259
7/10/79

DR. 2826

ORNL/SUB-79/42532

ENERGY

TECHNOLOGY

MASTER

APPLICATIONS OF THERMAL ENERGY STORAGE
TO WASTE HEAT RECOVERY IN THE
FOOD PROCESSING INDUSTRY

FINAL REPORT

Wayne L. Lundberg
James A. Christenson

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

WESTINGHOUSE ELECTRIC CORPORATION
ADVANCED ENERGY SYSTEMS DIVISION
P. O. BOX 10864
PITTSBURGH, PENNSYLVANIA 15236

Work Performed for
OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
Under Contract No. W-7405-eng-26

with the
U. S. DEPARTMENT OF ENERGY
OFFICE OF THE ASSISTANT SECRETARY FOR ENERGY TECHNOLOGY
DIVISION OF ENERGY STORAGE SYSTEMS

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy \$8.00; Microfiche \$3.00

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, contractors, subcontractors, or their employees, makes any warranty, express or implied, nor assumes any legal liability or responsibility for any third party's use or the results of such use of any information, apparatus, product or process disclosed in this report, nor represents that its use by such third party would not infringe privately owned rights.

ORNL/Sub-79/42532
Dist. Category UC-94a

FINAL REPORT
Contract No. EC-77-C-01-5002

APPLICATIONS OF THERMAL ENERGY STORAGE TO WASTE HEAT
RECOVERY IN THE FOOD PROCESSING INDUSTRY

Wayne L. Lundberg
James A. Christenson

Date Published: July 1979

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Work Performed by
WESTINGHOUSE ELECTRIC CORPORATION
Advanced Energy Systems Division
P.O. Box 10864
Pittsburgh, Pennsylvania 15236

Project Management by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

~~DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED~~

peg

JANUARY 1979

Advanced Energy Systems Division

**APPLICATIONS OF
THERMAL ENERGY STORAGE TO
WASTE HEAT RECOVERY IN THE
FOOD PROCESSING INDUSTRY**

FINAL REPORT

Contract No. EC-77-C-01-5002

**WESTINGHOUSE ELECTRIC CORPORATION
Advanced Energy Systems Division
P.O. Box 10864
Pittsburgh, Pennsylvania 15236**

APPLICATIONS OF THERMAL ENERGY STORAGE TO WASTE HEAT RECOVERY IN THE FOOD PROCESSING INDUSTRY

FINAL REPORT

Contract No. EC-77-C-01-5002

Prepared By

WAYNE L. LUNDBERG

JAMES A. CHRISTENSON

Approved By

DAVID L. BLACK

WESTINGHOUSE ELECTRIC CORPORATION

Advanced Energy Systems Division

P.O. Box 10864

Pittsburgh, Pennsylvania 15236

ABSTRACT

A project is discussed in which the possibilities for economical waste heat recovery and utilization in the food industry were examined. Waste heat availability and applications surveys were performed at two manufacturing plants engaged in low temperature (freezing) and high temperature (cooking, sterilizing, etc.) food processing. The surveys indicate usable waste heat is available in significant quantities which could be applied to existing, on-site energy demands resulting in sizable reductions in factory fuel and energy usage. At the high temperature plant, the energy demands involve the heating of fresh water for boiler make-up, for the food processes and for the daily clean-up operation. Clean-up poses an opportunity for thermal energy storage since waste heat is produced during the one or two production shifts of each working day while the major clean-up effort does not occur until food production ends. At the frozen food facility, the clean-up water application again exists and, in addition, refrigeration waste heat could also be applied to warm the soil beneath the ground floor freezer space. Systems to recover and apply waste heat in these situations were developed conceptually and thermal/economic performance predictions were obtained. The results of those studies indicate the economics of waste heat recovery can be attractive for facilities with high energy demand levels. Small factories, however, with relatively low energy demands may find the economics marginal although, percentagewise, the fuel and energy savings are appreciable.

ACKNOWLEDGEMENTS

The successful completion of this project is due in large part to the significant consultation and review efforts contributed by Mr. F. Wojnar, Manager - Energy Management, Heinz U.S.A. Division. Additional project support was provided by Mr. G. J. Trebilcox, Sr. Facilities Manager, U.S.A. Division, and by Mr. W. G. Goode and Mr. J. Pratt, Plant Manager and Plant Engineer, respectively, of the Heinz Lake City Factory.

TABLE OF CONTENTS

	<u>Page</u>
LIST OF FIGURES	vi
LIST OF TABLES	viii
1.0 INTRODUCTION	1
2.0 TECHNICAL TASK DESCRIPTIONS	2
3.0 FOOD INDUSTRY STRUCTURE AND ENERGY CONSUMPTION DATA	5
4.0 AN OVERVIEW OF THE HEINZ COMPANY & USA DIVISION	10
5.0 SURVEY SITE DESCRIPTIONS	14
5.1 PITTSBURGH FACTORY	15
5.1.1 Overview	15
5.1.2 Thermal Food Processing Systems	18
5.1.3 Factory Energy Supply System	26
5.1.4 Factory Operating Schedule	28
5.1.5 Waste Heat Applications	28
5.2 LAKE CITY FACTORY	30
5.2.1 Overview	30
5.2.2 Thermal Food Processing Systems	33
5.2.3 Factory Energy Supply System	33
5.2.4 Factory Operating Schedule	35
5.2.5 Waste Heat Applications	35
6.0 WASTE HEAT AVAILABILITY — PITTSBURGH FACTORY	39
6.1 POWER BUILDING	39
6.1.1 Continuous Cooker/Cooler	39
6.1.2 Can Washers	40

TABLE OF CONTENTS (Continued)

	<u>Page</u>
6.1.3 Horizontal Stationary Retorts for Canned Product Sterilization	41
6.1.4 Boiler Blowdown	43
6.2 MEAT PRODUCTS BUILDING	43
6.2.1 Horizontal Stationary Retorts for Glass Product Sterilization	43
6.2.2 Horizontal Stationary Retorts for Canned Product Sterilization	45
6.2.3 Can Washers	46
6.2.4 Bottle Washers	46
6.2.5 Continuous Pasteurizer	46
6.2.6 Berlin-Chapman Rotary Retorts	47
6.3 BEAN BUILDING	49
6.3.1 Horizontal Stationary Retorts for Canned Product Sterilization	49
6.3.2 Can Washers	50
6.3.3 Continuous Coolers	50
6.4 VINEGAR BUILDING	51
6.4.1 Heinz Rotary Retorts	51
6.5 WASTE WATER SUMMARY	53
7.0 WASTE HEAT RECOVERY SYSTEM DESIGN — PITTSBURGH FACTORY	55
7.1 HIGH TEMPERATURE COLLECTION SYSTEM	55
7.2 LOW TEMPERATURE COLLECTION SYSTEM	60
7.3 HEAT EXCHANGER SYSTEMS	60
7.4 SYSTEM OPERATION AND CONTROL SUMMARY	66

TABLE OF CONTENTS (Continued)

	<u>Page</u>
7.5 HEAT EXCHANGER SELECTION	66
7.6 HEAT EXCHANGER SIZING	67
7.7 WASTE HEAT RECOVERY SYSTEM PERFORMANCE	67
7.8 ECONOMICS ANALYSIS	73
8.0 WASTE HEAT AVAILABILITY — LAKE CITY FACTORY	77
9.0 WASTE HEAT RECOVERY SYSTEM DESIGN — LAKE CITY FACTORY	82
9.1 WATER HEATING SYSTEM	84
9.2 AIR HEATING SYSTEM	89
9.3 ECONOMICS ANALYSIS	95
10.0 PROJECTED FUEL AND ENERGY SAVINGS IN THE FOOD INDUSTRY	98
10.1 CANNING INDUSTRY PROJECTIONS	100
10.2 FROZEN FOOD INDUSTRY PROJECTIONS	101
10.3 TOTAL FOOD INDUSTRY IMPACT	102
11.0 CONCLUSIONS AND RECOMMENDATIONS	103
12.0 REFERENCES	105
APPENDIX A - CONDITIONS OF HEINZ'S PARTICIPATION	106
APPENDIX B - REPORT OF ADDITIONAL CONCEPTUAL DESIGN WORK	109

LIST OF FIGURES

Figure No.	Title	Page
1	H. J. Heinz Company Pittsburgh Complex	15
2	H. J. Heinz Company Pittsburgh Complex	17
3	Can Washer Schematic	19
4	Continuous Cooker/Cooler for Canned Food Products	20
5	Horizontal Stationary Retort Schematic	21
6	Continuous Pasteurizer Schematic (Meat Products Building)	24
7	Continuous Cooler Schematic	25
8	Energy Supply System — H. J. Heinz Pittsburgh Factory	27
9	H. J. Heinz Lake City Factory	31
10	Floor Plan — H. J. Heinz Lake City Factory	32
11	Lake City Factory Soft Water Distribution System Schematic	38
12	Horizontal Stationary Retort Cooldown Data — Can Operation	42
13	Horizontal Stationary Retort Cooldown Data — Glass Operation	44
14	Berlin-Chapman Rotary Retort Cooldown Predictions	48
15	Heinz Rotary Retort Cooldown Predictions	52
16	Waste Heat Recovery System — Pittsburgh Factory	56
17	Waste Water Collection System — Meat Products Building	57
18	Waste Water Collection System — Meat Products Building, 4th Floor	58
19	Three-Way Valve for Horizontal Retort (Glass) Drains	59

LIST OF FIGURES (Continued)

Figure No.	Title	Page
20	Low Temperature Accumulator and Pump(s) — Bean Building	61
21	Low Temperature Accumulator (LTA) — Bean Building, 1st Floor	62
22	System for Heating Boiler Make-Up & Power Building Food Process Water	63
23	Process Hot Water System — Power Building	64
24	Equipment Arrangement — Power Building, 1st Floor	65
25	HTHX Performance — 1st Shift	69
26	LTHX Performance — 1st Shift	70
27	LTHX Performance — 1st Shift	71
28	ROI vs. Cost/Benefit Ratio	76
29	Waste Heat Recovery System for Water Heating — Lake City Factory	85
30	Clean-Up Water Production and Usage Model — Single-Shift Operation	87
31	Clean-Up Water Production and Usage Model — Double-Shift Operation	88
32	Waste Heat Recovery System for Air Heating — Lake City Factory	91
33	Air Heating Condenser — Lake City Factory	94

LIST OF TABLES

Table No.	Title	Page
1	INDUSTRIAL ENERGY CONSUMPTION	5
2	TOTAL ENERGY USAGE IN THE FOOD INDUSTRY SUB-DIVISIONS - 1974	7
3	FOOD INDUSTRY FUEL AND ELECTRICITY CONSUMPTION DATA AS PERCENTAGES OF TOTAL ENERGY USAGE	9
4	MEMBER FACTORIES — HEINZ U.S.A. DIVISION	11
5	HEINZ U.S.A. FOOD PROCESSES	13
6	PITTSBURGH FACTORY PRODUCT LINE	14
7	COMPRESSOR DATA — LAKE CITY FACTORY	34
8	LAKE CITY FACTORY ENERGY DISTRIBUTION	36
9	WASTE WATER SUMMARY — PITTSBURGH FACTORY	54
10	WASTE HEAT RECOVERY SYSTEM DESIGN CONDITIONS	68
11	WASTE HEAT RECOVERY SYSTEM PERFORMANCE — PITTSBURGH FACTORY	72
12	ESTIMATED COSTS, PITTSBURGH FACTORY WASTE HEAT RECOVERY SYSTEM	74
13	ELECTRICAL LOAD AND WASTE HEAT ESTIMATES	79
14	ESTIMATED COSTS, LAKE CITY FACTORY WATER HEATING SYSTEM	90
15	ESTIMATED COSTS, LAKE CITY FACTORY AIR HEATING SYSTEM	96
16	LAKE CITY PROJECT COST SUMMARY	97
17	CANNING INDUSTRY OPERATING DATA	100
18	FROZEN FOOD INDUSTRY OPERATING DATA	101

1.0 INTRODUCTION

Westinghouse has completed a project to assess the potential for waste heat recovery in the food industry and to identify and evaluate practical heat recovery methods and systems. The project was undertaken with the cooperation of the H. J. Heinz Co. (U.S.A. Division) and terms and conditions of Heinz's participation in the project are presented in Appendix A. Exposure to typical manufacturing facilities in the food industry was necessary and Heinz U.S.A. satisfied that requirement and assisted the project by arranging plant visits, by providing Westinghouse with plant and system performance data and by installing special instrumentation for the measurement of waste water conditions. In addition, Heinz personnel were available throughout the project on a consultation and review basis and contributed in the areas of factory data interpretation and waste heat recovery system design and arrangement.

Two survey sites were selected from within the Heinz U.S.A. organization and a waste heat availability survey was completed for each site. In addition, waste heat recovery systems were designed conceptually for each site and the process of evaluating those designs technically and economically has been completed. The purpose of this report is to discuss the results of the completed work and to present recommendations for further work.

Upon completing the project, additional work was performed at the request of Oak Ridge National Laboratory. The purpose of that work was (1) to determine the investment return produced by the low and high temperature segments of the reference Pittsburgh Factory recovery system and (2) to predict the performance of independent waste heat recovery systems installed in individual factory buildings. The results of the add-on study were reported in October, 1978 and for completeness, they are included in this document as Appendix B.

2.0 TECHNICAL TASK DESCRIPTIONS

The project work plan consisted of four technical tasks and a single program management task. Program management involves cost plan development, liaison with the Department of Energy (DOE) Project Manager's office, direction of the technical work effort, etc. The four technical tasks pertain to the performance of waste heat surveys, waste heat recovery system design, the assessment of potential industry impact and the development of a commercialization plan. The particular objectives of the technical tasks are further described below.

Task 1: Waste Heat Availability Survey

The purpose of this task was to determine waste heat production rates and to identify potential waste heat applications. However, as a preliminary to that work, there were several sub-tasks that required completion. First of all, it was necessary to select two or three factories from within the Heinz U.S.A. organization that could serve as survey sites. The plants selected should be engaged in common food processing operations and preferably, they should involve a variety of waste heat sources; e.g., hot water, hot product, steam, refrigeration system condensers, etc. Satisfying these requirements would assure that the results of the project would be applicable to the largest possible segment of the food industry. Secondly, it was essential to become familiar with the food processing systems at each survey site. Accomplishing this required numerous plant visits — especially to the complex Pittsburgh Factory in which production operations occur on various floors of five, multi-story buildings.

At the selected survey sites, waste heat production rates were determined for each food processing system using information from various sources. Several systems were equipped with operating instrumentation which permitted the direct measurement of waste water temperatures. These data were then combined with known product flow rates and temperatures to determine waste water flow rates. Other systems were equipped with no instrumentation. In two of those cases, special instrumentation was installed by the Heinz Company and in others, waste

water temperatures and flow rates were directly measured using hand-held thermometers and by determining the weight of water collected over a known period of time. Uninstrumented systems suspected to be low waste heat producers were modeled mathematically to obtain predictions of waste heat production rates. Upon completing the waste heat availability study, the results were compared with energy demand rates and temperature requirements at the survey sites to determine if the demands could be met by waste heat.

Task 2: Energy and Fuel Savings in the Food Processing Industry

An energy and fuel savings study was required to permit an economics analysis of each waste heat recovery system concept and to demonstrate the benefits of waste heat recovery in terms of dollars and energy and fuel quantities. For this work, energy consumption data for the industry were required and they were obtained primarily from published studies that identify energy consumption rates for the various product groups within the industry. The Standard Industrial Classification (SIC) system is normally used in work of this type and it permitted the direct comparison of data and energy savings estimates from the survey sites with data from corresponding segments of the industry and from the industry in general.

Task 3: Waste Heat Recovery System Conceptual Design

The object of this task was to evaluate conceptual designs for systems that would recover waste heat from sources identified during Task 1 and apply it to factory energy demands. Recovery system design criteria were developed with major input from the Heinz U.S.A. Division. In addition to being cost-effective, the criteria require the system to be reliable and simple to operate and it should not increase the workload of the production system operators. Further, it was required that any credible recovery system malfunction should have no effect on food system or factory operations.

Task 4: Commercialization Plan Development

As noted earlier, an objective of this project was to assess the potential for waste heat recovery in the food industry and a necessary part of the work was

the development of a plan for introducing results of the project to the industry. In Task 4, a commercialization plan was conceived involving reports and oral presentations and the extension of the project into a demonstration phase which would be publicized within the industry.

3.0 FOOD INDUSTRY STRUCTURE AND ENERGY CONSUMPTION DATA

The food industry is engaged in the manufacture and distribution of food and beverage products primarily for human consumption but it also includes several segments producing prepared feeds for poultry and livestock and for domestic animals and pets. The industry total energy¹ consumption is currently rising at an average rate of nearly 2% per year and it reached 959×10^{12} Btu² in 1974. As indicated in Table 1, the food industry ranks sixth among the largest industrial users in terms of total energy consumption and is currently responsible for approximately 6% of the energy used by the nation's industrial sector.

TABLE 1
INDUSTRIAL ENERGY CONSUMPTION³

<u>Industry</u>	<u>Percent of Total Industry Usage</u>
Chemicals and Allied Products	24
Primary Metal Industries	19
Petroleum and Coal Products	10
Paper and Allied Products	8
Stone, Clay and Glass Products	8
Food and Kindred Products	6
Other Manufacturing	<u>25</u>
TOTAL	100%

---

¹Total energy — the energy content (i.e., heating value) of all purchased fuels and electricity.

²Except where noted otherwise, all food industry energy usage data have been obtained from Reference (a).

³Based upon Table 1-1 of Reference (b).

In the Standard Industry Classification (SIC) system, the Food and Kindred Products industry is assigned the two-digit number 20 and is subdivided into 47 four-digit groups according to product lines. During the past several years, extensive research efforts have compiled energy usage data for each of the 47 groups and some of the published data are presented in Table 2. The product groups represented within the H.J. Heinz Company U.S.A. Division are identified by asterisks and will be referred to again later in the report.

The food industry energy supply is provided by the fossil fuels — coal, oil and natural gas, and by commercially produced electricity. Between 1958 and 1974, as shown in Table 3, the fraction of the industry energy demand that was met by fossil fuels declined steadily while the fraction supplied by electricity was on the rise. These trends are probably the result of increased mechanization which relies in most cases upon electricity. Within the fossil fuel category, the percentage use of natural gas has increased steadily at the expense of reduced coal and oil consumption. Those trends reflect the advantages of natural gas in the areas of cost, cleanliness and storage and concerns over availability in the fuel oil case. In the near future, industry data are likely to show increased coal usage as a result of the current national energy policy which is stressing coal.

TABLE 2
TOTAL ENERGY USAGE IN THE FOOD INDUSTRY SUB-DIVISIONS - 1974

<u>SIC No.</u>	<u>Industry</u>	<u>Rank</u>	<u>Total Energy Usage (Btu x 10⁻¹²)</u>	<u>% of Total</u>
2063	Beet Sugar	1	81.5	8.5
2046	Wet Corn Milling	2	78.8	8.2
2011	Meat Packing Plants	3	77.1	8.0
2082	Malt Beverages	4	49.5	5.2
*2033	Canned Fruits and Vegetables	5	46.4	4.8
2026	Fluid Milk	6	43.7	4.6
2051	Bread, Cake and Related Products	7	43.7	4.6
2075	Soybean Oil Mills	8	43.3	4.5
2062	Cane Sugar	9	37.9	4.0
*2037	Frozen Fruits and Vegetables	10	31.4	3.3
2048	Prepared Feeds	11	31.4	3.3
2079	Shortening and Cooking Oils	12	26.6	2.8
2099	Food Preparations	13	26.3	2.7
2077	Animal and Marine Fats and Oils	14	23.9	2.5
2022	Cheese, Natural and Processed	15	23.2	2.4
2023	Condensed and Evaporated Milk	16	21.8	2.3
*2032	Canned Specialties	17	21.2	2.2
*2086	Bottled and Canned Soft Drinks	18	20.1	2.1
2016	Poultry Dressing Plants	19	17.4	1.8
2085	Distilled Liquor	20	17.1	1.8
2013	Sausage and Prepared Meats	21	15.7	1.6
2047	Pet Food	22	14.3	1.5
2061	Raw Cane Sugar	23	12.6	1.3
2065	Confectionery Products	24	12.6	1.3
*2038	Frozen Specialties	25	11.6	1.2

TABLE 2 (Continued)

<u>SIC No.</u>	<u>Industry</u>	<u>Rank</u>	<u>Total Energy Usage (Btu x 10⁻¹²)</u>	<u>% of Total</u>
2041	Flour and Other Grain Mill Products	26	11.6	1.2
2034	Dehydrated Food Products	27	11.2	1.2
2052	Cookies and Crackers	28	10.9	1.1
2095	Roasted Coffee	29	10.2	1.1
2083	Malt	30	9.2	<1.0
2043	Cereal Preparations	31	8.2	<1.0
2074	Cottonseed Oil Mills	32	7.2	<1.0
*2035	Pickles, Dressings, and Sauces	33	6.5	<1.0
*2024	Ice Cream and Frozen Desserts	34	6.1	<1.0
2021	Creamery Butter	35	5.5	<1.0
2066	Chocolate and Cocoa Products	36	5.1	<1.0
2087	Flavoring Extracts and Syrups	37	5.1	<1.0
2017	Poultry and Egg Processing	38	4.8	<1.0
2091	Canned and Cured Seafood	39	4.8	<1.0
2084	Wines, Brandy	40	4.1	<1.0
2092	Fresh or Frozen Packaged Fish	41	4.1	<1.0
2076	Vegetable Oil Mills	42	3.4	<1.0
2044	Rice Milling	43	2.7	<1.0
2097	Manufactured Ice	44	2.7	<1.0
2098	Macaroni and Spaghetti	45	2.4	<1.0
2045	Blended and Prepared Flour	46	2.0	<1.0
2067	Chewing Gum	47	1.7	<1.0
<u>TOTALS</u>				
20	Food and Kindred Products		958.8	100%

*Denotes a product group of the H.J. Heinz Co. U.S.A. Division

TABLE 3
FOOD INDUSTRY FUEL AND ELECTRICITY CONSUMPTION DATA
AS PERCENTAGES OF TOTAL ENERGY USAGE

Fuel	YEAR				
	1958	1962	1967	1971	1974
Fuel Oil (%)	22	16	15	15	16
Natural Gas (%)	36	43	50	58	57
Coal (%)	33	29	24	14	10
Other Fuels (%)	2	4	2	1	4
Electricity (%)	7	8	9	12	13
Total (%)	100	100	100	100	100
Total Energy Consumption (Btu x 10 ⁻¹²)	766	803	900	1,031	959

4.0 AN OVERVIEW OF THE HEINZ COMPANY & USA DIVISION

The H.J. Heinz Company is a major member of the food processing industry both nationally and internationally. The company was founded in 1869 in Sharpsburg, Pa. by Henry J. Heinz and has developed to the extent that its products are marketed worldwide in 150 countries and the familiar "Heinz 57 Varieties" has grown to 1500. Within the United States, the company operates the Heinz U.S.A. Division, Star Kist Foods (a tuna processor and pet food producer), Ore-Ida Foods (frozen potato products) and the Hubinger Company (corn syrups and starches). Company subsidiaries outside the United States include firms in England, Italy, Canada, Holland, Portugal, Venezuela, Australia, and Japan. World Headquarters for the H.J. Heinz Company are located in Pittsburgh, Pennsylvania.

As noted earlier in the report, this waste heat recovery project was undertaken with the cooperation of the Heinz U.S.A. Division and the survey sites and potential demonstration sites have been selected from within that division. Like the world organization, the U.S.A. Division is headquartered in Pittsburgh and consists of eleven processing and manufacturing plants that are distributed nationwide. The plants and their product lines are identified in Table 4.

As an early step in the project, operations at the eleven division factories were reviewed to become familiar with their product lines and to permit their classification according to food process type. The purpose of the work, of course, was the selection of one or two factories to serve as waste heat survey sites. It was intended that the sites selected should be engaged in different food process operations and would therefore exhibit different waste heat source types. Further, the process systems should be fairly common and ones that are used on a high volume basis by the remainder of the food industry. These survey site qualities would assure an industry-wide application for any waste heat systems resulting from the project thereby providing the potential for maximum energy and fuel saving.

TABLE 4

MEMBER FACTORIES — HEINZ U.S.A. DIVISION

Fremont, Ohio	The Fremont Factory is the company's major ketchup producer. The factory also produces a tomato paste (at harvest time) which is the "raw material" for ketchup production.
Holland, Michigan	This factory is a modern facility specializing in pickle and vinegar production.
Lake City, Pennsylvania	A refrigeration plant that produces frozen dessert products (pies, cakes and cookies) for institutional and retail markets.
Lithonia, Georgia } Schaumburg, } Illinois }	These factories manufacture frozen pizza. Pizza was the company's first frozen product and is distributed nationwide for sale to the school food service market.
Muscatine, Iowa	The Muscatine Factory produces a variety of canned and bottled products including ketchup, chili sauce, condensed soups and vinegar.
Pittsburgh, Pennsylvania	All company products and varieties except bottled ketchup and pickles are manufactured at the Pittsburgh Factory.
Stockton, } California } Tracy, California }	The Stockton and Tracy Factories are the Heinz West Coast production centers for products such as baby foods, pickles, ketchup, and tomato juice. They also affect production activities in other division factories since they process 70% of all tomatoes used by Heinz U.S.A. During the tomato season, Tracy and Stockton produce tomato paste that is transported in aseptic railway tank cars to Heinz plants in the Midwest and East for eventual use in soups, ketchup and sauces.
Watsonville, } California } Winchester, } Virginia }	These factories specialize in the production of bottled vinegar.

The food processing operations conducted by Heinz U.S.A. factories can be classified under five major headings which are identified in Table 5. These processes, with the exception of fermentation and pickling, are high energy consumers. Pasteurization and sterilization involve the simultaneous heating of the product, large volumes of water (the heat transfer medium) and the system structure. The refrigeration effect in the freezing process is achieved with the application of electrical energy to power the system compressors and the cooling processes are the result of applying thermal energy to heat the product and to evaporate water. Energy also flows away from these processes by various mechanisms and is unavailable for further use. With factories and food processes of the kind operated by Heinz U.S.A., the dominant sources of waste energy (in thermal form) are hot waste water streams and refrigeration condensing systems. Therefore, the waste heat recovery concepts evaluated during this project were based upon those two sources and due to their close proximity to the Westinghouse offices, the logical survey sites were the Heinz Pittsburgh and Lake City Factories.

The products manufactured by the Pittsburgh Factory are primarily in the Canned Specialties (SIC 2032) industry and the processes used are common not only to that industry but to Canned Fruits and Vegetables (SIC 2033) as well. Similarly, the Lake City products would place that factory, strictly speaking, within the Ice Cream and Frozen Desserts (SIC 2024) industry. However, similar food processes are also employed in the Frozen Specialties (SIC 2038) and Frozen Foods and Vegetables (SIC 2037) industries. Based upon data from Table 2, the annual energy consumption by these five industries (SIC 2032, 2033, 2024, 2038, and 2037), which are represented by our Pittsburgh and Lake City survey sites, totals to 117×10^{12} Btu (Canned to Frozen Ratio 60/40). Thus, the five industries account for over 12% of the total food industry (SIC 20) energy usage. If waste heat recovery systems were implemented to reduce their energy consumption by 10% the annual savings, nationwide, would amount to 0.012 quad* or approximately 1.3% of the current SIC 20 usage. This potential industry impact is significant and therefore it appeared that survey and conceptual system design work at the Pittsburgh and Lake City Factories would be very worthwhile. This, of course, was an additional and very important reason for selecting those factories for use as survey sites.

---

* 1 quad = 1×10^{15} Btu

TABLE 5

HEINZ U.S.A. FOOD PROCESSES

- Pasteurization and Sterilization - time-at temperature processes to rid the product of unwanted organisms or to retard their development.
- Fermentation and Pickling - fermentation (and oxidation) are the processes by which vinegar is produced from apple cider. In pickling, vegetables are prepared and preserved by soaking them in brine and vinegar.
- Freezing and Cold Storage - the preservation of foods by quick-freezing and maintaining the frozen condition until they are to be consumed.
- Evaporative Cooking - the process of evaporating a portion of the products natural water content to concentrate the product solids. Heinz uses this seasonal process to prepare tomato paste.
- Cooking - the heating process required for the production of certain prepared and ready-to-eat foods.

Factory	Pasteurization and Sterilization		Fermentation and Pickling		Freezing and Cold Storage		Evaporative Cooking		Cooking	
Fremont	x	x					x		x	
Holland	x	x								
Lake City					x				x	
Lithonia					x				x	
Schaumburg					x				x	
Muscatine	x	x							x	
Pittsburgh	x	x							x	
Stockton	x	x					x		x	
Tracy	x	x					x		x	
Watsonville										x
Winchester										x

5.0 SURVEY SITE DESCRIPTIONS

5.1 PITTSBURGH FACTORY

5.1.1 Overview

The Heinz Pittsburgh Factory is one component of the 24 acre Pittsburgh complex (Figure 1) which consists of the factory, the company's world headquarters, the U.S.A. Division offices and the Heinz Research Center. The factory employs over 2,000 production people and is the company's largest manufacturing facility. Products produced by the Pittsburgh Factory and their SIC categories are identified in Table 6:

TABLE 6
PITTSBURGH FACTORY PRODUCT LINE

Product	SIC 2032 - Canned Specialties	SIC 2033 - Canned Fruits & Vegetables	SIC 2035 - Pickles, Dressings & Sauces	SIC 2086 - Bottled & Canned Soft Drinks
Baby Foods and Juices	x			
Canned Soups	x			
Canned Bean Products		x		
Ketchup, Mustard and Sauces			x	
Bottled Vinegar			x	
Lemon Blend				x

Figure 1. H. J. Heinz Company Pittsburgh Complex

Of these products, the major ones are baby foods and juices and canned soups. Factory production operations occur primarily in the Meat Products, Bean, Vinegar, Power and Cereal Buildings that can be located in the factory layout of Figure 2.

Basically, the production of baby food and canned soups proceeds in several steps arranged in the following order:

- Food Preparation - ingredient blending and cooking
- Packaging - container washing, filling, sealing and final washing
- Sterilization or Pasteurization - depending upon product requirements
- Product Cooling
- Labeling and Packing

Thermal energy is applied to the product during the cooking process and leaves that process by various mechanisms — escaping vapors, radiant and convection heat losses, etc. Packaging requires thermal energy to heat wash water and most of that energy eventually exits the factory via the waste water drain and sewer system.* Sterilization and pasteurization are time-at-temperature processes that require heating the product in a steam atmosphere or by surrounding it with hot water. Ultimately, the product, whether heated during the preparation, packaging or sterilization/pasteurization process, must be cooled prior to the labeling and packing operation. Cooling is accomplished by water that flows to the drain system as waste after the cooling process. There it mixes with other waste water streams from various stages of the food processing operation. During the project, the waste heat of primary interest was the energy contained in those streams as they approach the drain system. As noted above, there are other waste heat sources — vapors, heat loss from equipment, etc. However, compared to hot waste water, those would be difficult to work with and they have not been considered.

---

* To eliminate the possibility of product contamination, all process waste water is sent to the drain and sewer system and none is recycled.

Figure 2. H. J. Heinz Company Pittsburgh Complex

5.1.2 Thermal Food Processing Systems

The Pittsburgh Factory operates several systems in its food processing operations that produce heated waste water. Factory systems which were studied and evaluated during the project are described below in addition to the processes that they perform.

Continuous Can Washers

As indicated in Figure 3, empty cans are washed (inside and out) by hot water sprays as they approach the filling system and the external surfaces of the cans are washed again after sealing. The wash water temperature is generally in the 170-190°F range as it enters the washer units and measurements indicate it loses less than 10-15°F before entering the drain system. Typical waste water temperatures and flow rates for an individual can line are noted in Figure 3.

Continuous Cooker/Cooler Systems

Figure 4 presents a schematic diagram of a continuous cooker/cooler unit. Product in sealed cans flows continuously through the unit by a conveyor system. As it enters the cooker, the product is warm (100-140°F) and its contact with the unit's steam atmosphere elevates the product temperature to approximately 240°F which is required for cooking and sterilization. The cooling process is accomplished in two stages during which the cooler pressure is controlled to prevent can deformation. Currently, cooling water leaving the system flows to a drain and exits the factory. The drain flow rate and temperature data of Figure 4 apply to a single cooker/cooler unit. The temperatures were measured using installed thermometers and the flow rates are the result of calculations that combined the cooling water temperatures with product temperature requirements and can rates.

Horizontal Stationary Retort

Products in sealed glass or can containers are batch sterilized in horizontal retorts - see Figure 5. A retort is a cylindrically-shaped pressure vessel with a diameter of 5 ft. and a length of 23 ft. The retort is loaded with several tons of product through a hinged door at one end of the cylinder. If the

Figure 3. Can Washer Schematic

Figure 4. Continuous Cooker/Cooler for Canned Food Products

- SPECIAL INSTRUMENTATION-INSTALLED ONLY ON RETORT NO. 10, 5th FLOOR, MEAT PRODUCTS BUILDING.

Figure 5. Horizontal Stationary Retort Schematic

product is can-packaged, the sterilizing process is performed in a steam atmosphere which is controlled automatically to maintain a constant product temperature for a specified period of time — say, 240°F for 1 hour. At the end of that period, steam flow is terminated and air pressure is applied to prevent can damage during the subsequent cooldown period. The flow of cooling water to the retort is controlled manually at approximately 100 gpm. Initially, some of the cooling water exits the retort at the bottom drain but much of it accumulates in the retort and surrounds the product until the overflow level is reached. That phase of the cooling process requires approximately 20 minutes and overflow, once it occurs, is allowed to continue for an additional 20 to 30 minutes to complete the process. When overflow does occur, the retort contains nearly 1400 gallons of water and the equilibrium temperature of the water, product and retort metal mass is in the vicinity of 120°F. Therefore, during the overflow period, waste water flowing to the drain is initially at 120°F and its temperature usually decays to 90°F by the time cooling is terminated. At that point, closure of the cooling water flow control valve occurs and the water contained by the retort is dumped to the drain system by fully opening the bottom drain flow control.

Glass-packaged products (baby foods) are sterilized in the same retorts using a process that differs significantly from the can procedure. Once the retort is loaded with a glass product, it is filled to the overflow level with water at 160 - 170°F. The process temperature (240 - 250°F) is then achieved and maintained for the required period by injecting the water with steam. This procedure is followed since it prevents severe thermal stresses in the glass containers that would occur if the steam atmosphere procedures were followed.

During the remainder of the time-at-temperature and cooldown process, the can and glass procedures are very similar. It is noted that the glass process consumes more energy and results in the delivery of more waste heat to the drain system since a large water volume (~1900 gal.) must be heated to the process temperature in addition to the product and the retort metal mass. Also, waste water temperatures are relatively high during the glass cooldown period due to the retort's initially-filled condition and the fact that overflow begins immediately.

Rotary Retorts

Products packaged in large cans are sterilized in rotary retorts which turn the product end-over-end during the time-at-temperature and cooldown processes. The rotation action mixes the product and produces uniform heating and cooling. As with the stationary retorts described above, the sterilization process is accomplished in a steam atmosphere and cooling is provided by flowing water that enters the drain system when it exits a retort.

Continuous Pasteurizers

The Pittsburgh Factory operates two continuous pasteurizers — one located in the Meat Products Building and one in the Cereal Building. Products such as baby juices in sealed glass jars are processed in these units and they move through the system by conveyor. As shown in Figure 6, the product encounters two hot sprays and a cooling section within the pasteurizer. The hot spray water is produced by injecting cold water with steam and after flowing over the product, the hot water streams merge with used cooling water and flow to a floor drain. To recover waste heat from the pasteurizer, it would be necessary to separate the hot and cold waste water streams and this could be accomplished easily by plumbing changes. The spray water flow rates identified in Figure 6 apply to the Meat Products Building pasteurizer. They are based upon Heinz U.S.A. calculations and the temperatures are measured values.

Continuous Coolers

Some canned products are hot as they exit the process and they require cooling prior to being labeled and packed. The factory operates several continuous coolers for this purpose and in each unit, heat is transferred from the moving product to a counter-flowing stream of cooling water. As it leaves the cooler, the water enters the factory drain system and measurements indicate that typically, the water temperature at that point is in the vicinity of 120°F. The product temperatures in the system schematic of Figure 7 were also obtained by actual measurements and the cooling water flow rate presented there is based upon those measurements and an assumed can rate.

Figure 6. Continuous Pasteurizer Schematic
(Meat Products Building)

Figure 7. Continuous Cooler Schematic

5.1.3 Factory Energy Supply System

The Power Building houses seven boilers having a combined steam generating capacity of 340,000 lb/hr. The steam is superheated — 750°F at 600 psia, the boiler feedwater temperature is typically 250°F and the maximum thermal energy delivery rate is 116 MW. Several years ago, the boilers were equipped to fire coal, oil or gas individually or in combinations of coal and oil or gas and oil. At present prices, the cost of coal is \$2.05 per million Btu's and the cost of gas and oil is approximately \$2.25 and \$2.35, respectively. Thus, due primarily to economics, the factory is currently maximizing the use of coal, while remaining within the air quality standards prescribed by Allegheny County, and the company is considering the installation of a baghouse which would increase further the factory's ability to burn coal.

Figure 8 depicts the factory energy supply system in schematic form. Steam produced by the boilers flows to twin turbine-generator sets and the surplus goes to pressure reducing and desuperheating stations. The turbines are back pressure units that exhaust steam, still slightly superheated, to the factory header. The turbine-generators typically produce two-thirds of the factory's electrical demand and the remainder is supplied by Duquesne Light Company. At current prices, the cost of factory-produced electricity is 1.5¢ per kWh which is approximately 40% of the commercial rate to industrial users. It is noted that electricity is a by-product of the factory's energy supply system; the system's main purpose is the production of thermal energy for use in the factory food processing operation. Based upon steam production data for 1976, the boilers deliver 9.4×10^{11} Btu annually. Of that total, only 6% was consumed by the turbine-generator sets. Twenty percent was applied to auxiliary site demands (heating, air conditioning, air compressors, pumps, etc.) while it is estimated that most of boiler energy output — nearly 75%, was used directly in food processing. Steam is used at the factory by a variety of food processes and several major ones are identified in Figure 8.

As Figure 8 indicates, condensate from the various factory processes is collected, supplemented by softened city water, and returned to the boilers as feedwater.

Figure 8. Energy Supply System — H. J. Heinz Pittsburgh Factory

Two thirds of the feedwater flow are make-up since most of the factory's steam production is used directly and eventually leaves the factory, in condensed form, as waste water. Therefore, make-up water treatment costs are significant and they would be reduced by any waste heat recovery system that would decrease the direct use of steam in the food processes.

5.1.4 Factory Operating Schedule

Under normal conditions, production activity at the Pittsburgh Factory occurs during the first and second shifts (7 a.m. to midnight) on five working days per week. Production generally peaks during first shift and depending upon demand, it is not uncommon for several systems to be taken out of service during second shift. The third shift of each working day and weekends are reserved for factory maintenance, equipment installation, etc. Another important activity that occurs during third shift is plant clean-up. During that period, hardware that contacts the product is disassembled and washed using water at temperatures in the 150 - 180°F range. The components of many food processing systems are of the quick-disconnect type to facilitate washing. Others not of this type are circulated with hot water to accomplish the required cleaning action. Floors and external system surfaces are also washed during third shift as part of a general area clean-up and the entire clean-up operation is observed and approved nightly by U.S. Department of Agriculture representatives.

5.1.5 Waste Heat Applications

During Task 1, waste heat applications were sought as well as waste heat sources and in the process, three major applications were found. They involve the heating of factory clean-up water, boiler make-up water and water for use in food processes that occur in the Meat Products and Power Buildings.

Clean-Up Water

Hot water for factory clean-up is currently produced by steam injecting cold well water at mixing stations distributed throughout the factory. A mixing station consists of a special wall or column-mounted valve that is permanently connected to a steam line on one side and to a cold water line on the other. An

operator manually controls the flow of steam and water to the valve to achieve a desired mixture temperature at the valve outlet. At some stations, the outlet is equipped with a temperature indicator to assist in controlling the steam and water flow rates. To determine the volumes of clean-up water required nightly at the Pittsburgh Factory, Heinz U.S.A. compared steam generation data for a typical third shift clean-up period with base load data recorded when the plant steam demand was essentially zero. The difference was assumed to reflect the clean-up steam demand and leads to an estimated nightly clean-up water volume of nearly 200,000 gallons (at temperatures in the 150 - 180°F range). Energy extracted from factory wastewater could be used to heat clean-up water thereby displacing steam as the energy source. The heated water would then be stored to bridge the gap between the production shifts, when most waste heat is produced, and third shift when the clean-up water is needed.

Boiler Make-Up Water

As reported earlier, condensate losses at the factory are significant. It is estimated that 60 - 70% of all boiler feedwater during the production shifts consists of make-up which corresponds to an average make-up water flow rate of approximately 250 gpm. Figure 8 indicates that make-up water is drawn from the city main, softened and then mixed with returning condensate at the hotwell. Waste heat could be easily applied to preheat the make-up water and the economics of this application are very favorable since wasted energy would be used as soon as it comes from the food processes and storage expenses would be avoided.

Heated Water for Food Processes

Hot water is required by a variety of food processing operations at the factory and several were discussed above. A major demand for hot process water is produced by the horizontal stationary retorts that are used to sterilize glass-packaged products. That process occurs in the Meat Products Building and requires nearly 40,000 gallons of 170°F water per shift. At the present time, the water is heated in the Power Building by steam injection and pumped to Meat Products as needed. Our analysis indicates that most of the energy required for this particular process and for a second hot water demand occurring in the Power Building could be provided by waste heat.

5.2 LAKE CITY FACTORY

5.2.1 Overview

The Heinz U.S.A. factory at Lake City is located in northwestern Pennsylvania near the south shore of Lake Erie. The factory is a modern, single story structure (see Figure 9) containing 73,000 ft² of floor area including 31,000 ft² of freezer floor space. One hundred and fifty production and office personnel are employed at the factory and are engaged in the manufacture of frozen dessert products (pies, cakes and cookies) for the retail and institutional markets.

A factory floor plan is presented in Figure 10. Single layer cakes produced in the bakery are carted to the pie and cake production area where toppings are applied automatically. Pie products do not require baking and their manufacture originates and is handled automatically in the pie and cake production area. The last step in the production of both pies and cakes is quick freezing in the blast freezer. The product moves continuously within the freezer and the freezer transit time is typically in the 30 to 45 minute range. Once it exits the blast freezer, the product is immediately covered, labeled and packed. Then, the finished cartons are removed by fork-lift to one of the storage freezers where they await shipment.

The production of cookies at the factory was initiated in October, 1977 and is therefore a relatively new operation. The cookie line is automated and the product requires neither baking nor blast freezing. As they leave the line, the cookies are packed and placed directly in storage.

All Lake City products fall within the SIC 2024 category — Ice Cream and Frozen Desserts. Freezing, however, is common to several food industries and therefore, the Lake City operation is similar if not identical to those in other frozen food groups such as SIC 2037 — Frozen Fruits and Vegetables, SIC 2038 — Frozen Specialties (pizza, french fries, etc.) and SIC 2092 — Fresh or Frozen Packaged Fish.

Figure 9. H. J. Heinz Lake City Factory

614986-1 C

Figure 10. Floor Plan — H. J. Heinz Lake City Factory

5.2.2 Thermal Food Processing Systems

Foods are processed thermally at the Lake City Factory by baking and freezing. The ovens shown in Figure 10 are gas fired and, as reported above, are used in cake production. Waste heat from the baking process occurs in the form of convective and radiative losses, stack losses and stored energy leaving the ovens via the product. These sources of wasted energy were not considered during this project.

The second thermal food process at Lake City is freezing. The refrigeration effect is provided by an ammonia vapor compression system which is driven by ten compressor units. The compressors (described in Table 7) deliver refrigerant vapor from evaporators in the various freezer compartments to seven evaporative condensers mounted on the factory roof. Vapor from Compressors 1, 2, 5, and 6 - 10 is condensed in six common-manifold units while compressors 12 and 13 are stages of a separate refrigeration cycle having its own condensing unit. The entire system has a refrigeration rating of 400 tons and is the largest individual consumer of energy (electrical) at the factory. Consequently, the system condensers represent the factory's major source of waste heat and systems to recover a portion of that energy were considered during this project.

5.2.3 Factory Energy Supply System

Energy demands at Lake City are satisfied by natural gas and electricity. Factory gas consumption currently totals to 14,000 MCF annually and of that amount, one-third is consumed by a gas-fired boiler and another 15% is used to heat air which is blown beneath the freezer floors. The factory space heating system requires an additional 15% of the natural gas input and the remaining 40% is consumed by the factory ovens. Two boilers are actually installed at the factory — one primary unit and one idle unit for standby purposes. The primary boiler rating is 4000 lb/hr at 100 psig and its output is applied to clean-up water heating and to heating kettles and two pasteurizers. As with the Pittsburgh Factory, hot clean-up water is produced at Lake City by the direct mixing of steam and softened city water at clean-up stations distributed throughout the production areas.

TABLE 7
COMPRESSOR DATA — LAKE CITY FACTORY

Compressor No.	Type	Motor Horsepower Rating	Application	Availability ⁴ (hrs/year)	Compressor Room No. ⁵
1	Compound Reciprocating	50	Storage Freezer	8736	1
2	Compound Reciprocating	75	Storage Freezer	5824	1
5	Reciprocating	40	Ice Bank ¹	7488	2
6	Rotary - 1st Stage	200	Blast Freezer ²	6864	3
7	Rotary - 1st Stage	75		4368	3
8	Reciprocating - 2nd Stage	60		3120 ³	3
9	Reciprocating - 2nd Stage	150		6864	3
10	Reciprocating - 2nd Stage	50	Blast Freezer ²	7488	4
12	Reciprocating - 2nd Stage	75	Storage Freezer	8736	4
13	Reciprocating - 1st Stage	75	Storage Freezer	8736	4

¹The ice bank is located in the boiler room. Ice produced in the bank is used to chill water for certain food processes.

²Available only during the production shifts.

³Compressor 8 is idle during the winter months.

⁴Heinz U.S.A. data

⁵See Figure 10 for room locations

The floor heating application is unique to refrigeration plants having ground-floor freezer compartments. A potential problem with that arrangement results from the freezing of the earth directly beneath the freezer compartments. The freezing action produces swelling which can cause the floor to heave upwards. To eliminate or minimize that problem at Lake City, 70°F air is blown beneath the freezer floor through spaces between the floor and the earth. Outdoor air is drawn in through a roof-mounted system composed of a vaneaxial fan and an air temperature controlled gas-fired heater. The modulated heater is activated whenever the outdoor temperature falls below 70°F. The system is rated at 7000 scfm and the annual air-heating energy demand is approximately 1.4×10^9 Btu.

Over a recent one year period, the total factory electrical demand was 3.71×10^6 /kWh. Of that total, the refrigeration compressors require 60-65% and the remainder is applied to plant services such as lighting, motors, office equipment, etc. In Table 8, the factory energy usage data are consolidated to identify the distribution among the various consumers at the factory.

5.2.4 Factory Operating Schedule

The evaporators in the blast and storage freezers are defrosted during the early hours of each working day and that process is usually completed by 4:00 a.m. Between 4:00 and 6:00 a.m., freezer operating temperatures are re-established after which production can begin. Factory production operations are currently divided between single and double shift days and for the current project, the split was assumed to be even — 110 days of single shift production per year and 110 days double shift. As with the Pittsburgh Factory, one shift of each working day is devoted to a thorough cleaning of the production areas and of all hardware that contacts the product.

5.2.5 Waste Heat Applications

An evaluation of waste heat sources and potential applications was performed at the Lake City Factory. During that study, the waste heat production rate at the condensers was determined as a function of time and the feasibility of using that energy to supply the following demands was assessed.

TABLE 8
LAKE CITY FACTORY ENERGY DISTRIBUTION

Annual Energy Availability

Natural Gas	- 14,000 MCF	=>	1.40×10^{10} Btu
Electricity	- 3.708×10^6 kWh	=>	1.27×10^{10} Btu
TOTAL			2.67×10^{10} Btu

Factory Energy Distribution — % of Total Consumption

Boilers	15
Floor Heating	8
Space Heating	8
Ovens	21
Compressors	30
Electrical Services	18
TOTAL	100%

Clean-Up Water

Heinz estimates the daily Lake City demand for heated (150°F) clean-up water at 8000 gallons* on single shift days and 10,000 gallons during double shift production. As indicated in Figure 11, clean-up water is softened city water that is steam injected at local clean-up stations. Our analyses indicate that energy rejected by the refrigeration system during the production shifts could be used to heat the required volume of clean-up water. That water would then be placed in storage for use as needed during the production shifts and during the major clean-up operation that occurs when the production day ends.

Floor Air Heating

Refrigeration waste heat could also be applied to satisfy the floor air heating demand. Compressors 12 and 13 drive a separate refrigeration system that serves a storage freezer and therefore those compressors are on line continuously except during brief defrost periods. Thus, waste heat from that system is ideally suited for this particular application which represents a 24 hour energy demand. Any part of the demand not satisfied by waste heat would be met by the already existing gas heater system.

---

* 2000 gallons are needed during each production shift and 6000 gallons during the clean-up shift.

LAKE CITY FLOOR PLAN & SOFT WATER DISTRIBUTION SYSTEM SCHEMATIC

Figure 11. Lake City Factory Soft Water Distribution System Schematic

6.0 WASTE HEAT AVAILABILITY — PITTSBURGH FACTORY

The first step in the design of a waste heat recovery system must be a determination of the waste heat quantities available. In particular, for the Pittsburgh Factory, this involved the prediction or direct measurement of waste water flow rates and temperatures and other parameters such as process cycle times, cycles per shift, number of production lines in operation, etc. These data were compiled for the Pittsburgh Factory during Task 1 and the results are presented in this section for the various production buildings and food processing systems.

6.1 POWER BUILDING

6.1.1 Continuous Cooker/Cooler

Figure 4 shows the product and cooling water paths through a cooker/cooler system in addition to process temperatures. The waste water produced by the system is the cooling water that currently flows to the drain from the two cooling units. The can size and the can processing rate establish the product mass flow. Therefore, neglecting heat losses, the following heat balances can be written to estimate the cooling water flow rates.

Pressure Cooler

$$W_p C_p (240 - 210) = W_c C_c (199 - 65)$$

$$\begin{aligned} W_p C_p &= 410 \left(\frac{\text{cans}}{\text{min}} \right) \times \left[\frac{2}{16} \left(\frac{\text{lbs. Metal}}{\text{can}} \right) \times 0.11 \left(\frac{\text{Btu}}{\text{lb F}} \right) \right. \\ &\quad \left. + \frac{9.8}{16} \left(\frac{\text{lbs. Product}}{\text{can}} \right) \times 1.0 \left(\frac{\text{Btu}}{\text{lb F}} \right) \right] \\ &= 410 (0.014 + 0.613) \\ &= 256.8 \frac{\text{Btu}}{\text{min-F}} \end{aligned}$$

$$Wc_1 = \frac{256.8 (240 - 210)}{1.0 (200 - 65)} = 57.1 \text{ lb./min.}$$

$$Wc_1 = 7.2 \text{ gpm @ } 200^\circ\text{F exit temperature}$$

Atmospheric Cooler

$$W_p C_p (210 - 100) = Wc_2 C_c (132 - 65)$$

$$Wc_2 = \frac{256.8 (210 - 100)}{1.0 (132 - 65)} = 421.6 \text{ lb./min.}$$

$$Wc_2 = 51.4 \text{ gpm @ } 132^\circ\text{F exit temperature}$$

The two streams currently merge as they approach the drain system and average values of waste water temperature and flow rate for each system are 140°F and 59 gpm, respectively. Four cooker/cooler systems are installed in the Power Building; for purposes of this study, two were assumed to operate during first shift and only one during second shift.

Waste Water Summary — Continuous Cooker/Cooler Systems

1st Shift - 117.2 gpm @ 140°F 2nd Shift - 58.6 gpm @ 140°F

6.1.2 Can Washers

Eight can lines are installed in the Power Building. For the waste water study, three lines were assumed to operate during first shift and one line during second shift. Each line was assumed to have one pre-fill washer unit (3.3 gpm per unit) and two post-fill units (4.5 gpm per unit) and the assumed wash water temperature at the floor drain was 175°F. The washer unit flow data were obtained by time and weight measurements performed on the No. 43 line in the Meat Products Building and are assumed to apply to can lines throughout the factory. Wash water drain temperatures were measured on several lines and 175°F is a fairly typical value.

Waste Water Production Summary — Can Washers

1st Shift - $3 \times (3.3 + 2 \times 4.5) \approx 37$ gpm @ 175°F

2nd Shift - $1 \times (3.3 + 2 \times 4.5) \approx 12$ gpm @ 175°F

6.1.3 Horizontal Stationary Retorts for Canned Product Sterilization

Retorts at the Pittsburgh Factory are not instrumented for cooling water flow rate and drain temperatures. To permit an evaluation of retort waste water conditions for both glass and can operation, Heinz U.S.A. equipped a Meat Products Building retort with an integrating flow meter on the cooling water line and with thermocouples on the retort drain lines — see Figure 5. Data were collected during can and glass operations and are assumed to represent the performance of other retorts in Meat Products and in the Bean and Power Buildings as well.*

Due mainly to congestion beneath the retort in the drain line area, the individual drains were not equipped with flow meters. Consequently, the drain flow split could not be measured directly but it was estimated realizing the retort water volume at the beginning of a cooldown cycle is zero. Then, using the retort sight glass and by accounting for the product volume, the average rate of water accumulation in the retort prior to overflow was determined during a typical cooldown. The difference between that average rate and the measured cooling water input was assumed to be the bottom drain flow rate. Once overflow occurred, the bottom drain flow was assumed to remain fixed at that value and the overflow rate could then be estimated during the remainder of the cooldown period. The results of these calculations using data from a typical can retort cooldown are presented in Figure 12.

---

*Glass products are retorted only in the Meat Products Building.

Figure 12. Horizontal Stationary Retort Cooldown Data — Can Operation

To obtain average flow rate and temperature values for the entire bank of Power Building retorts, it was assumed that of the fifteen retorts available, ten were in operation over the two shift period of each working day and that each retort cycled three times per shift. These assumptions and the data of Figure 12 lead to the following estimates of average waste water conditions:

Waste Water Production Summary — Horizontal Retorts (Cans)

1st and 2nd Shifts - 230 gpm @ 95°F

6.1.4 Boiler Blowdown

The boilers are blown down continuously to maintain the required water chemistry specifications. Boiler effluent flows to a flash tank at an average rate of approximately 15 gpm. Vapor produced at the flash tank is directed to the deaerator and the residual water (saturated at 212°F) is sent to the drain system at a rate of 10 - 12 gpm.

Waste Water Production Summary — Boiler Blowdown

1st and 2nd Shifts - 12 gpm @ 212°F

6.2 MEAT PRODUCTS BUILDING

6.2.1 Horizontal Stationary Retorts for Glass Product Sterilization

Waste water flow rate and temperature measurements were also taken from the instrumented retort during the processing of glass-packaged products. Typical data are plotted in Figure 13. Measurements were made on several different occasions and the temperature data show little variation from run to run while the cooling water flow rates range between 65 and 85 gpm. The flow variations are the result of the manual operating method and indicate the effect of the retort operator. To estimate average waste water conditions, the following retort operating data were applied:

Figure 13. Horizontal Stationary Retort Cooldown Data — Glass Operation

Retorts available for glass product sterilization	- 18
Retorts in operation	- 8
Cycles per retort per shift	- 2.5
Cool-down period (minutes)	- 60
Water volume to be dumped after each cooldown	- 1900 gal.

Then, on an average basis, the waste water flow and temperature conditions for the retorts during glass operation are as follows:

Waste Water Production Summary — Horizontal Retorts (Glass)

1st and 2nd Shifts - 316 gpm @ 140°F

6.2.2 Horizontal Stationary Retorts for Canned Product Sterilization

The Meat Products Building is equipped with a total of twenty-one horizontal stationary retorts. For this project, eight of those retorts were assumed to process glass products (see above) and of the remaining thirteen retorts, ten were applied to canned products. Thus, the number of operating can retorts is equal to that assumed earlier for the Power Building and with equal cycle frequencies, the total can retort waste water conditions for the Power and Meat Products Buildings are also equal.

Waste Water Production Summary — Horizontal Retorts (Cans)

1st and 2nd Shifts - 230 gpm at 95°F

6.2.3 Can Washers

Can line waste water estimates for the Meat Products Building assumed that only two of the five installed lines operate during first shift and that a single line operates during the second shift. Each line was assumed to be equipped with a pre-fill washer unit (3.3 gpm per unit) and with two post-fill units (4.5 gpm per unit). The wash water drain temperature is 175°F.

Waste Water Production Summary — Can Washers

1st Shift - $2 \times (3.3 + 2 \times 4.5) \approx 25 \text{ gpm @ } 175^\circ\text{F}$
2nd Shift - $1 \times (3.3 + 2 \times 4.5) \approx 12 \text{ gpm @ } 175^\circ\text{F}$

6.2.4 Bottle Washers

Four baby food lines are installed in the Meat Products Building. Three lines can operate simultaneously if 18 glass retorts and the STORK hydrostatic sterilizer are in production. Normally, 8 retorts and the STORK are available for glass product sterilization and, therefore, two baby food lines are usually in operation. On each line, the bottles are washed just prior to filling and measured values of wash water flow rate and drain temperature on one line were 3.6 gpm and 175°F, respectively, and they are assumed to represent waste water conditions on other baby food lines as well.

Waste Water Production Summary — Bottle Washers

1st and 2nd Shifts - 7.2 gpm @ 175°F

6.2.5 Continuous Pasteurizer

In the pasteurizing system, the product passes through two hot water spray sections. The spray inlet temperature and flow rate are 195°F and 60 gpm in

the first section and 150°F and 20 gpm in the second section. The flow rates are based upon Heinz U.S.A. calculations and the temperatures are measured values. After being in contact with the product, the hot water streams merge and flow to a floor drain. The assumed temperatures of the two streams as they approach the drain are 180°F (at 60 gpm) and 135°F (at 20 gpm), and the mixture temperature is 169°F.

Waste Water Production Summary — Meat Products Building Pasteurizer

1st and 2nd Shifts - 80 gpm @ 169°F

6.2.6 Berlin-Chapman Rotary Retorts

Products packaged in large No. 70 cans (46 oz.) are batch-sterilized in rotary retorts. During the process (240 - 250°F for 45-60 minutes) and during part of the subsequent cooldown period, the cans are turned end-over-end to produce a mixing action which assures uniform heating and cooling of the product. Heat for the sterilization process is provided by steam which surrounds the cans. At the end of the process, the retort is filled with cooling water (65°F inlet temperature) to the overflow level. Upon reaching that level, waste water flows from the retort to the drain system at approximately 10 gpm* and it continues flowing to the end of the cooldown period which requires a total of 30 to 40 minutes. Waste water and product temperature predictions for an individual retort during a cooldown period are presented in Figure 14.

The average flow rate and temperature of the waste water stream produced by the entire bank of Berlin-Chapman retorts were obtained by combining the individual unit data with the following retort operating assumptions:

---

*Based upon Heinz U.S.A. data.

Figure 14. Berlin-Chapman Rotary Retort Cooldown Predictions

Retorts available	- 15
Retorts in operation	- 10
Cycles per retort per shift	- 1.5
Cooldown period (minutes)	- 30

Assuming further that waste water at temperatures less than 100°F would not be used by the waste heat recovery system, the average waste water conditions for the retort bank are as given below.

Waste Water Production Summary — Berlin-Chapman Rotary Retorts

1st and 2nd Shifts - 10 gpm @ 136°F

6.3 BEAN BUILDING

6.3.1 Horizontal Stationary Retorts for Canned Product Sterilization

Fifteen horizontal retorts are located in the Bean Building for canned product sterilization. For this evaluation, ten retorts were assumed to be operating with the same frequency and cycle times that were assigned to the ten operating retorts in the Power Building. Therefore, the total waste water flow rates and temperatures will also be equal.

Waste Water Production Summary — Horizontal Retorts (Cans)

1st and 2nd Shifts - 230 gpm @ 95°F

6.3.2 Can Washers

Five can lines are installed in the Bean Building. Assumptions concerning the number of lines in operation, the number of washer units per line, washer unit flow rates and drain temperatures are identical to those described above for the Meat Products Building can lines.

Waste Water Production Summary — Can Washers

1st Shift $\approx$ 25 gpm @ 175°F

2nd Shift $\approx$ 12 gpm @ 175°F

6.3.3 Continuous Coolers

Three units for cooling canned soup products are installed in the Bean Building. For the waste water calculations reported herein, two coolers were assumed to be in operation during the first shift and one during second shift. In each system, the product flows through the cooler continuously and is cooled to an exit temperature in the 95 - 100°F range. Product and cooling water temperature measurements were performed on the line No. 6 unit that processes No. 43 cans and the results of the measurements are presented in Figure 7.

Upon leaving the cooler, the waste water flows to the drain system. The water flow rate was not measured but was estimated using a heat balance and known values of the product flow rate and cooler terminal temperatures. Then, if heat losses are neglected,

$$W_p C_p (200 - 97) = W_c C_c (122 - 65)$$

$$\begin{aligned} W_p C_p &= 400 \left(\frac{\text{can}}{\text{min.}} \right) \times \frac{2}{16} \left(\frac{\text{lbs. metal}}{\text{can}} \right) \times 0.11 \left(\frac{\text{Btu}}{\text{lb F}} \right) \\ &\quad + \frac{9.8}{16} \left(\frac{\text{lbs. product}}{\text{can}} \right) \times 1.0 \left(\frac{\text{Btu}}{\text{lb F}} \right) \\ &= 250.9 \frac{\text{Btu}}{\text{min. F}} \end{aligned}$$

$$W_c = \frac{250.5 (200 - 97)}{(1.0)(122 - 65)} = 452.7 \text{ lb./min.}$$

$$W_c = 54.9 \text{ gpm.}$$

This flow rate and the temperature data presented in Figure 7 are assumed to be typical of those for each of the three continuous coolers. Therefore, the total waste water production rate for two operating coolers would be approximately 110 gpm.

Waste Water Production Summary — Continuous Coolers

1st Shift - 2 x 54.9 ≈ 110 gpm @ 122°F

2nd Shift - 55 gpm @ 122°F

6.4 VINEGAR BUILDING

6.4.1 Heinz Rotary Retorts

Each Heinz-design rotary retort is functionally similar* to the Berlin-Chapman units but is larger in size and has a higher product capacity. Waste water and product temperature predictions are presented in Figure 15 for an individual Heinz retort during the cooldown period.

The Heinz retort temperatures of Figure 15 (and those presented earlier for the Berlin-Chapman units) were selected after analysis parameters such as the product heat transfer coefficient and area had been varied to determine their effect upon the predicted product temperature. It was understood that the actual product

---

*The main operational difference between the Heinz and Berlin-Chapman retorts occurs during the cooldown period. During that time, the water level in a Heinz retort is maintained in the lower half of the vessel and product rotation continues throughout the cooldown. In a Berlin-Chapman unit, the water level is high in the vessel and product rotation is discontinued after the high water level is achieved.

Figure 15. Heinz Rotary Retort Cooledown Predictions

temperature at the end of a 30 to 40 minute cooldown period is required to be in the vicinity of 100°F. Waste water temperature predictions associated with reasonable values of the heat transfer coefficient and area and with product temperature predictions which met that criterion were accepted as being the best estimates and were plotted in Figure 15.

Temperature and flow rate predictions for the total waste water stream from the Heinz retorts were based upon the following retort operating assumptions:

Retorts available	- 5
Retorts in operation	- 4
Cycles per retort per shift	- 3
Cooldown period	- 30 min

As in the Berlin-Chapman analysis, a cut-off temperature of 100°F was assumed resulting in the following average waste water conditions.

Waste Water Production Summary — Heinz Rotary Retorts

1st and 2nd Shifts - 29 gpm @ 128°F

The analytical waste water estimates were assumed adequate for the Berlin-Chapman and Heinz rotaries and instrument installation was not required since the waste water produced by those systems was suspected to be of low volume and therefore of relatively little value to the heat recovery system.

6.5 WASTE WATER SUMMARY

The results of the waste water survey for the Pittsburgh Factory are summarized in Table 9. The table entries apply to those systems selected for waste heat recovery. Systems not represented in Table 9 were neglected due to low temperature and/or low volume reasons and to high fouling potential in the case of the blowdown heat source.

TABLE 9
WASTE WATER SUMMARY — PITTSBURGH FACTORY

	<u>Average Flow Rate & Temperature</u>	
	<u>First Shift</u>	<u>Second Shift</u>
<u>Power Building</u>		
Continuous Cooker/Coolers	120 gpm - 140°F	60 gpm - 140°F
Can Washers	37 gpm - 175°F	12 gpm - 175°F
<u>Meat Products Building</u>		
Horizontal Stationary Retorts (Glass Products)	316 gpm - 140°F	316 gpm - 140°F
Can Washers	25 gpm - 175°F	12 gpm - 175°F
Bottle Washers	7 gpm - 175°F	7 gpm - 175°F
Continuous Pasteurizer	80 gpm - 170°F	80 gpm - 170°F
<u>Bean Building</u>		
Can Washers	25 gpm - 175°F	12 gpm - 175°F
Continuous Coolers	110 gpm - 120°F	55 gpm - 120°F
<u>Total Flow Rate & Average Temperature</u>	720 gpm - 145°F	554 gpm - 145°F

7.0 WASTE HEAT RECOVERY SYSTEM DESIGN — PITTSBURGH FACTORY

A system to recover waste heat at the Pittsburgh Factory is shown schematically in Figure 16. Waste water streams will be collected in the various factory buildings and segregated according to temperature — those at 140°F or greater are classified as "high temperature" and those below 140°F as "low temperature."

7.1 HIGH TEMPERATURE COLLECTION SYSTEM

As indicated in Figure 16, the high temperature streams to be used by the recovery system originate in the Meat Products and Power Buildings.* In Meat Products, constant temperature waste water from the pasteurizer and can washers will be piped directly to the high temperature drain. The drains from the batch process retorts (glass), however, will require a three-way valve arrangement to separate the high and low temperature streams. Figure 17 presents additional detail concerning the Meat Products collection and stream separation system and Figure 18 shows the same system in isometric view. In Figure 19, a three-way valve is shown which would be installed at three locations in the retort drain system. Each valve system will consist of two butterfly valves mounted on a flanged tee and operated by a single air cylinder. The action of the air cylinder will cause one valve to close as the other opens. A temperature probe located upstream of the tee will sense the transient retort waste water temperature and signal the valve positioner.

Referring to Figures 16 and 17, hot waste water collected on the 5th and 6th floors of the Meat Products Building will drain by gravity to a high temperature sump (HTS) located on the 4th floor. A water level sensor in the sump will operate a transfer pump to deliver waste water to the high temperature accumulator (HTA) on the third floor of the Power Building. The high temperature waste water sources in the Power Building are located on the 4th, 5th and 6th floors and will drain by gravity directly to the HTA.

---

*The Bean Building can washers are also high temperature sources. However, it has been considered impractical to include water from those units in the high temperature system with the HTS located in Meat Products.

Figure 16. Waste Heat Recovery System - Pittsburgh Factory

Figure 17. Waste Water Collection System — Meat Products Building

Figure 18. Waste Water Collection System — Meat Products Building, 4th Floor

Figure 19. Three-Way Valve for Horizontal Retort (Glass) Drains

7.2 LOW TEMPERATURE COLLECTION SYSTEM

The low temperature (<140°F) waste water accumulator (LTA) will be located in a presently unused room on the first floor of the Bean Building. Waste water will drain by gravity to the LTA from the three-way retort drain valves in the Meat Products Building and from the coolers and can washers on the floors above in the Bean Building. The low temperature accumulator is shown schematically in Figure 20 and isometrically in Figure 21. From the LTA, waste water will be pumped to the low temperature heat exchangers (LTHX) located on the first floor of the Power Building. There it will preheat boiler makeup water and process water for the Power Building.

7.3 HEAT EXCHANGER SYSTEMS

A schematic of the LTHX system is shown in Figure 22. One heat exchanger will be positioned between the city water softener and the hot well (see Figure 8) to heat make-up water while the second unit will preheat well water on its way to the Power Building hot water heater. Note that the flow of fresh water to the heat exchangers will not be controlled and the temporary absence of hot waste water will not affect the fresh water flow rate, only its temperature. Also note that the LTHX units will be equipped with bypass lines to be used whenever the heat exchangers require maintenance.

Figure 23 presents additional detail concerning the high temperature segment of the waste heat recovery system. Hot waste water from the HTA will flow to two high temperature heat exchangers (HTHX) arranged in series. At the HTHX, fresh water will be heated as it flows to the process hot water tanks (HWT) or to storage. Presently, well water is heated at the HWT by steam injection and it is pumped on demand to glass retorts in the Meat Products Building. When implementing waste heat recovery, the HWT system will be modified to supply heated water to the pasteurizer, can washers and clean-up stations as well as the retorts.

The high temperature heat exchangers in the lower center of Figure 23 are plate-type units. One heat exchanger could be used in this application, but two were selected due to space limitations in the Power Building and to accommodate future expansion needs. Space for the HTHX and LTHX units is available in the Power Building and Figure 24 presents a view of the area showing a workable equipment arrangement.

Figure 20. Low Temperature Accumulator and Pump(s) — Bean Building

Figure 21. Low Temperature Accumulator (LTA) — Bean Building, 1st Floor

Figure 22. System for Heating Boiler Make-Up & Power Building Food Process Water

Figure 23. Process Hot Water System — Power Building

Figure 24. Equipment Arrangement — Power Building, 1st Floor

7.4 SYSTEM OPERATION AND CONTROL SUMMARY

Referring to Figure 16, the waste water streams will be collected by the HTS, the HTA and the LTA. Each tank will discharge to a level controlled centrifugal pump and will be equipped with overflow connections. Thus, a pump failure or a flow blockage downstream will simply cause an overflow to the drain and will have no effect upon factory operations.

Waste water flow rates will be controlled by temperature-sensing or fresh water flow-sensing control valves at the heat exchanger exits and the final control strategy and system set points will be determined during system control and optimization studies. Low temperature system control would be straightforward and based upon the need to maximize heat recovery while achieving a prescribed minimum investment return rate. The high temperature system design would have the same objective with the added requirement that hot fresh water would be directed to storage only when the continuous food process demands were satisfied.

7.5 HEAT EXCHANGER SELECTION

The low and high temperature heat exchangers will be plate-type units. Plate heat exchangers consist of gasketed metal plates suspended between horizontal carrying bars and pressed together between one stationary and a movable pressure head. Boundary gaskets seal the fluids within the plate assembly and individual port gaskets create alternating channels in which the two fluids flow in a true counterflow pattern. This particular design was selected over shell-and-tube due to its favorable performance in other applications at the Pittsburgh Factory and because it exhibits a relatively high overall heat transfer coefficient (750 - 1000 Btu/hr-ft²-F) and poses a minimum space requirement. Plate units also have a low fouling potential and can be disassembled quickly both of which contribute to low maintenance demands. In addition, the plate design offers size flexibility so that future changes in waste water supply and/or fresh water demand can be easily met by installing new plates on the existing frame or by removing unnecessary ones.

7.6 HEAT EXCHANGER SIZING

Studies have been performed to estimate heat transfer areas for the LTHX and HTHX units. For analysis purposes, the overall heat transfer coefficient for each plate-type heat exchanger was assumed to be 750 Btu/hr-ft²-F and system performance has been evaluated with the primary goal of maximizing heat recovery and heat exchanger effectiveness. Design flow rates and temperatures used in the analysis are identified in Table 10.

For the series-mounted HTHX units, predictions of effectiveness and fresh water exit temperatures are presented in Figure 25 vs. heat transfer area and the sensitivity of those parameters to variations in fresh water flow rate is indicated. From the curves of Figure 25, it appears that the total HTHX heat transfer area should lie in the vicinity of 1600 ft² (800 ft² per heat exchanger). Beyond that value, the energy and dollar savings produced by the heat exchangers begin to flatten while hardware costs continue to rise. Therefore, the selected HTHX heat transfer area for cost and performance analysis was 800 ft² per unit which will yield an effectiveness of 88% and a fresh water outlet temperature of 150°F at 400 gpm. Of that flow rate, 250 gpm will be sent to the HWT and the remaining 150 gpm will be directed to the thermal storage tank.

A similar sizing analysis was performed for the LTHX heat exchangers under first shift conditions. In those calculations, the waste water available at the LTA (335 gpm @ 120°F) was proportioned between the make-up and Power Building applications according to their fresh water flow demands. Figures 26 and 27 indicate that heat transfer areas of approximately 600 and 400 ft² would yield effectiveness values of nearly 90% in the make-up and Power Building cases, respectively, and those areas were applied in the analysis of the system's thermal and economic performance.

7.7 WASTE HEAT RECOVERY SYSTEM PERFORMANCE

Table 11 summarizes the predicted performance of the Pittsburgh Factory waste heat recovery system. The analysis indicates that the daily heat recovery will be 3.23×10^8 Btu corresponding to 7.1×10^{10} Btu on an annual basis.* Applying

---

* Assuming 220 production days per year.

TABLE 10
WASTE HEAT RECOVERY SYSTEM DESIGN CONDITIONS

WASTE WATER

	<u>1st Shift</u>	<u>2nd Shift</u>
HTA	380 gpm @ 166°F	285 gpm @ 170°F
LTA	335 gpm @ 120°F	265 gpm @ 120°F

FRESH WATER¹

		<u>1st Shift</u>	<u>2nd Shift</u>
Food Processes	(HTHX)	250 gpm ²	200 gpm ²
Boiler Make-Up	(LTHX)	250	250
Power Building Water Heater	(LTHX)	180	180
Clean-Up Water	(HTHX)	150	130

¹ Assumed fresh water inlet temperature = 65°F.

² Totals of the fresh water flow rates required by the factory can and bottle washers, the horizontal stationary retorts (glass) and the Meat Products Building pasteurizer. Heated water for those applications would be supplied by the waste heat recovery system via the HWT.

Figure 25. HTHX Performance - 1st Shift

Figure 26. LTHX Performance - 1st Shift

Figure 27. LTHX Performance - 1st Shift

TABLE 11
WASTE HEAT RECOVERY SYSTEM PERFORMANCE — PITTSBURGH FACTORY

<u>Average Accumulator Conditions</u>	<u>1st Shift</u>		<u>2nd Shift</u>	
LTA	335 gpm @ 120°F		265 gpm @ 120°F	
HTA	380 gpm @ 166°F		285 gpm @ 170°F	
<u>LTHX Conditions</u>	<u>Lower Bldg. LTHX</u>		<u>Boiler Make-Up LTHX</u>	
Fresh Water	<u>1st Shift</u>	<u>2nd Shift</u>	<u>1st Shift</u>	<u>2nd Shift</u>
Flow Rate (gpm):	180	180	250	250
Inlet Temperature (°F):	65	65	65	65
Exit Temperature (°F):	104	99	104	99
Waste Water				
Flow Rate (gpm):	140	110	195	155
Inlet Temperature (°F):	120	120	120	120
Exit Temperature (°F):	72	68	71	68
Waste Heat Recovery (Btu/Shift x 10 ⁻⁷)	2.35	2.00	3.34	2.82
				<u>Daily Totals</u>
				10.51 x 10 ⁷ Btu

<u>HTHX Conditions</u>	<u>1st Shift</u>	<u>2nd Shift</u>
Fresh Water		
Flow Rate (gpm):	400	333
Inlet Temperature (°F)	65	65
Exit Temperature (°F)	150	150
Waste Water		
Flow Rate (gpm):	380	285
Inlet Temperature (°F)	166	170
Exit Temperature (°F)	77	71
HMT Flow Rate (gpm):	250	200
Thermal Storage Flow Rate (gpm):	150	130
Storage Accumulation (gal.):	63,000	56,000
Waste Heat Recovery (Btu/Shift x 10 ⁻⁷):	11.90	9.86

<u>SUMMARY</u>
Daily Waste Heat Recovery: 3.23 x 10 ⁸ Btu
Daily Storage Accumulation: 119,000 gal.
Annual Waste Heat Recovery: 7.10 x 10 ¹⁰ Btu

1976 fuel consumption data, the predicted recovery rate would reduce fossil fuel usage at the factory by 7.5% yielding an annual dollar saving of \$217,000 based upon current fuel prices.

7.8 ECONOMICS ANALYSIS

A cost estimate has been prepared for the Pittsburgh Factory system and results are presented in Table 12. The estimate components are based on vendor quotes and upon the extrapolation of equipment and installation costs from previous Westinghouse projects. Heinz U.S.A. experience is also reflected in the estimate primarily in the installation area. The Pittsburgh Factory production floors are congested and interferences will have a significant impact upon installation charges. Thus, Heinz experience with past projects at the factory was especially valuable in estimating those particular costs. It is noted that the installation costs contain a factor of 1.5 to account for weekend and third shift overtime work since hardware installation will be completed largely on an overtime basis to avoid interfering with production activities.

Return on investment (ROI) calculations have been performed for the waste heat recovery system using the Heinz U.S.A. discounted cash flow method. The method assumes depreciation at the rate of 12% per year, an income tax rate of 50% and the calculations applied an investment tax credit of 10%. The initial capital investment includes materials, installation and engineering costs and the annual savings produced by the system are based on current fuel prices with no escalation allowance. The ROI analysis was approached by adopting the point-of-view of a private company faced with the need to design and install an all-new system of the Pittsburgh Factory type. Therefore, the Table 12 costs do not account for equipment that may already exist* at the Pittsburgh Factory nor do they include special costs for diagnostic instrumentation, system performance evaluations, etc. The engineering charge considers the cost to perform a waste heat availability and applications survey and to design the waste heat recovery system. In estimating that cost, it was assumed that the work would be done by an engineering firm having experience with food industry operations and requiring, therefore, a minimum of orientation.

---

*There are several idle tanks at the Pittsburgh Factory which could be used as the HTS, HTA and the thermal storage tank.

TABLE 12
ESTIMATED COSTS
PITTSBURGH FACTORY WASTE HEAT RECOVERY SYSTEM

Item	Material Costs (\$)	Installation Costs (\$)
Tanks	90,000	—
Heat Exchangers	44,400	6,700
Pumps	13,400	6,000
Strainers	10,000	4,000
Valves	15,500	12,800
Piping	27,300 ¹	92,200 ²
Instrumentation & Controls	17,800	19,300
	<u>218,400</u>	<u>141,000</u>
Total Materials and Installation-	359,400	
Engineering (15% M&I)	- 53,900	
Total	- \$413,300	

Notes

¹ Including insulation

² Includes a factor of 2.0 to account for piping interferences

In Figure 28, ROI is plotted as a function of the cost to benefit ratio. For the cost and annual dollar savings estimates reported above (\$413,300 and \$217,000, respectively), the ratio value is 1.9 which corresponds to an annual return of 34%. As a demonstration of ROI sensitivity to variations in the cost to benefit ratio, ROI would increase to 40% with a 19% increase in savings or a 16% decrease in the total system cost.

Figure 28. ROI vs. Cost/Benefit Ratio

8.0 WASTE HEAT AVAILABILITY — LAKE CITY FACTORY

At Lake City, the refrigeration system condensers represent the waste heat source of most interest during this project. For conceptual design purposes, average refrigerant flow rates and waste heat production rates were estimated using Heinz U.S.A. data concerning the annual electrical load produced by all equipment (process and non-process) installed on the site. Those data were based upon nameplate ratings and estimates of annual operating time. The refrigeration system compressors are responsible for a large fraction of the total factory electrical load. In the absence of direct compressor electrical measurements, an estimate of that fraction was applied to the metered factory load to obtain a prediction of the annual electrical demand actually due to the compressors. That information, when combined with assumed state points, leads to estimates of average refrigerant flow rates and waste heat dissipation rates at the condensers. The development of values for those parameters is discussed below.

Nameplate data and annual operating time estimates yield an annual electrical demand rating for the entire factory of 6.73×10^6 kWh. Of that total, the refrigeration system compressors are responsible for 4.26×10^6 kWh or 63%. Over a recent one year period, the actual electrical consumption by the entire factory was 3.708×10^6 kWh. For conceptual design work, it was assumed that the compressors were responsible for 63% of that amount or approximately 2.35×10^6 kWh. It was further assumed that the actual energy consumption by an individual compressor is proportional to its horsepower rating, HP, and availability time, T_{av} , and could be expressed as

$$C (HP) T_{av}.$$

Here, C is a constant involving actual running time, full load percentage, and unit conversion factors. Assuming the C value is fixed for all compressors, the total compressor electrical load can then be written as,

$$C[(HP)_1(T_{av})_1 + (HP)_2(T_{av})_2 + \cdots + (HP)_{13}(T_{av})_{13}] = 2.35 \times 10^6 \text{ kWh}$$

Compressor horsepower ratings and availability times were presented earlier in Table 7 and their substitution in the foregoing equation leads to a value for C of 0.407. That value can then be applied to estimate the annual electrical demand by the individual compressors and the results of that calculation are presented in Table 13. The average energy consumption rate, Q_{ce} , for each unit is also tabulated and is equal to $C(HP)$. Neglecting piping heat losses, the waste heat dissipation rate at the condensers has two components — one that is equal to the rate at which the compressors deliver energy to the refrigerant and a second which represents the refrigeration effect. The first component, identified by Q_c , is easily obtained from Q_{ce} by accounting for the compressor's mechanical efficiency, η_{mech} . Thus,

$$Q_c = \eta_{mech} Q_{ce}$$

The refrigeration effect, Q_R , is related to Q_c by the system coefficient of performance, COP, which can be expressed as a ratio of refrigerant enthalpy differences. Thus,

$$COP = \frac{h_2 - h_1}{h_3 - h_2}$$

and

$$Q_R = Q_c \left(\frac{h_2 - h_1}{h_3 - h_2} \right)$$

where h_1 , h_2 and h_3 are enthalpies at the evaporator inlet, exit and compressor exit, respectively. Then, the total heat dissipation rate at the condensers is given by

$$Q_T = Q_c + Q_R$$

TABLE 13

ELECTRICAL LOAD AND WASTE HEAT ESTIMATES

COMPRESSOR NO.	ANNUAL kWh $C(HP)(T_{av}) \times 10^{-5}$	AVERAGE USAGE RATE, Q_c (kW) (Btu/hr $\times 10^{-5}$) ^e	REFRIGERANT FLOW RATE, W (lbm/hr)	WASTE HEAT PRODUCTION Q_T (Btu/hr $\times 10^{-5}$) Annual (Btu $\times 10^{10}$)		
1	1.77	20.3	0.693	620.0	3.534	0.309
2	1.77	30.5	1.041	931.4	5.309	0.309
5	1.22	16.2	0.553	553.0	3.152	0.236
6	5.57	81.2	2.771	—	—	—
7	1.33	30.5	1.041	—	—	—
8	0.76	24.4	0.833	668.0	3.808	0.119
9	4.18	60.9	2.078	3888.3 ¹	22.163	1.521
10	1.52	20.3	0.693	1390.5 ²	7.926	0.593
12	2.66	30.5	1.041	—	—	—
13	2.66	30.5	1.041	1862.8 ³	10.618	0.923
TOTALS	2.34 $\times 10^6$					4.015 $\times 10^{10}$ Btu

NOTES:

1. Based on Q_{ce} total for Compressors 6 and 9
2. Based on Q_{ce} total for Compressors 7 and 10
3. Based on Q_{ce} total for Compressors 12 and 13

or by

$$Q_T = \eta_{\text{mech}} Q_{ce} \left[1 + \frac{h_2 - h_1}{h_3 - h_2} \right]$$

and the annual waste heat production by the product of Q_T and T_{av} . The refrigerant flow rate can also be expressed in terms of the compressor electrical input and is written as follows:

$$W = \frac{\eta_{\text{mech}} Q_{ce}}{h_3 - h_2}$$

In the case of the staged compressors, Q_{ce} represents the sum of the electrical inputs to the two stages and it is noted that enthalpy values used in the calculations were based upon the following state point assumptions:

- Condenser refrigerant pressure: 150 psia
- The refrigerant is saturated liquid at the condenser exit and saturated vapor at the evaporator exit
- Evaporator refrigerant temperatures
  - Blast freezer : -50°F
  - Storage freezer: -20°F
  - Ice Bank : 10°F
- Compressor discharge conditions
  - Pressure 150 psia
  - Temperature: 185°F

Therefore,

$$\begin{aligned} h_1 &= 130 \text{ Btu/lb} \\ h_2 &= 594 \text{ Btu/lb (blast freezer)} \\ &= 605 \text{ Btu/lb (storage freezer)} \\ &= 615 \text{ Btu/lb (ice bank)} \\ h_3 &= 700 \text{ Btu/lb} \end{aligned}$$

Estimates of waste heat production rate and refrigerant flow rate for each compressor are presented in Table 13. The estimates were obtained by applying the foregoing equations and refrigerant conditions and an assumed mechanical efficiency for the compressors of 0.85. As shown in Table 13, the estimated annual waste heat production by the refrigeration system is 4×10^{10} Btu.

9.0 WASTE HEAT RECOVERY SYSTEM DESIGN — LAKE CITY FACTORY

The Lake City Factory has two energy demands, as noted in Section 5.2, that could be supplied by waste heat from the factory refrigeration system — clean-up water heating and floor air heating. In this section, systems to meet those demands are described in detail. Other potential applications of waste heat exist at the factory such as preheating oven air, space heating and supplying the floor air heating load with oven exhaust. These, however, were not evaluated in this work and would possibly be worthwhile topics for other projects. The water and air heating applications were chosen for study since waste heat recovery in those cases can be accomplished easily by conventional heat exchange and mainly because they are common in the frozen food industry. An additional favorable factor that contributed to their selection is that the waste heat source and application points can be located fairly close together to minimize piping expenses and heat losses.

The factory refrigeration system, as noted earlier, is arranged in two parts on the discharge side of the compressors. Compressors 1, 2 and 5 - 10 (Group 1) send vapor to six manifolded condensers while Compressors 12 and 13 (Group 2) discharge to their own condenser and do not interact with the Group 1 units. Therefore, the system condensers can be viewed as comprising two independent waste heat sources and the next step in the recovery system design process was to link each source with one of the two applications. The present floor air heating system draws outdoor air at 7000 scfm and distributes it beneath the freezer floors to warm the earth and to prevent its freezing. The system senses air temperature at the exit of the gas-fired heater and regulates the flow of natural gas to the burners to maintain that temperature at 70°F. Using an air inlet temperature of 20°F*, the maximum thermal energy input rate to the system is 0.378×10^6 Btu/hr and based upon the refrigerant flow and state point data of Section 8.0, ammonia vapor from Compressors 12 and 13 currently loses heat at the rate of 1.06×10^6 Btu/hr during the desuperheating and condensing process. Therefore, that waste

---

* During periods when the outdoor air temperature is less than 70°F, National Weather Service data for the Cleveland, O. area indicate that temperatures below 20°F occur less than 6% of the time.

energy supply would certainly satisfy the air heating load and, in addition, the refrigerant temperatures are sufficiently high to accomplish the energy transfer by conventional heat exchange. The compressor discharge temperature is normally in the 175 - 200°F range and ammonia vapor condensation occurs at 80°F (at 150 psia) while the maximum desired air temperature is only 70°F. Therefore, from the energy availability and temperature points of view, refrigerant from Compressors 12 and 13 qualifies as the energy source for the air heating system and it also qualifies from the timing viewpoint. Since the compressors serve a storage freezer, they are on-line continuously and waste heat is therefore available at all times.

Of the remaining compressors (Nos. 1, 2 and 5 - 10) the five blast freezer units consume most of the total compressor electrical load and they convey refrigerant containing major quantities of waste heat. Generally, the blast freezer begins operation at approximately 5 am and it continues to operate for 12 hours on single-shift production days and for nearly 20 hours per day during double-shift operation. Obviously, utilizing waste heat from that system in the production of hot clean-up water will require thermal storage since most of the daily clean-up water demand occurs after the production period when the blast freezer is down. As reported earlier, Heinz U.S.A. estimates that factory operations require 8,000 gallons of 150°F water per day for single-shift clean-up and 10,000 gallons for double-shift. To produce those volumes of hot water over freezer operating periods of 12 and 20 hours would require energy input rates of 0.472×10^6 and 0.354×10^6 Btu/hr, respectively. At the condensers that serve the Group 2 compressors, the average heat dissipation rate is 4.21×10^6 Btu/hr and if the waste heat recovery system reclaimed only the vapor superheat, the energy availability rate would be 0.517×10^6 Btu/hr. Thus, the energy supply is adequate. Reclaiming only superheat in this application is desired since it will simplify heat exchanger design by not requiring condensate provisions and it is actually required since only in the superheat do temperatures exist that are capable of producing high temperature clean-up water. After extracting the refrigerant superheat, its latent heat is still available but only at low temperatures in the vicinity of 80°F. Thus, for water heating by conventional heat exchange, the best system approach appears to be one that combines high refrigerant flow rates with a heat

exchanger design that focuses only upon superheat extraction. In summary then, two independent waste heat recovery systems have been considered for the Lake City Factory and those systems are described below in detail. One system would employ refrigerant superheat energy and a fraction of its latent heat in a low temperature air heating application. In the second system, only the vapor superheat energy will be recovered and it will then be applied to heating relatively high temperature clean-up water.

9.1 WATER HEATING SYSTEM

A system to heat clean-up water using waste heat from the refrigeration system is depicted schematically in Figure 29. The system will be located in the existing water distribution system (see Figure 11) at a point between the softener exit and the first clean-up station take-off. The thermal storage tank and its circulation loop would be solid at water main pressure with a storage capacity of approximately 6,000 gallons and would be sufficient to supply the factory's daily clean-up water needs. System control will center on the storage tank temperature and the refrigerant temperature at the heat exchanger exit. For tank temperatures less than a set point value (say 150°F), the centrifugal circulation pump will energize provided the refrigerant temperature is greater than a set point value representing the saturation temperature. With that condition satisfied, the temperature sensing flow control control valve would be open and water could circulate from storage to the heat exchanger and back to storage. The water would enter the thermal storage tank via a low velocity distribution ring near the tank top and horizontal baffling arranged along the height of the tank would promote stratification. The circulating pump would take its suction from the low temperature zone at the bottom of the tank and water to be delivered to the mixing stations would be withdrawn at the top. If the temperature-sensing flow control valve is full closed, the result of zero refrigerant flow, the pump will de-energize automatically or its starting will be prevented by the full-closed signal regardless of the tank temperature. Circulation with no heat addition would only mix the storage tank thereby reducing the water temperature in the upper section.

Figure 29. Waste Heat Recovery System for Water Heating – Lake City Factory

System performance and component sizing calculations have been performed assuming the following refrigerant and water conditions at the heat exchanger:

Refrigerant

Heat exchanger inlet temperature	185°F
Exit temperature	90°F
Flow Rate	7390 lb/hr*
Pressure	150 psia

Water

Heat exchanger inlet temperature	65°F
Flow rate	11 gpm

With perfect stratification in the storage tank, 150°F water could be produced at the rate of 11 gpm using a shell-and-finned tube heat exchanger. Based upon one vendor proposal, the heat exchanger would actually be composed of two units arranged in series with water flowing on the tube side and refrigerant vapor on the multi-pass shell side. Each unit would have a shell OD of 10 in., an overall length of 15 feet and a weight of approximately 1400 lbs.

The heat exchangers would be intended to operate as desuperheaters and under normal conditions, vapor will exit the units with 5 - 10°F of superheat still remaining. Net condensation could occur during off-design operation and to cover that situation, the heat exchangers will be mounted on the factory roof above the existing condensers to provide gravity drainage. Upon exiting the desuperheating heat exchangers, the refrigerant will flow to the existing condensers to complete the heat rejection process.

Figures 30 and 31 present clean-up water production and usage models for single-shift and double-shift operation. Referring to Figure 30, hot clean-up water production is assumed to begin at 5 am, coinciding with blast freezer startup, and continues throughout the freezer operating period at the rate of 11 gpm. That rate is sufficient to produce 2000 gallons of heated clean-up water for use during the production period and approximately 6000 gallons for the main clean-up

---

* Excluding Compressor No. 8 which operates only during the summer months.

Figure 30. Clean-Up Water Production and Usage Model — Single-Shift Operation

Figure 31. Clean-Up Water Production and Usage Model — Double-Shift Operation

effort that begins when production ends. On double-shift days, the 11 gpm circulation flowrate can meet the production period needs and, in addition, completely charge the 6000 gallon storage tank by 6 pm. Between 6 pm and midnight, the circulation pump would energize periodically to re-charge the tank as hot water is drawn from it for use in production areas.

Since the storage tank will operate at water main pressure, it will be built to ASME code specifications and would be fully insulated. The tank material will be carbon steel and its most suitable location will be outside the factory adjacent to the boiler room wall — see Figure 10; the circulating pump and the flow control valve will be installed within the boiler room.

Assuming 110 single-shift and 110 double-shift days per year, the annual energy saving to be achieved by heating clean-up water with waste heat totals to 1.4×10^9 Btu. At the present time, that energy is supplied by natural gas and the resulting annual fuel saving (assuming a 75% conversion efficiency) would be 1870 MCF corresponding to a dollar saving of \$3,870 at current fuel prices (\$2.07 per MCF). Therefore, installing a system to heat all clean-up water with waste heat would reduce the factory's natural gas consumption by 13% and its total energy demand (gas and electricity) by 7%.

The estimated cost to procure and install a water heating system is developed in Table 14. The material costs are based upon vendor estimates and the installation costs were obtained assuming all work was performed by outside contractors. The piping installation estimate contains a factor of 1.5 since the work will be performed on an overtime basis to avoid interfering with plant production activities. The other installation costs, however, are based on regular time because the components involved will not be located in production areas.

9.2 AIR HEATING SYSTEM

Figure 32 presents a schematic diagram of a waste heat recovery system to heat freezer floor air. As the figure indicates, outdoor air is presently warmed by an existing gas-fired heater and distributed to floor ducts by a fan. The fan operates continuously and air temperature control is achieved by regulating the

TABLE 14
ESTIMATED COSTS
LAKE CITY FACTORY WATER HEATING SYSTEM

Item	Material Costs \$	Installation Costs \$
Thermal Storage Tank (6000 gal)	8300 ¹	3000
Heat Exchangers	3500	1200
Pump	500	500
Water Flow Control Valve	1100	200
Temperature Sensor & Transmitters	3500	400
Piping ^{2,3}	2300 ¹	5000 ¹
	<u>19,200</u>	<u>10,300</u>
Total Materials & Installation	— \$29,500	
Engineering	— 7,400	
Total	— \$36,900	

¹Including insulation

²The clean-up water distribution system is presently uninsulated and supplies cold water to the clean-up stations and also to several sinks located in the production areas. Upon installing the waste heat recovery system, that piping will be insulated for hot water transport and new piping (included in the cost estimate) will be installed where needed to continue cold water service.

³The final system design will include a positive method to prevent outdoor water line freezing. Hardware to achieve that objective was not considered during the conceptual design.

Figure 32. Waste Heat Recovery System for Air Heating Lake City Factory

flow of natural gas to the heater. Waste heat from the factory refrigeration system could be utilized to preheat or completely heat floor air by installing an air-cooled condenser at the heater inlet. Refrigerant vapor from the storage freezer system would be routed through the condenser on its way to the existing evaporative condenser. The system control would cause the incoming air to bypass the new condenser in any proportion to maintain the gas heater inlet temperature at a set-point value. Thus, the fraction of the refrigerant condensing load handled by the new condenser would also be completely variable ranging from zero during warm weather operation to nearly one-fourth under design, cold-weather conditions. It is noted that the function of the recovery system would be to supplement the existing gas-fired system. Thus, any portion of the air heating load not satisfied by waste heat will be supplied automatically by the gas heater which will continue to operate with its own control system and independent of the waste heat recovery system.

As noted above, refrigerant vapor from Compressors 12 and 13 would be employed in the air heating application. For system design purposes, the following refrigerant conditions (based upon the waste heat survey of Section 8.0) and air stream parameter values have been applied:

Refrigerant

Condenser inlet temperature	185°F
Exit temperature	80°F
Flow rate	1860 lb/hr
Pressure	150 psia

Air

Condenser inlet temperature	20°F
Exit temperature	70°F
Flow rate	1000 scfm

For these air conditions, the required heat input rate is 0.378×10^6 Btu/hr. Entering the condenser at 1860 lb/hr and 185°F, the refrigerant vapor could supply energy at that rate via superheat and approximately 25% of its latent heat. Thus, under these design conditions, the refrigerant would exit the condenser as a two-phase mixture and would require additional heat exchange in the already existing evaporative condenser to complete the heat rejection process.

Calculations have been performed and several vendor inquiries were made regarding a condensing unit to serve as an air heater. The vendor responses typically involve units composed of steel* tubing (0.75 - 1.00 in. OD) with steel plate fins spaced at frequencies of 6 to 10 fins per inch. Parallel tubing runs, each with a length of approximately 20 ft, would be coiled between inlet and exit manifolds (see Figure 33) and would take 4 - 6 passes through the air stream. As the figure indicates, the air flow direction would be perpendicular to the tubes and refrigerant flow will occur on the inner tube surfaces. Typically, the vendor proposals involve outer surface heat transfer areas in the 1500 to 2000 ft² range and the tubing could be arranged in a space envelope that would be compatible with the existing air heating system ductwork. The dimensions of the gas heater inlet duct are 3 ft x 3 ft and the condenser envelope proposed by one prospective vendor measured approximately 4 ft x 4 ft x 2 ft. In that proposal, the tube runs parallel the long dimension and the air flow direction would lie parallel to the short dimension.

The installation of an air heating condenser will increase the system air flow resistance. Based upon vendor predictions, the condenser air side pressure drop will be less than 0.40 in. H₂O (at 7000 scfm) which is fairly small compared to the air distribution system pressure drop (1.5 - 2.0 in. H₂O). It may be possible to account for the increased resistance by changing the fan pulley size and/or increasing the fan motor rating from 5.0 to 7.5 hp. The latter alternative increases the system cost by approximately \$500.

An air heating system designed for the air flow rate and temperature conditions identified above would satisfy virtually all of the factory's annual floor air heating load. That load is 1.39×10^9 Btu based upon outdoor air temperature data for Cleveland, Ohio, which are compiled by the National Weather Service. Meeting that energy demand with waste heat will displace natural gas at the yearly rate of 1390 MCF (valued at \$2880) and reduce the factory's natural gas and total energy consumption by 10% and 5%, respectively. These estimates are based upon a conversion efficiency of 100% since combustion products and the air

---

* For compatibility with ammonia

Figure 33. Air Heating Condenser — Lake City Factory

stream mix directly at the heater. Applying that particular value is not completely realistic since thermal losses and system inefficiency are unavoidable. Therefore, the displacement estimates presented above are viewed as being somewhat conservative.

Material and installation costs for the air heating system are identified in Table 15. The costs are based upon vendor quotations and the assumption that all installation work would be performed by outside contractors. It was further assumed that the installation effort would not interfere with the factory production routine and could be performed during normal working hours.

9.3 ECONOMICS ANALYSIS

Return on investment calculations have been performed assuming the air and water systems were installed in separate projects and then as a unit. The calculations applied the Heinz U.S.A. discounted cost flow method using input assumptions described in Section 7.8. As in the Pittsburgh Factory evaluation, the analysis adopted the approach that all engineering (waste heat survey and system design) would be performed by an experienced engineering firm and costs related to special diagnostic instrumentation and data recording systems were neglected.

Treating the air and water heating systems as a unit, the total estimated cost of materials and system installation is \$41,300 (see Table 16). The engineering effort is valued at \$9,100 and the total estimated cost of the waste heat recovery system is \$50,400 with the potential for annual dollar savings of \$6750. From Figure 28, the project ROI would be 7%. Considered individually, the water heating system is less attractive from the ROI standpoint due mainly to thermal storage costs. The total estimated cost of that system is \$36,900 and the annual savings (\$3870) would produce an ROI of only 5%. The total cost of the air heating system is \$17,700 and that investment would return at the rate of 10% per year based upon annual dollar savings of \$2880.

TABLE 15
ESTIMATED COSTS
LAKE CITY FACTORY AIR HEATING SYSTEM

Item	Material Costs \$	Installation Costs \$
Condenser	2,800	1,800
Piping	600*	1,100*
Air Ducting	} 3,000	1,200
Controls		800
Fan Motor	500	—
	<u>6,900</u>	<u>4,900</u>
Total Materials & Installation — \$11,800		
Engineering	— 5,900	
	<u>— \$17,700</u>	

* Includes insulation

TABLE 16
LAKE CITY PROJECT COST SUMMARY

	Air Heating/Water Heating Unit		
		Water Heating	
			Air Heating
Materials	26,100	19,200	6,900
Installation	15,200	10,300	4,900
Engineering	9,100	7,400	5,900
Total Cost (\$)	50,400	36,900	17,700
Annual Savings (\$)	6,750	3,870	2,880
Cost/Benefit Ratio	7.47	9.53	6.15
ROI (%)	7	5	10

10.0 PROJECTED FUEL AND ENERGY SAVINGS IN THE FOOD INDUSTRY

This project has been concerned mainly with a study of waste heat availability at the Heinz Pittsburgh and Lake City Factories and with a technical and economics evaluation of waste heat recovery systems for installation at those factories. While the work has focused on those factories specifically, it is possible to extrapolate project results and to assess the potential for waste heat recovery in large segments of the food industry if recovery systems of the Pittsburgh and Lake City types were employed nationwide on a large-scale basis. This extrapolation or projection of results is the subject of this section of the report. In the discussion, the manufacturing unit labeled the "Canning Industry" is assumed to be composed of the Canned Specialties (SIC 2032) and Canned Fruits and Vegetables (SIC 2033) industrial groups. As noted earlier, the Pittsburgh Factory product line and food processes place the factory clearly within the Canning Industry and waste heat recovery techniques that are feasible at the Pittsburgh Factory should also be feasible at other factories within the industry due to product and process similarities. Similarly, the "Frozen Food Industry," as discussed in this section, is also a combination of several industrial groups — Ice Cream and Frozen Desserts (SIC 2024), Frozen Fruits and Vegetables (SIC 2037) and Frozen Specialties (SIC 2038). The Lake City refrigeration system performs freezing and storage functions that are common to all three of these groups and it is considered, therefore, that the Lake City results could also be used to project the potential for fuel and energy savings in the frozen food industry. The extrapolation method employed is based upon ratios of gross factory and industry data and is simplistic. Data used in this study were annual energy consumption, the number of production people employed and annual water usage. The method is centered, of course, on the assumption that the Heinz survey sites do represent industry averages in terms of waste heat availability per unit energy consumption, per employee, etc. The assumption appears to be valid since, in effect, it involves operating efficiencies which should be fairly uniform from factory to factory within the highly competitive food industry.

A less certain assumption inherent in the extrapolation method is that waste heat is available at the survey sites and throughout the industry at approximately the same temperature levels. This assumption is an important one since the ROI of and the potential for heat recovery by conventional heat exchange are directly related to the difference between the heat exchanger inlet temperatures. Both parameters are proportional to that difference and in the Pittsburgh Factory case, the temperature difference may tend to be somewhat higher than the industry average since a significant fraction (15 - 20%) of the total waste water flow considered during system design comes from the high temperature part of the glass retort cooldown cycle. Relative to other food processing systems, the glass retorts produce waste heat of a fairly high grade. However, while the other food processes occurring at the factory are very typical of the industry, glass retort operation is less common and is probably restricted to the small number of baby food producers and to manufacturers producing limited lines of other glass-packaged products which require sterilization.

The waste heat source temperature assumption also relates to the refrigeration system study. As noted earlier, the Lake City Factory employs an ammonia system which operates with vapor temperatures in the vicinity of 185°F at the compressor discharge. Holding that temperature fixed permits the extension of study results by simple ratioing. However, refrigeration plants do employ a variety of refrigerants which can operate at different temperature levels. Therefore, the true potential for waste heat recovery in the industry is likely to differ somewhat from that indicated by ratioing and further, recovery will be performed more or less economically depending upon the actual refrigerant temperatures.

A more detailed extrapolation of results was not undertaken since the main effort was concerned with waste heat availability, uses and recovery system design and because a study of that type could be handled more efficiently in separate work with the cooperation of industry trade associations. A detailed extrapolation considering uncertainties of the type discussed above would be beneficial. Trade associations should be involved in such efforts since they already possess much of the required information and data which basically concern the variety and number of food processing systems in operation and the

availability of waste heat applications. In addition, the associations have established lines of contact with individual companies and factories which would be needed when gathering industry data.

10.1 CANNING INDUSTRY PROJECTIONS

Table 17 presents a compilation of operating data for the Canning Industry and the Heinz Pittsburgh Factory and it is apparent that the data yield a fairly uniform set of Factory/Industry ratios.

TABLE 17
CANNING INDUSTRY OPERATING DATA

	INDUSTRY	PITTSBURGH ⁴ FACTORY	FACTORY TO INDUSTRY RATIO
Employees	~130,000 ¹	2000	0.015
Annual Water Consumption - gal.	59.0×10^9 ²	1.2×10^9	0.020
Annual Total Energy Consumption - Btu	67.6×10^{12} ³	1.283×10^{12}	0.019

In section 7.7, the annual waste heat recovery potential for the Pittsburgh Factory was estimated at 7.1×10^{10} Btu and this is projected to the industry using the Factory/Industry ratios from Table 17. Completing that operation places the industry potential, on an annual basis, in the 3.6×10^{12} to 4.7×10^{12} Btu range which represents 5 to 7% of industry's current total energy consumption. Using the smaller value for conservatism and an assumed dollar value of \$3.00 per million delivered Btu's, the potential energy and fuel savings in the

¹Based upon extrapolation of data presented in References (c) and (d)

²Reference (d)

³Reference (a)

⁴Supplied by the Heinz U.S.A. Division

industry are valued at $\$11 \times 10^6$ and are equivalent to 1.7×10^5 tons of coal, 4.7×10^6 MCF of natural gas or 7.8×10^5 barrels of oil.

10.2 FROZEN FOOD INDUSTRY PROJECTIONS

A similar compilation of data is presented in Table 18 for the Frozen Food Industry.

TABLE 18
FROZEN FOOD INDUSTRY OPERATING DATA

	INDUSTRY	LAKE CITY ⁴ FACTORY	FACTORY TO INDUSTRY RATIO
Employees	$\sim 100,000^1$	250	0.003
Annual Water Consumption - gal.	$60 \times 10^9^2$	9.4×10^6	0.0002
Annual Total Energy Consumption - Btu	$49.1 \times 10^{12}^3$	2.3×10^{10}	0.0005

Contrary to the Pittsburgh Factory/Industry ratios, the Lake City data are erratic. This is most likely due to the factory's small size and to the fact that it therefore provides a poor industry sampling. The Pittsburgh Factory, however, represented a much larger fraction of its industry and the variety of processes occurring there equates it, in effect, with several factories thereby providing a more suitable basis for industry projections. Due to the large uncertainty in the Lake City data, a single Factory/Industry ratio of 0.001 was selected to provide a very rough estimate of potential industry savings. Using that ratio value and the Lake City recovery potential of 2.8×10^9 Btu per year yields an annual industry potential of 2.8×10^{12} Btu. At \$3.00 per million delivered Btu's,

¹Based upon an extrapolation of data presented in Reference (c)

²Reference (d)

³Reference (a)

⁴Supplied by the Heinz U.S.A. Division

that quantity of energy is valued at $\$8.4 \times 10^6$ and its fuel equivalents are 1.4×10^5 tons of coal, 3.7×10^6 MCF of natural gas or 6.2×10^5 barrels of oil.

10.3 TOTAL FOOD INDUSTRY IMPACT

If systems of the types considered for the Pittsburgh and Lake City Factories were implemented throughout the Canning and Frozen Food Industries, the data presented above indicate the annual waste heat recovery would be in the vicinity of 6.4×10^{12} Btu. This corresponds to nearly 0.7% of the total energy currently consumed annually by the entire Food and Kindred Products Industry - SIC 20.

11.0 CONCLUSIONS & RECOMMENDATIONS

In this project, waste heat availability and uses were assessed at two food processing plants and waste heat recovery system concepts were evaluated. For the H. J. Heinz Pittsburgh Factory, the study indicates a system to extract thermal energy from hot waste water could be applied to heat fresh water in sufficient quantities to reduce the factory's fossil fuel usage by 7 to 8% and the investment required would return at the rate of 34% annually. At the Heinz Lake City Factory, a relatively small facility producing frozen food items, waste heat from the plant's refrigeration system could be applied to heating both fresh water and air. Natural gas usage would be reduced by as much as 23% and the annual ROI for the air and water heating systems considered as a unit would be approximately 7%. Based upon these results and upon other data presented in the text, it is clear that waste heat is available in the food industry (1) at temperatures to enable its recovery by conventional heat exchange and (2) in quantities that could cause the displacement of fossil fuels in significant amounts. Further, there are indications from the study that waste heat recovery in the industry can be performed economically. Realizing that these conclusions are based on conceptual designs and analyses, it is essential that they be verified for maximum impact on the industry. It is recommended, therefore, that a demonstration project be undertaken. Further, it is recommended that the Pittsburgh Factory serve as the demonstration site due primarily to the attractive performance prospects forecasted by the completed studies. The proposed project would consist of detailed design, installation, operation and evaluation phases and its purpose would be to evaluate actual system performance and to determine actual costs and benefits.

The demonstration system and the results obtained would serve as the basis of a project commercialization or industry penetration plan. The purpose of the plan would be to encourage the application of similar heat recovery systems within the industry and it would be implemented through trade journal publications and presentations at industry information exchange meetings, conferences,

etc. For first-hand exposure to the hardware, the plan would also involve seminars or workshops conducted at the demonstration site. Those sessions will represent a key part of the commercialization plan and would be attended by personnel from other firms for the purpose of becoming familiar with system operation and performance. That purpose will be accomplished through direct contact with H. J. Heinz Co. engineers and management who are responsible for the day-to-day operation of the system.

The Lake City and Pittsburgh Factories differ greatly in size, production capacity and energy demand and, as reported above, the ROI predictions for their waste heat recovery system concepts also differ significantly. The ROI difference suggests, of course, that the economics of waste heat recovery improve with increasing size and energy demand and it points to an area in which additional conceptual studies should be performed. Those studies would focus on the relationship between recovery economics and parameters such as energy demand level and waste heat source temperature and through them, it should become evident that new construction and retrofit projects for a specific range of factory sizes and conditions are more feasible and attractive than for others. Studies of this type would be valuable to firms considering the installation of waste heat recovery systems and they should be performed to supplement the project work already completed and reported herein.

12.0 REFERENCES

- a. Energy Saving Techniques for the Food Industry, Noyes Data Corporation, Park Ridge, New Jersey, 1977.
- b. Energy Consumption in Manufacturing, Ballinger Publishing Co., Cambridge, Massachusetts, 1974.
- c. Industrial Energy Study of Selected Food Industries, PB-237 316, Development Planning and Research Associates, Inc., July, 1974.
- d. 1967 Census of Manufactures.

APPENDIX A

CONDITIONS OF HEINZ'S PARTICIPATION

Heinz U.S.A.

February 23, 1977

Division of H. J. Heinz Company

P.O. Box 57
Pittsburgh, Pennsylvania 15230
Telephone: 412 237-5757

Mr. M.T. Johnson
General Manager
Advanced Energy Systems Division
Westinghouse Electric Corporation
P.O. Box 10864
Pittsburgh, PA 15236

Dear Mr. Johnson;

Heinz U.S.A, Facilities Engineering Department, and our Heinz U.S.A. Factory Managements, are interested in a continued participation with your group in your investigations to determine if waste heat recovery with thermal storage of that heat represents a viable energy conservation program.

We would understand that our participation would be a commitment that our personnel would cooperate at no charge with your team on a feasibility study to determine the firm potential and economics of such a heat recovery system.

Upon verification that such a program is feasible, we would provide the plant site, the use of certain existing facilities, and install and operate, maintain and use the demonstration heat recovery system at no charge.

We would expect:

- 1) To reserve the right of review and approval of final design.
- 2) Design would conform to Heinz U.S.A. Engineering Standards as well as standards of good engineering practice and any applicable regulatory authorities.
- 3) All components would be specified to operate within the 85 decibel noise level criteria.
- 4) All personnel assigned to the on-site project would be covered by insurance in accordance with our requirements.
- 5) To provide access at reasonable times and with reasonable frequency for monitoring by ERDA, Westinghouse, or designated contractors for some minimum agreed to period of time.
- 6) To participate with Westinghouse in formulating plans for the demonstration project.

Mr. M.T. Johnson
Page 2
February 23, 1977

- 7) To make utility operating, use and cost data available as is required for use in proper evaluation of the project.
- 8) To reserve the right to review and limit any disclosure or publication of information which Heinz U.S.A. considers to be proprietary information.
- 9) Heinz U.S.A. would not be required to make any new or capital investment but would provide use of certain existing facilities, as required for the project such as:
  - Delivery, unloading and storage facilities.
  - Floor space, utility connections and equipment installation for the demonstration plant site.
  - Clear water pipe line or other waste heat source access.
  - Maintenance equipment and shop facilities.
  - Certain limited instrumentation (monitoring).
  - Use of the recovered heat-thermal storage system.
- 10) Heinz U.S.A. not to be obligated to pay total net costs per MM BTU of recovered energy that are greater than would have been incurred through operation of their existing system. However within this limitation, Heinz will bear the following cost items:
  - A) Steam
  - B) Electricity
  - C) Water
  - D) Operating Supplies
  - E) Maintenance Supplies
  - F) Operating Labor
  - G) Maintenance Labor
  - H) Monitoring labor and appropriate expense assignments and allocations in accordance with Heinz U.S.A. accounting practices.

We appreciate the opportunity to work with your group under these terms and conditions and toward proving the feasibility of a heat recovery - thermal storage system.

Very truly yours,

G.J. TREBILCOX
SENIOR MANAGER,
FACILITIES ENGINEERING

SMW

APPENDIX B

REPORT OF ADDITIONAL CONCEPTUAL DESIGN WORK

APPLICATIONS OF THERMAL ENERGY STORAGE TO
WASTE HEAT RECOVERY IN THE FOOD PROCESSING
INDUSTRY - ADDITIONAL CONCEPTUAL DESIGN WORK

PREPARED BY
WAYNE L. LUNDBERG
OCTOBER, 1978

WESTINGHOUSE ELECTRIC CORPORATION
ADVANCED ENERGY SYSTEMS DIVISION
P. O. BOX 10864
PITTSBURGH, PENNSYLVANIA 15236

TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	1
2.0 DISCUSSION OF RESULTS	5
2.1 Task 1 - Effect of Low and High Temperature Systems on Overall System ROI	5
2.2 Task 1 Conclusion	7
2.3 Task 2 - System Decentralization Study	8
2.3.1 Waste Heat Recovery System Descriptions	8
2.3.2 System Evaluations	11
2.4 Task 2 Conclusion	20
Reference	21
Acknowledgement	21

1.0 INTRODUCTION

A project was recently completed to assess the potential for waste heat recovery in the food processing industry. In particular, applications of thermal storage were sought. The project was not restricted to those applications, however, and attention was also given to satisfying immediate energy needs with recovered waste heat. The primary purpose of the work was the study of waste heat recovery systems and methods that could have a significant impact upon the nation's energy consumption if the food industry applied them on a large-scale basis. The project was funded by the U.S. Department of Energy (under Contract EC-77-C-01-5002) and was conducted by Westinghouse with the cooperation of the H. J. Heinz Company. Heinz arranged access to two of their manufacturing plants (at Pittsburgh and Lake City, Pennsylvania) and permitted Westinghouse personnel to analyze factory and food system operations. At each factory, a waste heat availability study was performed and the resulting data were then applied as the basis for recovery system conceptual design. While sizeable fuel usage reductions were forecast for each survey site, the study did indicate that the Pittsburgh Factory system would perform more economically with the annual return-on-investment (ROI) predicted to lie in the 30 - 40% range.

The reference Pittsburgh Factory heat recovery system concept is discussed in the reference and is shown schematically in Figure 1. In that concept waste water streams at various temperatures are collected from processes occurring in three production buildings. The high temperature streams (i.e., those above 140°F) are collected in the high temperature accumulator (HTA) while all low temperature streams are channeled to a low temperature accumulator (LTA). The LTA and HTA will be insulated and will serve as surge tanks between the waste water source and application points. All of the waste water sources identified in Figure 1 produce continuous waste water streams except the retorts. Retort operation occurs on a batch basis and the temperature of the retort waste stream (emitted during cooldown) varies with time. It is intended, therefore, that the retort drain system will be equipped with temperature-sensing, three-way valves.

Figure 1. Reference Waste Heat Recovery System – Pittsburgh Factory

The valves will direct waste water to the HTA during the high temperature part of the cooldown and to the LTA when the waste water temperature falls below a set-point value. In studies performed to date, the set-point has been 140°F. The purpose in separating the waste water streams by temperature as opposed to mixing them pertains to the storage part of the system. Using high temperature waste water to achieve the highest possible stored water temperature minimizes the storage cost/benefit ratio.

From the HTA, waste water flows on demand to the high temperature heat exchanger (HTHX) located in the Power Building. At the HTHX, heat is transferred to incoming fresh water as it flows to various food processes. When those demands diminish while hot waste water is still available at the HTA, the system will automatically divert the flow of heated fresh water to storage. Water that accumulates in storage during the production period would then be used during third shift for clean-up purposes.

Waste water collected in the LTA will flow to two low temperature heat exchangers (LTHX) also located in the Power Building and mounted in parallel. Waste heat will be applied at that location to preheat fresh water for food processing and for boiler make-up. The parallel heat exchanger arrangement is necessary since the food processing and make-up applications require water from two different sources — on-site wells and the city water main, respectively.

The installed cost of the reference Pittsburgh Factory system, including engineering, is estimated at nearly \$415,000. At current fuel prices, the system would return that investment at the rate of 34% per year and reduce factory energy consumption by 5 to 6%. Since the predicted thermal and economic performance of the reference system is very attractive, the installation of a demonstration system at the Pittsburgh Factory is being considered. The demonstration project would involve design, installation, operation and evaluation phases and its primary purpose would be to permit the analysis of actual system performance and to determine real system costs and benefits. In recent discussions pertaining to a demonstration project, Oak Ridge National Laboratory (ORNL) inquired concerning the possibility of decentralizing the waste heat recovery system (i.e., equipping each building with its own system) and also

concerning the relative contributions of the low and high temperature parts of the system to the overall system ROI. In response to that inquiry, Westinghouse initiated a five-week study that was structured around the following tasks —

Task 1 - Effect of Low and High Temperature Systems on Overall System ROI

This task shall involve the separation of existing cost and benefit data into low and high temperature groups and the calculation of an ROI for each. This analysis is intended to indicate if either the low or high temperature segment of the system is suppressing excessively the overall ROI. As an additional level of refinement, the effect of the least attractive segment on the layout and, consequently, on the cost and ROI of the other segment shall also be considered. This analysis is necessary since it is conceivable that a decision to eliminate the low ROI segment from the system could change the physical location and arrangement of components in the other segment thereby reducing costs and increasing ROI even more. It is intended that the influence of thermal storage on ROI shall be examined and identified separately.

Task 2 - System Decentralization Study

This task involves an assessment of recuperation possibilities and thermal storage applications in individual factory buildings. The work shall focus on the Meat Products, Bean and Power Buildings to permit a direct comparison of cost and benefit results with those from the central system study. Applications for recuperative heat exchangers in each building shall be examined and sizing calculations shall be performed. Surge tanks and thermal storage tanks will be needed and sizing calculations for those items shall also be performed. Finally, system performance shall be assessed and materials and installation charges (for piping, tanks, valves, pumps, heat exchangers, etc.) shall be estimated to allow an ROI evaluation.

Work on this project has been completed and the purpose of this report is to present project results and conclusions.

2.0 DISCUSSION OF RESULTS

2.1 Task 1 - Effect of Low and High Temperature Systems on Overall System ROI

For this task, the reference system was divided into three components -

1. High Temperature (without thermal storage)
2. Low Temperature
3. Thermal Storage

The cost of each component and the component ROI were then determined by applying the unit prices, labor rates and engineering fees that were used to establish the reference system costs reported in the reference. In this work, the high temperature system included the high temperature sump (HTS)*, the high temperature accumulator (HTA), a fraction of the reference system high temperature heat exchanger (HTHX), and all hardware (pumps, valves, piping and controls) for the collection of waste water from the high temperature sources. The heat exchanger fraction was needed to distribute HTHX costs between the high temperature and storage systems and was defined as the HTHX heat transfer rate to the food process energy demands divided by the total HTHX heat transfer rate when the thermal storage feature is included. Similarly, the low temperature system comprised all components in the reference system associated with low temperature heat recovery and the storage segment was that portion involved in heating and storing fresh water and in transporting that water to and from the 100,000 gal. thermal storage tank. In the analysis of the thermal storage system, a fraction of the reference system HTHX costs was included and was equal, of course, to the difference between 1.0 and the fraction used in the high temperature analysis. Results of the Task 1 work are presented in Table 1. In the table, cost and benefit data are compiled for the reference system, for the three system components and for two combinations of those components. The data indicate, as expected, that heat recovery is performed most economically by a high temperature waste water system and least economically via storage. These results are due to the relatively high cost of thermal storage equipment per Btu and they reflect the

---

* See Figure 1

TABLE 1
REFERENCE SYSTEM COMPONENT COSTS¹, BENEFITS AND ROI

Item	Materials & Installation Costs					
	Reference ² System	High Temperature Component (No Thermal Storage)	Low Temperature Component	Thermal Storage Component	High Temperature Component (With Thermal Storage)	High & Low Temperature Components (No Thermal Storage)
Tanks	109,100	3,100	2,600	103,400	106,500	5,700
Heat Exchangers	51,100	19,200	19,700	12,200	31,400	38,900
Pumps	9,700	4,700	2,500	2,500	7,200	7,200
Strainers	4,600	2,300	2,300	0	2,300	4,600
Valves	28,300	13,700	7,300	7,300	21,000	21,000
Piping	119,500	47,900	62,900	8,700	56,600	110,800
Instrumentation/Controls ³	37,100	17,300	11,900	7,900	25,200	29,200
Total Materials & Installation, \$	359,400	108,200	109,200	142,000	250,200	217,400
Engineering (15% M&I), \$ ⁴	53,900	16,200	16,400	21,300	37,500	32,600
Total System Cost, \$	413,300	124,400	125,600	163,300	287,700	250,000
Annual Heat Recovery, Btu	6.9×10^{10}	3.0×10^{10}	2.1×10^{10}	1.8×10^{10}	4.8×10^{10}	5.1×10^{10}
Recovered Heat Value, \$	210,000	91,300	63,900	54,800	146,100	155,200
ROI, %	34	47	34	23	34	40

NOTES: ¹Assuming the installation of all new equipment.

²The pump and strainer cost estimates have been reduced from the values appearing in the reference through the elimination of spares and by the application of manual rather than automatic strainers. For this analysis, the resulting savings have been included in the tank cost for contingency purposes and therefore the total system cost estimate remains unchanged.

³Excludes diagnostic instrumentation and data acquisition hardware.

⁴Includes costs for a waste heat survey and recovery system design; excludes costs for system performance analyses and reports after start-up.

reflect the fact that the cost-to-benefit ratio of heat recovery by conventional heat exchange varies inversely with the difference between the heat exchanger inlet temperatures. As that difference increases, less heat transfer area is required per unit heat recovery and therefore heat exchanger costs also decline.

2.2 Task 1 Conclusion

The low temperature and storage components do suppress the overall system ROI. However, they also add appreciably to the total system heat recovery. Maximum values of both parameters are probably impossible to achieve simultaneously and a major task during the system design/analysis phase will be to reach an optimum balance between them. Recovery system design will be based largely upon a minimum ROI requirement. Once a target ROI is established, a system optimization study would then be performed to identify system component sizes and parameters that will yield that return with maximum heat recovery. The parameters of main interest during the study would be storage volume, heat exchanger flow rates and UA products and the glass retort cut-off temperature. The original study did not stress optimization and its main goal was to maximize heat recovery. Therefore, work to optimize the reference system is needed and it will probably indicate that an improved cost/benefit relationship can be obtained at the expense of reduced heat recovery by adjusting the contributions of the high temperature, low temperature and storage systems.

The arrangement of the reference system components was also reviewed during the project. It is presently considered that the elimination of the low temperature and/or storage component would not affect the arrangement of the high temperature system appreciably and therefore its cost estimate and ROI should remain virtually unchanged.

2.3 Task 2 - System Decentralization Study

Waste heat recovery system concepts have been devised and evaluated for each of three production buildings at the Pittsburgh Factory. The buildings considered (Meat Products, Bean and Power) are also the ones involved in the reference system design. In addition, waste water flow rates and temperatures from the original project were employed in the decentralization study as well as the same materials and installation costing rates.

2.3.1 Waste Heat Recovery System Descriptions

Meat Products & Bean Buildings

The system concept considered for application in the Meat Products and Bean Buildings is shown schematically in Figure 2. The concept employs a hot water storage feature (thermocline tank) since in each building, the waste water supply rate, W_w , will generally exceed the process water demand, W_p . Therefore, it appeared at the outset that a thermal storage capability would be beneficial. The system involves components to collect hot waste water from various food processes (see Table 2) and to pump that water to a plate heat exchanger where waste heat will be transferred to circulating fresh water.

TABLE 2
WASTE WATER SUMMARY — PITTSBURGH FACTORY

	<u>Average Flow Rate & Temperature</u>	
	<u>First Shift</u>	<u>Second Shift</u>
<u>Power Building</u>		
Continuous Cooker/Coolers	120 gpm - 140°F	60 gpm - 140°F
Can Washers	37 gpm - 175°F	12 gpm - 175°F
<u>Meat Products Building</u>		
Horizontal Stationary Retorts (Glass Products)	316 gpm - 140°F*	316 gpm - 140°F*
Can Washers	25 gpm - 175°F	12 gpm - 175°F
Bottle Washers	7 gpm - 175°F	7 gpm - 175°F
Continuous Pasteurizer	80 gpm - 170°F	80 gpm - 170°F
<u>Bean Building</u>		
Can Washers	25 gpm - 175°F	12 gpm - 175°F
Continuous Coolers	110 gpm - 120°F	55 gpm - 120°F

*Average cooldown water temperature

Figure 2. Meat Products & Bean Building Waste Heat Recovery System

The fresh water loop, circulating with a flow rate equal to W_F , will be designed to operate automatically whenever hot waste water is available and the storage tank temperature is less than a set-point value. With those conditions satisfied, energy storage will occur if W_F exceeds W_P . Otherwise, all heated fresh water will flow directly to the food processes. The storage tank size selection would be based upon optimization considerations and in any event, its volume will be no larger than the building's daily clean-up water need. Heinz U.S.A. clean-up water volume estimates are given in Table 3.

TABLE 3
PITTSBURGH FACTORY CLEAN-UP WATER DEMAND

	<u>Clean-Up Water - gal./day</u>
Power Building	53,000
Meat Products Building	80,000
Bean Building	27,000
Vinegar Building	20,000
Cereal Building	<u>20,000</u>
TOTAL	200,000

In pricing systems for the Bean and Meat Products Buildings (and the Power Building), it was assumed that new waste water drains would be installed specifically for waste heat recovery purposes. The drains will channel water from the upper floors to a point on the periphery of the first floor where the collection tank, waste pump, heat exchanger and fresh water loop will be located. Due to limited above-ground space, underground storage is a possibility and would occur in a pressurized and specially lined carbon steel tank. The inner surface preparation (sand blast and coating) will qualify the tank for use with potable water. The pressurized feature will eliminate the need to pump heated water to the clean-up stations and therefore, from the operator's point-of-view, the operation of those stations will not change from the present mode. For each building, the piping cost estimate includes 70 ft. of 4 in. pipe running from storage to a convenient 4th Floor connection with the existing water distribution system. The estimate also contains an allowance for piping to convey heated fresh water from storage to the various food processing systems such as the glass retorts, the pasteurizer and the can and bottle washers.

Power Building

The Power Building concept is shown schematically in Figure 3. Except for the absence of storage, it is identical to the Meat Products/Bean Building concept and the earlier discussion applies. The Power Building system does not include storage since the building food processes exert a large, continuous demand for heated fresh water. The demand is currently met by a water heater located on the building's 5th Floor. Under maximum flow conditions, the fresh water flow rate exceeds the available waste flow and it was considered, therefore, that most waste heat could be utilized in preheating fresh water and that storage would not be required. A storage capability could be added to the system if additional Power Building data indicate that the fresh water and waste water streams are frequently flowing out of phase.

2.3.2 System Evaluations

The individual building systems described above have been modeled and the effects of several key parameters on system performance (thermal and economic) have been examined. For each building, waste water conditions were fixed at the values given in Table 2. Annual heat recovery and ROI calculations were then performed for various UA product and fresh water flow rate combinations* in an attempt to identify optimum system conditions. The ROI estimates were based primarily upon materials and installation cost data from the original project and, in addition, they applied new cost information for pressurized, underground storage tanks. (In all previous work, the tanks were assumed to be above-ground and operating at atmospheric pressure.) All analyses for a particular building assumed fixed costs for piping, strainers, valves and controls. Heat exchanger, tank and pump costs, however, were obtained from variable cost models derived from the vendor-supplied data. The models are linear approximations to that data and are presented below with data ranges to which they apply:

<u>Item</u>	<u>Cost (Materials & Installation), \$</u>	<u>Data Range</u>
Plate Heat Exchanger	$2500 + 0.02 (UA)$	$UA = 0 \text{ to } 1,000,000 \text{ Btu/hr-F}$
Thermal Storage Tank	$5000 + 1.27 (V)$	$V = 0 \text{ to } 70,000 \text{ gal.}$
Centrifugal Pump	$1000 + 0.006 (W)$	$W = 0 \text{ to } 350,000 \text{ lb/hr}$

* In the Meat Products Building analysis, the glass retort cut-off temperature was also a variable.

Figure 3. Power Building Waste Heat Recovery System

The results of analyses performed to date are discussed in the remainder of this section.

Bean Building System

Analysis results for the Bean Building system are plotted in Figure 4. The curves show system ROI and annual heat recovery* as a function of the flow fraction, W_F/W_W , and the heat exchanger UA product. For $W_F/W_W < 0.2$, the flow of fresh water to the processes (can washers), W_P , exceeds W_F and storage, therefore, would not be a system feature. However, for flow fractions larger than 0.2, storage will be needed and the ROI curves indicate that it can improve the system's thermal and economic performance. Eventually, however, further increases in W_F fail to increase heat transfer appreciably while storage costs continue to rise in proportion to $(W_F - W_P)$. Therefore, the ROI curves peak and then decline when those costs become controlling. The ROI curves identify optimum values for both W_F/W_W and the UA product. However, an additional input to the system selection process would be the volume of heated water that can be used in one day's time. As indicated in Table 3, the Bean Building requires 27,000 gal. daily. That volume of heater water ($\sim 130^\circ\text{F}$) would be stored over a 14 hr. production period with a flow fraction of 0.5 and the Table 2 waste water conditions. Under those conditions, the heat exchanger would require a UA product no larger than 250,000 Btu/hr- $^\circ\text{F}$ and the annual ROI would be in the vicinity of 0.06. Thus, on an ROI basis, the Bean Building system analyzed herein would be a very poor performer due to the low flow ratio value and to the low waste water temperature that is dominated by the high volume, low temperature flow from the continuous coolers - see Table 2.** Estimated component costs for the Bean Building system are itemized in Table 4.

---

* As a fraction of the reference system heat recovery estimate — 6.9×10^{10} Btu/yr.

** A recuperative system with no storage and using only can washer waste water would probably operate more economically than the one evaluated during this project and could be analyzed at some future time.

Figure 4. Bean Building System Performance

TABLE 4

BEAN BUILDING SYSTEM COSTS*
 (UA = 250,000 $\frac{\text{Btu}}{\text{hr-F}}$, $\frac{W_F}{W_W} = 0.5$)

<u>Item</u>	<u>Materials & Installation, \$</u>
Tanks (Storage Volume = 27,000 gal.)	41,000
Heat Exchangers (UA = 250,000 Btu/hr-F)	7,500
Pumps	2,600
Strainer	2,300
Valves	9,100
Piping	32,000
Instrumentation & Controls	18,500
Total Materials & Installation, \$	113,000
Engineering (15% M&I), \$	17,000
Total System Cost, \$	130,000

*Table 1 notes 1, 3 and 4 apply.

Meat Products Building System

Similar curves of ROI and annual heat recovery are presented in Figure 5 for the Meat Products Building system. For that system, the analysis involved a third independent variable — the glass retort cut-off temperature. As noted in the introduction, the retort drains could be equipped with temperature-sensing, three-way valves to direct waste water first to the HTA and then the LTA. The transfer set-point, T_{CO} , has been termed the retort cut-off temperature. For this analysis, retort waste streams at temperatures less than T_{CO} were assumed to bypass the waste heat recovery system while those at higher temperatures were allowed to merge at the collection tank with streams from the pasteurizer and washers. This assumption is reflected in the heat recovery curves of Figure 5 since it causes waste flow to the system and, consequently, the heat recovery rate, to vary inversely with T_{CO} . ROI curves are presented in Figure 5 for three T_{CO} values — 100, 140 and 180°F. The peak in each curve occurs near the flow ratio at which storage begins. To the left of each peak, W_F is less than

Figure 5. Meat Products Building System Performance

W_p and the system ROI rises rapidly since storage costs are zero and because the heat recovery rate also rises rapidly with increasing W_F . At the peak, however, W_F exceeds W_p and storage begins which adds a significant new component to the total system cost. Further, as Figure 5 indicates, the ability of W_F to increase heat recovery diminishes as flow ratios greater than 1.0 are encountered and the heat recovery curves begin to flatten soon after the ROI peak is reached. Therefore, increasing system costs due to storage are not matched by benefit increases and the net result is a sharp decrease in ROI after it peaks.

The ROI curves for each T_{CO} value terminate at the flow fraction that would supply the food processes and produce 80,000 gal. of heated fresh water per day. They show that a UA of 750,000 Btu/hr-F combined with a T_{CO} value of either 100°F or 140°F would produce the desired heated volume with an ROI of about 30%. However, note that the annual heat recovery will be larger with $T_{CO} = 140^\circ\text{F}$ and it appears, therefore, that the optimum cut-off temperature will lie in the vicinity of 140°F and it could be identified more precisely through additional analysis.

The analysis of the Meat Products system indicates that the effect of storage on recovery system ROI is negative when the waste streams have high temperatures and if ROI were the only design criterion, storage would be omitted. However, maximum heat recovery is also an objective of system design. Therefore, storage volume and other system parameters such as T_{CO} , UA and W_F/W_W should be selected to meet a minimum ROI requirement while reclaiming the largest amount of process waste heat.

At the Pittsburgh Factory, a third design criterion would be storage volume. Space is limited at the factory and simply does not exist for a new tank of the size required to supply the daily clean-up water volume needed by Meat Products. A recovery system with a smaller volume (e.g., 5,000 - 15,000 gal.) would be much more feasible. The exact volume would be selected to maximize heat recovery within the space constraint, the small volume system would yield an ROI approaching 40% and it would provide, therefore, an attractive demonstration facility

with both recuperative and thermal storage features. Estimated costs for a Meat Products system having a storage volume of 10,000 gal. are presented in Table 5.

TABLE 5
MEAT PRODUCTS BUILDING SYSTEM COSTS*
(UA = 750,000 $\frac{\text{Btu}}{\text{hr-F}}$, $\frac{W_F}{W_W} = 0.7$, $T_{CO} = 140^\circ\text{F}$)

<u>Item</u>	<u>Materials & Installation, \$</u>
Tanks (Storage Volume = 10,000 gal.)	19,500
Heat Exchangers (UA = 750,000 Btu/hr-F)	17,500
Pumps	3,500
Strainer	2,300
Valves	14,600
Piping	61,900
Instrumentation & Controls	19,500
Total Materials & Installation, \$	138,800
Engineering (15% M&I), \$	20,800
Total System Cost, \$	159,600

* Table 1 notes 1, 3 and 4 apply.

Power Building System

ROI and heat recovery estimates for the recuperative Power Building system are shown in Figure 6. Values of those parameters are plotted vs. flow fraction for several UA products and the curves indicate that optimum system performance would be achieved with a UA of 750,000 Btu/hr-F and a value of W_F/W_W slightly greater than 1.0. During first shift, a flow fraction of 1.15 would provide a fresh water flow rate of 180 gpm which corresponds to the maximum demand by the 5th Floor water heater. Estimated costs for a recuperative Power Building system are presented in Table 6.

Figure 6. Power Building System Performance

TABLE 6

POWER BUILDING SYSTEM COSTS*

$$(UA = 750,000 \frac{\text{Btu}}{\text{hr-F}}, \frac{W_F}{W_W} = 1.0)$$

<u>Item</u>	<u>Materials & Installation, \$</u>
Tank	1,800
Heat Exchanger (UA = 750,000 Btu/hr-F)	17,500
Pump	1,500
Strainer	2,300
Valves	4,100
Piping	24,000
Instrumentation & Controls	10,800
Total Materials & Installation, \$	62,000
Engineering (15% M&I), \$	9,300
Total System Cost, \$	71,300

*Table 1 notes 1, 3 and 4 apply.

A system of the Power Building type is less complicated since storage is not required and the recuperative principle could be applied in an economical way at other locations throughout the factory where processes emit hot waste water and demand hot fresh water simultaneously. Heinz U.S.A. has noted, however, that a potential problem with small, independent systems scattered throughout the factory is the fact that system maintenance and operation will be less manageable than with a single large system having its major components located at a central point within the factory or building. This consideration must be factored into system design and it will favor the reference system concept and even the individual building systems discussed herein.

2.4 Task 2 Conclusion

For this task, the performance of two waste heat recovery system concepts has been analyzed. One concept (applied in the Bean and Meat Products Buildings) involved recuperation and thermal storage while the second concept (Power Building) was of the recuperative type with no storage. The study shows the Meat Product and

Power Building systems could be designed to perform very economically with annual investment returns approaching 40%. Further, when considered together, they would reclaim nearly 80% of the predicted reference system heat recovery. For demonstration purposes, it appears that the Meat Products system would be very appropriate due to its attractive ROI, its high heat recovery potential and to the fact that it would involve both recuperation and thermal storage.

Reference

W. L. Lundberg and J. A. Christenson, "Applications of Thermal Energy Storage to Waste Heat Recovery in the Food Processing Industry," Final Report, Contract EC-77-C-01-5002, to be issued.

Acknowledgement

Mr. F. Wojnar, Manager - Energy Management, Heinz U.S.A. Division, made significant contributions to the completion of this work by guiding the selection of system hardware arrangements and by reviewing the analysis results as the work progressed.

ORNL/Sub-79/42532
Dist. Category UC-94a

INTERNAL DISTRIBUTION

1. T. D. Anderson	25. M. Olszewski
2. M. Baker	26. J. L. Rich
3. G. D. Brunton	27. M. W. Rosenthal
4. S. Cantor	28. T. H. Row
5. R. S. Carlsmith	29. A. Solomon
6. R. M. Deal	30. W. Stockdale
7. D. M. Eissenberg	31. H. E. Trammell
8. L. Ferris	32. D. B. Trauger
9. E. C. Fox	33. E. K. Triegl
10. H. W. Hoffman	34. ORNL Patent Office
11. A. S. Holman	35-36. Central Research Library
12. L. Jung	37. Document Reference Section
13-22. R. J. Kedl	38-40. Laboratory Records Department
23. W. C. McClain	41. Laboratory Records (RC)
24. W. R. Mixon	

EXTERNAL DISTRIBUTION

- 42. Robert D. Allen, Division of Energy Storage Systems, Department of Energy, Washington, D.C. 20545
- 43. J. G. Asbury, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439
- 44. Frank Baylin, Solar Energy Research Institute, 1536 Cole Boulevard, Golden, CO 80401
- 45. Dan D. Edie, Department of Chemical Engineering, Clemson University, Clemson, SC 29631
- 46. Jerry Finnigan, Battelle Pacific Northwest Laboratories, P.O. Box 999, Battelle Boulevard, Richland, WA 99352
- 47. Galen R. Frysinger, Institute of Energy Conversion, University of Delaware, Newark, DE 19711
- 48. John A. Gahimer, Chemical and Thermal Storage Branch, Division of Energy Storage Systems, Department of Energy, Washington, D.C. 20545
- 49-51. Robert Holliday, Division of Energy Storage Systems, Department of Energy, 600 E Street Northwest, Room 416, Washington, D.C. 20545
- 52. Douglas Huxtable, Rocket Research Company, York Center, Redmond, WA 98052
- 53. George A. Lane, The Dow Chemical Company, Midland, MI 46840
- 54. Wayne Lundberg, Westinghouse Electric Corporation, Advanced Energy Systems Division, P.O. Box 10864, Pittsburgh, PA 15236
- 55. Arnold Manaker, Tennessee Valley Authority, 1360 Commerce Union Bank, Chattanooga, TN 37401
- 56-75. William Masica, NASA-Lewis Research Center, Cleveland, OH 44101

76. Charles F. Meyer, General Electric-TEMPO, Center for Advanced Studies, P.O. Drawer QQ, Santa Barbara, CA 93102
77. Allan Michaels, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439
78. James Minor, Battelle Pacific Northwest Laboratories, P.O. Box 999, Battelle Boulevard, Richland, WA 99352
79. Fred Molz, Water Resources Research Institute, Auburn University, Auburn, AL 36830
80. George Pezdirtz, Division of Energy Storage Systems, Department of Energy, Washington, D.C. 20545
81. Donald Reddell, Texas A&M Research Foundation, FE Box H, College Station, TX 77843
82. Ival Salyer, University of Dayton, Research Institute, Dayton, OH 45469
83. Tom Schneider, Electric Power Research Institute, 3412 Hillview Avenue, P.O. Box 10412, Palo Alto, CA 94303
84. Melvin Singer, New York State Energy Research and Development Authority, Empire State Plaza, Agency Building No. 2, Albany, NY 12223
85. James A. Stottlemire, Battelle Pacific Northwest Laboratories, P.O. Box 999, Richland, WA 99352
86. James W. Swisher, Division of Energy Storage Systems, Department of Energy, Washington, D.C. 20545
87. Phillip Thompson, Division of Energy Storage Systems, Department of Energy, Washington, D.C. 20545
88. Roy Thornton, General Electric Company, Research and Development Center, P.O. Box 8, Schenectady, NY 12301
89. Ronald Walter, Battelle Pacific Northwest Laboratories, P.O. Box 999, Battelle Boulevard, Richland, WA 99352
90. James Warman, Water Resources Research Institute, Auburn University, Auburn, AL 36830
91. William Wilson, Sandia Laboratories, Livermore, CA 94550
92. Charles Wyman, Solar Energy Research Institute, 1536 Cole Boulevard, Golden, CO 80401
93. Office of Assistant Manager, Energy Research and Development, DOE, ORO
- 94-350. Given distribution as shown in TID-4500 under category UC-94a, Energy Storage - Thermal