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BENEFICIAL USES OF WASTE HEAT AN EVALUATION

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BENEFICIAL USES OF WASTE HEAT--AN EVALUATION

by

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BENEFICIAL USES OF WASTE HEAT--AN EVALUATION

There are a number of proposed beneficial uses of the waste heat contained in power plant cooling water. Included are those for which the technical feasibility has been demonstrated in pilot programs and those which are, at best, imaginative ideas. So, where do we stand today, and what remains to be done to determine if waste heat can ever be widely used for beneficial purposes?

As representatives of a regulatory agency, we are concerned primarily with solving the environmental pollution problem. In the overall environmental-ecological framework, a beneficial use of waste heat must help reduce the thermal pollution problem directly or it must provide a profit to help offset the cost of cooling devices. Furthermore, the use must not result in additional pollution such as that resulting from untreated organic wastes.

With these thoughts in mind we would like to discuss some potential uses of waste heat in a little more detail. In our analysis the emphasis is placed on needs since accomplishments have been reviewed in detail by previous speakers.

Aquaculture already has been successfully carried out in small pilot projects so the feasibility of raising at least a few species at controlled, elevated temperature has been demonstrated. For example: Tilton and Kelley (1) have described a successful small-scale commercial operation in Texas where catfish are raised in cages in a power plant discharge canal which maintains suitable temperatures for optimum growth. Marine fishes have been raised in warmed sea water in Scotland (2) and University of Miami scientists (3) have been successfully raising shrimp in warm power plant effluent in Florida. But, although feasibility has been demonstrated on a small scale, we are still a long way from large-scale production and from solving the thermal pollution problem.

We still must answer questions about economic feasibility. It is one thing to raise fish in power plant effluent on a research basis with free support of the company but yet another to pay for distribution systems and perhaps purchase the hot water for a commercial enterprise.

Even if feasibility of warm-water aquaculture is demonstrated, has the pollution problem been alleviated or will it be compounded? In almost all conceivable instances no single aquacultural enterprise will be able to handle all the cooling water from a large power plant, so cooling devices will still be required. Even the water used for aquaculture may not be cooled sufficiently to meet water quality requirements. If not, how will it be treated? In view of the increasing stress on environmental quality, it is almost certain that warm-water aquaculture will have to be practiced in closed systems; there will be few, if any, instances where hot water will be dumped into natural water courses in hopes of increasing fish production. Water released from these systems will have to meet the same temperature requirements as those set for the power plants.

The problem or organic pollution has been largely ignored in past aquaculture studies and even in the building of government-owned hatcheries. This situation is changing, however, and anyone planning an aquacultural facility must be aware of the potential expense of waste treatment.

In a recently completed study in the Pacific Northwest, Bodien (4) found that 114 hatcheries were releasing approximately 23 tons of BOD per day. This is equivalent to a city of approximately 270,000 total population, or an average of about 2,400 people per hatchery. In addition, large amounts of nutrients were being lost to the receiving waters.

A large aquacultural set-up connected to a power plant might release many times this amount of organic waste. We know that small towns are being forced to treat their sewage so it is not likely that similar wastes from fish farming will be allowed to go without treatment.

We have a good start on solving problems related to waste heat use in aquaculture but much more needs to be done. Areas of concentration for future work are:

1. More research is needed to determine optimum conditions for some of the likely commercial species.

2. Systems must be designed to maintain proper temperature.

3. Marketing systems must be developed for the products.

4. Waste treatment procedures must be defined.

5. Economic analyses must be conducted to integrate all the costs and potential profits to determine whether a power company can make enough profit from the waste heat to warrant the trouble and expense of distribution.

We have heard several presentations on applications of waste heat in agriculture. As evidenced through these discussions, agricultural uses appear to hold considerable promise; this is one area where use of waste heat, in the true sense of the term, may have almost unlimited potential if proper techniques can be developed.

Here, again, economic feasibility is the most important consideration at the present time. Dr. Boersma and Mr. Miller have noted the increased crop quality and yield which have been indicated in their projects. What we need to know now is how much these benefits are actually worth in terms of dollars. Where warm-water irrigation is involved, we need to quantify the contribution due to <u>warm</u> water use as opposed to the value of irrigation with water of normal temperature. Once we have determined the benefit of warm-water use in terms of crop value, we can determine how much we can afford to invest in distribution and control systems.

The design of distribution, irrigation, and heating systems is important for minimizing cost while achieving the desired operational characteristics. In on-going projects, experimentation is necessary for finding the best method of supplying water and heat for optimum results. In the future a more cost-conscious optimization of entire systems will be required. Potential suppliers of warm water will need to know the overall economics of a proposed system; potential users of waste heat will need to know costs as well as specific design criteria for their local heat or water distribution systems.

As with other uses of waste heat, agricultural applications will need close scrutiny to detect undesirable effects which may occur. Pollutional side-effects could include: 1) changes in temperature or chemical characteristics of ground water, 2) spreading of pesticides, 3) stream warming through short-circuiting of return water. Temperature tolerance ranges for crops should be established so adverse effects of high temperatures can be avoided. Heat transfer and moisture relationships of different soils should be studied to enable control of optimum conditions without excessive soil drying. Finally, the effect of warm-water use on plant diseases and soil microorganisms needs evaluation.

Hot water or steam space heating, which has been used for years, is now mentioned as a possible use of waste heat. The city of Tapiola, Finland, with a population of 20,000 is supplied with hot water heating and electrical power from the same steam plant (5). In Iceland, geothermal discharges have been used for 25 years for heating and industrial uses in Reykjavik. When one thinks of all the Btu's lost by power plants each day and the number of Btu's needed for space heating, the natural reaction is: Why not use the waste heat to serve as a free substitute for fuel?

The first discouragement we encounter is the low temperature of typical power plant waste water. 120° F is a high temperature for cooling discharge water and 90-100° F is more nearly normal. But, hot water space heating systems generally require much higher temperatures. For example, the system at Reykjavik (6) uses water at 194°F and the Montreal Airport uses water at 375-500° F (7). If the job could be accomplished with 90-120° F water it would be with the penalty of unacceptably high pumping costs.

Another problem with space heating systems is their relatively low load factor. For example: At the Montreal Airport, the winter heating load is 160 million Btu/hr and the summer load is only 10 million Btu/hr (7). Auxilliary power plant cooling devices would certainly be needed for at least part of the year.

One approach to the problem is the design of dual systems which provide high quality steam taken from the steam cycle instead of from the cooling water. This system is used in Tapiola with apparently good results. But we are no longer using waste heat since this steam is still of value for production of electricity.

If we want this high value steam we will have to pay for it. The price is especially high if we take the steam from a power plant designed strictly for generation of electricity. For example, if we postulate a typical nuclear plant at 100% capacity, the steam at the end of the cycle, after passage through the turbines, will be 92° F at a pressure of 1.5" Hg. This plant will have a heat rate of about 10390 Btu/kwh of electricity produced. Using the same system but taking the steam at 61° F increases the backpressure to 9.0" Hg and increases the heat rate to 12000 Btu/kwh.

What is this in terms of dollar cost? If we use a typical fuel cost of \$ .20 per 10^6 Btu we determine that fuel cost at a heat rate of 10390 is 2.08 mills/kwh. If we want 161° F steam, the heat rate is 12000 Btu/kwh and the fuel cost is 2.40 mills/kwh. This is an increase in fuel cost of 0.32 mills/kwh, which will be added to bus-bar cost. If the plant generates 1000 mw for 7000 hours/year it produces 7×10^9 kwh/yr of electricity. At an additional cost of 0.32 mills/kwh, the increase in cost is $(7 \times 10^9$ kwh$) \times (0.32$ mills/kwh$) = 2.24 \times 10^9$ mills, or \$2,240,000 per year.

So, if an industry or housing complex takes all the available steam at 161° F from this plant, it will have to pay all distribution costs plus \$2,240,000 to the power company to make the operation economical. Of course, the cost of steam will decrease proportionally with a decrease in amount used.

The purpose of this exercise is to show that the heat in water or steam which is above the normal condenser temperature of 90-120° F is not waste and will not come without cost. When we speak of special designs for production of electricity and high quality hot water or steam we are speaking of production of a specific product, and not of waste heat utilization.

The many different industries in the United States use so much heat that we naturally think of supplying some of this demand with power plant waste heat. But, here again, we encounter the problem that higher temperatures are required than are available in waste water.

A 1960 study showed that most of the low temperature (up to 212° F) boiler units added to the food processing industry between 1945 and 1956 were below 30 thermal megawatts in capacity (8). A 1000 $\mathrm{MW_e}$ plant discharges about 2300 megawatts of thermal energy so it would take 70-80 ordinary-size food processing plants to use the waste heat from one power plant (7). And, most food processing is seasonal so the demand would not be steady.

Most chemical processes fall in the same category; they need water or steam at higher temperatures than 90-120° F. Benedict, et al., (7) state that: "Direct application of reactor waste heat is indeed limited. Drying and low temperature polymerization, of which paper and rubber production are examples, respectively, might be practical when hot water ranging from 180-200° F is made available. At temperatures lower than 180° F it is doubtful that even drying processes can be made economical." As we pointed out before, hot water or steam at these high temperatures is not waste, but a saleable product and it must be worth more as steam than as the corresponding amount of electricity it could produce.

If we wish to supply high quality heat for either space heating or industrial use, the overriding concern should be for the economics of providing this energy at such a price that it will compensate for the reduction in electrical production. This is where we need research emphasis right now.

Up to this point, we have emphasized the impracticality of many of the popularly suggested methods of waste heat use. We do this, not out of a desire to be pessimistic, but to illustrate that many of the proposed methods are not practical considered in the light of providing a profit or reducing pollution.

This country is experiencing ever increasing demands for electric power and, unless we go back and use candles for light and toast our bread on a green stick, those demands will have to be met. This will result in greatly increased amounts of waste heat, but in the temperature range of 90-120° F. If we wish to reduce this waste of money and resources, we have two alternatives.

First, we can find uses for hot water at present waste temperatures. So far, aquaculture and agriculture seem to be the outstanding candidates because they can use the water in fairly large amounts and at these temperatures. Right now we need information on design and economics of use systems to determine whether the benefits which seem apparent on a physiologic basis are economically feasible. These economic studies must include costs of waste treatment; we cannot substitute one kind of pollution for another.

Second, we can begin to design for the future when integrated systems may be built to produce electricity and steam for agro-industrial complexes. This does not imply tacking industrial and domestic uses of steam onto power plants like those of the present but calls for total design of systems which can use a progressively lower quality of heat in more than one process to get the best overall efficiency attainable.

Assessment of this integrated system of energy use also depends upon thorough economic analyses. Without these, we cannot even speculate intelligently on the feasibility of such systems.

In closing, let us repeat: our primary concern is for environmental protection. If a use of waste heat does not either reduce the pollution directly or provide a profit to be used for auxilliary cooling it really is not solving the problem.

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Some uses, such as the culture of certain fishes, are now at the pilot program, or even commercial, stage. Other uses, such as for industrial processes, require additional research. Integrated systems planned to produce steam as well as electrical power have been successful in special situations. In nearly all cases we need additional information on the overall economics of the proposed methods. This is especially true where high quality heat is taken directly from the power plant steam cycle for another use. Only with a complete economic analysis, including cost of distribution, waste treatment, etc., can we come to the final decision as to whether a "beneficial use" is truly beneficial in the long run.

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