

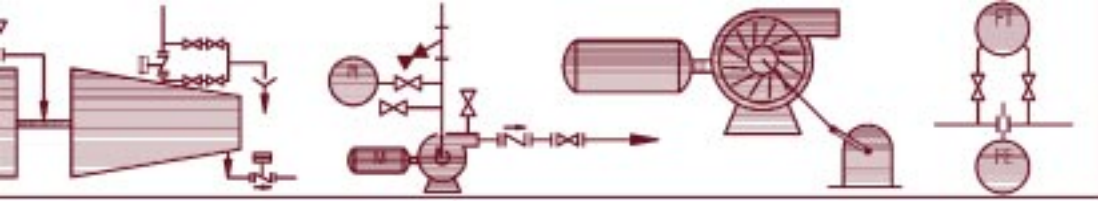
# ENERGY SOURCE

A Newsletter published by

**ESI Inc. of Tennessee**

for Industrial Steam and Power Users

Winter 2002



## Cogeneration - Designing the Cycle

By: Ronald T. Helton, P.E., Mechanical Engineering – Operations Manager, ESI

Editor's note: The following article discusses how to define and optimize the cogeneration cycle. A general article, "To Generate or Not Generate?" was presented in the Winter 2000 ENERGY SOURCE.

A significant part of answering the question: To Generate or Not Generate? requires looking at alternative options for generation and evaluating those options to determine which one best meets the needs for your facility. In this article, the information needed to establish and evaluate various systems and some of the methods used for system design will be discussed.

### System Evaluation

Steam pressures, temperatures and flows for the facility must be fully defined. Some of the typical questions that need to be answered are: Does the process require more than one pressure level? Does it require superheat? What is the range of pressures/temperatures required? Is there any required variation in the above? If so, can that variation be defined? Do the above pressures include allowances for piping pressure and temperature losses between the proposed cogeneration facility and the process user? Do they include allowances for flow measurement? What is the accuracy requirement for flow measurement? With the pressures and temperatures fully defined, the exit steam conditions at the cogeneration equipment can be established. Similar questions for steam flows must be answered. What is the required steam flow annually? What is the average flow for each month? Does the flow change during the day or on weekends? What are the instantaneous maximum and minimum steam loads that are to be accommodated? Are there representative flow charts available that show variations over a year's time? Are there any planned process changes that would increase or decrease the quantity of steam required?

Similar questions for the electrical energy needs of the plant must also be answered. What is the utility voltage connection? What are the distribution voltage levels within the plant? What is the electrical consumption for the plant (averages,

maximum, minimum along with seasonal variations)? In addition to electrical load information, a thorough understanding of the electrical power supply contract and pricing structure is necessary. In most cases, the facility is dependent on the utility to supply supplemental and/or back-up power. Determine whether there are ratchet charges that apply over extended periods based on short-term demand peaks, as this has a major impact on the system architecture and on the financial wellness of the project.

Energy costs are an important piece of the cogeneration puzzle. Consideration must be given to both present and predicted future costs and availability for various fuels.

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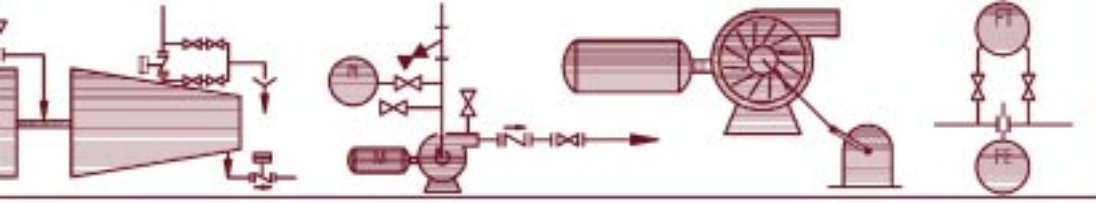
## ENERGY SOURCE

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Happy New Year  
Deanna White  
Managing Editor



## Cogeneration - Designing the Cycle *Continued from Page 1*

Because of the volatility of today's energy market, it is to the plant's advantage to try to build in opportunities for present or future use of alternative fuels. Flexibility is usually accompanied by a sizable price tag, so beware that a project can be overburdened to the point that it is not economically feasible.

Site conditions may have a significant impact on the selection of equipment for meeting the thermal and electrical needs for the facility. For instance, a combustion turbine is known to suffer output reduction as the ambient temperature increases. On the other hand, a backpressure steam turbine-generator's output is hardly impacted with such changes. If you are looking at condensing turbine-generators with heat rejected via cooling towers, ambient temperature will have a big impact on power output. Site design conditions need to be established for maximum and minimum temperatures expected, maximum and minimum temperatures for equipment performance design, design wet bulb temperature and site elevation above sea level. Another factor not normally considered to be a site condition is environmental emission limits and other regulations. There are cases where this alone determines whether a cogeneration option can even be considered.

The remaining piece of information needed is the cost and availability of capital. The cogeneration scheme selected must have the flexibility to meet both steam and electrical power requirements for all operating conditions encountered, while providing energy savings sufficient to justify the investment.

The above are not promoted to be a comprehensive list of information needed to optimize a cogeneration cycle design. Other factors that need to be considered include impact on operations staff, increase or decrease in maintenance due to new equipment, cost of water treatment (water and wastewater), space availability, possible increased traffic, noise, process reliability impacts and others.

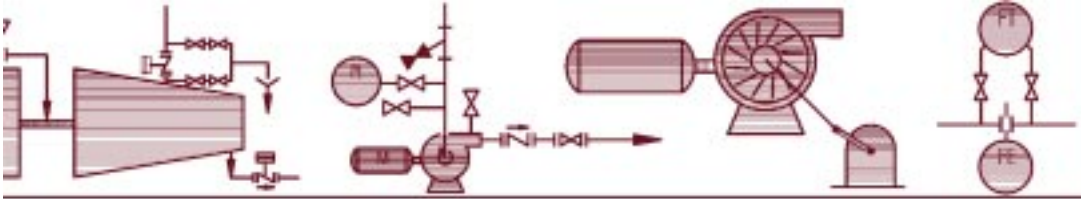
### System Design Methods

Once the background information discussed above is compiled, the challenge becomes putting together conceptual systems to satisfy the steam and electrical requirements of the facility. At this point, it is advisable to look at as many technologies as possible (assuming that they are not already eliminated by special constraints). The analysis of various alternates can be handled in a number of ways. The tools range from hand calculations all the way to sophisticated computer modeling programs capable of intricate calculations. Usually a simplified mass and energy balance computer program will allow calculations acceptable for zeroing in on one or more alternates.

This is where things get a little unclear. There is not one tried and true methodology to develop acceptable cogeneration systems. The most popular and most efficient cogeneration option, from a thermodynamic standpoint, is to utilize either combustion turbines (CT) with unfired heat recovery steam generators (HRSG's) or high-pressure boilers with backpressure steam turbine-generators (STG's). This will supply the plant steam needs while generating "cheap" electrical power, which accompanies that steam production. Since the plant steam and electrical requirements rarely match, usually the system must be modified by introducing provisions to meet the plant's needs.

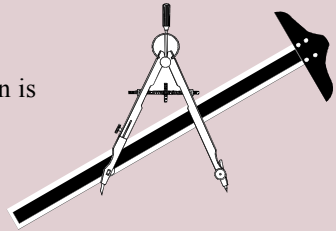
As an example, say that you are looking at a boiler/backpressure STG system, but the plant steam requirement during the summer is considerably lower than the yearly average, while summer electrical needs are a little higher than average. The plant wants to rely on the utility for supplemental and standby power, but the utility has a ratchet clause in the contract that imposes a huge economic penalty on the simple system due to the high net demand for summer electricity. Ways of

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## DESIGN TIPS

The success of any steam and power installation is the integration of hundreds of subtle design features that ensure everything operates satisfactorily.

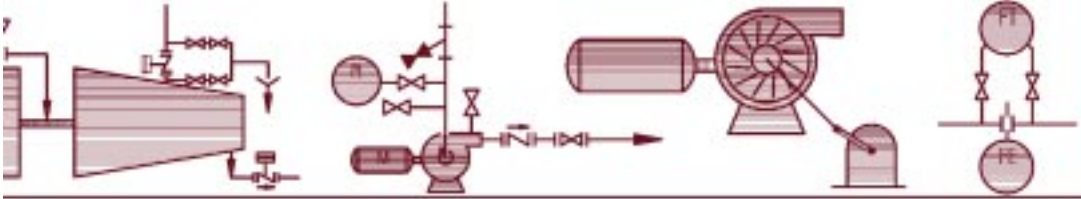


Following are a few design tips with respect to controls and instrumentation:

**Drum Level Control-** The boiler drum level control loop is used to automatically maintain the water level in the steam drum. While this critical control loop can be implemented using very simple methods to very complicated methods, it is typically done with a combination of single element drum level control at low loads and three element drum level control after 15-20% of full load steam flow is attained. Single element drum level control utilizes the drum level signal as the feedback signal and modulates the feedwater control valve to maintain the desired water level in the drum. This method works fine if the load swings do not cause excessive “shrink and swell” in the drum. The “shrink” of the drum level is a result of the collapse of steam bubbles caused either by an increase in steam drum pressure or by dumping relatively cool feedwater in the drum. The “swell” of the drum level is a result of the formation of steam bubbles caused by a decrease in steam drum pressure or the addition of heat. The characteristic “shrink and swell” of the drum level causes a single element drum level controller to initially react in the opposite manner than it should. For example: An increasing load swing, or increase in firing rate (heat), is generally in response to a header pressure that has dropped. The single element drum level controller closes the feedwater valve to reduce feedwater flow in response to the “swell” of the drum just when the boiler needs more water for the steam it is now producing. The typical result is a swinging drum level and the operator has to put the controller in manual, or worse the boiler trips on high or low drum level. The three element drum level control overcomes the “shrink and swell” effect associated with load swings by utilizing the drum level, feedwater flow and steam flow to control the drum level. This control scheme modulates the feedwater control valve to match the feedwater flow to the steam flow being produced with a much slower trim control based on the deviation between the drum level set point and the measured drum level. This control scheme in combination with single element at low loads provides reliable drum level control throughout the full firing range of the boiler.

**Speed Switch-** While the normal “Motor Run Confirm” from the motor control center starter works fine for verifying equipment operation for fans and pumps, it is not the preferred method for material handling conveyors. This is due to the fact that material handling equipment is far more prone to plugging/jamming and having belt/gearbox problems than liquid or gaseous handling equipment, such as fans and pumps. The preferred method of verifying equipment operation for conveyors is the use of speed switches. The speed switch will confirm that the actual material handling equipment is functioning and not just the motor. The location that the speed switch is installed is also very important. The speed switch should be installed at the opposite end of the conveyor from the motor driven end. This will allow the speed switch to verify that the motor is running, the gearbox is working, and that the conveyor is actually conveying material.

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reducing the summer demand could include going to a condensing STG with extractions. Then, heat rejection for the condenser is necessary. Possibilities are cooling towers, air-cooled condensers, or possibly even once-through water cooling systems (these systems were discussed in the article titled “*Selecting Cooling Systems For Steam Turbine Generating Facilities*” in the Spring 2001 *ENERGY SOURCE*). Any of these add to the complexity and cost of the overall system, have a significant effect on turbine backpressure/power output, and reduce the thermal efficiency of the overall system.

Let’s look at another example. The plant has steam and electrical loads that float along together. On the surface, the ideal option would be a backpressure STG. The system seems to fit well in that there are no significant spikes in purchased power, but the plant still has to purchase a rather significant amount of power.

Possibilities to investigate include a more efficient turbine, higher pressure/temperature levels into the turbine, and feedwater heating. Some of the pro’s and con’s are as follows:

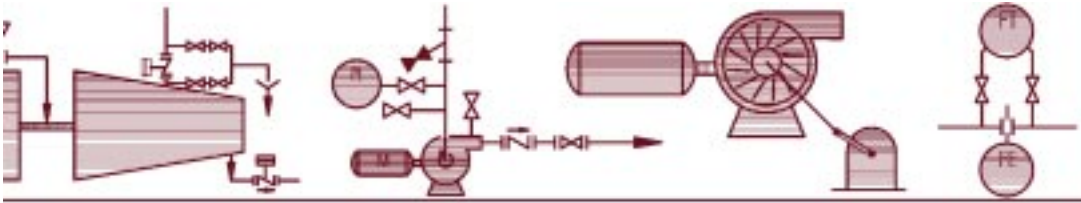
- **More efficient turbine** – There may be an opportunity to get a more efficient machine, but usually not for a dramatic efficiency increase. The efficiency is closely tied to the steam flow in the machine. Smaller machines generally will be less efficient than larger machines.
- **Higher pressure/temperature levels into the turbine** – The electrical output could be increased in this manner. Drawbacks include additional costs for better metallurgy in the steam path and more stringent steam purity requirements due to the higher pressures. When setting the pressure/temperature level at the boiler outlet, consideration must also be given to pressure losses in the main steam piping and steam flow elements.
- **Feedwater heating** – This may be a situation where additional equipment will actually increase power production and improve the cycle efficiency while maintaining the turbine exhaust flow. The downside is more equipment (a higher pressure extraction, feedwater heater, more piping and controls) and subsequently a more complicated cycle.

Before you get into detailed economic comparisons, the options should be carefully analyzed to make sure that all necessary operational modes are covered. This could involve the addition of items like pressure reducing valves (PRV’s) to assure plant steam supply in case of turbine mismatches or outages, addition of equipment to assure a satisfactory level of redundancy, factoring in the increased parasitic loads of the new equipment, emergency generators, etc.

If your company is evaluating the financial benefits of a potential cogeneration project or is considering signing a long-term power contract, call ESI today. ESI routinely performs low-cost engineering studies, which assist our customers greatly in their evaluation. Please contact us at 770-427-6200 or by e-mail at [info@esitenn.com](mailto:info@esitenn.com). Look for your next issue, *ENERGY SOURCE* Spring 2002, where we will discuss selecting equipment for a cogeneration facility.



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# ESI's Beginner Operator Test

## THE QUESTIONS

Test your boiler operator knowledge below with a few questions from ESI's Beginner Operator Test. Answers to the questions along with an explanation for each are provided below.

- It appears that a combustion control problem has occurred. A visual observation of the combustion in the furnace confirms that the flame is much darker than normal and dark smoke is coming out of the stack. This condition is indicative of:
  - Fuel rich mixture (too much fuel)
  - A fuel lean mixture (too much air)
  - A drop in steam pressure
  - An increase in steam pressure
  - None of the above
- When an oil-fired boiler is running with a fuel rich mixture, the proper action is to:
  - Add air to the burner
  - Reduce the fuel to the burner
  - Reduce the steam load
  - Try to manually regulate both the fuel and the air
  - None of the above
- Your plant needs additional steam now. If a burner which is being started up completes the purge cycle before start-up and proceeds through the cycle, but fails to get main flame, it is okay to:
  - Try to shorten the purge cycle to expedite the start-up.
  - Use jumpers in the panel to try for an immediate relight.
  - Pull the flame scanner and use a flame to fool it during the next relight.
  - Use jumpers to maintain the pilot to help insure a relight.
  - None of the above.

## THE ANSWERS

The given answers and explanations to these questions are those generally accepted by industry. There can be exceptions, so manufacturers' manuals should always be consulted.

- Answer a.** Fuel rich mixture (too much fuel)  
A dark, smoky furnace is certainly a reason for concern. The dark smoke is comprised mainly of unburned combustibles from the fuel. This means that: (1) fuel is being wasted, (2) stack emissions are probably in violation of the air permit, and (3) combustibles are available for further combustion under the right conditions. This usually takes the form of "rapid combustion" or more commonly, an explosion.  
**Answer b.** Reduce the fuel to the burner  
Once a fuel rich mixture exists in a furnace, one of the best ways to insure that a "puff" or "explosion" occurs is to add additional air (oxygen). Therefore, the safe and proper way to respond to this situation is to lower the amount of fuel being supplied to the furnace. Tripping the unit is not necessary, but would be preferred to allowing an extremely fuel rich situation to continue.  
**Answer e.** None of the above  
First and foremost, the burner logic and flame safety systems should be designed, installed and started up by qualified personnel. Thereafter, the system should be checked periodically for proper operation. Assuming that this has all been done, the burner should be allowed to function as originally designed with no outside interference. Trouble shooting should be done to determine why a successful light-off was not obtained. Usually, the burner management system will have a diagnostic read out to help determine the problem. After the problem is corrected, another light-off should be attempted using the normal burner management sequencing and procedures.
- Answer b.** Reduce the fuel to the burner  
When an oil-fired boiler is running with a fuel rich mixture, the proper action is to reduce the fuel to the burner.
- Answer e.** None of the above  
If a burner which is being started up completes the purge cycle before start-up and proceeds through the cycle, but fails to get main flame, it is okay to use jumpers to maintain the pilot to help insure a relight.

For additional Operator Test Questions, visit our web site @ [www.esitenn.com](http://www.esitenn.com) for ESI's Beginner, Intermediate, and Advanced Operator Tests. **Good Luck!**

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