TECHNICAL ANALYSIS #1

Problem

A pressure reducing valve will be replaced with a non-condensing (backpressure) steam turbine. A pressure reducing valve drops the building's steam pressure. In doing so, energy is consumed rather than produced.

Goal

Install a non-condensing (backpressure) steam turbine that produces energy while concurrently reducing the steam pressure. The energy produce by the turbine can then be directly connected to an electrical distribution panelboard. This arrangement will ultimately save money and energy.

Research Techniques

- Study existing conditions to gauge a firm understanding of the problem
- Interview construction team revision interests, concerns, and ideas
- Visit Civista for a firsthand evaluation
- Determine various solutions and individual benefits
- Determine a focused assessment of a solution to perform
- Perform analysis of proposed solution
- Publish a report of the MEP revision that highlights benefits and advantages to the new system.

Expected Results

The expected results of this technical assignment will solve the indicated problem in a manner that proves cost efficient, energy efficient, and beneficial in any way to the problem.

Background

The purpose of a steam turbine is pretty simple. It's part of a Combined Heat and Power System that converts otherwise wasted mechanical energy into useful electrical energy. Its main applications are in a Prime Mover and a Thermally Activated Machine. A Prime Mover is operated by steam that has been generated from an on-site boiler and used to produce electricity via an electric generator. A Thermally Activated Machine is operated by steam that has been generated by recycling waste thermal energy or by replacing steam pressure reduction valves. This type is often used in connection with applications where a need for low or medium pressure steam is necessary. Figure 1 shows a schematic of the cycle of a non-condensing backpressure turbine.

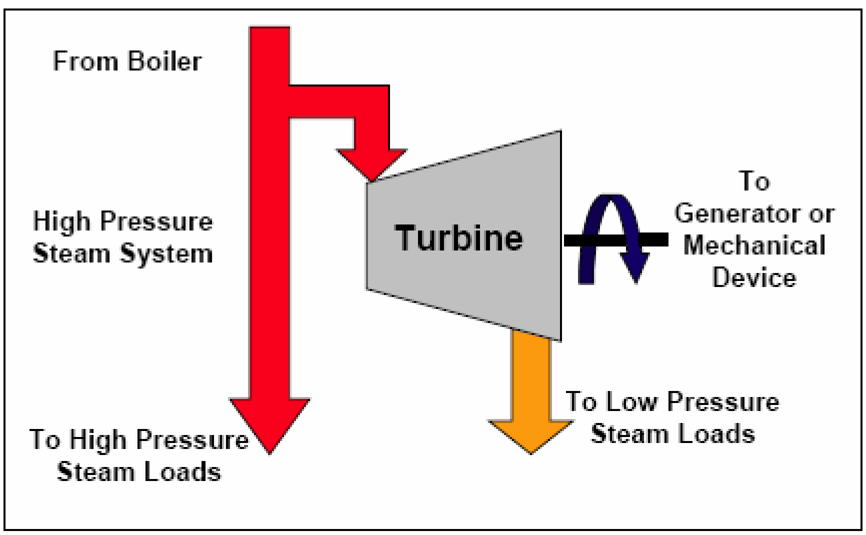


Figure 1: Steam Turbine Cycle

High pressure steam flows into the turbine and past its blades. In doing so, the blade shaft begins to spin. The blade shaft is directly connected to an electrical generator where it starts producing electrical power. The power output from the cycle is relative to the drop in steam pressure through the turbine. The larger the pressure drop, the larger the output. This cycle produce no emissions.

There are two different classifications of Combined Heat and Power Steam Turbines; condensing and non-condensing. In a condensing turbine, steam expands below atmospheric pressure (vacuum pressure). When it passes through the condenser (or series of condenses), a maximum pressure drop is experienced. Thus, the maximum amount of energy is extracted from each lbm of steam input. Condensing turbine systems are very efficient, operating at about 30-40% efficiency. However, they are typically more expensive than non-condensing turbines because of the required condenser. Its advantage allows steam pressure regulation, allowing for more steam to be used for thermal applications or for more steam to be used for electrical generation.

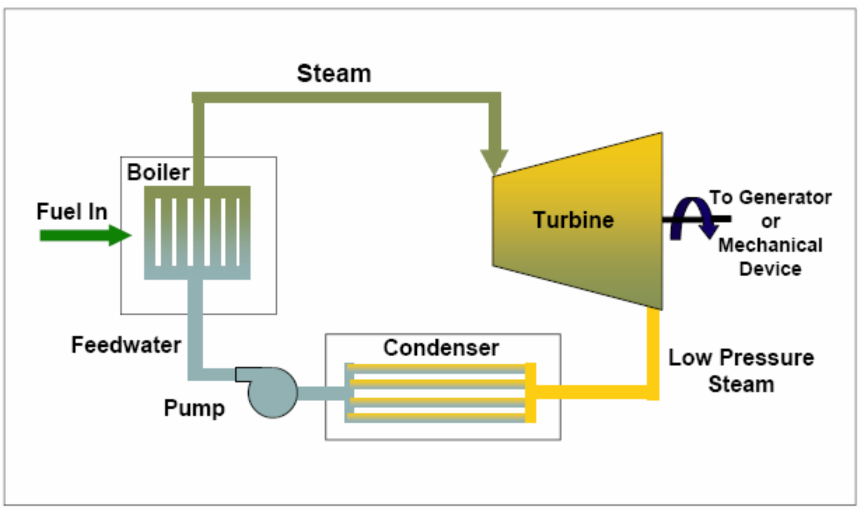


Figure 2: A Condensing Turbine

A non-condensing backpressure system is opposite from a condensing system in that it operates above or in excess of atmospheric pressure. It's commonly applied where medium to low pressure steam loads are required. As high pressure steam enters the non-condensing backpressure system, a portion of its thermal energy is converted into mechanical energy. It produces less useful work than that of a condensing turbine, but since unused steam from the turbine continues on to process thermal loads, the lower efficiencies (15-35%) are not of a concern. A non-condensing backpressure system is also usually less expensive.

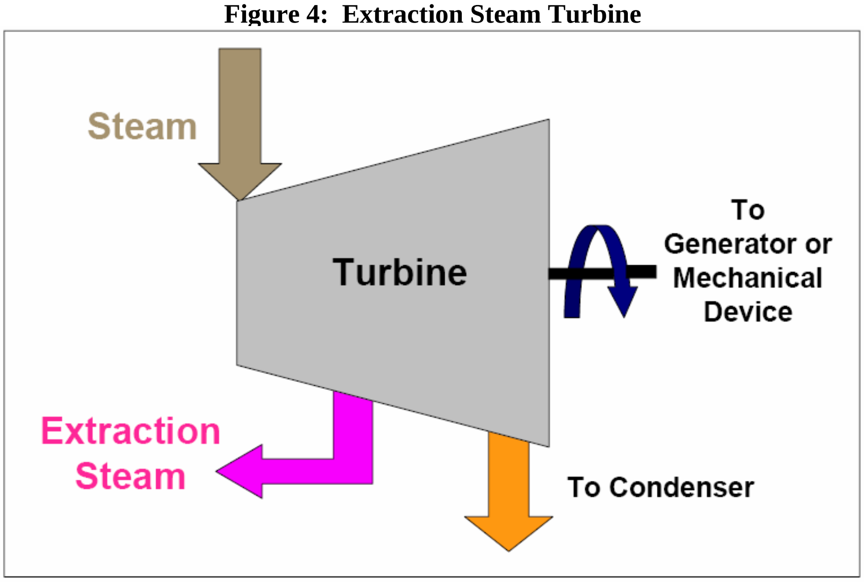
Steam Turbine Rules-of-Thumb

	Backpressure	Condensing
Power Generation Efficiency, %	15 - 35	30 - 40
Steam Exhaust Pressure	At or above atmospheric	Below atmospheric
Steam Required, lb/h per kW	20 - 100	7 - 10
Installed Cost, $/kW	300 - 400	500 - 700
O & M Cost, ¢/kWh	.15 – .35	.15 - .35

Figure 3 Condensing vs. Non-Condensing Backpressure Turbines

An extraction steam turbine is a multi-stage piece of equipment designed to withdraw steam from one or more stages, at one or more pressures to allow for intermediate pressure steam process applications. Extraction turbines can be either condensing or non-condensing backpressure. An extraction turbine is also known as a "bleeding" turbine since steam "bleeds" out of if at different locations.

Figure 4: Extraction Steam Turbine



<u>Redesign Steam PRV to Non-Condensing Backpressure Turbine</u>

Table 1 includes the existing Steam Pressure Reducing Valve present in Civista.

It will be replaced with a Non-Condensing Backpressure Turbine.

Table 1: Steam Pressure Reducing Valve Schedule

Steam Pressure Reducing Valve Schedule						
Tag	System	Total Capacity (lb/hr)	Inlet Pressure (psig)	Outlet Pressure (psig)	Body Size (in)	Remarks
PRV-1	Heating	3590	60	10	3	

To size the appropriate turbine, the following calculations were made:

Given:

- Temp. of Steam: 300^{o}F (est.)
- Inlet Pressure (P_i) = 60psig + 14.7 atm pressure = 74.7
- Outlet Pressure (P_o) = 10 psig + 14.7 atm pressure = 24.7
- Mass Flow Rate ($\dot{m}$) = 3590 lb/hr (max.)

Find Enthalpy using Steam Enthalpy Charts

- h_i = 269.8 BTU/lb
- h_o = 1190 BTU/lb
- Δ h = h_o – h_i = 920.5 BTU/lb

Find Power Rate

- Q = $\dot{m}$ Δ h = (3950 lb/hr) x (920.5 BTU/lb) = 3,635,975 BTU/hr

Factor in 20% Efficiency *(Non-Condensing Backpressure Turbines typically 15-35% efficiency rating)*

- Q = (3,635,975 BTU/hr) x (0.20) = 727,197 BTU/hr

Convert to kW

- (727,197 BTU/hr) x [(1 kW) / (3412 BTU)] = 213.13 kW

*** Equipment can now be sized according to kW output.*

It is impractical that a steam turbine would operate at a rate of maximum output. Since 213.13 kW reflects full capacity drive, Table 2 below describes the output as percentage of the maximum value. This chart is most helpful in the presence of steam charts. It aids in the determination of monthly production.

% of Turbine's Max Capacity	
10%	21.31
20%	42.63
30%	63.94
40%	85.25
50%	106.57
60%	127.88
70%	149.19
80%	170.50
90%	191.82
100%	213.13

Table 2: % output per Turbine's Max Capacity

Cost Analysis

Since steam charts are not available for Civista Medical Center, a cost analysis will be performed using a percentage of the turbines maximum capacity of 3590 lb/hr. It will be assumed that the steam turbine ran nonstop from the months of July 2006 to March 2007 at 40% maximum capacity during summer months (June-October) and 60% maximum capacity during winter months (November-May). The months represented are those after the new addition began receiving service. With that in mind, Table 3 illustrates Civista's monthly electrical consumption and cost per kWh with existing Steam Pressure Reducing Valve. Table 4 shows Civista's monthly electrical consumption and cost per kWh with a new Non-Condensing Backpressure Turbine.

Again it’s assumed to be operating at 40% maximum capacity during summer months and 60% during winter.

Electric Consumption / Costs			
Month-Year	**kWh**	**Costs**	**Cost/kWh**
Jul-06	535,073	$52,594.90	$0.0983
Aug-06	612,040	$56,174.06	$0.0918
Sep-06	707,883	$66,111.23	$0.0934
Oct-06	693,208	$67,835.81	$0.0979
Nov-06	647,974	$65,677.09	$0.1014
Dec-06	655,436	$65,858.73	$0.1005
Jan-07	700,920	$69,181.46	$0.0987
Feb-07	672,387	$65,779.59	$0.0978
Mar-07	534,237	$52,289.27	$0.0979

Table 3: Electric Consumption and Costs with PRV

Over the nine months evaluated, the PRV was part of a system that consumed a total of 5,759,158 kWh, costing exactly $508,907.24.

Electric Consumption / Costs			
Month-Year	**kWh**	**Costs**	**Cost/kWh**
Jul-06	471,646	$46,362.75	$0.0983
Aug-06	548,613	$50,362.63	$0.0918
Sep-06	646,502	$60,383.25	$0.0934
Oct-06	629,781	$61,655.51	$0.0979
Nov-06	555,902	$56,368.45	$0.1014
Dec-06	560,295	$56,309.62	$0.1005
Jan-07	605,779	$59,790.36	$0.0987
Feb-07	586,453	$57,355.10	$0.0978
Mar-07	439,096	$42,987.48	$0.0979

Table 4: Electric Consumption and Costs with Backpressure Turbine operating at 40% capacity during summer months and 60% during winter.

At a level where the Backpressure Turbine is operating at 40% its maximum load from July 2006 to September 2006 and at 60% its maximum load from October 2006 to March 2007, a noticeable savings can be noticed. A total of 5,044,064 kWh is consumed, 715,094kWh less than that of the Pressure Reducing Valve. This results in a cost savings of $17,332 after only ¾ of the year. Even if the percentage of the maximum load carried by the steam turbine was over estimate, there would still be significant savings.

Conclusion

The analysis of replacing the Steam Pressure Reducing Valve with a Non-Condensing Backpressure Steam Turbine proved to be a cost effective change. The initial costs incurred would be much higher, however, over an expected life cycle of over 20 years, the steam turbine has potential to save more than $20,000 a year in energy costs, not to mention to good it’s doing for the environment.