```
x_s = 0.9996;
lambda_1 = 964.472;
lambda_s = 950.151;
Cp = 1.00;
```

Delta T Calculations

```
deltaT_table = readtable('Lab 1 Error Propagation.xlsx','Sheet','Heat Transfer Coeffic
```

deltaT_table = 14×6 table

...

	Trial	TS [± 1 °F]	T2 [± 1 °F]	T3 [± 1 °F]	ΔT_lm [± ?? °F]
1	1	344	306	321	29.8750
2	2	344	303	324	29.2544
3	3	344	304	323	29.4868
4	4	344	304	324	28.8539
5	5	344	305	322	29.6933
6	6	344	306	320	30.4658
7	7	344	306	323	28.6647
8	8	344	305	320	30.8955
9	9	344	304	323	29.4868
10	10	344	303	324	29.2544
11	11	344	303	321	31.1377
12	12	344	306	323	28.6647
13	13	344	305	324	28.4504
14	14	344	304	324	28.8539

```
syms T_2 T_3 T_s
deltaT = ( (T_s - T_2) - (T_s - T_3) ) / log( (T_s - T_2) / (T_s - T_3) );

[errorFunction_deltaT, vars_deltaT, errors_deltaT, partials_deltaT] = errorFunc(deltaT
```

errorFunction_deltaT =

$$\sqrt{s_{T,2}{}^2 \left(\frac{1}{\sigma_1} - \frac{T_2 - T_3}{\sigma_1{}^2 \, (T_2 - T_s)}\right)^2 + s_{T,3}{}^2 \left(\frac{1}{\sigma_1} - \frac{T_2 - T_3}{\sigma_1{}^2 \, (T_3 - T_s)}\right)^2 + \frac{s_{T,s}{}^2 \left(\frac{T_2 - T_s}{(T_3 - T_s)^2} - \frac{1}{T_3 - T_s}\right)^2 (T_2 - T_3)^2 \, (T}{\sigma_1{}^4 \, (T_2 - T_s)^2}}$$

where

$$\sigma_1 = \log\left(\frac{T_2 - T_s}{T_3 - T_s}\right)$$

vars_deltaT = $\begin{pmatrix} T_2 & T_3 & T_s \end{pmatrix}$

errors_deltaT = $\begin{pmatrix} s_{T,2} & s_{T,3} & s_{T,s} \end{pmatrix}$

partials_deltaT =

$$\begin{pmatrix} \frac{T_2 - T_3}{\sigma_1} - \frac{1}{\log\left(\frac{T_2 - T_s}{T_3 - T_s}\right)} & \frac{1}{\log\left(\frac{T_2 - T_s}{T_3 - T_s}\right)} - \frac{T_2 - T_3}{\log\left(\frac{T_2 - T_s}{T_3 - T_s}\right)^2 (T_3 - T_s)} & \frac{\left(\frac{T_2 - T_s}{(T_3 - T_s)^2} - \frac{1}{T_3 - T_s}\right)(T_2 - T_3)}{\sigma_1} \end{pmatrix}$$

where

$$\sigma_1 = \log\left(\frac{T_2 - T_s}{T_3 - T_s}\right)^2 (T_2 - T_s)$$

```
vars_deltaT = [vars_deltaT(3), vars_deltaT(1:2)];

deltaT_data = deltaT_table.Variables;
[numTrials , ~] = size(deltaT_data);

for i = 1:numTrials
    for j = 1:numel(vars_deltaT)
        assignin("base", sprintf("%s", vars_deltaT(j)), deltaT_data(i, j + 1))

        assignin("base", sprintf("%s", errors_deltaT(j)), 1)
    end
    deltaT_data(i,end) = vpa(sqrt(subs(errorFunction_deltaT)));
end

deltaT_table.Variables = deltaT_data;

dispTable_deltaT = removevars(deltaT_table, deltaT_table.Properties.VariableNames(2:en
```

dispTable_deltaT = 14×3 table

	Trial	ΔT_lm [± ?? °F]	ΔT_lm Error [°F]
1	1	29.8750	1.1209
2	2	29.2544	1.1358
3	3	29.4868	1.1301
4	4	28.8539	1.1338
5	5	29.6933	1.1252
6	6	30.4658	1.1186
7	7	28.6647	1.1265
8	8	30.8955	1.1200
9	9	29.4868	1.1301
10	10	29.2544	1.1358

	Trial	ΔT_lm [± ?? °F]	ΔT_lm Error [°F]
11	11	31.1377	1.1255
12	12	28.6647	1.1265
13	13	28.4504	1.1319
14	14	28.8539	1.1338

M dot calculations

```
syms S_dot L1_dot q_loss T_2 T_3
m_dot = (x_s * lambda_s * S_dot - L1_dot * lambda_1 - q_loss) / (T_3 - T_2);
[errorFunction_m_dot, vars_m_dot, errors_m_dot, partials_m_dot] = errorFunc(m_dot);

m_dot_table = readtable('Lab 1 Error Propagation.xlsx','Sheet','Heat Transfer Coefficie
m_dot_data = m_dot_table.Variables;

m_dot_data = [deltaT_data(:, 3), ones(numTrials, 1), deltaT_data(:, 4), ones(numTrials
vars_m_dot = [vars_m_dot(3), vars_m_dot(4), vars_m_dot(2), vars_m_dot(1), vars_m_dot(5
errors_m_dot = [errors_m_dot(3), errors_m_dot(4), errors_m_dot(2), errors_m_dot(1), er

for i = 1:numTrials
    for j = 1:numel(vars_m_dot)
        assignin("base", sprintf("%s", vars_m_dot(j)), m_dot_data(i, 2 * j - 1 ) )

        assignin("base", sprintf("%s", errors_m_dot(j)), m_dot_data(i, 2 * j))
    end
    m_dot_data(i,end) = vpa(sqrt(subs(errorFunction_m_dot)));
end
m_dot_table.Variables = m_dot_data(:, 5:end);
dispTable_m_dot = removevars(m_dot_table, m_dot_table.Properties.VariableNames(1:end-2
```

dispTable_m_dot = 14×2 table

	m_dot [± ?? lb/min]	m_dot Error [lb/min]
1	17.572133333333340	1.673309721864642
2	18.616333333333326	1.370942786107463
3	20.458370526315793	1.488635155509358
4	16.588289999999994	1.418753317744007
5	19.515635294117658	1.596765391071660
6	23.561364285714301	1.833915491700150
7	19.515635294117651	1.585150487366038
8	24.153850000000002	1.768245042840934
9	17.461357894736842	1.494307808719159
10	15.798371428571432	1.378373160851778
11	18.537361111111121	1.541201724246620

	m_dot [± ?? lb/min]	m_dot Error [lb/min]
12	20.353035882352941	1.598146576648146
13	16.904197894736829	1.465950898658468
14	16.778959999999991	1.427890566487600

Q Dot calculations

```
syms m_dot T_3 T_2
q_dot = m_dot * Cp * (T_3 - T_2);
[errorFunction_q_dot, vars_q_dot, errors_q_dot, partials_q_dot] = errorFunc(q_dot);

q_dot_table = readtable('Lab 1 Error Propagation.xlsx','Sheet','Heat Transfer Coefficie
table_vals_q_dot = q_dot_table.Variables;

q_dot_data = [deltaT_data(:, 3), ones(numTrials, 1), deltaT_data(:, 4), ones(numTrials
for i = 1:numTrials
    for j = 1:numel(vars_q_dot)
        assignin("base", sprintf("%s", vars_q_dot(j)), q_dot_data(i, 2 * j - 1 ) )

        assignin("base", sprintf("%s", errors_q_dot(j)), q_dot_data(i, 2 * j))
    end
    table_vals_q_dot(i,end) = vpa(sqrt(subs(errorFunction_q_dot)));
end
q_dot_table.Variables = table_vals_q_dot
```

q_dot_table = 14×2 table

	Q_dot [± ?? BTU/min]	Q_dot Error [BTU/min]
1	2.635820000000001e+02	5.943122208488163
2	3.909429999999999e+02	6.246012134147916
3	3.887090400000001e+02	6.360882397206255
4	3.317657999999999e+02	6.067696488624291
5	3.317658000000002e+02	6.221847779164065
6	3.298591000000002e+02	6.485760739431342
7	3.317658000000001e+02	6.210731791497098
8	3.623077500000001e+02	6.576262094766252
9	3.317658000000000e+02	6.134197704531616
10	3.317658000000001e+02	6.046944465650963
11	3.336725000000002e+02	6.178099133093849
12	3.460016100000000e+02	6.291306639695093
13	3.211797599999998e+02	6.058510270505683
14	3.355791999999998e+02	6.093415542288322

U Calculations

```
syms Q_dot A deltaT
u = Q_dot / ( A * deltaT );
[errorFunction_u, vars_u, errors_u, partials_u] = errorFunc(u);

u_table = readtable('Lab 1 Error Propagation.xlsx','Sheet','Heat Transfer Coefficient'
u_data = u_table.Variables;

u_data = [u_data(:, 1:2), table_vals_q_dot, deltaT_data(:, end-1:end), u_data(:, end-1
for i = 1:numTrials
    for j = 1:numel(vars_u)
        assignin("base", sprintf("%s", vars_u(j)), u_data(i, 2 * j - 1 ) )

        assignin("base", sprintf("%s", errors_u(j)), u_data(i, 2 * j))
    end
    u_data(i,end) = vpa(sqrt(subs(errorFunction_u)));
end
u_table.Variables = [u_data(:, 1:2), u_data(:, end-1:end)];
u_table_disp = removevars(u_table, u_table.Properties.VariableNames(1:end-2));
u_table_disp.Properties.VariableNames = {sprintf('U[%s ?? BTU / (ft%s %sF min)]', char
                                         sprintf('U Error [BTU / (ft%s %sF min)]'
```

u_table_disp = 14×2 table

	U[± ?? BTU / (ft² °F min)]	U Error [BTU / (ft² °F min)]
1	6.607218152027502	1.122994729983282
2	7.176230927201972	1.045643371872066
3	6.940590526003992	1.014279381894383
4	6.945653118429747	1.072819960738243
5	6.759051089427762	1.044165117612300
6	6.575339658859022	1.029571031181422
7	6.951956461528870	1.054923580698903
8	6.491597729758416	0.998443111620054
9	6.821130068880839	1.055998038953239
10	6.773955757721260	1.043623333069601
11	6.406612722891881	1.016283472828577
12	6.908120672236293	1.042834797007780
13	6.904086574278687	1.078944698362566
14	6.819527644654922	1.045900292753169

Confidence Interval section

```
data_table = readtable('Lab 1 Error Propagation.xlsx','Sheet','Confidence Intervals',
data = data_table.Variables;
mass_data = data(1:5, 1);
temp_data = data(1:end-1, 2);
length_data = data(1:7, 3);
```

```
period_data = data(:, end);

p = 0.95;

[mass_mean, mass_CI] = mean_CI(p, mass_data)
```

```
mass_mean =
  66.280433945816952
mass_CI =
   0.421206404999705
```

```
[temp_mean, temp_CI] = mean_CI(p, temp_data)
```

```
temp_mean =
     2.112037330042676e+02
temp_CI =
   1.663300798869087
```

```
[length_mean, length_CI] = mean_CI(p, length_data)
```

```
length_mean =
  99.891378093683599
length_CI =
   1.115080102182427
```

```
[period_mean, period_CI] = mean_CI(p, period_data)
```

```
period_mean =
   5.249422027874295
period_CI =
   0.023418032948809
```

```
results = table({'Mean';  '95 % CI'}, [mass_mean; mass_CI], ...
                [temp_mean; temp_CI], [length_mean;length_CI], ...
                [period_mean; period_CI]);
names = cat(2, {'Type'},data_table.Properties.VariableNames);
results.Properties.VariableNames = names
```

results = 2×5 table

	Type	Mass [kg]	Temperature [°C]	Length [m]	Period [s]
1	'Mean'	66.2804339458...	2.112037330042676e+02	99.8913780936...	5.2494220278...
2	'95 % CI'	0.42120640499...	1.663300798869087	1.11508010218...	0.0234180329...