

**Determining Load Characteristics for
Transient Performance**
Volume 3: Load-Composition Data Analysis

**EL-850, Volume 3
Research Project 849-1**

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Prepared by

GENERAL ELECTRIC COMPANY
Electric Utility Systems Engineering Department
1 River Road
Schenectady, New York 12345

Authors
T. Gentile
S. Ihara
A. Murdoch
N. Simons

Prepared for

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

EPRI Project Manager
J. V. Mitsche

Power Systems Planning and Operation Program
Electrical Systems Division

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Prepared by
General Electric Company
Schenectady, New York

ABSTRACT

This study evaluated a prototype load modeling procedure developed by the University of Texas at Arlington (UTA) in EPRI project RP849-3. Tests were run on three different power systems to evaluate the procedure's accuracy in modeling the dynamic power response of loads (active and reactive) when subjected to limited excursions of voltage and frequency. In support activities, guidelines were developed for the load modeling procedure, and possible data sources for it were investigated.

The period of performance was September, 1976 to July, 1980. The work accomplished by General Electric is reported in a final report of four volumes, the contents of which are as follows:

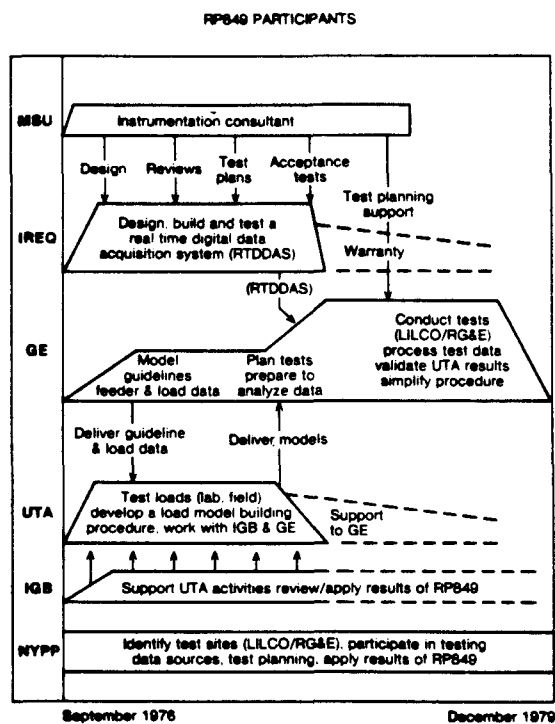
- Volume I: Executive Summary
An overview and summary of results are presented. Recommendations are made for the research necessary to develop a production grade load modeling procedure.
- Volume II: Load Model Guidelines
Guidelines are developed for a load modeling procedure. Induction motor characteristics and their effect on system stability are examined.
- Volume III: Load Composition Data Analysis
Possible data sources for the load modeling procedure are identified and analyzed as to their potential for use in determining the composition of bus load by component. A methodology is proposed.
- Volume IV: Test Data Analysis
Test results on three power systems are reported and analyzed. An evaluation of the UTA load modeling procedure is made.

EPRI PERSPECTIVE

PROJECT DESCRIPTION

RP849 involved several participants (see figure below) including three major contractors: Institut de Recherche de l'Hydro Quebec (IREQ), General Electric Company (GE), and the University of Texas at Arlington (UTA). This research was performed to better understand and model the dynamic characteristics of power system loads particularly when they are subjected to abnormal voltage or frequency changes. This 48-month effort was the first large-scale research aimed at forming load models as accurate as those commonly used for generators and other power system components. A mobile, real-time digital data acquisition system (RTDDAS) was designed, built, and used to record load characteristics in substation tests at Long Island Lighting Company (LILCO) and Rochester Gas and Electric (RG&E).

The four volumes comprising EPRI Final Report EL-850, together with EPRI Final Reports EL-849 and EL-851, document the load-model building and testing research performed in RP849. Through this research, significant progress has been made in understanding and modeling the dynamic characteristics of load. However, as discussed in EPRI EL-850, many important problems remain to be resolved. Further research built upon the results of this project should result in a procedure through which utility engineers can significantly improve the accuracy of power system analysis.



SCOPE OF GE WORK

As shown in the figure, the work done by GE was central to the load-modeling research done in RP849. Their overall role was to evaluate the load-model building procedure developed by UTA. This was done by comparing the

responses of utility feeders during staged disturbances to the simulated responses using data describing those feeders. Specifically, the tasks were:

1. To illustrate the effect of varying the types of load models used in computer simulations of power systems
2. To identify and evaluate the utility data sources required in the load-modeling procedure
3. To plan and conduct several power system field tests
4. To use the field test results to evaluate the UTA load-modeling procedure performance and to suggest possible improvements if necessary

CONCLUSIONS

As a result of this work, it was found that a load model can be synthesized by combining the characteristics of individual components that make up the load (e.g., air conditioners, pumps, heaters). To construct this load model the user must know the number of each component that is "on" at the time of interest. Typical response characteristics of each of these components are then combined to form a composite model. This procedure is less expensive, more versatile, and more accurate than the use of field tests to measure load response.

As one part of their work, GE identified sources of data used to count what components of load are "on" at any given location and time. Up to this time, these data, which are now being collected by many utilities for load research and other studies, have not been utilized to study power system transient performance.

The discussion of the use of load models in this report, although somewhat oversimplified, does accentuate the importance of modeling loads in computer studies. The treatment of induction motor modeling, its impact on simulation results, and the computer modeling data supplied are substantial contributions to the body of knowledge of computer analysis of power systems.

The extensive work done to test and analyze the model building procedures developed by UTA has identified both the successes and shortcomings of this procedure. The comparison and analysis of predicted and recorded results demonstrate the validity of the principles of this research and emphasize

the limited validity and usefulness of the present modeling procedure. The large reservoir of unique and valuable test data collected has not yet been fully explored. The analyses and recommendations reported here can be used to plan and perform future research.

Follow-on research is needed to correct the inaccuracy that exists in the reactive power and dynamic response characteristics of the load models. The load-model building procedure must also be simplified before it is suitable for routine use by utility engineers.

James V. Mitsche, Project Manager
Electrical Systems Division

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SUMMARY

The overall objective of General Electric's research in the EPRI RP849-1 project was to evaluate, through field tests, the load modeling procedure developed by the University of Texas at Arlington (UTA) in EPRI project RP849-3. The UTA load modeling procedure was used to develop load models for four different load buses on three electric utility systems for different seasons of the year. Extensive field tests at these load buses were conducted to evaluate the load models.

The philosophy implemented in the UTA load modeling procedure is to develop the load characteristics and model for a system bus based on the composition of the system load by component (air conditioning, lighting, etc.) and the voltage and frequency characteristics of those components. When the RP849 research began, it was not certain that sufficient data existed to support such a load modeling procedure. An important part of the General Electric research was to determine the availability and accuracy of data which could be used to synthesize the load composition of a system bus. Subsequently, this data was used as inputs to the UTA procedure to develop load models for the load buses to be tested. The field tests then are being used to not only evaluate the analytical techniques of the UTA load modeling procedure, but also the very load modeling philosophy being attempted.

Early in the overall RP849 project, the EPRI project manager (T. Yau) requested guidance to define the most important characteristics for inclusion in the UTA load component and composite load models. GE provided guidelines for these decisions using transient stability studies with various load models which existed before the RP849 project began. The particular concern was to demonstrate the sensitivity of system performance to various uncertainties in the load model characteristics.

The research and results are summarized here under the three main areas - load model guidelines, load composition data analysis, and load model evaluation.

LOAD MODEL GUIDELINES

Studies were made with a simple 2-machine system to demonstrate the effect of load model characteristics on system transient stability. The measure of stability used in this case was the maximum angle swing between the two machines. The system loads were modeled using models of the traditional polynomial and exponential form, the objective being to demonstrate the effect of present uncertainties in the parameters for such models. UTA, in the RP849-3 project, was to later determine the most appropriate model structures.

The system studies demonstrate the significant effect which load characteristics have on power system stability. Active power characteristics are shown to be most significant, and the nature of the effect of load characteristics on system stability is shown to be dependent on the network configuration, that is, the relationship of the major load and generation areas to one another. One study demonstrated the importance of load model representation relative to excitation system performance, an item generally carefully studied and represented in system stability studies and one representing an investment of up to one million dollars. Although transient stability was the major concern, some consideration was also given to dynamic stability.

Special attention was given to the effect of induction motor load and its dynamics because of the significant portion of the total load made up of this component. Studies were made with the same 2-generator system with induction motor load modeled at a load bus. These results demonstrated that the induction motor load can cause significantly less stable results than for the constant current load model, generally felt to incorporate a significant portion of induction motor load. Some detailed results of these simulations have been documented to indicate the effect of motor load on overall system performance. Motors ranging in size from 10 hp to 5500 hp were considered in the studies. The effects of various modeling assumptions for induction motor characteristics are shown, and the importance of data on motor size, initial loading and shaft load characteristics is demonstrated. Curves showing the steady-state voltage and frequency characteristics of motors of various ratings, initial loadings and shaft load characteristics are provided for reference purposes.

LOAD COMPOSITION DATA ANALYSIS

Fundamental to the load modeling philosophy being attempted in this project is the need for data to synthesize the composition, by component, of the load bus of

interest. The review of load data sources available to the typical US utility resulted in contacts with nearly all of the components (marketing, planning, economic research, etc.) of a present-day utility.

The data analysis has demonstrated that the load composition of a system bus can be synthesized using data sources which define the devices connected to the bus (load inventory data) and data sources which define the portion of those connected loads which are on at the time of interest (load utilization data). Sources of load inventory data are utility appliance saturation surveys, US census data, component sales data, and utility billing data. Sources of load utilization data are largely made up of load research studies conducted by the electric utilities. These studies make use of demand recorders on sample sets of devices or loads to record the demand at regular intervals (typically 30 minutes) over some period of time (typically 1 year).

Although the data sources in the commercial and industrial sectors are not as prevalent as in the residential sector, the classification by the government and utilities of establishments by Standard Industrial Classification (SIC) is tending to make this data more available as are recent government regulations which require the collection of this data. Also, many commercial and industrial establishments are metered for demand as well as energy.

The methodology of determining load composition using the data sources has been applied to four different utility substations, and an example calculation for one substation is provided. Although problems do exist in obtaining the desired data at all substations, the component method should provide utilities with a significantly more accurate load modeling procedure than exists today.

LOAD MODEL EVALUATION

The UTA load modeling procedure has been evaluated using results from extensive tests at four different substations. Two test sites were used on the Long Island Lighting Company system, and one test site was used on the Rochester Gas & Electric Company system. The fourth test site was located on the Montana-Dakota Utilities Company System. It should be noted that the UTA load modeling procedure itself does not require field tests. On the contrary, the whole thrust of the RP849 Project is to be able to develop load models from typical utility data sources without resorting to field tests.

The LILCO test sites provided mainly residential, rural load areas while the Rochester Gas & Electric Company test site, which consisted of a major portion of downtown Rochester, provided a mainly commercial load. Thus, different classes of loads were tested. Tests were run at each test site during the summer of 1978, the following winter and at one test site on the Long Island Lighting Company system during the summer of 1979. The series of tests at each test site made possible an evaluation of the ability of the UTA load modeling procedure to 'track' the seasonal changes in load composition. Many tests were run during each of these test series, lasting typically a week at each test site. The load tap-changing (LTC) transformers were used to change voltage over a maximum range of $\pm 10\%$. Significant changes in voltage were also accomplished by switching of capacitor banks. At the Southold, LILCO test site a gas turbine-generator, delivering reactive power only, was tripped off the line to produce the most significant changes in voltage. The Southold test site also provided the unique opportunity to determine the frequency response of loads. This load was isolated on the gas turbine-generator, and frequency was varied over a range from 57 to 63 Hz. Changes in voltage were also made in this isolated condition. Several such isolated tests were run during the three different seasons, providing a bank of frequency response data which is unique.

The fourth test site was provided in conjunction with a staged fault test on the Montana-Dakota Utilities Company system in November of 1978. A portion of the Bismarck, North Dakota load was monitored during this fault test, during which voltage reached a low of approximately 40%. This test provided an excellent opportunity to evaluate the capability of the UTA load modeling procedure to model load dynamics. Steady-state voltage change tests were also made at this test site.

The test data from all tests was recorded on magnetic tape with a real time digital data acquisition system (RTDDAS) developed by the Institut de Recherche de l'Hydro-Quebec (IREQ). The data recorded consists of the three phase voltages and currents sampled at rates of from 60 to 150 samples per cycle. These tapes are available for future research. Data processing programs were developed to calculate active and reactive power from the instantaneous voltages and currents.

The UTA load modeling procedure has been found to accurately model the steady-state active power voltage characteristics. Further, the procedure has been found to correctly 'track' the changes in load composition that occur from the summer to

winter seasons. Although there are differences between model and test results at some test sites, the UTA load modeling procedure provides a significant improvement over present load modeling procedures.

The tests indicate that there are significant differences between the model and test results for the steady-state reactive power voltage characteristics. The model consistently predicts a lower nominal value of reactive power, and a lower sensitivity to voltage changes than observed during the tests. The most likely sources of error in the model reactive power voltage characteristics are shown to be the component models used for induction motors, fluorescent lights, and distribution transformers. Future research in the load component area would improve the modeling of the reactive power voltage characteristics.

Although there are significant differences on a percentage basis between the model and test results for the active power frequency response, both agree that active power is quite insensitive to frequency changes for the Southold substation. There are significant differences, however, between the model and test reactive power frequency responses. In several cases, the model and test results gave changes in reactive power in opposite directions. The tests also indicated a greater sensitivity of reactive power to frequency changes at high voltages and low frequencies; the model structure is unable to match this characteristic. It may be attributable to saturation of distribution transformers. Again, future research is required.

Identification of load dynamics was aided by the use of the load admittance characteristics in preference to the active and reactive power characteristics. Load admittance allows a separation of the static and dynamic components of load and removes the compounding effect of system voltage changes during transients. As predicted by the model, the dynamic load responses were approximately exponential. However, the active and reactive power responses had different time constants, both of which were significantly greater (2 to 10 times greater) than the single time constant predicted by the UTA load modeling procedure. The UTA model does not adequately model load dynamics.

The recommended research on components should improve the capability of the UTA procedure to model the reactive power voltage and frequency characteristics. A different approach will likely be necessary to model load dynamics.

Section 1

INTRODUCTION

The objective of EPRI Project 849 is to develop a modeling procedure for bus load based on knowledge of the components (air conditioners, furnaces, motors, etc.) which make up the load. The knowledge required of the load components falls into two categories: (1) knowledge of the composition of the bus load by component, and (2) knowledge of the voltage and frequency characteristics of each component type. A part of the overall RP849 project has been to develop a data base on load component voltage and frequency characteristics; this research has been conducted by the University of Texas at Arlington (UTA) in EPRI Project RP849-3 and reported in final report EL849. This volume reports the research by General Electric of the data sources that might be used to determine the composition of a load bus by component.

A fundamental question to be asked in this research was whether there was sufficient data to identify the composition of a load bus by component. Given such data sources, consideration was given as to their potential for accuracy, ease of acquisition, and universality of use among utilities. Section 2 reports the conclusions of this load composition data analysis.

Section 3 of this volume identifies two basic types of data, both of which are required to determine load composition, and suggests sources for these types of data. Also, an example is given in Section 4 of the use of this data in a methodology to determine load composition by component.

Appendix A describes a detailed study of data sources for motor loads, made to investigate possible methods of acquiring more detailed data on this load component.

Section 2

CONCLUSIONS

Sufficient data exists to allow a determination of bus load by component. Although a detailed composition cannot always be found, sufficient data does exist to support the component based load modeling philosophy proposed in this project. The available load composition data provides the basis for a significantly more accurate load modeling procedure than exists today.

The review of load data sources available to the typical U.S. electric utility has resulted in contacts with nearly all of the components of a present-day utility. The data analysis has demonstrated that the load composition of a load bus can be identified by working with data sources which define the devices connected to the load bus (load inventory data) and data sources which define the portion of those connected loads which are on at the time of interest (load utilization data). The data sources available to identify the connected load of a bus are utility appliance saturation surveys, U.S. census data, component sales data, and utility billing data. The data sources available to identify the portion of connected load on at any particular time are largely made up of load research studies conducted by the electric utilities. These studies make use of demand recorders on samples of devices or loads to record the demand at regular intervals (typically 30 minutes) over some period of time (typically one year).

Although the data sources in the commercial and industrial classes are not as prevalent, the classification by the government and utilities of establishments by standard industrial classification is tending to make this data more available as is recent government regulations which require the collection of load research data for all classes.

Section 3

ANALYSIS OF DATA SOURCES

The data sources which are required to determine load composition can be divided into two groups: (1) those which identify the components which make up the load and the potential load they represent, termed load inventory data; (2) those which identify the portion of this potential load 'on' at any particular time, termed load utilization data.

LOAD INVENTORY DATA

Appliance Saturation Surveys

Many companies make surveys yearly or every few years to determine the number of appliances each residential customer has. One type of survey is normally handled by a mailing requesting customers to check off the number and type of each component possessed. Another is handled by a door-to-door type of survey. Usually the sample is adequate to define the saturation for the utility as a whole. Table 3-1 is an example of such information for one utility. Occasionally, the sample taken may be sufficient to allow the determination of appliance saturation for specific areas or substations of the company as well as for the company as a whole.

Even though appliance saturation surveys identify the number of appliances of particular types in an area, they do not typically identify ratings. Thus, this information is often left to be supplied as a part of the utilization data.

Census Data

The United States Bureau of the Census has programs which gather basic facts on agriculture, construction, economic statistics, governments, housing, manufacturing, mineral industries, population, retail trade, services, transportation, and wholesale trade. Our analysis of census data has revealed several data sources which can be of use in determining load composition by component. Some utilities used census data to identify appliance saturation before they had their own surveys in place. Most useful in a determination of load inventory are the Census of Housing and Population, and the censuses classified as Economic Censuses.

Table 3-1

1974-76 ELECTRIC CLASS OF CUSTOMER STUDY
 APPLIANCE SATURATION STUDY
 (based on all Residential Classes Composite Response)
 (saturation expressed in Unit Percentage*)

	1974	1975	1976
Average Total Residential Customers	766,612	776,178	784,359
Characteristic or Appliance	%	%	%
<u>Type of Home Sampled</u>			
Summer	2.8	2.2	1.7
Year Round	97.2	97.8	98.3
<u>Space Heating Fuel</u>			
Electric	2.1	2.1	2.5
LILCO Gas	17.8	17.7	17.5
Oil	79.2	78.9	79.2
Bottled Gas	.9	1.3	.8
<u>Water Heating Fuel</u>			
Electric	6.4	6.5	6.7
LILCO Gas	23.3	23.2	22.9
Oil	69.6	69.0	68.4
Bottled Gas	.7	1.3	2.0
<u>Air Conditioning</u>			
Window/Wall	113.6	117.7	102.0
Central	11.2	10.1	11.5
Dehumidifier	19.1	10.2	16.0
Attic Fan	19.5	20.4	**
<u>Range</u>			
Electric	51.0	49.8	47.4
Gas	50.4	52.6	52.6
<u>Refrigerator</u>			
Conventional Electric	49.6	48.3	49.3
Frost Free -			
Refrigerator - Freezer	64.3	64.7	67.8
Freezer (Separate)	26.5	26.7	27.1
<u>Clothes Washer</u>	86.7	86.2	83.7
<u>Clothes Dryer</u>			
Electric	50.8	48.5	45.5
Gas (LILCO and Bottled)	18.4	16.9	19.6
<u>Dishwasher</u>	60.1	50.9	51.7
<u>Television</u>			
Black and White	105.5	101.2	92.4
Color	89.0	94.0	104.8

* NOTE: Unit Percentage = $\frac{\text{Total Units}}{\text{Total Customers}} \times 100$
 ** Inconclusive data

The Economic Censuses are composed of the Censuses of Retail Trade, Wholesale Trade, Selected Service Industries, Construction Industries, Manufacturers, Mineral Industries, Transportation, Outlying Areas, and the Enterprise Statistics Program. They gather facts about these businesses and industries in the United States. These censuses are now taken at five year intervals for the years ending in "2" and "7". The 1972 Economic Censuses covered approximately 5.0 million establishments, representing about 4.5 million companies.

The results of the Economic Censuses are tabulated on the basis of the Standard Industrial Classification (SIC) (1) system. The SIC system is used to classify establishments by the type of activity in which they are engaged. It divides the nation's economic activities into 10 broad industrial divisions, 2-digit major groups, 3-digit industry subgroups, and 4-digit detailed industries. Many utilities now use the SIC system to classify their commercial and industrial customers. Besides this tabulation by industry, other tabulations are made by geographic area.

All of the economic censuses might conceivably be of use in identifying load composition. As an example, the Census of Manufacturers (2) is chosen here to describe the types of information available.

The reports on the results of the Census of Manufacturers provide two types of statistics: (1) general statistics - number of establishments, employment, payroll, workhours, cost of materials, value of shipments, capital expenditures, and inventories; (2) quantity and value of materials consumed and products shipped. The statistics are presented in three different forms: by industries, geographic areas and subjects.

The industry series (for 1977) presents statistics for each of the 451 manufacturing industries giving industry totals of general statistics for the United States as a whole and individual states. Tables present U.S. totals for quantity and value of shipments of the products classified in the industry, and quantity and cost of materials consumed by establishments in the industry. Also, for each industry, some data is shown by geographic region and state.

The most convenient report for the RP849 project is the Area Series (51 reports). A separate report for each state and the District of Columbia presents data for industries and industry groups on value of shipments, value added by manufacturing, employment, payrolls, man-hours, new capital expenditures, inventories,

assets, rents, and number of manufacturing establishments. Similar totals for all manufacturing industries are also shown for counties, standard metropolitan statistical areas (SMSA's) and their central cities, and other cities with significant manufacturing activity. For selected SMSA's and larger counties, data are shown by industry groups. For example, the report for New York State will present the data for each industry (such as boat building and repairing) for the whole state, for the SMSA's such as Rochester and for the counties.

Among the subject series is a report on Fuels and Electric Energy consumed. This series reports, among other data, the annual electric energy used by geography and by industry. Thus, using the area and subject series we can identify the types of industries in an area and the annual energy use of each. Apriori knowledge of the industries might suggest typical load compositions if better data is not available.

The Census of Population and Housing is conducted every ten years and provides significant amounts of data that can be used to determine load inventory. The publication of the Census of Housing is most helpful. The publication consists of separate reports for the United States as a total and each of the states. The data is derived from a questionnaire sent by mail and includes, for places of 10,000 to 50,000 inhabitants, such information as house heating fuel, water heating fuel, cooking fuel, and numbers of the following appliances: clothes washers, clothes dryers, dishwashers, home food freezers, and televisions. Thus, it presents significant appliance saturation data for the residential sector.

A simple way of accessing the Census of Population and Housing data is a program called SITE II (3) developed by CACI, Inc. This program, available on the GE MARK III system, accesses a library of demographic and housing data obtained from the 1970 Census, plus annual updates of population and household counts. It contains the following information on over 60,000 small and large geographic areas: total population, population by race, age, and sex, family income, median income, home values and rental prices, units in structure, including mobile homes, occupation, automobiles, achieved educational level of adults over 25, household and family composition, and major household appliances. The appliances included are: television, washer, dryer, dishwasher, air conditioner, and freezer, and the data is reported in the form of 'households with'. The unique feature of the program is its ability to request data on either a user specified, geometrically defined area (for example, circle of radius r at latitude x and

longitude y) or at one of six different levels of geography: the total United States, states, counties, census tracts or minor civil divisions, standard metropolitan statistical areas and metropolitan ZIP codes. This capability makes the program very useful since it enables the specification of an area that may be closer to the area for which a load model is desired than might otherwise be the case.

NEMA Data

The National Electrical Manufacturers Association (NEMA) reports sales and/or orders of items manufactured by its member companies. This data is not broken down by region or by application. It can be helpful, however, in discovering the trends (ratings, loadings, etc.) in manufactured items such as motors and air conditioners.

NEMA data is one example of a much broader data source that might be termed 'marketing data'. Manufacturers themselves will often keep very detailed records of sales. These records will often contain detailed information on the types of devices sold to various areas of the country. One drawback with much marketing data is that it may not separate out those devices that are going to original equipment manufacturers - for example, motors bought for incorporation in pumps for later sale.

Appendix A gives the results of an analysis of motor marketing data, including both NEMA and manufacturer marketing data. It demonstrates for one type of device, motors, the knowledge that can be gained.

Billing Data

Many utilities have special rates for customers with certain electric loads such as water heating and space heating. If such is the case for a particular utility, billing records can be used to identify the number of customers with particular electric loads. Also, the larger commercial and industrial customers are almost always demand metered. This information could be used to help break down the load by types of commercial and industrial establishments.

LOAD UTILIZATION DATA

Load Research Data

The most extensive source of utilization data is that collected in load research studies. Sometimes termed load survey studies, load research studies are conducted to determine the diversified demand of a particular load or component. The studies are run by placing demand recorders on a statistically meaningful sample of the load. As an example, one utility ran a study on residential electric water heating by placing demand recorders on units in 72 customers' homes. The tests extended from March of 1964 through March of 1965. Table 3-2 shows some of the information that was extracted from this data. The controlled heaters had units set to operate between the hours of 10:30 p.m. and 9:00 a.m. Also, two different types of heaters, NEMA and quick recovery, were included in each group, and data on these two is shown separately in Table 3-2. Considering the uncontrolled units only, the data shows that the maximum diversified demand of the sample group during the winter was 1.04 KW. Row 25 shows that the diversified demand at the time of the system winter peak was 0.60 KW. Thus, if load composition were being determined for the winter peak of this system, 0.60 KW would be allowed for each water heater.

Whereas Table 3-2 shows data for only a few specific times, data exists for a much more thorough analysis if necessary. For example, Figure 3-1 shows the load curves for the summer and winter, for the system and water heater group peaks.

In many cases the sample study data will have to be adjusted to account for the sample size. For example, the typical region under study will have more of a particular component than the sample number; this will give greater diversity, and some allowance should be made for this factor.

The diversified demand data reflects both lifestyle and temperature. By using the results of many studies around the country, like the example water heater study, it is our opinion that a bank of data could be put together, correlated to lifestyle (or region) and temperature. A utility not possessing such detailed data could refer to the data bank. Some component diversity figures may be relatively independent of temperature and/or region.

Table 3-2
RESIDENTIAL ELECTRIC WATER HEATING STUDY
SUMMARY OF GROUP LOAD CHARACTERISTICS

		<u>Controlled</u>		<u>Uncontrolled</u>
		<u>NEMA</u>	<u>Quick</u>	<u>NEMA</u>
		<u>Units</u>	<u>Recovery</u>	<u>Units</u>
1	Period of Test			
2	From	Dec 1964		Mar 1964
3	To	Mar 1965		Feb 1965
4	<u>Water Heating</u>			
5	Tank, size gal	72	82	56
6	Upper element, kw	2.45	3.14	1.86
7	Lower element, kw	1.73	3.14	1.21
8	Annual energy use			
9	Kwh	3,300	4,200	4,780
10	As % of total house	39	47	47
11	Max diversified demand			
12	Winter			
13	Date	Jan 6	Jan 15	Dec 24
14	Hour ended	12 MN	1 AM	8 PM
15	Kw	2.02	2.88	1.04
16	Summer			
17	Date	---	---	Aug 24
18	Hour ended	---	---	1 PM
19	Kw	---	---	1.00
20	Annual			
21	Date	Feb 13	Mar 29	Mar 21
22	Hour ended	12 MN	12 MN	7 PM
23	Kw	2.05	3.01	1.08
24	Coincident demand			
25	Winter, kw (a)	0	0	0.60
26	Summer, kw (b)	0	0	0.70

- (a) Monday, December 21, 1964, hour ended 6 PM
(b) Friday, September 11, 1964, hour ended 8 PM.

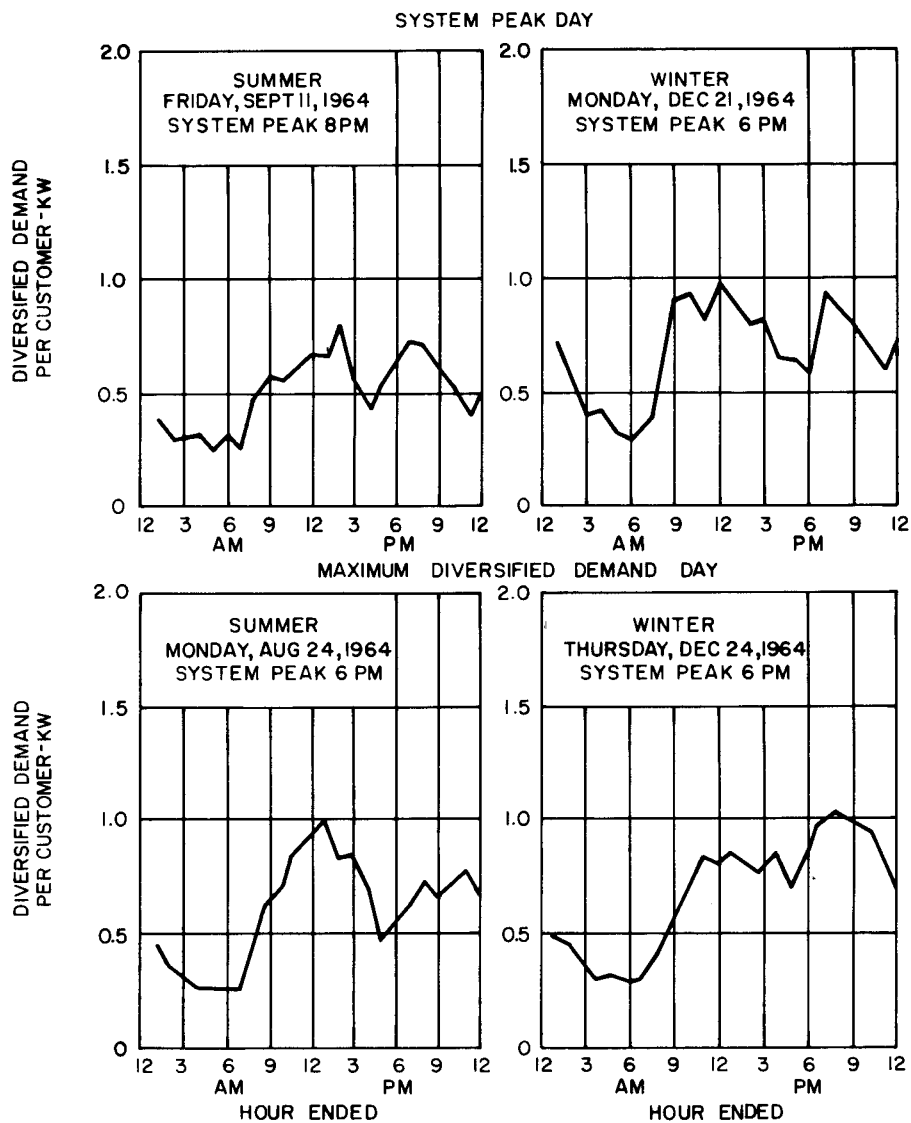


Figure 3-1. Residential electric water heating study - daily load curves for controlled NEMA units.

The most significant source of load research data is that made available through the work of the Load Research Committee of the Association of Edison Illuminating Companies. Member utilities make available the results of their load research studies to the Committee for printing. The load research reports are then incorporated in the annual minutes of the AEIC. Table 3-3 is an example page from the "Cumulative Index of Subjects, Load Research Committee Reports, 1959-1974" of AEIC. It gives an indication of the types of reports that are available.

AXCESS Program

In the course of the RP849-1 research, the need for utilization data in the commercial sector has seemed most acute. One such source of published data is that presented by the Edison Electric Institute (EEI) in its manual for the energy analysis program, AXCESS (4). The AXCESS program is designed to provide accurate economic comparisons among the different energy systems which may be used in structures of all types. Many of the inputs to this program represent component utilization data, and the users manual includes reference data on air conditioning, heating, occupancy, lighting and receptacles for various buildings. Table 3-4 reproduces some of this data. The manual also includes some typical profiles of occupancy, lighting, elevator, and hot water load as a function of time for various buildings; Figure 3-2 is an example of such curves.

Table 3-3

PORTION OF "CUMULATIVE INDEX OF SUBJECTS, LOAD RESEARCH
COMMITTEE REPORTS, 1959-1974" OF AEIC

<u>Specific Loads</u> , continued	<u>Page(s)</u>	<u>Report Year</u>
Air-conditioning, Residential (continued)		
With room units		
Baltimore, Maryland	214,215	1972-73
Long Island, New York	143,146	1966-67
Fresno, California	135,174	1965-66
Central Eastern Pennsylvania	135,186	
Newark, New Jersey	144,183	1961-62
Appliances (see also Dryers, Ranges, Water heaters)		
Effect on annual residential use		
^b Oregon	129	1963-64
Freezers		
Washington, D.C.	58, 91	1960-61
Refrigerators (refrigerator-freezers)		
Various utilities	214,245	1972-73
Baltimore, Maryland	95	1966-67
Fresno, California	135,170	1965-66
Washington, D.C.	58, 91	1960-61
Television		
Various utilities	100,101	1973-74
Washington, D.C.	114	1959-60

^bInterpretive paper.

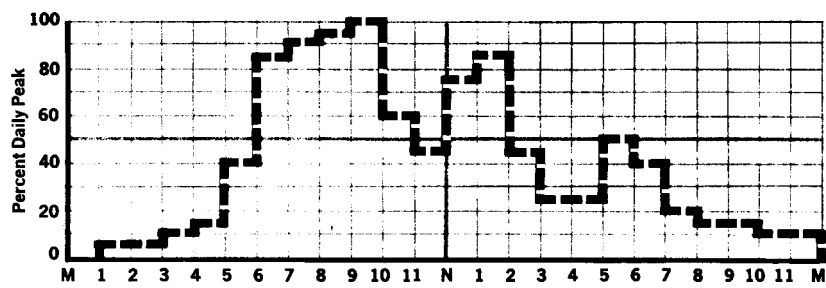
Table 3-4
REFERENCE UTILIZATION DATA FOR
BUILDINGS FOR AXCESS PROGRAM

<u>Building Type</u>	<u>Sq.Ft./Ton</u>	<u>Air Conditioning Tons/Person</u>	<u>CFM/Sq.Ft.</u>	<u>Heating BTUH/Cu.Ft.</u>
Airlines Terminal	---	0.14-0.41	---	---
Apartment	350-450	0.14-0.41	1.1-2.5	4.9
Bank	200-250	0.14-0.41	1.1-2.5	3.2
Cafeteria	200-250	0.14-0.41	1.1-2.5	3.2
Church	---	0.05	---	3.2
Computer Room	50-150	---	---	3.2
Department Store				
Basement	---	0.07-0.13	0.75-1.2	3.2
Main	200-250	0.08-0.15	0.85-2.0	3.2
Upper	---	0.10-0.23	0.75-1.2	3.2
Dormitories	350-450	0.14-0.41	1.1 -2.5	4.9

REFERENCES

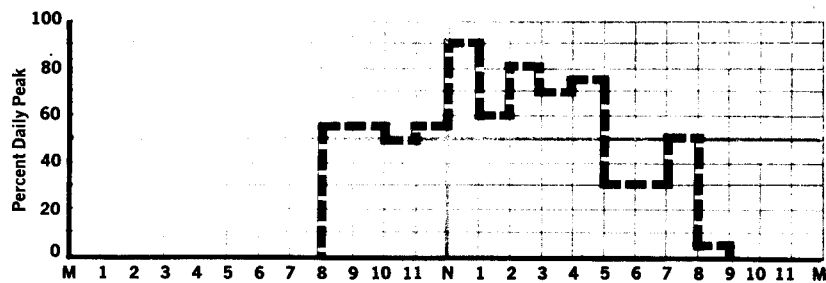
1. Standard Industrial Classification Manual, published by the U.S. Department of Commerce, Washington, D.C.
2. Census of Manufacturers, U.S. Department of Commerce, Washington, D.C., 1972.
3. SITE II User's Manual, C.A.C.I., 1815 North Fort Myer Drive, Arlington, Virginia 22209.
4. The Engineering Costs Section of AXCESS, Alternate Choice Comparison for Energy System Selection, Electric Energy Association, 90 Park Avenue, New York, New York 10016.

NURSING HOME



**Daily Peak of 1350 BTUH/Resident
not Including Conversion or System Losses.**

OFFICE BUILDING



**Daily Peak of 100 BTUH/Person
not Including Conversion or System Losses.**

Figure 3-2. Profiles of domestic hot water consumption for AXCESS program.

Section 4

PROPOSED METHODOLOGY

DESCRIPTION

Residential

The total demand of the residential sector can be synthesized by adding the demand of each type of component. A component is defined simply as an appliance (appliance includes heating and cooling types). The total demand of each type of appliance can be determined by multiplying the number of that particular appliance by the diversified demand of the appliance for the time of interest. The total reactive power of an appliance type could be determined by using an average power factor for that particular appliance type. It is assumed that the total active and reactive power of the residential portion of the load is known or can be measured; therefore, a check on the calculations is possible. Unless there are other considerations, it is suggested that the demand of each appliance type be adjusted the same amount so that the synthesized total demand equals the known total demand. Most care is required in data acquisition and interpretation on those components which make up the major portion of the load.

The diversified demand of an appliance type gives the average demand of one appliance of that type for some particular time of interest. Thus, it takes account of the potential or maximum demands of an appliance type as well as the percentages of those maximums that are to be supplied by the power system at any particular time (appliances of a particular type have different maximum demands and are used at different times).

Commercial

The determination of the composition of commercial load is potentially more difficult than that for residential loads. There are several reasons for this, among which are:

1. A more diverse mix of types of establishments. For example, whereas one may tend to have a 'typical home', it is apparently less feasible to define a 'typical motel'; there are many more variables at play in the case of the motel.

2. A more diverse mix of load components as well as their size, function and operating cycles.
3. Fewer viable statistics on commercial load components brought about at least partially by the apparent frustration of identifying and inventorying the most important commercial load components.

The above problem, though real, seems to be counterbalanced by several factors which, from our investigations, seem to be characteristic of commercial loads and may provide sufficient information regarding commercial load composition.

Among these factors are:

1. A trend among the utilities analyzed to inventory commercial customers by United States Standard Industrial Classification (SIC) Code number. Such a classification would allow the application of typical compositions for those classifications. Although not as accurate as a component by component analysis as is possible for the residential sector, sufficient data has been gathered on the space conditioning, water heating, and lighting needs of commercial buildings and establishments to lend some support to this method.
2. An apparent natural ordering of commercial loads into:
 - a. Small customers with similar load characteristics which lend themselves to grouping.
 - b. Large customers which are sufficiently important to warrant fairly sophisticated metering and specific testing to assess specific characteristics.
3. The availability of billing demand metering data as well as energy metering data for almost all commercial customers. Also, some initial analysis of load components is generally done when the customer is initially connected to the system in order to estimate annual revenue for the utility.

Further, this situation seems destined to improve since numerous utilities and agencies have recognized the need for more commercial and industrial demand data, and there are extensive plans to add to the store of knowledge in this area.

Industrial

Most of the comments about the commercial sector apply also to the industrial sector. In fact, many utilities do not separate the two by function, but only by the magnitude of their demands.

The one point peculiar to the industrial sector is the fact that there may be some very large customers in this category, limited to such small numbers that they may be considered one by one. Many such large industrial customers have very detailed data available on the composition of their loads.

EXAMPLE

An example is presented here of load composition determination for the summer peak for one of the RP849-1 test sites, the Southold substation. The procedure used for this substation was very rigorous in order to remove as much as possible the load composition determination as an unknown. It is not intended that this procedure be followed in detail; neither is it clear that such detail is necessary.

A summer peak load of 4800 KW (at 8 p.m.) was predicted for this substation which feeds a mainly rural area with no major industrial loads. The known, uncorrected power factor of this station was 0.86 lagging. The problem was to determine the composition of this 4800 KW by component. The residential composition was first determined because there was more data available to support it.

Residential

Table 4-1 presents the calculations for the residential load. Billing records indicated that there were 2922 residential customers fed by the two feeders that make up the Southold substation.

Table 4-1
SOUTHOLD RESIDENTIAL LOAD COMPOSITION
Summer Peak at 8 PM

<u>Appliance</u>	<u>Column 1 Number</u>	<u>Column 2 Diversified Demand (KW)</u>	<u>Column 3 Total Demand (KW)</u>
Electric Heat	--	--	--
Electric Water Heating	795	.70	557
Window A/C	700	.28	196
Central A/C	146	2.00	292
Dehumidifier	292	.20	58
Attic Fan	584	.30	175
Range	1455	.20	291
Conventional Refrigerator	1412	.21	297
FF Refrigerator-Freezer	1890	.45	851
Freezer	781	.16	125
Washer	2335	.02	47
Dryer	1330	.10	133
Dishwasher	707	.10	71
Black & White TV	2957	.02	59
Color TV	2747	.05	137
Lighting & Misc.	2922	.20	<u>584</u>
TOTAL			3873

Column 1 gives the number of each appliance in the total substation load. Since LILCO has separate rates for customers with electric water heating, with electric space heating, and with both electric water heating and electric space heating, billing records allowed an exact determination of the number of electric water heaters.

Three sources of appliance saturation data were available to determine the numbers of the other appliances. These were as follows:

- (1) Results of an appliance saturation study, Table 3-1. (Data was available through 1975 at the time of these calculations.)
- (2) Results from an older appliance saturation study (1962-1965) that identified appliance saturations by substation, including Southold.
- (3) A SITE run which gave the following data on 'households with' (note that such data does not account for homes that may have more than one of a particular appliance): TV, 91.3%; washer, 79.9%; dryer, 45.5%; dishwasher, 24.2%; air conditioner, 5.7%; freezer, 28.1%.

In general, the 1975 appliance saturation data was used. Since this data applies theoretically only to the total system, some exceptions were made. The older, more detailed study (which gave us a relationship between the Southold and total system saturations) led us to use saturations for window and central air conditioning that were 20% and 50%, respectively of the total system saturations given in the 1975 study. Also, the SITE saturation figures were used for the washer, dryer, and dishwasher components. (The SITE data for air conditioning seemed unreasonably low to LILCO customer service personnel.)

Column 2 gives the diversified demand of each component at the time of the summer peak, 8 p.m. The figures for electric water heating and air conditioning were taken from load research studies which LILCO had conducted on those appliances. Such study results present the most accurate data sources and should be used when available. The other values were derived from the following references:

- (1) W.L. Tadlock, "Evaluation of Incompletely Diversified Loads," AIEE Transactions, November 1943, pp. 485-492.
- (2) "Three Texas Companies Study Characteristics of Five Appliance Loads," Electrical World article, August 11, 1958, pp. 40-46.
- (3) F.G. Hamner, J.W. Crawford, "Demand and Diversity Characteristics of Residential Loads," Engineering and Operation Section, Southeastern Electric Exchange, New Orleans, Louisiana, April 4-5, 1963.

Of particular help was the Tadlock paper. Although quite old, it provides a good understanding of diversity and how to account for it. The paper demonstrates a method of determining unknown composite load demands from known component load demands. With test data on the probability of individual loads being on, the maximum total demand is found in terms of the maximum individual demands. Data for a few appliances was deduced from information on how similar appliances diversify; that is, what portion of connected load would typically be 'on' at a particular time.

Column 3 gives the total demand of each appliance type, and is determined by multiplying the corresponding terms from columns 1 and 2. Note that air conditioning and refrigeration loads, which are represented by the same component model in the UTA load modeling program, make up 42% of the load. Similarly, the water heating, lighting, and miscellaneous categories account for 29% of the load. These are the components on which to concentrate.

The value of 3873 KW was taken as accurate for the residential load, and the difference (927 KW) was assumed to be commercial load (LILCO does not separate commercial and industrial loads).

Commercial

The determination of commercial load composition was simplified by an existing report by Dubin-Bloome Associates entitled "A Study of Existing Energy Usage on Long Island and the Impact of Energy Conservation, Solar Energy, Total Energy and Wind Systems on Future Requirements." This report gave the following breakdown of commercial load composition:

Lighting	41.4%
Cooling	27.4%
Mechanical Equipment	17.7%
Industrial Process	6.5%
Miscellaneous	7.0%

These figures were derived by identifying the type of commercial and industrial customers which made up the load (SIC classifications) and then using for them typical data like that presented in Table 3-4 which would indicate the composition of the loads. This data was felt to be accurate for the total system by the LILCO load research personnel.

Since the Southold, or any, substation probably does not have the typical composition, effort was expended to better define the particular Southold commercial load. Billing data was investigated to determine whether there was one particular type of commercial load that would account for a significant portion of the total, which would in turn be investigated in more detail to determine load composition.

An examination of the billing data for Southold gave the following breakdown:

<u>Rate Classification</u>	<u>Number of Customers</u>	<u>Annual Energy (KWH)</u>
280	291	1,507,673
281	92	5,843,533
290	13	451,036
291	3	143,440
780	<u>26</u>	<u>70,863</u>
	425	8,016,545

The 92 customers of the 281 rate classification, representing 22% of the customers, consumed 73% of the energy. Examining the demand billing data (maximum summer demands) for 40 of the largest of these customers gave an undiversified total demand of 1343 KW and an annual energy total of 4,240,528 KWH. Thus, these 40 customers accounted for over 50% of the annual energy. Assuming the same demand to energy ratio would hold, the undiversified demand for the total commercial load would be 2538 KW. Since the total commercial load was to be 927 KW, the coincidence factor was taken to be 0.365 (927/2538), and this was applied to each of the 40 largest commercial load billing demands which were to be modeled individually. Customer service representatives were then consulted to obtain load compositions for these establishments.

Connected load data for two customers follows to give an indication of the type of data which can be provided by the commercial customer representatives:

Customer 1	19 HP refrigeration, (2) 15 ton air conditioners, part gas and part electric heat.
Customer 2	40 HP pump (water pump station).

Again, each of the individual loads was multiplied by the 0.365 factor to get the load at the time of the summer peak. The rest of the commercial load was assumed to have the composition presented in the Dubin-Bloone Associates report.

In representing individual commercial loads, the methodology is to determine which ones represent the major portion of the load. In this way, the number of customers or types of customers that must be examined in detail is decreased.

It is unlikely that the load composition determination for other substations on other systems would proceed exactly as in this example case. However, it is hoped that the correct thought processes have been suggested.

Appendix A

MOTOR DATA SOURCE ANALYSIS

MARKET DATA

The National Electrical Manufacturers Association (NEMA) reports motor sales and/or orders for its member companies. Some of this data has been extracted from the NEMA report and is presented in Table A-1. Some of the data is available on an orders basis and some on a sales basis. In order to present data for each size category for the years 1956-1975, both are used, the time difference being relatively insignificant for the purposes of this project.

The NEMA data is not broken down by region or by application. It gives the total sales or orders in each size category for the country as a whole; internal sales (sales to divisions of the same member company) are not included. By looking at this data for a 20 year period, we do get one estimate of the distribution of motor load by size in the country as a whole. For some years the 1-20 and 21-200 HP categories are broken down into more than one range. An examination of this data indicates that approximately 75% of the motors in the 1-20 HP category fall in the range of 1-5 HP, the remaining portion falling in the 6-20 HP range. Of the motors in the 21-200 HP category, approximately 60% fall in the 21-50 HP range, 32% fall in the 51-125 HP range, and approximately 8% fall in the 126-200 HP range. In order to get some estimate of the total horsepower in each of the three-phase categories, an average rating was assumed for each category as follows: 2 HP for the 1-5 HP range, 10 HP for the 6-20 HP range, 30 HP for the 21-50 HP range, 70 HP for the 51-125 HP range, 150 HP for the 126-200 HP range, 300 HP for the 201-500 HP range, and 1000 HP for the 501-7500 HP range; also, the data for all 20 years was added. Using these average ratings, the distribution of motor horsepower is as shown below in Table A-2.

Although helpful, a classification of the induction motor load by various rating categories for the country as a whole does not allow the development of the type of load model envisioned in this project. Data must be developed that will allow a characterization of the motor load of a particular bus or at least a reasonably small region of the country. For this reason, our investigation considered various classifications of motors that exist, either by industry in which they are used or by end use. Another data source would be required to define the number of such industries or end use applications in the load area to be modeled.

Table A-1

NEMA INDUCTION MOTOR MARKET DATA SUMMARY

YEAR	SALES			ORDERS	
	1Ø IND.	3Ø IND.	3Ø IND.	3Ø IND.	3Ø IND.
	MOTORS	MOTORS	MOTORS	MOTORS	MOTORS
		1-20 HP	21-200 HP	201-500 HP	501-7500 HP
1956	194,015	912,732	88,733	2,738	961
1957	154,421	712,933	78,286	2,519	913
1958	161,608	569,667	55,667	1,418	526
1959	214,859	718,514	70,761	1,497	568
1960	197,678	736,808	74,812	1,755	839
1961	188,317	706,499	73,814	1,795	575
1962	193,819	753,560	76,390	1,631	680
1963	167,214	826,410	86,500	2,232	710
1964	190,456	939,331	108,306	3,448	1,173
1965	233,304	1,041,856	128,982	4,913	1,572
1966	286,227	1,263,617	178,055	5,202	2,343
1967	227,870	1,105,884	148,178	4,193	1,888
1968	248,432	1,096,415	138,813	4,547	2,051
1969	243,728	1,236,900	159,545	5,579	1,873
1970	243,000	1,098,142	148,178	5,812	2,234
1971	187,076	993,019	148,766	5,566	2,338
1972	218,312	1,197,221	179,253	6,028	2,734
1973	289,887	1,440,110	216,826	6,797	3,343
1974	305,494	1,566,931	225,423	10,206	4,579
1975	179,504	1,078,452	212,815	7,346	3,771

Table A-2
DISTRIBUTION OF THREE-PHASE MOTOR HORSEPOWER BY
HORSEPOWER RANGE

<u>Range (HP)</u>	<u>Total Horsepower (10⁶)</u>	<u>Percent of Total</u>
1- 20	80.0	29%
21- 200	136.2	49%
201- 500	25.6	9%
501-7500	35.7	13%

NEMA provides a breakdown of the sales billed to its member companies' domestic customers by standard industrial classification (SIC) numbers. The SIC numbers are put in 52 groupings as listed in Table A-3. More complete descriptions of the SIC groups can be obtained from the Standard Industrial Classification Manual. The breakdown for AC induction motors is given for two different size groups, 1-200 HP and 201-500 HP. Table A-4 lists example data for the years 1966-1970 in the 1-200 HP range. The data is released in terms of the percent of dollar value of domestic gross orders received as reported to NEMA. Although the data is in terms of percent of dollar value, the total dollar sales are known, and an estimate can be made to relate dollars to HP rating. Examination of this data for a number of years should give a good indication of the amount of motor load in the 1-200 HP range for any of the SIC numbers for the country as a whole. A similar process could be used for the 201-500 HP range. Indeed, a comparison of the values for the two rating ranges may be very helpful in defining a load model if average motor rating turns out to be a significant parameter. As an example, Table A-5 presents data for the two rating ranges for 1975. Again, the assumption is made that a utility has available to it the number of customers that fit into each category. This is often a part of billing records, and utilities regularly report KWHR sales by SIC number to the Edison Electric Institute (EEI).

The availability of the NEMA data by SIC number is noted here, but no attempt has been made to develop this data for the 52 groupings shown in Table A-3. Also, no attempt has been made to determine the variance of motor load for a SIC number for different areas of the country. It would seem, however, that this classification of motor load by SIC number would be an improvement over the classification for the country as a whole. Another difficulty with a classification by SIC

Table A-3

NEMA GROUPINGS OF STANDARD INDUSTRIAL CLASSIFICATION NUMBERS

GROUP NO.	SIC GROUP AND DESCRIPTION
1	1000/1099 Metal Mining 1100/1299 Coal Mining
2	1300/1399 Crude Petroleum and Natural Gas Products 2900/2999 Petroleum Refining and Natural Gas Products
3	1500/1599 Building Construction - General Contractors and Operative Builders 1600/1699 Construction other than Buildings - General Contractors 1700/1799 Construction - Special Trade Contractors 8911 Engineering and Architectural Services
4	2000/2099 Food and Kindred Products 4100/2199 Tobacco Manufacturers
5	2200/2399 Textile Mill Products and Apparel and other Textile Prod.
6	2600/2699 Pulp and Paper Products
7	2700/2799 Printing and Publishing
8	2800/2899 Chemical and Allied Products
9	3000/3099 Rubber and Miscellaneous Plastic Products
10	3200/3299 Stone, Clay, Glass Products
11	3300/3325 Iron and Steel
12	3331/3399 Primary Non-ferrous and Miscellaneous Primary Metal Prod.
13	3400/3499 Fabricated Metal Products Including Ordnance
14	3510/3519 Engines and Turbines, Except Electrical
15	3520/3529 Farm and Garden Machinery
16	3531 Construction Machinery
17	3532 Mining Machinery
18	3533 Oil Field Machinery
19	3537 Industrial Trucks
20	3567 Industrial Furnaces and Ovens
21	3559 Other Special Industry Machinery
22	3569 Other General Industrial Machinery Including Packaging Machinery 3590/3599 Miscellaneous Machinery, Except Electrical
23	3534 Elevators and Moving Stairways
24	3535 Conveyors and Conveying Equipment, Except Electrical
25	3536 Hoists, Cranes and Monorails, Except Electrical
26	3541 Machine Tools, Metal Cutting Types
27	3542 Machine Tools, Metal Forming Types
28	3544/3549 Metalworking Machinery, Except Machine Tools
29	3551 Food Products Machinery
30	3552 Textile Machinery
31	3553 Woodworking Machinery
32	3554 Paper Industry Machinery
33	3555 Printing Trades Machinery
34	3561 Pumps and Pumping Equipment
35	3563 Air and Gas Compressors
36	3564 Blowers and Fans
37	3566&3568 Mechanical Power Transmission Equipment
38	3570/3579 Office and Computing Machines 3581 Automatic Merchandising Machines 3586 Measuring and Dispensing Pumps 3589 Other Service Industry Machinery
39	3582 Commercial Laundry Equipment
40	3585 Air Conditioning, Refrigeration and Heating Equipment
41	3600/3699 Electric and Electronic Equipment
42	3710/3719 Motor Vehicles and Equipment
43	3720/3729 Aircraft and Parts 3730/3739 Ship and Boat Building and Repairing 3740/3749 Railroad Equipment 3750/3799 Motorcycles, Bicycles, and Parts and Miscellaneous Transportation Equipment Manufacturers
44	4000/4899 Transportation and Communication
45	4900/4999 Electric, Gas, and Sanitary Services - Public Utilities
46	5060/5068 Electrical Goods, Wholesale 5000/5199 Wholesale Trade
47	9100/9799 Government - Federal, State, Local and International
48	0100/0999 Agriculture, Forestry and Fishing 2400/2599 Lumber, Wood Products and Furniture and Fixtures
49	3800/3873 Instruments and Related Products
50	3100/3199 Leather and Leather Products 3562 Ball and Roller Bearings 3565 Industrial Patterns 3900/3999 Miscellaneous Manufacturers (Jewelry, Musical Instruments, Toys and Others Not Elsewhere Classified)
51	5200/6799 Retail Trade and Finance, Insurance and Real Estate
52	7000/8999 Services, Including Electrical Repair Shops, Except 8911 9900/9999 Nonclassifiable and All Other SIC Numbers Not Listed Above

Table A-4

NEMA ORDERS DATA FOR 1-200 HP RANGE OF AC INDUCTION MOTORS;
PERCENT OF DOLLAR VALUE OF ORDERS RECEIVED; 1966-1970

Market %
As Reported by NEMA
1-200 HP

Group No.	1966	1967	1968	1969	1970
1	.462	.337	.432	.260	.334
2	.615	.481	.523	.371	.411
3	1.748	1.625	1.231	1.313	1.460
4	.424	.339	.332	.367	.295
5	.276	.340	.195	.127	.102
6	.078	.127	.080	.216	.178
7	1.848	2.028	1.333	1.429	1.306
8	1.558	1.412	1.404	1.243	1.322
9	.120	.110	.084	.095	.064
10	.575	.468	.512	.662	.667
11	.940	1.362	1.321	.928	1.099
12	.098	.083	.129	.081	.040
13	.543	.538	.399	.539	.533
14	.227	.244	.194	.294	.177
15	3.056	3.439	3.553	2.716	2.793
16	.382	.496	.498	.291	.469
17	2.937	2.942	3.210	2.639	2.966
18	1.291	1.467	1.335	1.311	1.020
19	2.132	2.256	2.478	2.099	2.405
20	.425	.450	.376	.545	.516
21	.078	.113	.124	.188	.138
22	1.013	.849	.664	.874	.637
23	4.201	3.606	4.118	4.196	4.213
24	.337	.319	.329	.521	.701
25	1.673	1.647	1.658	1.755	1.866
26	.966	1.168	1.118	.883	.888
27	4.597	4.441	3.431	4.153	3.220
28	1.267	1.211	.992	.959	.831
29	.873	.785	.710	.802	.656
30	1.949	1.818	1.730	1.877	1.972
31	4.137	1.248	1.393	1.428	1.015
32	.813	.897	.986	1.057	.778
33	.549	.676	.565	.761	.674
34	.364	.307	.495	.361	.394
35	16.685	19.078	18.997	19.885	20.505
36	4.885	4.743	4.836	5.694	5.714
37	.785	.732	.770	.733	.486
38	.825	.953	1.009	1.187	.972
39	1.141	1.125	.908	1.047	.868
40	3.895	4.225	3.097	3.745	3.998
41	1.819	1.596	1.196	1.317	1.377
42	1.123	.586	.314	.324	.325
43	1.525	2.607	3.712	1.452	1.443
44	.068	.158	.092	.173	.142
45	.555	.488	.447	.331	.323
46	19.446	19.581	20.968	22.333	23.508
47	.268	.234	.251	.126	.082
48	.011	.028	.015	.034	.025
49	.191	.261	.301	.315	.630
50	4.274	3.976	4.345	3.963	3.462
TOTAL	100.000	100.000	100.000	100.000	100.000

Table A-5

NEMA ORDERS DATA FOR 1-200 HP AND 201-500 HP RANGES OF
AC INDUCTION MOTORS; PERCENT OF DOLLAR VALUE OF ORDERS
RECEIVED - 1975

<u>GROUP NO.</u>	<u>1-200 HP (%)</u>	<u>201-500 HP (%)</u>
1	.445%	2.098%
2	.678	1.850
3	1.538	6.050
4	.617	.347
5	.123	.123
6	1.453	2.337
7	.117	1.983
8	1.671	4.013
9	.077	.200
10	.302	1.274
11	.866	2.071
12	.324	.386
13	1.261	1.787
14	.421	.731
15	2.826	.111
16	.644	.829
17	3.235	2.159
18	1.309	.798
19	.122	.999
20	.363	.235
21	1.351	.782
22	.771	.275
23	.336	.405
24	1.789	1.058
25	.708	.857
26	1.788	.584
27	.441	.861
28	.259	.111
29	1.525	.591
30	.903	.116
31	.387	.025
32	.384	.160
33	.083	.456
34	23.368	25.978 INC. #38
35	2.877	6.914
36	3.744	2.434
37	.926	.204
38	.714	INCLUDED IN #34
39	.527	.072
40	4.138	3.348
41	1.776	.856
42	.327	.227
43	.850	1.330
44	.213	.288
45	.310	5.459
46	27.557	11.924
47	.179	.083
48	.348	.158
49	.156	.315
50	.623	.272
51	1.223	1.667
52	1.027	1.809

number is that of separating end users of motors from those which use motors in manufactured products. This limitation would suggest that individual industry or trade associations might be used as the sources of data on motor load composition.

A grouping of market data by industry, including end users and original equipment manufacturers together, may improve the usefulness of data by SIC numbers. Table A-6 is such a grouping with the list of SIC numbers in each group. As an example of what is accomplished by such a grouping, note that the group for the paper industry includes SIC number 2600 for paper and allied products manufacturers as well as SIC numbers 3553-3555 which cover manufacturers of machinery for this industry. The pump and compressor category is included separately because its end products are so widely distributed among industries. Table A-7 presents the resulting data for the 201-7500 HP range for the years 1966-1976. The data has been taken from NEMA orders information. Actual data has been used for the years 1971-1976, and the breakdown by industry for previous years has been taken to be the same as 1971. For the industries included, this type of classification would appear to be an improvement over the classification by single SIC numbers.

More detailed information can be obtained from individual manufacturers' data. General Electric's Large Generator and Motor Department has provided a further breakdown of the 1976 data by major industry to indicate the applications within each industry. Table A-8 lists the applications and a reference number for each, and Table A-9 gives the breakdown of the 1976 data in two horsepower ranges, 201-500 HP and 501-2500 HP. This data is available only because the marketing organization 'sees' its markets in this way; the data does not exist for years prior to 1976. It is likely that other manufacturers could offer similar data, although probably broken down differently.

Assuming again that it may be necessary to understand how the motors are applied in order to determine the load characteristics accurately, the breakdown shown in Table A-9 is a valuable one. For example, for the paper industry the motor orders are broken down to indicate the number applied to pumps and fans, compressors, wood chippers, pulpers, and refiners. This type of data could be used to get measures of both inertia and shaft load characteristics.

Table A-6

GROUPINGS OF SIC NUMBERS BY MAJOR INDUSTRY

<u>MAJOR INDUSTRY</u>		<u>SIC NUMBERS INCLUDED</u>	
1. Utility		3564	9856
		3511	7399
		3443	8931
		4911	9144
		1621	9189
		8911	9289
2. Process Engineering		1621	
3. Petroleum Chemical		2810	3313
		2820	2899
		2822	4610
		2824	2911
		2813	
4. Paper		2600	3555
		3554	3553
5. Pump & Compressor		3561	
6. Mines & Machinery		1011	3534
		1200	3535
		1400	3537
		3531	3530
		3532	3200
		3533	3229
		3559	3241
		3536	
7. Metal Industries		3310	3554
		3320	3555
		1021	3400
		3351	2400
		1051	3982
		3352	3999
		3399	3541
		3548	3542
		3567	3523
		3561	
8. General Manufacturing		3552	3569
		3559	3564
		3551	3811

Table A-7

INDUCTION MOTOR ORDERS BY MAJOR INDUSTRY
(Number of Motors)

YEAR	HP RANGE	UTILITY	PROC. ENG.	PETRO CHEM.	PAPER	PUMP COMPR.	MINES	METAL INDUS.	GEN'L MFG'G	TOTAL
1966	201- 500	936	208	239	416	1040	390	312	1661	5202
	501-2500	392	87	100	174	436	163	131	696	2179
	2501-7500	30	7	7	13	32	12	10	53	164
	TOTAL	1358	302	346	603	1508	565	453	2410	7545
1967	201- 500	755	168	193	335	839	314	252	1337	4193
	501-2500	313	69	80	139	347	130	104	555	1737
	2501-7500	27	6	7	12	30	11	9	49	151
	TOTAL	1188	264	304	527	1319	495	396	2105	6598
1968	201- 500	818	182	209	363	909	341	273	1452	4547
	501-2500	340	75	87	151	377	142	113	602	1887
	2501-7500	30	7	8	13	33	12	10	51	164
	TOTAL	1188	264	304	527	1319	495	396	2105	6598
1969	201- 500	578	210	117	461	1068	479	391	2275	5579
	501-2500	487	37	77	37	337	51	114	564	1704
	2501-7500	48	4	8	4	33	5	11	56	169
	TOTAL	1113	251	202	502	1438	535	516	2895	7452
1970	201- 500	712	243	122	596	1384	434	226	2095	5812
	501-2500	360	137	267	113	363	72	140	559	2011
	2501-7500	40	15	30	13	40	8	16	61	223
	TOTAL	1112	395	419	722	1787	514	382	2715	8046
1971	201- 500	897	272	139	682	1099	347	354	1776	5566
	501-2500	811	18	133	56	278	77	50	583	2006
	2501-7500	74	6	27	9	41	47	21	107	332
	TOTAL	1782	296	299	747	1418	471	425	2466	7904
1972	201- 500	957	290	270	569	1301	569	324	1748	6028
	501-2500	827	92	177	54	398	123	71	631	2373
	2501-7500	148	0	27	0	24	0	0	162	361
	TOTAL	1932	382	474	623	1723	692	395	2541	8762
1973	201- 500	628	347	256	749	1347	573	643	2254	6797
	501-2500	592	130	245	141	462	107	191	940	2808
	2501-7500	219	0	39	0	35	0	0	242	535
	TOTAL	1439	477	540	890	1844	680	834	3436	10140
1974	201- 500	576	773	529	1316	2828	1255	875	2054	10206
	501-2500	1021	279	415	257	1141	251	273	432	4069
	2501-7500	129	10	46	15	72	82	36	66	458
	TOTAL	1726	1062	990	1588	4041	1588	1184	2552	14733
1975	201- 500	745	214	174	919	2212	1094	864	1126	7348
	501-2500	1140	219	120	161	879	271	193	384	3367
	2501-7500	113	34	26	4	162	30	15	20	404
	TOTAL	1998	469	320	1084	3253	1395	1072	1530	11119
1976	201- 500	840	142	192	1275	1832	880	668	1670	7499
	501-2500	1231	90	285	195	570	315	225	706	3617
	2501-7500	199	14	9	9	46	9	19	98	403
	TOTAL	2270	246	486	1479	2448	1204	912	2474	11519

Table A-8

MAJOR INDUSTRY APPLICATION NUMBERS

<u>Reference Number</u>	<u>Application</u>
<u>ELECTRIC UTILITY</u>	
902	Electric Utility
904	Coolant Pump Motor for Pressurized Water Reactors
905	Vertical Motors for Boiling Water Reactor Recirculating Pumps
907	Horizontal Pump, Fan and Blower Motors
909	Vertical Pump Motors
910	Coal Pulverizer Motors
912	Nuclear Standby Generators
<u>FLUID HANDLING</u>	
916	Petroleum Pipeline Pump Motors
920	Heavy Industry Pump and Fan Motors
926	Gas Turbine Starting Motors
927	Industrial Vertical Pump Motors
930	Plant Air Centrifugal Compressor Motors
931	Heavy Industry Compressor (Other than Reciprocating) and Blower Motors
936	Plant Air Reciprocating Compressor Motors
937	Process Gas Reciprocating Compressor Motors
940	Wind Tunne Motors
<u>NAVY AND MARINE</u>	
947	Ship Propulsion Motors
948	Ship Propulsion Generators
950	Marine Ship Service Standby and Emergency Generators
951	Navy Combat Ship Service and Emergency Generators
<u>MATERIAL HANDLING</u>	
953	Material Handling
955	Crane and Hoist Motors
956	Conveyor Motors
958	Dredge Pump and Cutter Motors
960	Motors for Erie Excavator M-G Set Service
<u>MATERIAL PROCESSING</u>	
963	Material Processing - Papermaking Processes
965	Wood Chipper Motors
966	Beater and Pulper Motors
967	Refiner Motors
968	Options and Accessories
969	Rubber and Plastic Processes Motors
971	Material Processing - Size Reduction
972	Ball, Rod and Other Grinding Mill Motors
973	Crusher Motors

Table A-9

NUMBER OF INDUCTION MOTORS BY MAJOR INDUSTRY

NEMA MARKET - ORDERS BASIS, 201-500 HP, 1976									
REFERENCE NUMBER	UTILITY	PROC. ENG.	PETRO CHEM.	PAPER	PUMP COMPR.	MINES	METAL INDUS.	GEN'L MFG'G	TOTAL
907	605				36			84	725
910	59			13				50	122
916									0
920	59	92	125	1033	458	475	501	1002	3745
930					37				37
931	17		67	89	550	62	33	234	1052
936					476				476
937					165			17	182
938					110				110
950									0
956	100	30				88	13	150	381
960						9	13		22
965				26			27	33	86
966				38				17	55
967				76				17	93
969								33	33
973		20				246	53	33	352
978							28		28
TOTAL	840	142	192	1275	1832	8817	668	1670	7499
NEMA MARKET - ORDERS BASIS, 501-2500 HP, 1976									
REFERENCE NUMBER	UTILITY	PROC. ENG.	PETRO CHEM.	PAPER	PUMP COMPR.	MINES	METAL INDUS.	GEN'L MFG'G	TOTAL
907	616				148			28	792
910	480								480
916			91						91
920	74	38	74	170	154	211	137	184	1042
930					131			14	145
931		7	111	8	51	16	25	318	536
936					11				11
937		23	9		46				78
938					29				29
950									0
956	49	7				16	45		117
960								14	14
965				17			9		26
966									0
967								113	113
969								28	28
973	12	15				72	9	7	115
TOTAL	1231	90	285	195	570	315	225	706	3617

INDUSTRIAL FACILITY SURVEY

The question was asked as to whether a survey of the motor compositions of several of one particular type of industrial facility might reveal a 'typical' motor composition for that type of facility. Such a survey was undertaken and covered a total of 25 facilities. Included in the survey were four steel mills, seven paper mills, six general manufacturing plants, two mine-ore refineries, five petro-chemical plants, and one food processing plant. The results are tabulated in Tables A-10 to A-14, and total figures are given in Table A-15.

An examination of the data for any one of these types of industrial facilities where several samples were included indicates a large variation in the composition of the induction motor load. Also, the split between induction and synchronous motors is highly variable. Thus, this data could not support a typical motor composition for any of the types of industrial facilities examined. It is significant that this type of data can be gathered for large industrial plants. Also, if more were known about the actual work within the plants of each type, it might be possible to better define a 'typical' motor composition. For example, paper mills can differ considerably in installed machinery, and thus installed motors, because of the different kinds of products manufactured. The 'paper mill' designation is not sufficiently definitive to determine motor composition.

PUBLISHED REPORTS

Two published reports, which are available to the public, were determined to contain data which would be of use in better defining motor load composition. These two reports are: "Energy Efficiency and Electric Motors" by Arthur D. Little, Inc. (1) and the Census of Manufacturers published by the U.S. Department of Commerce.

The report by Arthur D. Little, Inc. was prepared in 1976 for the Federal Energy Administration to help determine the energy that might be saved from more efficient electric motors. This report has been studied, with the following points being most significant to this project.

1. 1 to 125 HP, 3 phase, induction motors are the predominant energy consumers. They are used principally to drive pumps, compressors, and blowers in the process industries such as chemical, primary metals, paper, and the like. These motors consume about 26% of the total electric power generated in this country.
2. Of the approximately 290 billion kw-hrs of electric energy consumed in

Table A-10

SURVEY RESULTS - STEEL MILL MOTOR COMPOSITION

NUMBER OF MOTORS AND TOTAL HORSEPOWER
INDUCTION MOTORS

<u>Facility</u>	<u>0-100 HP</u>		<u>101-500 HP</u>		<u>500-7500 HP</u>		<u>>7500 HP</u>	
	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>
1	5	203	14	4,614	38	59,624	2	19,400
2	---	---	4	1,000	9	12,200	---	---
3	14	3,335	41	26,725	28	41,280	---	---
4	592	12,410	9	3,200	26	24,850	---	---

SYNCHRONOUS
MOTORS

<u>Facility</u>	<u>QTY</u>	<u>TOT HP</u>
1	4	31,400
2	---	---
3	48	137,080
4	---	---

PERCENTAGE BREAKDOWN BY HORSEPOWER

<u>Facility</u>	<u>TOTAL INDUCTION HP</u>	<u>0-100HP %</u>	<u>101-500HP %</u>	<u>500-7500 %</u>	<u>>7500HP %</u>	<u>TOTAL SYNCHRONOUS HP</u>
1	83,841	.24	5.5	70.95	23.09	31,400
2	13,200	---	7.57	92.35	---	---
3	71,340	4.67	37.41	57.8	---	137,080
4	40,460	30.65	7.9	61.38	---	---

Table A-11

SURVEY RESULTS - PAPER MILL MOTOR COMPOSITION

NUMBER OF MOTORS AND TOTAL HORSEPOWER

Facility	INDUCTION MOTORS						SYNCHRONOUS MOTORS	
	0-100 HP		101-500 HP		500-7500 HP		QTY	TOT HP
	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>		
1	123	10,875	208	34,160	118	105,750	24	14,440
2	245	8,453	31	8,050	1	600	9	2,250
3	1,444	29,877	29	8,500	---	---	19	10,150
4	651	23,981	174	44,365	23	17,800	106	60,460
5	57	3,105	21	6,450	6	7,800	1	700
6	1,755	29,122	125	28,825	7	4,440	42	19,600
7	2	200	87	24,800	9	7,600	58	53,265

PERCENTAGE BREAKDOWN BY HORSEPOWER

Facility	TOTAL INDUCTION HP	0-100HP %	101-500HP %	500-7500 %	>7500HP %	TOTAL SYNCHRONOUS HP
	<u>HP</u>	<u>%</u>	<u>%</u>	<u>%</u>	<u>%</u>	<u>HP</u>
1	150,785	7.21	22.65	70.13	---	14,440
2	17,103	49.42	47.07	3.51	---	2,250
3	38,377	77.85	22.15	---	---	10,150
4	86,146	27.84	51.45	20.66	---	60,460
5	17,355	17.89	37.16	44.94	---	700
6	62,347	46.71	46.23	7.01	---	19,060
7	32,600	.61	76.07	23.3	---	53,265

Table A-12

SURVEY RESULTS - GENERAL MANUFACTURING PLANT MOTOR COMPOSITION

NUMBER OF MOTORS AND TOTAL HORSEPOWER

Facility	INDUCTION MOTORS						SYNCHRONOUS MOTORS	
	0-100 HP		101-500 HP		500-7500 HP		QTY	TOT HP
	QTY	TOT HP	QTY	TOT HP	QTY	TOT HP		
1	307	15,111	37	9,426	10	8,770	---	---
2	3,754	24,965	45	9,475	---	---	2	600
3	65	1,338	11	1,825	1	1,500	---	---
4	35	2,520	8	2,545	---	---	---	---
5	188	14,430	83	21,025	21	25,850	31	75,625
6	198	11,775	56	11,430	39	50,188	42	28,169

PERCENTAGE BREAKDOWN BY HORSEPOWER

Facility	TOTAL INDUCTION HP	0-100HP %	101-500HP %	500-7500 %	>7500HP %	TOTAL SYNCHRONOUS HP
1	33,307	45.37	28.3	26.33	---	---
2	34,440	72.49	27.51	---	---	600
3	4,663	28.69	39.14	32.17	---	---
4	5,065	49.75	50.25	---	---	---
5	61,305	23.54	34.3	42.17	---	75,625
6	73,393	16.04	15.57	68.38	---	28,169

Table A-13

SURVEY RESULTS - MINES-ORE REFINERIES AND
FOOD PROCESSING PLANTS MOTOR COMPOSITION

NUMBER OF MOTORS AND TOTAL HORSEPOWER

MINES-ORE REFINERIES

<u>Facility</u>	INDUCTION MOTORS						SYNCHRONOUS MOTORS	
	0-100 HP		101-500 HP		500-7500 HP		<u>QTY</u>	<u>TOT HP</u>
	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>		
1	---	---	12	3,800	14	33,200	4	14,400
2	1,077	15,715	102	26,798	33	33,600	96	67,130

FOOD

<u>Facility</u>	INDUCTION MOTORS						SYNCHRONOUS MOTORS	
	0-100 HP		101-500 HP		500-7500 HP		<u>QTY</u>	<u>TOT HP</u>
	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>		
1	140	4,735	4	525	---	---	---	---

MOTOR COMPOSITION, PERCENTAGE BREAKDOWN BY HORSEPOWER

MINES - ORE REFINERIES

<u>Facility</u>	<u>TOTAL INDUCTION HP</u>	<u>0-100HP %</u>	<u>101-500HP %</u>	<u>500-7500 %</u>	<u>>7500HP %</u>	<u>TOTAL SYNCHRONOUS HP</u>
1	37,000	---	10.27	89.73	---	14,400
2	76,113	20.65	35.21	44.14	---	67,130

FOOD

<u>Facility</u>	<u>TOTAL INDUCTION HP</u>	<u>0-100HP %</u>	<u>101-500HP %</u>	<u>500-7500 %</u>	<u>>7500HP %</u>	<u>TOTAL SYNCHRONOUS HP</u>
1	5,250	90.02	9.98	---	---	---

Table A-14

SURVEY RESULTS - PETRO-CHEMICAL PLANT MOTOR COMPOSITION

NUMBER OF MOTORS AND TOTAL HORSEPOWER

Facility	INDUCTION MOTORS						SYNCHRONOUS MOTORS	
	0-100 HP		101-500 HP		500-7500 HP		QTY	TOT HP
	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>		
1	527	37,199	442	106,075	91	110,050	8	7,800
2	160	12,200	114	24,675	36	45,750	15	9,700
3	166	5,975	30	8,550	11	11,500	---	---
4	324	4,364	62	17,550	10	12,000	3	4,500
5	5,543	61,831	108	26,625	17	11,400	---	---

PERCENTAGE BREAKDOWN BY HORSEPOWER

Facility	TOTAL INDUCTION HP	0-100HP %	101-500HP %	500-7500 %	>7500HP %	TOTAL SYNCHRONOUS HP
	<u>HP</u>	<u>%</u>	<u>%</u>	<u>%</u>	<u>%</u>	<u>HP</u>
1	253,324	14.68	41.87	43.44	---	7,800
2	82,625	14.77	29.86	55.37	---	9,700
3	26,025	22.96	32.85	44.19	---	---
4	33,914	12.87	51.75	35.38	---	4,500
5	99,856	61.92	26.66	11.42	---	---

Table A-15

SUMMARY OF SURVEY RESULTS - MOTOR COMPOSITION OF INDUSTRIAL FACILITIES -
TOTALS FOR EACH TYPE OF FACILITY

<u>Facility</u>	INDUCTION MOTORS								SYNCHRONOUS MOTORS	
	0-100 HP		101-500 HP		500-7500 HP		>7500 HP		<u>QTY</u>	<u>TOT HP</u>
	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>	<u>QTY</u>	<u>TOT HP</u>		
STEEL MILLS	611	15,948	68	35,539	101	137,954	2	19,400	52	168,480
PAPER MILLS	4,275	105,613	588	155,150	155	143,950	---	---	201	160,325
GENERAL MAN.	4,547	70,139	240	55,726	71	86,308	---	---	75	104,394
MINING	1,077	15,715	114	30,598	47	66,800	---	---	100	81,130
PETRO- CHEM.	6,720	121,569	756	183,475	165	190,700	---	---	26	22,000
FOOD	140	4,735	4	525	---	---	---	---	---	---

the commercial and industrial sectors of the U.S. economy in 1972, about 60% was used to power electric motors in industrial and commercial process equipment. Approximately 51 million motors are in use in the industrial and commercial sectors of our economy, and despite the predominance of fractional HP motors, integral HP units consume about 93% of the electrical energy consumed by the two sectors.

3. Five process industries, chemicals, primary metals, paper, food, and petroleum products, consume 50% of all motor drive electric power supplied to the industrial and commercial sectors.
4. 76% of the total industrial electrical consumption in 1972 was consumed by industrial motor drives. 63% of the total commercial electrical consumption was consumed by commercial motor drives.
5. Approximately 50% of all motors sold are purchased by original equipment manufacturers - manufacturers of pumps, blowers, machine tools, and a myriad of other equipment ultimately supplied to end users complete with motors.
6. The power consumed by industrial motors is predominately (65%) associated with general purpose rather than special industry machinery; i.e., pumps (31%), compressors (18%), and blowers and fans (16%).
7. The 200 billion kw-hrs of electrical consumption in the commercial sector in 1972 was broken down as follows: air conditioning - 110 billion kw-hr, refrigeration compressors - 70 billion kw-hr, and other motor applications - 20 billion kw-hr.

The Census of Manufacturers is a major source of information on manufacturers and their products, including motors. For the 1972 Census of Manufacturers, questionnaires were mailed to all multi-unit companies and all single-unit establishments with 10 or more paid employees. For approximately 130,000 single-unit establishments with less than 10 employees, information is obtained from administrative records. Although these small firms account for about 40 percent of all manufacturing firms, they account for less than three percent of manufacturing activity.

The Census of Manufacturers can be of use in determining motor load composition. Two reports are of particular interest - the Industry Series and the Area Series.

- 1) The Industry Series of reports can be used to determine the quantity and values of the motors shipped by motor manufacturers, and in some cases to determine the quantity and value of the motors used in end products by other manufacturers.
- 2) The Area Series of reports can be used to gather data on motor production and use by area of the country (city and state).

REFERENCES

1. "Energy Efficiency and Electric Motors", Arthur D. Little, Inc., prepared for Federal Energy Administration, under Contract No. C0-04-50217-00, May 1976.