Vizualization of FrED Run Conditions.

Various methods to vizualize FrED Run Conditions (time-invariant) in preparation for regression analysis.

Uses auto porcessed run condition data - "Run Condition Data Summary.csv"

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In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sn
from mpl_toolkits.mplot3d import Axes3D
```

In [2]:
```python
# load run condition data into dataframe
# current file - 050820 11:06pm
path_local = 'C:/Users/cuiff/Dropbox/Python Common Library/python-fred/data/Reports/'
data = pd.read_csv(path_local + 'Run Condition Data Summary.csv')
data
```

Out[2]:

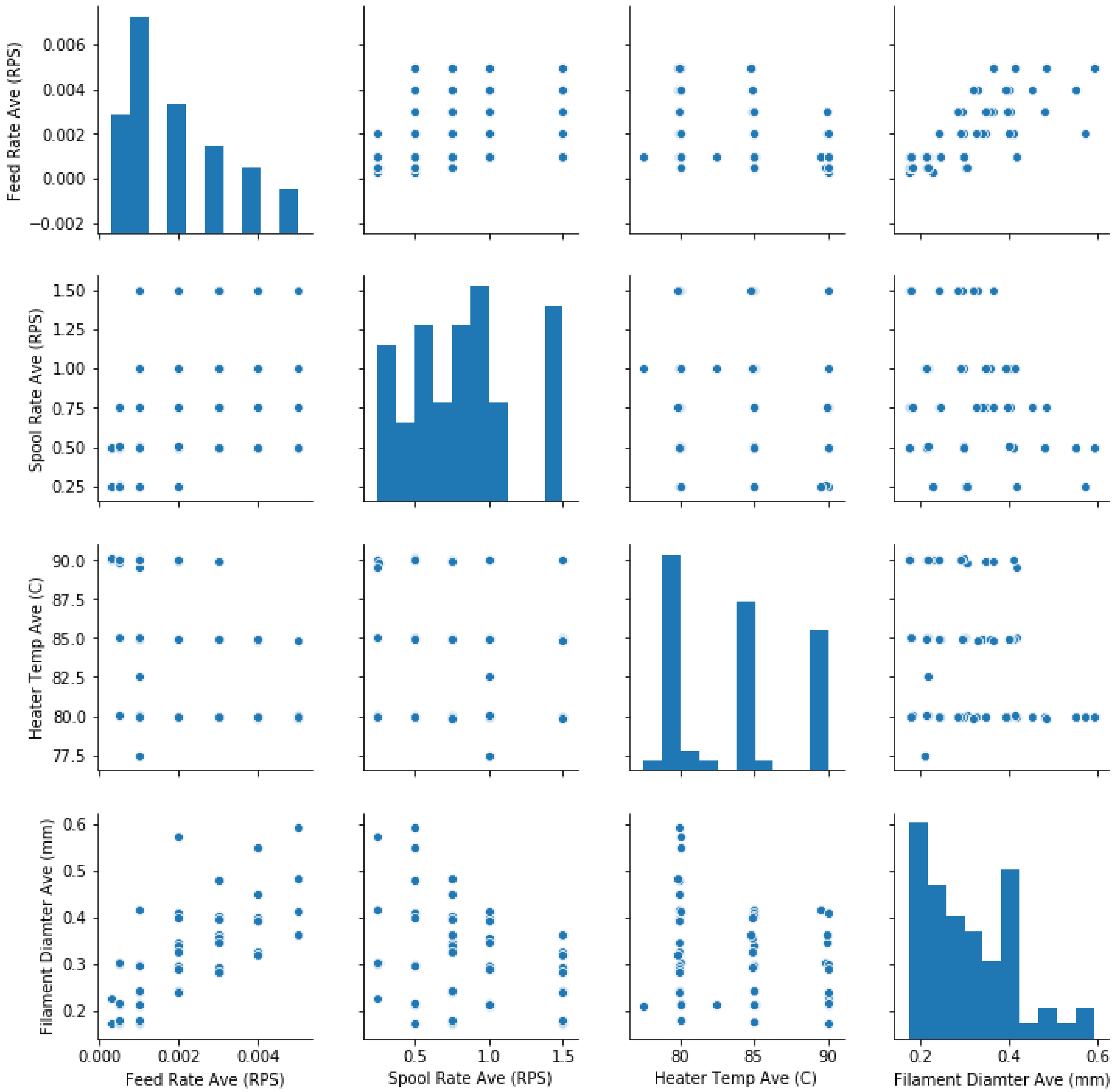
	Run File	Feed Rate Ave (RPS)	Spool Wind Rate Set (RPS)	Spool Rate Ave (RPS)	Wind BF Rate Ave (PPS)	Heater Set (C)	Heater Temp Ave (C)	Filament Diamter Ave (mm)	Filament Std Dev (mm)	System Power Ave (W)	System Power Std Dev (W)	C
0	log_Manual Control__2020-04-12_12-13-50.csv	0.001000	1.00	1.000132	127.730719	90.0	90.009313	0.213487	0.016746	29.041052	1.000198	1
1	log_Manual Control__2020-04-12_17-26-48.csv	0.000312	0.25	0.250982	20.426288	90.0	90.068162	0.228383	0.044286	30.064674	1.123981	1
2	log_Manual Control__2020-04-12_17-26-48.csv	0.000312	0.50	0.499899	28.561457	90.0	90.080434	0.172805	0.012332	29.126951	1.001411	1.
3	log_Manual Control__2020-04-12_17-49-04.csv	0.000500	0.25	0.254232	45.159629	90.0	89.850642	0.302968	0.022932	28.685025	1.093912	1.
4	log_Manual Control__2020-04-12_17-49-04.csv	0.000500	0.50	0.499777	63.865360	90.0	90.043857	0.217002	0.014405	28.366543	0.931641	1
...	...	...	...	...	...	...	...	...	...	...	...	
56	log_Manual Control__2020-05-26_10-47-57.csv	0.004000	0.75	0.749697	221.236095	80.0	79.951250	0.450721	0.029310	25.648463	2.279616	1.
57	log_Manual Control__2020-05-26_10-47-57.csv	0.004000	0.50	0.499585	180.638516	80.0	79.994511	0.549398	0.042787	24.219703	9.242227	1.
58	log_Manual Control__2020-05-26_10-47-57.csv	0.005000	1.00	0.998329	285.614571	80.0	80.010143	0.412343	0.052719	24.840470	9.815740	1.
59	log_Manual Control__2020-05-26_10-47-57.csv	0.005000	0.75	0.749777	247.349474	80.0	79.871364	0.484278	0.036691	25.306375	1.619509	1.
60	log_Manual Control__2020-05-26_10-47-57.csv	0.005000	0.50	0.499643	201.960000	80.0	79.916287	0.593511	0.051736	24.807645	5.906214	1.

61 rows × 17 columns

Fiber Diameter - Key Parameters

Start by exploring the key paramters that determine fiber diameter: Feed Speed, Spool Speed, Heater Temperature.

In [3]:
```python
# start by taking a look at a pair plot and correlation matrix
# create reduced feature dataframe
df = data[['Feed Rate Ave (RPS)','Spool Rate Ave (RPS)','Heater Temp Ave (C)','Filament Diamter Av
e (mm)']]
#sn.heatmap(df.corr(), annot=True)
#plt.show()
sn.pairplot(df)
plt.show()
df.corr()
```



Out[3]:

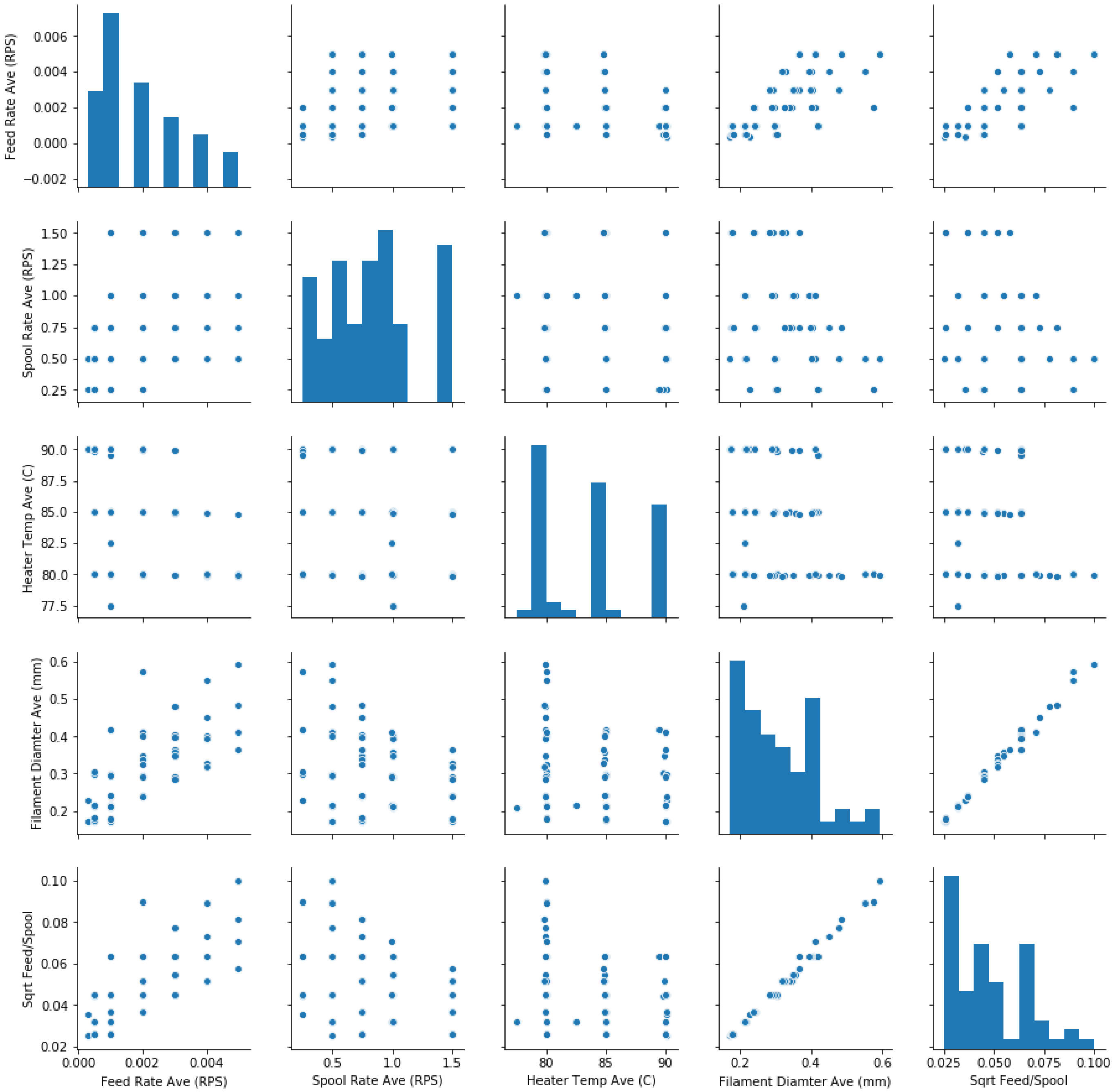
	Feed Rate Ave (RPS)	Spool Rate Ave (RPS)	Heater Temp Ave (C)	Filament Diamter Ave (mm)
Feed Rate Ave (RPS)	1.000000	0.325072	-0.338853	0.689340
Spool Rate Ave (RPS)	0.325072	1.000000	-0.114830	-0.352166
Heater Temp Ave (C)	-0.338853	-0.114830	1.000000	-0.282535
Filament Diamter Ave (mm)	0.689340	-0.352166	-0.282535	1.000000

In [4]:
```python
# add a dataframe column that includes sqrt(feed speed / spool speed) as shown in our basic model
data['Sqrt Feed/Spool'] = np.sqrt(data['Feed Rate Ave (RPS)'] / data['Spool Rate Ave (RPS)'])
data.head()
```

Out[4]:

	Run File	Feed Rate Ave (RPS)	Spool Wind Rate Set (RPS)	Spool Rate Ave (RPS)	Wind BF Rate Ave (PPS)	Heater Set (C)	Heater Temp Ave (C)	Filament Diamter Ave (mm)	Filament Std Dev (mm)	System Power Ave (W)	System Power Std Dev (W)	Cu
0	log_Manual Control__2020-04-12_12-13-50.csv	0.001000	1.00	1.000132	127.730719	90.0	90.009313	0.213487	0.016746	29.041052	1.000198	17
1	log_Manual Control__2020-04-12_17-26-48.csv	0.000312	0.25	0.250982	20.426288	90.0	90.068162	0.228383	0.044286	30.064674	1.123981	19
2	log_Manual Control__2020-04-12_17-26-48.csv	0.000312	0.50	0.499899	28.561457	90.0	90.080434	0.172805	0.012332	29.126951	1.001411	18
3	log_Manual Control__2020-04-12_17-49-04.csv	0.000500	0.25	0.254232	45.159629	90.0	89.850642	0.302968	0.022932	28.685025	1.093912	18
4	log_Manual Control__2020-04-12_17-49-04.csv	0.000500	0.50	0.499777	63.865360	90.0	90.043857	0.217002	0.014405	28.366543	0.931641	17

In [5]:
```
# ook at a pair plot and correlation matrix again
# create reduced feature dataframe
df = data[['Feed Rate Ave (RPS)','Spool Rate Ave (RPS)','Heater Temp Ave (C)','Filament Diamter Av
e (mm)','Sqrt Feed/Spool']]
#sn.heatmap(df.corr(), annot=True)
#plt.show()
sn.pairplot(df)
plt.show()
df.corr()
```

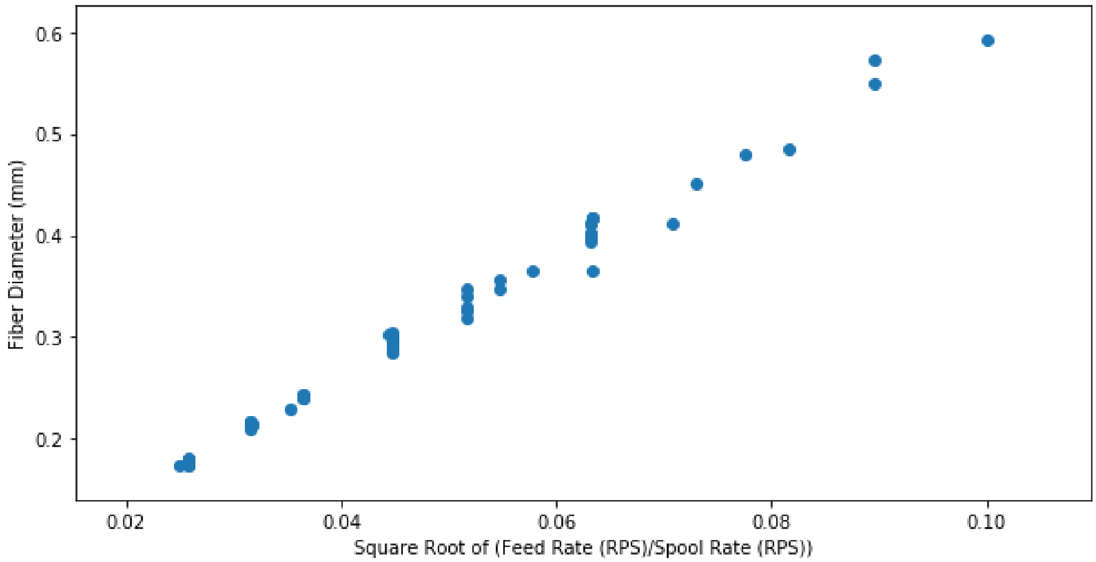


Out[5]:

	Feed Rate Ave (RPS)	Spool Rate Ave (RPS)	Heater Temp Ave (C)	Filament Diamter Ave (mm)	Sqrt Feed/Spool
Feed Rate Ave (RPS)	1.000000	0.325072	-0.338853	0.689340	0.733815
Spool Rate Ave (RPS)	0.325072	1.000000	-0.114830	-0.352166	-0.314407
Heater Temp Ave (C)	-0.338853	-0.114830	1.000000	-0.282535	-0.298767
Filament Diamter Ave (mm)	0.689340	-0.352166	-0.282535	1.000000	0.995249
Sqrt Feed/Spool	0.733815	-0.314407	-0.298767	0.995249	1.000000

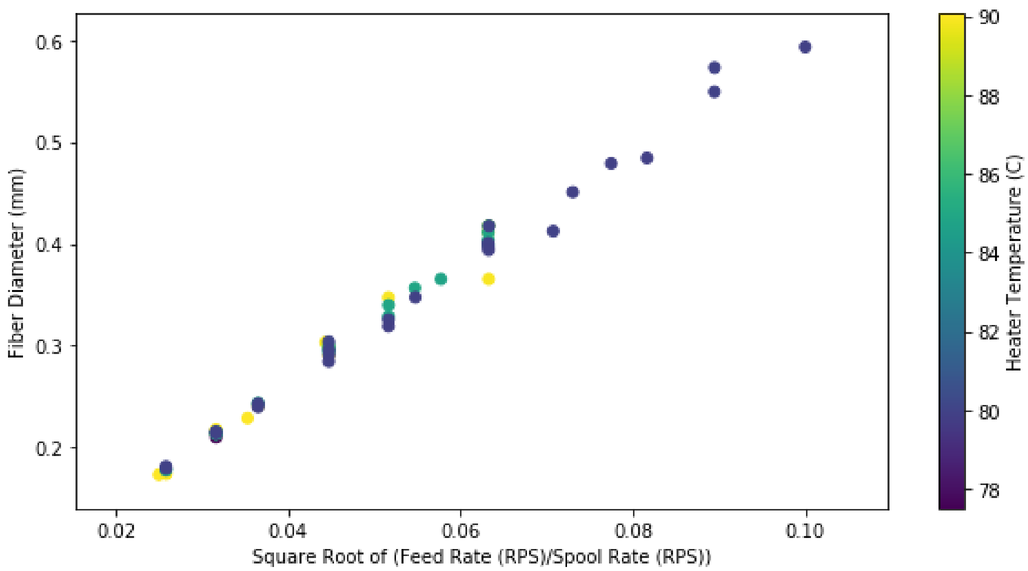
In [6]:
```python
# plot filament diameter versus sqrt(feed/spool)
fig, ax1 = plt.subplots()
fig.set_size_inches(10,5)
ax1.scatter(data['Sqrt Feed/Spool'],data['Filament Diamter Ave (mm)'])
ax1.set_xlabel('Square Root of (Feed Rate (RPS)/Spool Rate (RPS))')
ax1.set_ylabel('Fiber Diameter (mm)')
print('Fiber Diameter versus Sqrt(Feed/Spool)')
```

```
Fiber Diameter versus Sqrt(Feed/Spool)
```



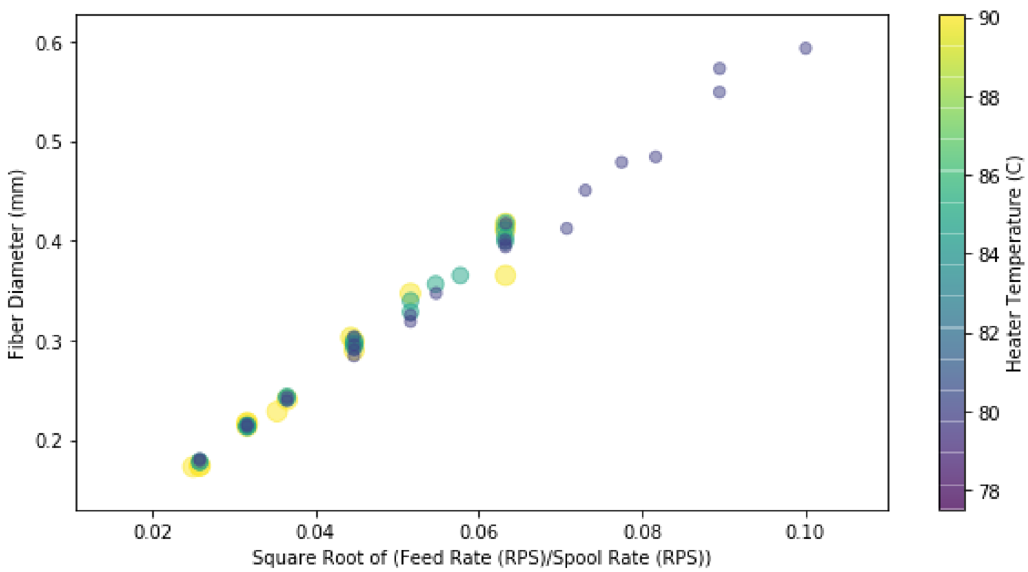
In [7]:
```python
# plot filament diameter versus sqrt(feed/spool) and temperature
fig, ax1 = plt.subplots()
fig.set_size_inches(10,5)
pl = ax1.scatter(data['Sqrt Feed/Spool'],data['Filament Diamter Ave (mm)'],c=data['Heater Temp Ave
(C)'])
plt.colorbar(pl, label='Heater Temperature (C)')
ax1.set_xlabel('Square Root of (Feed Rate (RPS)/Spool Rate (RPS))')
ax1.set_ylabel('Fiber Diameter (mm)')
print('Fiber Diameter versus Sqrt(Feed/Spool)')
```

```
Fiber Diameter versus Sqrt(Feed/Spool)
```

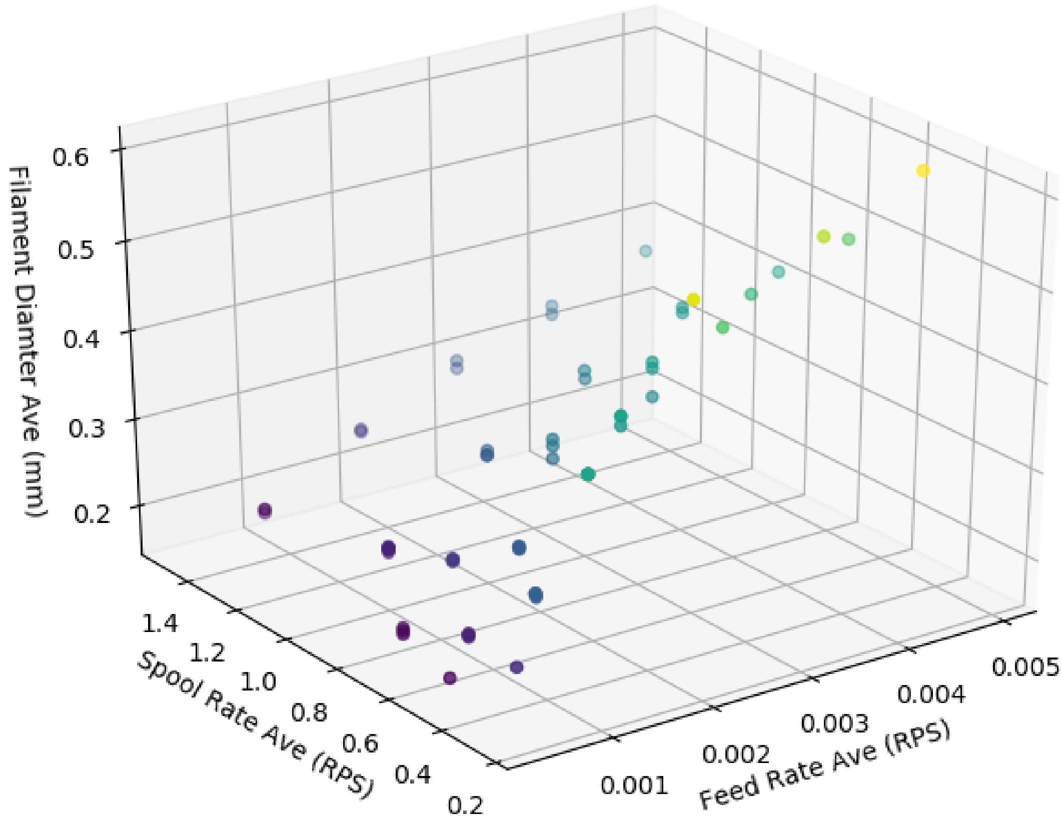


In [8]:
```
# plot filament diameter versus sqrt(feed/spool) and temperature (both size and color)
fig, ax1 = plt.subplots()
fig.set_size_inches(10,5)
pl = ax1.scatter(data['Sqrt Feed/Spool'],data['Filament Diamter Ave (mm)'],c=data['Heater Temp Ave (C)'],s=((data['Heater Temp Ave (C)']-75)*8 ),alpha=.5)
plt.colorbar(pl, label='Heater Temperature (C)')
ax1.set_xlabel('Square Root of (Feed Rate (RPS)/Spool Rate (RPS))')
ax1.set_ylabel('Fiber Diameter (mm)')
print('Fiber Diameter versus Sqrt(Feed/Spool)')
```

```
Fiber Diameter versus Sqrt(Feed/Spool)
```

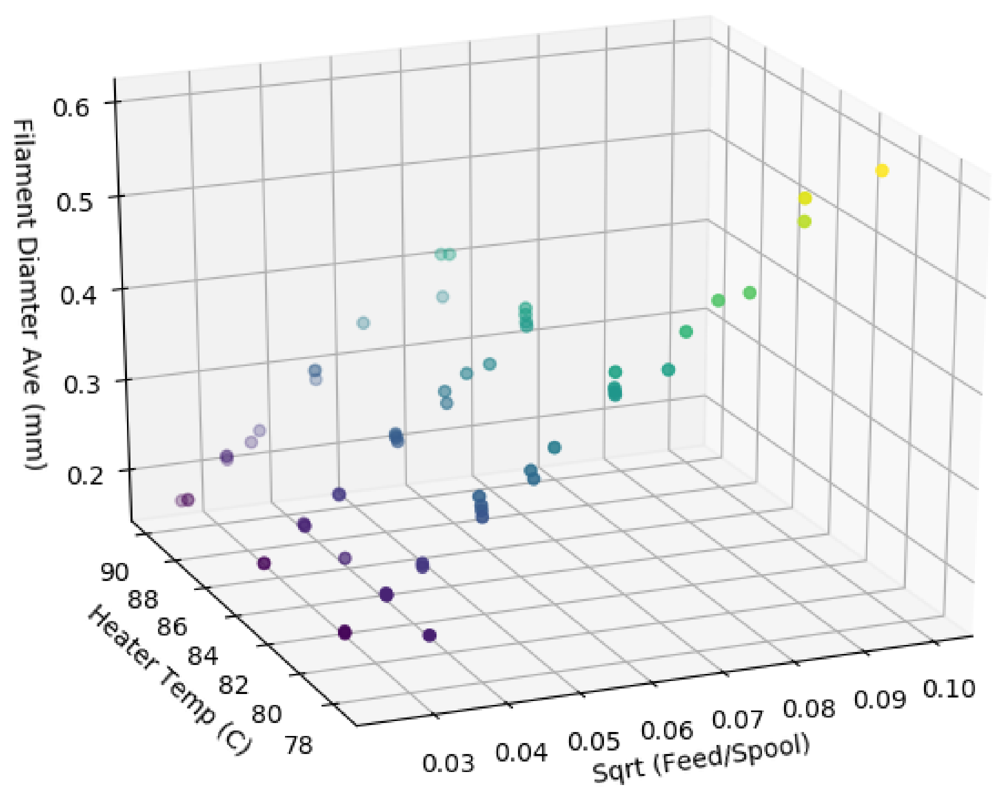


In [9]:
```
# 3D plot - feed, spool, diameter
%matplotlib notebook
fig = plt.figure()
ax1 = Axes3D(fig)
ax1.scatter(data['Feed Rate Ave (RPS)'],data['Spool Rate Ave (RPS)'],data['Filament Diamter Ave (m
m)'],c=data['Filament Diamter Ave (mm)'])
ax1.set_xlabel('Feed Rate Ave (RPS)')
ax1.set_ylabel('Spool Rate Ave (RPS)')
ax1.set_zlabel('Filament Diamter Ave (mm)')
print('Fiber Diameter versus Feed and Spool Speed')
```




```
Fiber Diameter versus Feed and Spool Speed
```

In [10]:
```
# 3D plot - sqrt(feed/spool), temp, diameter
fig = plt.figure()
ax1 = Axes3D(fig)
ax1.scatter(data['Sqrt Feed/Spool'],data['Heater Temp Ave (C)'],data['Filament Diamter Ave (mm)'],
c=data['Filament Diamter Ave (mm)'])
ax1.set_xlabel('Sqrt (Feed/Spool)')
ax1.set_ylabel('Heater Temp (C)')
ax1.set_zlabel('Filament Diamter Ave (mm)')
print('Fiber Diameter versus Feed and Spool Speed')
```




```
Fiber Diameter versus Feed and Spool Speed
```

Fiber Diameter - Standard Deviation

Explore the factors that influence the standard deviation of fiber diameter, a measure of quality.

In [11]:

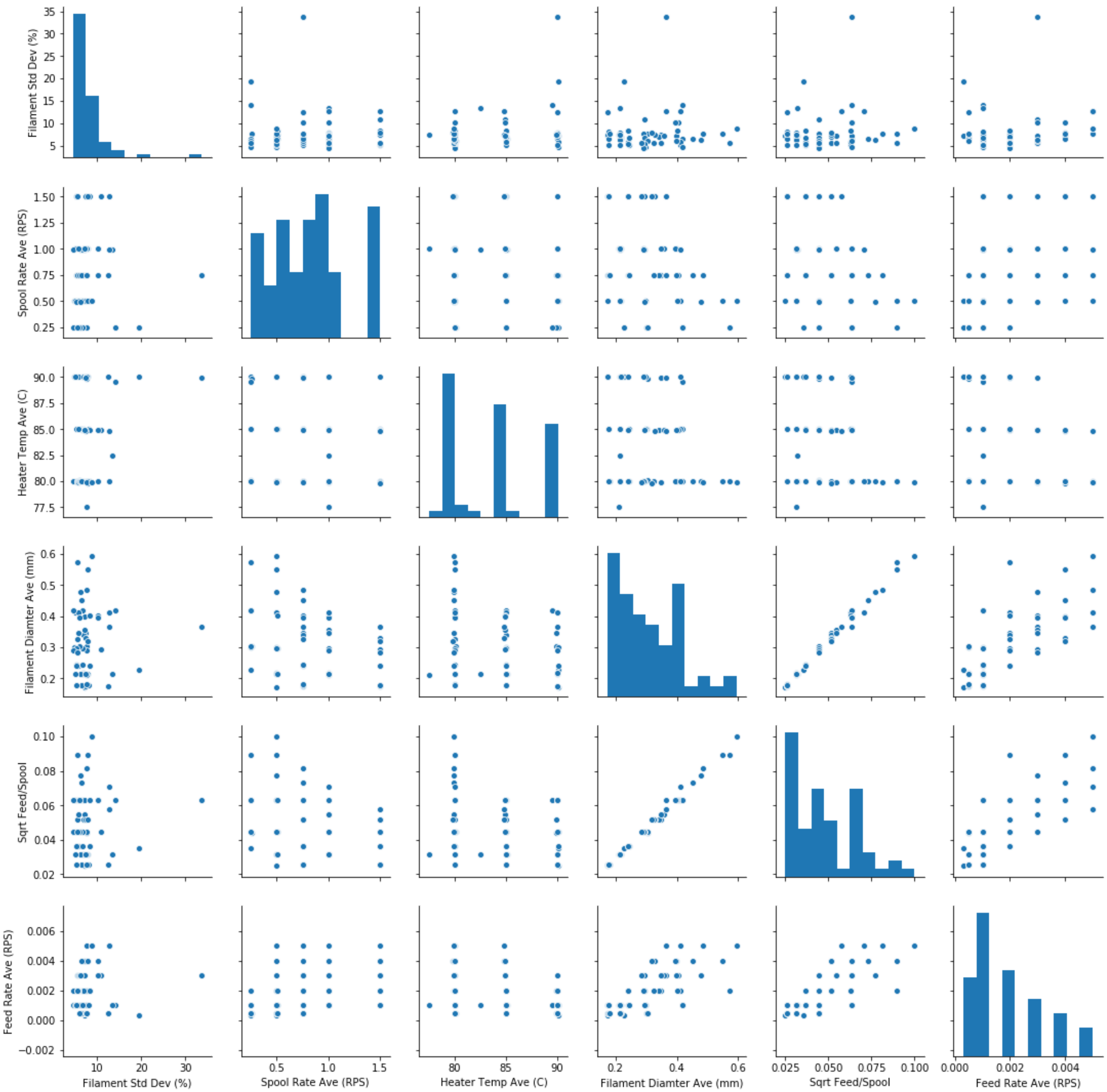
```python
# add a dataframe column that includes % std dev of fiber diameter
data['Filament Std Dev (%)'] = 100 * data['Filament Std Dev (mm)'] / data['Filament Diamter Ave (mm)']
data
```

Out[11]:

	Run File	Feed Rate Ave (RPS)	Spool Wind Rate Set (RPS)	Spool Rate Ave (RPS)	Wind BF Rate Ave (PPS)	Heater Set (C)	Heater Temp Ave (C)	Filament Diamter Ave (mm)	Filament Std Dev (mm)	System Power Ave (W)	System Power Std Dev (W)	C
0	log_Manual Control__2020-04-12_12-13-50.csv	0.001000	1.00	1.000132	127.730719	90.0	90.009313	0.213487	0.016746	29.041052	1.000198	1
1	log_Manual Control__2020-04-12_17-26-48.csv	0.000312	0.25	0.250982	20.426288	90.0	90.068162	0.228383	0.044286	30.064674	1.123981	1
2	log_Manual Control__2020-04-12_17-26-48.csv	0.000312	0.50	0.499899	28.561457	90.0	90.080434	0.172805	0.012332	29.126951	1.001411	1
3	log_Manual Control__2020-04-12_17-49-04.csv	0.000500	0.25	0.254232	45.159629	90.0	89.850642	0.302968	0.022932	28.685025	1.093912	1
4	log_Manual Control__2020-04-12_17-49-04.csv	0.000500	0.50	0.499777	63.865360	90.0	90.043857	0.217002	0.014405	28.366543	0.931641	1
...	...	...	...	...	...	...	...	...	...	...	...	
56	log_Manual Control__2020-05-26_10-47-57.csv	0.004000	0.75	0.749697	221.236095	80.0	79.951250	0.450721	0.029310	25.648463	2.279616	1
57	log_Manual Control__2020-05-26_10-47-57.csv	0.004000	0.50	0.499585	180.638516	80.0	79.994511	0.549398	0.042787	24.219703	9.242227	1
58	log_Manual Control__2020-05-26_10-47-57.csv	0.005000	1.00	0.998329	285.614571	80.0	80.010143	0.412343	0.052719	24.840470	9.815740	1
59	log_Manual Control__2020-05-26_10-47-57.csv	0.005000	0.75	0.749777	247.349474	80.0	79.871364	0.484278	0.036691	25.306375	1.619509	1
60	log_Manual Control__2020-05-26_10-47-57.csv	0.005000	0.50	0.499643	201.960000	80.0	79.916287	0.593511	0.051736	24.807645	5.906214	1

61 rows × 19 columns

In [13]:
```
# explore with correlation matrix
# create reduced feature dataframe
df = data[['Filament Std Dev (%)','Spool Rate Ave (RPS)','Heater Temp Ave (C)','Filament Diamter Ave (mm)','Sqrt Feed/Spool','Feed Rate Ave (RPS)']]
#sn.heatmap(df.corr(), annot=True)
#plt.show()
%matplotlib inline
sn.pairplot(df)
plt.show()
df.corr()
```

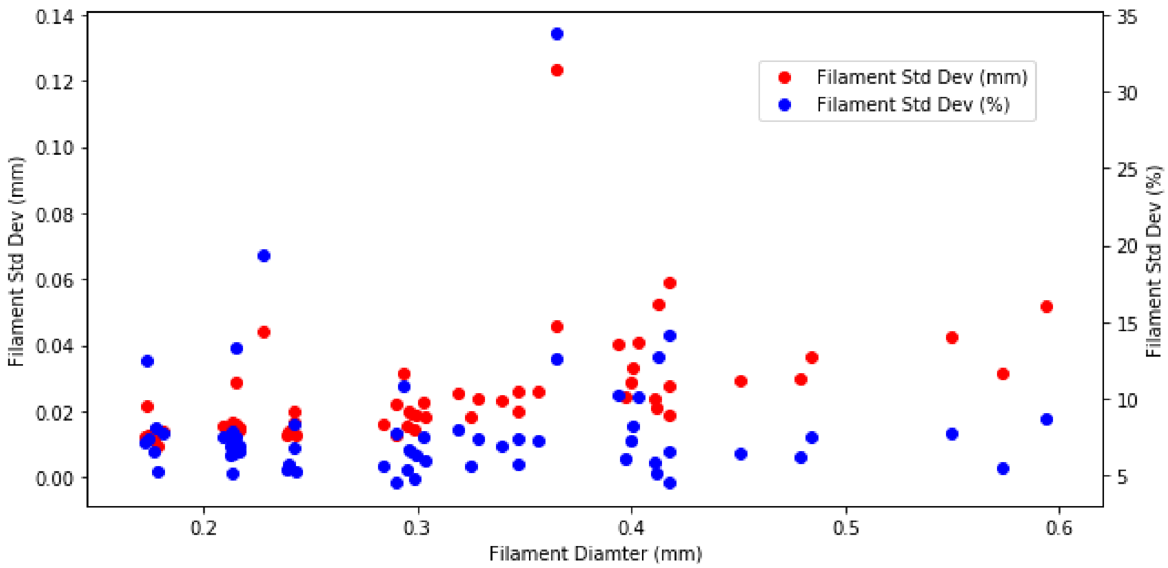


Out[13]:

	Filament Std Dev (%)	Spool Rate Ave (RPS)	Heater Temp Ave (C)	Filament Diamter Ave (mm)	Sqrt Feed/Spool	Feed Rate Ave (RPS)
Filament Std Dev (%)	1.000000	-0.008717	0.291560	0.049799	0.096607	0.160502
Spool Rate Ave (RPS)	-0.008717	1.000000	-0.114830	-0.352166	-0.314407	0.325072
Heater Temp Ave (C)	0.291560	-0.114830	1.000000	-0.282535	-0.298767	-0.338853
Filament Diamter Ave (mm)	0.049799	-0.352166	-0.282535	1.000000	0.995249	0.689340
Sqrt Feed/Spool	0.096607	-0.314407	-0.298767	0.995249	1.000000	0.733815
Feed Rate Ave (RPS)	0.160502	0.325072	-0.338853	0.689340	0.733815	1.000000

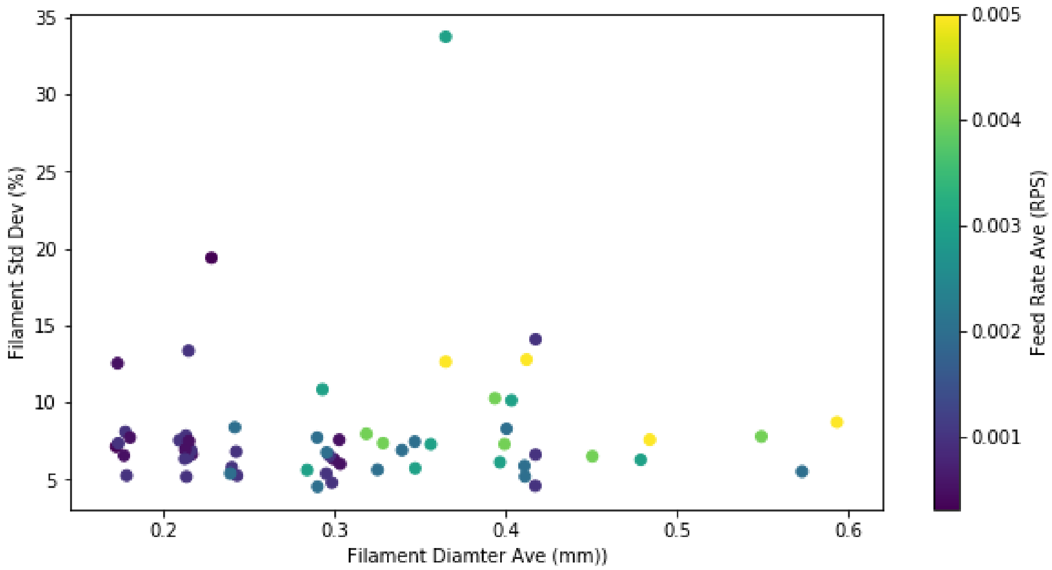
In [14]:
```
# plot std dev versus filament diameter
%matplotlib inline
fig, ax1 = plt.subplots()
fig.set_size_inches(10,5)
ax2 = ax1.twinx()
ax1.scatter(data['Filament Diamter Ave (mm)'],data['Filament Std Dev (mm)'], c='red')
ax1.set_xlabel('Filament Diamter (mm)')
ax1.set_ylabel('Filament Std Dev (mm)')
ax2.scatter(data['Filament Diamter Ave (mm)'],data['Filament Std Dev (%)'], c='blue')
ax2.set_ylabel('Filament Std Dev (%)')
fig.legend(bbox_to_anchor=(.8,.8))
print('Standard Deviation veruses Fiber Diameter')
```

```
Standard Deviation veruses Fiber Diameter
```



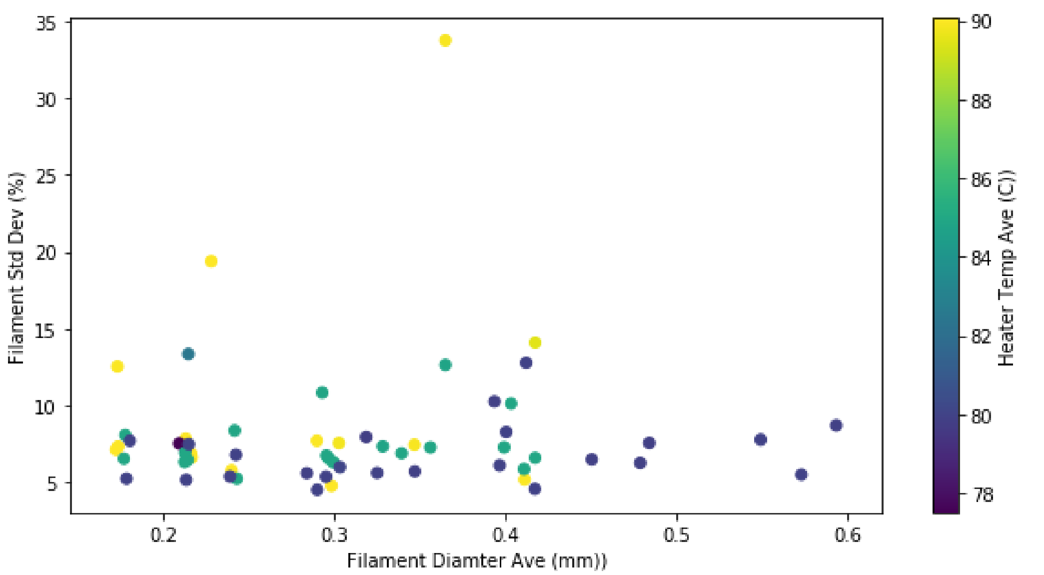
In [15]:
```python
# use std dev % and add color for feed speed
fig, ax1 = plt.subplots()
fig.set_size_inches(10,5)
pl = ax1.scatter(data['Filament Diamter Ave (mm)'],data['Filament Std Dev (%)'],c=data['Feed Rate
 Ave (RPS)'])
plt.colorbar(pl, label='Feed Rate Ave (RPS)')
ax1.set_xlabel('Filament Diamter Ave (mm))')
ax1.set_ylabel('Filament Std Dev (%)')
print('Standard Deviation veruses Fiber Diameter and Feed Speed')
```

```
Standard Deviation veruses Fiber Diameter and Feed Speed
```

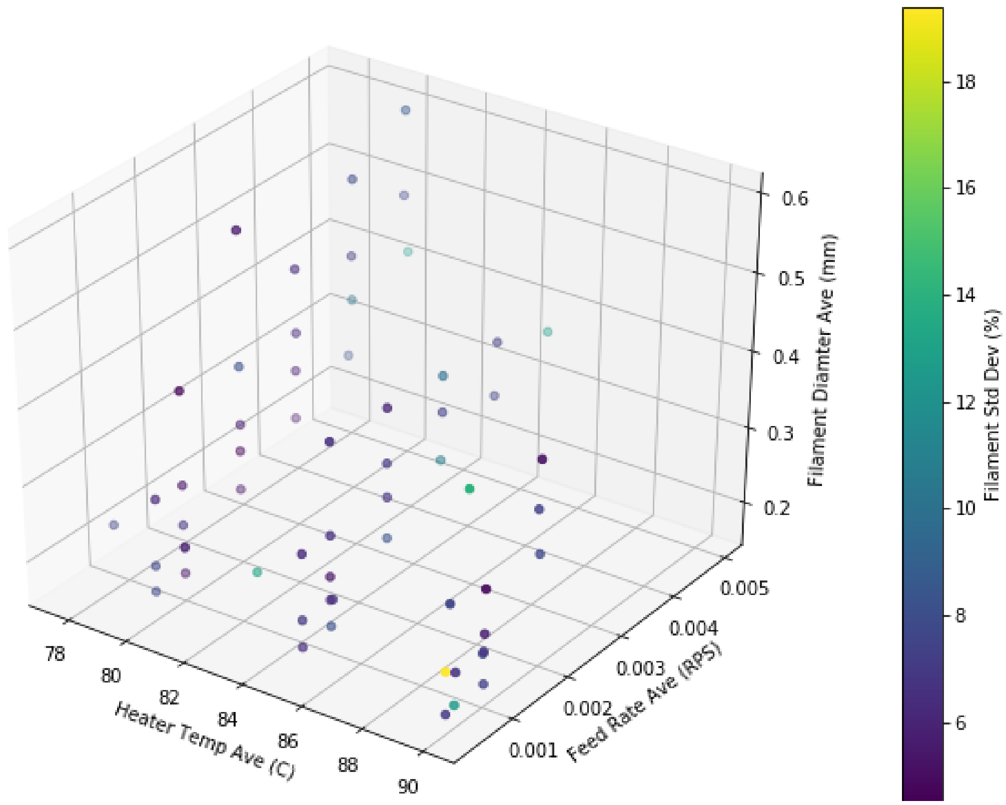


In [16]:
```python
# use std dev % and add color for temperature
fig, ax1 = plt.subplots()
fig.set_size_inches(10,5)
pl = ax1.scatter(data['Filament Diamter Ave (mm)'],data['Filament Std Dev (%)'],c=data['Heater Tem
p Ave (C)'])
plt.colorbar(pl, label='Heater Temp Ave (C))')
ax1.set_xlabel('Filament Diamter Ave (mm))')
ax1.set_ylabel('Filament Std Dev (%)')
print('Standard Deviation veruses Fiber Diameter and Heater Temp')
```

```
Standard Deviation veruses Fiber Diameter and Heater Temp
```

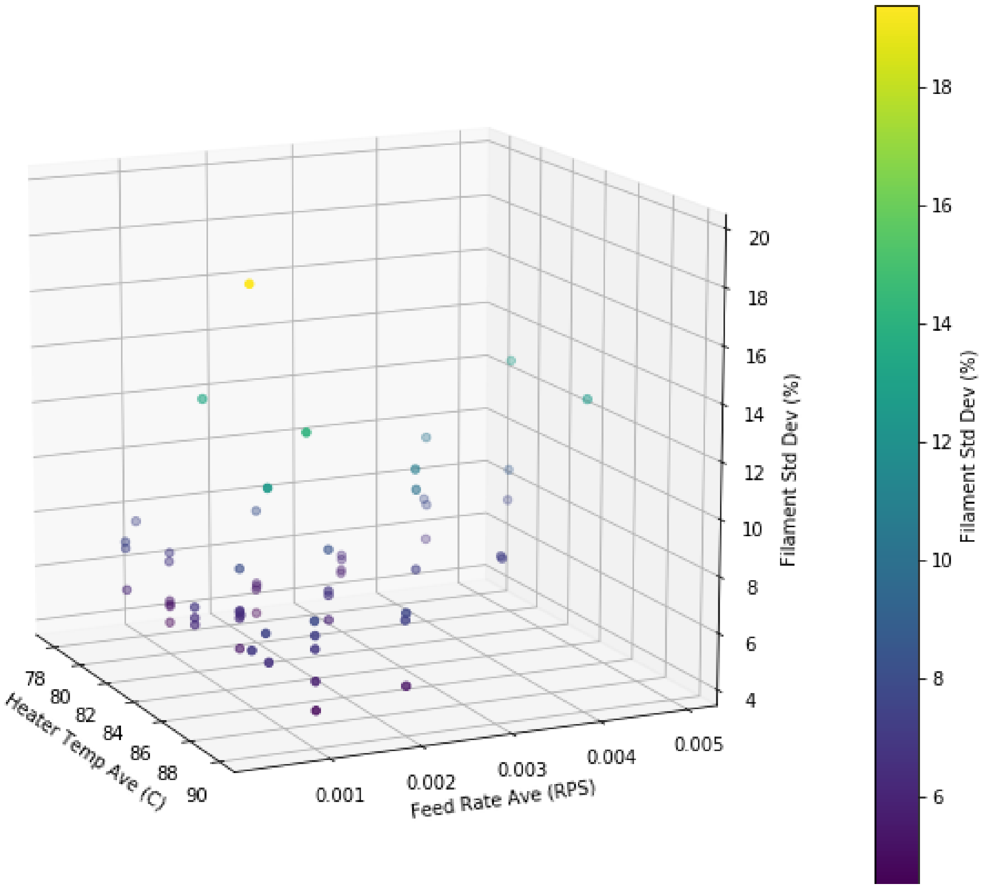


In [18]:
```
# 3D plot - feed, spool, diameter
%matplotlib notebook
# get rid of errant datapoint
df = data[data['Filament Std Dev (%)'] < 20.0]
fig = plt.figure()
ax1 = Axes3D(fig)
pl = ax1.scatter(df['Heater Temp Ave (C)'],df['Feed Rate Ave (RPS)'],df['Filament Diamter Ave (m
m)'],c=df['Filament Std Dev (%)'])
ax1.set_xlabel('Heater Temp Ave (C)')
ax1.set_ylabel('Feed Rate Ave (RPS)')
ax1.set_zlabel('Filament Diamter Ave (mm)')
plt.colorbar(pl, label='Filament Std Dev (%)')
print('Fiber Diameter versus Feed Speed and Heater Temp (colored with % Std Dev)')
```



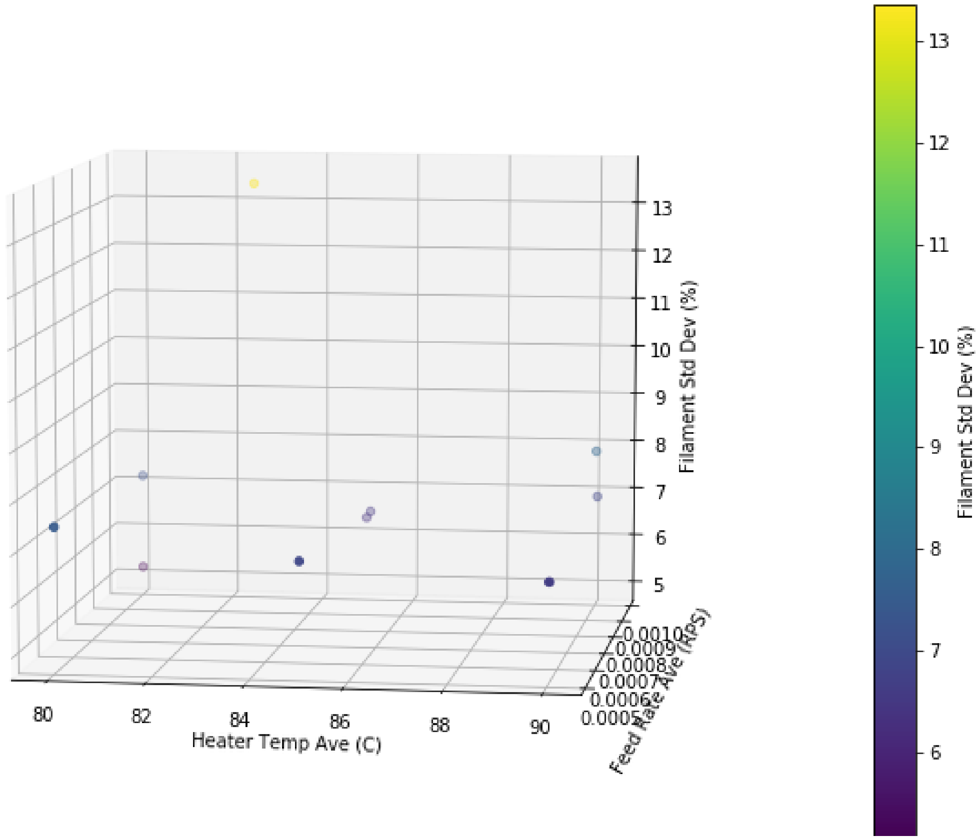

```
Fiber Diameter versus Feed Speed and Heater Temp (colored with % Std Dev)
```

In [19]:
```
# 3D plot - feed, spool, diameter
fig = plt.figure()
ax1 = Axes3D(fig)
pl = ax1.scatter(df['Heater Temp Ave (C)'],df['Feed Rate Ave (RPS)'],df['Filament Std Dev (%)'],c=
df['Filament Std Dev (%)'])
ax1.set_xlabel('Heater Temp Ave (C)')
ax1.set_ylabel('Feed Rate Ave (RPS)')
ax1.set_zlabel('Filament Std Dev (%)')
plt.colorbar(pl, label='Filament Std Dev (%)')
print('Fiber Diameter versus Feed Speed and Heater Temp (colored with % Std Dev)')
```



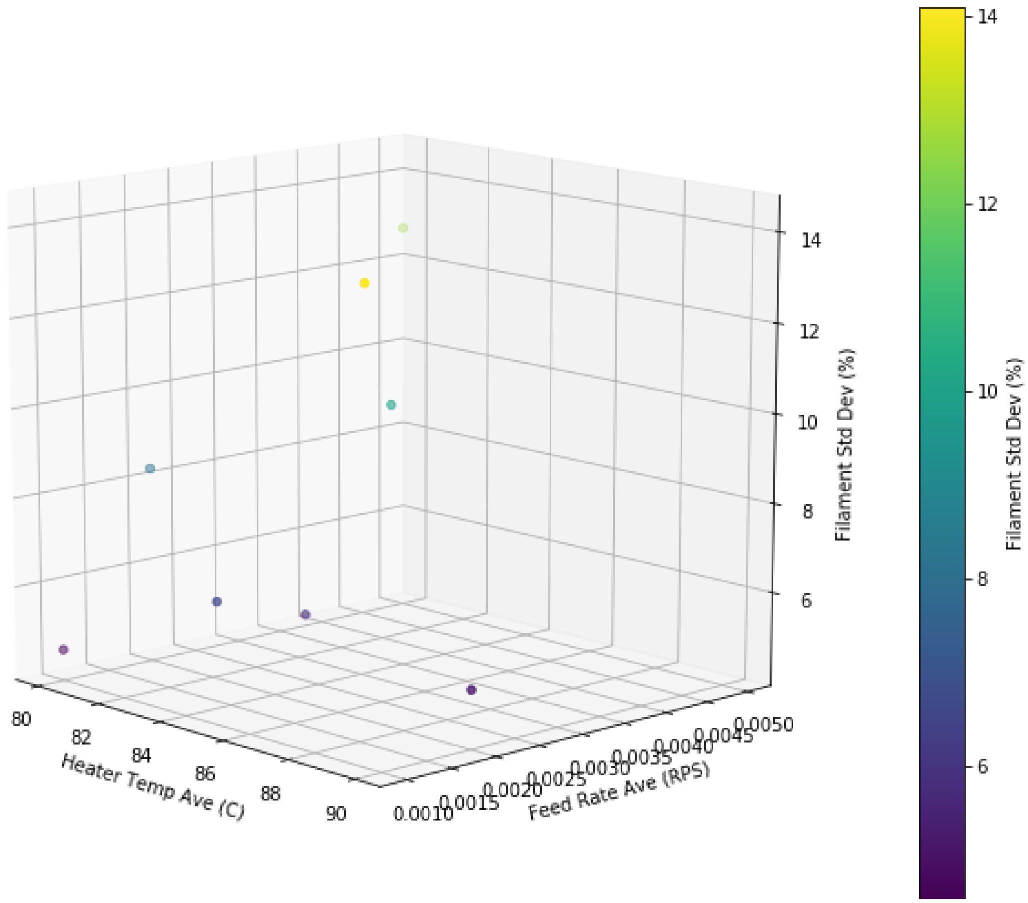

```
Fiber Diameter versus Feed Speed and Heater Temp (colored with % Std Dev)
```

In [20]:
```
# look a two separate fiber diameters - nom. .214mm
df = data[data['Filament Diamter Ave (mm)'] < .22]
df = df[df['Filament Diamter Ave (mm)'] > .21]
#df
# 3D plot - feed, spool, diameter
fig = plt.figure()
ax1 = Axes3D(fig)
pl = ax1.scatter(df['Heater Temp Ave (C)'],df['Feed Rate Ave (RPS)'],df['Filament Std Dev (%)'],c=
df['Filament Std Dev (%)'])
ax1.set_xlabel('Heater Temp Ave (C)')
ax1.set_ylabel('Feed Rate Ave (RPS)')
ax1.set_zlabel('Filament Std Dev (%)')
plt.colorbar(pl, label='Filament Std Dev (%)')
print('Filament Std Dev (%) versus Feed Speed and Heater Temp (.215mm nominal)')
```




```
Filament Std Dev (%) versus Feed Speed and Heater Temp (.215mm nominal)
```

In [21]:
```
# look a two separate fiber diameters - nom. .41mm
df = data[data['Filament Diamter Ave (mm)'] < .42]
df = df[df['Filament Diamter Ave (mm)'] > .4]
#df
# 3D plot - feed, spool, diameter
fig = plt.figure()
ax1 = Axes3D(fig)
pl = ax1.scatter(df['Heater Temp Ave (C)'],df['Feed Rate Ave (RPS)'],df['Filament Std Dev (%)'],c=
df['Filament Std Dev (%)'])
ax1.set_xlabel('Heater Temp Ave (C)')
ax1.set_ylabel('Feed Rate Ave (RPS)')
ax1.set_zlabel('Filament Std Dev (%)')
plt.colorbar(pl, label='Filament Std Dev (%)')
print('Filament Std Dev (%) versus Feed Speed and Heater Temp (.215mm nominal)')
```

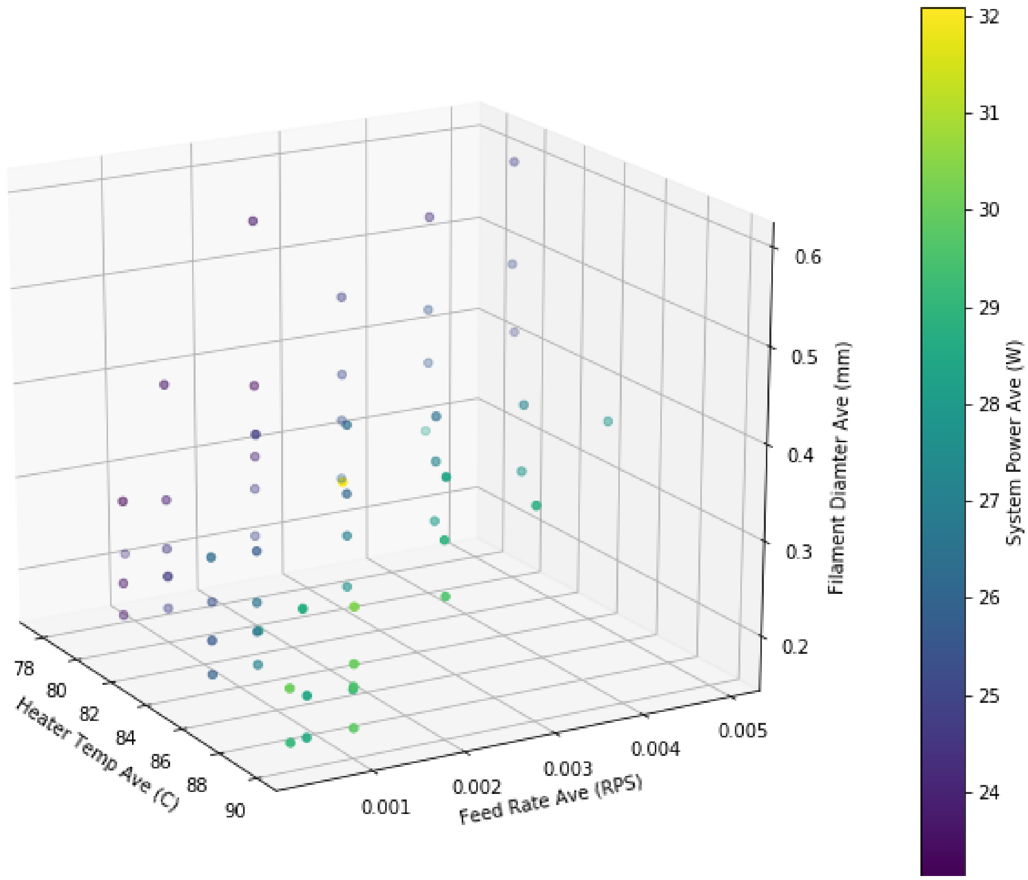



```
Filament Std Dev (%) versus Feed Speed and Heater Temp (.215mm nominal)
```

Power Consumption

Explore power consumption to optimize cost

In [22]:
```
# 3D plot - feed, diameter, temperature, power
%matplotlib notebook
fig = plt.figure()
ax1 = Axes3D(fig)
pl = ax1.scatter(data['Heater Temp Ave (C)'],data['Feed Rate Ave (RPS)'],data['Filament Diamter Av
e (mm)'],c=data['System Power Ave (W)'])
ax1.set_xlabel('Heater Temp Ave (C)')
ax1.set_ylabel('Feed Rate Ave (RPS)')
ax1.set_zlabel('Filament Diamter Ave (mm)')
plt.colorbar(pl, label='System Power Ave (W)')
print('Fiber Diameter versus Feed Speed and Heater Temp (colored with Power)')
```




```
Fiber Diameter versus Feed Speed and Heater Temp (colored with Power)
```

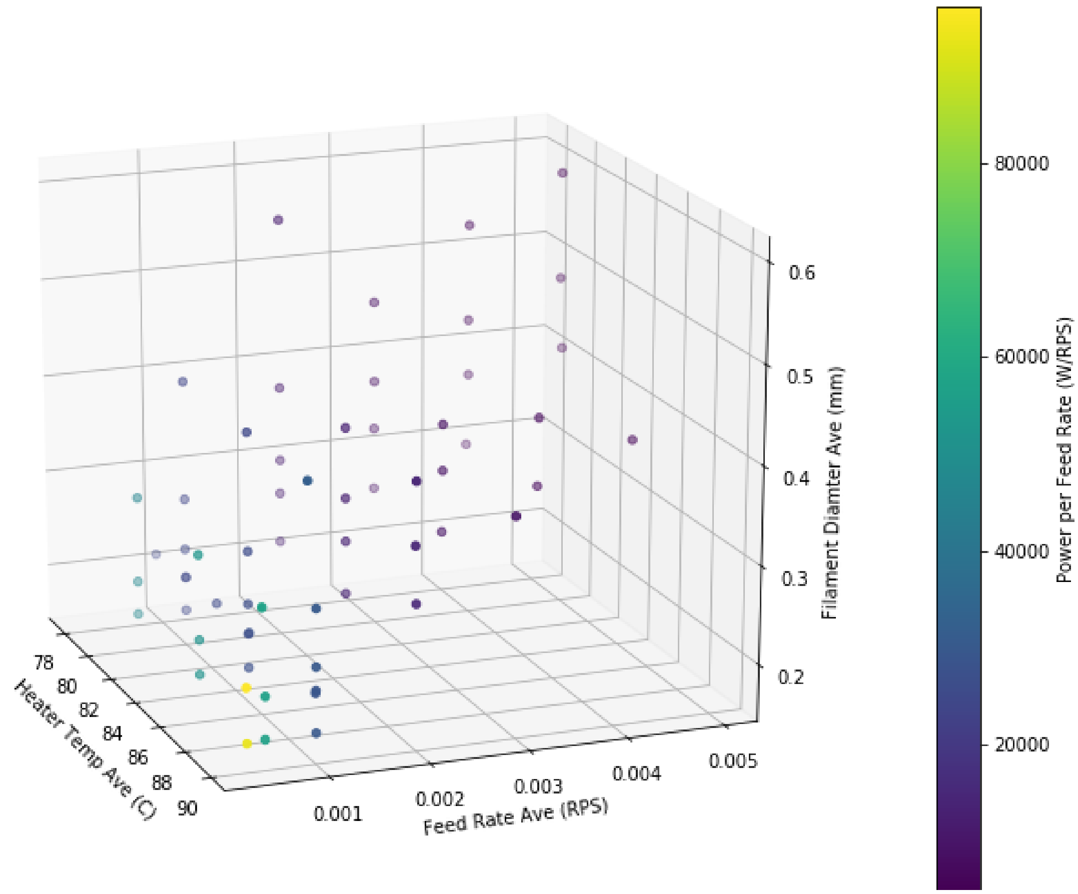
In [23]:
```python
# add a dataframe column that includes power per feed rate
data['Power per Feed Rate (W/RPS)'] = data['System Power Ave (W)'] / data['Feed Rate Ave (RPS)']
data
```

Out[23]:

	Run File	Feed Rate Ave (RPS)	Spool Wind Rate Set (RPS)	Spool Rate Ave (RPS)	Wind BF Rate Ave (PPS)	Heater Set (C)	Heater Temp Ave (C)	Filament Diamter Ave (mm)	Filament Std Dev (mm)	System Power Ave (W)	System Power Std Dev (W)	C
0	log_Manual Control__2020-04-12_12-13-50.csv	0.001000	1.00	1.000132	127.730719	90.0	90.009313	0.213487	0.016746	29.041052	1.000198	1
1	log_Manual Control__2020-04-12_17-26-48.csv	0.000312	0.25	0.250982	20.426288	90.0	90.068162	0.228383	0.044286	30.064674	1.123981	1
2	log_Manual Control__2020-04-12_17-26-48.csv	0.000312	0.50	0.499899	28.561457	90.0	90.080434	0.172805	0.012332	29.126951	1.001411	1.
3	log_Manual Control__2020-04-12_17-49-04.csv	0.000500	0.25	0.254232	45.159629	90.0	89.850642	0.302968	0.022932	28.685025	1.093912	1.
4	log_Manual Control__2020-04-12_17-49-04.csv	0.000500	0.50	0.499777	63.865360	90.0	90.043857	0.217002	0.014405	28.366543	0.931641	1
...	...	...	...	...	...	...	...	...	...	...	...	
56	log_Manual Control__2020-05-26_10-47-57.csv	0.004000	0.75	0.749697	221.236095	80.0	79.951250	0.450721	0.029310	25.648463	2.279616	1.
57	log_Manual Control__2020-05-26_10-47-57.csv	0.004000	0.50	0.499585	180.638516	80.0	79.994511	0.549398	0.042787	24.219703	9.242227	1.
58	log_Manual Control__2020-05-26_10-47-57.csv	0.005000	1.00	0.998329	285.614571	80.0	80.010143	0.412343	0.052719	24.840470	9.815740	1.
59	log_Manual Control__2020-05-26_10-47-57.csv	0.005000	0.75	0.749777	247.349474	80.0	79.871364	0.484278	0.036691	25.306375	1.619509	1.
60	log_Manual Control__2020-05-26_10-47-57.csv	0.005000	0.50	0.499643	201.960000	80.0	79.916287	0.593511	0.051736	24.807645	5.906214	1.

61 rows × 20 columns

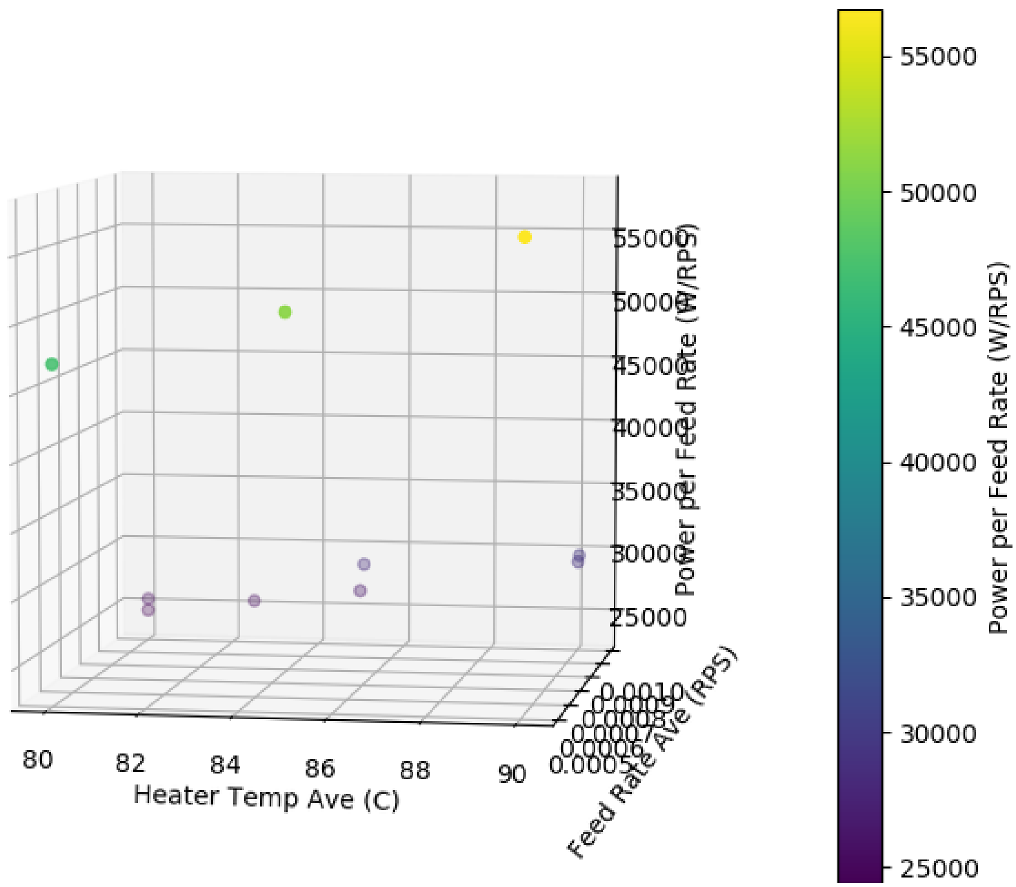
In [24]:
```
# 3D plot - feed, diameter, temperature, power metric
%matplotlib notebook
fig = plt.figure()
ax1 = Axes3D(fig)
pl = ax1.scatter(data['Heater Temp Ave (C)'],data['Feed Rate Ave (RPS)'],data['Filament Diamter Av
e (mm)'],c=data['Power per Feed Rate (W/RPS)'])
ax1.set_xlabel('Heater Temp Ave (C)')
ax1.set_ylabel('Feed Rate Ave (RPS)')
ax1.set_zlabel('Filament Diamter Ave (mm)')
plt.colorbar(pl, label='Power per Feed Rate (W/RPS)')
print('Fiber Diameter versus Feed Speed and Heater Temp (colored with Power metric)')
```




```
Fiber Diameter versus Feed Speed and Heater Temp (colored with Power metric)
```

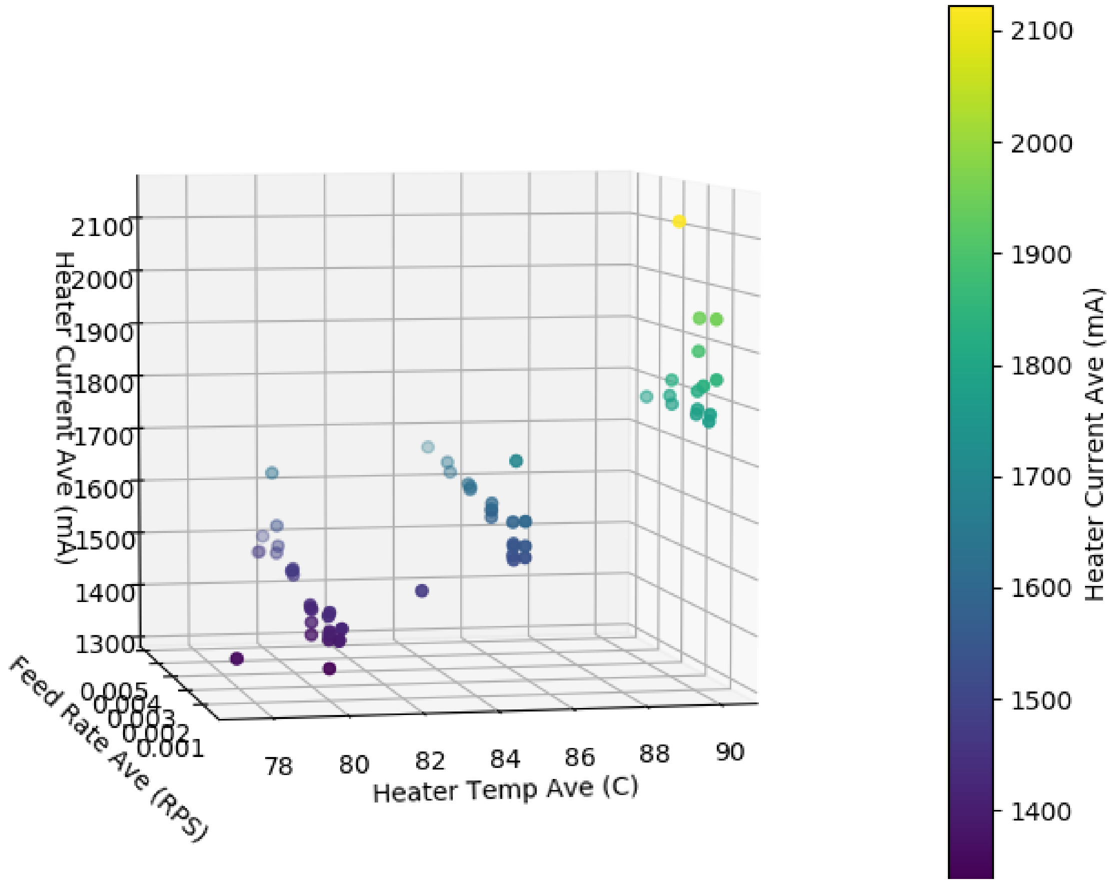
In [30]:

```
# look a example fiber diameter - nom. .214mm
df = data[data['Filament Diamter Ave (mm)'] < .22]
df = df[df['Filament Diamter Ave (mm)'] > .21]
#df
# 3D plot - feed, spool, diameter
fig = plt.figure()
ax1 = Axes3D(fig)
pl = ax1.scatter(df['Heater Temp Ave (C)'],df['Feed Rate Ave (RPS)'],df['Power per Feed Rate (W/RP
S)'],c=df['Power per Feed Rate (W/RPS)'])
ax1.set_xlabel('Heater Temp Ave (C)')
ax1.set_ylabel('Feed Rate Ave (RPS)')
ax1.set_zlabel('Power per Feed Rate (W/RPS)')
plt.colorbar(pl, label='Power per Feed Rate (W/RPS)')
print('Power per Feed Rate (W/RPS) versus Feed Speed and Heater Temp (.215mm nominal)')
```



Power per Feed Rate (W/RPS) versus Feed Speed and Heater Temp (.215mm nominal)

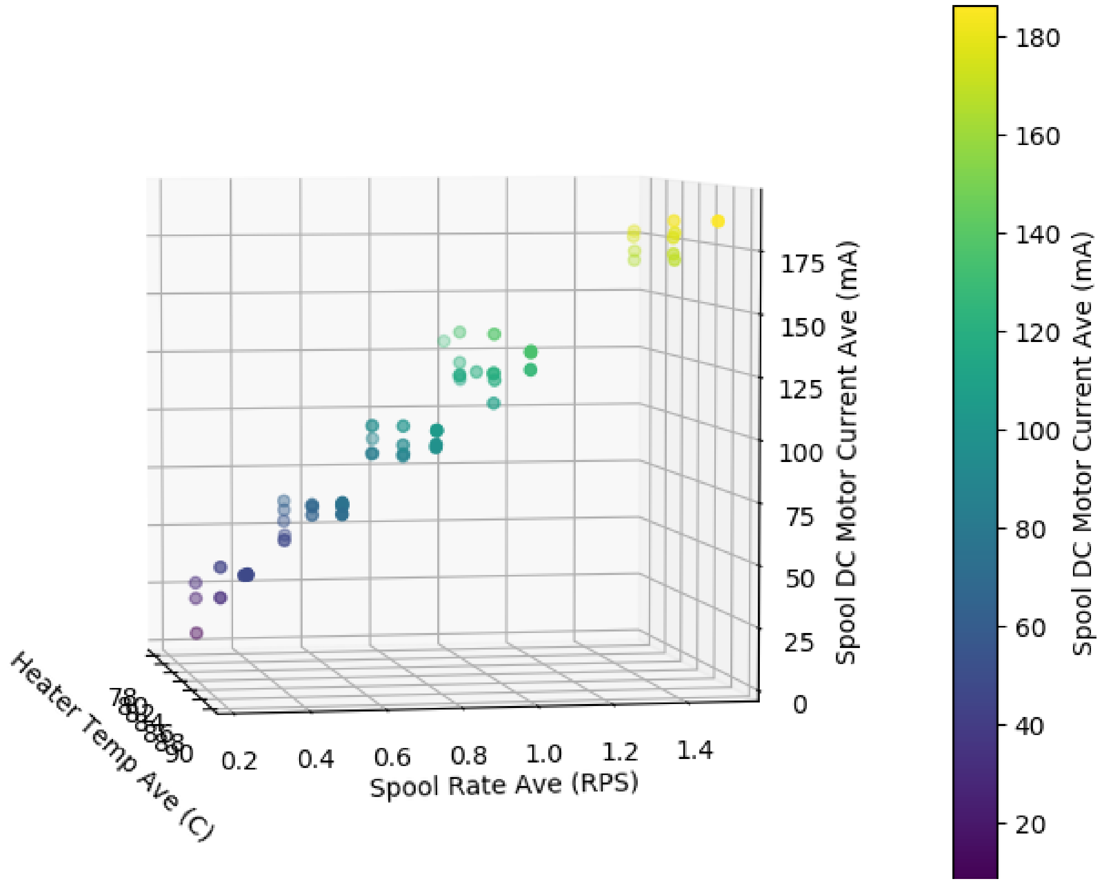
In [33]:
```
# Look at Power (current) Components - Heater
fig = plt.figure()
ax1 = Axes3D(fig)
pl = ax1.scatter(data['Heater Temp Ave (C)'],data['Feed Rate Ave (RPS)'],data['Heater Current Ave (mA)'],c=data['Heater Current Ave (mA)'])
ax1.set_xlabel('Heater Temp Ave (C)')
ax1.set_ylabel('Feed Rate Ave (RPS)')
ax1.set_zlabel('Heater Current Ave (mA)')
plt.colorbar(pl, label='Heater Current Ave (mA)')
print('Heater Current Ave (mA) versus Feed Speed and Heater Temp')
```




```
Heater Current Ave (mA) versus Feed Speed and Heater Temp
```

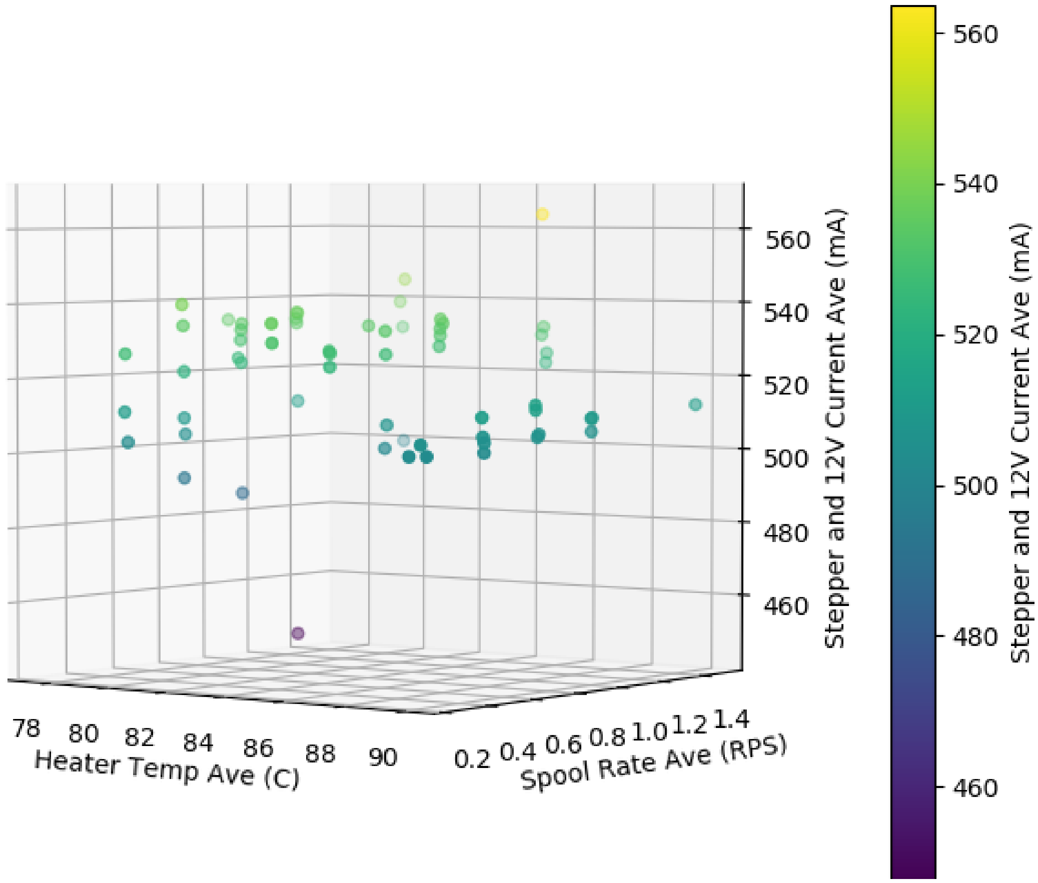
In [35]:

```python
# Look at Power (current) Components - Spool
fig = plt.figure()
ax1 = Axes3D(fig)
pl = ax1.scatter(data['Heater Temp Ave (C)'],data['Spool Rate Ave (RPS)'],data['Spool DC Motor Cur
rent Ave (mA)'],c=data['Spool DC Motor Current Ave (mA)'])
ax1.set_xlabel('Heater Temp Ave (C)')
ax1.set_ylabel('Spool Rate Ave (RPS)')
ax1.set_zlabel('Spool DC Motor Current Ave (mA)')
plt.colorbar(pl, label='Spool DC Motor Current Ave (mA)')
print('Spool DC Motor Current Ave (mA) versus Feed Speed and Heater Temp')
```



Spool DC Motor Current Ave (mA) versus Feed Speed and Heater Temp

In [36]:
```
# Look at Power (current) Components - Feed & Ancillary
fig = plt.figure()
ax1 = Axes3D(fig)
pl = ax1.scatter(data['Heater Temp Ave (C)'],data['Spool Rate Ave (RPS)'],data['Stepper and 12V Cu
rrent Ave (mA)'],c=data['Stepper and 12V Current Ave (mA)'])
ax1.set_xlabel('Heater Temp Ave (C)')
ax1.set_ylabel('Spool Rate Ave (RPS)')
ax1.set_zlabel('Stepper and 12V Current Ave (mA)')
plt.colorbar(pl, label='Stepper and 12V Current Ave (mA)')
print('Stepper and 12V Current Ave (mA) versus Feed Speed and Heater Temp')
```




```
Stepper and 12V Current Ave (mA) versus Feed Speed and Heater Temp
```

In [ ]:

/