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**The University of Calgary**
**Department of Chemical & Petroleum Engineering**

**ENCH 501: Transport Phenomena Quiz #3** **September 30, 2008**

**Time Allowed: 30 mins.** **Name:**

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In the Separation Processes I course, one of the topics studied is distillation. For the multi-stage process in a column, we normally assume that the column is isothermal. The department has a pilot distillation unit which students run and collect data from. The following is a set of temperature measurements (in °C) recorded from each of nine trays by different groups of students operating the system under similar conditions.

| Tray # / Groups | Gp A | B | C | D | D | D |
|---|---|---|---|---|---|---|
| | | | | Set 1 | Set 2 | Set 3 |
| Tray 1 | 89.16 | 92.09 | 91.29 | 90.65 | 90.61 | 90.61 |
| 2 | 88.82 | 90.59 | 90.74 | 90.54 | 90.43 | 90.38 |
| 3 | 88.02 | 89.47 | 90.52 | 90.18 | 90.22 | 90.22 |
| 4 | 86.30 | 87.87 | 87.72 | 89.36 | 89.23 | 89.25 |
| 5 | 85.51 | 86.45 | 86.22 | 88.45 | 88.24 | 88.22 |
| 6 | 84.41 | 85.12 | 84.71 | 86.82 | 86.52 | 86.57 |
| 7 | 84.07 | 84.30 | 84.07 | 85.33 | 85.08 | 85.33 |
| 8 | 84.07 | 84.17 | 83.96 | 84.62 | 84.45 | 84.59 |
| 9 | 83.87 | 83.76 | 83.62 | 83.83 | 83.74 | 83.86 |

If you can assume that the groups worked without consulting one another and the variations are due to random fluctuations in the flow rates of the fluids, but the measurements done by group D were all by the same person (assume data correlated),

a) estimate the mean temperatures and the errors for each tray. Explain your logic.
b) What are the estimates for the average temperatures and the errors for the column, for all nine trays, as recorded by each group?
c) Estimate the error for the average temperature for the entire column.

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The data gathered by gp D is correlated. Therefore calculate the mean values and the errors first. Then use the mean values as an independent set with gps A, B and C.

| Gp D | | $T_{mean}$, °C | Error $\left[\sum_{i=1}^{3} \lvert(T_i - T_{mean})\rvert\right]/N$ |
|---|---|---|---|
| Trays | 1 | 90.62 | 0.0178 |
| | 2 | 90.45 | 0.06 |
| | 3 | 90.21 | 0.0178 |
| | 4 | 89.28 | 0.0533 |
| | 5 | 88.30 | 0.0967 |
| | 6 | 86.64 | 0.123 |
| | 7 | 85.25 | 0.11 |
| | 8 | 84.55 | 0.07 |
| | 9 | 83.81 | 0.05 |

where $N = 3$

assume these errors are relatively small.

True compared with those in (a) below.

(a)

where $N = 4$

$$\pm\Delta T = \sqrt{\frac{(T_i - \bar{T})^2}{N-1}}$$

| Tray | A | B | C | D | $\bar{T}$ | $\pm\Delta T$ |
|---|---|---|---|---|---|---|
| 1 | 89.16 | 92.09 | 91.29 | 90.62 | 90.79 | $\sqrt{4.603/3} = 1.24$ |
| 2 | 88.82 | 90.59 | 90.74 | 90.45 | 90.15 | $\sqrt{2.401/3} = 0.89$ |
| 3 | 88.02 | 89.47 | 90.52 | 90.21 | 89.56 | $\sqrt{3.72/3} = 1.11$ |
| 4 | 86.30 | 87.87 | 87.72 | 89.28 | 87.79 | $\sqrt{4.45/3} = 1.22$ |
| 5 | 85.51 | 86.45 | 86.22 | 88.30 | 86.62 | $\sqrt{4.24/3} = 1.19$ |
| 6 | 84.41 | 85.12 | 84.71 | 86.64 | 85.22 | $\sqrt{2.94/3} = 0.99$ |
| 7 | 84.07 | 84.3 | 84.07 | 85.25 | 84.42 | $\sqrt{0.948/3} = 0.56$ |
| 8 | 84.07 | 84.17 | 83.96 | 84.55 | 84.19 | $\sqrt{0.197/3} = 0.26$ |
| 9 | 83.87 | 83.76 | 83.83 | 83.81 | 83.82 | $\sqrt{0.0063/3} = 0.046$ |

Average for column

(b)

| | A | B | C | D |
|---|---|---|---|---|
| $\bar{T}_{est.}$ | 86.03 | 87.09 | 86.98 | 87.68 |
| $\sqrt{\frac{\Sigma(T_i - \bar{T})^2_{est.}}{N-1}}$ | $\sqrt{\frac{37.01}{8}}$ | $\sqrt{\frac{75.21}{8}}$ | $\sqrt{\frac{79.03}{8}}$ | $\sqrt{\frac{57.42}{8}}$ |
| where N = 9 | $\pm 2.15$ | $\pm 3.07$ | $\pm 3.14$ | $\pm 2.68$ |

$\bar{T}_{est.}$ ← mean T values for column by each group

Errors for column, each way arrived at independent ($\Delta T'$)

(c) Given that there are 4 independent sets of data, the average of the mean values for groups,

$$\bar{\bar{T}}_{est} = \frac{1}{4}(86.03 + 87.09 + 86.98 + 87.68)$$

$$= 86.945\ ^\circ C$$

$$\Delta\bar{\bar{T}}_{est} = \sqrt{\frac{\{(86.03 - 86.945)^2 + (87.09 - 86.945)^2 + (86.98 - 86.945)^2 + (87.68 - 86.945)^2\}}{N-1}}$$

$$= 0.683\ ^\circ C$$

$$\text{Error in average temp} = \frac{\Delta\bar{\bar{T}}_{est}}{\sqrt{4}}$$

$$= 0.34\ ^\circ C$$

$\therefore$ Average temp of Column $= 86.95 \pm 0.34\ ^\circ C$