Cold Storage On-Site Electrical Generation & Waste Heat Recovery

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The cold storage industry is being encouraged by government and environmental authorities to save energy to reduce environmental pollution. Overall oil prices continue to increase and an energy climate surcharge has been imposed on the industry of 0.46p/kw hour.

FJB Systems are a well established company which offers one stop cold storage and food plant design and project management services on a fee basis, covering architecture planning applications, engineering design, project management and commissioning as well as other technical services.

Total energy is about the effective use of all energy used in creating electricity. Some of the large UK generating stations are very efficient. On average these turbines can convert some 33% of the energy input into electricity but, after transmission losses, the total electricity conversion could drop to 25% efficiency. The remaining 67% is dissipated as waste heat by means of cooling towers and losses from the boiler plant. The concept of total energy centres around locating electricity generation plants close to heat consuming industries so that at least some of the 67% waste heat can be sensibly utilised. Figure 1 shows a typical power station heat/energy balance.

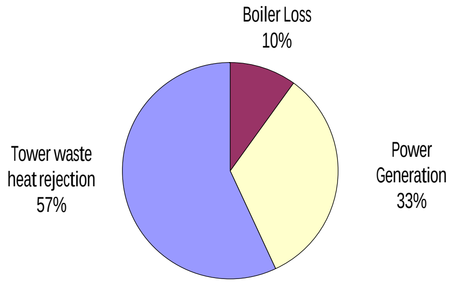

Fig 1. Typical Power Station Heat Balance

Small industrial steam turbines may be as inefficient as 6%, meaning that there could be up to 94% of the energy, created by means of oil or gas, being thrown away as waste heat. However, such inefficient conversion can most satisfactorily be utilised in conjunction with a processing plant where the processing factory's main energy requirement is heat.

Cold stores use large amounts of electricity. Over 95% of the total site power usage is usually electricity. However, if the cold store facility is located on a site where there are other industries which require heat, then the generation of power on a cold storage site and the passing of waste heat over to steam using industries can result in an energy efficient solution.

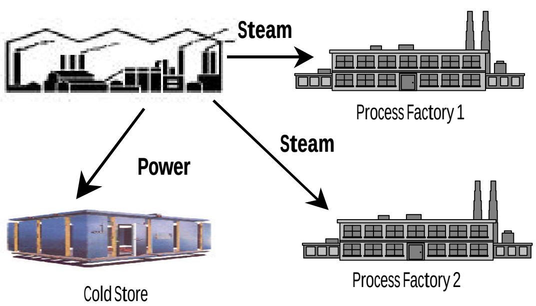

Fig 2. Industrial Site Power/Heat Requirement

To better understand the concept, figure 2 shows an industrial site with the cold storage complex surrounded on two sides by process factories which would normally have their own separate boiler plant producing steam. A total energy solution would be to generate power on the site as shown, passing the power to the cold store operator who would then pass the waste heat (normally despatched to atmosphere) to the two respective factories.

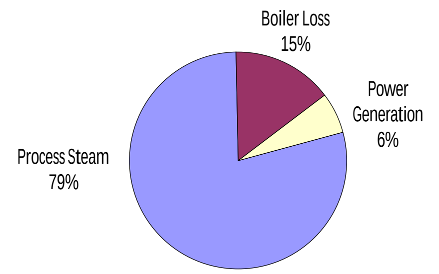

Fig 3. Typical On-site Turbine Power Generation

Figure 3 demonstrates a typical industrial low cost steam turbine performance showing energy conversion into electricity and process steam The 6% power generation may appear small but this power is generated at nearly 100% efficiency rather than buying from a power station with an efficiency of 30%-35% to which transmission loss must be added, making the power station achieve a final energy conversion efficiency of no more than 25%.

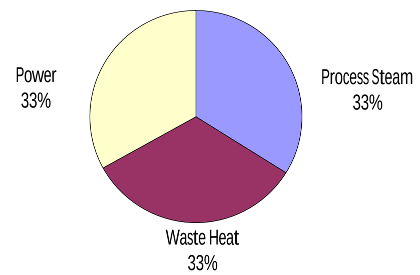

Fig 4. Typical On-site Gas Engine Power Generation

Figure 4 shows similar figures for a diesel or gas engine operation where it will be noted that nearly 35% of the fuel input can be converted to electricity with 67% waste heat, of which some 35% can be reclaimed for process steam.

The selection of the type of generator steam turbine or gas engine to use for a particular application depends upon the balance between the total site's requirement for electricity as against the requirement for heat. A site which requires a large heat input will be suited to the steam turbine application in Figure 3, while a site with less use for waste heat could benefit from a diesel or gas engine solution.

A typical cold storage site could be using up to 2000 kW of electricity. If this typical cold store was located on an industrial site similar to figure 2, with a process plant close by, which may have an electrical requirement of, say, 1000 kW, and some 12000 kW of heating representing just over 40,000 lbs. of steam/hour, then if the plant was designed conventionally, the following approximate energy costs would be applicable: -

1. Cold Storage Site

2000 kW constant usage at 5p/kWh for 250 days/year - £600,000/annum

2. Process Factory

1000 kW of electricity usage continuously for 250 days/year at 5p/kWh - £300,000/annum

Constant usage of 12000 kW of heating for 250 days/year Oil/gas cost at 20p/ltr - £1,446,000/annum

3. Combined Energy Cost

Cold storage	£ 600,000
Process plant	£1,746,506
Total site cost	£2,346,506 per annum.

Let us now look at the same complex being serviced by a total energy plant. We will assume in this instance that a light industrial steam turbine is installed.

From Figure 3 with a 6% energy conversion to electricity and 79% waste heat from turbine exhaust steam, then the size of the plant should be determined by the constant heating requirement of the processing plant, which at 40,000 lbs steam/hour is approximately 12000 kW.

This means that the boiler to raise steam for the turbine should be sized at approximately 15000 kWs, which would result in 920 kW of onsite electricity generation and 12000 kW of steam being produced and passed to the process industries.

The oil and gas required to raise this necessary steam with a boiler efficiency rating of 85% would give, at a price of 20p/lt., a yearly running charge of £1,556,000/annum.

On the basis of raising only 920 kW from onsite generation, this means that a further 2080 kW of grid power would have to be bought for the total site, which at the previous charge of 5p/kwh would represent a cost of £624,000.

Thus the total energy costs for operating this way would be as follows: -

1. Grid electricity charge	£624,000
2. Oil/gas charge	£1,556,000
3. Total site energy cost	£2,180,000

This compares with the previous cost of operating conventionally of £2,346,000 and represents a saving of approximately £166,000/annum in energy costs.

From an operational point of view, maintenance and capital charges would not significantly rise. The process industry would already require a boiler of 14000 kW in any case, which is now being substituted with a boiler of 15000 kW. With the steam turbine and steam reticulation services this would represent an additional capital cost of some £150,000. Furthermore, the operational costs from a maintenance point of view on a 15000 kW boiler would be approximately the same as the 14000 kW boiler and the steam turbine maintenance costs would be virtually negligible, the single steam turbine purely acting as an expansion valve from the higher boiler pressure down to the process steam pressure.

Thus for an extra capital input of some £150,000 more than would otherwise be the case by building the factories conventionally, an ongoing saving of some £165,000/year would be made in energy charges, which would gradually increase as the years went by as energy charges increased. Furthermore, if the boiler operated at a higher pressure and a more efficient turbine was purchased, the savings would be considerably higher.

Let us now look at the same site using a diesel/gas engine as represented on Figure 4 above. In this instance the energy conversion to electricity would be approximately 35% with 65% as waste heat. However, as Figure 3 shows, the waste heat recoverable to steam would mainly occur from the exhaust gas emissions, which would mean only approximately half the 65% of waste heat would be recoverable and sensibly useable. Thus for practical purposes, the gas/oil input to the generator would have 1/3 of its energy converted to electricity, 1/3 to process steam and 1/3 to unrecoverable waste heat.

On the basis that both sites' total electrical requirement still remains at 3000 kW, then the machine should be sized for a 3000 kW continuous load. This would mean an energy input to the machinery of approximately 9000 kW of oil/gas and 3000 kw of this would be converted into use as steam at no additional energy cost. The economics of this arrangement would be as follows:

1. 9000 kW of energy input by means of oil or gas to the diesel generator using a price of 20p/lt. of oil, running 250 days/year – approximately £922,000.

2. The production of 9000 kW of steam from a conventional boiler to make up the additional steam requirement for the processing plant, again using oil or gas at 20p lt. and running 250 days/year – approximately £1,084,200.

3. Total site energy cost £2,006,000

This compares with a total energy cost for the sites under conventional arrangements of £2,345,506, and results in an increased saving of some £300,000 for this particular heat balance.

The reason why the diesel engine saves more energy than the turbine is that in this particular heat balance a total elimination of grid power usage has been achieved whose efficiency after transmission losses may be under 25%.

If low grade heat was required for office heating etc, then some of the 33% unrecoverable waste heat could be utilised. However, to operate diesel generators could represent a high maintenance cost and a higher capital cost compared with a very economical and easy to run steam turbine. The savings also depend very much upon the price of diesel fuel or gas required for the diesel engine in question.

The figures given above are only representative. Exact savings can only be calculated by taking energy requirements for the site on an hourly and daily basis and computing results accurately that way.

Further advantages of on-site generation and using total energy concepts may accrue from the possibility of government grants for such projects, thus reducing the capital input to the project and, furthermore, it is understood that the increasing climate energy surcharge of 0.46 pence per kW hr would be waived on such plants, representing further energy cost savings, giving an additional £45,000 saving for both the examples above.

CONCLUSION

The balancing of the design of a total energy plant with the requirements of an overall site are complicated. An example of a cold store complex located next to process industries has been analysed and two examples of how power could be generated and waste heat utilised have been given. A cold storage operation consuming 2000 kW of electricity could make a saving to the overall site energy costs of some £150-250,000 per annum after a generous allowance for additional maintenance of generation machinery. All this could be achieved by either co-operating with process plant users on the same industrial site or, alternatively, deciding to locate a new cold storage plant close by such a processing industry. Co-operation between the parties can result in considerable yearly energy savings, making the cold storage operator in question that much more efficient in providing low cost services to his customers. Such on-site power generation should always be carefully calculated, taking into account all the individual factors of the industries involved before a project goes ahead.