

Cogeneration

A Northwest Medical Facility's Answer To the Uncertainties of Deregulation

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Not so long ago, in the good old days, the energy supply to a health care facility was one of the most stable. The local utility provided what was needed at a reasonable cost. Now the energy industry is being deregulated. Major uncertainties exist in all parts of the energy industry. Since reasonably priced and readily available energy is mandatory for a health care facility operation, the energy industry uncertainties reverberate through the health care industry.

The health care industry also is changing. The facilities departments of health care organizations have to be inventive to assist their organization's bottom line in the delivery of efficient, quality health care at reasonable costs. Since 1982 Valley Medical Center (Valley) in Renton, Washington, has implemented energy efficiency projects. Energy reduction has become a tradition.

Cogeneration is the next energy reduction step after all the conventional conservation approaches have been exhausted. The impending deregulation was viewed as an opportunity to further reduce energy costs, particularly electricity costs since 80% of Valley's energy cost is for electricity.

This article reviews how the uncertainty of electric utility deregulation was converted to an opportunity to implement the ultimate

energy conservation project—cogeneration. The project development was made essentially risk free by tailoring project development to deregulation. Costs and financial exposure were minimized by taking numerous small steps in sequence.

Valley Medical Center, by persevering with the development of a cogeneration plant, has been able to reduce its energy costs and more importantly, stabilize its energy supply and costs for many years to come. This article reviews activities in two arenas, internal project development and external energy industry developments, by periodically updating each arena and showing how external developments affected the project.

Facility Description

Valley Medical Center's 41-acre main campus consists of 333 beds, 1,071,000 square feet in 6 main buildings. In addition, nine off-campus clinics provide primary care, occupational health and other medical services to the community. The Public Hospital District is the now also the largest district in the state.

Valley Medical Center (Valley) has grown while maintaining one of the lowest hospital district tax rates in the state. Only 1.5% of the revenue comes from taxes and is used exclusively for facilities and equipment. Over 6% of the revenue is returned to the citizens in the form of free or inexpensive community programs. At the same time Valley's average charges to patients are lower than neighboring hospitals' and most statewide hospitals'.

Close and continual management of facility operating costs helps Valley to achieve these type of financial results. Energy costs, 80% as electricity, are a significant portion of the facility operating costs. Any reduction in energy costs, particularly electricity, contributes directly to the bottom line.

External Energy Industry Developments

Energy costs have been in a turmoil in most of the United States since the energy crisis of the 1970's. The Pacific Northwest has enjoyed

relative tranquillity with relatively cheap and stable energy supplies. The Pacific Northwest was in a unique position. It has huge amounts of electric power generated by the hydro system. The power was dedicated to Northwest use with any excess amounts being exported to California. Western Canada is a major natural gas supplier to western United States. The Northwest being close to the gas supply had plenty of natural gas.

Accepted thinking in the late 1980's and early 1990's was that cogeneration plants of any type were not feasible in the Northwest. This was due to the low cost of electric power (\$.0488 per kWh in 1994) and the high cost of delivered natural gas (\$3.22 per million Btu in 1994). For a cogeneration system to be feasible the differential in gas and electric power costs has to be large enough to justify the capital. The electric power rates were based on the hydro power systems and were expected to stay low for a long time so the cost differential probably will not be reached.

Economies of scale were considered the only way to counteract the low cost differential. If a cogeneration system was truly desired it had to be large, 50 MW or more. This is, of course, much more power than any facility could use. The excess power has to be sold to the local power company. In most cases the power company did not need any additional power. If it did it was willing to pay \$.025 per kWh further reducing the cost differential. Additional economies of scale are required. A few turns around the circle rapidly convinced the cogeneration builder that it was not feasible. The size of plant was much too large to be able to sell the power produced.

By 1990 the energy supply world had changed drastically. Natural gas was being deregulated. Contrary to previous projections gas prices were falling. That is, wholesale and large direct purchaser prices were falling. The price of gas delivered by local gas companies was remaining steady or slightly increasing. The industry was starting to talk about deregulation of electric power production and transmission.

In the West, California was a leader in electric deregulation. Northwestern states seemed to be lagging far behind. This was understandable since electricity cost in California was \$0.10 per kWh while the Northwest price was approximately half of that. By 1994 the only thing certain about the energy industry was that there would be numerous changes due to deregulation. What the changes would be were as numerous as the number of people commenting on them.

The energy industry was in the process of transforming from total predictability and certainty to total **unpredictability**. These trends continued to evolve as Valley contemplated installing a 3.8 MW cogeneration plant.

Valley Energy Use

The main hospital building of the current Valley campus was built in 1969 when electricity was very cheap. Almost all residential and many commercial facilities built at that time were all electric. The Valley facility was designed with gas-fired boilers providing steam for hot water and space heating. All other energy systems were electric.

Over the years as the campus grew and energy costs increased, new construction reflected the higher costs with energy-saving facilities. Energy conservation was instituted in existing facilities whenever conservation was economic. Valley has had an aggressive energy cost cutting tradition since the early 1980's. Valley has earned an Excellence in Energy Efficiency Award in 1985 and the Governor's Award for Energy Management in Hospitals 1984-89.

The various energy conservation projects demonstrated that there was a limit to energy cost reduction by demand management, the modern name for conservation. Once the limit is reached, the next logical step has to be supply management. Valley's 1994 total cost of energy was over \$1,160,000. Eighty percent of the costs was for electricity, 20% for natural gas. With Valley's energy cost reduction tradition and an uncertain energy industry, the stage for considering cogeneration was set.

Cogeneration is the classic technology for reducing energy costs. The high thermodynamic efficiencies of the cycle provide cost reduction without special laws, taxes or subsidies. A cogeneration system, once installed, will provide reduced energy costs over the entire life of the cogeneration plant.

Examination of cogeneration as an alternate energy supply source was initiated. Overall management guidelines for the project were established. The project should (1) significantly reduce energy costs, (2) cause minimal, disruption of existing operations, (3) be operable by existing facilities staff without an increase in manpower (4) provide additional redundancy for existing energy systems (5) improve energy system reliability (6) return the invested capital in six years or less and (7) have a long useful life. The cogeneration project was launched.

Internal Project Development

In early 1995 a consultant was retained to validate Valley internal staff conclusions that a cogeneration plant was technically and thermally feasible. The study showed that supply of Valley's energy by a cogeneration plant was technically feasible. It also was economically feasible if (1) the cogeneration cycle was as efficient as possible, (2) all generated electric power was used to offset utility purchased power without any power sales to the utility, (3) all boiler steam production was displaced by cogenerated thermal energy, (4) all environmental requirements could be met without expensive emission control systems, and (5) the price of natural gas could be reduced. Various cogeneration systems were examined. It was concluded that spark fired internal combustion engines using natural gas were the prime movers that best met the above criteria. The consultant's report was reviewed by Valley District Commissioners. Further work in developing a cogeneration system was authorized.

In mid 1995, Wieland Lindgren Engineers were retained by Valley to provide designs, specifications, thermodynamic calculations and economic calculations required to obtain District Commissioner approval and, if approved, for the construction of the cogeneration plant. All work was performed in a step-by-step sequence. This approach minimized Valley's engineering cost in case the cogeneration plant was not feasible. It also allowed rapid response to external changes that have significant impacts on the project.

Step 1. Develop Existing System Energy Balance

The first step developed an energy flow diagram of the Valley campus. This was relatively easy since an energy data and control system had been installed as a key part of Valley's energy conservation program. Actual energy use data for 1994 were used, estimates or guesses did not have to be made. Existing steam users and their thermal demands were identified. Winter and summer energy balance diagrams indicating maximum and minimum energy flows were developed. The existing energy flow diagram is shown in Figure 1. The data were then used to select and configure the cogeneration system to best meet the thermal and electrical needs of Valley.

Step 2. Add Cogeneration System to Energy Balance

The cogeneration system was then superimposed on the energy

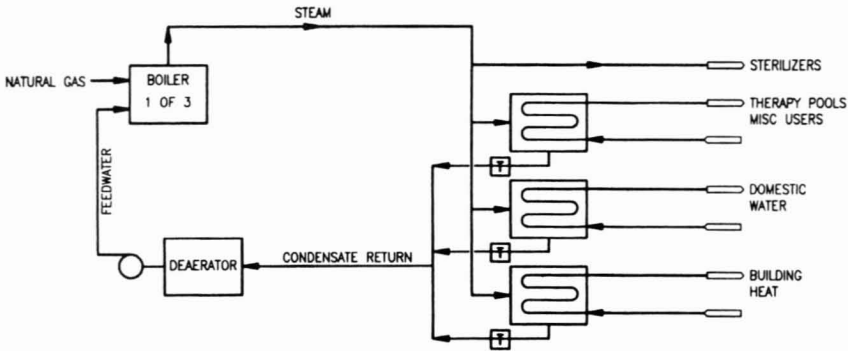


Figure 1. Valley Medical Center Existing System (simplified)

flow diagram. The energy balance was reworked to show what the situation would have been if the cogeneration plant had been in operation in 1994. The existing boilers were shut down and the thermal energy supplied by the cogeneration plant. An internal combustion engine provides two types of thermal energy. Engine jacket cooling provides hot water at 185°F. Engine exhaust passing through a waste heat boiler generates steam. Both the hot water and the steam must be used. The cogeneration flow diagram is shown in Figure 2.

Any unused thermal energy reduces the cogeneration cycle effi-

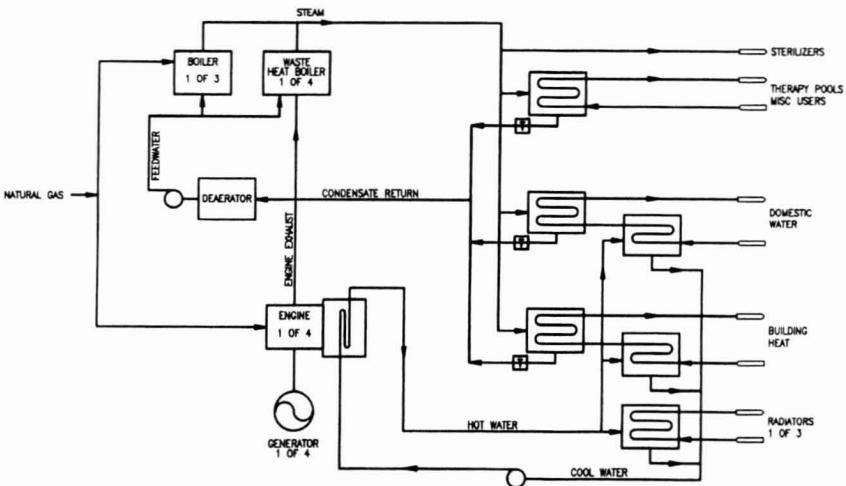


Figure 2. Valley Medical Center Cogeneration System (simplified)

ciency. The energy balance showed that the current Valley system is not in balance. Thermal demands are low compared to electric demands. In addition, the thermal energy peak is in winter and the electric power use peak is in summer.

An unbalanced system means that it is not as efficient as a balanced system. It allows two extreme operating modes (1) Thermal Demand Following—match operation to thermal demands and supplement electrical demand with purchased power or (2) Power Demand Following—match electrical generation and waste thermal energy.

The first mode is most efficient thermally—as much of the energy in the fuel is used as possible. The second mode could be the most desirable economically. The cost of generated power will be below the utility cost as long as enough of the thermal energy is used. Actual operation could be anywhere between the two extreme conditions.

The selected cogeneration train operating characteristics showed that three separate cogeneration modules would best fit the year around thermal and electrical demands of Valley. It was concluded that four engine/generator/waste heat boiler trains would be employed. Three trains will provide normal demands and at full load will provide peak power generation, the fourth train will be a standby. The Valley thermal and electrical demands and cogeneration train capability and the operating conditions are shown in Figure 3.

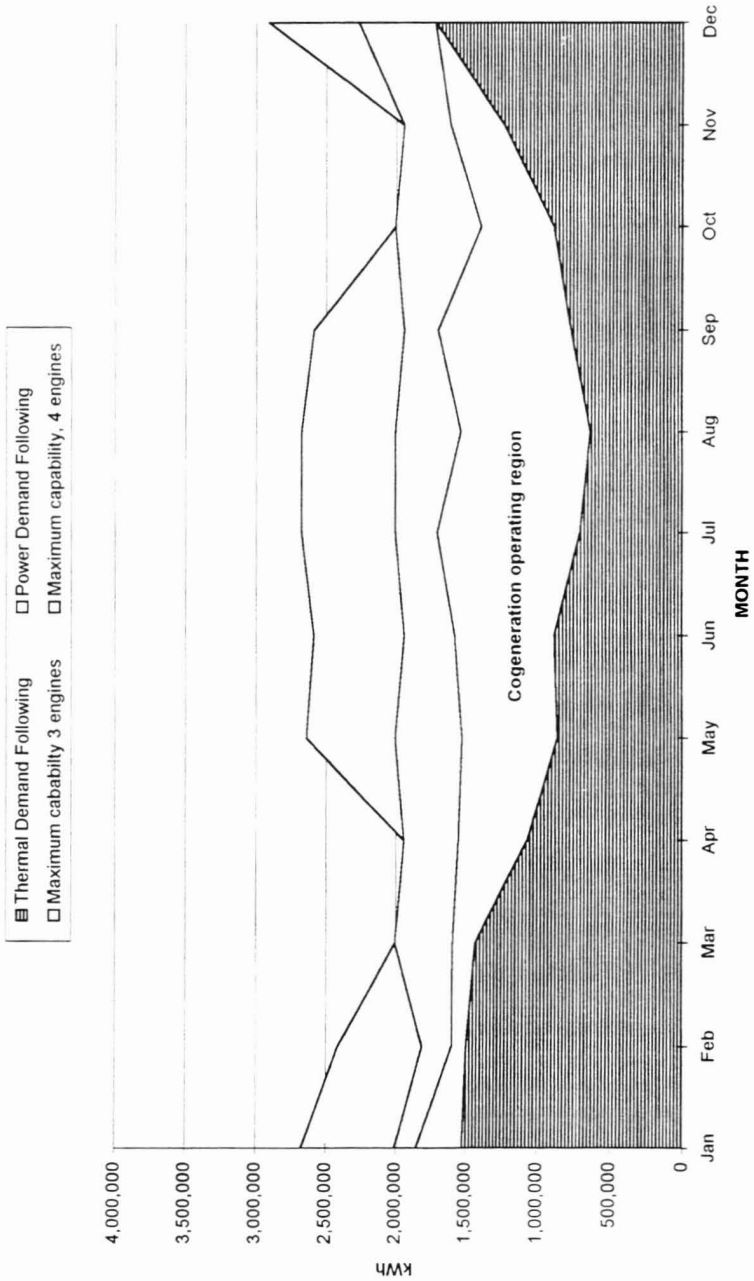
Step 3. Prepare Request for Proposal

It was decided that Valley's interests would be best served if one organization was responsible for the detailed design, construction and start-up of the cogeneration plant. A fixed price lump sum contract with cogeneration plant performance guarantees would ensure that Valley would get the plant it wanted. A Request for Proposal (RFP) was prepared. The RFP specified in detail the types of equipment, methods of construction, acceptable materials of construction, and equipment and system performance that would meet the cogeneration plant criteria. The winning Contractor was responsible for the detailed design of the plan within the limits of the RFP documents and must guarantee the plant performance. The RFP was issued early in December 1995.

External Development

About halfway through the RFP response period, the power company management requested a meeting with Valley management and

**Figure 3. Cogeneration System Operating Limits
Basis—1994 actual thermal and electrical demands**



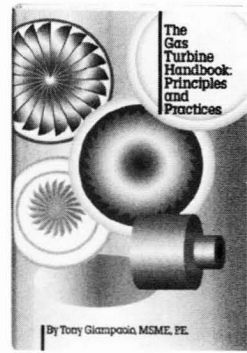
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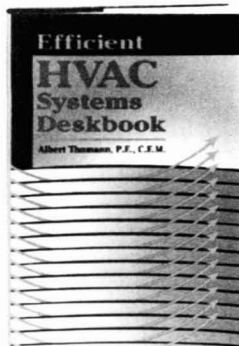


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project team. The power company gave reasons for not building the cogeneration plant. Among them were the impending deregulation of the electric industry. The power company did not know what would result but felt very strongly that electricity costs would be reduced or, as a minimum, remain constant.

It was suggested that Valley should not take any action until the effects of electric utility deregulation were better understood. The meeting ended with a request for a specific price to buy out the project at its current stage of development. Valley's response—reduce electric power costs by a minimum of \$380,000 per year.

Internal Development

Project useful life needed definition. Since the proposed cogeneration project of four engine/generator trains will follow a rigorous maintenance schedule including major periodic overhauls, the life theoretically could be infinite. Engine technology would be updated as it evolved. It was agreed that a 30-year cogeneration project life would be used for comparison with alternates.

Development of the cogeneration project moved forward. The environmental permit application was filed with the City of Renton. Work was started on the air emission permit application.

External Development

The power company proposed a 5-year contract that effectively reduced Valley's power costs by \$150,000 per year for the next 5 years. The power company's proposal was examined in detail. It was desirable in the short term. It was not desirable in context to the 30-year life of the cogeneration plant. Once the cogeneration plant was installed it would continue to provide benefits for 30 years. The power company's proposal reduced the benefits for the first 5 years but said nothing about what would happen later. Since Valley is a long-term facility dedicated to serving its functions into the far off future the short-term offer was rejected and work on the cogeneration plant continued.

Internal Development

It should be noted that the power company's offer, had it been accepted, would have provided a very handsome return to the approximately \$50,000 that had been invested in the project to date.

Step 4. Obtain Fuel Supply

Gas deregulation allowed gas to be purchased directly from the gas producer. For the larger gas user this resulted in substantial savings. Valley's annual gas use in the boilers is too low to interest serious gas producers. Boiler gas continued to be purchased from the local gas company.

The cogeneration plant will increase gas use. Many gas producers are interested in supplying the gas. Discussions about the cogeneration plant fuel supply were initiated in the fall of 1995. Available terms were spot prices, 5-year term at a fixed price and a 10-year term at a fixed price. The quoted prices declined as the project approached reality though the issuance of the RFP, obtaining of permits and selection of contractor.

The Valley gas price is made up of three components: 67% of the price goes to the producer in Canada for the gas and transportation to the Canadian border; 10% of the price goes to the gas interstate pipeline company for approximately 100 miles of transport from Canada to Renton; the remaining 23% goes to the local gas company for 1.5 miles of transport from the interstate pipeline to the project site. A 10-year fixed price gas supply contract was selected. This removed all fuel risk and in effect, guaranteed the cost of energy produced by the cogeneration plant for the next 10 years.

Valley left the local gas company and started buying natural gas directly from a gas producer in 1997.

Step 5. Select Bidder

Three responses to the RFP were received. The bid lump sum cost of the project ranged from \$5.3 to \$6.1 million. The bid cost was somewhat higher than expected. The best bid from the most qualified bidder was selected. The winning bidder was notified and informed that the cost was greater than Valley was willing to pay. The bidder was given a choice (1) Value engineer the bid to ensure that equipment redundancy has not been included in the bid or (2) Allow Valley to invalidate all bids, clarify the RFP by adding more detail and rebid. The winning bidder elected to value engineer the bid. The final cost of \$4.7 million for the cogeneration plant was accepted by Valley.

Step 6. Obtain Permits

Obtaining environmental permits is a big unknown to most contractors. They compensate by including contingencies. Since the Owner

is the ultimate bearer of the permit risk anyway, it is in the Owner's interest to obtain the permits directly and avoid the contractor's contingencies and mark ups. The environmental permit application was filed in December 1995. The project was issued a Determination of Non Significance (DNS) in February, 1996. A citizen's group appealed the DNS finding. The appeal resulted in a hearing and the filing of a revised application. The DNS ruling was reissued and the project approved in July, 1996.

The Puget Sound Air Pollution Control Agency has stricter emission standards than those of the national EPA and the rest of the state of Washington. Emission producing projects are strictly controlled. Best Available Control Technology (BACT) is required for new projects. The permit application demonstrated that the selected project was BACT. An air permit was granted in short order.

External Development

The power company had been working on merging with the local gas company. As part of the merger, a new rate schedule was published allowing larger customers to purchase their power from any supplier with the power company providing wheeling to the site. Deregulation of transmission arrived in Washington state much sooner than anyone had imagined. The new rate schedule included recapture of stranded capital and other charges which, in effect, kept the cost of power the same as it had been. Rate relief could only be expected in 4 or 5 years.

Internal Development

Step 7. Obtain FERC Qualified Facility Certification

The FERC regulations specify obligations to provide interconnection, backup power, wheeling and other conditions between the FERC certified Qualified Facility (QF) and the local power company. The FERC QF certification for the cogeneration plant was filed to ensure that these benefits would be available to Valley if they were ever required. The QF status also gives the cogeneration plant standing with FERC in case of disputes with the power company. QF status was granted in November 1996.

Step 8. Build the Plant

The construction contract was signed in August, 1996. Ground was broken in November, 1996. Construction was on schedule and, with a

fixed-price contract, on budget. The plant is in the start-up process with commercial operation scheduled for August, 1997.

Immediate Benefits of the Cogeneration Project

Valley will reap benefits as soon as the cogeneration project becomes operational. Financial benefit from lower electricity costs will begin to accrue immediately. Less tangible benefits will also be present. The entire facility will have greater energy reliability. Currently electricity is supplied by the utility. If the utility fails, the emergency generators start. In the future the cogeneration plant will increase generation. If the cogeneration plant fails, the utility will provide the power.

Use of the emergency generators should decrease drastically. Currently steam is supplied by the boilers. With the cogeneration plant, heat to the heaviest users, domestic water heating and building space heating will be supplied by the engine jacket cooling water. If the water circuits fail, heating will be provided by cogeneration steam being used in the existing water heater. If cogeneration fails, the existing boilers can be operated to provide steam.

Long -Term Benefits of the Cogeneration Project

Events show that the electric power deregulation is moving forward much faster than anticipated just a year ago. Open transmission promises lower power costs to California and other high power costs regions. It promises the opposite to the low cost regions such as the Pacific Northwest. Deregulation will encourage the power producers to wheel their power to the highest return areas. Cheap Northwest power will find its way to California until the local rates rise high enough to keep it in the Northwest.

The Valley cogeneration plant will be in operation just as open wheeling becomes fact. With the cogeneration plant, Valley no longer is affected by deregulation. It provides a ceiling on Valley energy costs for the next 10 years. The cogeneration plant is the key in controlling future energy costs. Additional energy cost reduction steps implemented after the cogeneration plant is in operation include:

1. Install a bypass gas pipeline to reduce the cost local gas transport from 23% to 6% of fuel cost.
2. Install an on-site laundry to utilize the essentially free steam and hot water available from the cogeneration plant.

3. Replace the existing chillers with absorption chillers, as they age, to increase thermal use and reduce electrical demand.
4. Expand traditional energy conservation projects to include thermal/electrical balance projects.
5. As wheeling of electricity is implemented, power can be wheeled to the satellite clinics of Valley, further reducing the purchased power.
6. The price of gas is still low and may continue to fall. Valley could secure its long-term energy costs by purchasing gas production wells for its own future use.
7. If Valley is able to achieve thermal and electrical balance to match the cogeneration plant, it will obtain highly reliable energy at costs that are lower than possible from any other source.
8. Who knows where deregulation will lead? With its own cogeneration plant and a fixed price fuel supply, Valley does not really care. Valley is able to participate no matter what.

COGENERATION PLANT TECHNICAL SPECIFICATIONS

PARTICIPANTS:

Owner	Valley Medical Center
Consulting Engineer	Wieland Lindgren Engineers
Designer/Constructor	Diamond B Constructors
Design Engineer	Energistics

PHYSICAL PLANT:

Building	New 2-story cogeneration building
Distance from existing boiler room	90 feet
Cogeneration building size	First floor 4724 square feet Second floor 1046 square feet
Construction	Cement masonry unit, reinforced, grout filled
Sizing	5 cogeneration trains, 4 installed, 1 future

Crane	2 ton overhead for engine maintenance
Building noise emission	50 dBA at 3 feet
Earthquake zone	3
Control room	965 square feet on second floor
Existing campus controls	Move to new control room

PLANT EQUIPMENT:

Number of cogeneration trains	4
Prime movers	Spark ignition internal combustion engines
Engine manufacturer	Jenbacher Energiesysteme
Engine configuration	V
Number of cylinders	20
Engine speed	1500 RPM
Fuel rate	8,048,908 Btu/hr
Generator manufacturer	Kato
Rated electrical output	898 kW
Generator voltage	12,470 Volts
Generator speed	1800 RPM
Waste heat boiler manufacturer	Cain Industries
Steam flow	1,808 lb/hr
Steam pressure	90 psi
Feedwater temperature	228 F
Steam flow control	Exhaust gas bypass
Engine jacket hot water flow	139 GPM
Hot water leaving engine	185 F
Hot water return to engine	158 F
Electrical efficiency	38.1 %
Thermal efficiency	45.6 %
Total efficiency	83.7 %
NO _x emissions	1.00 g/bhp hr
CO emissions	2.00 g/bhp hr

Hot water primary use	Domestic water heating
Hot water secondary use	Building space heating
Hot water excess	Cooled in radiators
No. hot water circulating pumps	2
Pump control	Variable speed
No. domestic water heat exchangers	2
No. space heating exchangers	1
No. radiators	3
Radiator fan control	Variable speed
Historic winter steam demand	11,000 lb/hr
Cogeneration steam demand	5,200 Lb/hr

COGENERATION OPERATION:

Thermal load following	Purchase power to meet demand
Electric power following	Bypass excess exhaust gas, use radiators
Island operation	Use only when power company is down

POSTSCRIPT

The article "A Northwest Medical Facility's Response to Electric Utility Deregulation" was prepared in the summer of 1997 while the cogeneration plant was under construction. The following are the most significant developments since the paper was originally written.

The cogeneration plant was started up and went into operation at the end of August, 1997 as scheduled. It has been in continuous operation since that date.

Emission and performance testing was completed during the fall and winter of 1997. The systems meet or exceed expectations and guarantees.

Loss of utility power supply has been experienced numerous

times. The cogeneration plant picks up the load in a bumpless transfer. It provides for the medical center in an "island" operation mode until the utility is restored. Restoring utility power supply is also bumpless.

The cogeneration plant is operated in the "thermal demand following" mode during the low electric demand hours of 7 PM to 7 AM. One engine is base loaded and the other one is allowed to follow the steam demand. On average, the system is close to being in electrical/thermal balance most of the time. Electric system transients are satisfied by exporting excess to the power company and importing during deficiencies.

Plant operation is switched to "power demand following" around 7 AM as staff arrives, electric demand increases and thermal demand (from space heating) declines. Cogeneration plant controls are set to import a maximum of 4 kW. This operating mode minimizes the overall electric power cost even though not all thermal energy is utilized due to the daytime electrical/thermal imbalance.

Initial studies show that the daytime unused thermal energy is adequate for a laundry. The currently used contract laundry could be replaced by an internal laundry. Construction of a laundry to utilize the thermal energy is being evaluated.

Developments in the electric utility arena continue to indicate the cogeneration project was a good decision. The 1998 electric rate schedules applicable to Valley effectively increased rates by 2.13%. As promised by deregulation the actual rate per kilowatt hour did not increase, however, a new surcharge was imposed so costs went up. Since contract gas prices are fixed for the next 10 years, the electricity costs increases make the cogeneration plant ever more attractive.

VALLEY MEDICAL CENTER TODAY

Figures 4-7 show details of this plant's housing, parking lot, and some of its internal systems.



Figure 4. The cogeneration facility at the Valley Medical Center is housed in an attractive building which fits in with the overall architecture of the medical complex.



Figure 5. From the parking lot, the four engine/generator trains can be seen through large plate glass windows. If the engines ever have to be removed, the windows and their frames will be removed.

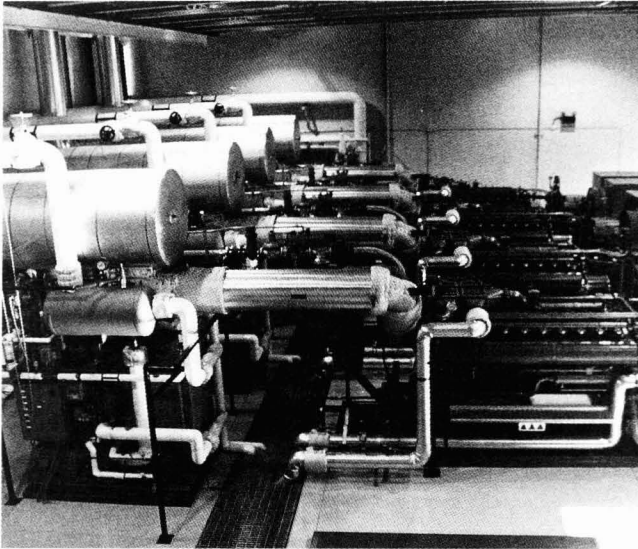


Figure 6. This view from the control room shows the four Jenbacher Energiesysteme internal combustion engines. Number of cylinders: 20; Engine speed: 1500 rpm; Fuel rate: 8,048,908 Btu/hr. Generator manufacturer is Kato: generator voltage is 12,470 Volts, rated output is 898 kW.

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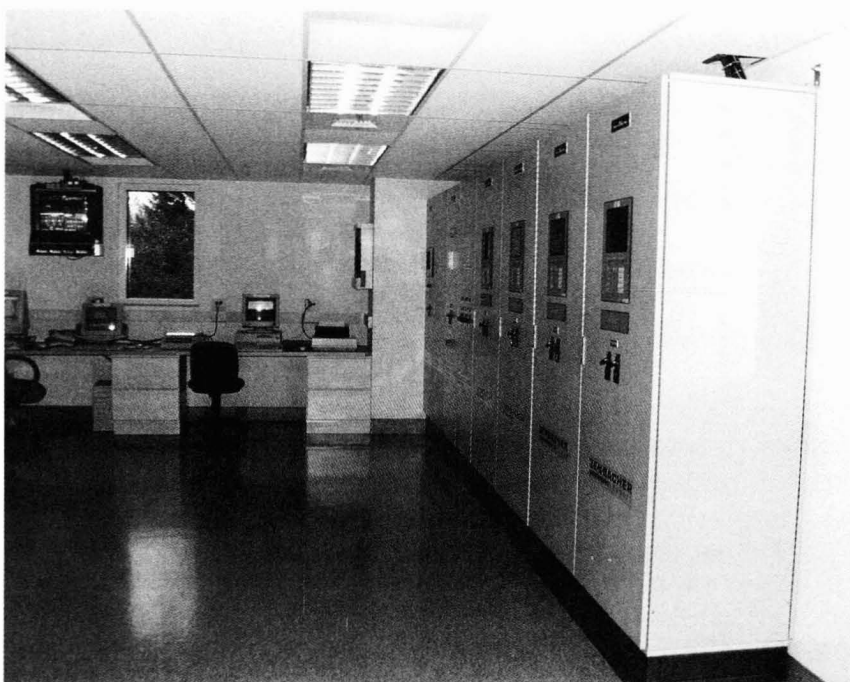


Figure 7. The cogeneration control room is clean and professional-looking. Engine controls are banked along the wall, right.

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