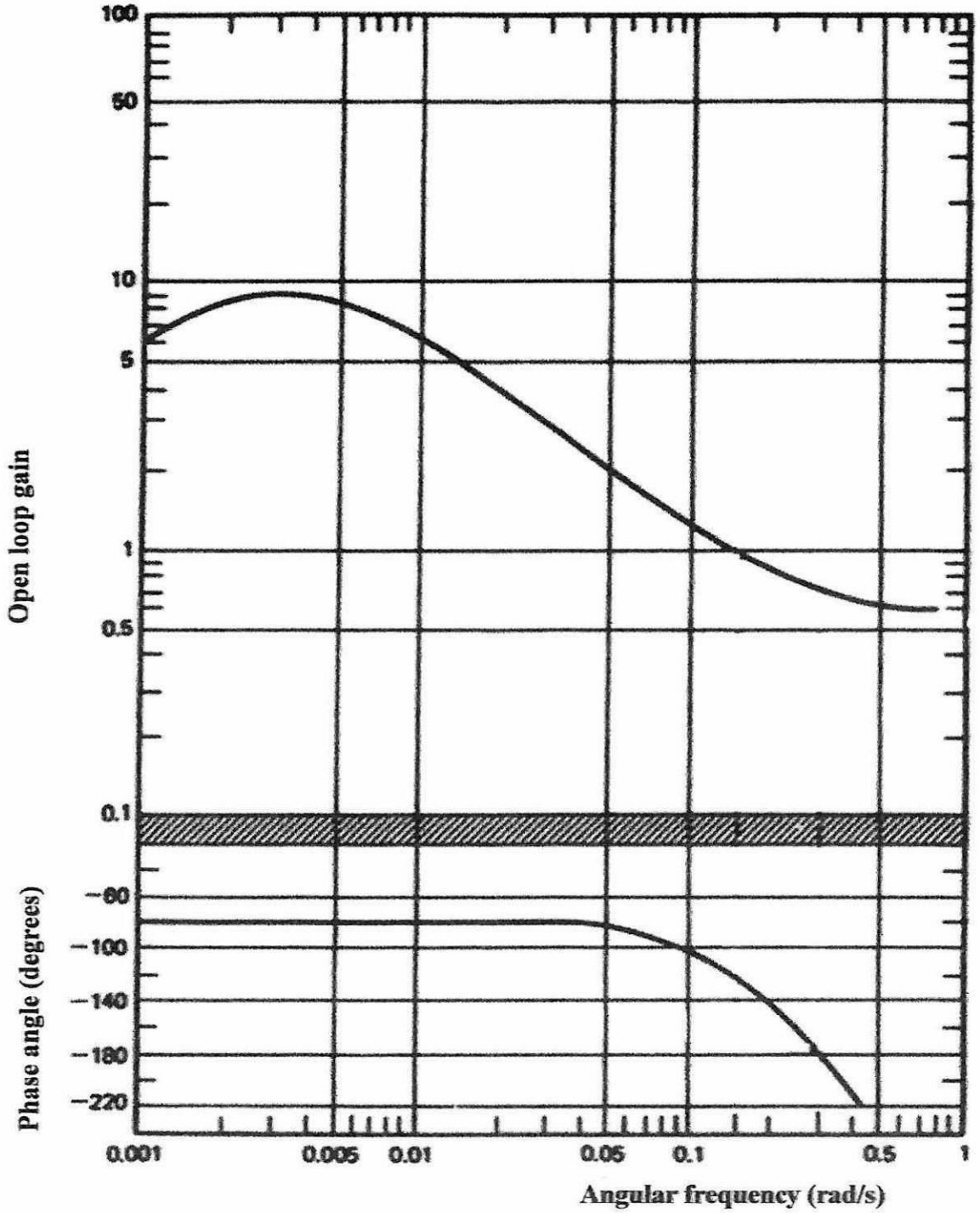


**Figure Q5(a)**

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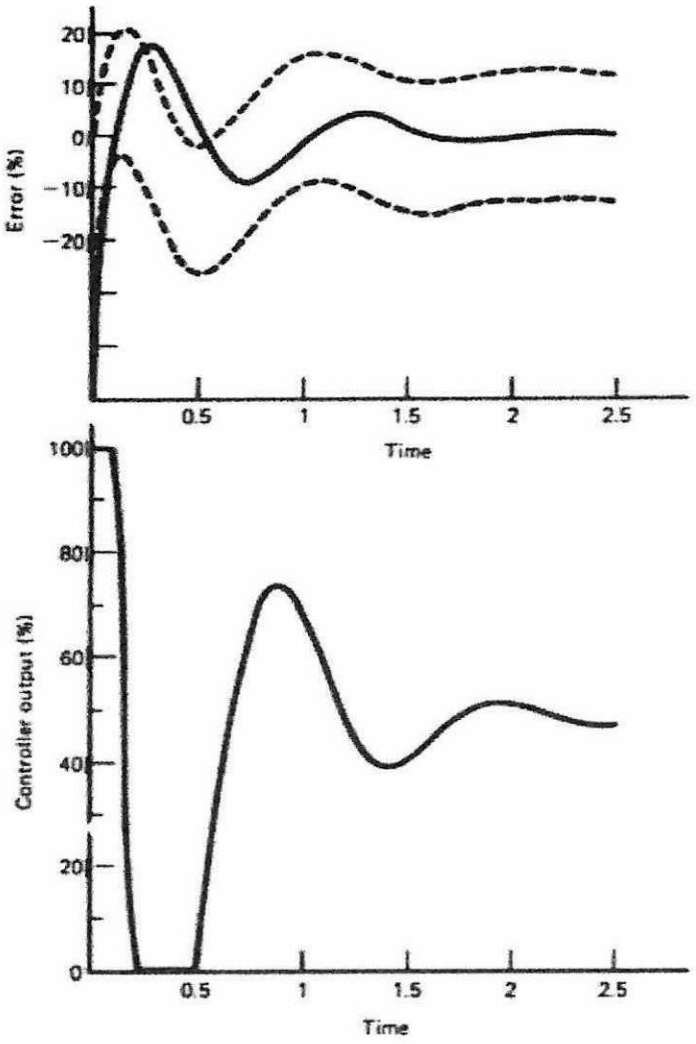


**Figure Q5(b)**

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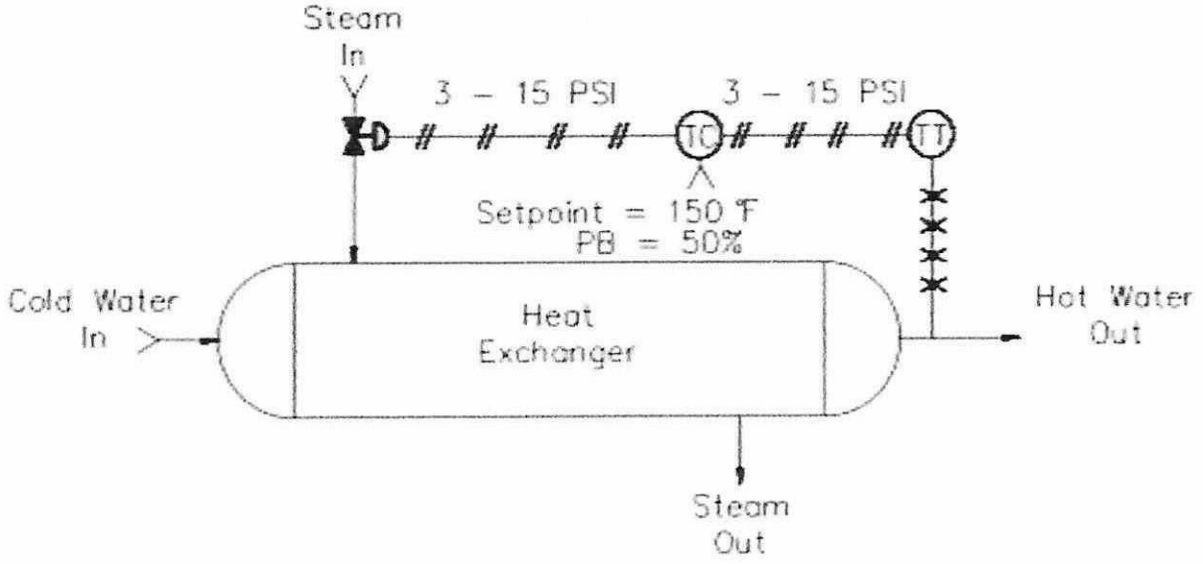


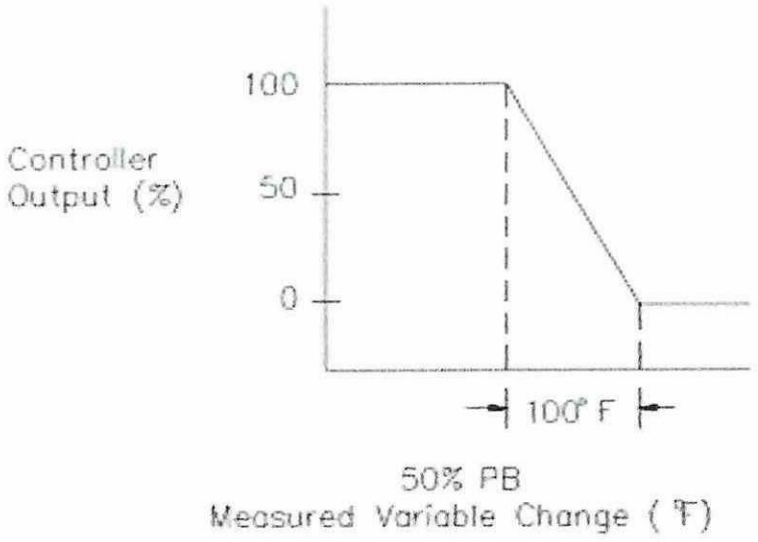


**Figure Q5(c)**

| PRESSURE CONVERSION TABLE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PSI | ATM | $kgf/cm^2$ | $in.H_2O$ | mmHg | in.Hg | Kpa | Bar | $mm\ H_2O$ |
| 1 | 0.068046 | 0.070307 | 27.7276 | 51.715 | 2.03602 | 6.895 | 0.6895 | 704.28104 |
| 14.696 | 1 | 1.0332 | 407.484 | 760 | 29.921 | 101.325 | 1.01325 | 10350.0936 |
| 14.2233 | 0.96784 | 1 | 394.38 | 735.559 | 28.959 | 98.096 | 0.98067 | 10000 |
| 0.036092 | 0.002454 | 0.00253 | 1 | 1.8651 | 0.07343 | 0.249 | 0.00249 | 25.4 |
| 0.019336 | 0.001315 | 0.001359 | 0.53616 | 1 | 0.03937 | 0.1333 | 0.001333 | 13.618464 |
| 0.491154 | 0.0033421 | 0.03453 | 13.6185 | 25.4 | 1 | 3.3864 | 0.033864 | 345.9099 |
| 0.145 | 0.00987 | 0.010197 | 4.0186 | 7.5006 | 0.2953 | 1 | 0.01 | 102.07244 |
| 14.5038 | 0.98692 | 1.01972 | 402.156 | 750.062 | 29.53 | 100 | 1 | 10214.7624 |