

## INDUSTRIAL STORAGE APPLICATIONS

### Program Area Synopsis:

The major tasks in this program element are the implementation of a technology demonstration for the food processing industry, development and technology demonstrations for selected near-term, in-plant applications and advanced industrial applications. These tasks will be supported by an on-going system studies activity which will assess advanced applications, solar industrial applications, and heat transport requirements. An important adjunct to this activity is the continued implementation of technology transfer through information collection and dissemination.



## INDUSTRIAL STORAGE APPLICATIONS OVERVIEW

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Significant conservation benefits and the substitution of domestic non-critical fuels for critical fuels (oil and natural gas) are possible through the use of thermal energy storage (TES) of industrial process and reject heat for subsequent use. The use of TES can either provide conservation through reject energy recovery and reuse or permit a shift in fuel from oil or natural gas to other non-critical fuels. One of the goals of the Department of Energy's (DOE) Division of Energy Storage Systems is to provide the storage technology capability to provide at least 10% of the industrial process heat or energy requirements of the U.S. industry by the year 2000. The purpose of Industrial Storage Applications, one element of DOE's Thermal Energy Storage Program, is to develop TES systems capable of contributing to the achievement of DOE's goal for the year 2000.

In order to achieve this long range goal it is clear that in the mid-term time frame (CY 85-90) demonstration of conservation of significant amounts of critical fuels is required. The groundwork to do this was started with an Energy Research and Development Administration (ERDA) funded study to determine the economic and technical feasibility of TES in conjunction with waste heat recovery (Ref. 1). This study was directed toward identifying industrial processes characterized by fluctuating energy availability and/or demand, a key criterion for TES applicability.

At least twenty (20) industries were identified as areas where thermal energy storage had potential for application to some degree. After the conclusion of this general feasibility study program, ERDA issued a Program Research and Development Announcement (PRDA). This PRDA requested proposals for individual studies of specific industries which were to be selected by each proposer. The overall objective was to identify specific applications of TES in specific industries through these system studies, and in subsequent work develop and validate potential systems, demonstrate feasibility on a large scale, and then transfer the technology to the total industry to result in widespread implementation.

As a result of this PRDA (and after the then recent metamorphosis from ERDA to DOE) DOE's Division of Energy Storage Systems awarded five contracts to study five industries with potential significant energy savings through the use of TES systems. These industries were paper and pulp, food processing, steel and iron, cement, and primary aluminum. The aluminum study produced results that were applicable to district heating systems. Because of this distinct application the aluminum study results (Ref. 2) and subsequent follow-on work are being discussed under Building Heating and Cooling Applications and will not be discussed here.

The other four system studies were conducted with each one having a similar generalized task breakdown structure. An analytical survey was conducted for each industry to determine the potential total recoverable energy. Candidate storage systems and applications for using the recovered energy were evaluated. Preliminary conceptual designs were evolved for which performance analyses were conducted. Economic analyses were made for the most promising designs, and the potential technical feasibility and economic benefits were assessed and summarized. Any development required was identified, and each study was concluded with a commercialization plan being formulated.

The results of these studies indicated that within these industries thermal energy storage of process and reject heat for subsequent in-plant use appears to be economically and technically feasible with significant near-term conservation benefits. Potential annual fuel savings with large scale implementation of near-term TES systems for these industries is over  $9 \times 10^6$  bbl of oil. This savings is due to recuperation and storage in the food processing industry, direct fuel substitution in the paper and pulp industry, and reduction in electric utility peak fuel use through in-plant production of electricity from utilization of reject heat in the steel and cement industries.

The technology identified falls into three categories: (1) Existing operational TES system applications for which detailed information has not been made public; (2) Promising system applications that involve current technology, require no development, and are ready for immediate technology demonstration to stimulate commercial introduction; and (3) Promising system applications that require development prior to a large scale industrial technology demonstration.

The paper and pulp application (category 1) is summarized in Figure 1. For mills with hog fuel (wood waste) boilers with excess steam generation capacity, TES would allow the substitution of more hog fuel for oil or natural gas. Typically, the base loaded hog fuel boilers with slow response times are augmented by oil or gas boilers to meet rapid steam demands. TES through the use of a steam accumulator can provide a load smoothing capability that would directly reduce the use of oil or natural gas. The results of this study are presented in Ref.3.

Mills, both in the U.S. and the Scandanavian countries, have been identified with such TES systems in place. However, information on these systems has not been made publicly available. A contract will soon be awarded for a program to obtain, analyze and disseminate this information to the U.S. paper and pulp industry. A more detailed discussion of this program appears later in this same section.

The food processing application (category 2) is summarized in Figure 2. TES in conjunction with recuperation can reduce energy consumption in a typical food canning plant. Preheating fresh make-up water through conventional heat exchange with the waste hot water stream results in a direct conservation of energy. In addition, when the process demands diminish while waste hot water is still available, the heated incoming fresh water can be diverted to storage. Hot water that accumulates in storage during the production period would then be used during the equipment clean-up period. Results of this study are presented in Ref. 4.

It was concluded that waste heat recovery from selected food processes is technically feasible and can be performed economically using available, off-the-shelf hardware. Therefore, a contract is being negotiated to proceed with a technology demonstration in a food canning plant. This demonstration will be used to evaluate actual hardware performance, to optimize the system design, and to determine actual costs and benefits resulting from the waste heat recovery and storage system. The results will then be publicized to encourage the installation of similar waste heat recovery systems within the food processing industry.

The steel and iron application (category 3) is summarized in Figure 3. Hot gas in the primary fume evacuation system of electric arc steel remelting furnaces is the reject heat energy source. The fume stream would charge a solid sensible heat storage packed bed. Discharge of the TES system through a heat exchanger would generate steam to drive a turbogenerator. TES is used to permit electric power to be generated during peak demand times instead of continuously. The economic benefits to be derived from the use of TES for peak power generation is a direct function of either a demand charge, time of day pricing, or a combination of both. Results of this study are presented in Ref. 5.

Although the TES concept of this study yielded favorable predictions of critical fuel displacement and investment returns, the approach is not ready to be applied directly to a full scale demonstration without an interim concept development period. Therefore, any further work will have to be as a result of competition with other applications in a similar state of readiness. This will be discussed further after the next system study discussion.

The cement application (category 3) is summarized in Figure 4. Hot gas from a long, dry-process cement kiln would be used in a waste heat boiler to produce steam for driving a turbogenerator to produce electricity for in-process use. Approximately 80-90% of the kiln exit gas would go directly through the waste heat boiler with the rest being used to charge a solid sensible heat storage packed bed. When the kiln is down for maintenance the packed bed would be discharged through the waste heat boiler thereby eliminating a power demand charge which could be significant. Results of this study are presented in Ref. 6.

The results of the cement study are similar to those of the steel study. Favorable predictions of critical fuel savings and investment returns resulted, but an interim concept development period would be required.

A procurement activity is in progress for the development and technology demonstration of thermal energy storage systems for industrial process and reject heat applications. This will be a competitive procurement with multiple awards planned. Because of the pending contracts involving TES in the paper and pulp and food processing industries, these industries are being excluded from this procurement. The emphasis of this procurement is to more fully evaluate U.S. industry for other applications of in-plant use of stored thermal energy using cost-effective near-term technology. In-plant use is being specified to preclude proposals for district heating applications which are being adequately covered by the follow-on effort to the aluminum study.

The objective of this procurement is to develop, if needed, and demonstrate TES systems that offer the potential of saving significant quantities of energy or critical fuels in the near-term on a cost-effective basis. Specific goals are to: contribute to the DOE goal of providing 10% of the U.S. industry's process heat or energy requirements by the year 2000 through thermal energy storage; be cost-effective by providing a return-on-investment that will significantly attract broad scale implementation; be acceptable by the industry as being operationally safe and reliable; and be environmentally acceptable. Cost-sharing will be an important factor in contract awards for this procurement.

Figure 5 summarizes in a schedular form the major activities under the Industrial Storage Applications element. Line 1 shows the continuing System Studies and Supporting Technology activity. The PRDA system studies discussed in this paper produced significant results that were transferred to other activities. The Technology Transfer to Paper and Pulp Industry activity is anticipated as being an 18 month program from early 1980 to mid-1981. The Technology Demonstration for Food Processing Industry activity is a three-year program from early 1980 to 1983. The Development and Technology Demonstration for Selected Near-Term In-Plant Applications is anticipated as being a five-year program from mid-1980 to mid-1985. Continuing System Studies activities include Heat Transport Applications, Solar Industrial Applications and New or Advanced Applications. Significant results from this activity will be transferred in early 1982 to Development and Technology Demonstration for Advanced Applications. An important factor in all of these activities is the continued implementation of technology transfer through information collection and dissemination.

## REFERENCES

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4. Lundberg, W. L.; and Christenson, J. A.: Applications of Thermal Energy Storage to Waste Heat Recovery in the Food Processing Industry. Westinghouse Electric Corporation (CONS/5002-1), 1979.
5. Katter, L. B.; and Peterson, D. J.: Applications of Thermal Energy Storage to Process Heat and Waste Heat Recovery in the Iron and Steel Industry. Rocket Research Co. (CONS/5081-1), 1978.
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SYSTEM STUDY RESULTS

INDUSTRY: PAPER AND PULP

CONTRACTOR: BOEING E&C/WEYERHAEUSER/SRI INTERNATIONAL

HEAT SOURCES IN PAPER AND PULP MILL

- 0 EXCESS STEAM FROM HOG FUEL (WOOD WASTE) BOILER DURING LOW STEAM DEMAND PERIOD

ENERGY END USE APPLICATIONS

- 0 PROCESS STEAM
- 0 FEEDWATER HEATING

RECOVERY/STORAGE/REUSE SYSTEM SELECTED

- 0 GENERATE EXCESS STEAM DURING LOW DEMAND PERIODS
- 0 STORE IN STEAM ACCUMULATOR
- 0 PROVIDE PROCESS STEAM DIRECTLY OR USE FOR FEEDWATER HEATING DURING HIGH DEMAND PERIODS
- 0 SAVE 100,000 BBL OIL/MILL ANNUALLY; 30% RETURN ON INVESTMENT

Figure 1

SYSTEM STUDY RESULTS

INDUSTRY: FOOD PROCESSING

CONTRACTOR: WESTINGHOUSE/HEINZ

HEAT SOURCES IN FOOD PROCESSING PLANTS

- 0 HOT WASTE WATER FROM FOOD PROCESSING

ENERGY END USE APPLICATIONS

- 0 EQUIPMENT CLEAN UP
- 0 PREHEAT INCOMING WATER FOR FOOD PROCESSING

RECOVERY/STORAGE/REUSE SYSTEM SELECTED

- 0 CAPTURE HEAT FROM WASTE WATER
- 0 STORE 2% IN HOT WATER TANK; USE REST FOR PREHEAT
- 0 USE TOPPED-OFF STORED WATER FOR EQUIPMENT CLEAN UP
- 0 SAVE 3-5% OF FUEL USAGE; 3 YEAR PAYBACK PERIOD

Figure 2



SYSTEM STUDY RESULTS

INDUSTRY: STEEL AND IRON

CONTRACTOR: ROCKET RESEARCH/BETHLEHEM STEEL/SEATTLE CITY LIGHT

HEAT SOURCES IN ELECTRIC ARC STEEL PLANT

- o PRIMARY FUME STREAM FROM ELECTRIC ARC FURNACE
- SOAK PIT STACK GASES
- BAR MILL FURNACE STACK GASES

ENERGY END USE APPLICATIONS

- o ELECTRICAL ENERGY GENERATION
- INGOT PREHEATING
- COMBUSTION AIR PREHEATING
- SCRAP PREHEATING

RECOVERY/STORAGE/REUSE SYSTEM SELECTED

- o CAPTURE HEAT FROM ELECTRIC ARC FURNACE FUME STREAM
- o STORE IN PACKED BED
- o GENERATE STEAM TO PRODUCE ELECTRICITY DURING PEAK PERIODS
- o SAVE  $2 \times 10^6$  BBL OIL ANNUALLY; 5 YEAR PAYBACK PERIOD

Figure 3

SYSTEM STUDY RESULTS

INDUSTRY: CEMENT

CONTRACTOR: MARTIN MARIETTA AEROSPACE/M. M. CEMENT/PORTLAND CEMENT ASSOCIATION

HEAT SOURCES IN DRY KILN CEMENT PLANTS

- o KILN EXIT GAS
- o CLINKER COOLER WASTE GAS
- KILN SMELL HEAT LOSS

ENERGY END USE APPLICATIONS

- o ELECTRICAL ENERGY GENERATION
- RAM MATERIAL DRYING
- FUEL DRYING
- OIL VISCOSITY REDUCTION

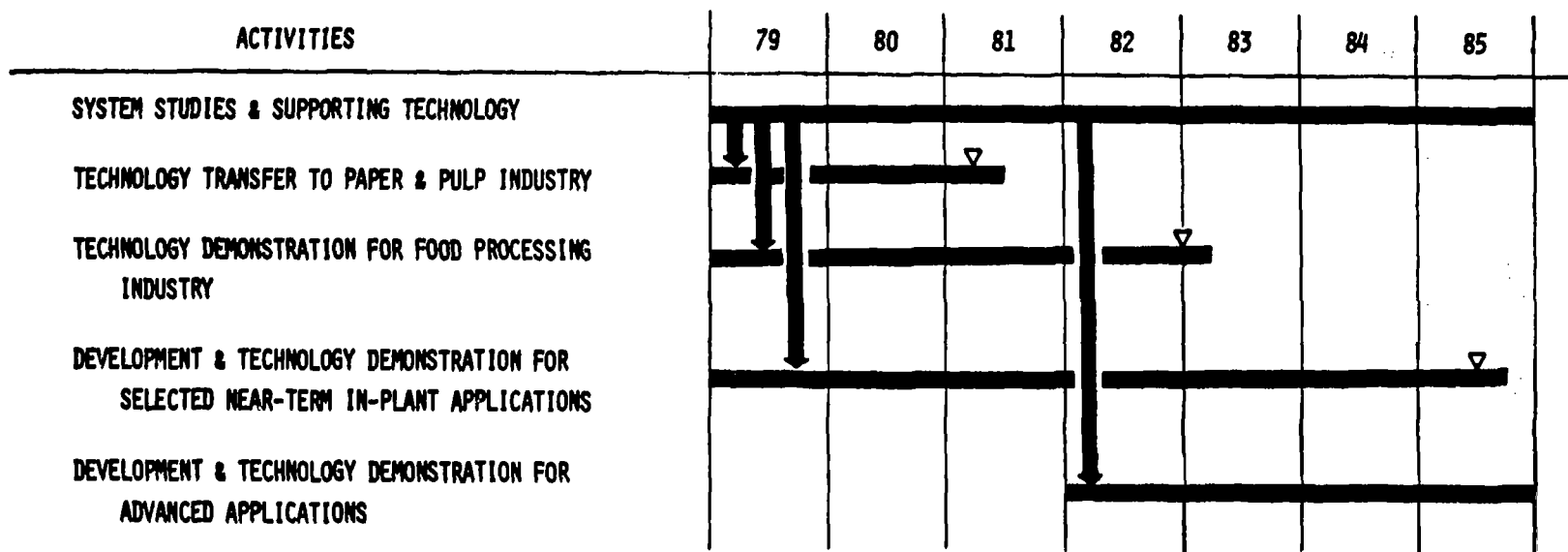
RECOVERY/STORAGE/REUSE SYSTEM SELECTED

- o CAPTURE HEAT FROM KILN EXIT GAS AND CLINKER COOLER WASTE GAS
- o STORE IN PACKED BED
- o GENERATE STEAM TO PRODUCE ELECTRICITY EVEN WHEN KILN IS DOWN
- o SAVE  $4 \times 10^6$  BBL OIL ANNUALLY FOR INDUSTRY; 50% ROI FOR COMBINED SYSTEM

Figure 4

# INDUSTRIAL THERMAL STORAGE APPLICATIONS

## SUMMARY - SCHEDULE



94

▽ TRANSFER TECHNOLOGY TO INDUSTRY

↓ TRANSFER RESULTS

Figure 5