Solutions to the Online Steam Turbine Experiment
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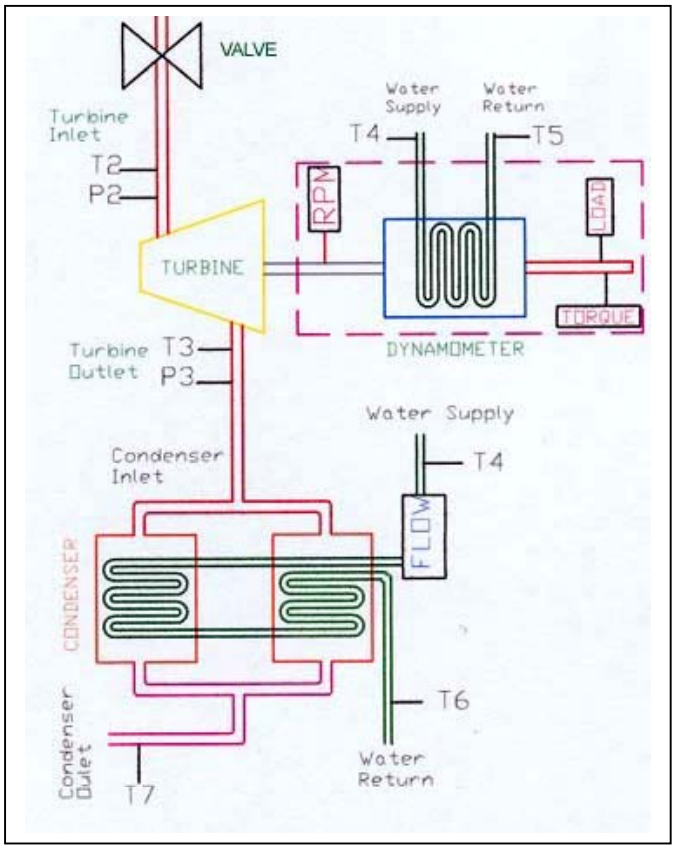
Name
Date

Objective: The objective of this exercise is to use the on-line version of the steam turbine experiment to reinforce theoretical thermodynamics concepts discussed in class, including use of the property charts to determine phases and fix states, performing energy balances, and



Apparatus: A schematic of the apparatus is shown to the right. The locations of the turbine, dynamometer, and condenser are shown, as well as the temperature (T2, T3, T4, T5, T6, and T7), pressure (P2 and P3) and flow (FLOW) sensors.

Approach: For this experiment, the load and RPM of the steam turbine were varied with the dynamometer. The resulting variation in power output and isentropic efficiency of the turbine will be analyzed.

Data: The data from this experiment are shown in Table 1. The calculations performed on the data are shown in Table 2. Sample calculations are shown in Appendix A.

Data Set 1						
Load	20	50	80	20	50	80
RPM	1600	1600	1600	2200	2200	2200
flow cv [gal/min]	90.8	91.5	91.5	92.7	92.3	93.9
T4 [deg F]	76	82	86	92	90	88
T6 [deg F]	86	99	120	100	108	130
torque [ft-lb]	6.2	32.5	63.8	6.8	27.8	65.4
T2 [deg F]	277	327	298	297	324	320
P2 [psig]	33.3	86.4	51.8	50.8	82.4	77.1
T7 [deg F]	208	166	184	183	194	188
T3 [deg F]	210	210	211	210	211	211
P3 [psig]	0	0	0.1	0	0	0.3

Table 1. Data from Steam Turbine Experiment

Data Set 2						
Load	20	50	80	20	50	80
RPM	2000	2000	2000	2600	2600	2600
flow cv [gal/min]	94.8	95.5	95.5	96.7	96.3	97.9
T4 [deg F]	80	86	90	96	94	92
T6 [deg F]	90	103	124	104	112	134
torque [ft-lb]	8.2	34.5	65.8	8.8	29.8	67.4
T2 [deg F]	281	331	302	301	328	324
P2 [psig]	34.3	87.4	52.8	51.8	83.4	78.1
T7 [deg F]	212	170	188	187	198	192
T3 [deg F]	212	212	213	212	213	213
P3 [psig]	0.2	0.2	0.3	0.2	0.2	0.5
Average						
Load	20	50	80	20	50	80
RPM	1800	1800	1800	2400	2400	2400
flow cv [gal/min]	92.8	93.5	93.5	94.7	94.3	95.9
T4 [deg F]	78	84	88	94	92	90
T6 [deg F]	88	101	122	102	110	132
torque [ft-lb]	7.2	33.5	64.8	7.8	28.8	66.4
T2 [deg F]	279	329	300	299	326	322
P2 [psig]	33.8	86.9	52.3	51.3	82.9	77.6
T7 [deg F]	210	168	186	185	196	190
T3 [deg F]	211	211	212	211	212	212
P3 [psig]	0.1	0.1	0.2	0.1	0.1	0.4

Table 1 (cont.) Data from Steam Turbine Experiment

h2 g @ T2 [Btu/lbm]	1174	1188	1180	1180	1186.7	1184
s2 g @ T2 [Btu/lbmR]	1.66	1.6	1.64	1.64	1.6	1.61
Turbine power [HP]	2.467631	11.48134	22.20868	3.564356	13.1607	30.342727
Turbine power [W]	1840.113	8561.636	16561.01	2657.941	9813.93	22626.571
Turbine power [Btu/hr]	6278.715	29213.47	56508.44	9069.255	33486.5	77204.944
h7 f @ T7 [Btu/lbm]	178.15	135.97	154.02	153.02	164.06	158.04
h4 f @ T4 [Btu/lbm]	46.09	52.09	56.09	62.06	60.07	58.07
h6 f @ T6 [Btu/lbm]	56.07	69.05	90	70.05	78.02	100
T ave 4-6 [deg F]	83	92.5	105	98	101	111
vf at Tave [ft3/lbm]	0.016	0.016	0.0161	0.0161	0.0161	0.0162
rho 4-6 [lbm/ft3]	62.5	62.5	62.1118	62.1118	62.1118	61.728395
m dot w [lbm/hr]	46520.64	46871.55	46580.42	47178.25	46979	47481.156
Qdot [Btu/hr]	464276	794941.5	1579542	376954.2	843273	1990884.9
h3 [Btu/lbm]	1160.712	1150.709	1144.563	1155.872	1147.64	1145.6993
m dot steam [lbm/hr]	472.5156	783.3949	1594.622	375.8821	857.349	2015.7606
P3 [psia]	14.8	14.8	14.9	14.8	14.8	15.1
hg @ P3 [Btu/lbm]	1150	1150	1150	1150	1150	1151
hf @ T3 [Btu/lbm]	179.16	179.16	180.17	179.16	180.17	180.17
hg @ T3 [Btu/lbm]	1150.1	1150.1	1150.5	1150.1	1150.5	1150.5
sf @ T3 [Btu/lbmR]	0.3106	0.3106	0.3121	0.3106	0.3121	0.3121
sg @ T3 [Btu/lbmR]	1.7606	1.7606	1.7568	1.7606	1.7568	1.7568
x 3s	0.930621	0.889241	0.919153	0.916828	0.89147	0.8983872
h 3s [Btu/lbm]	1082.737	1042.56	1072.052	1069.345	1045.19	1051.9021
Isen. Turbine Power [Btu/hr]	43123.26	113936.9	172137.1	41593.4	121327	266277.83
Isentropic efficiency	0.145599	0.2564	0.328276	0.218046	0.276	0.2899413

Table 2. Calculations for Steam Turbine Experiment

Results and Discussion:

1. The data show that the turbine power is about 30 HP at 80% load and 2400 RPM. Thus, the measurements validate the rated power.
2. Turbine power increases with the mass flow rate of steam. Mass flow rate of steam increases with RPM and with load.
3. The maximum isentropic efficiency occurs at a turbine power of 56000 Btu/hr. The optimal power range is about 56000 to 77000 Btu/hr.
4. The h-s diagram for this experiment has the turbine inlet on the saturated vapor line. The diagram in the book plots it in the superheated vapor phase.
5. Fluctuations in the measurements could arise from the sensors and from randomly occurring fluctuations in the quantities being measured.

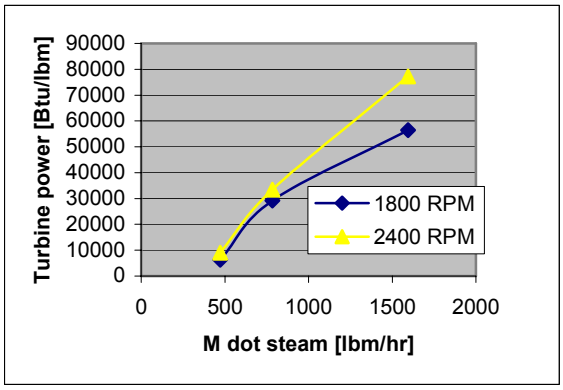


Figure 1. Turbine power as a function of mass flow rate and RPM

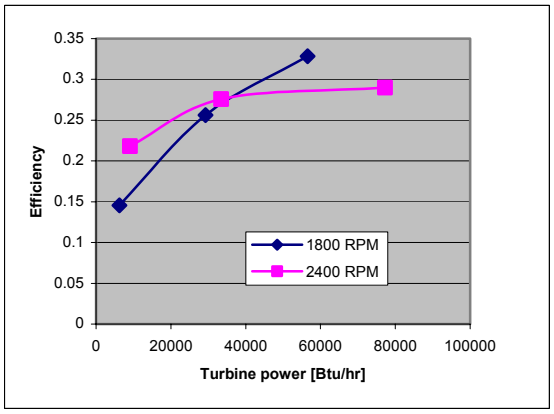


Figure 2. Isentropic efficiency as a function of turbine power

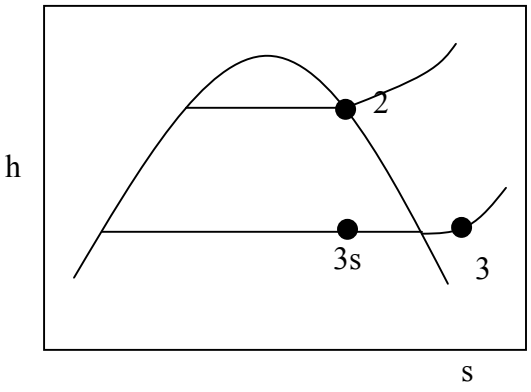


Figure 3. h-s diagram of Case 1: 1800 RPM and 20% Load.