Food Products

Textiles

Lumber & Wood

Paper

Chemicals

Petroleum

Rubber & Plastics

Glass

Metals

Machinery

Transportation Equipment

Instruments

ENERGY ANALYSIS OF 108 INDUSTRIAL PROCESSES

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SECTION I

Industrial Process Data Base

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SECTION I

INDUSTRIAL PROCESS DATA BASE

Description of Data Base

The data base of 108 industrial processes is an outgrowth of an effort initiated in 1976 by Drexel University under contract to the Energy Research and Development Administration. Its purpose was to provide a preliminary assessment of the quantity and quality of waste energy which may be economically practical to recover in the industrial sector. As part of the initial effort, a two-digit industrial data base was developed to characterize and correlate industrial energy utilization and waste energy sources. Identification of major waste streams at this level permitted a preliminary analysis of waste energy recovery potential to be undertaken.

It became apparent, however, that waste energy sources as identified at the two-digit standard industrial classification (SIC) level were too generalized to accurately represent diverse industrial waste streams. Further efforts to characterize the type and state condition of waste streams more realistically and to make accurate estimates of recovery potential would require data at the four- and five-digit level. Consequently, in 1977 Drexel University under contract to the Department of Energy proceeded into a continuation of the initial Industrial Applications program. Among the goals of this phase was the establishment of an industrial energy data base at the four-digit level.

A further conclusion drawn from the initial Industrial Applications effort was that a realistic assessment of industrial waste energy potential would require more detailed process definition. Waste stream and end use* characteristics such as composition, state conditions, contaminant levels, and temporal profiles are all necessary considerations for adequately defining the interface with recovery technologies. Therefore, the data base developed in the program would have to encompass this level of detail.

The result of this effort is an industrial data base consisting of energy utilization data for 60 four-digit SIC industries. Selected on the basis of energy consumption as given in the 1976 Annual Survey of Manufacturers, these four-digit industries represent over 70 percent of the United States industrial manufacturing energy consumption. This is based on energy consumed as purchased fuels. The data base includes industries from 13 of the 20 two-digit SIC's (20-39) in the industrial manufacturing sector as shown in Table 1. A curve of the number of four-digit industries versus the cumulative percentage of energy use is presented in Figure 1.

It should be noted that within each four-digit industry there may exist many processes. An example of this is SIC 2812–Alkalies and Chlorine. At least four major processes account for approximately 90 percent of the energy demand of this four-digit group. Consequently, several of the four-digit industries included in the data base were further disaggregated to accurately represent all relevant processes. In total, 108 industrial processes are defined in the data base and are given five-digit designations. These are listed in Table 2. The 108 industrial processes contained in the data base account for approximately 72 percent of the industrial manufacturing energy consumption.

*End use is defined as a particular process or unit operation energy requirement (e.g., steam, hot water, refrigeration, product perheat, etc.).

Methodology for Constructing Data Base

In order to construct an industrial data base, two options are available. The first option is the use of primary data. This may be collected through plant surveys, questionnaries and other data sources for every different industry and region. This information is at the plant level and is then reaggregated to the four-digit level and eventually to the two-digit level if desired. The major difficulty with this approach is the great specificity of energy data to plant location and plant size, as well as the difficulties in obtaining large enough sample sizes in sufficient detail to be statistically significant. Thousands of plant surveys and questionnaries may be required to obtain the necessary data.

The second option and the one utilized in the development of this data base is to use process flow sheets, industrial consultants, Census of Manufacturers data, other reports and secondary and tertiary sources to obtain aggregated data at the SIC level desired. The basic approach is to use this aggregated data to obtain a synthesized plant within a given industry. In addition, a limited number of on-site plant surveys are conducted to review process flow diagrams and to supplement the aggregated data. Besides providing a check of the data, this information is used to develop scaling factors for the synthesized plants. Plants are sized (small to large) to establish parameters for energy conservation potential.

The procedure followed in developing the industrial data base is outlined in Figure 2. As already mentioned, the 60 four-digit industries included in the data base were selected on the basis of energy consumption. The primary information for this selection was gathered from the 1976 Survey of Manufacturers published by the Census Bureau. It should be noted, however, that the Census information excluded certain fuel categories (i.e., non-purchased fuels, fuels converted to other types, etc.) and as such had to be corrected with data from the Bureau of Mines, Edison Electric Institute, and Federal Power Commission. Again several of the four-digit SIC industries were further disaggregated to accurately represent the varied product lines and processes. In total, 108 industrial processes are defined in the data base and were given five-digit SIC designations as presented in Table 2.**

Once the industries were selected, typical process flow configurations were collected from various sources and a composite diagram was developed from them to represent each industry or sub-process in that industry. The resultant flow diagrams and heat and mass balances are presented in the following section for each of the 108 processes. The process configurations selected represent typical industry plants and as such have the most prevalent operations or industrial practices integrated into them. Concurrently with this step, two on-site surveys were conducted for each four-digit industry to provide a review of the general process configurations and to provide supplemental information for the energy analysis to be performed to each process.

The final step involved developing the energy and mass balances on a per unit basis (e.g., per pound product, per pound input) for each of the unit operations that comprise the industrial processes. Using this methodology, data such as process temperature and pressure, fuel requirements, thermal efficiency, and radiation and convection losses were determined for each operation. All inlet and outlet process streams and their respective state conditions (i.e., temperature, pressure, mass flow, specific heat, energy content, etc.) were identified. Figure 3 presents the type of information available at the unit operation level.

**The five-digit code was developed at Drexel. The first four digits are defined by the Census SIC, the last digit designates the Drexel process number within the four-digit SIC.

TABLE 1

Two-digit Standard Industrial Classifications

SIC	Description	Represented in Data Base
20	Food and Kindred Products	x
21	Tobacco Products	
22	Textile Mill Products	x
23	Apparel, Other Textile Products	
24	Lumber and Wood Products	x
25	Furniture and Fixtures	
26	Paper and Allied Products	x
27	Printing and Publishing	
28	Chemicals and Allied Products	x
29	Petroleum and Coal Products	x
30	Rubber, Misc. Plastic Products	x
31	Leather and Leather Products	
32	Stone, Clay, and Glass Products	x
33	Primary Metals Industries	x
34	Fabricated Metal Products	x
35	Machinery, Except Electric	x
36	Electric and Electronic Equipment	
37	Transportation Equipment	x
38	Instruments and Related Products	x
39	Miscellaneous Manufacturing	

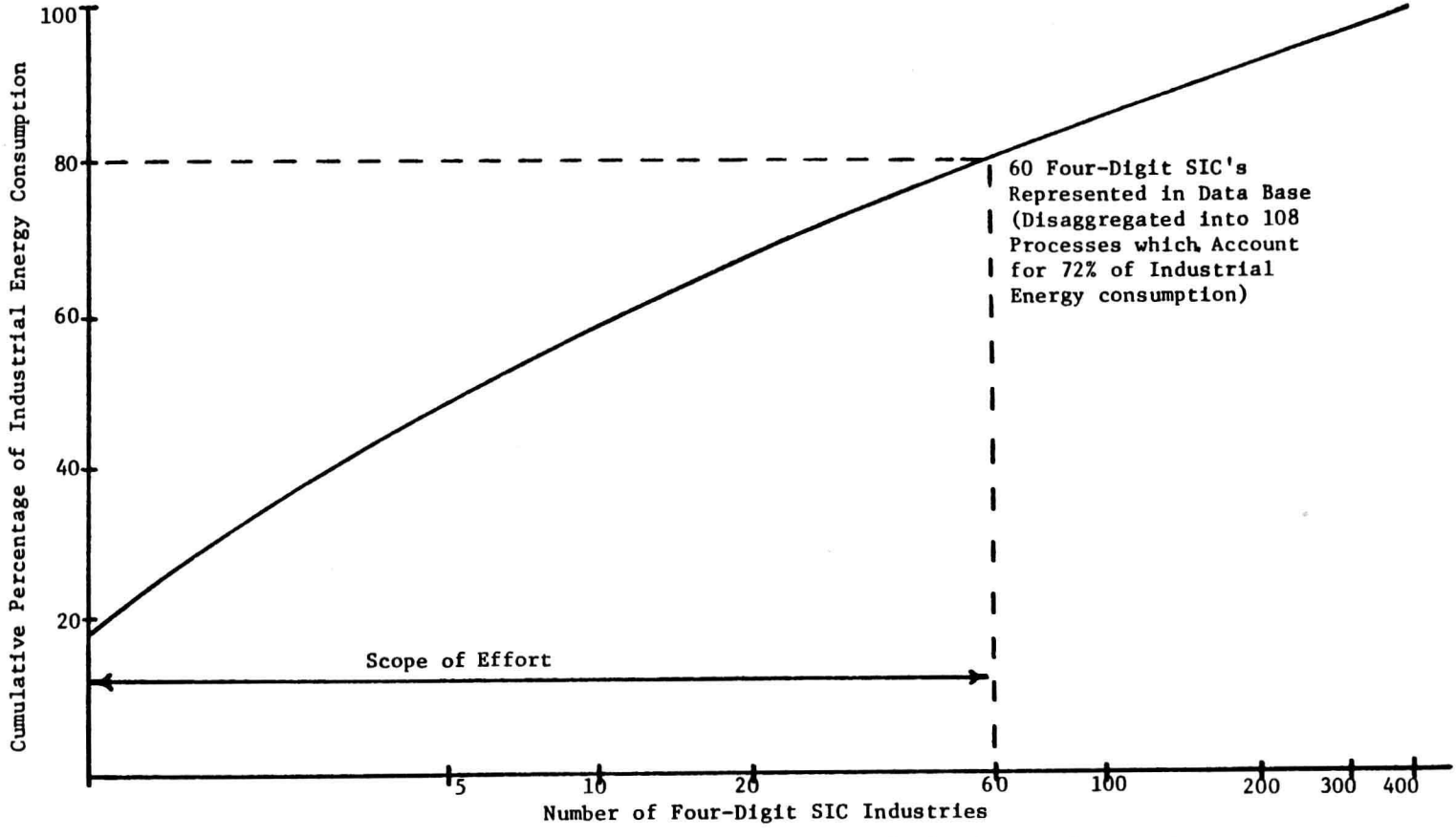

Figure 1. Number of Four-Digit SIC Industries vs. Cumulative Energy Consumption (Base Year 1976)

TABLE 2

Process Industries Contained in Industrial Data Base

SIC*	Process Description	Base Units for Energy Balance
2011	Meat Packing	Pound of meat products
2026	Fluid Milk	Pound of whole milk
2033-1	Canned Fruits	Equivalent case of fruit products
2033-2	Canned Vegetables	Equivalent case of vegetable products
2033-2	Fruit and Vegetable Juices	Equivalent case of juice products
2046	Wet Corn Milling	Pound of corn input
2051-1	Bread Baking	100 pounds of bread product
2051-2	Cakes and Pies Baking	100 pounds of cake product
2062	Cane Sugar Refining	100 pounds of sugar product
2063	Beet Sugar Refining	Pound of raw beet input
2075	Soybean Oil Mills	Pound of oil product
2082	Malt Beverages	Pound of beverage product
2221	Weaving Mills, Man-made Fibers	Pound of textile product (60% Grey Goods, 40% Finished Goods)
2262	Finishing Mills, Man-made Fibers	Pound of finished goods
2411	Logging Camps	Pound of rough cut wood
2421	Sawmills and Planing Mills	Pound of lumber product
2499	Wood products, NEC (Fiberboard)	Square foot of fiberboard
2611-1	Pulp Mills (sulfate or Kraft)	Pound of market pulp (dried)
2611-2	Pulp Mills (sulfite, NSCC)	Pound of market pulp (dried)
2611-3	Pulp Mills (Mechanical)	Pound of market pulp (dried)
2621-1	Paper Mills (Finishing)	Pound of paper product
2621-2	Paper Mills (Integrated)	Pound of paper product
2631-1	Paper Board Mills (Finishing)	Pound of paper board product
2631-2	Paper Board Mills (Integrated)	Pound of paper board product
2653	Corrugated, Solid Fiber Boxes	Square foot of corrugated product
2661-1	Building Paper (Finishing)	Pound of building paper product
2661-2	Building Paper (Integrated)	Pound of building paper product
2812-1	Alkalies and Chlorine (Caustic Soda and Chlorine-diaphragm cell)	Pound of chlorine product (1.5 pounds 76% caustic soda)
2812-2	Alkalies and Chlorine (Caustic Soda and Chlorine-mercury cell)	Pound of chlorine product (1.5 pounds 76% caustic soda)

*Five digit codes are obtained from the standard four-digit SIC codes by appending a fifth digit to differentiate between industrial processes within the four-digit group.

Table 2 (Continued)

Process Industries Contained in Industrial Data Base

SIC*	Process Description	Base Units for Energy Balance
2812-3	Alkalie and Chlorine (Soda Ash-solvay process)	Pound $NaCO_3$ product
2812-4	Alkalies and Chlorine (Soda Ash-trona process)	Pound $NaCO_3$ product
2813-1	Inorganic Gases ($N_2 + O_2$ – air separation)	Pound oxygen product
2813-2	Inorganic Gases (H_2 – steam reforming)	Pound hydrogen product
2813-3	Inorganic Gases (Acetylene – from natural gas)	Pound of acetylene product
2816-1	Inorganic Pigments (TiO_2 – chloride process)	Pound of TiO_2 product
2816-2	Inorganic Pigments (TiO_2 – sulfate process)	Pound of TiO_2 product
2816-3	Inorganic Pigments (ZnO – French process)	Pound of ZnO product
2816-4	Inorganic Pigments (ZnO – American process)	Pound of ZnO product
2816-5	Inorganic Pigments (ZnO – electro process)	Pound of ZnO product
2819-1	Industrial Inorganic Chemicals (Alumina-bauxite refining)	Pound of alumina product
2819-2	Industrial Inorganic Chemicals (sulfuric acid – contact process)	Ton of concentrated H_2SO_4
2819-3	Industrial Inorganic Chemicals (Phosphorous – elect furnace)	Pound of phosphorus product
2819-4	Industrial Inorganic Chemicals (Potash-flotation method)	Pound of potash product
2819-5	Industrual Inorganic Chemicals (Soldium Metal – electrolysis)	Pound of sodium product
2821-1	Plastic Materials and Resins (PVC) Suspension	Pound of PVC product
2821-2	Plastic Materials and Resins (Polystyrene) Mass	Pound of polystyrene product
2821-3	Plastic Materials and Resins (LDPE)	Pound of polyethylene product

*Five digit codes are obtained from the standard four-digit SIC codes by appending a fifth digit to differentiate between industrial processes within the four-digit group.

Table 2 (Continued)

Process Industries Contained in Industrial Data Base

SIC*	Process Description	Base Units for Energy Balance
2821-4	Plastic Materials and Resins (HDPE) Slurry Process	Pound of Polyethylene product
2821-5	Plastic Materials and Resins (HDPE) Solution Process	Pound of polyethylene product
2822-1	Synthetic Rubbers (SBR)	Pound of synthetic rubber product
2822-2	Synthetic Rubbers (Butyl)	Pound of synthetic rubber product
2822-3	Synthetic Rubbers (Polybutadiene)	Pound of synthetic rubber product
2822-4	Synthetic Rubbers (Polyisoprene)	Pound of synthetic rubber product
2822-5	Synthetic Rubbers (EP Rubber)	Pound of synthetic rubber product
2823-1	Cellulosic Man-made Fibers (Rayon)	Pound of rayon product
2823-2	Cellulasic Man-made Fibers (Acetate)	Pound of acetate yarn product
2824-1	Organic Fibers, Non-Cellulosic (Polyester)	Pound of polyester product
2824-2	Organic Fibers, Non-cellulosic (Polypropylene)	Pound of polypropylene product
2824-3	Organic Fibers, Non-Cellulosic (Acrylics)	Pound of acrylic fiber (30% wet spin, 70% dry spin)
2824-4	Organic Fibers, Non-Cellulosic (Nylon 6, 6)	Pound of nylon product
2824-5	Organic Fibers, Non-Cellulosic (Nylon 6)	Pound of nylon product
2834	Pharmaceutical Preparations	Dollar of sales
2865-1	Cyclic Crudes and Intermediates (Ethylbenzene and Styrene)	Pound of styrene product
2865-2	Cyclic Crudes and Intermediates (Cumene and Phenol)	Pound of phenol product
2865-3	Cyclic Crudes and Intermediates (Cyclohexane)	Pound of cyclohexane product
2869-1	Industrial Organic Chemicals (Ethylene)	Pound of ethylene product (ethane feed)
2869-2	Industrial Organic Chemicals (Methanol)	Pound of methanol product
2869-3	Industrial Organic Chemicals (Formaldehyde)	Pound of formaldehyde product

*Five digit codes are obtained from the standard four-digit SIC codes by appending a fifth digit to differentiate between industrial processes within the four-digit group.

Table 2 (Continued)

Process Industries Contained in Industrial Data Base

SIC*	Process Description	Base Units for Energy Balance
3331	Primary Copper	Pound of refined copper
3334	Primary Aluminum	Pound of refined aluminum
3341-1	Secondary Non-ferrous Metals (Aluminum)	Pound of aluminum ingot
3341-2	Secondary Non-ferrous Metals (Lead)	Pound of cast lead
3341-3	Secondary Non-ferrous Metals (Zinc)	Pound of cast zinc
3341-4	Secondary Non-ferrous Metals (Copper)	Pound of cast copper
3353	Aluminum Finish Forming	Pound of aluminum products
3462	Iron and Steel Forging	Pound of forged product
3523	Farm Machinery and Equipment	Dollar of sales
3531	Construction Machinery	Dollar of sales
3711	Motor Vehicles and Car Bodies	Pound of finished product
3714	Motor Vehicles Parts and Acces.	Pound of finished product
3861-1	Photographic Film	Pound of film product
3861-2	Photographic Equipment – Fabrication & Assembly	Dollar of equipment sales

*Five digit codes are obtained from the standard four-digit SIC codes by appending a fifth digit to differentiate between industrial processes within the four-digit group.