ANALYSIS AND FORECAST OF ELECTRICAL DISTRIBUTION SYSTEM MATERIALS

FINAL REPORT

VOLUME II

TASK REPORTS

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VOLUME II

TASK REPORTS

ANALYSIS AND FORECAST OF ELECTRICAL DISTRIBUTION SYSTEM MATERIALS

A B S T R A C T

This report documents the methodology and the results of a one-year study on the availability of input materials for electrical distribution equipment. It contains (1) three electrical usage scenarios for the period 1976-2000, (2) the associated equipment and input materials requirements forecasts, (3) an analysis of the availability of these inputs from a raw material and manufacturing capacity perspective, (4) an analysis of potential material substitutions that could be made to alleviate shortages, and (5) r&d and policy recommendations.

ANALYSIS AND FORECAST OF ELECTRICAL DISTRIBUTION SYSTEM MATERIALS

Final Report

Volume II

TASK REPORTS

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CHAPTER 1

OVERVIEW OF STUDY TASKS

1.1 Introduction

The Westinghouse Electric Corporation was contracted by the Energy Research and Development Administration under Contract No. E(49-18) 2050 to conduct a one-year study on the availability of materials used in electrical distribution equipment. The primary objective was to identify potential input material shortages and make r&d and policy recommendations that would alleviate the potential availability problems.

The time interval considered in the study was the 1975-2000 interval.

1.2 Task Definitions and Their Relationship

The future availability of inputs for the manufacture of electrical distribution equipment (as purchased by the electric utilities) was forecasted by performing the following three basic analysis steps:

1. Forecast of distribution equipment material requirements for three electrical energy usage scenarios.
2. Forecast of the availability of these inputs and an analysis of the timing of any potential shortages, the severity of the shortages, and their sensitivity to the economic and energy scenarios.
3. Identification of possible substitutes for inputs that are forecasted to have restricted availability and r&d and policy recommendations for alleviating potential input shortages.

These three basic steps in the analysis were divided into seven tasks each of which is briefly discussed in the following sections.

1.2.1 Forecast of Material Requirements

The forecast of distribution equipment material input requirements involved three tasks. They were:

1. Forecast of Electrical Energy Usage (Task 1) - Three electrical energy usage scenarios were developed that provide a realistic span of electrical usage between 1975 and 2000.
2. Forecast of Distribution Equipment Requirements (Task 2) - Unit forecasts were made for each of the electrical usage scenarios for approximately 20 equipment categories.
3. Forecast of Material Requirements (Task 3) - A matrix was developed that specifies the input materials required to manufacture a unit of each equipment type. This matrix was then multiplied by the unit equipment forecasts to yield the material requirements. Approximately 50 input materials were considered. Forecasted changes in future material usage patterns were analyzed.

1.2.2 Forecast the Availability of Input Materials

The forecasts of input material availability involved two tasks. They were:

1. Raw Material Availability (Task 4) - The raw materials that are required to produce the direct inputs to the manufacture of electrical distribution equipment were analyzed from a resource base, cumulative demand, and security of supply perspective.

2. Input Material Availability (Task 5) - Capacity forecasts for the various sectors that are involved in transforming the raw materials into the inputs for distribution equipment were developed and compared with demand forecasts. Alternative economic forecasts were considered. The input materials were then assigned to one of three supply-status categories; (1) shortage, (2) marginal, and (3) no shortage.

1.2.3 Substitute Materials and R&D and Policy Recommendations

The final two tasks were concerned with identifying substitutes and/or making recommendations that would alleviate the problems caused by limited availability of certain inputs. The final two tasks were:

1. Potential Material Substitutes (Task 6) - The functional characteristics of the input materials were analyzed to determine the potential for substitution, including the development of new materials and altered designs. Emphasis was placed on those materials forecasted to be in the shortage and marginal supply categories.
2. R&D and Policy Recommendations (Task 7) - Recommendations were developed for r&d programs and policies that would, over the long term, circumvent several of the material availability problems. R&D recommendations were made to allow technical innovations to take place.

The succeeding chapters in this volume report the work done on each of the seven tasks. Where appropriate, a summary of results section is included for the reader's convenience.

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CHAPTER 2

FORECAST OF U. S. ELECTRICAL ENERGY USAGE

2.1 Task Description

Task 1 is concerned with developing electrical energy usage scenarios that provide a realistic span of electrical usage between 1975 and 2000. These scenarios are used in subsequent tasks to develop equipment and material usage forecasts. Specifically, Task 1 is composed of the following two work elements.

1. Construct three scenarios that provide a reasonable span of future U. S. electrical usage.
2. Develop supporting details for the scenarios, i.e., electrical energy by end-use market sector, estimate customers by class, etc.

2.2 Summary of Results

Table 2.1 presents the electrical usage of major end-use categories for three scenarios (low, base, and high) for 1975-2000. Table 2.2 presents the compound annual growth rates for the five-year intervals.

2.21 Base Electrical Energy Scenario

The base scenario shows an annual compounded growth of around 5.0% for total kw-hrs sales. The residential growth (5% annual compounded) is spurred primarily by increasing household formation rising from 71.2 million in 1975 to 112 million by the year 2000. Average kw-hr use per household rises from 8200 kw-hrs/year in 1975 to 14,500 kw-hr/year by 2000. This increased use per household is primarily accounted for by increased saturations of electric water heating (45%), air conditioning (59%), and space heating (35%) by the year 2000.

Table 2.1

ELECTRICAL ENERGY SALES (10^9 kw-hrs)

<u>Year</u>	<u>TOTAL</u>	<u>residential</u>	<u>industrial</u>	<u>commercial and other</u>	<u>transportation</u>
		<u>b a s e c a s e</u>			
1975	1735	587	651	497	-
1980	2290	760	920	610	-
1985	3059	985	1260	814	-
1990	3848	1241	1627	980	-
1995	4751	1563	2043	1145	-
2000	5765	1980	2474	1311	-
		<u>h i g h g r o w t h c a s e</u>			
1975	1735	587	651	491	6
1980	2590	853	1030	675	32
1985	3999	1388	1627	884	100
1990	5561	1867	2324	1114	255
1995	7331	2274	3265	1393	400
2000	8818	2667	3879	1699	573
		<u>l o w g r o w t h c a s e</u>			
1975	1735	587	651	497	-
1980	2157	695	877	586	-
1985	2916	972	1257	687	-
1990	3567	1168	1610	789	-
1995	4430	1543	1995	892	-
2000	5054	1717	2336	1001	-

Table 2.2

ELECTRICAL ENERGY SALES (compound growth rates %)

<u>Year</u>	<u>TOTAL</u>	<u>residential</u>	<u>industrial</u>	<u>commercial and other</u>	<u>transportation</u>
		<u>b a s e</u>	<u>c a s e</u>		
1975-1980	5.7	5.3	7.16	4.18	-
1980-1985	5.96	5.32	6.49	5.93	-
1985-1990	4.7	4.73	5.25	3.78	-
1990-1995	4.3	4.72	4.66	3.16	-
1995-2000	3.94	4.8	3.9	2.74	-
		<u>h i g h</u>	<u>g r o w t h</u>	<u>c a s e</u>	
1975-1980	8.34	7.76	9.6	6.57	39.7
1980-1985	9.07	10.2	9.57	5.54	25.6
1985-1990	6.81	6.1	7.39	4.73	20.6
1990-1995	5.68	4.0	7.03	4.57	9.4
1995-2000	3.76	3.24	3.5	4.05	7.5
		<u>l o w</u>	<u>g r o w t h</u>	<u>c a s e</u>	
1975-1980	4.45	3.4	6.14	3.35	-
1980-1985	6.21	6.9	7.5	3.23	-
1985-1990	1.04	3.7	5.07	2.8	-
1990-1995	4.42	5.7	4.4	2.48	-
1995-2000	2.67	2.2	3.2	2.33	-

The industrial growth (5.5% compounded annually) is driven by increasing production as forecasted by Federal Reserve Board Production Indices and by continuing trends in increasing electrical intensiveness in industry. These trends are detailed by SIC code for mining and manufacturing.

The basic driving force behind the commercial growth (4% compounded annual) is the increase in commercial floor space. In the model, the floor space increase was forecasted at about the same growth as GNP. For this base case, space heating saturations increased from 4.7% in 1975 to 10% by 2000. Commercial air conditioning saturations increased from 60% in 1975 to 90% in 2000. It was assumed that lighting (6.2 kw-hr/sq ft/yr), and air conditioning (5.3 kw-hrs/sq ft/yr) intensities remained constant throughout the forecast period to reflect continuing conservation.

2.22 High Growth Electrical Scenario

The high electrical growth case differs from the base case through the substitution of electricity for many previous natural gas uses. This high growth scenario shows an annual compounded growth of around 6.7% for total kw-hr sales, and is considered to be the upper bound on electrical usage unless extreme efforts were undertaken to substitute electricity for oil and gas in the industrial sector.

The residential growth (6.3%) is accelerated above the base by increased penetration of electric space heating, water heating, ranges, electric dryers, and air conditioning. Average kw-hr use per household rises from 8200 kw-hrs/year in 1975 to 23,500 kw-hrs/year in 2000.

The industrial growth (7.5%) is accelerated above the base case through substitution for natural gas. The limited availability of natural gas to industry is reflected in the model through increasing natural gas prices which force substitution through the cross elasticity effects.

This mechanism was used even though prices may be regulated and substitutions mandated by allocation of available supplies. Artificially high prices were inputted to the model which, when coupled with input elasticities, caused an adjustment of electricity demands to account for shortages of gas in various industries.

It was assumed that substitution for natural gas would occur in those industries which use process steam and direct heat. Since viable technology now exists for substituting for these end uses at increased efficiencies, it was assumed that electricity is substituted for 25% of these uses in 1985 and for 75% of these uses by 2000. An efficiency improvement of 100% was assumed. This does not account for all natural gas shortages, but it was assumed that other uses would be more easily and less expensively substituted with oil.

The commercial growth (5.3%) is accelerated over the base case through increased penetration of electric space heating in the sector.

The transportation sector assumes a most optimistic growth in the use of electrified rail, bus, and personal vehicles. This use rises from 6.1 billion kw-hrs in 1975 to 572 billion kw-hrs in the year 2000. This scenario includes 58 million vehicles on the road by the year 2000 with each averaging 10,000 miles/year and 3.1 miles per kw-hr.

2.23 Low Electrical Growth Scenario

The low electrical growth case differs from the base case in that it is driven by a much more slowly expanding economy. This low growth scenario shows an annual compounded growth of approximately 4.4% for total kw-hr sales.

Residential sales differ from the base case in that a much lower penetration of electric space heating is evident.

Commercial sales are lowered by little penetration in space heating and no saturation increase in air conditioning.

Industrial sales are lowered by the lower production levels assumed in the macro-economic driving variables.

2.3 Methodology

The previously developed Westinghouse Electric Energy Demand Model was used to develop the forecasts presented in the previous section. This model is a simulation type model as contrasted with simple trend projection and econometric types.

Conventional utility load forecasting techniques quite often have relied on historical trends and simple econometric relationships between energy sales, peak load, and market demand factors. While these models are probably valid and quite useful for short-term (a few quarters or even a few years) forecasting, they are inconvenient for long-term forecasting.

Obviously, all models rely on our knowledge of the present and the past and our conceptions of the future. In developing a long-term forecast using trend or econometric techniques, we know that lifestyle and technology changes will change the trend or regression coefficients, but it is not explicitly clear or convenient to adjust these. In using a simulation model, explicit input variables for technology (i.e., number of households, number of appliances, average use per appliance) are used and may be adjusted directly in the forecast. In either case, our estimate of the future is critical in the long-term forecast; however, the mechanics of implementing these estimates are simplified with the simulation technique. In addition, general calculations of almost any type (e.g., highly non-linear or discontinuous functional forms) may be included in simulation methodology, whereas the econometric techniques are limited to forms that can ultimately be expressed in a linear regression form.

Some advantages may be delineated for using a computer model in analyzing electrical energy demand. First of all, it provides a consistent framework for the investigation. Using a computer model automates most of the bookkeeping and some of the documentation. All assumptions in the computer modeling process must be clearly stated and quantified, thus enabling all who scrutinize the model input data and output results to see the logic of the decision processes used. Sensitivity analysis requiring large numbers of calculations may be performed, whereas without the model these would be time consuming, expensive, and tedious.

2.31 Structure of the Model

A system block diagram of the electrical energy demand model is shown in Figure 2.1. The model is structured such that the major decomposition is defined by the residential, industrial, and commercial market sectors. Other end uses, such as transportation, street and highway

FIG. 2.1 -Electrical energy demand model system block diagram

lighting, public authorities, and interdepartmental uses, are treated as exogenous inputs which are added in the model to obtain the total forecast.

2.32 Residential Market Sector

The residential market model uses population and household formation data forecasts to estimate future households. Input appliance data allow the model to calculate saturations for 15 appliances over the time period under investigation. Saturation in this model is defined as the number of households having a particular appliance installed divided by the total number of households. Using base values and annual rates of change inputs, the annual uses for each of 15 appliances plus space heating are estimated. The appliance saturations values are then multiplied by the households to obtain the number of installed appliances. The annual use for each appliance is multiplied by the number of each type of appliance and summed to obtain the base residential demand.

This base demand is adjusted using electricity and competing fuel prices. Using self- and cross-elasticities, which are input to the model, the fuel and electricity price ratios are used to calculate demand adjustment factors. If short-run elasticities are used, then these adjustments are applied directly to the base demand. If long-run elasticities are used, then additional appliance replacement rate input data are used to calculate the amount of the adjustment to be applied on an annual basis.

2.33 Industrial Market Sector

The base demand for the industrial market sector is estimated by multiplying the value added in industry by an electrical energy intensiveness factor and then multiplying this product by the Federal Reserve Board Production Index. The electrical energy intensiveness factor is a ratio of the kw-hrs used in industry in a base year divided by the dollars of value added in that year. This methodology is used for each of 20 manufacturing sectors and five mining sectors.

The base industrial demand is adjusted to reflect electricity and competing fuel prices in a manner similar to that described for the residential sector.

2.34 Commercial Market Sector

The commercial market model uses an input describing gross national product growth to estimate the additions to commercial floor space. Lighting, space heating, air conditioning, and miscellaneous uses are then calculated based on the average requirements for each square foot of floor space.

Intensiveness factors defining the average kw-hrs used for each square foot of floor space for lighting, space heating, and air conditioning are input to the model. Using other inputs defining the electrical heating and air conditioning saturations over time and multiplying by these intensity factors yields estimates of the base commercial demand.

The base commercial demand is adjusted to reflect electricity and competing fuel prices in a manner similar to that described for the residential sector.

2.4 Electrical Energy Scenarios

Three scenarios (base, high, and low growth) have been developed which provide a reasonable span for future electrical growth. The three electrical growth scenarios are based on two macro forecasts of the economy. The base macro-economic forecast is taken from the DRI (reference 1) TREND LONG (12/75). A low growth economic forecast has been obtained from the base forecast by scaling the base forecast for lower GNP growth.

Both the base and high electrical growth scenarios are developed from the base macro-economic forecast (Tables 2.3 and 2.4). The rationale being that the high electrical growth differs from the base case only through substitution of electricity for scarce natural gas. It is assumed that this is a dollar-for-dollar substitution, thus the macroeconomy for both cases can be the same. On a Btu basis, electricity is on the order of five times more expensive than natural gas, but the number of Btus of electricity used to replace natural gas processes in the high growth scenario will be considerably less. This is true because the electrical processes are inherently more efficient and because additional capital equipment

Table 2.3

DEMOGRAPHIC AND HOUSEHOLD FORECAST

<u>Year</u>		<u>Population</u> (10 ⁶)	
1975		213.4	
1980		221.8	
1985		230.9	
1990		239.1	
1995		245.6	
2000		250.6	

<u>housing starts</u>		(base and high electrical growth cases)	
		(millions of units)	
single family		multi family	
5 yr. ann.		5 yr. ann.	
<u>ave.</u>	<u>cum.</u>	<u>ave.</u>	<u>cum.</u>
76-80	1.31 6.532	.732	3.659
81-85	1.35 13.267	.851	7.913
86-90	1.43 20.4	.674	11.283
91-95	1.43 27.567	.674	14.653
96-2000	1.43 34.72	.674	18.023

		mobile home shipments	
5 yr. ann.		5 yr. ann.	
<u>ave.</u>	<u>cum.</u>	<u>ave.</u>	<u>cum.</u>
		.51	2.553
		.73	6.21
		.71	9.76
		.71	13.31
		.71	16.86

<u>housing starts</u>		(low electrical growth case)	
		(millions of units)	
single family		multi family	
5 yr. ann.		5 yr. ann.	
<u>ave.</u>	<u>cum.</u>	<u>ave.</u>	<u>cum.</u>
76-80	1.31 6.532	.732	3.659
81-85	1.29 13.0	.82	7.75
86-90	1.0 18.0	.47	10.1
91-95	.5 20.5	.2	11.1
96-2000	.3 22	.18	12.0

		mobile home shipments	
5 yr. ann.		5 yr. ann.	
<u>ave.</u>	<u>cum.</u>	<u>ave.</u>	<u>cum.</u>
		.51	2.553
		.705	6.08
		.484	8.5
		.4	10.5
		.4	12.5

Table 2.3 (continued)

ESTIMATES OF CUSTOMERS FOR LOW, BASE, AND HIGH GROWTH CASES

	<u>Residential</u> <u>(households)</u>	<u>Industrial</u>	<u>Commercial</u>	<u>TOTAL</u>
Low				
1975	71,214,142	369,893	10,312,228	81,896,263
High				
Low	"	475,820	9,840,000	90,970,365
1980	79,640,061	520,979	11,425,180	91,587,220
High	"	"	"	"
Low	"	591,626	11,480,000	104,431,620
1985	88,910,280	648,163	12,744,916	102,246,822
High	"	"	"	"
Low	95,639,997	707,850	13,120,000	109,467,840
1990	96,101,285	786,767	13,628,426	110,516,478
High	"	"	"	"
Low	98,239,997	847,598	14,760,000	113,847,590
1995	104,111,511	926,161	14,690,626	119,728,698
High	"	"	"	"
Low	100,239,997	988,765	16,400,000	117,628,950
2000	112,075,134	1,068,116	16,811,270	128,886,404
High	"	"	"	"

Table 2.4

MACROECONOMIC FORECASTbase and high electrical growth case[†]

	<u>GNP (58\$ x 10⁹)</u>	<u>value added in manufacturing (58\$ x 10⁹)</u>	<u>value added in mining (58\$ x 10⁹)</u>
1975	797	293.2	20.8
1980	1013	402	22.8
1985	1223	468	26.2
1990	1405	546	29.9
1995	1624	600	34.4
2000	1832	726	39.6

low electrical growth case

	<u>GNP (58\$ x 10⁹)</u>	<u>value added in manufacturing (58\$ x 10⁹)</u>	<u>value added in mining (58\$ x 10⁹)</u>
1975	792	293.2	20.8
1980	950.4	381.2	22.8
1985	1108.8	466	26.3
1990	1267.2	540	29.9
1995	1425.6	586	34.4
2000	1584.0	686	39.6

Non-residential Structures (58\$ x 10⁹)

	<u>low electrical growth</u>	<u>base and high electrical growth</u> [†]
1975	24.5	24.5
1980	25.2	26.17
1985	29.3	33.3
1990	33.6	39.1
1995	37.3	44.7
2000	41.2	50.5

[†] Source: Data Resources, Inc., Long-Term Forecast (12/75).

expenditures will be made for conservation at the same time substitution is implemented. It is assumed that the additional expansion in electrical capacity that is needed to meet substitution requirements is approximately counterbalanced by the declining expansion of natural gas production and transmission capacity.

The low electrical growth case arises from a low macro-economic growth and the lack of a need for electrical substitution. The macro-economic variables used for the two economic scenarios are given in Table 2.4.

2.5 Model Performance on Past History

To show that reasonable outputs are obtained for reasonable inputs, the model was used with historical values as input. The historical period under investigation was from 1967 to 1975 as shown in Table 2.5.

The historic period 1965 through 1969 was used to develop parameters for the model (e.g., household formation rate, annual use change, commercial floor space growth, industrial production increase, and relative price changes). With these parameters, the model was then used to estimate kw-hr sales for 1968 through 1975. Comparison of the results with actual historic values is documented in Table 2.5. One might question why the period 1965-69 was used for parameter estimation for the model. Since the projection starting year was 1967, this assumed some knowledge of the "future." This was justified by the fact that in any given year trends into the near future are established by the system inertia. Using the two future years, 68 and 69, in establishing the trends fairly compensates for this knowledge.

It should be emphasized that the errors obtained in Table 2.5 are not comparable to errors obtained in fitting the model to past history. If all historical values are used over the time period 67 to 75, then virtually zero error occurs. This "fitting of the model" would be analogous to the procedure used in econometric modeling where the independent and dependent variables are regressed against historical values to obtain a set of regression coefficients.

Table 2.5 MODEL PERFORMANCE ON PAST HISTORY (10⁹ kw-hrs)

<u>R e s i d e n t i a l</u>				<u>C o m m e r c i a l</u>		
	<u>model est</u>	<u>actual</u>	<u>% error</u>	<u>model est</u>	<u>actual</u>	<u>% error</u>
1967	332	332	0	243	243	0
68	367	368	- .2	263	265	- .7
69	404	408	- .1	284	287	-1
70	442	448	-1.3	308	313	-1.6
71	482	479	+ .6	333	334	- .3
72	523 *	511	+2.3 *	361 *	362	- .2 *
73	566 (555)	554	+2.1 (.1)	390 (379)	397	-1.8 (-4.7)
74	611 (574)	555	+9.2 (3.3)	422 (393)	393	+6.8 (0)
75	658 (585)	587	+10.8 (-.3)	457 (402)	416	+9 (-3.5)

<u>I n d u s t r i a l</u>				<u>T O T A L</u>		
	<u>model</u>	<u>actual</u>	<u>% error</u>	<u>model est</u>	<u>actual</u>	<u>% error</u>
1967	486	486	0	1107	1107	0
68	516	519	- .6	1197	1202	- .4
69	548	557	-1.6	1291	1307	-1.2
70	579	573	+1	1387	1391	- .3
71	618	593	+4	1494	1466	1.9
72	658 *	640	+2.7 *	1607 *	1578	1.8 *
73	699 (657)	687	+1.7 (-4.5)	1720 (1656)	1703	.9 (-2.8)
74	742 (638)	689	+7.1 (-7.7)	1839 (1669)	1701	7.5 (-1.9)
75	786 (628)	651	+17.2 (-3.7)	1967 (1681)	1720	12.5 (-2.3)

* assumes an increasing electrical energy price scenario beginning in 1972;
see text for comment

The results in Table 2.5 show forecast errors of less than 0.5% for the first projection year with errors of around 1.5% after three years. In the 1972-75 period, the model performs poorly with the input assumption of slightly decreasing real prices of electricity. This assumption would have most likely been carried through if one were making a projection in 1967. However, if one had developed an increasing price scenario, then performance would have been considerably improved as shown in Table 2.1.

2.6 Comparisons with Other Studies

Many other recent studies have examined the electrical growth for the future. These studies are briefly referenced and listed in Table 2.6. The results of these studies with regard to electrical energy output and capacity growth are compared in Table 2.7.

The scenarios presented here generally span the range of other forecasts. However, the high growth case falls short of the 10 trillion kw-hrs and 2250 GW installed of some of these previous studies.

2.7 Sensitivity Analysis

Some of the results of a sensitivity analysis on input variables to the Electrical Energy Demand Model are shown in Figures 2.2 through 2.6.

In Figure 2.2, the sensitivity of the 1980 base forecast to variables in the high and low growth cases is shown. The positive kw-hr changes when totaled and added to the base case approximate the high growth total kw-hr sales. The negative kw-hr changes when totaled and subtracted from the base case approximate the low growth total kw-hr sales.

Examination of Figure 2.2 shows that the rapidly increasing penetration of residential space heating, industrial substitution for natural gas, and the substitution of other natural gas competing appliances in the residential sector provide the major positive perturbations to the base case. A much lower expansion of the economy impacts the commercial and industrial market sectors to provide the major negative perturbations. Lower penetration of the residential space heating market than in the base case also provides a major negative perturbation.

Table 2.6

REFERENCE LISTING OF OTHER ELECTRICAL ENERGY AND CAPACITY FORECASTS*

1. This study.
2. Electrical World, 26th Annual Electrical Industry Forecast
(September 1975).
3. Westinghouse FEA Study Base Case, "Electrical Loads Offering
Major Potential for the Use of Off-Peak Power,"
June 30, 1975 Contract 14-0001-1892.
4. Westinghouse FEA Study Energy Substitution Case.
5. Chase Manhattan Bank Study.
6. Resources for the Future.
7. Department of Interior.
8. Stanford Research Institute.
9. Federal Power Commission.
10. Council on Environmental Quality.
11. Lawrence Livermore Laboratory.
12. Atomic Energy Commission.
13. National Academy of Engineering.
14. Energy Policy Project.
15. Federal Energy Administration.
16. Electrical World (1974).
17. ERDA Scenario I (1975)
18. ERDA Scenario II (1975)
19. ERDA Scenario III (1975)
20. ERDA Scenario IV (1975)
21. ERDA Scenario V (1975)

* See References 3 and 4 for more complete reference and details of these studies.

Table 2.7

COMPARISON OF FORECASTS

Forecast Reference	C a p a c i t y (GW)		Electrical Energy 10 ¹² kw-hrs	
	1985	2000	1985	2000
1 *	676+756+988	1110+1424+1811	3.2+3.4+4.4	5.5 + 6.4 + 9.6
2	755	1524 *	3.15	6.52 *
3	-	-	3.09	5.41
4	-	-	3.32	6.43
5	-	-	4.40	-
6	-	2228	-	10.8
7	915	1880	4.10	9.00
8	-	-	3.90	-
9	1070	2250	4.4	10.2
10	-	-	-	6.0
11	-	-	3.4	-
12	903	2220	4.0	10.1
13	982	-	-	-
14	-	-	2.3	3.3
15	922	-	4.0	-
16	781	-	3.6	-
17	-	-	3.0	5.0
18	-	-	3.0	7.0
19	-	-	3.5	9.0
20	-	-	3.0	5.0
21	-	-	3.0	5.0

* Extrapolated Electrical World forecast.

The load factor was assumed to be 61% except for the low growth case where 65% and 68% load factors were assumed for 1985 and 2000. Transmission and distribution losses were assumed to be 9.1% in 1985 and 9% in 2000. Reserved margin was assumed to be 20%.

Listing of Forecast Variables for Sensitivity Analysis

1. Residential Space Heating
2. Substitution of Residential Electric Appliances
3. Industrial Substitution for Natural Gas
4. Commercial Space Heating
5. Residential and Commercial Air Conditioning
6. Transportation
7. U. S. Economy Effects on Residential Consumption
8. U. S. Economy Effects on Commercial Consumption
9. U. S. Economy Effects on Industrial Consumption
10. Fuel and Electricity Price Effects on Residential Consumption
11. Fuel and Electricity Price Effects on Commercial Consumption
12. Fuel and Electricity Price Effects on Industrial Consumption

Fig. 2.2 – Sensitivity of the 1980 base forecast to variables in the high and low growth cases

Listing of Forecast Variables for Sensitivity Analysis

1. Residential Space Heating
2. Substitution of Residential Electric Appliances for Gas
3. Industrial Substitution for Natural Gas
4. Commercial Space Heating
5. Residential and Commercial Air Conditioning
6. Transportation
7. U. S. Economy Effects on Residential Consumption
8. U. S. Economy Effects on Commercial Consumption
9. U. S. Economy Effects on Industrial Consumption
10. Fuel and Electricity Price Effects on Residential Consumption
11. Fuel and Electricity Price Effects on Commercial Consumption
12. Fuel and Electricity Price Effects on Industrial Consumption

Fig. 2.3 – Sensitivity of the 1985 base forecast to variables in the high and low growth cases

Listing of Forecast Variables for Sensitivity Analysis

1. Residential Space Heating
2. Substitution of Residential Electric Appliances for Gas
3. Industrial Substitution for Natural Gas
4. Commercial Space Heating
5. Residential and Commercial Air Conditioning
6. Transportation
7. U. S. Economy Effects on Residential Consumption
8. U. S. Economy Effects on Commercial Consumption
9. U. S. Economy Effects on Industrial Consumption
10. Fuel and Electricity Price Effects on Residential Consumption
11. Fuel and Electricity Price Effects on Commercial Consumption
12. Fuel and Electricity Price Effects on Industrial Consumption

Fig. 2.4 – Sensitivity of the 1990 base forecast to variables in the high and low growth cases

Listing of Forecast Variables for Sensitivity Analysis

Fig. 2.5 – Sensitivity of the 1995 base forecast to variables in the high and low growth cases

Listing of Forecast Variables for Sensitivity Analysis

Fig. 2.6 – Sensitivity of the 2000 base forecast to variables in the high and low growth cases

In Figure 2.4 the sensitivity of the 1990 base forecast to these same variables is examined. The same relative order of effects are present with the exception that the sum of the positive perturbations when compared to the sum of the negative perturbations is much greater than in 1980. The rapidly expanding residential and transportation uses explain this effect.

Table 2.8 provides quantitative detail on the input variables used to carry out the sensitivity analysis. Figures 2.2 through 2.6, in conjunction with Table 2.8, can be used to construct alternative scenarios that fall between the high and low cases.

Table 2.8

FORECAST VARIABLES FOR SENSITIVITY ANALYSIS

1. residential space heating

- high	75% of new housing, electric heat				
- base	50%	"	"	"	"
- low	30%	"	"	"	"

2. substitution of residential electric appliances for gas saturations

- high	1980 range	(63%)	water htr	(44%)	dryer	(48%)
	1990	(84%)		(80%)		(67%)
	2000	(89%)		(98%)		(81%)
- base	1980 range	(55%)	water htr	(33%)	dryer	(45%)
	1990	(55%)		(39%)		(55%)
	2000	(55%)		(45%)		(65%)
- low	1980 range	(55%)	water htr	(33%)	dryer	(45%)
	1990	(55%)		(39%)		(55%)
	2000	(55%)		(45%)		(65%)

3. industrial substitution for natural gas

- high	10% of process steam and direct heat by 1980, 50% by 1990, 75% by 2000 with 100% efficiency improvement, substitution of other needs with oil and coal				
- base }	all demands substituted with oil and coal				
- low }					

4. commercial space heating

- high	10% saturation by 1980			
	40%	"	"	1990
	80%	"	"	2000
- base }	5%	"	"	1980
- low }	7%	"	"	1990
	10%	"	"	2000

5. commercial air conditioning

- high	70% saturation by 1980			
	90%	"	"	1990
	90%	"	"	2000
- base	70%	"	"	1980
	90%	"	"	1990
	90%	"	"	2000
- low	60%	"	"	1980
	60%	"	"	1990
	60%	"	"	2000

Table 2.8 (continued)

6. transportation
 - high 1 million electric vehicles, 200% increase (over 1975)
in electric rail by 1980
19 million electric vehicles, ten times electrified
rail use (kw-hrs) by 1990
58 million electric vehicles by 2000, 20 times
electrified rail use in 2000
 - base } less than 1% of total use for all years
 - low }
7. U. S. economy effects on residential consumption
 - high } 80 million households by 1980
 - base } 96 million households by 1990
112 million households by 2000
 - low } 80 million households by 1980
92 million households by 1990
104 million households by 2000
8. U. S. economy effects on commercial consumption
(direct effect of GNP on commercial floor space construction)
 - high GNP from Table 2.3 ($\sim 3.5\%$ compounded annual growth)
 - base
 - low GNP from Table 2.3 ($\sim 2.8\%$ compounded annual growth)
9. U. S. economy effects on industrial consumption
 - high Table 2.3 ($\sim 4.5\%$ compounded annual growth in real
value added for manufacturing and 2.8%
compounded annual growth for mining)
 - base
 - low Table 2.3 ($\sim 4.2\%$ compounded annual growth in real
value added for manufacturing and 2.8%
compounded annual growth for mining)
10. fuel and electricity price effects on residential consumption
(prices relative to 1975)
 - high no increase in real prices of electricity
30% increase in real price of gas by 1980
no increase in real prices of oil
70% increase in real price of gas by 1990
100% increase in real price of gas by 2000
 - base } no increase in real fuel prices
 - low }

Table 2.8 (continued)

- 11. fuel and electricity price effects on commercial consumption
(same assumptions as 10.)
- 12. fuel and electricity price effects on industrial consumption
 - high no increase in real prices of electricity
 120% increase in price of natural gas by 1980
 200% increase in price of natural gas by 1990
 300% increase in price of natural gas by 2000
 - base } no increase in real fuel prices
 - low }

References

1. Data Resources, Inc., "The Data Resources U. S. Long-Term Bulletin," Winter, 1976.
2. "Electric Loads Offering Major Potential for the Use of Off-Peak Power," Final Report to FEA on Westinghouse Contract 14-001-1892, June, 1975.
3. "Megastar, The Meaning of Energy Growth: An Assessment of Systems, Technologies and Requirements," Auburn University Engineering Systems Design Summer Faculty Fellows Final Report, NASA CR-120338, September, 1974.
4. G. D. Friedlander, "Energy's hazy future," IEEE Spectrum, May, 1975.

CHAPTER 3

TASK 2 - FORECAST OF DISTRIBUTION SYSTEM EQUIPMENT REQUIREMENTS

3.1 Task Description

Task 2 is composed essentially of three work elements:

1. Develop a 15-year historical data base (where possible) of equipment unit sales for equipment categories.
2. Define the independent variables (indicators) and estimate the coefficients (weights) for forecasting unit sales for each equipment category.
3. Develop unit forecasts for each category for the base, high, and low electrical energy usage scenarios.

The distribution equipment categories are forecasted by the following product categories:

Distribution Transformers

Residential Applications

Overhead

Low Growth and Upgrading
New Housing Units

Underground

Commercial Applications

Overhead

Single Phase
Three Phase

Underground

Network

Power Centers

Substation

Dry Type

Instrument

Voltage Regulators

Meters and Sockets

Switchgear

Fuses

Capacitors

Circuit Breakers

Arresters

Insulators

Cable

Overhead

Underground

Connectors

Poles

Wood

Concrete

3.2 Summary of Results

The detailed projections for 33 equipment categories for the base, high, and low electrical energy scenarios are given in Appendix 3A. A summary of these results is presented in this section.

Table 3.1 contains the historical and forecasted compounded annual growth rates for unit sales for five-year intervals between 1960 and 2000 for major equipment categories for the base case scenario. Table 3.2 gives the forecasted rates for the high and low usage scenarios. (Note that since equipment sales were severely depressed in 1975, the compound annual growth rates between 1975 and 1980 are unusually high.)

In general, most of the equipment categories have historically had rather uneven growth patterns and are forecasted to continue that pattern. For the base case, the requirement for most of the equipment categories is under 5 percent compounded annual growth for the 1975-2000 period. For the high usage case, few categories exceed 7 percent per year. When further disaggregation of equipment categories are discussed in later sections, the variations in growth rates are much more pronounced.

Two simple ways of checking the credibility of the model forecasts are by comparing growth rates of the product lines with each other and by comparing the model forecasts with time trend forecasts. These two gross comparisons are made below.

It can be seen from Tables 3.1 and 3.2 that the forecasted compound growth rates are reasonably consistent, banded in the range of zero to 7 percent, while electricity sales are projected to grow at approximately 5 percent per year for the base case. Transformers, switchgear, and connectors will grow at over 3 percent. Many of the more pole-oriented product lines are forecasted to grow more slowly because of the increased penetration of underground distribution.

Time trend forecasts are shown and compared to model projections on Table 3.3. If kw-hr sales were expected to continue at the historical 7% per year, projections for such major equipment categories as residential transformers, meters, and cable would be expected to grow as indicated by their time trend forecast. But since electricity growth is forecast at less than 5%, the time trend forecasts would be expected to overestimate equipment

Table 3.1

COMPOUND ANNUAL GROWTH RATES
FOR DISTRIBUTION EQUIPMENT UNIT SALES
(USING 1975 TECHNOLOGY)

BASE ELECTRICAL DEMAND CASE

EQUIPMENT TYPE	1960-1965	1965-1970	1970-1975	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	1975-2000
TRANSFORMERS									
RESIDENTIAL	4.73	6.43	-13.37	18.59	3.57	0.43	1.57	1.42	4.91
COMMERCIAL		6.84	-2.56	16.58	6.30	3.81	3.18	2.94	6.44
SUBSTATION	1.90	2.60	-0.03	7.84	4.49	0.53	2.54	2.20	3.49
DRY TYPE	11.70	5.95	4.52	6.96	5.45	3.64	3.26	2.75	4.40
INSTRUMENT	5.51	-1.44	-1.61	6.17	2.93	2.55	2.52	2.20	3.27
VOLTAGE REGULATORS				0.99	0.71	0.91	1.09	0.62	0.87
ISOLATORS	-0.84	1.82	-2.26	2.71	2.24	0.62			1.11
SWITCHGEAR	3.16	2.93	0.87	5.49	3.44	2.19	3.47	2.44	3.40
FUSES		5.44	-9.99	10.40	2.89	-0.65	2.00	-2.92	2.25
CAPACITORS	8.75	7.40	-5.49	0.22	11.90	1.58	5.22	-6.05	2.40
BREAKERS + RECLOSERS	0.67	0.47	-2.32	3.73	1.12	1.01	1.17	0.84	1.57
ARRESTERS			-7.73	9.92	2.41	-0.25	1.56	-1.81	2.29
POLES			1.01	0.47	0.35	0.21	0.14	0.03	0.24
INSULATORS		-0.29	-1.00	2.65	3.08	-0.70	2.12	-3.09	0.79
CABLE (OH + UG)			-0.22	5.78	3.41	-1.63	1.06	-0.31	1.63
CONNECTORS	3.42	7.05	-15.12	23.85	4.34	-0.42	2.62	-3.04	5.07

Table 3.2

COMPOUND ANNUAL GROWTH RATES
FOR DISTRIBUTION EQUIPMENT UNIT SALES
(USING 1975 TECHNOLOGY)

HIGH ELECTRICAL DEMAND CASE

LOW ELECTRICAL DEMAND CASE

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EQUIPMENT TYPE	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	1975-2000	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	1975-2000
TRANSFORMERS												
RESIDENTIAL	25.33	6.95	1.61	2.18	-2.13	6.37	15.30	5.64	-3.51	2.44	-5.15	2.69
COMMERCIAL	19.23	5.81	4.83	4.64	4.27	7.61	15.47	3.33	2.83	2.51	2.54	5.22
SUBSTATION	15.81	9.10	2.00	2.44	-3.30	5.00	2.60	9.61	-2.77	5.33	-5.79	1.65
DRY TYPE	6.96	5.45	3.64	3.26	2.75	4.46	4.67	5.16	3.34	2.70	2.32	3.63
INSTRUMENT	6.17	2.33	2.55	2.52	2.20	3.27	4.61	2.50	2.41	1.86	1.79	2.65
VOLTAGE REGULATORS	3.76	2.22	2.17	1.80	1.65	2.32	-1.84	-0.85	-0.89	-1.24	-0.65	-1.03
METERS	3.66	1.66	0.32			1.12	2.71	2.07	-3.56	-4.80	-1.85	-1.13
SWITCHGEAR	5.49	3.44	2.19	3.47	2.44	3.40	4.21	3.74	2.56	2.14	1.88	2.90
FUSES	13.75	4.96	6.80	1.74	-2.32	3.64	7.82	4.11	-1.90	2.19	-3.26	1.71
CAPACITORS	8.41	14.02	4.47	3.51	-3.64	5.19	-14.16	22.19	-3.36	11.73	-6.84	1.03
BREAKERS + RECLOSERS	4.05	1.74	1.77	1.83	1.42	2.16	3.47	0.98	0.80	1.02	0.70	1.39
ARRESTERS	12.48	4.36	1.23	1.66	-1.14	3.61	7.61	2.90	-1.68	1.33	-2.34	1.50
POLES	0.47	0.36	0.21	0.14	0.03	0.24	0.47	0.36	0.21	0.14	0.03	0.24
INSULATORS	5.97	5.23	0.83	1.82	-2.42	2.24	0.07	4.41	-2.02	2.34	-3.48	0.22
CABLE (OH + UG)	7.16	5.00	0.29	1.58	0.49	2.87	3.30	3.48	-5.61	-0.21	-1.39	-0.14
CONNECTORS	29.07	7.07	1.84	2.39	-1.63	7.23	18.76	5.71	-3.15	2.54	-4.52	3.55

Table 3.3

COMPARISON OF EQUIPMENT FORECASTS
WITH TIME TREND FORECASTS

(Forecasts for year 2000)

Major Equipment Category	Units (000)			Time Trend Forecast
	Model Low	Forecasts Base	High	
Transformers				
Residential	1122	1195	2710	3353
Commercial	196	262	344	236
Substation	4	4	8	3
Dry Type	95	114	114	88
Instrument	637	739	739	634
Voltage Regulators	6	10	14	+
Meters	2134	3735	3743	5474
Switchgear	87	99	99	80
Fuses	1518	1730	2429	2938
Capacitors	31	43	84	80
Breakers and Reclosers	25	26	30	23
Arresters	1437	1742	2405	4552
Poles	3003	3003	3003	3288
Insulators	9620	11068	15829	18149
Cable	110	170	231	252
Connectors	6129	8826	14674	16688

+/ Insufficient data for time trend.

requirements. As expected, the time trend forecasts do exceed model projections for these basic items. The forecasts for other categories, such as dry type transformers, show higher than traditional growth due to changes in the type of equipment used to serve certain loads.

It is emphasized that the equipment requirements forecasts are based on the assumption that the factors that historically determined equipment requirements will continue to provide good estimates of future requirements. Thus, the effect of any substantial changes in the distribution system, such as load management and use of photovoltaic technologies, are not included in the equipment forecasts. Such major changes are discussed in Section 4.5.

3.3 Methodology

The distribution system is made up of several heterogeneous products. Each type of equipment provides a unique function. Likewise, characteristics of price and unit volume are different among the various types of equipment. This wide variance of price and volume is accompanied by differences in price changes and market growth. Consequently, an accurate projection of requirements for distribution equipment as a whole must be composed of projections for each major equipment category.

Each equipment category was projected individually as shown by the following block diagram.

In most cases, the historical data for each category of equipment are dollar of sales statistics as released by the National Electrical Manufacturers Association (NEMA). These data were converted to constant dollars of sales by using an appropriate price index. Unit sales were obtained

by using a reference year to obtain the ratio of constant dollars per unit of equipment. Adjustments were made to account for the less than 100 percent coverage of the NEMA surveys.

In a few cases, multiple sources of historical data were available and, thus, checks could be made on the completeness and accuracy of the data. In other cases, it was necessary to estimate product category sales from more aggregated data. In all cases, the sources and estimation procedure used to assemble the historical data are clearly documented.

Regression analysis was used to develop forecast models for most equipment categories. Independent variables were selected on the basis of knowledge of the basic driving force leading to equipment use and our ability to obtain reliable long-term forecasts of the variables. Thus, the choice of independent variables was restricted to electrical energy usage variables and the more aggregate macro-economic variables.

In some equipment categories, particularly transformers, causal factors, such as houses per transformer, were used in conjunction with regression analysis to develop the forecasts. These causal factors were not formally forecasted, but rather were projected based on well-established trends and knowledge of equipment usage.

No attempt was made to account for short-term cyclical phenomena, since they cannot be forecast over the long term with any accuracy and historical data on such items as inventory levels are not available.

For all equipment categories, forecasts are made for 1975, 1980, 1985, 1990, 1995, and 2000 for three electrical energy usage scenarios given in Table 2.1. Since we are not attempting to capture short-term cyclical variations in this analysis, the forecasts for 1985, for example, should be interpreted as the unit usage for an "average" 1985 year for that particular scenario.

3.4 Distribution Transformers

The distribution transformer market is disaggregated extensively to properly analyze and forecast its components. Table 3.4 gives the level of disaggregation used to forecast transformer unit sales.

Table 3.4 DISTRIBUTION TRANSFORMER EQUIPMENT CATEGORIES

The residential and commercial applications are separated because of the difference in the basic factors that determine their requirements. The residential application is subdivided between overhead and underground because the proportions have been changing significantly. A further split of overhead is made to distinguish between load growth and upgrading and applications for new housing units. The commercial portion consists of overhead and underground categories for various voltage levels, plus network transformers and power centers.

Substation, dry type, and instrument transformers are each forecasted as separate equipment types.

3.4.1 Distribution Transformer Historical Market (≤ 500 KVA)

Table 3.5 shows the dollar value of the distribution transformer market as reported by NEMA. Table 3.6 gives two price indexes for distribution transformers as reported by the Department of Labor. These indexes were converted to a 1972 base and used with the average unit prices from the 1972 Census of Manufacturers to calculate the average unit prices given in Table 3.7. The distribution transformer unit market (Table 3.8) was then calculated by dividing the NEMA dollar market by these derived average unit prices.

3.4.2 Distribution Transformers for Residential Applications

3.4.2.1 Underground-Overhead Split

Between 1960 and 1975, the portion of new single family housing units served by underground distribution increased at a rapid rate. The underground market growth rate is expected to decrease from its recent historical rate as underground approaches saturation. Table 3.9 gives estimates from several sources of the historical penetration of underground distribution. The same table shows the most likely and high and low estimates for 1976 to 2000 that were used for this study. This information is shown graphically in Figure 3.1. The spread between the three cases for the year 2000 is quite wide, and thus should isolate any associated potential material problems.

Table 3.5

DISTRIBUTION TRANSFORMER MARKET \$(000,000)
 (≤ 500 KVA)
 Source: National Electrical Manufacturers Association

	Overhead				Underground			Total
	Single	Phase	Three Phase	Total	Single	Three	Total	Overhead and Underground
	5 KVA to 100 KVA	167 KVA to 500 KVA	15 KVA to 500 KVA		Phase to 500 KVA	Phase to 500 KVA		
1958				221.3				221.3
1959				253.3				253.5
1960				238.4			0	238.4
1961			CALCULATED **	224.2			3.0	227.2
1962				223.7		ESTIMATED*	8.0	231.7
1963				199.4			14.0	213.4
1964				217.2			23.0	240.2
1965				233.0			34.0	267.0
1966				266.7	23.9	21.4	45.3	312.0
1967				291.8	32.1	29.4	61.6	353.4
1968				261.2	45.8	37.4	83.3	344.5
1969	255.4	29.3	12.4	297.1	52.5	30.9	83.4	380.5
1970	273.5	29.0	10.0	312.5	68.3	36.1	104.3	416.8
1971	235.2	23.7	9.2	268.1	76.3	38.2	114.5	382.6
1972	251.4	22.7	10.2	284.2	98.8	43.5	142.3	426.5
1973	301.0	28.0	12.6	341.6	163.7	67.2	231.0	572.5
1974	327.1	41.5	15.5	384.1	130.1	97.9	228.0	612.1

Overhead and underground were not reported individually prior to 1969.

Figures for underground from 1966 through 1968 were obtained through a subsequent NEMA survey.

* Underground sales from 1961 through 1965 estimated by trending from reported sales in 1966 to zero sales in 1960.

** Overhead sales from 1958 through 1965 calculated by subtracting estimated underground sales from total.

Table 3.6

DISTRIBUTION TRANSFORMER PRICE INDEXES

Source: U. S. Department of Labor, Bureau of Labor Statistics

	25 KVA		225 KVA	
	Code 11-74-01-11		Code 11-74-01-15	
	<u>1967 = 100</u>	<u>1972 = 100</u>	<u>1967 = 100</u>	<u>1972 = 100</u>
1958	118.8	144.5		
1959	117.8	143.3		
1960	116.1	141.2		
1961	114.6	139.4		
1962	109.0	132.6		
1963	97.1	118.1		
1964	95.9	115.3	97.5	120.7
1965	93.5	113.7	94.6	117.1
1966	94.1	114.5	96.0	118.7
1967	100.0	121.7	100.0	123.8
1968	102.9	125.2	100.8	124.8
1969	93.7	114.0	96.2	119.1
1970	97.1	118.1	95.4	118.1
1971	90.4	110.0	84.4	104.5
1972	82.2	100.0	80.8	100.0
1973	85.4	103.9	88.6	109.7
1974	94.6	115.1	98.2	121.5

Table 3.7

DERIVED AVERAGE PRICES FOR DISTRIBUTION TRANSFORMER MARKET (Dollars)
(≤ 500 KVA)

	<u>O v e r h e a d</u>				<u>U n d e r g r o u n d</u>			<u>T O T A L</u>
	<u>Single Phase</u>		<u>Three Ø</u>	<u>Total</u>	<u>Single Ø</u>	<u>Three Ø</u>		<u>Overhead and Underground</u>
	<u>5-100</u>	<u>167-500</u>	<u>15-500</u>		<u>5-500</u>	<u>15-500</u>		
	<u>KVA</u>	<u>KVA</u>	<u>KVA</u>		<u>KVA</u>	<u>KVA</u>	<u>Total</u>	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1958				344				344
1959				341				341
1960				336				336
1961				332			881	335
1962				316			838	323
1963				281			746	293
1964				274			729	291
1965				271			719	294
1966				273	564	2073	860	303
1967				290	600	2162	917	329
1968				280	617	2179	910	336
1969	247	1155	875	277	562	2079	771	322
1970	256	1146	868	283	582	2062	774	336
1971	239	1014	768	263	542	1825	709	324
*1972	217	970	735	238	493	1746	632	300
1973	225	1064	806	248	512	1915	651	330
1974	250	1179	893	282	567	2121	827	374

Prices derived by applying price index 11-74-01-11 for Columns 1 and 5 and index 11-74-01-15 for Columns 2, 3, and 6. 1972 used as base year. Columns 4, 7, and 8 are weighted averages.

* Average prices for 1972 taken from the 1972 Census of Manufacturers, Department of Commerce, Bureau of Census.

Table 3.8

DISTRIBUTION TRANSFORMER MARKET UNITS (000)
(≤ 500 KVA)

	<u>O v e r h e a d</u>				<u>U n d e r g r o u n d</u>			<u>T O T A L</u>
	<u>Single Phase</u>		<u>Three Ø</u>		<u>Single Ø</u>	<u>Three Ø</u>		
	5-100	167-500	15-500		5-500	15-500		Overhead and Underground
	<u>KVA</u>	<u>KVA</u>	<u>KVA</u>	<u>Total</u>	<u>KVA</u>	<u>KVA</u>	<u>Total</u>	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1958	628.9		14.4	643.3			0.0	643.3
1959	724.2		19.2	743.4			0.0	743.4
1960	689.1		20.4	709.5	0.0	0.0	0.0	709.5
1961	653.4		21.9	675.3	3.0	0.4	3.4	678.7
1962	684.4		23.5	707.9	7.6	1.9	9.5	717.4
1963	690.8		18.8	709.6	14.0	4.8	18.8	728.4
1964	774.4		18.3	792.7	22.0	9.6	31.6	824.3
1965	831.3		28.5	859.8	37.0	10.3	47.3	907.1
1966	936.2		40.7	976.9	42.4	10.3	52.7	1029.6
1967	959.5		46.7	1006.2	53.6	13.6	67.2	1073.4
1968	897.4		35.4	932.8	74.3	17.2	91.5	1024.3
1969	1032.4	25.4	14.2	1072.0	93.4	14.8	108.2	1180.2
1970	1068.4	25.3	11.5	1105.2	117.3	17.5	134.8	1240.0
1971	984.1	23.4	12.0	1019.5	140.7	20.9	161.6	1181.1
1972	1159.5	23.4	13.9	1195.8	200.3	24.9	225.2	1421.0
1973	1337.8	26.3	15.6	1379.7	319.8	35.1	354.9	1734.6
1974	1308.4	35.2	17.5	1361.1	229.4	46.2	275.6	1636.7

Units calculated by dividing NEMA Dollar Market (Table) by Derived Market Prices (Table

* Overhead single phase 167-500 KVA and three phase 15-500 KVA are apportioned from overhead total on the basis of (w) internal data for the years 1958 through 1968.

** Overhead single phase 5-100 KVA is calculated as the difference

*** Apportioned from underground total for 1960 through 1965 judging from 1966 through 1974 data.

Table 3.9

UNDERGROUND—SERVED PORTION OF NEW SINGLE-FAMILY HOMES (%)

Various Industry Surveys							Estimates for this Study		
T&D Mag. 5-69	EDIE Rsch. 7-69	E W Mag. 10-69	EDIE Rsch. 5-70	T&D Mag. 9-71	Ⓜ Dist.Syst. 5-73	T&D Mag. 7-73	Most Likely 11-75	High 11-75	Low 11-75
1960							0		
1961							2	↑	↑
1962							4		
1963							7		
1964							10	S	S
1965						14	14	A	A
1966						18	19	M	M
1967		24				23	24	E	E
1968						37	33		
1969	47	43				41	42		
1970		46		52	51	47	49		
1971	57	51	59	62	56	56	55		
1972		56		65		59	60		
1973		64		66	59	62	64		
1974				72		66	67		
1975					72	69	69	69	65
1976	76						71	71	64
1977							72	72	63
1978		80			78	70	73	73	62
1979							74	74	61
1980							75	79	60
1985							75	89	55
1990							75	100	50
1995							75	100	45
2000							75	100	40

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Figure 3.1

3.4.2.2 Overhead Transformers for New Housing Units

Table 3.10 gives the historical data for new housing starts by housing type for the years 1958 through 1974. The weighted total new units, column (4), comprise new single and mobile units plus 20% of multi-unit starts. (This is our estimate of the portion that is not high-rise apartment application.) Using the data from Table 3.9 that specifies the overhead-underground split, the number of new housing units with overhead installations is computed; Table 3.10, column (5). The assumed number of units per transformer, column (6), is then divided into the number of units with overhead installations to derive the number of overhead transformers used for new housing units, column (7).

The forecasts for overhead units are developed in an analogous manner. Table 3.11, column (1), gives the forecast of weighted new housing units. Using the forecasts of the overhead-underground split from Table 3.9 and forecasts of housing units per transformer, the forecasts for overhead transformers are calculated as shown in column (5), Table 3.11, and plotted in Figure 3.2. It is believed that a low economic growth rate would result in greater use of overhead installations, while a strong economy with high electricity usage would produce saturation for the underground market. Consequently, the highest unit sales for overhead transformers are forecasted for the low electrical usage scenario which is based on a low economic growth rate.

3.4.2.3 Overhead Transformers for Load Growth and Upgrading

The historical unit sales for overhead transformers for residential load growth and upgrading are calculated by subtracting the overhead sales for new housing units, Table 3.10, column (7), from the total overhead residential use, Table 3.8, column (1). The results are shown in Table 3.12.

Forecasts are developed by relating historical sales to change in kw-hr sales. The historical and forecasted unit sales are shown in Figure 3.3.

3.4.2.4 Total Overhead Transformers for Residential Applications

The forecast for overhead transformers for residential applications is simply the sum of the forecasts for new housing units, Table 3.11, and upgrading and load growth, Table 3.12. The sum of these forecasts is given in Figure 3.4.

Table 3.10

RESIDENTIAL OVERHEAD TRANSFORMERS FOR NEW HOUSING UNITS
Units (000)

Single Phase 5 to 100 KVA

	New Housing Units			* Total	% Overhead	OH	Units	Resid OH
	<u>Single</u>	<u>Multi</u>	<u>Mobile</u>			<u>New</u> <u>Units</u>	<u>Per</u> <u>TX</u>	<u>TX for</u> <u>New Units</u>
	(1)	(2)	(3)	(4)		(5)	(6)	(7)
1958	1202	180	102	1340	100	1340	7.50	179
1959	1229	302	121	1410	100	1410	7.25	194
1960	987	287	104	1148	100	1148	7.00	164
1961	961	376	90	1126	98	1103	6.75	163
1962	973	496	118	1190	96	1142	6.50	176
1963	1021	590	151	1290	93	1200	6.25	192
1964	972	558	191	1275	90	1148	6.00	191
1965	965	545	216	1290	86	1109	5.75	193
1966	780	416	217	1080	81	875	5.50	159
1967	845	477	240	1180	76	897	5.25	171
1968	900	645	318	1347	67	902	5.00	180
1969	811	689	413	1362	58	790	4.70	168
1970	815	654	401	1347	51	687	4.45	154
1971	1153	932	497	1836	45	826	4.20	197
1972	1312	1066	576	2101	40	840	3.90	215
1973	1133	925	567	1885	36	679	3.70	184
1974	889	464	329	1311	33	433	3.40	127
1975	886	296	238	1183	31		3.3	

* Total is the sum of single, 20% of multi, and mobile.

Table 3.11

FORECAST OF OVERHEAD TRANSFORMERS FOR NEW HOUSING UNITS APPLICATION
(000)

<u>Year</u>		<u>Housing Starts*</u>	<u>% O H</u>	<u>O H Units</u>	<u>Units Per TX</u>	<u>Transformers Forecast</u>
		(1)	(2)	(3)	(4)	(5)
1975	Low	1050	31	326	3.6	110
	Base	1183	31	367	3.3	110
	High	1250	31	438	3.3	110
1980	Low	1966	40	413	4.6	171
	Base	1966	25	492	3.8	120
	High	1966	21	786	3.0	138
1985	Low	2159	45	237	5.8	168
	Base	2250	25	563	4.4	124
	High	2250	11	1013	3.0	83
1990	Low	1578	50	0	6.8	116
	Base	2308	25	577	4.9	117
	High	2308	0	1154	3.0	0
1995	Low	940	50	0	7.8	66
	Base	2308	25	577	5.4	107
	High	2308	0	1269	3.0	0
2000	Low	736	60	0	9.0	49
	Base	2308	25	577	6.0	96
	High	2308	0	1385	3.0	0

*Housing starts are computed as in Table 3.10, i.e., the sum of single, 20% of multi, and mobile. Forecasts of new housing units are given in Table 3.3.

Figure 3.2

Table 3.12

OVERHEAD TRANSFORMERS FOR LOAD GROWTH AND UPGRADING

<u>Year</u>	<u>RESIDENTIAL USE</u>	<u>5 - 100 KVA</u>	<u>Units</u> <u>(000)</u>
1958			450
1959			530
1960			525
1961			490
1962			508
1963			499
1964			583
1965			638
1966			777
1967			789
1968			717
1969			864
1970			914
1971			787
1972			745
1973			1154
1974			1181

Figure 3.3

Figure 3.4

3.4.2.5 Underground Transformers for New Housing Units

The forecast of single phase underground transformers is based on housing starts. Only 20 percent of the multi-unit starts is used to compute adjusted total housing units. This is our estimate of the portion that is not high-rise apartment application. This adjusted total is then multiplied by the percent of underground installations and divided by the assumed number of housing units per transformer. The result is the number of single phase underground transformers demanded.

Table 3.13 gives the historical data for underground transformers. Column (8) gives the historical and forecasted average number of housing units per underground transformer. Note that we have used six units per transformer for a base case and an increasing differential with time for each of the high and low cases. Figure 3.5 gives the historical and forecasted unit sales.

3.4.2.6 Forecasted KVA Additions for Residential Transformers

In order to obtain an estimate of capacity additions in KVA for residential distribution transformers, we forecasted the average KVA per unit for overhead and underground transformers and multiplied by the forecasted unit requirements. The additions include both upgrading and new housing unit applications. Thus, the KVA additions are not net additions to capacity. It is emphasized that these estimates of KVA additions, given below, are not used elsewhere in the study. (All material usage calculations in Chapter 4 are based on unit transformer requirements.)

KVA ADDITIONS FOR RESIDENTIAL TRANSFORMERS

Base Case

<u>Year</u>	<u>KVA/Unit</u>		<u>No. of Units (000)</u>		<u>Total KVA Additions (10⁶)</u>
	<u>Overhead</u>	<u>Underground</u>	<u>Overhead</u>	<u>Underground</u>	
1975	26	63	513	65	17.4
1980	30	72	1129	227	50.2
1985	35	81	1342	274	69.2
1990	40	90	1363	288	80.4
1995	45	100	1497	288	96.2
2000	50	110	1628	288	113.1

KVA ADDITIONS FOR RESIDENTIAL TRANSFORMERS (cont'd)

High Growth Case

<u>Year</u>	<u>KVA/Unit</u>		<u>No. of Units (000)</u>		<u>Total KVA Additions (10⁶)</u>
	<u>Overhead</u>	<u>Underground</u>	<u>Overhead</u>	<u>Underground</u>	
1975	26	63	513	65	17.4
1980	30	72	1511	277	65.3
1985	35	81	2116	385	105.2
1990	40	90	2229	481	132.5
1995	45	100	2493	524	164.6
2000	50	110	2133	577	170.1

Low Growth Case

1975	26	63	513	65	17.4
1980	30	72	994	184	43.1
1985	35	81	1375	175	62.3
1990	40	90	1187	110	57.4
1995	45	100	1406	56	68.9
2000	50	110	1085	37	58.3

3.4.3 Distribution Transformers for Commercial Applications

The commercial transformer group is composed of the following segments.

- Single phase, overhead 167 - 500 KVA
- Three phase, overhead 15 - 500 KVA
- Three phase, underground 15 - 500 KVA
- Three phase, underground 500 - 2500 KVA
- Network
- Power Centers

The commercial transformers are handled as a group to control the total projections of all the various products which serve a similar purpose. The market has traditionally been served by overhead units, networks, and power centers. The strong emergence since 1960 of underground transformers implies that the traditional products are being displaced.

Table 3.14 contains the historical sales in KVA and the percent of total KVA for each line in the commercial category. Table 3.15 contains the forecasts of total KVA. These forecasts are made by using commercial and other kw-hr sales as the independent variable.

Table 3.13

UNDERGROUND TRANSFORMERS FOR NEW HOUSING UNITS †

		SINGLE PHASE		5 - 500 KVA				
Year	Housing		Units	*Total	% Underground	UG New Homes	TX Units	Housing Units
	Single	Multi	Mobile					per
	(1)	(2)	(3)					T X
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1961	961	376	90	1126	2	23	3.0	7.7
1962	973	496	118	1190	4	48	7.6	6.3
1963	1021	590	151	1290	7	90	14.0	6.4
1964	972	558	191	1275	10	128	22.0	5.8
1965	965	545	216	1290	14	181	37.0	4.9
1966	730	416	217	1080	19	205	42.4	4.3
1967	845	477	240	1130	24	283	53.6	5.3
1968	900	645	318	1347	33	445	74.3	6.0
1969	811	609	413	1362	42	572	93.4	6.1
1970	815	657	401	1347	49	660	117.3	5.6
1971	1153	132	497	1836	55	1010	140.7	7.2
1972	1312	1066	576	2101	60	1261	200.3	6.3
1973	1133	925	567	1885	64	1206	319.8	3.8
1974	889	464	329	1811	67	878	229.4	3.8
1975								6.0
Low								6.4
1980								6.0
High								5.6
Low								6.8
1985								6.0
High								5.2
Low								7.2
1990								6.0
High								4.8
Low								7.6
1995								6.0
High								4.4
Low								8.0
2000								6.0
High								4.0

† All numbers are in thousands of units except for columns (5) and (8).

* Total is the sum of single, 20% of multi, and mobile.

Figure 3.5

Table 3.14

COMMERCIAL TRANSFORMERS

	T O T A L K V A							P E R C E N T					
	1Ø, OH 167-500	3Ø, OH 15-500	3Ø, UG 15-500	3Ø, UG 500-2500	Net- work	Pwr Cntr	TOTAL	1Ø, OH 167-500	3Ø, OH 15-500	3Ø, UG 15-500	3Ø, UG 500-2500	Net- work	Pwr Cntr
1961	3623	435	100	480	2000	962	7600	.477	.057	.013	.063	.263	.127
1962	3146	728	475	840	1600	1216	8005	.393	.091	.059	.105	.200	.152
1963	2749	518	1200	1080	1600	858	8005	.343	.065	.150	.135	.200	.107
1964	2972	420	2400	1440	1700	1600	10532	.282	.040	.228	.137	.161	.152
1965	4696	645	2575	1800	1800	2378	13894	.333	.046	.185	.130	.130	.171
1966	6783	915	2575	2400	2200	2604	17477	.388	.052	.147	.137	.126	.149
1967	7560	1140	3400	2760	2100	2580	19540	.387	.058	.174	.141	.107	.132
1968	5203	1043	4300	3720	1900	2376	18542	.281	.056	.232	.201	.102	.128
1969	6178	1065	3700	3240	2300	2450	18933	.327	.056	.195	.171	.121	.123
1970	6224	863	4375	3960	1800	2944	20166	.309	.043	.217	.196	.089	.146
1971	5780	900	5225	4680	1700	2538	20823	.278	.043	.251	.225	.082	.122
1972	5803	1043	6225	5640	1900	2496	23107	.251	.045	.269	.244	.082	.108
1973	6549	1560	8775	7200	2000	2940	29024	.226	.054	.302	.248	.069	.101
1974	8800	1950	11550	10200	2000	3600	37900	.232	.046	.305	.269	.053	.095
1975	4596	1094	6347	5472	1960	2408	21887	.210	.050	.290	.250	.090	.110

Table 3.15

FORECASTED TOTAL KVA (000)			
<u>Year</u>	<u>Low</u>	<u>Base</u>	<u>High</u>
1975	22715	22715	22715
1980	39381	41300	46212
1985	47133	56957	62253
1990	54962	69621	79906
1995	62867	82285	101320
2000	71233	95026	124806

Table 3.16 contains historical estimates of KVA per unit by category and the values predicted to the year 2000. Note that the KVA per unit is not forecasted to differ substantially from the historical values.

By using the total KVA forecast for commercial transformers (Table 3.15) and the forecast of KVA per unit (Table 3.16), the forecasts for unit sales by category are calculated and shown in Table 3.16 and in Figures 3.6 through 3.11.

3.4.4 Substation Transformers (liquid 501 - 10,000 KVA)

Table 3.17 contains the historical NEMA dollar market, BLS indexes used to convert the current dollar market to constant dollars, and the calculated average unit prices and market units for substation transformers.

Substation transformers are forecasted by using change in kw-hr sales. The historical data and forecasts are shown in Figure 3.12.

3.4.5 Dry Type Transformers

Dry type transformers are expected to show strong growth in the future because they are being used to distribute power to commercial and industrial locations in a more efficient and ecologically acceptable manner.

Table 3.16

COMMERCIAL TRANSFORMERS

		U n i t s (000)						K V A / U n i t					
		1Ø, OH 167-500	3Ø, OH 15-500	3Ø,UG 15-500	3Ø,UG 500-2500	Net- work	Pwr Cntr	1Ø,OH 167-500	3Ø,OH 15-500	3Ø, UG 15-500	3Ø, UG 500-2500	Net- work	Pwr Cntr
61	1961	16.1	5.8	0.4	.4	2.0	1.3	225	75	250	1200	1000	740
	1962	13.8	9.7	1.9	.7	1.6	1.6	228	75	250	1200		760
	1963	11.9	6.9	4.8	.9	1.6	1.1	231	75	250	1200		780
	1964	12.7	5.6	9.6	1.2	1.7	2.0	234	75	250	1200		800
	1965	19.9	8.6	10.3	1.5	1.8	2.9	236	75	250	1200		820
	1966	28.5	12.2	10.3	2.0	2.2	3.1	238	75	250	1200		840
	1967	31.5	15.2	13.6	2.3	2.1	3.0	240	75	250	1200		860
	1968	21.5	13.9	17.2	3.1	1.9	2.7	242	75	250	1200		880
	1969	25.4	14.2	14.8	2.7	2.3	2.7	244	75	250	1200		900
	1970	25.3	11.5	17.5	3.3	1.8	3.2	246	75	250	1200		920
	1971	23.4	12.0	20.9	3.9	1.7	2.7	247	75	250	1200		940
	1972	23.4	13.9	24.9	4.7	1.9	2.6	248	75	250	1200		960
	1973	26.3	15.6	35.1	6.0	2.0	3.0	249	100	250	1200		980
	1974	35.2	17.5	46.2	8.5	2.0	3.6	250	100	250	1200	1000	1000
	1975	19.2	5.1	19.3	5.9	2.0	3.5	250	100	250	1200	1000	1000
Low		23.2	19.7	54.5	9.8	2.1	3.6						
Base	1980	24.3	20.6	57.2	10.3	2.2	3.8	255	100	250	1200	1000	1100
High		27.2	23.1	64.0	11.6	2.5	4.2						

Low		18.1	23.6	72.8	13.1	1.9	3.5						
Base	1985	21.9	28.5	87.9	15.8	2.3	4.3	260	100	250	1200	1000	1200
High		23.9	31.1	96.1	17.3	2.6	4.7						

Low		12.4	27.5	91.2	16.5	1.9	3.4						
Base	1990	15.8	34.8	115.6	20.9	2.4	4.3	265	100	250	1200	1000	1300
High		18.1	40.0	132.6	24.0	2.8	4.9						

Low		5.8	31.4	110.6	20.2	1.9	3.1						
Base	1995	7.6	41.1	144.8	26.4	2.5	4.1	270	100	250	1200	1000	1400
High		9.4	50.7	178.3	32.5	3.0	5.1						

Low		0.0	35.6	132.2	23.7	1.9	2.8						
Base	2000	0.0	47.5	176.4	31.7	2.5	3.8	275	100	250	1200	1000	1500
High		0.0	62.4	231.6	41.6	3.2	5.0

Figure 3.6

Figure 3.7

Figure 3.8

Figure 3.9

Figure 3.10

Figure 3.11

Table 3.17

NETWORK, POWER CENTER, AND SUBSTATION TRANSFORMERS

	NEMA Market \$(000,000)			BLS Price Index		*Average Prices \$			Market Units (000)			
	Ntwk.	Pwr.	Substa.	5000 Kva Tx		Ntwk.	Pwr.	Substa.	Ntwk.	Pwr.	Substa.	Total
	Tx	Cntrs.	Tx	11-74-01-03		Tx	Cntrs.	Tx	Tx	Cntrs.	Tx	
				'67=100	'73=100							
1960	17.9	10.1	21.4	90.7	92.4	8095	6735	11,088	2.21	1.50	1.93	5.64
1961	15.1	8.3	16.0	85.4	87.0	7622	6341	10,440	1.98	1.31	1.53	4.82
1962	11.8	9.7	17.6	83.3	84.8	7429	6181	10,176	1.59	1.57	1.73	4.89
1963	11.5	6.6	13.7	80.7	82.2	7202	5992	9,864	1.60	1.10	1.39	4.09
1964	12.8	12.3	17.5	85.0	86.6	7587	6312	10,392	1.69	1.95	1.68	5.32
1965	13.8	18.5	22.5	86.9	88.5	7753	6451	10,620	1.78	2.87	2.12	6.77
1966	15.2	21.5	24.4	92.6	94.3	8262	6874	11,316	2.21	3.13	2.16	7.50
1967	18.9	22.1	33.3	100.0	101.8	8919	7420	12,216	2.12	2.98	2.73	7.83
1968	17.9	21.1	38.0	104.7	106.6	9339	7770	12,792	1.92	2.72	2.97	7.61
1969	20.5	19.9	39.7	98.4	100.2	8779	7304	12,024	2.34	2.72	3.30	8.36
1970	15.6	22.5	28.2	95.9	97.4	8533	7099	11,688	1.83	3.17	2.41	7.41
1971	14.2	18.1	23.7	91.5	93.2	8165	6793	11,184	1.74	2.66	2.12	6.52
1972	15.9	17.8	21.5	94.1	95.8	8393	6983	11,496	1.89	2.55	1.87	6.31
1973	17.2	21.9	21.7	98.2	100.0	8761	7289	12,000	1.96	3.00	1.81	6.77
1974	22.0	33.1	25.6	124.7	127.0	11,165	9257	15,240	1.97	3.58	1.68	7.23

*Average Prices determined by applying Price Index to 1973 Benchmark Price as estimated from W Internal information

Figure 3.12

This more efficient manner brings the primary distribution voltage into a dry type transformer at point of use, rather than using a long secondary which causes significant losses. Growth in use of dry types for this function is a new application, so it does not displace any other transformers. But in addition, dry types may also be used in place of both small power and distribution-size transformers as objections to PCBs and oil grow stronger. Dry types avoid the problems of the nonbiodegradable PCBs and the possibility of catastrophic failure with oil. (The forecast of dry type transformers does not account for greater than trend displacement of other transformers.)

Dry type transformers for distribution typically range from 45 to 10,000 KVA. Dry types, 30 KVA and under, are excluded as specialty transformers. Among the dry type distribution transformers, there is a distinction made between small and large by coil design. Small types have layer wound coils, while large types have pancake high voltage windings and cylindrical low voltage windings. Usually, but not always, units below 500 KVA are of the small dry type design, and those above 500 KVA are of the large dry type design. For convenience, 500 KVA is normally used as the distinction between small and large.

The use of dry type transformers is quite varied. All small dry type transformers are used in distribution applications. However, most are used inside commercial, institutional, and industrial buildings rather than on electric utility distribution systems. Approximately 90% of large dry type transformers are used for distribution of power to commercial or industrial loads. The remaining 10% are used in conjunction with nuclear generation stations, but it is felt that they should be included here. Additionally, although some of the other large dry types have ratings above 5000 KVA, which is usually considered a transmission rating, the application is clearly for the distribution of power, so they have also been included.

Table 3.18 contains the historical data used to calculate unit sales for dry type transformers. These historical unit sales are related to new plant and equipment expenditures to develop forecasts of unit sales. The historical and forecasted values are shown in Figure 3.13.

Table 3.18

D R Y T Y P E T R A N S F O R M E R S

Source: National Electrical Manufacturers Association Sections 8-ST and 8-TR-II

	8-ST Small Dry 45-500 kva. \$(000,000)	8-TR-II-5,7 Large Dry 500-10,000 kva. \$(000,000)	BLS Price Index Dry Type Tx 11-74-01-31 <u>1967-100</u> <u>1974-100</u>		Small Dry Avg. Price \$	Large Dry Avg. Price \$	Small Units (000)	Large Units (000)	Total Dry Type Units (000)	
1960	9.3	* {	19.0	107.3	91.3	822	9130	11.3	2.1	13.4
1961	9.9		17.0	99.9	85.0	765	8500	12.9	2.0	14.9
1962	10.1		15.0	96.7	82.3	741	8230	13.6	1.8	15.4
1963	9.9		18.0	96.1	81.8	736	8180	13.5	2.2	15.7
1964	12.7		21.0	97.8	83.2	749	8320	17.0	2.5	19.5
1965	15.2	* {	23.0	96.9	82.5	742	8250	20.5	2.8	23.3
1966	18.6		25.5	96.2	81.9	737	8190	25.2	3.1	28.3
1967	22.1		25.5	100.0	85.1	766	8510	28.9	3.0	31.9
1968	22.5		24.0	101.2	86.1	775	8610	29.0	2.8	31.8
1969	23.6		20.8	103.4	88.0	792	8800	29.8	2.4	32.2
1970	24.1	18.8	108.2	92.1	829	9210	29.1	2.0	31.1	
1971	21.2	17.0	109.1	92.9	836	9290	25.4	1.8	27.2	
1972	22.3	16.2	109.9	93.5	842	9350	26.5	1.7	28.2	
1973	31.4	19.2	112.1	95.4	859	9540	36.6	2.0	38.6	
1974	37.2	27.2	117.5	100.0	900	10,000	41.3	2.7	44.0	

*Large Dry Type is approximated for the years 1960 through 1965 on the basis of the Data Series from 1966 through 1974

Figure 3.13

3.4.6 Instrument Transformers

Table 3.19 contains the historical data for instrument transformers. Distribution instrument transformers are estimated from the historical sales data by summing the low voltage sales and 15 percent of the high voltage.

The instrument transformer forecasts are developed by using non-residential structures as the independent variable in the forecasting equation. Figure 3.14 gives the historical and forecasted unit sales.

3.5 Meters and Sockets

Table 3.20 contains the historical unit sales for meters and sockets. Approximately 60 percent of the meters sold annually are installed to serve new customers with the other 40 percent being used to replace meters in service. The number of new housing starts is used to forecast unit meter sales. Historically, meter sockets have averaged 82 percent of unit meter sales (when a meter is replaced, it is not always necessary to replace the socket), and, therefore, are not separately forecasted. The material requirements for meters in Task 3 include the associated socket material requirements.

The unit sales history and forecasts on meters are given in Figure 3.15.

3.6 Switchgear Assemblies

Table 3.21 contains the historical market data for low and medium voltage switchgear. These two product lines are combined and forecasted as a whole. Distribution transformer unit sales are used to forecast switchgear sales. The history and forecasts are shown in Figure 3.16.

3.7 Insulators

The market for distribution insulators appears to grow in relation to, but at a slower rate than, the distribution transformer market. Insulators are forecast from the projection of distribution transformers.

Table 3.19

I N S T R U M E N T T R A N S F O R M E R S

Source: National Electrical Manufacturers Association

Section 8-EI-2

	(1) Total \$(000,000)	(2) Low Voltage <15 Kv. \$(000,000)	(3) High Voltage 15-500 Kv. \$(000,000)	(4)=(3)*.15 15% High Voltage \$(000,000)	(5)=(2)+(4) Distribution Instrument Transformers \$(000,000)	(6) BLS Price Index Elec. Dir. Meas. Instr. 11-72-01 1967=100	(7) 1974=100	(8) Average Price \$	(9)=(5)÷(8) Distribution Instrument Transformers Units(000)
1960	16.0				11.0	85.6	60.8	37.2	295.7
1961	17.4				12.0	87.7	62.3	38.1	315.0
1962	17.4				12.0	88.9	63.2	38.7	310.1
1963	16.9				11.7	88.8	63.1	38.6	303.1
1964	19.5				13.5	88.9	63.2	38.7	348.8
1965	21.8				15.0	89.2	63.4	38.8	386.6
1966	24.9	16.4	8.5	1.3	17.7	94.9	67.4	41.2	429.6
1967	25.3	15.2	10.1	1.5	16.7	100.0	71.1	43.5	383.9
1968	27.3	17.3	10.0	1.5	18.8	106.2	75.5	46.2	406.9
1969	27.7	17.5	10.2	1.5	19.0	110.8	78.7	48.2	394.2
1970	26.4	16.9	9.5	1.4	18.3	117.1	83.2	50.9	359.5
1971	27.6	18.6	9.0	1.4	20.0	125.0	88.8	54.3	368.3
1972	29.2	20.6	8.6	1.3	21.9	127.9	90.9	55.6	393.9
1973	32.3	22.2	10.1	1.5	23.7	129.5	92.0	56.3	421.0
1974	34.1	24.6	9.5	1.4	26.0	140.7	100.0	**61.2	424.8

*Column (5) estimated for the years 1960 thru 1965 by applying .69 to the total in Column (1). (.69 is the average ratio of Column (5) to Column (1) from 1966 thru 1970)

**Average Price for 1974 determined by using \$58 for the Low Voltage portion and \$1600 for the High Voltage portion

Figure 3.14

Table 3.20

M E T E R S A N D S O C K E T S Units (000)

Source: National Electrical Manufacturers Association Section 8-EI-1,5

	M E T E R S						M E T E R S O C K E T		P O S I T I O N S
	Watt-Hour	Demand	Other	Total	Demand	Other	Round	Other	Total
					%	%			
1955	3130	107	213	3,450	3.1	6.2	1657	750	2408
1956	3096	123	196	3,415	3.6	5.7	1315	793	2108
1957	2634	117	167	2,918	4.0	5.7	874	648	1521
1958	2726	99	140	2,965	3.3	4.7	799	748	1547
1959	2906	116	116	3,138	3.7	3.7	726	841	1566
1960	2815	127	88	3,030	4.2	2.9	587	667	1253
1961	2613	122	76	2,811	4.3	2.7	450	703	1153
1962	2606	134	73	2,813	4.8	2.6	420	725	1144
1963	2678	140	73	2,891	4.8	2.5	355	777	1133
1964	2734	158	72	2,964	5.3	2.4	332	1082	1413
1965	2648	165	92	2,905	5.7	3.2	368	1050	1418
1966	2513	187	117	2,817	6.6	4.2	239	1163	1402
1967	2369	159	93	2,621	6.1	3.5	234	1304	1538
1968	2649	170	98	2,917	5.8	3.4	232	2528	2760
1969	2789	178	106	3,073	5.8	3.4	255	2789	3043
1970	2892	177	110	3,179	5.6	3.5	225	2548	2772
1971	3302	188	115	3,605	5.2	3.2	*212	*2634	*2846
1972	3750	217	122	4,089	5.3	3.0	NA	NA	NA
1973	3941	253	132	4,326	5.8	3.1	162	3714	3875
1974	3510	255	111	3,876	6.6	2.9	164	2890	3055

*Totals for the year are estimated as twice the sales reported for the first six-months

Figure 3.15

Table 3.21

S W I T C H G E A R A S S E M B L I E S

Source: National Electrical Manufacturers Association

Section 8-SG-V

(Price Index has been lagged one year to account for lead time)

Low Voltage - 600 V - All Distribution						Medium Voltage - 1 to 23 kV - All Distribution				
Market \$(000,000)	*Price Index 11-75-04-41		**Average Price \$	Market Units (000)		Market \$(000,000)	*Price Index 11-75-04-43		**Average Price \$	Market Units (000)
	1967=100	1974=100					1967=100	1974=100		
1960	33.9	85.5	69.8	1634	20.7	63.9	85.5	72.3	6665	9.6
1961	31.4	85.4	69.7	1632	19.2	53.5	85.5	72.3	6665	8.0
1962	26.4	85.4	69.7	1632	16.2	49.3	85.4	72.2	6655	7.4
1963	25.2	85.1	69.5	1627	15.5	35.7	85.4	72.2	6655	5.4
1964	35.4	89.5	73.1	1711	20.7	58.6	85.1	71.9	6628	8.8
1965	44.0	92.1	75.2	1760	25.0	72.9	89.5	75.7	6978	10.4
1966	49.1	95.4	77.9	1824	26.9	77.5	92.1	77.9	7181	10.8
1967	56.6	100.0	81.6	1910	29.6	94.9	95.4	80.6	7430	12.8
1968	53.5	101.2	82.6	1934	27.7	110.5	100.0	84.5	7789	14.2
1969	48.8	98.9	80.7	1889	25.8	93.5	104.5	88.3	8139	11.5
1970	55.7	104.6	85.4	1999	27.9	105.0	103.5	87.5	8066	13.0
1971	59.8	108.4	88.5	2072	28.9	109.9	108.5	91.7	8453	13.0
1972	54.9	106.3	86.8	2032	27.0	112.0	117.3	99.2	9144	12.2
1973	60.6	107.1	87.4	2046	29.6	98.8	116.2	98.2	9052	10.9
1974	76.8	122.5	100.0	2341	32.8	114.3	118.3	100.0	9218	12.4

*Prior to 1967 Price Index 11-75-04 is used for both High and Low Voltage because the individual Price Indices shown were not recorded prior to 1967

**Average Prices for 1974 were determined by dividing the market \$ value by the number of units reported through NEMA (units have been reported by NEMA only in recent years as shown above)

Figure 3.16

The market figures for distribution insulators are unusually high in the years 1965 through 1967. This results in a poorer correlation with transformers than would otherwise be expected. But the surge is easily explained. During this period, the use of insulators surged as major utilities interconnected or pooled their transmission systems. The distribution insulators series is derived from the NEMA reported total insulators by taking the estimated distribution portion from each category. Since this portion is assumed to be the same for all years, unusually high use of all insulators from 1965 through 1967 produces correspondingly high levels for the derived distribution insulators series. It is most unlikely that such a surge will recur, so the correlation with transformers should produce a good forecast of future demand for insulators.

Tables 3.22 and 3.23 give the historical sales data for insulators and the factors used to estimate the portion attributable to distribution. Historical and forecasted unit sales are shown in Figure 3.17.

3.8 Cutouts, Links, and Fuses

The historical data series developed for this market results from expansion of the single NEMA reported series for cutouts and links to include the estimated market for fuses. The reported NEMA series was increased in all years by the ratio of the estimated fuse market in 1974 to the cutout and link market.

Table 3.24 contains the historical NEMA data for cutouts and links and the estimated data for fuses. These three product lines are forecasted as an aggregate as a function of new plant and equipment expenditures. The historical and forecasted unit market are shown in Figure 3.18.

3.9 Capacitors

Capacitors are forecasted using the method developed by the NEMA statistical committee for the capacitor section. The method was developed, implemented, and approved in 1973.

Table 3.22

I N S U L A T O R S \$ (000,000)

(Excludes Intraplant Transfers)

Source: National Electrical Manufacturers Association
High Voltage Insulator Section (8-HV)

Item No.	Type of Insulators	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
1	Guy Strain	.8	.6	.4	.5	.9	.9	.8	.7	.6	.6	.7	.7	.8	.9
2	Lo Voltage Pin and Post	2.5	2.3	2.2	2.4	3.4	3.7	3.1	2.6	3.0	5.6	5.2	5.6	6.2	7.9
3	Hi Voltage Pin and Post	4.1	4.5	5.3	6.1	6.9	8.5	8.9	6.6	6.5	5.6	6.2	8.0	9.0	12.3
4A	Under 7-1/2" Disc Suspension	5.5	4.6	4.1	4.6	7.6	9.3	7.7	6.3	8.4	8.2	8.2	8.7	10.3	12.7
4B	Over 7-1/2" Disc Suspension	12.0	11.5	10.0	12.3	19.5	22.8	23.4	21.7	20.5	19.5	18.8	18.0	22.7	29.2
5	Switch & Bus Insulators	8.8	9.5	10.2	11.2	14.9	18.1	20.4	19.6	21.1	21.4	18.8	19.8	21.9	26.1
6	Porcelain Components	2.9	2.8	3.3	3.5	3.8	4.1	4.8	4.0	4.3	5.6	6.3	7.0	8.0	14.4
Total		36.6	35.9	35.7	40.5	56.9	67.5	69.2	61.4	64.4	66.5	64.2	67.9	78.8	103.4
Hardware									7.7	8.0	8.3	10.3	10.1	13.8	17.4

D I S T R I B U T I O N I N S U L A T O R S \$ (000,000)

Respective Proportions

	<u>Dist.</u>	<u>Trans.</u>	<u>OEM</u>												
1	1.00			.8	.6	.4	.5	.9	.9	.8	.7	.6	.6	.7	.8
2	1.00			2.5	2.3	2.2	2.4	3.4	3.7	3.1	2.6	3.0	5.6	5.2	6.2
3	.65	.35		2.7	2.9	3.4	4.0	4.5	5.5	5.8	4.3	4.2	3.6	4.0	5.9
4A	.80	.20		4.4	3.7	3.3	3.7	6.1	7.4	6.2	5.0	6.7	6.6	6.6	7.0
4B	.10	.90		1.2	1.2	1.0	1.2	2.0	2.3	2.3	2.2	2.1	2.0	1.9	1.8
5	.25	.75		2.2	2.4	2.6	2.8	3.7	4.5	5.1	4.9	5.3	5.4	4.7	5.0
6			1.00												
Subtotal				13.8	13.1	12.9	14.6	20.6	24.3	23.3	19.7	21.9	23.8	23.1	25.3
*Hardware				1.9	1.8	1.8	2.0	2.9	3.4	3.3	2.8	2.9	3.0	3.7	3.6
Total				15.7	14.9	14.7	16.6	23.5	27.7	26.6	22.5	24.8	26.8	26.8	28.9

*Hardware for distribution insulators estimated in the following manner:

1968 thru 1974 36% of total hardware - same proportion as distribution
insulators comprise out of total insulators1961 thru 1967 14% of distribution insulators - same proportion as
average of 1968 thru 1972

Table 3.23

INSULATORS

Source: National Electrical Manufacturers Association - Section 8-CC

	<u>Market</u>	<u>Price</u>	<u>Index</u>	<u>**Average</u>	
	<u>\$ (000,000)</u>	<u>Nonmet</u>	<u>Min 13</u>	<u>Price</u>	<u>Market</u>
		'67 = 100	'72=100	\$	Units (000)
1960					
1961	15.7	97.6	75.9	2.38	6,597
1962	14.9	97.6	77.4	2.47	6,032
1963	14.7	97.1	77.0	2.41	6,100
1964	16.6	97.3	77.2	2.42	6,860
1965	23.5	97.5	77.3	2.42	9,710
1966	27.7	98.4	78.0	2.44	11,352
1967	26.6	100.0	79.3	2.48	10,726
1968	22.5	103.7	82.2	2.57	8,755
1969	24.8	107.7	85.4	2.67	9,288
1970	26.8	112.9	89.5	2.80	9,571
1971	26.8	122.4	97.1	3.04	8,816
1972	28.9	126.1	100.0	3.13	9,240
1973	33.9			3.53	* { 9,590
1974	42.7			3.86	* { 11,070

* Units for the years 1972 through 1974 were approximated from the EEI-NEMA Stores Survey Data.

** Average prices were developed by applying the BLS price index to the average price for 1972, which was determined by dividing the NEMA sales by the approximated units.

Figure 3.17

Table 3.24

CUTOUTS, LINKS, AND FUSES

Source: National Electrical Manufacturers Association

Section 8-SG-II

	NEMA Sales	90% Dist.	BLS Price Index Metal + Products		**Avg. Price	NEMA Market	***Fuses Estimated Market	Cutouts, Links, and Fuses
	\$(000,000)	\$(000,000)	'67=100	'71=100	\$	Units (000)	Units (000)	Units (000)
			<i>One year lag</i>					
1960								
1961			91.9					
1962	17.2	15.5	91.2	77.2	17.35	893	234	1127
1963	16.7	15.0	91.3	76.6	17.21	872	229	1101
1964	17.7	15.8	93.8	76.7	17.23	917	240	1157
1965	20.1	18.1	96.4	78.8	17.71	1022	268	1290
1966	23.6	21.3	98.8	81.0	18.20	1170	307	1477
1967	23.1	20.7	100.0	83.0	18.65	1110	291	1401
1968	25.0	22.5	102.6	84.0	18.87	1192	312	1504
1969	28.4	25.5	108.5	86.2	19.37	1316	345	1661
1970	30.3	27.3	116.6	91.2	20.49	1332	349	1681
1971	27.3	24.5	119.0	98.0	22.02	1113	292	1405
1972 ***	31.6	28.4	123.5	100.0	22.47	* 1264	331	1595
1973	33.9	30.5	132.8	103.8	23.32	1308	343	1651
1974	36.0	32.4	171.9	111.6	25.08	1292	339	1631

* Units for the year 1972 were approximated from EEI-NEMA Stores Survey Data.

** Average prices were developed by applying the BLS Price Index to the average price for 1972, which was determined by dividing NEMA dollar sales by approximated units.

*** Total sales reported by Census of Manufacturers was \$31.0 million.

Figure 3.18

The capacitor GVAR demand in a particular year is determined by multiplying the increase in peak load[†] by a factor of .75. Units of capacitors are determined from projected GVAR by dividing the projected GVAR by a value representing KVAR per unit. This KVAR per unit is expected to increase from about 180 today to about 260 by the year 2000. Finally, the number of distribution capacitors is extracted from the total projected units by applying a "percent distribution." This value is also expected to increase from approximately 25% today to 50% by the year 2000.

Table 3.25 contains the historical data for capacitors and shows the method for computing unit sales. Figure 3.19 shows the historical and forecasted unit market.

3.10 Connectors

Although power connectors are reported through NEMA, only two of the four relevant categories are available from regular reports. To obtain more complete data for all four categories, the NEMA field survey reports were also used. Both series, regular reports and FS reports, are shown on Table 3.26. In order to establish a single data series for each category, the higher number of the two series was chosen for each year. The resulting data series are shown as the upper half of Table 3.27.

Since this series includes both transmission and distribution ratings, the distribution sales are extracted within each of the four categories. This is done by applying an estimated "% Distribution" to the dollar sales in each category. The estimate of "% Distribution" was derived by talking with various individuals in the industry. The resulting dollar value of distribution connectors is shown as the lower half of Table 3.27.

[†] Appendix 3 shows the peak load forecasts for the three energy scenarios.

Table 3.25

CAPACITORS

Source: NEMA Statistical Committee of the Capacitor Section

	Annual Shipments	Cumulative Shipments	Peak Load	Ratio	KVAR/	Annual Shipments	NEMA	Avg	Distribution		
	GVAR	GVAR	GW	GVAR/GW	Unit	Units(000)	Sales	Price	Sales	%	Shipments
	$1=2(t)-2(t-1)$	2	3	$4=2 \div 3$	5	$6=1 \div 5$	7	$8=7 \div 6$	9	$10=9 \div 7$	$11=6 + 10$
1960	8	70	133	53	150	53.3					14.4
1961	7	77	142	54	152	46.1					12.4
1962	7	84	153	55	154	45.5					12.3
1963	9	93	162	57	156	57.7					15.6
1964	10	103	175	59	158	63.3					17.1
1965	13	116	186	62	160	81.3					21.9
1966	11	127	203	63	162	67.9					18.3
1967	16	143	214	67	164	97.6					26.4
1968	19	162	238	68	166	114.5					30.9
1969	16	178	258	69	168	95.2					25.7
1970	19	197	275	72	170	111.8	12.8		3.6	28	31.3
1971	18	215	292	74	172	104.7	11.9		3.9	33	34.6
1972	19	234	319	73	174	109.2	11.7		2.6	22	24.0
1973	20	254	344	74	175	114.3	10.5	92	2.3	22	25.1
1974	25	279	350	80	184	135.9	13.8	101	4.4	32	43.5

↑
27 %
↓

Figure 3.19

Table 3.26

CONNECTORS (\$000,000)

Source: National Electrical Manufacturers Association

	8 - CC - I Power		8 - CC - II Pressure		8 - CC - III Overhead		8 - CC - IV Underground	
	<u>Reg.</u>	<u>FS</u>	<u>Reg.</u>	<u>FS</u>	<u>Reg.</u>	<u>FS</u>	<u>Reg.</u>	<u>FS</u>
1960	5.2				14.3			
1961	5.1				13.6			
1962	4.7				13.1			
1963	4.9				13.0			
1964	5.8	6.2		16.7	14.1	12.9		
1965	7.0	7.1		19.0	15.5	14.6		
1966	8.5	8.5		22.8	17.1	16.0		
1967	9.4	9.7			16.3	15.8		
1968	9.9	10.3		16.1	17.4	16.5		7.0
1969	10.6	10.9		19.1	18.0	18.8		10.7
1970	11.8	12.4		19.7	20.2	21.5		15.7
1971	11.1	11.6		20.4	19.5	21.9		18.8
1972	11.4	11.5		23.0	22.1	25.9		25.5
1973	12.5	13.3		31.3	24.7	32.0		35.8
1974	16.1	16.5		35.1	28.0	40.1	7.8	37.6

Table 3.27

CONNECTORS \$ (000,000)

SOURCE: NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION
(Regular Reports OR FS, Whichever Greater)

Item No.	Description	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
8-CC-I	Power	5.2	5.1	4.7	4.9	6.2	7.1	8.5	9.7	10.3	10.9	12.4	11.6	11.5	13.3	16.5
8-CC-II	Pressure					16.7	19.0	22.8		16.1	19.1	19.7	20.4	23.0	31.3	35.1
8-CC-III	Overhead	14.3	13.6	13.1	13.0	14.1	15.5	17.1	16.3	17.4	18.8	21.5	21.9	25.9	32.0	40.1
8-CC-IV	Underground									7.0	10.7	15.7	18.8	25.5	35.8	37.6
	Total									50.8	59.5	69.3	72.7	85.9	112.4	129.3

DISTRIBUTION CONNECTORS \$ (000,000)

	% Dist.	% Trans.														
8-CC-I	40	60	2.1	2.0	1.9	2.0	2.5	2.8	3.4	3.9	4.1	4.4	5.0	4.6	4.6	5.3
8-CC-II*	50	50	8.0	8.0	8.0	8.0	8.4	9.5	11.4	9.0	8.1	9.6	9.9	10.2	11.5	15.7
8-CC-III	85	15	12.2	11.6	11.1	11.1	12.0	13.2	14.5	13.9	14.8	16.0	18.3	18.6	22.0	27.2
8-CC-IV**	90	10	0.0	0.1	0.3	0.5	1.0	2.0	3.0	4.0	6.3	9.6	14.1	16.9	23.0	32.2
Subtotal			22.3	21.7	21.3	21.6	23.9	27.5	32.3	30.8	33.3	39.6	47.3	50.3	61.1	80.4
OEM			5.5	5.4	5.3	5.4	5.9	6.8	8.0	7.7	8.3	9.9	11.8	12.5	15.2	20.0
Line Connectors			16.8	16.3	16.0	16.2	18.0	20.7	24.3	23.1	25.0	29.7	35.5	37.8	45.9	60.4

*Estimated as constant from 1960 thru 1963

** Estimated by trending to zero from 1967 back to 1960 - Separable Connectors comprise most of this category.

A significant discrepancy exists between the NEMA reported volume of \$85.9 million of transmission and distribution connectors sold in 1972 and the 1972 Census of Manufacturers reported volume of \$52.0 million. The difference is primarily due to connectors which are sold to other electrical equipment manufacturers (OEMs) and then sold as part of another piece of equipment, such as a transformer. Of the \$60.4 million worth of distribution connectors sold in 1973, it is estimated that about \$20 million, or 33%, were used for OEM purposes. The OEM sales are excluded from this series because they are accounted for as part of the ultimate shipment on which it is used.

Table 3.28 gives the historical data for connectors, and Figure 3.20 shows the historical and forecasted unit sales.

3.11 Circuit Breakers and Reclosers

This section includes only what is termed outdoor distribution circuit breakers because indoor breakers serve primarily as components of switchgear assemblies and are included in the material analysis as part of switchgear. Only a portion of all outdoor circuit breakers are considered distribution. The rest is made up of subtransmission, transmission and EHV ratings. Distribution ratings are 14.4 to 38.0 KV, 750 MVA and under. Distribution breakers account for approximately 14% of the total dollar volume and 38% of the unit volume of all outdoor circuit breakers, according to 1974 NEMA statistics. This amounts to \$18.0 million and 2,628 units. Outdoor distribution breakers were exclusively oil prior to 1970, but since then changeover to the vacuum breaker has been extremely rapid. The vacuum breaker accounts for almost 50% in 1975, is expected to comprise 75% by 1980, and 100% by 2000. The historical data for circuit breakers are given in Table 3.29.

There are very limited data available on reclosers, making it impossible to estimate a formal model for forecasting future sales. Table 3.30 contains estimates of unit sales from 1970-74. The average unit sales for these years is 17,400 units, and it is assumed that this level of sales will continue in the future.

Table 3.28

C O N N E C T O R S

	Market Sales \$(000,000)	Price Index Metals - 10 1967=100 1974=100		Average Price \$	Market Sales Units (000)
1960	16.8	92.4	53.8	4.8	3500
1961	16.3	91.9	53.5	4.8	3396
1962	16.0	91.2	53.1	4.8	3333
1963	16.2	91.3	53.1	4.8	3375
1964	18.0	93.8	54.6	4.9	3673
1965	20.7	96.4	56.1	5.0	4140
1966	24.3	98.8	57.5	5.2	4673
1967	23.1	100.0	58.2	5.2	4442
1968	25.0	102.6	59.7	5.4	4630
1969	29.7	108.5	63.1	5.7	5211
1970	35.5	116.6	67.8	6.1	5820
1971	37.8	119.0	69.2	6.2	6097
1972	45.9	123.5	71.8	6.5	7062
1973	60.4	132.8	77.3	7.0	8629
1974	69.2	171.9	100.0	9.0	7689

Figure 3.20

Table 3.29

CIRCUIT BREAKERS

Units (000)

Source: NEMA Report 8-SG-III

14.4 KV - 38 KV

< 750 MVA

<u>Year</u>	<u>Units</u>
1960	1199
1961	1367
1962	1192
1963	1288
1964	1924
1965	1826
1966	2059
1967	2249
1968	2233
1969	1798
1970	2278
1971	2500
1972	2555
1973	2677
1974	2628

Table 3.30

R E C L O S E R S

	Total NEMA Market	75 % Distribution	Price Index		* Average Price	Distribution Market
	\$(000)	\$(000)	Switchgear 67 = 100	11-75 74 = 100	\$	Units (000)
1970	9157	6867	106.7	.807	392	17.5
1971	9653	7239	111.3	.842	409	17.7
1972	9432	7074	111.4	.843	410	17.3
1973	9805	7354	113.1	.856	416	17.7
1974	11010	8258	132.2	1.000	486	17.0

* Average price calculated by applying price index to 1974 estimated price.

Figure 3.21 shows the historical and forecasted unit sales for circuit breakers and reclosers. The forecast is developed by forecasting circuit breaker sales as a function of kw-hr sales and then adding 17.4 (thousand) to account for the reclosers.

3.12 Arresters

Table 3.31 contains the historical data for arresters as reported by NEMA. NEMA reports unit sales. However, there appears to be a data error for 1972 unit sales since the implied price is lower than in 1971. Thus, as shown in Table 3.31, a derived unit volume was calculated by using NEMA dollar volume and the price index for arresters. Arresters are forecasted using kw-hr sales as the independent variable. Figure 3.22 shows the historical and forecasted unit sales.

3.13 Voltage Regulators

No NEMA statistics are reported for voltage regulators, so two other data sources are used to identify this market. These two sources are the 1972 Census of Manufacturers data and the 1975 National Rural Electric Cooperative Association (NRECA) survey.

There are two types of distribution voltage regulators - - station type and line type. Station regulators, which are used in conjunction with substation transformers, are fading into obsolescence as the transformers are now equipped with automatic load tap changers to serve the purpose. It appears that line regulators also are being replaced in urban and suburban locations by increased use of capacitors, and less power correction is required at the higher distribution voltages which are becoming more common. Yet REC utilities continue to be big users of line regulators because of the extreme length of their distribution lines.

Although station type regulators are almost negligible in terms of units, an estimate of dollar value was made and subtracted from Census of Manufacturers data for 1972 to determine about how much the line regulator market had changed since it was reported in 1967. It appears from the historical data shown in Table 3.32 that the line regulator market is increasing slowly and that over half of the units are used by RECs. However, the REC survey data indicate the market is growing much more rapidly.

Figure 3.21

Table 3.31

D I S T R I B U T I O N A R R E S T E R S

Source: National Electrical Manufacturers Association Section 8-LA

	<u>N E M A Reported Sales</u>			<u>Arrester Price Index 11-71-01-05</u>		² <u>Derived Price</u>	³ <u>Derived Units</u>
	<u>Dollars</u>	<u>Units</u>	¹ <u>Price</u>				
	<u>\$(000,000)</u>	<u>Units (000)</u>	<u>\$</u>	<u>67=100</u>	<u>75=100</u>	<u>\$</u>	<u>Units (000)</u>
1968	15.1	1218	12.4	101.7	80.4	12.50	1208
1969	17.9	1377	13.0	99.8	78.9	12.27	1459
1970	17.8	1472	12.1	100.2	79.2	12.32	1445
1971	18.2	1549	11.8	102.8	81.3	12.64	1440
1972	21.0	2016	10.4	102.7	81.2	12.63	1663
1973	20.7	1784	11.6	105.0	83.0	12.91	1603
1974	21.9	1717	12.7	116.3	91.9	14.29	1533
1975	15.3	984	15.5	126.5	100.0	15.55	984

¹This price series is determined by dividing dollar sales by unit sales, both reported through NEMA.

²This price series is derived by applying the 75=100 index to the 1975 price of \$15.5 determined from NEMA data.

³Units are derived by dividing NEMA sales dollars by the derived price series.

Figure 3.22

Table 3.32

VOLTAGE REGULATORS

Source: 1972 Census of Manufacturers

		Price Index		*Average Price		Estimated Split				
		Vltg	Reg 76.2 KVA	Station	Line	Station	Line	***	Station	Line
	<u>Market</u>	<u>11 - 74 - 01 - 21</u>		<u>Type</u>	<u>Type</u>	<u>Type</u>	<u>Type</u>		<u>Type</u>	<u>Type</u>
	Million \$	67=100	74=100	\$	\$	Mill \$	Mill \$		Units	Units
1967	33.7	100.0	.733	47,645	2932	12.4	21.3		260	7265
1972	33.2	119.1	.873	56,745	3492	5.7	27.5		100	7875
1974		136.5	1.000	65,000	4000					

Source: 1975 National Rural Electric Cooperative Association Survey

	Units	
1975	4,665	
1976	4,465	
**1978	5,290	
1980	7,020	(appears unlikely)

*Average price approximated by applying price index to estimated price for 1974.

**Revised estimate from 1973 survey.

***Estimated to determine line type regulator market trend.

Since the data from the two available sources are inconclusive, the high, base, and low projections shown in Figure 3.23 span a wide range and are extrapolations based on very limited historical data.

3.14 Poles

The market for distribution poles is primarily one of replacement since it is expected that approximately 75% of new installations will be underground. New poles will continue to be required for the remaining 25 percent of new installations and in areas where underground systems are fed by overhead lines.

Wood is used for virtually all distribution poles, with concrete and steel being used by a few utilities. Concrete is used primarily in areas where ground decay is a serious problem (Florida). However, there are only approximately 60,000 concrete poles used per year which is only 0.4% of the wood pole market. The use of steel poles for distribution is even smaller and probably does not exceed 200 units per year.

The number of wood poles used for distribution has been increasing in recent years. However, the total production of wood poles for all purposes has been decreasing. This information is contained in Table 3.33.

The demand for poles is projected by first using a time trend to project total wood pole production (decreasing) and then multiplying by the percentage which represents distribution poles (increasing). The result is a slowly growing demand for poles that reaches 2.95 million units by the year 2000. (Because the forecast is a time trend, there are no alternative forecasts.)

Note that although we have used data from the Wood Preservers' Association to forecast pole demand (because historically almost all the poles were wood), this does not imply that all the poles in the future will be wood. In fact, there are promising developments using flyash that could make a significant penetration in the forecasted market as shown in Figure 3.24. We do not foresee a significant penetration of the concrete pole in the distribution market because of cost, and forecast that approximately 60,000 of the poles per year will continue to be made of concrete.

Figure 3.23

Table 3.33

P O L E S Units (000)

Source: Wood Preservation Statistics, American Wood Preservers' Association

	R E P O R T E D D A T A			Trend % Dist. (4)	A D J U S T E D D A T A			Trend All Poles (8)	Projected Distribution Poles (9) = (4) * (8)
	All Poles (1)	Distribution Poles (2)	% Dist. (3) = (1) ÷ (2)		Source Coverage (5)	All Poles (6) = (1) ÷ (5)	Dist. Poles (7) = (3) * (6)		
1959	6035				.984	6133		6014	
1960	5647				.981	5756		5970	
1961	5472				.990	5527		5926	
1962	5452				.990	5507		5882	
1963	5516				.973	5669		5838	
1964	5798				.970	5677		5793	
1965	5979				.975	6132		5749	
1966	7012	3328	47.5	45.7	.990	7083	3364	5705	2607
1967	5920	2666	45.0	46.4	.976	6066	2730	5661	2627
1968	5244	2475	47.2	47.1	.940	5579	2633	5617	2646
1969	4852	2346	48.4	47.8	.940	5162	2498	5573	2664
1970	5290	2492	47.1	48.6	.940	5628	2651	5528	2687
1971	4854	2356	48.5	49.3	.930	5219	2531	5484	2704
1972	4828	2373	49.2	50.0	.940	5136	2527	5440	2720
1973	4879	2570	52.7	50.7	.920	5303	2795	5396	2736
1974				51.4				5352	2751
1975				52.1				5309	2766
1980				55.7				5087	2833
1985				59.3				4866	2886
1990				62.8				4645	2917
1995				66.4				4424	2938
2000				70.0				4204	2943

Figure 3.24

3.15 Distribution Pole Crossarms

The market for distribution pole crossarms has decreased in the past, and is projected to continue to decrease in the future despite the fact that demand for distribution poles is projected to increase. Thus, the ratio of crossarms to poles is decreasing. In the late 1960s, sales of crossarms had exceeded sales of poles by one-fourth to one-third. The most recent data for 1972 and 1973 indicate that sales of crossarms are now about the same as for poles. From now until 2000, sales of crossarms are projected to continue to decrease to about one-half the current level, which will also be one-half of the pole market at that time. (Data from the 1975 National Rural Electric Cooperative Association Survey indicate that the ratio of crossarms to poles is almost exactly one-half for 1975 through 1980.)

Crossarms are projected by the same method used for poles. A trend is developed for all crossarms (decreasing) and for the distribution portion (increasing). The projection is made by taking the product of the two trends. The result is shown in Table 3.34.

3.16 Cable

Distribution cable is split into overhead conductor and underground cable and defined in the aggregate as cable. Three phase and single phase are lumped together by converting the three phase to single phase equivalent. Table 3.35 contains the historical usage in miles as reported in the Electrical World survey. These data include only primary distribution and, thus, do not include "service drop" usage. The material usage for cable, Chapter 4, is calculated from the primary distribution requirements by applying historical ratios to obtain the associated secondary requirements.

Overhead conductor is forecasted as a function of change in kw-hr sales and the number of new customers. Underground cable is forecasted as a function of all underground transformers. The historical and forecasted miles of cable are shown in Figure 3.25.

Table 3.34

P O L E C R O S S A R M S

Units (000)

	Total Crossarms Reported (1)	Source Coverage (2)	Total Crossarms Adjusted (3) = (1) ÷ (2)	Total Crossarms Trend (4)	Pole Ratio of Dist./Util. Actual Trend (5) (6)		Estimated Actual Distribution Crossarms (7) = (3) * (5)	Projected Distribution Crossarms (8) = (4) * (6)
1959	3878	.984	3941	4449				
1960	3994	.981	4071	4376				
1961	3773	.990	3811	4303				
1962	3384	.990	3418	4231				
1963	3476	.973	3572	4158				
1964	3782	.970	3899	4085				
1965	5886	.975	6037	4013				
1966	6060	.990	6121	3940	.928	.907	5680	3574
1967	4821	.976	4940	3867	.877	.910	4332	3519
1968	3138	.940	3338	3795	.913	.913	3048	3465
1969	2962	.940	3151	3722	.922	.916	2905	3409
1970	3992	.940	4247	3649	.927	.919	3937	3353
1971	2953	.930	3175	3576	.929	.922	2950	3297
1972	2471	.940	2629	3504	.920	.925	2419	3241
1973	2528	.920	2748	3431	.926	.928	3177	3184
1974				3358		.931		3128
1975				3285		.934		3068
1980				2922		.950		2776
1985				2559		.965		2469
1990				2195		.980		2151
1995				1832		.995		1823
2000				1469		1.000		1469

Table 3.35

C A B L E[†]

Source: Electrical World, 10th Annual T&D Construction Survey
Single Phase Equivalent - Miles (000)

	<u>Reported Data</u>			<u>% Coverage</u>	<u>Adjusted Data</u>		
	<u>OH</u>	<u>UG</u>	<u>Total</u>		<u>OH</u>	<u>UG</u>	<u>Total</u>
1965							
1966	66						
1967	66						
1968	69	29	98	81.0	85	36	121
1969	71	20	91	82.0	87	24	111
1970	73	22	95	83.0	88	27	114
1971	77	20	97	81.0	95	25	120
1972	76	18	94	81.0	94	22	116
1973	88	54	142	80.6	109	67	176
1974	68	35	103	87.1	78	40	118

[†]
Primary distribution only.

Figure 3.25

CHAPTER 4

TASK 3 - FORECAST OF DISTRIBUTION SYSTEM MATERIAL REQUIREMENTS

4.1 Task Description

Task 3 is concerned with developing a material matrix that gives the amount of material required per unit of production of each equipment category. This matrix is then multiplied by the equipment forecasts to obtain material requirements. Specifically, Task 3 is composed of the following work elements:

1. Determine present material usage in the distribution system as related to equipment type.
2. Determine the changes presently being planned in the distribution system as related to material usage and equipment types.
3. Study emergent technologies and predict when they will be a factor in the distribution system.

Material usage data for transformers were obtained at a different level of disaggregation than used to forecast the equipment requirements. Thus, the equipment categories were aggregated as shown in Section 4.2 for the material requirements analysis.

4.2 Summary of Results

Materials usage is discussed in two contexts: In the first case, material usage is forecast under the assumption that present technology is used to produce the equipment. In the second case, the effects of forecasted technological change in the manufacture of distribution equipment induced by economics, technology advancement, environmental considerations, or other factors are discussed with regard to their potential impact on material usage. In general, the material usage patterns for each equipment

TRANSFORMER CATEGORIES

<u>Material Analysis Category</u> (Task 3)	<u>Equipment Requirements Category</u> (Task 2)
Overhead Transformers	Residential Load Growth and Upgrading 1 Ø, 5 - 100 KVA
	Residential - New Homes 1 Ø, 5 - 100 KVA
	Commercial Transformers 1 Ø, 167 - 500 KVA
	Commercial Transformers 3 Ø, 15 - 500 KVA
Underground Transformers	Residential - New Homes 1 Ø, 5 - 100 KVA
	Commercial Transformers 3 Ø, 15 - 500 KVA
Small Power Transformers	Commercial Transformers UG, 3 Ø 500-2500 KVA
	Commercial Transformers Network
	Commercial Transformers Power Centers
	Substation Transformers

category are not expected to change significantly over the next 25 years. The primary exceptions to this rule will be those materials whose use is prohibited, such as PCB, or in cases where there presently exist well-established trends as discussed in section 4.2.2.

4.2.1 Material Usage Forecasts with Present Technology

Table 4.1 gives the per unit material requirements for each equipment category using present technology. Table 4.2 gives the forecasted material usage between 1975 and 2000 for the three electrical usage scenarios. These material requirements use the equipment projections given in Table 3.3 and the present technology material requirements matrix, Table 4.1. It is emphasized that these material forecasts are based on 1975 technology and that, in some cases, drastic changes in usage will occur before 2000. (For example, PCB is currently being eliminated from use.)

Table 4.3 gives the ratio of usage in 2000 to usage in 1975 if present technology were maintained. Note that even in the low electrical growth case, most material requirements are substantially higher in 2000 than in 1975.

Table 4.1

MATERIAL REQUIRED PER 1000 UNITS IN 1974
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			TRANSFORMERS			
			OVERHEAD	UNDERGROUND	SMALL POWER	DRY TYPE INSTRUMENT
1974 UNITS (1000S):			1361.100	275.600	15.800	44.000 424.800
LBS.	1	STEEL	89817.06	219375.91	4260126.58	420909.09 9171.37
	2	STNLS STEEL	286.53	703.92	4050.63	
	3	ELEC STEEL	145690.99	355878.08	2894303.80	431363.64 34322.03
	4	ALUMINUM	16398.50	40058.06	768997.34	63136.36 6120.53
	5	COPPER	17147.90	41872.28	24810.13	52636.36
	6	BRASS	310.04	754.72	1012.66	
	7	BRONZE	41.14	101.60	632.91	
	8	SILVER	4.56	10.89	18.99	
	9	LEAD	90.88	222.79	2354.43	
	10	TIN	1.98	5.08	50.63	
	11	ZINC, CD	146.94	355.59	19.94	
	12	TUNGSTEN	20.57	50.80		
	13	ALNICO, BAFE				
	14	NI, NI-CK				
	15	SI-CARBIDE				
	16	BORIC ACID				
	17	CU SALTS				
	18	NAF				
	19	ZN PHOSPHATE	28.65	113.93	2025.32	145.45 1.18
	20	SAND				
	21	CONCRETE				
	22	PORCELAIN	11828.67	27213.35	23481.01	15909.09 353.11
	23	GLASS	1520.83	3628.45	5063.29	2318.18
	24	ALUMNA, BERYL	357.35	928.88	3354.43	250.00 6026.37
	25	GASKET MATLS	2204.10	5079.83	7278.48	2272.73 89.45
	26	PAPER, FIBER	14032.77	32656.02	427215.19	21363.64 35.31
	27	PHENOLIC RESN	36.73	188.68	3607.59	63.64 11.77
	28	POLYESTER	1263.68	2902.76	2215.19	1931.82
	29	EPOXY	426.13	928.88	6329.11	681.82 710.92
	30	SILICONE	54.37	5.08	139.24	22.73
	31	POLYPROPYLENE				
	32	MSC PLASTICS	51.43	145.14	16772.15	8181.82
	33	POLYETHYLENE				
	34	PVC				
	35	ETPRP RUBBER				
	36	Ca, KSLF POLY				
	37	BUTYL RUBBER				3295.67
	38	NEOPRENE				
	39	MISC INSUL				
	40	PENTA				
GAL.	41	PCB OR SUBST			79113.92	
	42	INSL OIL	15942.99	87808.42	265822.78	440.21
	43	INSL VARNISH	74.94	435.41	3164.56	61.36 112.99
	44	FINISHES	180.00	449.93	6645.57	409.09 3.53
	45	SOLVENTS	229.96	562.41	4746.84	436.36 3.53
	46	CREOSOTE		33.02		
UNIT	47	POLES				
	48	CROSS ARMS				
CUFT	49	ARGON	22775.70			

Table 4.1(continued)

MATERIAL REQUIRED PER 1000 UNITS IN 1974

		VOLTAGE REG	METERS	SWITCHGEAR	FUSES	CAPACITORS
1974 UNITS (1000S):		7.800	3876.000	45.200	1636.000	43.500
Lbs.	1 STEEL	1242307.69	487.62	2031858.41	3328.85	17434.48
	2 STNLS STEEL	3923.08	178.02	20265.49	314.18	
	3 ELEC STEEL	1340384.62	1678.02			
	4 ALUMINUM	191794.87	999.48	54823.01		9239.54
	5 COPPER	196153.85	994.32	256415.93	3419.32	323.68
	6 BRASS	1198.72	429.82	16725.66	375.31	132.41
	7 BRONZE	474.04	12.90	7300.88		
	8 SILVER			805.31	41.69	
	9 LEAD	839.10	20.64			23.54
	10 TIN		29.88			23.54
	11 ZINC, CD	326.92	8.05			
	12 TUNGSTEN			121.68		
	13 ALNICO, BAFE		147.57			
	14 NI, NI-CR		0.03	44.25		
	15 SI-CARBIDE					
	16 BORIC ACID				82.52	
	17 CU SALTS					
	18 NAF					
	19 ZN PHOSPHATE	1176.92	10.11	553.10		2.94
	20 SAND				1039.12	
	21 CONCRETE					
	22 PORCELAIN	18162.39		369469.03	7900.37	1029.89
	23 GLASS	4649.57	1973.68	35398.23	586.80	
	24 ALUMNA, BERYL	3378.21		17699.12		
	25 GASKET MATLS	5067.31	77.40	9070.80		
	26 PAPER, FIBER	257179.49	293.34	884.96	213.94	14712.64
	27 PHENOLIC RSN		291.54			
	28 POLYESTER	2915.06	0.95	49778.76	391.20	
	29 EPOXY	3923.08	82.56	2212.39		
	30 SILICONE	125.32		553.10		
	31 POLYPROPYLENE					22068.97
	32 MSC PLASTICS	6538.46	42.57	3982.30	30.56	331.03
	33 POLYETHYLENE					
	34 PVC					
	35 ETPRP RUBBER					
	36 CH, RSLF POLY					
	37 BUTYL RUBBER					
	38 NEOPRENE					
	39 MISC INSUL					
	40 PENTA					
GAL.	41 PCB OR SUBST					2648.28
	42 INSL OIL	92307.69				
	43 INSL VARNISH	1024.36	0.18			
	44 FINISHES	12423.08	3.46	2654.87		17.66
	45 SOLVENTS	3160.26	20.64	3539.82		16.18
	46 CREOSOTE					
UNIT	47 POLES					
	48 CROSS ARMS					
CUFT	49 ARGON					

Table 4.1(continued)

MATERIAL REQUIRED PER 1000 UNITS IN 1974

1974 UNITS (1000S):			BREAKERS	ARRESTERS	WOOD POLES	CONCR POLES	INSULATORS
			19.600	1725.000	2795.000	60.000	11070.000
LBS.	1	STEEL	634693.88	2910.14		400000.00	343.27
	2	STNLS STEEL	7857.14				
	3	ELEC STEEL					
	4	ALUMINUM	61734.69	115.94			198.74
	5	COPPER	120204.08	1.16			
	6	BRASS	714.29	82.32			
	7	BRONZE					
	8	SILVER	484.69				
	9	LEAD					
	10	TIN					
	11	ZINC,CD					
	12	TUNGSTEN	484.69				
	13	ALNICO,BAFE					
	14	NI,NI-CR					
	15	SI-CARBIDE		6376.81			
	16	BORIC ACID					
	17	CU SALTS			121.65		
	18	NAF			196.78		
	19	ZN PHOSPHATE	91.84				
	20	SAND					
	21	CONCRETE				4000000.00	
	22	PORCELAIN	56122.45	15652.17			695.57
	23	GLASS					
	24	ALUMNA,BERYL					
	25	GASKET MATLS	7653.06	463.77			
	26	PAPER,FIBER	13775.51				
	27	PHENOLIC RESIN	1785.71				
	28	POLYESTER					
	29	EPOXY					
	30	SILICONE					
	31	POLYPROPYLENE					
	32	MISC PLASTICS	484.69	347.83			
	33	POLYETHYLENE					
	34	PVC					
	35	ETPRP RUBBER					
	36	CH,RSLE POLY					
	37	BUTYL RUBBER					
	38	NEOPRENE					
	39	MISC INSUL					
	40	PENTA			4865.83		
GAL.	41	PCB OR SUBST					
	42	INSL OIL	11479.59				
	43	INSL VARNISH					
	44	FINISHES	551.02				
	45	SOLVENTS	408.16				
	46	CRESOTE			8944.54		
	47	POLES			5330.95		
UNIT	48	CROSS ARMS			919.50		
CUFT	49	ARGON			905.19		

Table 4.1(continued)

MATERIAL REQUIRED PER 1000 UNITS IN 1974

1974 UNITS (1000S):			OH COND	UG CABLE	CONNECTORS
			76.400	40.400	7689.000
LBS.	1	STEEL	1205943.08		
	2	STNLS STEEL			
	3	SLC STEEL			
	4	ALUMINUM	2522632.11	2346888.74	260.11
	5	COPPER	507729.86	1503935.52	2145.92
	6	BRASS			
	7	BRONZE			
	8	SILVER			
	9	LEAD		174955.38	
	10	TIN			
	11	ZINC,CD	2392.04		
	12	TUNGSTEN			
	13	ALNICO,BAFE			
	14	NI,NI-CR			
	15	SI-CARBIDE			
	16	BORIC ACID			
	17	CU SALTS			
	18	NAF			
	19	ZN PHOSPHATE			
	20	SAND			
	21	CONCRETE			
	22	PORCELAIN			
	23	GLASS			
	24	ALUMINA,BERYL			
	25	GASKET MATLS			
	26	PAPER,FIBER	5057.01	82136.43	
	27	PHENOLIC RSN			
	28	POLYESTER			
	29	EPOXY			
	30	SILICONE			
	31	POLYPROPYLENE			
	32	MSC PLASTICS			
	33	POLYETHYLENE	2738746.97	1388141.00	
	34	PVC	975688.99	1109761.44	
	35	ETPRP RUBBER	669560.07	328736.03	
	36	CH,RSLE POLY	488276.45	173265.76	
	37	BUTYL RUBBER	175826.77	73352.19	
	38	NEOPRENE	67878.05	21019.50	
	39	MISC INSUL	60263.23		
	40	PENTA			
GAL.	41	PCB OR SUBST			
	42	INSL OIL			
	43	INSL VARNISH			
	44	FINISHES			
	45	SOLVENTS			
	46	CREOSOTE			
UNIT	47	POLES			
	48	CROSS ARMS			
CUFT	49	ARGON			

Table 4.2

**TOTAL MATERIAL REQUIREMENTS FOR LOW ELECTRICAL DEMAND CASE
(USING 1975 TECHNOLOGY)**

YEAR:		1975	1980	1985	1990	1995	2000
LBS.	1 STEEL	385719307	528972446	646034772	611202410	669676653	658979498
	2 STNLS STEEL	2119974	2826693	3346408	3292273	3460628	3419190
	3 ELEC STEEL	191751987	340339035	421235127	391029002	428820468	394686472
	4 ALUMINUM	319083113	369435778	465984102	364121780	368953894	345561494
	5 COPPER	131587330	177094971	206947436	175086799	177286744	166228970
	6 BRASS	2656734	3476551	4075084	3798124	3777451	3603014
	7 BRONZE	391502	507019	608183	651643	709825	752159
	8 SILVER	87889	120287	144661	143876	159257	153132
	9 LEAD	5851392	7259043	7495633	6475765	5754665	5783451
	10 TIN	87478	101300	113246	94898	76317	69250
	11 ZINC, CD	329025	490472	609547	478337	499649	431661
	12 TUNGSTEN	29024	49900	59950	55127	59383	54242
	13 ALNICO, BAFE	418522	478285	529914	442115	345703	314875
	14 NI, NI-CR	1963	2405	2882	3242	3579	3918
	15 SI-CARBIDE	6313043	9108287	10509929	9655679	10313319	9160634
	16 BORIC ACID	81932	119359	145968	132644	147823	125260
	17 CU SALTS	336472	344623	351070	354841	357395	358004
	18 NAF	544293	557478	567907	574007	578140	579123
	19 ZN PHOSPHATE	122279	174455	207593	202972	213999	212981
	20 SAND	1031742	1503041	1838120	1670335	1861477	1577346
	21 CONCRETE	240000000	240000000	240000000	240000000	240000000	240000000
	22 PORCELAIN	56309307	80950826	97535100	93319849	102216924	95323703
	23 GLASS	9011799	11786839	13706132	12318457	11671462	10926798
	24 ALUMINA, BERYL	3111436	4132189	4828911	5237365	5753288	6110244
	25 GASKET MATLS	3071696	5366238	6552199	5922256	6365270	5687755
	26 PAPER, FIBER	23817600	38729606	47357854	43709871	47604200	43947511
	27 PHENOLIC RESN	949886	1140295	1279077	1103628	935175	873531
	28 POLYESTER	3569494	5340619	6535692	6545773	7218865	7122814
	29 EPOXY	1016444	1521838	1824168	1737179	1833612	1756947
	30 SILICONE	57052	91199	118739	113471	130369	117650
	31 POLYPROPYLENE	520828	242737	661297	557528	970726	681159
	32 MSC PLASTICS	1322221	1748106	2113700	2192669	2414548	2464003
	33 POLYETHYLENE	267619915	312426558	379480923	277968878	280169105	257910598
	34 PVC	115333770	135899464	160424600	120791262	119004666	111276169
	35 ETHER RUBBER	65081343	75955977	92338209	67580825	68163151	62717986
	36 CH, KSLF POLY	45300638	52733671	64611616	46932098	47634449	43641830
	37 BUTYL RUBBER	17760957	20795555	25271671	19040243	19416633	18160902
	38 NEOPRENE	6197823	7208182	8856227	6415794	6526246	5970207
	39 MISC INSUL	4896086	5653474	7097321	5035896	5211925	4712162
	40 PENTA	13458891	13784902	14042791	14193631	14295814	14320143
GAL.	41 PCB OR SUBST	1154271	1503733	1944150	2168248	2594414	2730473
	42 INSL OIL	20730341	43540424	51677153	45353206	47047386	42730099
	43 INSL VARNISH	169160	298528	353411	335331	357553	347888
	44 FINISHES	474855	690915	828365	814923	889562	869105
	45 SOLVENTS	25237473	26107852	26748315	26991969	27252013	27261684
	46 CREOSOTE	14748193	15110463	15393285	15557006	15667817	15694561
UNIT	47 POLES	2543335	2604941	2653674	2682179	2701488	2706086
	48 CROSS ARMS	2503750	2564397	2612372	2640433	2659442	2663968
CUFT	49 ARGON	12237382	23609833	32275712	27936418	32879792	25531533

Table 4.2(continued)
TOTAL MATERIAL REQUIREMENTS FOR BASE ELECTRICAL DEMAND CASE
(USING 1975 TECHNOLOGY)

YEAR:		1975	1980	1985	1990	1995	2000
LBS.	1 STEEL	385719307	599946069	722216793	744906795	842742353	856769747
	2 STNLS STEEL	2119974	3080472	3597519	3784787	4244178	4336910
	3 ELEC STEEL	191751987	410373075	503027628	527653209	598080873	581645803
	4 ALUMINUM	319083113	440993168	524599851	494144673	528691673	521292811
	5 COPPER	131587330	205666724	243396399	242858311	263736507	261563679
	6 BRASS	2656734	3738488	4330942	4490919	4902810	4897347
	7 BRONZE	391502	549621	651944	712204	828541	902393
	8 SILVER	87889	132460	153853	158078	179127	176053
	9 LEAD	5851392	8761615	10104220	10816956	11443429	12077067
	10 TIN	87478	102541	115526	119285	120498	119829
	11 ZINC,CD	329025	567349	683695	642780	698987	646930
	12 TUNGSTEN	29024	58349	69313	70985	79327	76052
	13 ALNICO,BAFE	418522	478285	534405	551217	551217	551217
	14 NI,NI-CR	1963	2552	3017	3354	3961	4455
	15 SI-CARBIDE	6313043	10129744	11408231	11268910	12173333	11109579
	16 BORIC ACID	81932	134369	154960	149952	165578	142791
	17 CU SALTS	336472	344623	351070	354841	357395	358004
	18 NAF	544293	557478	567907	574007	578140	579123
	19 ZN PHOSPHATE	122279	198983	239239	258919	291888	302443
	20 SAND	1031742	1692051	1951351	1888287	2085058	1798113
	21 CONCRETE	240000000	240000000	240000000	240000000	240000000	240000000
	22 PORCELAIN	56309307	91620543	107365728	109528948	123113350	118513715
	23 GLASS	9011799	12621663	14620626	15146463	16251357	16154434
	24 ALUMNA,BEAYL	3111436	4541999	5332387	5909814	6755262	7339199
	25 GASKET MATLS	3071696	6340101	7610764	7771688	8694261	8232175
	26 PAPER,FIBER	23817600	46725474	57035816	59940270	67700767	66131303
	27 PHENOLIC RSN	949886	1173943	1333133	1391428	1432080	1443179
	28 POLYESTER	3569494	6069211	7273312	7669228	8832119	8994749
	29 EPOXY	1016444	1735716	2071981	2189680	2448276	2451709
	30 SILICONE	57052	105764	129037	130534	151686	141200
	31 POLYPRPYLENE	520828	526477	923608	998908	1288188	942168
	32 MSC PLASTICS	1322221	1954633	2359259	2586042	2946441	3090752
	33 POLYETHYLENE	267619915	347382949	412857113	368869608	388706045	376410080
	34 PVC	115333770	153483222	181307825	168090035	177211712	175108813
	35 ETPRP RUBBER	65081343	84413341	100342501	89546187	94360224	91314785
	36 CH,RSLE POLY	45300638	58346950	69477227	61339022	64627664	62160726
	37 BUTYL RUBBER	17760957	23013489	27330350	24672245	26149262	25553110
	38 NEOPRENE	6197823	7962938	9487791	8344225	8791153	8436855
	39 MISC INSUL	4896086	6167941	7385258	6295579	6630040	6246404
	40 PENTA	13458891	13784902	14042791	14193631	14295814	14320143
GAL.	41 PCB OR SUBST	1154271	1791184	2323175	2721689	3258459	3514959
	42 INSL OIL	20730341	53981053	65679380	68819431	76587468	75152973
	43 INSL VARNISH	169160	359819	436792	470471	529509	540148
	44 FINISHES	474855	807074	968285	1034929	1179640	1199673
	45 SOLVENTS	25237473	26229243	26887511	27227356	27569801	27621947
	46 CREOSOTE	14748193	15112737	15397272	15563619	15676480	15704145
UNIT	47 POLES	2543335	2604941	2653674	2682179	2701488	2706086
	48 CROSS ARMS	2503750	2564397	2612372	2640433	2659442	2663968
CUFT	49 ARGON	12237382	28498044	35204120	33573153	38662109	31241035

Table 4.2(continued)
TOTAL MATERIAL REQUIREMENTS FOR HIGH ELECTRICAL DEMAND CASE
(USING 1975 TECHNOLOGY)

YEAR:		1975	1980	1985	1990	1995	2000
LBS.	1 STEEL	385719307	654162001	849229301	935150101	1070881152	1117909903
	2 STNLS STEEL	2119974	3317224	4071413	4447366	5001458	5158449
	3 ELEC STEEL	191751987	474630683	652293843	750833860	862535565	882198196
	4 ALUMINUM	319083113	474782517	611468992	632730207	693060271	710858430
	5 COPPER	131587330	226588904	296630179	328001803	365326663	379745186
	6 BRASS	2656734	4045089	4882799	5231484	5727956	5767438
	7 BRONZE	391502	569479	694236	774204	901543	984928
	8 SILVER	87889	145375	180652	193947	217955	214996
	9 LEAD	5851392	9518061	12597444	15458621	17421943	19672837
	10 TIN	87478	108249	120104	123583	125477	125320
	11 ZINC, CD	329025	640781	848896	882730	968833	937049
	12 TUNGSTEN	29024	66587	88438	99467	112326	112691
	13 ALNICO, BAFE	418522	500809	543696	552370	552370	552370
	14 NI, NI-CR	1963	2556	3019	3354	3961	4456
	15 SI-CARBIDE	6313043	11367177	14071072	14961301	16243066	15336627
	16 BORIC ACID	81932	156037	198738	206776	225405	200414
	17 CU SALTS	336472	344623	351070	354841	357395	358004
	18 NAF	544293	557478	567907	574007	578140	579123
	19 ZN PHOSPHATE	122279	218411	283741	327896	378497	406742
	20 SAND	1031742	1964908	2502627	2603849	2838435	2523734
	21 CONCRETE	240000000	240000000	240000000	240000000	240000000	240000000
	22 PORCELAIN	56309307	102652089	131334798	143098722	160429128	157722961
	23 GLASS	9011799	13685010	16454175	17629623	19069564	19208042
	24 ALUMNA, BERYL	3111436	4697229	5691574	6444495	7379309	8039111
	25 GASKET MATLS	3071696	7317448	9819420	11003981	12404121	12309734
	26 PAPER, FIBER	23817600	53899178	73970440	85718703	98739136	102017261
	27 PHENOLIC RESIN	949886	1243331	1416409	1498993	1569936	1611826
	28 POLYESTER	3569494	6668752	8617590	9609340	11031207	11373965
	29 EPOXY	1016444	1927846	2489696	2800478	3163853	3254955
	30 SILICONE	57052	123184	164618	177365	201828	190730
	31 POLYPROPYLENE	520828	779829	1502919	1870058	2222279	1846157
	32 MSC PLASTICS	1322221	2099912	2681375	3061445	3530904	3772055
	33 POLYETHYLENE	267619915	369396696	468199846	454820010	486565223	484407731
	34 PVC	115333770	163829693	209447010	214521627	232487779	239595965
	35 ETHER RUBBER	65081343	89751918	113726950	110285817	117931744	117268163
	36 CH, KSLF POLY	45300638	61969593	78327860	74755243	79611883	78277017
	37 BUTYL RUBBER	17760957	24362598	30667485	29785049	31908676	31819923
	38 NEOPRENE	6197823	8454059	10676175	10130463	10772425	10547589
	39 MISC INSUL	4896086	6528014	8184831	7401831	7769858	7331323
	40 FENIA	13458891	13784902	14042791	14193631	14295814	14320143
GAL.	41 PCB OR SUBST	1154271	1966127	2803531	3522746	4401167	5005637
	42 TSSL OIL	20730341	62473079	87167416	103037691	118106061	124036770
	43 INSL VARNISH	169160	404715	551442	654532	757672	813567
	44 FINISHES	474855	905929	1192458	1371841	1588213	1676381
	45 SOLVENTS	25237473	26335334	27128189	27585876	27995354	28106530
	46 CREOSOTE	14748193	15113847	15401007	15570629	15685530	15715677
UNIT	47 POLES	2543335	2604941	2653674	2682179	2701488	2706086
	48 CROSS ARMS	2503750	2564397	2612372	2640433	2659442	2663968
CUFT	49 ARGON	12237382	35554752	49461342	52079203	58146102	50007252

Table 4.3

NORMALIZED MATERIAL REQUIREMENTS FOR PROJECTION YEAR 2000
(USING 1975 TECHNOLOGY)

ELECTRICAL DEMAND CASE:		LOW	BASE	HIGH
LBS.	1 STEEL	1.7084	2.2212	2.8982
	2 STNLS STEEL	1.6128	2.0457	2.4333
	3 ELEC STEEL	2.0583	3.0333	4.6007
	4 ALUMINUM	1.0830	1.6337	2.2278
	5 COPPER	1.2633	1.9878	2.8859
	6 BRASS	1.3562	1.8434	2.1709
	7 BRONZE	1.9212	2.3050	2.5158
	8 SILVER	1.7423	2.0031	2.4462
	9 LEAD	0.9884	2.0640	3.3621
	10 TIN	0.7916	1.3698	1.4326
	11 ZINC,CD	1.3119	1.9662	2.8480
	12 TUNGSTEN	1.8689	2.6203	3.8828
	13 ALNICO,BAFE	0.7523	1.3171	1.3198
	14 NI,NI-CR	1.9961	2.2703	2.2704
	15 SI-CARBIDE	1.4511	1.7598	2.4294
	16 BORIC ACID	1.5288	1.7428	2.4461
	17 CU SALTS	1.0640	1.0640	1.0640
	18 NAF	1.0640	1.0640	1.0640
	19 ZN PHOSPHATE	1.7418	2.4734	3.3263
	20 SAND	1.5288	1.7428	2.4461
	21 CONCRETE	1.0000	1.0000	1.0000
	22 PORCELAIN	1.6929	2.1047	2.8010
	23 GLASS	1.2125	1.7926	2.1314
	24 ALUMNA,BERYL	1.9638	2.3588	2.5837
	25 GASKET MATLS	1.8517	2.6800	4.0075
	26 PAPER,FIBER	1.8452	2.7766	4.2833
	27 PHENOLIC RSN	0.9196	1.5193	1.6969
	28 POLYESTER	1.9955	2.5199	3.1864
	29 EPOXY	1.7285	2.4120	3.2023
	30 SILICONE	2.0622	2.4750	3.3431
	31 POLYPRPYLENE	1.3078	1.8090	3.5447
	32 MSC PLASTICS	1.8635	2.3375	2.8528
	33 POLYETHYLENE	0.9637	1.4065	1.8101
	34 PVC	0.9648	1.5183	2.0774
	35 ETPRP RUBBER	0.9637	1.4031	1.8019
	36 CH,KSLF POLY	0.9634	1.3722	1.7279
	37 BUTYL RUBBER	1.0225	1.4387	1.7916
	38 NEOPRENE	0.9633	1.3613	1.7018
	39 MISC INSUL	0.9624	1.2758	1.4974
	40 PENTA	1.0640	1.0640	1.0640
GAL.	41 PCB OR SUBST	2.3655	3.0452	4.3366
	42 INSL OIL	2.0612	3.6253	5.9833
	43 INSL VARNISH	2.0566	3.1931	4.8094
	44 FINISHES	1.8303	2.5264	3.5303
	45 SOLVENTS	1.0802	1.0945	1.1137
	46 CREOSOTE	1.0642	1.0648	1.0656
UNIT	47 POLES	1.0640	1.0640	1.0640
	48 CROSS ARMS	1.0640	1.0640	1.0640
CUFT	49 ARGON	2.0864	2.5529	4.0864

Table 4.4 gives the percent of the total amount of each material used in distribution equipment by each equipment category for the 1985 base case. For example, approximately 45 percent of the electrical steel used in distribution equipment is used in the manufacture of overhead transformers. Similarly, approximately 53 percent of the copper is used in overhead and underground cable. This table gives a good indication of which equipment categories would be most affected if a material is in short supply or undergoes a substantial price increase. The detailed material usage forecasts by equipment category are given in Appendix 4.

4.2.2 Material Usage Forecasts with Forecasted Technological Change

In this section, "forecasted technological change" is defined as changes in the material requirements of distribution equipment induced by economics, new or improved materials, and environmental considerations. Substitutions of materials due to shortages are discussed in Chapter 7.

Materials whose usage is expected to depart from present usage are discussed in the following paragraphs. Where possible, quantitative estimates are made of expected change.

STEEL - Increases in the use of iron and steel are anticipated because of the advantages of automating various distribution functions, such as meter reading, load management, time-of-day monitoring, and monitoring and control of capacitor banks, switches, and transformers. It is estimated that such devices will be a part of 5% of the meters in ten years, and will reach 50% saturation by the year 2000. Devices on line equipment should be installed at least as rapidly. Each device for monitoring and control will require about three pounds of ferrites or powdered iron for couplers for meters, and about eight pounds for other equipment. This implies an additional demand for ferrites or powdered iron of 20.5 million lbs in 2000. Future developments might decrease the quantity requirements. Steel enclosures for the units will require 1.4 pounds per meter installations and 4.2 pounds for other equipment or about 10.5 million lbs in 2000. This added material usage would be an insignificant part of the domestic powdered iron and steel demand.

Table 4.4

PROJECTION YEAR 1985 (3)

BASE ELECTRICAL DEMAND CASE
PERCENT OF TOTAL MATERIALS REQUIRED
TRANSFORMERS

PROJECTION (1000S):		OVERHEAD	UNDERGROUND	SMALL POWER	DRY TYPE	INSTRUMENT
		1545.688	368.150	27.964	70.826	516.473
LBS.	1 STEEL	19.22	11.18	16.50	4.13	0.66
	2 STNLS STEEL	12.31	7.20	3.15		
	3 ELEC STEEL	44.77	26.05	16.09	6.07	3.52
	4 ALUMINUM	4.83	2.81	4.10	0.85	0.60
	5 COPPER	10.89	6.33	0.29	1.53	
	6 BRASS	11.07	6.42	0.65		
	7 BRONZE	9.75	5.74	2.71		
	8 SILVER	4.58	2.60	0.35		
	9 LEAD	1.39	0.81	0.65		
	10 TIN	2.65	1.62	1.23		
	11 ZINC,CD	33.22	19.15	0.08		
	12 TUNGSTEN	45.87	26.98			
	13 ALNICO,BAFE					
	14 NI,NI-CK					
	15 SI-CARBIDE					
	16 BORIC ACID					
	17 CU SALTS					
	18 NAF					
	19 ZN PHOSPHATE	18.51	17.53	23.67	4.31	0.25
	20 SAND					
	21 CONCRETE					
	22 PORCELAIN	17.03	9.33	0.61	1.05	0.17
	23 GLASS	16.08	9.14	0.97	1.12	
	24 ALUMINA,BERYL	10.65	6.41	1.76	0.33	58.37
	25 GASKET MATLS	44.76	24.57	2.67	2.12	0.61
	26 PAPER,FIBER	38.03	21.08	20.95	2.65	0.03
	27 PHENOLIC RSN	4.26	5.21	7.57	0.34	0.46
	28 POLYESTER	26.86	14.69	0.85	1.88	
	29 EPOXY	31.79	16.50	8.54	2.33	17.72
	30 SILICONE	65.13	1.45	3.02	1.25	
	31 POLYPROPYLENE					
	32 MSC PLASTICS	3.37	2.26	19.88	24.56	
	33 POLYETHYLENE					
	34 PVC					
	35 ETPRP RUBBER					
	36 CH,RSLE POLY					
	37 BUTYL RUBBER					6.23
	38 NEOPRENE					
	39 MISC INSUL					
	40 PENTA					
GAL.	41 PCB OR SUBST			95.23		
	42 INSL OIL	37.52	49.22	11.32		0.35
	43 INSL VARNISH	26.52	36.70	20.26	1.00	13.36
	44 FINISHES	28.73	17.11	19.19	2.99	0.19
	45 SOLVENTS	1.32	0.77	0.49	0.11	0.01
	46 CREOSOTE		0.08			
UNIT	47 POLES					
	48 CROSS ARMS					
CURT	49 ARGON	100.00				

Table 4.4(continued)

PROJECTION YEAR 1985 (3)

BASE ELECTRICAL DEMAND CASE
PERCENT OF TOTAL MATERIALS REQUIRED

PROJECTION (1000S):		VOLTAGE REG	METERS	SWITCHGEAR	FUSES	CAPACITORS
		8.600	3621.247	66.082	1877.888	41.851
LBS.	1 STEEL	1.48	0.24	18.59	0.87	0.10
	2 STNLS STEEL	0.94	17.92	37.23	16.40	
	3 ELEC STEEL	2.29	1.21			
	4 ALUMINUM	0.31	0.69	0.69		0.07
	5 COPPER	0.69	1.48	6.96	2.64	0.01
	6 BRASS	0.24	35.94	25.52	16.27	0.13
	7 BRONZE	0.63	7.17	74.00		
	8 SILVER			34.59	50.88	
	9 LEAD	0.07	0.74			0.01
	10 TIN		93.65			0.85
	11 ZINC, CD	0.41	4.26			
	12 TUNGSTEN			11.60		
	13 ALNICO, BAFB		100.00			
	14 NI, NI-CR		3.10	96.90		
	15 SI-CARBIDE					
	16 BORIC ACID				100.00	
	17 CU SALTS					
	18 NAF					
	19 ZN PHOSPHATE	4.23	15.31	15.28		0.05
	20 SAND				100.00	
	21 CONCRETE					
	22 PORCELAIN	0.15		22.74	13.82	0.04
	23 GLASS	0.27	48.88	16.00	7.54	
	24 ALUMINA, BERYL	0.54		21.93		
	25 GASKET MATLS	0.57	3.68	7.88		
	26 PAPER, FIBER	3.88	1.66	0.10	0.70	1.08
	27 PHENOLIC RESIN		79.19			
	28 POLYESTER	0.34	0.05	45.23	10.10	
	29 EPOXY	1.63	14.43	7.06		
	30 SILICONE	0.84		28.33		
	31 POLYPROPYLENE					100.00
	32 MSC PLASTICS	2.36	6.53	11.15	2.43	0.59
	33 POLYETHYLENE					
	34 PVC					
	35 BUTHR RUBBER					
	36 CH, ASLE POLY					
	37 BUTYL RUBBER					
	38 NEOPRENE					
	39 MISC INSUL					
	40 PENTA					
GAL.	41 PCB OR SUBST					4.77
	42 INSL OIL	1.21				
	43 INSL VARNISH	2.02	0.15			
	44 FINISHES	11.03	1.29	18.12		0.08
	45 SOLVENTS	0.10	0.28	0.87		
	46 CREOSOTE					
UNIT	47 POLES					
	48 CROSS ARMS					
CURT	49 ARGON					

Table 4.4(continued)

PROJECTION YEAR 1985 (3)

BASE ELECTRICAL DEMAND CASE
PERCENT OF TOTAL MATERIALS REQUIRED

PROJECTION (1000S):		BREAKERS	ARRESTERS	WOOD POLES	CONCR POLES	INSULATORS
		22.227	1789.018	2886.000	60.000	12073.376
LBS.	1 STEEL	1.95	0.72		3.32	0.57
	2 STEEL STEEL	4.85				
	3 ELEC STEEL					
	4 ALUMINUM	0.26	0.04			0.46
	5 COPPER	1.10				
	6 BRASS	0.37	3.40			
	7 BRONZE					
	8 SILVER	7.00				
	9 LEAD					
	10 TIN					
	11 ZINC, CO					
	12 TUNGSTEN	15.54				
	13 ALNICO, BARE					
	14 NI, NI-CH					
	15 SI-CARBIDE		100.00			
	16 BORIC ACID					
	17 CU SALTS			100.00		
	18 NAF			100.00		
	19 ZN PHOSPHATE	0.85				
	20 SAND					
	21 CONCRETE				100.00	
	22 PORCELAIN	1.16	26.08			7.82
	23 GLASS					
	24 ALUMINA, BERYL					
	25 GASKET MATLS	2.24	10.90			
	26 PAPER, FIBER	0.54				
	27 PHENOLIC RESIN	2.98				
	28 POLYESTER					
	29 EPOXY					
	30 SILICONE					
	31 POLYPROPYLENE					
	32 MSC PLASTICS	0.46	26.38			
	33 POLYETHYLENE					
	34 PVC					
	35 BUTHR RUBBER					
	36 CH, ASLF POLY					
	37 BUTYL RUBBER					
	38 NEOPRENE					
	39 MISC INSUL					
	40 PENTA			100.00		
GAL.	41 PCB OR SUBST					
	42 INSL OIL	0.39				
	43 INSL VARNISH					
	44 FINISHES	1.26				
	45 SOLVENTS	0.03			96.01	
	46 CREOSOTE				99.92	
UNIT	47 POLES			100.00		
	48 CROSS ARMS			100.00		
CURT	49 ARGON					

Table 4.4(continued)

PROJECTION YEAR 1985 (3)

BASE ELECTRICAL DEMAND CASE
PERCENT OF TOTAL MATERIALS REQUIRED

PROJECTION (1000S):			OH COND.	UG CABLE	CONNECTORS	TOTAL
			122.550	55.631	9238.775	
LBS.	1	STEEL	20.46			100.00
	2	STNLS STEEL				100.00
	3	ELEC STEEL				100.00
	4	ALUMINUM	58.93	24.89	0.46	100.00
	5	COPPER	25.56	34.37	8.15	100.00
	6	BRASS				100.00
	7	BRONZE				100.00
	8	SILVER				100.00
	9	LEAD		96.33		100.00
	10	TIN				100.00
	11	ZINC,CD	42.88			100.00
	12	TUNGSTEN				100.00
	13	ALNICO,BAFE				100.00
	14	NI,NI-CR				100.00
	15	SI-CARBIDE				100.00
	16	BORIC ACID				100.00
	17	CU SALTS				100.00
	18	NAF				100.00
	19	Zn PHOSPHATE				100.00
	20	SAND				100.00
	21	CONCRETE				100.00
	22	PORCELAIN				100.00
	23	GLASS				100.00
	24	ALUMNA,BERYL				100.00
	25	GASKET MATLS				100.00
	26	PAPER,FIBER	1.09	8.01		100.00
	27	PHENOLIC RESIN				100.00
	28	POLYESTER				100.00
	29	EPOXY				100.00
	30	SILICONE				100.00
	31	POLYPROPYLENE				100.00
	32	MISC PLASTICS				100.00
	33	POLYETHYLENE	81.30	18.70		100.00
	34	PVC	65.95	34.05		100.00
	35	ETPRP RUBBER	81.77	18.23		100.00
	36	CH,KSLE POLY	86.13	13.87		100.00
	37	BUTYL RUBBER	78.84	14.93		100.00
	38	NEOPRENE	87.68	12.32		100.00
	39	MISC INSUL	100.00			100.00
	40	PENTA				100.00
GAL.	41	FCB OR SUBST				100.00
	42	INSL OIL				100.00
	43	INSL VARNISH				100.00
	44	FINISHES				100.00
	45	SOLVENTS				100.00
	46	CRESOTE				100.00
UNIT	47	POLES				100.00
	48	CROSS ARMS				100.00
CUFT	49	ARGON				100.00

ELECTRICAL STEEL - Transformers. Since lower losses in transmission and distribution of power would mean more available power per unit of generating capacity, efforts are being made toward developing low loss core steels for transformers. Estimates are that losses could be reduced as much as 30%. However, there is also the possibility that the availability of an improved core material would be used to allow the design of smaller units or to reduce noise level. Thus, the availability of improved core steels could reduce the material requirements for transformers or it could not alter overall material usage but decrease electrical losses.

ALUMINUM AND COPPER - Cable. The large quantities of aluminum and copper used in distribution cables could be reduced somewhat by borrowing from aircraft technology and using smaller wire and improved insulation to allow operation at higher temperatures. In addition, the well-established trend toward high distribution voltages will substantially reduce the amount of material required per cable mile. It is estimated that shifting from the present mix of new installations (which are very heavily concentrated in the 15 kv category) to higher voltages (such as over 50 percent 35 kv or above by 2000) could reduce the aluminum requirement to approximately 30 percent of what would be required with the present voltage mix. (This assumes that the type of residential load does not change.) Thus, we estimate that the material requirements forecast for cable for the year 2000 can reasonably be expected to be reduced by 25 percent from the forecast assuming present technology. Part of this reduction could be nullified by a deteriorating residential load factor.

COPPER - Circuit boards. Additional copper requirements are anticipated for circuit boards for automated meter control (see discussion under Steel). This amount is estimated at 0.02 pounds per meter or approximately 37,000 additional pounds of copper in the year 2000 or .25% of total distribution usage.

LEAD - Transformers, meters, cables. Lead used as armoring on cables could be replaced by steel, and, as confidence grows in organic coverings, eventually could be replaced by them. A decrease in the use of lead is expected.

SILICON CARBIDE - Arresters. A new family of ceramic oxide voltage limiters has recently been developed which is steadily replacing existing low-voltage protective devices. These ceramics appear to be useful not only in low voltage, low current areas, but also in applications where the magnitude of voltage, current, and energy approach that of lightning and switching surges experienced on high voltage transmission lines. Evidence to date strongly suggests that this ceramic oxide voltage limiter has the potential of replacing the present day high voltage surge arresters consisting of power gaps and silicon carbide blocks.

SULFUR HEXAFLUORIDE - Switchgear, small power transformers. Although SF_6 is just starting to be used in distribution equipment, its use is expected to grow. For instance, if zirconia becomes too scarce for use in arc chutes in switchgear and if Corderite (titanium) is not satisfactory, breakers would then be designed for SF_6 . This gas could also be used for small power transformers. For breakers of 35 kv rating or less, SF_6 and vacuum units will gradually replace oil breakers.

GLASS - Circuit boards. Use of automated load management will require glass fiber for construction of the circuit boards. Each unit will use 0.2 pounds of glass.

SILVER - Fuses. The quantity of silver used in sand-filled current limiting fuses may be decreased somewhat by the use of film-type elements formed on ceramic substrates rather than wire or ribbon-type elements.

POLYESTER, EPOXY - Transformers, switchgear, fuses, meters. Because of their versatility, use of epoxies would be expected to increase. If material supplies are adequate, epoxies may increasingly replace porcelain and epoxies as electrical insulation in many distribution equipment. These new materials are cheaper than porcelain and epoxy materials, and require minimal energy for processing.

MISCELLANEOUS PLASTICS - Used in most distribution equipment. An increase in the usage of polytetrafluoroethylene plastics is probable with increased use of sulfur hexafluoride in switchgear and transformers.

<u>POLYETHYLENE,</u>	}	- Cables.
<u>POLYVINYLCHLORIDE,</u>		
<u>ETHYLENE PROPYLENE RUBBER,</u>		
<u>CHLOROSULFONATED POLYETHYLENE,</u>		
<u>BUTYL RUBBER,</u>		
<u>NEOPRENE,</u>		
<u>MISCELLANEOUS INSULATION</u>		

Use of higher distribution voltages (to 69 kv) will lead to increased voltage stress in insulations and thereby reduce the amount of insulation used for cables. Use of higher temperature insulations would allow smaller diameter conductors, with consequent decrease in insulation volume. There is an increasing use of crosslinked polyethylene and PVC.

PCB - Capacitors, transformers. Within a year or so, PCB is expected to be replaced in capacitors because of environmental restrictions. It will be replaced by an assortment of aromatic hydrocarbons (perhaps halogenated) or silicone fluids. Because a significant fraction of all capacitors are used indoors, there is a strong desire for the liquid to be non-flammable. Of the materials being considered for this application, many will be used initially; however, of the few which turn out to be the best, probably none will prove to be an ideal replacement for PCB.

Replacement of PCB in small power transformers will extend over a longer time (perhaps 3-5 years), but the change is inevitable. For transformers, a wider range of approaches is available, but they involve design changes or substitution of a less desirable fluid. Design changes include use of dry type transformers, insulating materials, such as hexafluoroethane, resin-cast coils (requiring no steel tank), or vapor-cooled units using fluorocarbon refrigerants and oil. Fluids available for substitution include silicones and halogenated hydrocarbons.

INSULATING OIL - Transformers, reclosers. Paraffinic oils are already replacing the less available naphthenics. Should these too have to be replaced, the design and material options described above are available. For reclosers, there is already a trend toward vacuum units, and these plus gas-insulated units will eventually replace the present oil-insulated equipment.

INSULATING VARNISH, FINISHES, SOLVENTS

Organic finishes (paints and coatings) in organic solvents are already being replaced in many manufacturing operations. Several recent developments are responsible for this change. One of these is the action by state and federal governments in limiting the amount of organic vapors which may be allowed to escape into the atmosphere. Although EPA restrictions have relaxed somewhat, the trend away from solvent-type finishes has begun, and the restrictions may be expected to be intensified in the future.

A second development leading to reduction of solvent-type finishes is the requirement to meet OSHA standards. Solvent vapors in the area of a paint or varnish line or drying ovens are considered to be potentially hazardous. They are also generally flammable and pose a potential fire problem.

In addition, the energy shortage has led to efforts to minimize bake schedules and to find alternatives to the use of organic solvents, which are becoming increasingly scarce and expensive. Decreases in lead content of paints have already been mandated, and more severe restrictions are anticipated.

The changes in finishes could come in various forms. Finishes in water-reducible form are already being used in some industries. Coatings with higher solids content (80% or more) would minimize the use of solvents. Powder coatings (100% solids) have been used, and possibly will be used to a greater extent in distribution equipment. Elimination of baking ovens would result from use of ultraviolet curable coatings or reactive polyurethane coatings, both of which will probably grow during the years ahead.

4.3 Methodology

The material usage forecasts were developed by first estimating the amount of material used by equipment category in 1974. This information was collected by interviewing suppliers of the equipment. Persons contacted included engineering, marketing, and purchasing representatives. In those cases where Westinghouse is a supplier

Table 4.5

TOTAL MATERIAL REQUIRED IN 1974

		TRANSFORMERS				
		OVERHEAD	UNDERGROUND	SMALL POWER	DRY TYPE	INSTRUMENT
1974 UNITS (1000S):		1361.100	275.600	15.800	44.000	424.800
LBS.	1 STEEL	122250000	60460000	67310000	18520000	3896000
	2 STNLS STEEL	390000	194000	64000		
	3 ELEC STEEL	198300000	98080000	45730000	18980000	14580000
	4 ALUMINUM	22320000	11040000	12150000	2778000	2600000
	5 COPPER	23340000	11540000	392000	2316000	
	6 BRASS	422000	208000	16000		
	7 BRONZE	56000	28000	10000		
	8 SILVER	8200	3000	300		
	9 LEAD	123700	61400	37200		
	10 TIN	2700	1400	800		
	11 ZINC, CD	200000	98000	315		
	12 TUNGSTEN	28000	14000			
	13 ALNICO, BAFE					
	14 NI, NI-CK					
	15 SI-CARBIDE					
	16 BORIC ACID					
	17 CU SALTS					
	18 NAF					
	19 ZN PHOSPHATE	39000	31400	32000	6400	500
	20 SAND					
	21 CONCRETE					
	22 PORCELAIN	16100000	7500000	371000	700000	150000
	23 GLASS	2070000	1000000	80000	102000	
	24 ALUMNA, BERYL	500000	256000	53000	11000	2560000
	25 GASKET MATLS	3000000	1400000	115000	100000	38000
	26 PAPER, FIBER	19100000	9000000	6750000	940000	15000
	27 PHENOLIC RESIN	50000	52000	57000	2800	5000
	28 POLYESTER	1720000	800000	35000	85000	
	29 EPOXY	580000	256000	100000	30000	302000
	30 SILICONE	74000	1400	2200	1000	
	31 POLYPROPYLENE					
	32 MSC PLASTICS	70000	40000	265000	360000	
	33 POLYETHYLENE					
	34 PVC					
	35 ETPRP RUBBER					
	36 CH, KSLF POLY					
	37 BUTYL RUBBER					1400000
	38 NEOPRENE					
	39 MISC INSUL					
	40 PENTA					
GAL.	41 PCB OR SUBST			1250000		
	42 INSL OIL	21700000	24200000	4200000		187000
	43 INSL VARNISH	102000	120000	50000	2700	48000
	44 FINISHES	245000	124000	105000	18000	1500
	45 SOLVENTS	313000	155000	75000	19200	1500
	46 CREOSOTE		9100			
UNIT	47 POLES					
	48 CROSS ARMS					
CUFT	49 ARGON	31000000				

Table 4.5(continued)

TOTAL MATERIAL REQUIRED IN 1974

1974 UNITS (1000S):			VOLTAGE REG	METERS	SWITCHGEAR	FUSES	CAPACITORS
			7.800	3876.000	45.200	1636.000	43.500
LBS.	1	STEEL	9690000	1890000	91840000	5446000	758400
	2	STNLS STEEL	30500	690000	916000	514000	
	3	BLEC STEEL	10455000	6504000			
	4	ALUMINUM	1496000	3874000	2478000		401920
	5	COPPER	1530000	3854000	11590000	5594000	14030
	6	BRASS	9350	1666000	756000	614000	5760
	7	BRONZE	3698	50000	330000		
	8	SILVER			36400	68200	
	9	LEAD	6545	80000			1024
	10	TIN		115800			1024
	11	ZINC,CD	2550	31200			
	12	TUNGSTEN			5500		
	13	ALNICO,BAFE		572000			
	14	NI,NI-CR		100	2000		
	15	SI-CARBIDE					
	16	BORIC ACID				135000	
	17	CU SALTS					
	18	NAF					
	19	ZN PHOSPHATE	9180	39200	25000		123
	20	SAND				1700000	
	21	CONCRETE					
	22	PORCELAIN	141657		16700000	12925000	44800
	23	GLASS	36267	7650000	1600000	960000	
	24	ALUMINA,BERYL	26350		800000		
	25	GASKET MATLS	39525	300000	410000		
	26	PAPER,FIBER	2005000	1137000	40000	350000	640000
	27	PHENOLIC RESN		1130000			
	28	POLYESTER	22738	3700	2250000	640000	
	29	EPOXY	30600	320000	100000		
	30	SILICONE	978		25000		
	31	POLYPROPYLENE					950000
	32	MISC PLASTICS	51000	165000	180000	50000	14400
	33	POLYETHYLENE					
	34	PVC					
	35	ETPRF RUBBER					
	36	CH,RSLE POLY					
	37	BUTYL RUBBER					
	38	NEOPRENE					
	39	MISC INSUL					
	40	PENTA					
GAL.	41	PCB OR SUBST					115200
	42	INSL OIL	720000				
	43	INSL VARNISH	7990	700			
	44	FINISHES	96900	13400	120000		768
	45	SOLVENTS	24650	80000	160000		704
	46	CREOSOTE					
UNIT	47	POLES					
	48	CROSS ARMS					
CUFT	49	ARGON					

Table 4.5(continued)

TOTAL MATERIAL REQUIRED IN 1974

1974 UNITS (1000S):		BREAKERS	ARRESTERS	WOOD POLES	CONCK POLES	INSULATORS
		19.600	1725.000	2795.000	60.000	11070.000
LBS.	1 STEEL	12440000	5020000		24000000	3800000
	2 STNLS STEEL	154000				
	3 ELEC STEEL					
	4 ALUMINUM	1210000	200000			2200000
	5 COPPER	2356000	2000			
	6 BRASS	14000	142000			
	7 BRONZE					
	8 SILVER	9500				
	9 LEAD					
	10 TIN					
	11 ZINC,CD					
	12 TUNGSTEN	9500				
	13 ALNICO,BAFE					
	14 NI,NI-CR					
	15 SI-CARBIDE		11000000			
	16 BORIC ACID					
	17 CU SALTS			340000		
	18 NAF			550000		
	19 ZN PHOSPHATE	1800				
	20 SAND					
	21 CONCRETE				240000000	
	22 PORCELAIN	1100000	27000000			7700000
	23 GLASS					
	24 ALUMINA,BERYL					
	25 GASKET MATLS	150000	800000			
	26 PAPER,FIBER	270000				
	27 PHENOLIC ASN	35000				
	28 POLYESTER					
	29 EPOXY					
	30 SILICONE					
	31 POLYPROPYLENE					
	32 MSC PLASTICS	9500	600000			
	33 POLYETHYLENE					
	34 PVC					
	35 ETPRP RUBBER					
	36 CH,ASLF POLY					
	37 BUTYL RUBBER					
	38 NEOPRENE					
	39 MISC INSUL					
	40 PENTA			13600000		
GAL.	41 PCB OR SUBST					
	42 INSL OIL	225000				
	43 INSL VARNISH					
	44 FINISHES	10800				
	45 SOLVENTS	8000		25000000		
	46 CREOSOTE			14900000		
UNIT	47 POLES			2570000		
	48 CROSS ARMS			2530000		
CUFT	49 ARGON					

Table 4.5(continued)
TOTAL MATERIAL REQUIRED IN 1974

1974 UNITS (1000S):			OH COND	UG CABLE	CONNECTORS	TOTAL
			76.400	40.400	7689.000	
LBS.	1	STEEL	92134051			519454451
	2	STNLS STEEL				2952600
	3	ELEC STEEL				392629000
	4	ALUMINUM	192729093	94814305	2000000	352291318
	5	COPPER	38790561	60758995	16500000	178577637
	6	BRASS				3853110
	7	BRONZE				477698
	8	SILVER				123600
	9	LEAD		7068197		7378066
	10	TIN				121724
	11	ZINC,CD	182751			514816
	12	TUNGSTEN				57000
	13	ALNICO,BAFE				572000
	14	NI,NI-CR				2100
	15	SI-CARBIDE				11000000
	16	BORIC ACID				135000
	17	CU SALTS				340000
	18	NAF				550000
	19	ZN PHOSPHATE				184608
	20	SAND				1700000
	21	CONCRETE				240000000
	22	PORCELAIN				90432467
	23	GLASS				13498267
	24	ALUMINA,BERYL				4206350
	25	GASKET MATLS				6352525
	26	PAPER,FIBER	386355	3318312		43952667
	27	PHENOLIC RSN				1331800
	28	POLYESTER				5556438
	29	EPOXY				1718600
	30	SILICONE				104578
	31	POLYPROPYLENE				960000
	32	MSC PLASTICS				1804900
	33	POLYETHYLENE	209240268	56080896		265321165
	34	PVC	74542639	44834362		119377001
	35	ETPRP RUBBER	51154390	13280936		64435325
	36	CH,MSLF POLY	37304321	6999937		44304258
	37	BUTYL RUBBER	13433165	2963429		17796594
	38	NEOPRENE	5185883	849188		6035071
	39	MISC INSUL	4604110			4604110
	40	PENTA				13600000
GAL.	41	PCB OR SUBST				1365200
	42	INSL OIL				51232000
	43	INSL VARNISH				331390
	44	FINISHES				735368
	45	SOLVENTS				25837054
	46	CREOSOTE				14909100
UNIT	47	POLES				2570000
	48	CROSS ARMS				2530000
CURT	49	ARGON				31000000

of equipment to the distribution industry, the appropriate Westinghouse Division was the source of information. By consideration of differences in design and material usages among various suppliers and respective market shares, a summary of materials usage was obtained. For those cases where Westinghouse is not a supplier (e.g., poles, cables), outside sources were contacted. Since Westinghouse is not a competitor in these specific markets, good cooperation was obtained from these outside sources.

In order to keep the materials usage on a common basis, the year 1974 was used for the production data in all cases except for poles, where 1973 data were the latest obtainable. The resulting estimated material usage for 1974 is given in Table 4.5.

This information was then divided by the 1974 unit sales by equipment category developed in Task 2 to obtain the per unit material usage matrix given in Table 4.1.

Changes from the present material usage patterns, discussed in section 4.2.2, arising from technology changes, environmental problems, and economic considerations were investigated by surveying the present research in the area and examining the functional requirements of each material to determine feasible substitutes.

4.4 Background Information on Present Material Usage

In the survey of materials used in distribution apparatus, certain generalizations became evident. First of all, it became apparent that the distribution industry has considerable inertia. There are several reasons for this.

Items manufactured for this industry are built to last at least 20-30 years, and most last considerably longer. This implies that in most cases any conversion procedure other than a gradual change-over would be prohibitively expensive. Equipment presently in use is reliable, and there is little incentive to replace it. In some cases (transformers, for example), where increased electrical loads are encountered, the units are replaced by units with greater capacity, but the older units are subsequently installed elsewhere.

In many other industries, manufacturers can advantageously reduce the size of their products, but in most of the distribution industry there is essentially no restriction on equipment size, and thus no great incentive to reduce it. As a matter of fact, code limitations on maximum temperature rise preclude size reduction in some equipment, and changes in such codes are slow in evolving.

The market for equipment described in this study is primarily the utilities and, secondarily, contractors. Although many items are standard, there are also many items which are built to specific requirements of individual utilities. In all cases, there are industry standards to be met.

It was also noted that since this industry uses relatively small quantities of most materials, selections are made, as far as possible, from readily available materials rather than from special formulations.

4.4.1 Material Categories

STEELS - In order to minimize the number of material categories to be tabulated (see Table 4.1), various metal alloys were combined into broader classes. Thus, the item designated "steel" includes carbon and low-alloy steels (and excludes stainless and electrical steels). These steels are used primarily as structural materials. Examples of steels in this category include AISI 1008, 1010, 1012, 1045, 1050, 1070, 1095, 1137, 1144, 1215, 4130, 4140, 4340, 4615, 6150, 8620, etc.

Various stainless steels have been grouped into one category. These include AISI 301, 302, 304, 309, 316, 321, 347, 403, 410, 420, 430, ASTM A267, SA 479, etc.

Similarly, all electrical steels are grouped together. The predominant electrical steel used for transformers contains 2.9 to 3.1% silicon. However, other electrical steels containing various amounts of silicon are included in this category.

OTHER METALS - Copper is used in electrical distribution equipment primarily in pure form for bus bars and cables. Low alloys of copper with nickel, silicon, beryllium, chromium, tin, or aluminum have also been included in the copper listing.

Various brasses (copper-zinc alloys) and bronzes are listed separately from copper. The brasses range in copper content from 60 to 95%. Alloying elements, such as lead, tin, aluminum, and manganese, are also added in small quantities (less than 1%) to obtain special properties. Major varieties of bronzes which are used include phosphor bronze (copper-tin alloys), silicon bronze (copper-silicon-manganese alloys), aluminum bronze (copper-aluminum alloys), and aluminum-silicon bronze (copper-aluminum-silicon alloys).

Electrical conductor, or EC grade, aluminum alloy accounts for all but a minor proportion of materials included as "aluminum." Various alloys included are 1100, 6101, 6063, 3003, 5052, 5056, 356, 360, 380, 385, etc.

Pure silver is used mainly in current limiting fuses as the resistance wire and as anodes for silver plating.

Silver-tungsten alloys, with silver content ranging from 35-50%, are used as contacts in distribution equipment. Since the quantity of these alloys will be used to determine primarily the amount of silver, all figures for these alloys were calculated for a reference alloy containing 50% silver. Various other silver-base alloys are used for brazing purposes. Examples of these are: 50 silver-34 copper-16 zinc, 46 silver-22 copper-21 zinc-11 cadmium, etc. These alloys have been grouped together, and the figure given is the total of pure silver (68,200 pounds), plus the silver in a 50% reference alloy.

Lead is used for cable sheaths, for casting, and for sealing purposes, and tin is used for anodes in tin plating. Various lead-tin soldering alloys, containing 40-60% lead, were assumed to be 50:50 lead-tin for incorporation into the Table.

MAGNETS - Where magnets are used, particularly in meters, Alnico magnets and barium ferrite magnets are used, depending on the choice of the manufacturer. Thus, they are combined as one item.

CHEMICALS - Copper salts and sodium fluoride are used for treating distribution poles, the former for initial treatment and the latter for field treatment.

Zinc phosphate is used for rust protection and adhesion promotion for paint finishes on steel products.

PORCELAIN - A typical electrical porcelain is composed by weight of approximately 50% clay, a hydrated alumino silicate ($\text{Al}_2\text{O}_3 \cdot 2 \text{SiO}_2 \cdot 2 \text{H}_2\text{O}$); 25% feldspar, an alkali-alumino silicate ($\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6 \text{SiO}_2$); and 25% silica (SiO_2). Improved electrical, mechanical, and thermal properties are required for particular applications, thus necessitating special porcelain formulations. The improvement in properties is achieved by substituting other refractory compounds for all or part of the silica in the typical formulation. The two most common substitutes are alumina (Al_2O_3) and zircon ($\text{ZrO}_2 \cdot \text{SiO}_2$). The alumina porcelains are used in applications requiring higher strengths, e.g., post insulators; whereas the zircon porcelains are used where improved dielectric strength and thermal shock resistance at elevated temperatures are required, e.g., arc chute plates in air circuit breakers.

ALUMINA, BERYL - These materials are used as fillers in polyester and epoxy compounds to promote improved electrical performance, particularly arc resistance.

GASKETS - In this study of the various products, it was noted that design decisions by the various manufacturers have resulted in a variety of materials being selected for certain types of applications. Thus, gaskets of a variety of elastomers, fillers, and design are used; since this implies that critical materials are not required, listing of rubber types was not attempted.

PAPER, FIBER - Included in this category are various natural organic fibers, such as paper, vulcanized fiber, string, wood flour fillers, etc. Glass fibers used for resin reinforcement are included in the glass category.

POLYESTERS AND EPOXIES - For items made of polyester and epoxy resins, a wide range of catalysts, accelerators, flame retardants, fillers, and other resin modifiers are used. Selection of the proper ingredients is based on desired properties, curing conditions, and cost. For items requiring arc resistance, for example, fillers such as alumina and

zirconium oxide are used; for flame retardance, antimony oxide is frequently used. Catalysts cover a wide range of compounds, such as amines, anhydrides, and peroxides. In structural applications, glass fiber is used as a reinforcing filler. From time to time, some of these individual items have been in short supply (particularly anhydride catalysts, antimony oxide, and zirconium oxide).

Since such a variety of compositions exists, no attempt was made to separate and report all of the ingredients of the molded structures. In case of shortages of individual components, resin systems would have to be modified to use chemicals which are satisfactory, if not the most desirable.

MISCELLANEOUS PLASTICS - In many small components, a variety of plastics materials are used. Since each manufacturer makes his own selections, based on his design, knowledge of materials, performance requirements, and costs, several different materials can be used in a similar application. The quantities of these materials are inevitably small compared to the quantities produced each year. Therefore, the total usage of these miscellaneous materials is reported as miscellaneous plastics. This category includes nylons (including Nomex^(TM) wire insulation), polycarbonates, melamines, polyvinyl chloride, etc.

INSULATIONS - Quantities of material used in production of cables are sufficiently large that, although the materials are in many cases interchangeable, they are listed separately to show the magnitudes presently being used. The compounds used include significant quantities of fillers, carbon black, stabilizers, plasticizers, etc., for proper performance.

Assorted insulation materials used in smaller quantities are included under miscellaneous insulations. These include nylons, fluorinated materials, polyurethanes, etc.

FINISHES - A variety of organic finishes and wire enamels are combined in this category. Again, each manufacturer selects the material required for his purposes. Thus, all such coatings are listed without defining the base materials. In many cases, the use of lead-containing

and solvent-reduced finishes is being discouraged because of health and environmental considerations.

SOLVENTS - The same situation exists for solvents, which are used for paint reduction and for cleaning, and will necessarily vary among manufacturers. The dominant amount of solvent is the large quantity of petroleum solvent used to treat wood poles.

EXPENSE ITEMS - Processing oils such as lubricants, cutting oils, and hydraulic oils were not reported. The same is true of metal preparation compounds, etc. These were found to be conventional materials common to general manufacturing processes, and usage would be relatively small. Other expense materials and maintenance items were also not reported.

4.4.2 Equipment Categories

UG AND OH TRANSFORMERS - Underground and overhead transformers are quite similar in materials of construction. Ratings range from 5 kv through 1,000 kv, 1 phase and 3 phase, both protected and unprotected. Sales are primarily to utilities, but customers also include contractors. Life expectancy is 25-30 years.

Variations occur in type of gasketing used, type of wire insulation, and insulator materials. Copper is used for fine wire requirements, but for heavier wire, the trend is toward aluminum.

Oil frequently is recovered from obsolete or damaged units.

Transformers for underground distribution are primarily pad-mounted. Underground installation is expensive and would be used only if pad-mounted units result in problems. Present installations are predominantly overhead.

SMALL POWER TRANSFORMERS - Small power transformers cover a range of 500 kva through 5,000 kva. They are sold to utilities and to contractors, and life expectancy is at least 20 years.

These transformers are filled with oil or with polychlorinated biphenyl, and have either epoxy or porcelain bushings. A gasket operating in contact with the biphenyl compound requires a special adhesive, which could be a critical item. Silicone oils have been shown to be less of a fire/explosion hazard than hydrocarbon oils, and may be considered in the future.

DRY TYPE TRANSFORMERS - Dry type transformers are supplied to utilities, industrial concerns, and contractors. Dry type sealed transformers are charged with C_2F_6 gas.

This type of transformer may increase in popularity if a significant trend grows to reduce the use of polychlorinated biphenyl liquid insulation. Expected life is at least 30 years.

INSTRUMENT TRANSFORMERS - Instrument transformers are sold to utilities, industrial concerns, and contractors.

Small units (below 25 kv) are molded, with either butyl rubber or epoxy resin as the encapsulating material, with some trend toward the latter. Larger units are frequently oil-filled. If distribution systems move toward higher voltages, increased demand for reliability will result. Life of the product is estimated at greater than 30 years.

VOLTAGE REGULATORS - Sales of voltage regulators are small compared to transformer sales in terms of number of units. However, the units are considerably more complex and, for a given kVA rating, are larger and more expensive. The quantities of materials used are small.

METERS - Because utilities usually specify certain details in meter design, meter styles number in the thousands. However, differences in materials requirements are not great. Major categories include metals, glass cover, phenolic base, encapsulation materials, and gaskets.

Variations include the following:

1. A small portion of production is made with molded polycarbonate covers for high security areas.
2. Magnet suspensions include both Alnico and barium ferrite magnets.
3. A variety of materials is used for the various gasketing applications and blade seals.
4. Bearings are extremely small and amount to 2,000-3,000 pounds of material for the industry. This small quantity could be troublesome because of the low sales incentive.
5. Glass fiber mat used as a filter is also a small quantity criticality.
6. Small quantities of silicone oils and greases are used in the various types of meters. In the case of thermal meters, the preferred grease is no longer in production.
7. Considerable solvent is used for cleaning purposes. Also, zinc phosphate is used on many areas which are not subsequently painted.

SWITCHGEAR - Switchgear is provided in metal enclosures, essentially on a custom basis, for industrial customers and for utilities. The equipment is expected to last 20-50 years, and should any become obsolete in its original distribution system, it is re-installed in another location.

Materials used for bus insulation vary from one manufacturer to another, and although track-resistant polyesters are used extensively in low voltage breakers, phenolics or epoxies have been used. Use of asbestos in switchgear equipment is rapidly decreasing. Arc chutes often contain zirconium oxide, which is costly and scarce. Alternatives, such as Corderite, might be adequate as a substitute, or SF_6 breakers could be used.

Effective lubrication in electrical and non-electrical contacts requires a variety of greases and lubricants (containing graphite, molybdenum disulfide, fluorocarbons, etc.).

Fluorocarbon polymers are required in certain applications because of temperature and chemical resistance. Special steel alloys are also required in some areas.

FUSES, CURRENT LIMITING AND EXPULSION - Current limiting fuses are tubes, usually made from melamine formaldehyde plastic, containing sand and a silver wire. Expulsion fuses have boric acid rather than sand, copper rather than silver, and the tubes can be vulcanized fiber, epoxy-fiberglass, etc.

FUSE CUTOUTS - Although butyl rubber is used by at least one supplier, most of the suppliers use porcelain insulation. Paper is used in a few cases as an alternate to glass reinforced polyester parts.

CAPACITORS - The insulator which separates the layers of aluminum foil has been changed in recent years from paper to polypropylene film. Liquid insulation surrounding the capacitor is generally polychlorinated biphenyl, although environmental concern will preclude its use in the near future.

RECLOSERS - Units are oil-insulated or vacuum-insulated, with a slight trend toward the latter. Equipment is expected to last more than 20 years.

ARRESTERS - The use of silicon carbide in arresters is gradually being converted to zinc oxide.

POLES - Poles are supplied with preservatives. The choice of poles and preservatives is based on price, weight, availability, and service requirements. For poles up to 45 feet long, pine is usually used. Above that, red cedar or fir is used. In wet areas, pine tends to rot; either cedar is used instead or concrete poles are used. Cedar is not always available, and fir is being used in increasing quantities. Fir is used for cross arms.

The poles and cross arms are treated in a variety of processes for impregnation with a preservative. Creosote and pentachlorophenol (penta) are about equal in cost, but penta is used in more products. Creosote is used by itself or mixed with coal tar, penta, or petroleum solvent. Penta is used as a solution in petroleum solvent. Copper salts, such as copper arsenate, are also used.

As alternatives to wood poles, concrete, glass-reinforced polyester, and steel have been considered. Concrete poles are more expensive and require heavier installation equipment; they also require different fixtures for attaching conductors. However, they are used where rot in wood poles has been a problem. Plastics are about three times the cost of wood, and steel about ten times; therefore, these are not presently being used. Polyester-glass pieces are being used as pole extensions for installation of higher voltage lines. To replace wood cross arms, plastics and steel devices are available, but are considerably more expensive and can carry only one 3-phase circuit.

It is expected that wood poles, with a 40-year life expectancy, will continue to be used, since underground installations cost 3-5 times as much as overhead. Field treatment with sodium fluoride is used to prolong the life of poles, and such treatments are reported to be increasing because of the cost and availability of new poles.

INSULATORS - Aside from the various insulators installed as parts of distribution equipment, there are insulators on distribution poles.

Porcelain is used in preference to glass because of better impact resistance. At this time, there is no incentive to develop organic materials to replace the relatively inexpensive porcelain.

CABLES - Cables in the distribution industry are classed as primary, with ratings of 5 kV through 69 kV, and secondary, with ratings of 600 V. Both classes are installed overhead and underground.

Organic materials used for insulation and jacketing (and metals used for conductors) are selected from a variety of suitable materials, and can be changed as costs, special properties, etc., dictate. Although the materials are essentially interchangeable, they are listed individually because of the large quantities used.

Customers for cables are primarily the utilities, but also construction companies and large industries. Replacement of cables is a significant factor (partly to install increased power ratings), and is included in the totals. Cables which are removed from service are presently being processed to recover the metal.

CONNECTORS - Connectors (or terminals) are sold to original equipment manufacturers and to equipment users, such as utilities. The OEMs supply equipment with and without such connectors, depending on the desires of the customer.

Parts are either aluminum or a copper alloy (such as ASTM-B30, 9-D, and 4-B). Although various metals are in the alloys (e.g., tin, lead, zinc, aluminum, nickel, and iron), they are listed as aluminum and copper. The quantities in the table are for those parts sold directly to the end user (those sold to OEMs are included in the totals for the equipment).

4.5 Developments with Potential Major Impacts on Distribution Systems

In this section, two developments, load management and photovoltaic systems, are discussed. These two areas were selected for discussion because their future course is uncertain at this time and because they have the potential of altering the equipment requirements and, hence, material requirements for distribution systems.

4.5.1 Load Management

Load management is an emerging technology that could have significant long-term impacts on distribution systems. We cannot, however, identify any unique material availability problems before 2000 attributable to its introduction.

Load management may be defined as the orderly regulation and influence of electric utility loads in a manner which improves the effective utilization of generation, transmission, and distribution equipment, and encourages judicious use of electricity. It involves the influence of electric load growth to maximize the effectiveness of utility equipment and to minimize total cost (utility, customer, societal). This control is implemented by adding future loads and modifying conventional loads so that the utilities' power demand curve is more uniform over time. The control may be of the direct type (i.e., interruptible power contracts) or of the indirect type (i.e., influence through differential pricing).

Load management is still in its infancy and sufficient data on disaggregated loads, customer response, and equipment costs are not available to allow accurate calculations of benefits and costs. Thus, it is not possible at this point in time to make specific estimates of its impact on distribution material requirements.

However, a few general statements can be made regarding the potential impact of load management on distribution systems. Load management, if successfully implemented, should increase the overall utilization of existing distribution equipment in the sense that the ratio of kw-hrs delivered to capital investment attributable to existing equipment will substantially increase. However, to obtain this increase, additional capital investments in communication and control equipment, energy storage, and metering will be necessary. The net effect will probably be to increase the overall capital investment attributable to distribution and to alter somewhat the mix of purchased equipment. The added investment cost will be recovered in transmission and generation investments and/or fuel savings.

We do not anticipate a rapid movement toward load management, particularly those approaches that require substantial utility investment and/or manpower increases. This forecast is based on (1) the fact that the benefits of load management vary widely among utilities and, hence, may never be implemented in some instances, (2) a substantial amount of operating experience is traditionally required by utilities before large capital commitments are made, and (3) a rapid movement toward load management would require massive amounts of utility manpower to handle the metering and billing requirements.

Thus, if load management does produce attractive returns, we foresee an orderly and gradual implementation using carefully selected situations. We cannot identify any unique material problems before 2000 under these conditions. The communication and control equipment will use standard components and be an insignificant part of their overall demand. Most of the proposed end-use storage devices (water tanks, for example) use readily available products and, again, would be an insignificant part of the total demand. If "standard" components should not be used, this will increase equipment costs which, in turn, will decrease the penetration rate of load management and alleviate availability problems attributable to the need for specialized equipment.

4.5.2 Residential Photovoltaic Systems

Residential photovoltaic systems that use electricity supplied by an electric utility as a complementary power source or backup source will require a completely new line of power conditioning equipment and storage at the end-use point. Whether or not the utility would own this equipment is a question that is still very much undecided and will probably receive considerable debate.

One can conceive of a total energy residential system that uses photovoltaic cells to provide a portion of the residential electric and heating and cooling loads. The electric utility could own all the power conditioning, control, and storage equipment. Under such a scenario, the utility's investment inside the home would be substantially increased and such a system would probably be coupled with an overall load management scheme.

The distribution material implications of such a future system require a much more detailed system design than is presently available, including a definition of the utility interface (where does the distribution system end?). It is important to note, however, that before any large implementation plans are funded for photovoltaic systems for residential applications, future equipment requirements and availability should be carefully analyzed. The successful coupling of photovoltaic systems with existing distribution systems will require that new equipment be designed, sufficient manufacturing capacity be developed, and manpower be trained to install and maintain the equipment.

The analysis of the distribution implications of residential photovoltaic systems is outside the scope of this study, and has been discussed to highlight its potential major impact on future distribution equipment requirements and associated material requirements.

CHAPTER 5

TASK 4 - AVAILABILITY OF RAW MATERIAL INPUTS

5.1 Task Description

The purpose of Task 4 was to identify materials which are critical to the distribution system based on possible raw material shortages and the impact of such shortages on the availability of distribution equipment. The specific objectives of the task were as follows:

1. Evaluate general raw material availability by comparing estimates of future U. S. demand relative to currently known reserves and resources.
2. Determine U. S. dependence on material from foreign sources and evaluate the probability of continued availability of material from these sources.
3. Assess the relative importance of these raw materials to distribution equipment production.
4. Using information from the above, specify the raw materials which could be in short supply and which, if scarce, would have a relatively large impact on distribution equipment availability. These materials are then highlighted as candidates for substitution.

5.2 Summary of Results

Table 5.1 contains the relative ranking of raw materials used in electrical distribution equipment according to their availability and their importance to distribution equipment. Based solely on this criterion, those materials in the "critical," "watch closely," and "watch" categories, in that order, should be considered for substitution possibilities. The presence of aluminum on the list is questionable. The analysis of aluminum was based on its current raw material source, bauxite. Over the long run, it is expected that other sources of aluminum will become available, and, hence, aluminum should probably assume a position of lesser importance than that shown in the table. Note also that cobalt, manganese, and nickel are listed as materials to be watched closely. This is because they are in

Table 5.1 [†]

RELATIVE RANKING OF DISTRIBUTION EQUIPMENT RAW MATERIALS
 ACCORDING TO THE POTENTIAL FOR SHORTAGES AND THE IMPACT OF SUCH
 SHORTAGES ON DISTRIBUTION EQUIPMENT AVAILABILITY

<u>Critical</u>	<u>Watch Closely</u>	<u>Watch</u>	<u>No Apparent Problem</u>
Chromium	Aluminum (Bauxite)	Fluorine	Argon
Natural Gas	Copper	Gold	Barium
Oil	Silver	Graphite	Beryllium
	Alloying Metals for Steel	Tungsten	Boron
	Cobalt	Zinc	Cadmium
	Manganese		Chlorine
	Nickel		Coal
	Timber		Feldspar
	Tin		Lead
			Phosphates
			Silicon
			Zirconium

[†]Note that Tables 5.1 and 5.13 are related. Table 5.1 differs from Table 5.13 in that Table 5.13 examines criticality of distribution equipment raw materials only from the viewpoint of domestic availability relative to total U. S. needs. Table 5.1 also considers the relative criticality of the material to distribution equipment availability.

potential short supply to the United States due to lack of domestic reserves, and they are important to distribution equipment, not in and of themselves, but because of their use in stainless and electrical steels.

5.3 Methodology

The question of resource base availability was examined in two steps. The first step was to determine which of the raw materials used in distribution equipment might be of limited availability to the United States through the 1973-2000 period. This part of the problem involved examining the domestic reserve and resource base, the amount of the material being imported, the reliability of the import source(s), and the foreign reserve and resource base situation. The second step was to take those materials which appear to have problems (or political problems) and examine them in terms of their importance to the production of distribution equipment.¹ The purpose of this step is to determine which materials, if in short supply, would have the greatest negative impact on the various distribution equipment categories. The specific methodology used in each step is discussed below.

5.3.1 Availability of Distribution Equipment Raw Materials: The U. S. Perspective

1. From the material list developed in Task 3, derive the basic raw materials used in producing distribution equipment.
2. Gather historical data on domestic production, recycling, imports, import sources, exports, consumption, and reserves and resources for each of the raw materials.

¹The assumption was that if a material is not an availability problem from a U. S. perspective (i.e., given the total U. S. demand and supply perspective), then it is not a problem for distribution equipment availability. In fact, the assumption does not have to hold and is used here for convenience only.

3. Assemble the data, together with estimates of future consumption, in a form which will reveal potential availability problems. The categories used are shown in Table 5.2. After assembling the data as shown in Table 5.2, each material is given a ranking of 1, 2, or 3 for each category. A ranking of 1 represents a relatively high potential for future availability problems, while 3 represents a relatively low potential. For each category the ranking was based on the following criteria: a) for categories (1) and (5), a rating of 1 was given if the ratio was 0-49, 2 if it was 50-109, and 3 if it was greater than 110; b) for categories (2) and (6), a 1 was given if the ratio was 0-249, a 2 if it was 250-999, and a 3 if it was 1000+; c) for category (3), a rating of 1 was given if the ratio was greater than .6, a 2 if it was between .26 and .59, and a 3 if it was less than .25; and d) for category (4), the ranking was rather subjective, but was based on the existence of a cartel or producers' group, the dominance of one major supplying country, and the degree of development and political philosophy(ies) of the supplying country(ies).
4. Using the information above, divide the raw materials into the four categories shown in Table 5.1 (i.e., critical, watch closely, watch, and no apparent problem) according to the apparent potential for supply limitations of that material.

5.3.2 Importance of Potentially Scarce Raw Materials to the Production of Distribution Equipment

1. Calculate for each equipment category and each material the value of the direct material usage as a percent of total sales. Use an average 1974 price for each material and multiply it by the quantity of that material used in each equipment category. The result is then divided by the values of sales in 1974 for that particular category.

Table 5.2

RATIOS USED TO EVALUATE THE FUTURE AVAILABILITY
TO THE UNITED STATES OF RAW MATERIALS USED
IN DISTRIBUTION EQUIPMENT

- 1) $\frac{\text{U. S. Reserves}}{\text{Cumulative Demand (1973-2000)}}$
- 2) $\frac{\text{U. S. Resources}}{\text{Cumulative Demand}}$
- 3) $\frac{\text{Net U. S. Imports}}{\text{Demand (1970-1973)}}$
- 4) Vulnerability of Import Source
- 5) $\frac{\text{Foreign Reserves}}{\text{Cumulative Demand (1973-2000)}}$
- 6) $\frac{\text{Foreign Resources}}{\text{Cumulative Demand}}$

-
2. Use the U. S. Department of Commerce's 1967 input-output table to determine the direct and indirect amounts of each material needed to produce the various equipment types² (i.e., determine the amount of material distribution equipment industries use directly, plus the amounts used by other industries in manufacturing products which are

²The 1967 input-output table was used simply because it is the latest one available.

sold to the distribution equipment industries for use in their production processes). The sequence of calculations is as follows:³

- a. Using Bureau of Mines information, assign total U. S. consumption of a material (in 1967) to the appropriate first processing stages. Thus, for example, chromite would be assigned to the chemical, refractories, and steel industries.
- b. Use the Department of Commerce's input-output tables to determine the dollar output of these processing industries. Then divide the tonnage of the material going to that industry by the value of its output to get the tons of material required per dollar of output.
- c. Assign the distribution equipment categories to appropriate input-output sectors from the 1967 tables. Thus, for example, meters is assigned to sector 53.01, "electric measuring instruments."
- d. For each processing industry and each equipment sector, select from the 1967 tables the appropriate "inverse coefficient." The inverse coefficient shows the dollar amount of direct and indirect purchases by the consuming (electrical distribution equipment) industry from the primary processing industry per dollar of output of the consuming industry going to final demand.⁴

³For further information on the approach used see: Mark W. Levine and Irving W. Yabroff, Department of Defense Materials Consumption and the Impact of Material and Energy Shortages, Menlo Park, Calif., Stanford Research Institute, March, 1975, p. 20 ff.

⁴For additional information on the "inverse coefficient" see: William H. Miernyk, The Elements of Input-Output Analysis, New York: Random House, Inc., 1969, pp. 24-27.

- e. Multiplying the appropriate inverse coefficient by the result of (b) gives the total material required (both directly and indirectly) for each dollar of the equipment category output delivered to final demand. The calculation is made for each material and each distribution equipment category.
- f. Finally, multiplying the results in (e) by the total value of the output of the equipment industry in question gives an estimate of the total amount (tonnage) of material used directly and indirectly by that equipment category. To repeat, the equation used is:

$$\left[\begin{array}{l} \text{tons of material (by processing sector)} \\ \hline \$ \text{ output (of processing sector)} \end{array} \right] \times \begin{array}{l} \text{inverse} \\ \text{coefficient} \end{array} \left[\begin{array}{l} \text{(amount of direct} \\ \text{and indirect pur-} \\ \text{chases by the} \\ \text{consuming industry} \\ \text{from the processing} \\ \text{industry per \$ out-} \\ \text{put going to final} \\ \text{demand-a constant)} \end{array} \right]$$

$$\times \begin{array}{l} \text{total \$ output of the} \\ \text{consuming industry} \\ \text{going to final demand} \end{array}$$

(f)

If this last result is divided by total U. S. usage of that material, one has an estimate of the percent of total material consumption in 1967 required to support the deliveries to final demand of that equipment category. Again, this is done for each material and each equipment category.

3. Using the information collected in parts (1) and (2), together with part (4) of the previous section, select those raw materials which, from an availability standpoint, have the greatest probability of having a disruptive impact on the future supply of electrical distribution equipment.

5.4 Work Detail

The details of the work outlined in the "methodology" section are presented in this section.

5.4.1 Availability of Distribution Equipment Raw Materials: The U. S. Perspective

- 1) List of basic raw materials. The list of basic raw materials used in electrical distribution equipment is shown in Table 5.3.

- 2) Collection of historic data. Historical data were collected from a number of sources, but since there was considerable variation in definitions and coverage, it was decided to use U. S. Bureau of Mines information as the primary source. The data gathered for copper are shown in Tables 5.4 - 5.10 to illustrate some of the data collected. Similar tables have been prepared for each of the raw materials shown in Table 5.3. This information is presented in Appendix 5. Note that 1973 was the last year for which data were collected. This was simply because this was the last year for which comprehensive data were available.

- 3) Assemblage of data into informational categories. As outlined in the section on methodology, the data from step 2 were assembled into categories designed to provide information on future availability. Table 5.11 shows the information for each material.

Although asbestos appears on the raw material list, it is not included in Table 5.11. Because of its health and environmental problems, asbestos is being rapidly replaced as a material input for distribution equipment. For this reason, its future availability is not of concern in this report. Note also that the estimates of U. S. and foreign cumulative demand are either those of the Bureau of Mines or were derived using their point estimates of future consumption.

Table 5.3

BASIC RAW MATERIALS USED IN
ELECTRICAL DISTRIBUTION EQUIPMENT

Aluminum	Cobalt	Nickel
Argon	Copper	Petroleum
Asbestos	Feldspar	Phosphate
Barite	Fluorine	Silicon
Beryl	Gold	Silver
Boron	Graphite	Timber
Cadmium	Iron	Tin
Chromite	Lead	Tungsten
Chlorine	Manganese	Zinc
Coal	Natural Gas	Zircon

The numerical rankings associated with the estimated availability problem level for each material and each category are shown in Table 5.12.

4) Relative ranking of raw materials according to their potential for future shortages. There is no agreed upon theoretical framework for determining the relative criticality of materials. Hence, it was decided that the raw materials would be placed into "critical," "watch," or "no apparent problem" categories by consensus of those participating in the study. The decision was based on the information available from steps (1) through (3), together with each participant's knowledge of the materials in question. The relative ranking is that shown in Table 5.13.

Table 5.4

COPPER - U.S. CONSUMPTION
(Thousand Short Tons)

<u>Year</u>	<u>Industrial Consumption^x</u>	<u>Consumption of Refined</u>
1950		1,424
1951		1,417
1952		1,480
1953		1,494
1954		1,255
1955		1,502
1956		1,521
1957		1,352
1958		1,251
1959		1,463
1960		1,350
1961		1,463
1962		1,600
1963		1,744
1964	2,040	1,825
1965	2,126	2,005
1966	2,433	2,360
1967	2,032	1,936
1968	2,061	1,880
1969	2,271	2,142
1970	2,076	2,043
1971	2,072	2,020
1972	2,409	2,239
1973	2,384	2,437

Sources: U.S. Bureau of Mines, Minerals Yearbook, 1950-1963^xU.S. Bureau of Mines, Minerals in the U.S. Economy, 1975

Table 5.5

COPPER - U.S. CONSUMPTION BY MAJOR END USE CATEGORY
(Thousand short tons)

<u>Category</u>	<u>SIC Code</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>
Electrical	36	1,046	1,193	1,101	1,113	1,252	1,445
Construction	344	316	341	328	351	432	336
Machinery	35	239	254	251	243	300	240
Transportation	37	193	198	173	192	227	187
Ordinance	348	164	172	119	69	78	57
Other		103	113	104	104	120	119
TOTAL		2,061	2,271	2,076	2,072	2,409	2,384

Source: U.S. Bureau of Mines, Minerals in the U.S. Economy, 1975

Table 5.6

COPPER - UNITED STATES SUPPLY

(Thousand Short Tons)

Year	Mine Production	(%)	Old Scrap	(%)	Total Scrap	Imports	(%)	Net Imports	(%)	Total Supply ¹
1950	909	52.6	485	28.1	977	690	39.9	335	19.3	1,729
51	928	53.5	458	26.4	932	489	28.2	348	20.1	1,734
52	925	52.1	415	23.4	903	619	34.9	435	24.5	1,775
53	926	49.1	429	22.8	959	676	35.8	531	28.1	1,886
54	836	53.9	407	26.2	840	603	38.9	309	19.9	1,552
55	999	53.8	515	27.7	989	588	31.7	344	18.5	1,858
56	1,104	59.1	469	25.1	931	559	29.9	296	15.8	1,869
57	1,087	61.1	445	25.0	842	658	37.0	248	13.9	1,780
58	979	73.2	411	30.7	797	365	27.3	-53	(-3.9)	1,337
59	825	59.7	471	34.1	931	257	18.6	86	6.2	1,382
1960	1,080	89.8	429	35.7	871	198	16.5	-306	(-25.5)	1,203
61	1,165	95.0	411	33.5	849	119	9.7	-349	(-28.4)	1,227
62	1,228	85.9	416	29.1	922	136	9.5	-215	(-15.0)	1,429
63	1,213	82.9	422	28.8	974	155	10.6	-171	(-11.7)	1,464
64	1,247	76.7	474	29.2	1,093	270	16.6	-95	(-5.8)	1,626
65	1,352	80.0	513	30.3	1,253	198	11.7	-174	(-10.3)	1,691
66	1,429	67.5	535	25.3	1,334	447	21.1	153	7.2	2,117
67	954	51.2	483	25.9	1,160	649	34.8	427	22.9	1,864
68	1,205	57.9	521	25.1	1,218	710	34.1	354	17.0	2,080
69	1,545	66.6	575	24.8	1,376	414	17.8	201	8.6	2,321
1970	1,720	73.5	504	21.5	1,248	424	18.1	117	5.0	2,341
71	1,522	74.1	445	21.7	1,200	331	16.1	88	4.2	2,055
72	1,665	72.3	458	19.9	1,301	416	18.1	180	7.8	2,303
73	1,718	72.9	473	20.1	1,451	418	17.7	167	7.0	2,358

¹Total = mine production + old scrap + net imports

Sources: U. S. Bureau of Mines, Minerals Yearbook (1950-1972)

Table 5.7

COPPER - MAJOR U.S. IMPORT SOURCES
(Short Tons)

Country	1970		1971		1972		1973	
	Amount	% of Total U.S. Imports	Amount	%	Amount	%	Amount	%
Canada	96,845	24.7	135,428	37.7	150,803	36.3	155,179	37.2
Peru	110,026	28.0	102,410	28.5	93,249	22.4	99,977	24.0
Chile	114,880	29.3	51,651	14.4	60,131	14.5	58,763	14.1
Republic of South Africa	28,946	7.4	21,247	5.9	23,609	5.7	26,360	6.4
Philippines	18,700	4.8	13,616	3.8	30,122	7.2	17,842	4.3
Mexico	4,361	1.1	7,640	2.1	18,617	4.5	16,711	4.0
TOTAL IMPORTS	392,480		359,479		415,611		417,434	

Source: U.S. Bureau of Mines, Minerals Yearbook, 1970-1973

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COPPER - MAJOR U.S. IMPORT SOURCE INFORMATION
(1970-1973)

Country	% of World Production	% of Country's Production Exported to U.S.	% of U.S. Demand Supplied	% of World Reserves ^x
Canada	10.8	17.4	6.0	9.3
Peru	3.4	42.2	4.5	7.0
Chile	11.2	8.9	3.2	16.3
Republic of South Africa	2.5	14.1	1.1	N.A.
Philippines	3.1	9.2	.9	N.A.
Mexico	1.1	15.2	.5	21.0
(U.S.)	(23.2)			

Sources: U.S. Bureau of Mines, Minerals Yearbook, 1970-73^xU.S. Bureau of Mines, Commodity Data Summaries, 1975

Table 5.9

COPPER - RESERVES AND RESOURCES

Domestic †

Reserves¹ ~ 90,000,000 short tons

Resources *

1)	Identified	~ 76	million	short	tons
2)	Hypothetical	~100	"	"	"
3)	Speculative	~120	"	"	"
4)	Subeconomic	~110	"	"	"

~ 496 x 10⁶ short tons

Foreign *

Reserves² ~ 340,000,000 short tons

Resources

1)	Identified	~ 268	million	short	tons
2)	Hypothetical	~ 300	"	"	"
3)	Speculative	~ 200	"	"	"
4)	Subeconomic	~ 370	"	"	"

~ 1.408 x 10⁹ short tons

Sources:

- † U. S. Bureau of Mines, Commodity Data Summaries 1975.
 U. S. Geological Survey Professional Paper 820, 1973.

- * U. S. Bureau of Mines, Commodity Data Summaries, 1975.

¹ At 1973 primary copper consumption levels, this is a forward reserve of 47 years.

² At 1973 primary copper consumption levels, this is a forward reserve of 54 years.

Table 5.10

COPPER - FOREIGN SUPPLY AND DEMAND
(Thousand Short Tons)

<u>Year</u>	<u>Mine Production</u>	<u>Consumption (Primary)</u>
1950	2,758 ^x	1,447
1951	2,900	1,656
1952	3,017	1,712
1953	3,055	1,543
1954	3,111	1,969
1955	3,416	2,103
1956	3,786	2,242
1957	3,892	2,479
1958	3,780	2,768
1959	4,024	2,783
1960	4,652	3,263
1961	4,848	3,519
1962	5,084	3,471
1963	5,088	3,629
1964	5,297	4,008
1965	5,549	3,970
1966	5,485	3,887
1967	5,224	4,098
1968	5,641	4,494
1969	6,224	4,880
1970	6,638	5,061
1971	6,653	5,212
1972	7,314	5,676
1973	7,857	6,269
1974	7,940 ^{xx}	

Sources: Metal Statistics, Metallgesellschaft Aktiengesellschaft
Frankfurt am Main (1950-1973)

^xU.S. Bureau of Mines, Minerals Yearbook

^{xx}U.S. Bureau of Mines, Commodity Data Summaries, 1975

Table 5.11

RELATIVE CRITICALITY OF DISTRIBUTION EQUIPMENT
RAW MATERIALS: SUMMARY OF INFORMATION
(U.S. Perspective)

Material	U.S. Reserves/ Cumulative Demand 1973-2000	U.S. Resources/ Cumulative Demand 1973-2000	Net Imports (1970-1973) Cumulative Consumption (1970-1973)	Vulnerability of Major Import Sources (1970-1973)	Foreign Reserves Cumulative Demand 1973-2000	Foreign Resources Cumulative Demand 1973-2000
Aluminum (10^6 ST)	$\frac{6}{360} \approx 2\%$ (Bauxite)	$\frac{30 - 38}{360} \approx 8-11\%$ (Bauxite) (all aluminum resources are 2-10 times cumula- tive demand)		-bauxite cartel -Jamaica 43% Surinam 19%, Australia 24% Guyana 4%	$\frac{3560}{1060} \approx 336\%$	Huge 1060
Argon (10^9 Ft ³)	$\frac{\infty}{245} \approx$ No Problem (Argon is produced from air - in its uses it is returned)	No Problem	0%		$\frac{\infty}{112} \approx$ No Problem	
Barite (10^3 ST)	$\frac{65,000}{50,000} \approx 130\%$	$\frac{526,000}{50,000} \approx 1050\%$	40%	-Ireland 27%, Peru 26%, Mexico 20% Canada 9% Greece 9%	$\frac{135,000}{68,000} \approx 199\%$	$\frac{1,797,000}{68,000} > 2650$
Beryllium (ST)	$\frac{28,000}{27,000} \approx 104\%$	>1200% of min. anticipated demand	30%	-Brazil 62%, S. Africa 14%, Argentina 7%	not known 13,370	
Boron (10^3 ST)	$\frac{88,000}{4,700} \approx 1870\%$	No Problem	$\sim 0\%$	-Turkey 100%	$\frac{124,000-154,000}{11,530}$ $\approx 1025 - 1336\%$	Very large 11,530
Cadmium (10^3 ST)	$\frac{360}{260} \approx 140\%$	$\frac{2410}{360} \approx 927\%$	23%	-Canada 27%, Australia 16%, Bel-Lux 12%, Peru 9%	$\frac{1040}{786} \approx 132\%$	$\frac{18,103}{786} > 2290$

Table 5.11 (continued)

RELATIVE CRITICALITY OF DISTRIBUTION EQUIPMENT
RAW MATERIALS: SUMMARY OF INFORMATION

(U.S. Perspective)

Material	U.S. Reserves/ Cumulative Demand 1973-2000	U.S. Resources/ Cumulative Demand 1973-2000	Net Imports (1970-1973) Cumulative Consumption (1970-1973)	Vulnerability of Major Import Sources (1970-1973)	Foreign Reserves/ Cumulative Demand 1973-2000	Foreign Resources/ Cumulative Demand 1973-2000
Chlorine (10^6 ST)	$\frac{36,000}{615} \approx 5850\%$	2000% of min. anticipated demand	.5%	-Canada	Large 961	
Chromium (10^3 ST)	$\frac{-}{17,400} \approx 0\%$	$\frac{1600}{17,400} \approx 9.2\%$	85%	-USSR 31%, Rep. of S. Africa 29%, Turkey 17%, Phillippines 15%	$\frac{1,863,000}{257,480} \approx 722\%$	$\frac{8,882,000}{257,580} > 3680$
Copper (10^3 ST)	$\frac{90,000}{96,000} \approx 94\%$	$\frac{496,000}{86,000} \approx 577\%$	6%	-producer's group exists -Canada 34%, Peru 26%, Chile 18%, S. Africa 7%, Phillippines 6%	$\frac{340,000}{357,000} \approx 95\%$	$\frac{1,408,000}{357,000} > 394\%$
Feldspar (10^3 ST)	$\frac{600,000}{40,400} \approx 1485\%$	2000% of min. anticipated demand	$\approx 0\%$	-Canada 88%, Sweden 4%, U.K. 4%	$\frac{400,000}{116,260} \approx 345\%$	Very Large $\frac{116,260}{116,260}$
Fluorine (10^3 ST)	$\frac{6000}{37,000} \approx 16.2\%$	$\frac{28,000}{37,000} \approx 76\%$	77%	-Mexico 74%, Spain 14%, Italy 7%	$\frac{141,500}{99,600} \approx 142\%$	$\frac{389,000^+}{99,600} > 391\%$
Graphite (10^3 ST)	$\frac{-}{1,800} \approx 0\%$	$\frac{10,500}{1,800} \approx 585\%$	95%	-Mexico 78%, Malagasy 8%, Norway 5%, Sri Lanka 4%	Very Large $\frac{23,300}{23,300}$	

Table 5.11 (continued)

RELATIVE CRITICALITY OF DISTRIBUTION EQUIPMENT
RAW MATERIALS: SUMMARY OF INFORMATION

(U.S. Perspective)

Material	U.S. Reserves/ Cumulative Demand 1973-2000	U.S. Resources/ Cumulative Demand 1973-2000	Net Imports (1970-1973) Cumulative Consumption (1970-1973)	Vulnerability of Major Import Sources (1970-1973)	Foreign Reserves Cumulative Demand 1973-2000	Foreign Resources Cumulative Demand 1973-2000
Iron & Steel (10^6 ST)	$\frac{2000}{2600} = 77.0\%$	1200% of min. anticipated demand	29%	-producers group exists -Canada 51%, Venezuela 31%, Liberia 6%, Brazil 5%	$\frac{269,000}{25,000} = 1150\%$	Huge $\frac{25,000}{25,000}$
Lead (10^3 ST)	$\frac{29,000}{29,800} = 198\%$	300% of min. anticipated demand	18%	-Canada 30%, Peru 22%, Australia 21%, Mexico 10%, Honduras 5%	$\frac{101,000}{105,700} = 96\%$	$\frac{1,500,000}{105,700} > 1420$
Nickel (10^3 ST)	$\frac{200}{6510} = 3.1\%$	$\frac{14,000}{6,500} = 215\%$	63%	-Canada 79%, Norway 8%, U.K. 3%, S. Africa 2%	$\frac{48,800}{32,000} = 153$	Very Large $\frac{30,000}{30,000}$ (Potential from ocean nodules)
Phosphate (10^6 ST)	$\frac{3000}{2000} = 150\%$	1200% of min. anticipated demand	0%	-Morocco is the major foreign producer	$\frac{11,000}{5,960} = 185\%$	Very Large $\frac{5960}{5960}$
Silicon (10^3)	Large $\frac{22,180}{22,180} = \text{Adequate}$	No Problem	3%	-Norway 36%, Sweden 15%, France 14%, Canada 13%	Not known	
Silver (10^6 Tr. Oz.)	$\frac{1500}{4000} = 37.5\%$	$\frac{7100}{4000} = 178\%$	39%	-Canada 44%, Mexico 23%, Peru 17%, Australia 3%, Honduras 3%	$\frac{4,500}{11,260} = 40\%$	$\frac{21,200}{11,260} > 188$

Table 5.11 (continued)

RELATIVE CRITICALITY OF DISTRIBUTION EQUIPMENT
RAW MATERIALS: SUMMARY OF INFORMATION
(U.S. Perspective)

Material	U.S. Reserves/ Cumulative Demand 1973-2000	U.S. Resources/ Cumulative Demand 1973-2000	Net Imports (1970-1973) Cumulative Consumption (1970-1973)	Vulnerability of Major Import Sources (1970-1973)	Foreign Reserves/ Cumulative Demand 1973-2000	Foreign Resources/ Cumulative Demand 1973-2000
Tin (10^6 ST)	$\frac{42}{2000} \approx 2.1\%$	$\frac{195}{2000} \approx 9.8\%$	80%	-producer-consumer group exists -Malaysia 57%, Thailand 23%, Bolivia 6%, Indonesia 4%	$\frac{9940}{6000} \approx 166\%$	$\frac{37000}{6000} > 620\%$
Tungsten (10^3 ST)	$\frac{120}{480} \approx 25\%$	$\frac{360-480}{480} \approx 75-100\%$	$\sim 0\%$	-producer group exists -Canada 35%, Bolivia 17%, Peru 11%, Thailand 10%, Australia 4%, -China has most of world reserves	$\frac{3360}{2620} \approx 128$	Not known 2620
Zinc (10^3 ST)	$\frac{30,000}{57,500} \approx 52.5\%$	$\frac{542,000}{57,500} \approx 943\%$	51%	-Canada 42%, Mexico 11%, Peru 8%, Australia 5%, Japan 4%	$\frac{101,000}{204,200} \approx 50\%$	$\frac{5,244,000}{204,200} > 2570$
Zircon (10^3 ST)	$\frac{12,000}{7,650} \approx 157\%$	200% of min. anticipated demand	45%	-Australia 94%, Canada 2%	$\frac{26,000}{12,800} \approx 203$	Not known 12,800
Natural Gas (10^{12} Ft. ³)	$\frac{250}{1030} \approx 24.3\%$	$\frac{550-3100}{1030} \approx 53-300\%$	4%	-Canada 98%, Mexico 2%	$\frac{2150}{1540} \approx 140\%$	Very Large 1540

Table 5.11 (continued)

RELATIVE CRITICALITY OF DISTRIBUTION EQUIPMENT
RAW MATERIALS: SUMMARY OF INFORMATION
(U.S. Perspective)

Material	U.S. Reserves/ Cumulative Demand 1973-2000	U.S. Resources/ Cumulative Demand 1973-2000	Net Imports (1970-1973) Cumulative Consumption (1970-1973)	Vulnerability of Major Import Sources (1970-1973)	Foreign Reserves Cumulative Demand 1973-2000	Foreign Resources Cumulative Demand 1973-2000
Coal (10 ⁶ ST)	$\frac{1,581,000}{19,410} \approx 8144\%$	$\frac{3,210,000}{19,410} \approx 16,535\%$	0%		$\frac{10,178,000}{102,700} \approx 9910\%$	Huge 102,700
Oil (Barrels (10 ⁶))	$\frac{35,300}{258,160} \approx 13.7\%$	$\frac{242,000-960,000}{258,160} \approx 94-372\%$	27%	-Cartel exists -Canada 22%, Venezuela 22%, Netherlands Antilles 10%, Virgin Islands 6%, Nigeria 5%, Trinidad & Tobago 5%, Saudi Arabia 5%, Indonesia 3%	$\frac{591,000}{754,700} \approx 78\%$	$\frac{2-4,500,000}{754,700} \approx 265-297\%$
Cobalt (10 ³ ST)	$\frac{28}{243} \approx 11.5\%$	$\frac{840}{243} \approx 346\%$	73%	-Zaire (incl Bel-Lux) Norway 11.2% one major producing country	$\frac{2702}{586.2} \approx 461$	Huge 586.2
Manganese (10 ³ ST)	$\frac{49,800}{49,800} \approx 0\%$	$\frac{196,000}{49,800} > 393\%$	79%	-Brazil 29%, Gabon 19%, Rep SA 16%, France 10%	$\frac{6,000,000}{269,174} \approx 2229$	$\frac{28,000,000}{269,174} > 10,402$
Gold (10 ⁶ Tr. Oz.)	$\frac{120,000}{282,556} \approx 42.5\%$	Very large $\frac{282,556}{282,556} > 150\%$	64%	-Canada 37%, S.A. 31%, USSR 17%	$\frac{1,200}{1,254} \approx 95\%$	Very large 1,254
Wood Products (Round Wogds) (10 ⁹ ft ³)	$\frac{466.5}{535.5} \approx 87.1$ (At 1970 timber levels and 1970 relative prices)	%	20%	-Canada 95%, Mexico .1%	?	?

Table 5.12

RELATIVE CRITICALITY OF DISTRIBUTION EQUIPMENT

RAW MATERIALS: RANKING BY CATEGORY

<u>MATERIAL</u>	<u>U. S. Reserves¹</u> <u>Cumulative Demand</u>	<u>U. S. Resources²</u> <u>Cumulative Demand</u>	<u>Net Imports³</u> <u>Demand</u>	<u>Vulnerability of⁴</u> <u>Import Source</u>	<u>Foreign Reserves¹</u> <u>Cumulative Demand</u>	<u>Foreign Resources²</u> <u>Cumulative Demand</u>
Aluminum	1	3(incl other resources than bauxite)	1	A)1 C)3 B)2 D)1 1	3	3
Argon	3	3	3	3	3	3
Barium	3	2-3	2	A)3 C)3 B)3 D)2-3 3	3	3
Beryllium	2	3	2-3	A)3 C)3 B)1 D)2 2	3	3
Boron	3	3	3	A)3 C)2 B)1 D)2 2-1	3	3
Cadmium	3	2-3	3-2	A)3 C)2-3 B)3 D)3 3	3	3
Chlorine	2	3	3	A)3 C)3 B)1 D)3 2-3	3	3
Chromium	1	1	1	A)3 C)1-2 B)1-2 D)2 1	3	3
Copper	2	2	3	A)1 C)3 B)2 D)2 2-1	2	2
Feldspar	3	3	3	A)3 C)3 B)1 D)3 2-3	3	3

Table 5.12 (continued)

<u>MATERIAL</u>	<u>U. S. Reserves¹</u> <u>Cumulative Demand</u>	<u>U. S. Resources²</u> <u>Cumulative Demand</u>	<u>Net Imports³</u> <u>Demand</u>	<u>Vulnerability of⁴</u> <u>Import Source</u>	<u>Foreign Reserves¹</u> <u>Cumulative Demand</u>	<u>Foreign Resources²</u> <u>Cumulative Demand</u>
Fluorine	1	1	2-1	A)3 C)3 B)1 D)2 2	3	2
Graphite	1	2	1	A)3 C)3 B)1 D)2 2	3	3
Iron	2	3	2-3	A)1 C)3 B)1-2 D)3-2 1-2	3	3
Lead	3	?	1	A)3 C)3 B)2 D)3-2 3	2	3
Nickel	1	1-2	1-2	A)3 C)3 B)1 D)3 2-3	3	3
Phosphate	3	3	3	2	3	3
Silicon	3	3	3	3	3	3
Silver	1	1	2	A)3 C)3 B)2 D)2-3 3	1	1
Tin	1	1	1	A)1 C)2 B)2 D)2-1 1	3	2
Tungsten	1	1	3	A)1 C)3 B)2 D)2-3 2	3-2	?
Zinc	2	2-3	2	A)3 C)3 B)2 D)3-2	1-2	3
Zirconium	3	1-2	2	A)3 C)2 B)1 D)3 2-1	3	2

<u>MATERIAL</u>	<u>U. S. Reserves¹ Cumulative Demand</u>	<u>U. S. Resources² Cumulative Demand</u>	<u>Net Imports³ Demand</u>	<u>Vulnerability of Import Source⁴</u>	<u>Foreign Reserves¹ Cumulative Demand</u>	<u>Foreign Resources² Cumulative Demand</u>
Natural Gas	1	1-2	3	A)3 C)3 B)1 D)3 2-3	3	2-3
Coal	3	3	3	3	3	3
Petroleum	1	1-2	2-3	A)1 C)3-2 B)3 D)2-1 2-1	2	2
Timber	2	?	3	A)3 C)3 B)1 D)3 3	?	?
Cobalt	1	2	1	A)3 C)2 B)1 D)1 1-2	3	3
Gold	1-2	1-2	1	A)3 C)2-3 B)2 D)3	2	2(?)
Manganese	1	2	1	A)3 C)3 B)2 D)2	3	3

¹Categories: 0 - 49% = 1; 50 - 109% = 2; 110% + = 3.

²Categories: 0 - 249% = 1; 250 - 999 = 2; 1000% + = 3.

³Categories: if net imports > 60% = 1; if 26 - 59% = 2; if < 25% = 3.

⁴Categories:

- A) if a producers' cartel exists = 1; if no group = 3.
- B) if 60%+ of imports come from one country = 1; if 30-59% = 2; if < 30% then = 3.
- C) if > 50% of imports come from communist-influenced countries = 1; other = 2; Western Hemisphere and non-communist = 3.
- D) if underdeveloped countries send > 50% of imports = 1; if developing countries = 2, if developed countries = 3.

RELATIVE RANKING OF DISTRIBUTION EQUIPMENT RAW MATERIALS:
POTENTIAL FOR FUTURE U. S. RAW MATERIAL SHORTAGES

<u>Critical</u>	<u>Watch</u>	<u>No Apparent Problem</u>
Chromium	Aluminum (Bauxite)	Argon
Natural Gas	Cobalt	Barium
Oil	Copper	Beryllium
Silver	Fluorine	Boron
Tin	Gold	Cadmium
	Graphite	Chlorine
	Manganese	Coal
	Nickel	Feldspar
	Timber	Lead
	Tungsten	Phosphates
	Zinc	Silicon
		Zirconium

[†] Note that Tables 5.1 and 5.13 are related. Table 5.1 differs from Table 5.13 in that Table 5.13 examines criticality of distribution equipment raw materials only from the viewpoint of domestic availability relative to total U. S. needs. Table 5.1 also considers the relative criticality of the material to distribution equipment availability.

5.4.2 Importance of Selected Raw Materials to the Production of
Distribution Equipment

1) The value of material inputs as a percent of total product value. Table 5.14 shows the value of each material used directly in distribution equipment as a fraction of total value for each distribution equipment category. Table 5.15 presents the value of each material as a fraction of the value of the entire distribution equipment system. The entries in Table 5.15 are arranged in order of importance of each material's contribution to total value.

Table 5.14

CONTRIBUTION OF MATERIALS TO TOTAL VALUE OF EQUIPMENT TYPES IN 1974

		TRANSFORMERS			DRY TYPE	INSTRUMENT
		OVERHEAD	UNDERGROUND	SMALL POWER		
1	STEEL	0.0795691	0.0662939	0.1396473	0.1244624	0.0374615
2	STNLS STEEL	0.0030461	0.0025526	0.0015934		
3	ELEC STEEL	0.2065087	0.1720702	0.1518008	0.2040860	0.2243077
4	ALUMINUM	0.0493934	0.0411579	0.0857054	0.0634758	0.0850000
5	COPPER	0.0729185	0.0607368	0.0039037	0.0747097	
6	BRASS	0.0014283	0.0011860	0.0001726		
7	BRONZE	0.0002624	0.0002211	0.0001494		
8	SILVER	0.0009298	0.0007579	0.0001434		
9	LEAD	0.0001288	0.0001077	0.0001235		
10	TIN	0.0000281	0.0000246	0.0000266		
11	ZINC, CU	0.0003385	0.0002794	0.0000017		
12	TUNGSTEN	0.0004009	0.0003377			
13	ALNICO, BAFE					
14	NI, NI-CR					
15	SI-CARBIDE					
16	BORIC ACID					
17	CU SALTS					
18	NAF					
19	ZN PHOSPHATE	0.0000010	0.0000014	0.0000027	0.0000017	0.0000002
20	SAND					
21	CONCRETE					
22	PORCELAIN	0.0012575	0.0009868	0.0000924	0.0005645	0.0001731
23	GLASS	0.0001617	0.0001316	0.0000199	0.0000823	
24	ALUMINA, BERYL	0.0001953	0.0001684	0.0000660	0.0000444	0.0147692
25	GASKET MATLS	0.0046863	0.0036842	0.0005726	0.0016129	0.0008769
26	PAPER, FIBER	0.0049727	0.0039474	0.0056017	0.0025269	0.0000577
27	PHENOLIC RESIN	0.0000325	0.0000570	0.0001183	0.0000188	0.0000481
28	POLYESTER	0.0017912	0.0014035	0.0001162	0.0009140	
29	EPOXY	0.0011325	0.0008421	0.0006224	0.0006048	0.0087115
30	SILICONE	0.0004335	0.0000138	0.0000411	0.0000605	
31	POLYPROPYLENE					
32	MSC PLASTICS	0.0001276	0.0001228	0.0015394	0.0067742	
33	POLYETHYLENE					
34	PVC					
35	ETPRP RUBBER					
36	CH, RSLF POLY					
37	BUTYL RUBBER					0.0204615
38	NEOPRENE					
39	MISC INSUL					
40	PENTA					
41	PCB OR SUBST			0.0425311		
42	INSL OIL	0.0293778	0.0551930	0.0181245		0.0037400
43	INSL VARNISH	0.0013278	0.0026316	0.0020747	0.0003629	0.0092308
44	FINISHES	0.0025514	0.0021754	0.0034855	0.0019355	0.0002308
45	SOLVENTS	0.0004889	0.0004079	0.0003734	0.0003097	0.0000346
46	CREOSOTE		0.0000220			
47	POLES					
48	CROSS ARMS					
49	ARGON	0.0028248				
TOTAL		0.4663150	0.4175146	0.4586495	0.4825469	0.4051037

Table 5.14 (continued)

CONTRIBUTION OF MATERIALS TO TOTAL VALUE OF EQUIPMENT TYPES IN 1974

	VOLTAGE REG	METERS	SWITCHGEAR	FUSES	CAPACITORS
1 STEEL	0.0712500	0.0055134	0.1201465	0.0420216	0.0430909
2 STNLS STEEL	0.0027000	0.0241540	0.0143799	0.0475926	
3 ELEC STEEL	0.1230000	0.0303571			
4 ALUMINUM	0.0374000	0.0384236	0.0110220		0.0776436
5 COPPER	0.0540000	0.0539650	0.0727786	0.2071852	0.0038400
6 BRASS	0.0003575	0.0252719	0.0051429	0.0246358	0.0017018
7 BRONZE	0.0001957	0.0010502	0.0031083		
8 SILVER			0.0109714	0.1212444	
9 LEAD	0.0000770	0.0003734			0.0000931
10 TIN		0.0054049			0.0009309
11 ZINC, CU	0.0000487	0.0002366			
12 TUNGSTEN			0.0001583		
13 ALNICO, BAFE		0.0136826			
14 NI, NI-CR		0.0000072	0.0000649		
15 SI-CARBIDE					
16 BORIC ACID				0.0006667	
17 CU SALTS					
18 NAF					
19 ZN PHOSPHATE	0.0000027	0.0000046	0.0000013		0.0000003
20 SAND				0.0010494	
21 CONCRETE					
22 PORCELAIN	0.0001250		0.0026217	0.0119676	0.0003055
23 GLASS	0.0000320	0.0026779	0.0002512	0.0008889	
24 ALUMNA, BERYL	0.0001162		0.0006279		
25 GASKET MATLS	0.0006975	0.0021004	0.0012873		
26 PAPER, FIBER	0.0059000	0.0013267	0.0000209	0.0010802	0.0145455
27 PHENOLIC RESIN		0.0032964			
28 POLYESTER	0.0002675	0.0000173	0.0047096	0.0079012	
29 EPOXY	0.0006750	0.0028005	0.0003925		
30 SILICONE	0.0000647		0.0002943		
31 POLYPROPYLENE					0.0632727
32 MSC PLASTICS	0.0010500	0.0013477	0.0006593	0.0010802	0.0022909
33 POLYETHYLENE					
34 PVC					
35 ETHER RUBBER					
36 CH, KSLF POLY					
37 BUTYL RUBBER					
38 NEOPRENE					
39 MISC INSUL					
40 PENTA					
41 PCB OR SUBST					0.1073455
42 INSL OIL	0.0110118				
43 INSL VARNISH	0.0011750	0.0000408			
44 FINISHES	0.0114000	0.0006254	0.0025118		0.0006982
45 SOLVENTS	0.0004350	0.0005601	0.0005024		0.0000960
46 CREOSOTE					
47 POLES					
48 CROSS ARMS					
49 ARGON					
TOTAL	0.3219814	0.2132377	0.2516530	0.4673139	0.3158548

Table 5.14 (continued)

CONTRIBUTION OF MATERIALS TO TOTAL VALUE OF EQUIPMENT TYPES IN 1974

		BREAKERS	ARRESTERS	WOOD POLES	INSULATORS	CABLE
1	STEEL	0.1182510	0.0573059		0.0222482	0.0206690
2	STRLS STEEL	0.0175665				
3	ALUM STEEL					
4	ALUMINUM	0.0391065	0.0077626		0.0437939	0.2193215
5	COPPER	0.1074981	0.0001096			0.1071962
6	BRASS	0.0006920	0.0084292			
7	BRONZE					
8	SILVER	0.0208061				
9	LEAD					0.0025370
10	TIN					
11	ZINC, CD					0.0001066
12	TUNGSTEN	0.0019867				
13	ALUMICO, BARE					
14	NI, NI-CA					
15	SI-CARBIDE		0.2360731			
16	BORIC ACID					
17	CU SALTS			0.0010303		
18	NAF			0.0007619		
19	ZN PHOSPHATE	0.0000007				
20	SAND					
21	CONCRETE					
22	PORCELAIN	0.0012548	0.0369863		0.0054098	
23	GLASS					
24	ALUMINA, BERYL					
25	GASKET MATLS	0.0034221	0.0219178			
26	PAPER, FIBER	0.0010266				0.0003324
27	PHENOLIC RESIN	0.0003327				
28	POLYESTER					
29	EPOXY					
30	SILICONE					
31	POLYPROPYLENE					
32	MISC PLASTICS	0.0002529	0.0191781			
33	POLYETHYLENE					0.0619019
34	PVC					0.0224957
35	ETPAP RUBBER					0.0260193
36	CH, KSLF POLY					0.0397562
37	BUTYL RUBBER					0.0055911
38	NEOPRENE					0.0032493
39	MISC INSUL					0.0020657
40	PENTA			0.0223723		
41	PCB OR SUBST					
42	INSL OIL	0.0044487				
43	INSL VARNISH					
44	FINISHES	0.0016426				
45	SOLVENTS	0.0001825		0.0649351		
46	CREOSOTE			0.0354762		
47	POLES			0.3337662		
48	CROSS ARMS			0.0191667		
49	ARGON					
	TOTAL	0.3184703	0.3877626	0.4775087	0.0714520	0.5112420

Table 5.14 (continued)

CONTRIBUTION OF MATERIALS TO TOTAL VALUE OF EQUIPMENT TYPES IN 1974

	CONNECTORS	TOTAL
1	STEEL	0.0503748
2	STNLS STEEL	0.0036753
3	ELEC STEEL	0.0651639
4	ALUMINUM	0.0245665
5	COPPER	0.2861272
6	BRASS	0.0020834
7	BRONZE	0.0003568
8	SILVER	0.0029540
9	LEAD	0.0011712
10	TIN	0.0002020
11	ZINC,CU	0.0001282
12	TUNGSTEN	0.0001301
13	ALNICO,BAFE	0.0004865
14	NI,NI-CK	0.0000054
15	SI-CARBIDE	0.0021451
16	BORIC ACID	0.0000090
17	CU SALTS	0.0000988
18	NAF	0.0000730
19	ZN PHOSPHATE	0.0000008
20	SAND	0.0000141
21	CONCRETE	0.0004979
22	PORCELAIN	0.0011301
23	GLASS	0.0001685
24	ALUMNA,BERYL	0.0002618
25	GASKET MATLS	0.0015962
26	PAPER,FIBER	0.0017928
27	PHENOLIC RSN	0.0001381
28	POLYESTER	0.0009279
29	EPOXY	0.0005348
30	SILICONE	0.0000990
31	POLYPRPYLENE	0.0001155
32	MSC PLASTICS	0.0005187
33	POLYETHYLENE	0.0230015
34	PVC	0.0086858
35	ETPRP RUBBER	0.0096561
36	CH,RSLE POLY	0.0145848
37	BUTYL RUBBER	0.0022831
38	NEOPRENE	0.0011871
39	MISC INSUL	0.0007289
40	PENTA	0.0021443
41	PCB OR SUBST	0.0023224
42	INSL OIL	0.0110537
43	INSL VARNISH	0.0006875
44	FINISHES	0.0011561
45	SOLVENTS	0.0064322
46	CREOSOTE	0.0034024
47	POLES	0.0319904
48	CROSS ARMS	0.0018371
49	ARGON	0.0004502
	TOTAL	0.3106936
		0.4381086

Table 5.15

CONTRIBUTION OF MATERIALS TO TOTAL VALUE OF EQUIPMENT IN 1974

	TOTAL
1 ALUMINUM	0.0966861
2 COPPER	0.0829652
3 ELEC STEEL	0.0651639
4 STEEL	0.0503748
5 POLES	0.0319904
6 POLYETHYLENE	0.0230015
7 CH, ASLF POLY	0.0145848
8 INSL OIL	0.0110537
9 ETPRF RUBBER	0.0096561
10 PVC	0.0086858
11 SOLVENTS	0.0064322
12 STNLS STEEL	0.0036753
13 CREOSOTE	0.0034024
14 SILVER	0.0029540
15 PCB OR SUBST	0.0023224
16 BUTYL RUBBER	0.0022831
17 SI-CARBIDE	0.0021451
18 PENTA	0.0021443
19 BRASS	0.0020834
20 CROSS ARMS	0.0018371
21 PAPER, FIBER	0.0017928
22 GASKET MATLS	0.0015962
23 NEOPRENE	0.0011871
24 LEAD	0.0011712
25 FINISHES	0.0011561
26 PORCELAIN	0.0011301
27 POLYESTER	0.0009279
28 MISC INSUL	0.0007289
29 INSL VARNISH	0.0006875
30 EPOXY	0.0005348
31 MSC PLASTICS	0.0005187
32 CONCRETE	0.0004979
33 ALNICO, BAFE	0.0004865
34 ARGON	0.0004502
35 BRONZE	0.0003568
36 ALUMNA, BERYL	0.0002618
37 TIN	0.0002020
38 GLASS	0.0001685
39 PHENOLIC RSN	0.0001381
40 TUNGSTEN	0.0001301
41 ZINC, CU	0.0001282
42 POLYPROPYLENE	0.0001155
43 SILICONE	0.0000990
44 CU SALTS	0.0000988
45 NAF	0.0000730
46 SAND	0.0000141
47 BORIC ACID	0.0000090
48 NI, NI-CR	0.0000054
49 ZN PHOSPHATE	0.0000008
TOTAL	0.4381086

2) Calculation of the direct and indirect material usage.

As mentioned in the methodology section, it is important to account for both the direct-indirect amount of materials required in the production of a goods. Only in that way can the impact of a material shortage on the production of a goods be analyzed. Table 5.16 shows the tons of each raw material required per million dollars of distribution equipment delivered to final demand. Table 5.17 shows the total amount of each raw material used to produce distribution equipment as a percent of total U. S. usage in 1967.

There are several provisos attached to the use of Tables 5.16 and 5.17 that should be recognized. The first is that the calculations of direct and indirect requirements were made for 1967 only. The 1967 input-output table is the Department of Commerce's latest; hence, its use. However, the table shows the technical relationship existing in 1967 between industries, and since it is known that in the case of several equipment types that the relationship has changed (i.e., for cables), the results shown in Tables 5.16 and 5.17 are undoubtedly dated. Second is the problem of aggregation. Since the government's input-output table only has 380 industrial sectors, distribution equipment categories must be assigned to input-output sectors that are not unique to that category. For example, meters used in distribution systems are only part of the sector "electric measuring instruments." Thus, to the extent that the other products in the sector are of a different nature than meters, the results for meters are biased. An in-depth study of these problems is beyond the scope of the present study. The problems are noted and the tables should, accordingly, be viewed with some skepticism. Nonetheless, the concept under which the tables were constructed is valid and was used to provide completeness to the analysis.

Table 5.16

SHORT TONS OF MATERIAL REQUIRED PER MILLION DOLLARS OF OUTPUT
(END USE CATEGORY) DELIVERED TO FINAL DEMAND
(1967)

Material	<u>End Use Category</u>								
	Transformers and Volt. Regulators	Meters	Switchgear, Reclosers, Connectors, Breakers, Power Fuses	Capacitors	Arresters	Poles	Insulators	Cable	Total Distribution Equipment
Aluminum (ST)	14.7480	9.2400	14.0819	20.0893	23.8213	1.1793	12.4590	71.8662	167.485
Chromium (ST)	1.7750	.4305	.82667	.6884	1.7732	.7483	2.8857	.4785	9.6063
Cobalt (ST)	.1007	.0218	.0667	.0610	.1283	.0128	1.7835	.0505	2.2258
Copper (ST)	24.1360	6.7730	18.2228	16.1110	21.3870	.6527	2.1425	200.1898	289.6148
Fluorine (ST)	1.550	.5033	.7769	.8333	1.6406	1.7251	.9285	1.2652	4.2229
Gold (ST)	.00027	.0003	.00015	.00037	.00141	.00007	.00015	.00108	.0038
Graphite (ST)	.0685	.0250	.0586	.0917	.0593	.0449	1.6122	.0378	1.9979
Manganese (ST)	7.1751	1.7949	3.2274	2.6429	7.2834	2.8241	1.7159	2.2206	28.8843
Nickel (ST)	.7129	.1748	.3715	.2906	.72696	.2351	.1699	.6433	3.3250
Silver (ST)	.0058	.0075	.0048	.0025	.0373	.0150	.0098	.0316	.1276
Tin (ST)	.3158	.1281	.2001	.2397	.7039	.0635	.0993	.9935	3.1878
Tungsten (ST)	.0296	.0064	.0137	.0147	.0527	.0049	.0067	.0257	.1544
Zinc (ST)	4.856	2.6326	9.3896	4.4462	18.8907	1.4041	2.4278	151.5201	191.5671
Natural Gas (10 ⁹ ft. ³)	.0342	.0190	.0245	.0298	.0420	.0639	.0717	.0473	.3324
Petroleum (10 ⁶ BRLS)	.0039	.0016	.0017	.0022	.0019	.0060	.0024	.0024	.0221
Timber (10 ⁶ ft. ³)	.0046	.4460	.0072	.01383	.0049	.6234	.0039	.0078	1.1116

Table 5.17

SHORT TONS OF MATERIAL REQUIRED (BOTH DIRECTLY AND INDIRECTLY)
TO SUPPORT END USE OUTPUT AS A PERCENTAGE OF 1967 TOTAL MATERIAL USAGE

Material	End Use Category								Total Distribution Equipment
	Transformers and Volt. Regulators	Meters	Switchgear, Reclosers, Connectors, Breakers, Power Fuses	Capacitors	Arresters	Poles	Insulators	Cable	
Aluminum (ST)	.3570	.255	.2581	.1183	.0896	.0003	.0006	.564	1.6429
Chromium (ST)	.3570	.099	.1262	.0338	.0556	.0015	.0117	.0237	.7085
Cobalt (ST)	.6060	.166	.3359	.0987	.1327	.0009	.238	.1089	1.6871
Copper (ST)	1.130	.362	.6461	.1835	.1557	.00031	.002	3.039	5.5186
Fluorine (ST)	.327	.122	.1244	.0429	.050	.0037	.0394	.0867	.7961
Gold (ST)	.105	.125	.0391	.0331	.0815	.000004	.0011	.1309	.5157
Graphite (ST)	.116	.048	.0779	.0262	.0157	.0008	.055	.0208	.3604
Manganese (ST)	.565	.1615	.1925	.0507	.0892	.0023	.0027	.0568	1.1207
Nickel (ST)	.288	.081	.1141	.0287	.0458	.00096	.0014	.0846	.6444
Silver (ST)	.0789	.1152	.0491	.0414	.0788	.0021	.0027	.1395	.5077
Tin (ST)	.420	.195	.2018	.0776	.1458	.00085	.0027	.429	1.4726
Tungsten (ST)	.370	.091	.1294	.045	.1031	.00062	.0017	.1043	.8451
Zinc (ST)	.329	.20	.483	.0734	.2098	.00096	.0004	3.341	4.6376
Natural Gas (10 ⁹ ft. ³)	.184	.117	.100	.039	.035	.0035	.0077	.0826	.5688
Petroleum (10 ⁶ BRLS)	.081	.038	.026	.0110	.0062	.00125	.0010	.0161	.1806
Timber (10 ⁶ ft. ³)	.0351	.039	.0418	.0258	.0057	.0482	.0001	.0193	.2150

3) Final ranking of raw materials. Table 5.1 (reproduced here) is the final ranking of raw materials according to their relative potentials for future shortage and the relative impact of such shortages on distribution equipment availability. The materials in the "critical," "watch carefully," and "watch" groupings are those for which, other things being equal, substitution possibilities should be examined.

Table 5.1[†]

RELATIVE RANKING OF DISTRIBUTION EQUIPMENT RAW MATERIALS
ACCORDING TO THE POTENTIAL FOR SHORTAGES AND THE IMPACT OF SUCH
SHORTAGES ON DISTRIBUTION EQUIPMENT AVAILABILITY

<u>Critical</u>	<u>Watch Closely</u>	<u>Watch</u>	<u>No Apparent Problem</u>
Chromium	Aluminum (Bauxite)	Fluorine	Argon
Natural Gas	Copper	Gold	Barium
Oil	Silver	Graphite	Beryllium
	Alloying Metals for Steel	Tungsten	Boron
	Cobalt	Zinc	Cadmium
	Manganese		Chlorine
	Nickel		Coal
	Timber		Feldspar
	Tin		Lead
			Phosphates
			Silicon
			Zirconium

[†]Note that Tables 5.1 and 5.13 are related. Table 5.1 differs from Table 5.13 in that Table 5.13 examines criticality of distribution equipment raw materials only from the viewpoint of domestic availability relative to total U. S. needs. Table 5.1 also considers the relative criticality of the material to distribution equipment availability.

CHAPTER 6

TASK 5 - AVAILABILITY OF DISTRIBUTION SYSTEM MATERIAL INPUTS

6.1 Task Description

The unprecedented shortages of a variety of basic and finished commodities during the 1973-74 era were related primarily to supply-side constraints on capacity, raw materials, transportation, and energy, coupled with the simultaneous peaking of domestic and world demand. While the decline in economic activity during the recent recession has alleviated shortages in all but a few of the previously afflicted commodities, a number of market studies have raised the possibility of severe supply problems reappearing for specific products during and after the current (1976) economic recovery.

Task 5 thus has the overall objective of providing a qualitative assessment of those potential supply problems that could impose significant constraints on the future availability of products directly consumed in the production of distribution equipment. The specific sub-tasks include:

- (1) Assignment of the (4 or more digit SIC code) products designated by Task 3 as being consumed in the production of distribution equipment to a particular (2 or 3 digit SIC code) industry;
- (2) an historical summary for each product and corresponding industry that includes information on markets, pricing, financial performance, production, investment, and capacity;
- (3) calculation of the relative susceptibility of the various products to energy and mineral constraints;

- (4) forecasts (1976-2000) of production, investment, and (where relevant) capacity for each industry;
- (5) forecasts of production (1976-2000), "required" capacity expansion (1976-2000), and presentation of "announced" capacity expansion (1976-78) for the most important products within an industry group and several important raw materials required by those products;
- (6) given information provided by the aforementioned sub-tasks concerning capacity, raw materials, fuels, and other potential constraints, provide a qualitative assessment of the potential for supply shortfalls in each product market on a year-by-year basis out to 1980 and at various time intervals (to 2000) thereafter.

Table 6.1 contains the industries and corresponding products included in this study. The analysis is conducted at both industry and product level so as to incorporate maximum available information, particularly on commodities produced in multi-product plants, into the potential shortage evaluation. Two products, petroleum and natural gas, of indirect importance to the distribution equipment industry have also been included. The forecasts are predicated upon a long-range "trend" macroeconomic forecast and a "cycle" alternative (the latter being used in an industry sensitivity analysis) supplied by Data Resources, Inc. (DRI). Table 6.2 contains projected values for real GNP, potential real GNP, and the wholesale price index for all commodities.

The potential shortage evaluation, while based upon information derived from econometric models, is essentially qualitative, with information generated by subtasks 1-5 being used on a judgmental basis to assign each product to one of three availability categories ("shortage," "marginal," and "no shortage") over specified time intervals. The three supply-status categories are defined as follows:

Table 6.1

MAJOR INDUSTRY AND PRODUCT CATEGORIES

- (1) Natural Gas and Natural Gas Liquids
- (2) Petroleum Refinery Products (SIC 29)
- (3) Chemicals and Allied Products (SIC 28)
 - Products:
 - Basic Chemicals
 - Resins
 - Synthetic Rubber
 - Miscellaneous Allied Products
- (4) Lumber and Wood Products (SIC 24)
 - Products:
 - Lumber
 - Poles and Cross Arms
- (5) Pulp and Paper Products (SIC 26)
 - Products:
 - Wood Pulp
 - Electrical-Grade Paper
- (6) Stone, Clay, and Glass Products (SIC 32)
 - Products:
 - Portland Cement
 - Specialty Electrical Porcelain
 - Glass Products

Table 6.1 (continued)

(7) Primary Iron and Steel (SIC 331)

Products:

- Raw Steel
- Stainless Steel
- Oriented Electrical Steel
- Non-oriented Electrical Steel

(8) Primary Nonferrous Metals (SIC 333)

Products

- Aluminum
- Copper
- Lead and Zinc
- Miscellaneous Nonferrous Metals

Table 6.2

SUMMARY OF MACRO GROWTH FORECASTS

		<u>TREND</u>	<u>SCENARIO</u>				
		<u>Y e a r</u>					
		<u>75</u>	<u>80</u>	<u>85</u>	<u>90</u>	<u>95</u>	<u>2000</u>
Real GNP	(bill. 1958 \$)	798	1013	1223	1405	1605	1834
Potential Real GNP							
	(bill. 1958 \$)	921	1077	1266	1472	1698	1951
Wholesale Price Index							
	(1967 = 1.0)	1.75	2.25	2.62	2.95	3.37	3.67

	<u>CYCLE</u>	<u>SCENARIO</u>				
	<u>Y e a r</u>					
	<u>75</u>	<u>80</u>	<u>85</u>	<u>90</u>	<u>95</u>	<u>2000</u>
Real GNP (bill. 1958 \$)	798	989	1240	1373	-	-
Potential Real GNP (bill. 1958 \$)	921	1084	1271	1480	-	-
Wholesale Price Index (1967 = 1.0)	1.75	2.36	3.08	4.00	-	-

Source: Data Resources, Inc. ("Trend Long 12/75" and "Cycle Long 10/75" simulations, respectively). Forecasts from 1991 to 2000 are based on extrapolations of forecasted growth rates for prior (1976-1990) years.

- (1) Shortage - The product is judged to be extremely susceptible to a national supply shortfall (relative to the "trend" demand forecast) that would be characterized by a near-zero price elasticity of short-run supply, rapid extension of delivery lead-times, inordinately low inventories, and other phenomena usually associated with tight-supply situations.
- (2) Marginal - The conclusion that supply and demand for the product would be in approximate balance under the "trend" forecast is severely qualified by one or more caveats stipulated in the body of this report.
- (3) No Shortage - The product's supply is judged adequate, without severe qualification, to meet all plausible demand projections without exceeding "normal" (i.e., historical average) utilization rates and delivery schedules.

6.2 Summary of Results

Table 6.3 summarizes the results of the potential shortage analysis. Assuming the absence of an oil embargo, twenty-six (26) products are projected to be in adequate supply over the entire forecast period, including copper, tin, lead, brass, elastomers, phenolic resins, and paper (including electrical-grade) products. Seventeen (17) products, including aluminum, silver, wood, and most resins, find themselves in the "marginal" category for one or more time periods. Finally, steel (virtually all types), zinc, polypropylene, polyvinyl chloride (PVC), and polychlorinated-biphenyls (PCB) have been placed in the "shortage" category for varying lengths of time.

While, as indicated in the preceding summary, the supply-status does vary between products, this study does not foresee a repeat of the 1973-74 debacle (in which a large number of products were in simultaneous short supply) during the next three years. Many of the primary processing

Table 6.3

SUPPLY STATUS*

1 9 7 6 - 2 0 0 0

	1976 - 1980			1981 - 1985			1986 - 2000		
	No Shortage	Marginal	Shortage	No Shortage	Marginal	Shortage	No Shortage	Marginal	Shortage
Steel			x			x		x	
Stnls Steel			x			x			x
Elec Steel			x			x		x	
Aluminum		x		x			x		
Copper	x			x			x		
Brass	x			x			x		
Bronze	x			x			x		
Silver		x			x			x	
Lead	x			x			x		
Tin	x			x			x		
Zinc, Cd			x			x			x
Tungsten		x			x			x	
ALNICO	x			x			x		
Ni, Ni-Cr	x			x			x		
Si-Carbide	x			x			x		
Boric Acid	x			x			x		
Cu Salt	x			x			x		
NAF	x			x			x		
Zn Phos		x			x			x	
Sand	x			x			x		
Concrete		x			x			x	
Porcelain		x		x			x		
Glass		x			x			x	
Alumina, BRYL	x			x			x		
Gasket Mat	x			x			x		
Paper	x			x			x		
Phenolic	x			x			x		
Polyester		x		x			x		
Epoxy		x		x			x		
Silicone		x			x			x	

Table 6.3 (continued)

SUPPLY STATUS

	1976 - 1980			1981 - 1985			1986 - 2000		
	No Shortage	Marginal	Shortage	No Shortage	Marginal	Shortage	No Shortage	Marginal	Shortage
Polyprop			x		x		x		
Msc Plastics		x		x			x		
Poly Ethy		x		x			x		
PVC			x		x			x	
ETPRP Rubber	x			x			x		
CH, RSLF Poly		x		x			x		
Butyl Rubber	x			x			x		
Neoprene	x			x			x		
Misc Insul	x			x			x		
Penta	x			x			x		
PCB			x			x			x
Ins1 Oil		x			x			x	
Ins1 Varnish	x			x			x		
Finish	x			x			x		
Solvent	x			x			x		
Creosote	x			x			x		
Poles		x			x			x	
Cross Arm		x			x			x	
Argon	x			x			x		
Lumber		x			x		x		

* An x indicates that the product has been placed into the supply-status category named at the top for one or more years within the indicated time interval. See text for details.

industries (as of July 1976) are still operating with comfortable capacity margins, and it seems unlikely that the disastrous exogenous shocks that contributed to the previous across-the-board supply problems will make a simultaneous reappearance during the progressing economic recovery.

6.3 Methodology

Industry versus product-levels of analysis

As noted earlier, the analysis is conducted at both the "Industry" (2- or 3-digit SIC code) and "Product" (4 or more digit SIC code) level so as to incorporate as much information as possible, particularly on materials produced in multi-product plants, into the potential shortage evaluation. In addition to the sectors that directly contribute inputs to the distribution equipment producers (as specified in Task 3), several products and industries (such as natural gas) that are important indirect suppliers have also been included. The list of major industrial sectors (Table 6.1, with corresponding products) thus includes natural gas (SIC 492) and petro refining (SIC 29), lumber (SIC 24 and 0192), paper (SIC 26), stone, clay, and glass (SIC 32), primary steel (SIC 331), primary nonferrous metals (SIC 333), and chemicals and allied products (SIC 28).

Industry-level analysis

Industry-level information utilized by the potential shortage evaluation includes projections of supply and demand for the natural gas and lumber industries and projections of production, investment, and capacity for the remaining industries. The projected supply-demand balances for the natural gas and lumber industries have been derived (with some modifications to insure consistency with the present study's macro assumptions) from published authoritative studies and, while short sketches of techniques and assumptions are given in the respective "Results" section of this report, the reader is referred to the original sources for details.¹

The forecasts of production, investment, and capacity for the remaining six industries are predicated upon either a long-range "trend" macroeconomic forecast (1976-2000) or a "cycle" alternative (the latter being used in a sensitivity analysis for the years 1976-1990) supplied by the Data Resources, Inc. Quarterly Econometric Forecasting Model.² As indicated by data presented in Table 6.2, the "trend" macro forecast assumes a smooth gradual recovery from the 1975 recession and subsequent steady growth that is free of exogenous shocks.³ The "cycle" alternative, by contrast, simulates cyclical divergence from the base-line (trend) forecast in response to exogenous shocks and capricious monetary policy somewhat characteristic of the past 15 years of U. S. economic history.

DRI uses a set of input-output "bridge" and econometric equations to translate the given macro forecasts of "Final Demands" (consumption, investment, government expenditures, net exports) into projections of Federal Reserve Board (FRB) production indexes for various industries.⁴ These projections can be interpreted as the output that must be forthcoming from the indicated industries to support the forecasted macroeconomic final demands.

DRI specifies that the relationship between each industry's net investment and changes in its output (as measured by the FRB indexes) can be described by a distributed lag function; that is, the total response of net investment to a given increase in output is assumed to be distributed over a number of quarters.⁵ Replacement investment is assumed to be proportional to capital stock (the latter expressed in constant 1958 dollars). Gross (= net + replacement) investment is thus a (distributed lag) function of the forecasted changes in the production index and the (beginning-of-period) capital stock. Given an initial capital stock (K_t), a forecast of gross investment (GI_{t+1}) and a (constant) depreciation rate (r), a forecast of capital stock (K_{t+1}) is obtained from the following relationship:

$$K_{t+1} = GI_{t+1} + (1 - r) K_t . \quad (6.1)$$

Thus, DRI's forecasting service provides forecasts of production, investment, and capital stock for each industry. Translation of the projected capital stock growth into projections of capacity and capacity utilization for each industry is, however, accomplished by a set of equations developed specifically by and for this study. The approach is described in the following paragraphs.

First, a declining balance depreciation scheme (as in equation 6.1) was applied to McGraw-Hill estimates of each industry's capital expenditures on pollution abatement equipment (PABE) over the 1958:1 to 1975:4 historical interval to develop a quarterly stock of pollution abatement equipment series (KPABE).⁶ Subtraction of $KPABE_t$ from the aforementioned "gross" capital stock (K_t) over the historical interval yielded a series purporting to measure the productive or "effective" capital stock (KE_t) for each industry.

Secondly, it was assumed that the historical variation in an industry's capital productivity (i.e., the ratio of the FRB production index to the corresponding effective capital stock) equaled the sum of a cyclical and a secular component, with the latter being the ratio of capacity output to effective capital stock.⁷ The cyclical component is a function of the difference between real GNP and potential GNP. The secular component is hypothesized to be a function of technology and capital intensity.⁸ Combining these two functions, and using a time trend as a proxy for the secular variables, yields an equation for each industry whose parameters have been estimated by ordinary least squares from quarterly historical data. Table 6.4 contains the estimated parameters ($\hat{\alpha}$ and $\hat{\delta}$, respectively) for the real-potential GNP variable and the time trend.⁹

Third, the cyclical component is removed from the historical capital productivity series by setting the gap between real and real potential GNP equal to zero. Multiplication of the remaining secular component by the industry's effective capital stock (KE) then yields

Table 6.4

ESTIMATED PARAMETERS FOR CAPITAL
PRODUCTIVITY EQUATIONS

(Production Index/Capital Stock Index) = constant + a * (real GNP/potential
real GNP)

+ b * Time TREND *

(numbers in parenthesis are t-statistics)

<u>SIC</u>	<u>Industry</u>	<u>Constant</u>	<u>$\hat{a}$</u>	<u>$\hat{b}$</u>	<u>Interval</u>
26	Paper	-	1.2544 (52.77)	0.00064 (2.33)	1958:1 to 75:4
28	Chemicals	-0.93426 (-13.34)	1.3776 (19.04)	0.00728 (54.57)	1958:1 to 75:4
29	Petro	0.28111 (4.68)	0.45692 (7.36)	0.00323 (28.24)	1958:1 to 75:4
32	Stone/Clay	0.59827 (3.22)	0.91562 (4.76)	-0.00278 (-7.84)	1958:1 to 75:4
331	Steel	-	0.95512 (8.12)	0.00293 (2.45)	1965:1 to 75:4
333	Nonferrous	-	1.75848 (14.29)	-0.00344 (-2.75)	1965:1 to 75:4

* Time TREND: 1947 = 1.0

the capacity output series. This derived capacity index may be interpreted as measuring the output which can be produced at minimum total unit cost, given the stock of effective capital, technology, and factor prices.¹⁰

Fourth, each industry's capacity utilization series is derived by dividing the production index by the capacity series, multiplying by 100, and then normalizing so that the highest value over the historical period equals 100 %. Finally, as a short-hand assessment of market tightness, capacity margin is defined as the ratio of each time period's utilization rate to the average historical utilization rate minus one. The resulting value represents the percent increase (if positive) or decrease (if negative) in production that could be handled by existing capacity without exceeding average historical utilization rates.

Thus, for each industry (excluding natural gas and lumber), historical and forecasted values are available for production, gross, net, and net effective (i.e., $KE_t - KE_{t-1}$) investment, the corresponding capital stocks, capacity, and capacity utilization. Table 6.5 contains the 1975 annual utilization rate, average historical utilization rates, and percent changes in capacity between 1973:4 and 1975:4 for each industry. Additional historical detail can be found in Appendix 6-A.

The gap between forecasted net and net effective investment is bridged by distributing DRI's pollution abatement expenditure forecast for "All Manufacturing" over the individual industries on the basis of the proportions given in the McGraw-Hill surveys of historical and expected 1975-78 pollution abatement expenditures.¹¹ Forecasts of the capacity indexes are predicated on the forecasted effective capital stocks and the continuation of the secular productivity trends embodied in the Table 6.4 equations.

The previous discussion has concentrated on each industry's investment response to changes in output. Recently, there has been a debate over whether there will be sufficient capital funds available

Table 6.5

HISTORICAL CAPACITY AND CAPACITY
UTILIZATION DATA BY MAJOR
INDUSTRY GROUP

<u>SIC Code</u>	<u>Industry Title</u>	<u>Avg. Historical Utilization Rate (%)</u>	<u>% Change in Capacity (73:4-75:4)</u>	<u>1975 Utilization Rate (%)</u>
26	Paper	92	9	78
28	Chemicals and Allied Prds.	92	15	80
29	Petro Refining	95	8	90
32	Stone/Clay/Glass	89	3	79
331	Primary Steel	83	2	70
333	Primary Nonferrous	86	10	67

Source: Each industry's capacity series is derived from capital stock series provided by Data Resources, Inc. and the corresponding capacity equation given in Table 6.4. Capacity utilization for each industry is derived by dividing the FRB production index by the capacity series, multiplying by 100 and normalizing so that the highest historical value equals 100%. Data shown represent annualized versions of original quarterly values.

to support the capacity expansion that will be "required" in coming years.¹² While the question of whether the national savings rate will be sufficient to finance future capital needs (at some "reasonable" interest rate) is still subject to debate, there is little doubt that the various industries differ significantly in their relative abilities to generate or raise capital funds. For this reason, the industry capacity evaluation is supplemented by historical profitability data, such as that contained in Table 6.6.

Finally, from a technical or engineering standpoint, some industries are far more capital intensive than others; that is, a given (constant) dollar's worth of balanced capacity expansion requires a relatively greater (constant) dollar outlay of capital expenditures. Consequently, the various industries have been ranked (Table 6.7) and evaluated with respect to Battelle-Columbus estimates of their capital-output ratios.¹³

Product-level analysis

Product-level information utilized by the potential shortage analysis includes projections of production and required capacity additions (to maintain "efficient" utilization rates), coupled with announced capacity additions. Projections of raw material and mineral availability, along with historical information on price movements and energy intensiveness, have also contributed to the analysis.

Product-level production forecasts are generally derived from econometric equations that relate domestic physical production (consumption or shipments in some cases) of a product to variables presumed to measure economic activity in that product's principal end-markets. Forecasts of end-market activity variables are obtained from the same DRI macro model used to generate the industry-level projections. In many cases, forecasts generated by these single-equation product models have been modified to incorporate long-range market and technological information from outside sources.

Table 6.6

NET INCOME AS A PERCENT OF SALES AND AS A
PERCENT OF EQUITY FOR SELECTED INDUSTRIES
(1971-75)

<u>Industry</u>	After Tax Net Income as % of:	<u>Year</u>				
		<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>
Paper (26)	sales	2.3	4.1	5.6	7.9	5.3
	equity	4.3	8.4	11.9	19.5	11.4
Chemicals (28)	sales	7.4	7.8	8.3	8.3	7.6
	equity	12.2	13.6	15.8	17.7	15.4
Petro (29)	sales	11.9	10.4	11.8	11.9	7.1
	equity	10.1	9.3	12.5	18.6	11.1
Stone/Clay/Glass (32)	sales	4.9	5.1	5.3	4.5	3.8
	equity	8.9	10.2	11.4	10.0	8.6
Steel (331)	sales	3.1	3.3	4.4	6.4	4.7
	equity	4.7	5.6	8.8	14.5	9.2
Nonferrous (333)	sales	3.7	3.9	5.8	7.0	3.4
	equity	4.5	5.2	10.0	13.7	5.1

Source: Compiled by Data Resources, Inc. from Federal Trade
Commission, Quarterly Financial Report.

Table 6.7

CAPITAL-OUTPUT RATIOS
FOR SELECTED INDUSTRIES

<u>SIC Code</u>	<u>Industry</u>	<u>Capital-Output Ratio</u> [*]
331	Primary Steel	1.210
281	Industrial Chemicals	1.050
282	Synthetic Rubber and Plastics	0.900
291+299	Petro Refining	0.800
3334	Primary Aluminum	0.665
321-3	Glass	0.640
26 exc. 265	Pulp and Paper	0.616
24	Lumber and Products	0.528
3331	Primary Copper	0.295

* Change in capital per unit of balanced expansion of capacity. 1970-75 technology and 1970 prices are assumed.

Source: Battelle - Columbus Laboratories, Previews 85: Capital Coefficients, United States, 1975, December 5, 1974. Methodology is given in: Fisher, W.H. and Chelton, C., An Ex Ante Capital Matrix for the United States, 1970-75. Columbus: Battelle Memorial Institute, March 1971.

The "rated" capacity measures used at this disaggregated level do not have a consistent interpretation across all products.¹⁴ In some cases, the term "capacity" refers to an engineering concept of maximum physical output from around-the-clock operation. In other cases, the term refers to an hypothetical efficient or least-cost output level for a given plant. Nevertheless, utilization rates constructed from these capacity measures, when compared with past values, can serve as useful indicators of developing bottlenecks.

Utilizing information from various trade and technical magazines, a target utilization rate has been selected for each product which allows the manufacturer to get as close as possible to a stated "efficient" (or preferred) rate while still leaving sufficient slack to accommodate unexpected demands. Division of the forecasted production level by the target utilization rate, and comparing the result with the base period (1975) level of capacity, yields an estimate of required capacity expansion. The latter is then compared with announced (as reported in various trade magazines and other publications) capacity expansion over the near-term (usually out to 1978). Historical production and capacity data are given in Appendix 6-B.

Thus far, it has been implicitly assumed that the energy and minerals necessary to support future expansions of capacity and production will be readily available. For many products, however, there is at least a *prima facie* case for challenging this assumption. Consequently, the potential shortage analysis incorporates: (1) information on the relative susceptibility of the various products to energy and mineral constraints, and (2) supply-status assessments for key fuels and minerals required by the products under consideration.

Table 6.8 presents summary statistics on energy consumption by the most energy-intensive products considered in this study.¹⁵ Historical information on the important minerals can be found in Task 4. Additional information on possible energy and mineral constraints is provided on a product-by-product basis in this chapter's "Results" section.

Table 6.8

DOMESTIC ENERGY REQUIREMENTS FOR SELECTED PRODUCTS: 1973

<u>Product</u>	Energy Required*	
	Per Net Ton of Product (10 ⁶ BTU's)	Total (10 ¹² BTU's)
Aluminum Ingot	244.0	1408.0
Refined Copper	112.0	221.0
Zinc Ingot	65.0	92.0
Lead Ingot	27.0	23.9
Steel Slabs	24.0	3350.0
Glass Containers	17.4	216.0
Portland Cement	7.6	688.0

* Energy required by all stages of production (including mining, processing, and transportation), converted to British Thermal Units (BTU's).

Sources: Battelle - Columbus Laboratories, Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing: Phase 4 - Energy Data and Flowsheets, High Priority Commodities (NTIS No. PB245 759 AS, National Technical Information Service, Springfield, VA, 1975); Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing: Phase 5 - Energy Data and Flowsheets, Intermediate Priority Commodities (NTIS No. PB246 347 AS, *ibid*). These studies were supported by the Bureau of Mines. A summary is given in E.T. Hayes, "Energy Implications of Materials Processing," Science, Vol. 191, February 20, 1976.

Finally, while no attempt has been made to forecast the price that will eventually clear each market, historical price behavior (such as that portrayed in Table 6.9) and the related literature has been evaluated for clues as to causes and severity of past shortages, price elasticities of supply and demand, and product profitability.

Supply-Status Categories

This study provides a qualitative assessment of each product's potential for being in short supply (over a specified time interval) relative to the "trend" demand forecast. The probability of occurrence, severity, and duration of a "potential" shortage will, of course, vary from product to product. Consequently, the information generated by the previously discussed sources, models, and techniques is used on a judgmental basis to assign each product directly consumed by the distribution equipment manufacturers into one of three "supply-status" categories ("shortage," "marginal," or "no shortage") over specified time intervals. These three supply-status categories are defined as follows:

- (1) Shortage - The product is judged to be extremely susceptible to a national supply shortfall (relative to the "trend" demand forecast) that would be characterized by a near-zero short-run price elasticity of supply, rapid extension of delivery lead times, inordinately low inventories, and/or other phenomena (such as extension of the average work week for the affected industry) usually associated with tight markets.
- (2) Marginal - The conclusion that supply and demand for the product would be in approximate balance under the "trend" forecast is severely qualified by one or more of the following:
 - (a) the possibility of a tight market under plausible alternative demand forecasts;
 - (b) the product has a history of being assigned a low priority by its multi-product supplier;

Table 6.9

WHOLESALE PRICE INDEXES FOR SELECTED PRODUCTS
(1967 = 1.0)

<u>BLS Code</u>	<u>Product</u>	<u>Year</u>				
		<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>
1013	Steel Mill Prds.	1.23	1.30	1.34	1.70	1.97
1020	Nonferrous Metals	1.15	1.17	1.35	1.87	1.72
1061	Industrial Chemicals	1.02	1.01	1.03	1.52	2.07
1066	Plastics	.89	.89	.92	1.44	1.81
1071102	Synthetic Rubber	1.01	1.01	1.02	1.31	1.46
1057	Refined Petro	1.07	1.09	1.29	2.23	2.58
1081	Lumber	1.36	1.59	2.05	2.07	1.93
1091	Paper	1.14	1.16	1.21	1.49	1.73
1380	Glass	1.32	1.35	1.39	1.56	1.80
0000	All Products	1.14	1.19	1.35	1.60	1.75

Source: U.S. Department of Commerce, Bureau of Labor Statistics,
Wholesale Prices and Price Indexes, various years.

- (c) the product has a history of transitory regional shortages that can be expected to reoccur;
 - (d) the assessment is extremely sensitive to the assumed timing of a shift in resource base, a proposed plant expansion, or similar contingency.
- (3) No Shortage - The product's supply is judged adequate, without severe qualification, to meet all plausible demand projections without exceeding "normal" (i.e., historical average) utilization rates and delivery schedules.

The supply-status evaluations are made on a year-by-year basis out to 1980, and for five- or ten-year periods (out to the year 2000) thereafter. The likelihood of a product being placed into the "shortage" category is positively related to the number of causal factors involved, the product's past cyclical behavior, the severity of past (1973-74) shortages, and, of course, the expected severity of the constraint judged to be binding. Published historical information was unattainable for a number of products. This was particularly the case with capacity data on those specialized products manufactured in multi-product plants. In these latter cases, the shortage evaluation relied heavily on fragmentary data and communications with industry representatives and specialists.

6.4 Analysis and Results

The format for this section follows that given in Table 6.1. Generally, each industry discussion has been sub-divided into four sections: "Background," "Industry Forecast," "Product Forecast," and "Potential Shortage Evaluation." As noted earlier, each major product's historical production and capacity data has been relegated to Appendix 6-B. To further enhance continuity and clarity, the product forecasting equations have been placed in Appendix 6-C. Finally, the abbreviation "BOM" is used to cite information derived from the U. S. Department of the Interior, Bureau of Mines, Commodity Data Summaries - 1976.

- Natural Gas (SIC 492)

Background

The domestic natural gas industry consists of nearly 8000 crude oil and natural gas producers, 1000 natural gas pipeline companies, and some 1700 gas utility distributors providing "dry" gas to industrial (45 % of 1975 consumption, according to the BOM), commercial (12%), residential (25%), and electric utility (15%) users (the remaining three percent being consumed as pipeline fuel). The major coproducts include ethane, butane, propane, and other natural gas liquids processed by 768 plants and used as feedstocks for important petrochemicals and as fuels.

Inadequate domestic reserves of natural gas have been the binding constraints on both natural gas and natural gas liquid supply during the past five years. Proved reserves (according to the Federal Power Commission) have been declining, and natural gas distribution companies have curtailed supplies to industrial users (and refused to take on new customers) with increasing frequency. While mild winters and the recession have mitigated recent shortages, the total of new demand (by old and potential new customers) over the past five years has doubtless exceeded new supply by a substantial margin.¹⁶

The sale, transportation, and price of natural gas moved in interstate trade is regulated by the Federal Power Commission (FPC). Further, the Federal Energy Administration (FEA) has the power to

allocate and impose price ceilings on natural gas liquids. Most observers seem to agree that the elimination of FPC ceiling prices at the wellhead would provide significant supply relief over the long run. Supply response during the short run, however, would probably not be dramatic.¹⁷

Industry Forecast

The long-range projections of domestic natural gas supply and demand contained in Table 6.10 are based on 1974 growth projections generated by the Hudson-Jorgenson energy model; updated over the 1975-80 interval in accordance with recent historical data and BOM projections.¹⁸ While no major shift in Federal energy policy is assumed, gas price controls are presumed to be relaxed sufficiently to allow wellhead prices to rise at an average annual rate of 6.5 % over the 1975-2000 time interval.

Domestic production of natural gas is projected to make it back to 1974 levels by 1980. Thereafter, total gas production (natural plus synthetic) is expected to increase slowly and at a decreasing rate. Synthetic gas processed from coal becomes economically feasible in the mid-80s, and accounts for about 10 percent of total gas supply by the year 2000. Despite projected continuous reductions in the consumption of gas per-unit-of-output by major industrial users¹⁹ and absolute declines in household consumption, total domestic consumption is projected to rise faster than domestic production; thereby placing increasing reliance on net imports to fill the gap.

Product Forecasts (Natural Gas Liquids)

Natural gas liquid processing capacity has declined from 74.6 billion cubic feet per day (cfd) in 1973 to about 73.9 billion cfd in 1975. Inadequate reserves of natural gas, rather than processing capacity, will, however, be the constraining factor for the remainder of the decade.

Ethane production should increase at approximately the same rate as natural gas production over the 1975-80 time interval. Thereafter, new cryogenic techniques will begin extracting a greater proportion of the ethane contained in the natural gas; thereby allowing ethane

Table 6.10

NATURAL AND SYNTHETIC GAS PRODUCTION
AND CONSUMPTION*

	<u>Y e a r</u>									
	<u>73</u>	<u>74</u>	<u>75</u>	<u>76</u>	<u>77</u>	<u>78</u>	<u>80</u>	<u>85</u>	<u>90</u>	<u>2000</u>
Natural Gas Production	21.7	20.7	19.3	19.6	20.2	20.5	21.0	22.1	22.2 . . .	22.3
Synthetic Gas Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.8 . . .	3.0
Consumption	22.1	21.2	19.7	20.4	21.6	22.4	23.4	25.9	27.5 . . .	29.0

*All production and consumption figures are
x 10¹⁰ cubic feet.

production to grow at a slightly faster rate than natural gas production.²⁰ Propane, by contrast, is already being extracted at the maximum rate and, given that future natural gas will be "drier" (i.e., contain less liquids), future extraction of propane from natural gas should decline slowly.

Potential Shortage Evaluation

Natural gas fuel commitments over (at least) the next five years will have to be made against a declining or (at best) stagnant proved reserve base. Excess demand for natural gas should, therefore, continue to grow, and curtailments of gas fuels to industry can be expected to increase in both frequency and severity. Post-1980 projections are far more contingent upon assumed regulatory policies and technological innovations. It would, however, take rather optimistic assumptions concerning the effects of price decontrol, user substitutions, and synthetic fuel availability to project much more than very gradual reductions in the fuel shortfall during the post-1980 era. Further, projected ethane and other natural gas liquid supplies cannot possibly meet their petrochemical (much less their fuel) demands unless a major shift in petrochemical feedstocks is effected. This latter shift from natural gas to crude oil as a basic chemical feedstock is currently underway and will be discussed in future sections.

- Petroleum Refining and Related Products (SIC 29)

Background

This sector includes establishment primarily engaged in petroleum refining, paving and roofing materials, and compounding lubricating oils and greases. About 90 % of value-of-shipments for this sector is accounted for by the petroleum refining (SIC 2911) sector, and better than 80 % of refinery capacity appears to be controlled by about 20 major domestic integrated oil companies. These companies, together with the independents, are primarily engaged in the transformation of crude oil into refined products (gasoline, kerosene, distillate and residual fuel, and various coproducts), and the subsequent delivery of

these products to end users. BOM estimates for 1975 (in 42-gallon barrels) indicate that 89% of refined products are consumed as fuels, 6% as petrochemical feedstocks, and the remainder in the form of asphalts, lubricants, and other products.

The integrated oil companies also own vast coal reserves, control a significant percent of total natural gas processing capacity, and are now poised to make major inroads into that portion of the petrochemicals market traditionally controlled by the chemical industry. Concerning the latter, oil companies, as of 1974, controlled 70% of U. S. benzene capacity, 40-45% of ethylene capacity and better than 60% of total propylene capacity.²¹ This trend is encouraged by expected declines in gasoline growth rates and the relative profitability of olefins vis-à-vis fuels and lubricants (see "Chemicals and Allied Products").

The United States is a net importer of crude oil (35% of consumption in 1975) and, with both reserves and production declining, it appears that imports will have to assume an even greater importance in satisfying demands during the next five years. Since the OPEC oil embargo of late 1973, various Federal programs have been proposed that would attempt to lessen U. S. vulnerability to another embargo.²² Little effective action has been taken, however, and no comprehensive national energy policy has emerged. While dependence on imports is likely to increase during the next few years, simulations by the aforementioned Hudson-Jorgenson model (see "Natural Gas") indicate that crude price increases averaging 4.5 %, and increasing efficiencies in the use of petroleum fuels could lead to a declining need for imports during the post-1980 era.²³ Moreover, given known world reserves and the absence of an embargo, it seems likely that sufficient crude oil will be available from domestic plus foreign sources to support the moderate (relative to historical) projected growth rates in demand for petro products.

This leaves capacity as the major supply question mark. Our industry-level capacity study indicates that the oil companies have been able to maintain high capacity utilization rates with minimum cyclical

variation (Table 6.5). With the highest profitability (as a percent of sales or equity) of any industry considered in this study (Table 6.6), petroleum companies have also had little trouble in generating (or borrowing) the funds needed to finance capital expansion. While real investment growth has slacked off in recent years, investment levels are still impressive between 1973:4 and in 75:4 was expanded by an estimated 8 %, even while production was declining. Two recent Congressional actions - the removal of the depletion allowance and refusal to remove controls on "old" oil prices - will doubtless (as was the intention) have at least moderate negative effects on oil industry net income. Few observers outside the industry, however, believe that the companies will have any trouble generating cash flow or borrowing to meet future capital needs.²⁴

Industry Forecast (SIC 29)

As indicated in Table 6.11, the trend projection has industry demand rising sharply between 1975 and 1977, with capacity growth just keeping pace. By 1980, however, utilization rates have fallen below historical average rates, and capacity margins have begun to expand. Thereafter, declines in the growth rate of fuel consumption (caused by rising petro prices and conservation measures) are only partially offset by the expanding use of crude oil as a petrochemical feedstock (the latter due to the declining availability of natural gas liquids), and significant excess industry capacity begins to develop. The last decade is then one of capacity retrenchment, as the industry moves into a more mature phase. As indicated by the results of the Cycle simulation (Table 6.11), the industry production and capacity projections are not overly sensitive to relatively violent swings in the business cycle.

Potential Shortage Evaluation

Under the trend demand assumption, refined products should fall into the "No Shortage" category for all years. There are, however, several caveats. First, of course, this forecast is contingent upon the absence of an OPEC oil embargo. Second, if demand recovers at a slightly

Table 6.11

PETRO REFINING AND RELATED PRODUCTS (SIC29)

'TREND' Production, Capacity and Capacity Utilization

					Y	E	A	R									
	1973	1974	1975	1976	1977	1978	1979	1980	1985	1990							2000*
Production (1975 = 1.0)	1.02	1.00	1.00	1.07	1.10	1.16	1.19	1.23	1.38	1.65	-	-	-	-	-	-	2.02
Capacity (1975 = 1.0)	.93	.96	1.00	1.05	1.10	1.15	1.20	1.25	1.52	1.78	-	-	-	-	-	-	1.92
Capacity Utiliz. (%)	99	94	90	94	95	95	94	93	87	84	-	-	-	-	-	-	95
Capacity Margin (%)	-4	1	5	1	0	0	1	2	9	13	-	-	-	-	-	-	0

'TREND' Cumulative Real (1958 \$) Investment

			Y	E	A	R				
	1971-75	1976-80	1981-85	1986-1990	1991-2000*					
Gross	22.73	31.39	33.76	33.34	68.45					
Net	10.42	17.64	18.01	15.25	26.78					
Net Effective	9.27	17.31	17.42	14.64	26.00					

'CYCLE' Production and Capacity Utilization

			Y	E	A	R			
	1975	1976	1977	1978	1979	1980	1985	1990	
Production (1975 = 1.0)	1.00	1.07	1.10	1.16	1.19	1.23	1.39	1.65	
Capacity Utiliz. (%)	90	94	95	95	94	93	86	83	

* Production for the year 2000 is a function of GNP58. Corresponding capacity index indicates capacity required (not projected) to maintain indicated utilization rate. The latter has been set equal to its average historical (1958-75) level. Corresponding investment required between 1991-2000 is derived from 1986-90 marginal capital stock/capacity ratio.

faster pace over the 1976-78 interval, then utilization rates will be pushed above historical average rates, and certain refinery-produced liquefied petroleum gases may become short as capacity is converted to the production of higher priority products (i.e., gasoline). Third, projected raw steel shortages (see "Iron and Steel") in the late 1970s and thereafter could imply a shortage of the "Oil Country" steel products needed to effect expansion of refinery capacities. In general, however, we expect the petro refining industry to have sufficient capacity over the 1976-2000 interval to meet its fuel and petrochemical demands with comfortable margins.

- Chemicals and Allied Products (SIC 28)

Background

The industry consists of establishments primarily engaged in producing (1) basic (organic and inorganic) chemicals; (2) intermediate (synthetic fibers and elastomers, plastics, etc.) products that will undergo further processing; and (3) finished chemical products (fertilizers, drugs, cosmetics, paints, etc.). The basic organic and intermediate sectors, accounting for about two-thirds of industry dollar sales, contain most of the products of special interest to this study. Products in the latter categories have in common their dependence upon natural gas or crude oil as ultimate feedstocks.

As illustrated in Table 6.12, many of the top-20 basic chemical producers obtain less than half of their total revenue from chemicals. The major integrated oil companies (Exxon, Shell, etc.) have, in recent years, increased their market share, and this trend is expected to continue. The seven biggest primary chemical producers (DuPont, Dow, Union Carbide, Monsanto, W. R. Grace, Allied, and Celanese) compete with each other, the oil companies, and many other firms in thousands of product lines ranging from basic organic and inorganic chemicals to finished products. The "Big Seven" companies have, in recent years, been integrating backwards to oil and gas reserves in an effort to secure their hydrocarbon supply lines.²⁵

Table 6.12

TOP TWENTY BASIC CHEMICAL COMPANIES

(1974)

<u>Rank</u>	<u>Company</u>	<u>Chemical Sales</u> (\$ Millions)	<u>Chemical Sales as</u> <u>% of Total Sales</u>
1	Dupont	5400	78
2	Dow	4300	87
3	Union Carbide	3250	61
4	Monsanto	3110	89
5	Exxon	2787	7
6	Celanese	1726	90
7	W. R. Grace	1714	49
8	Occidental Petroleum	1580	29
9	Allied Chemical	1510	68
10	Hercules	1375	90
11	Shell Oil	1140	15
12	Phillips Petroleum	1046	21
13	American Cynamid	1035	58
14	Eastman Kodak	992	22
15	Rohm & Haas	980	96
16	F M C	949	46
17	Borden	942	29
18	Gulf Oil	895	5
19	Mobil Oil	871	5
20	Texaco	850	4

Source: Chemical & Engineering News, May 5, 1975, p. 33.

During the 1960s, domestic and foreign (the United States is a net exporter) demand for synthetics and their chemical building blocks (principally ethylene, benzene, propylene, styrene, and butadiene) grew at phenomenal rates. Capacity more than kept pace; with the result being overcapacity and declining returns on investment starting in the mid-1960s. Low profitability, coupled with dwindling availability of the natural gas liquids hitherto used as feedstocks for ethylene and other chemicals, then led to a reluctance to invest in new capacity during the early 70s. By late 1973, peak demands exceeded capacity for virtually all petrochemicals and rationing became necessary.²⁶ Plastics and resin materials were very short during late 1973 and early 1974 due to a lack of capacity and monomer (particularly ethylene and co-products) support. Synthetic rubber, while having sufficient capacity, lacked sufficient supplies of butadiene and styrene and, consequently, a shortage of synthetic rubber developed in late 1973 and lasted well into 1974. Price increases between the third quarter of 1973 and 74 averaged 50% for all chemicals and allied products, and profits improved dramatically.

The chemical industry has responded vigorously to the 1973-74 capacity shortage. Gross investment in basic chemicals and synthetics grew (in current dollars) by 62 % in 1974, 17% in 1975, and is expected to be up 23 % this year.²⁷ Further our econometric estimates indicate that capacity in SIC 28 expanded by 15 % between 1973:4 and 1975:4. This capacity expansion, coupled with declines in demand, left the industry with comfortable capacity margins going into 1976.

For the industry to continue to grow, however, the feedstock base must be shifted from natural gas liquids to petroleum-derived heavier feeds (naptha and gas oil). This shift in resource base, while currently underway, is being viewed with some trepidation by the industry because it involves sizable investment, more complex and capital-intensive operations, and some risks with respect to marketing strategy.²⁸

Industry Forecast (SIC 28)

Demand is expected to recover quickly and set a new record in 1976 (Table 6.13). Thereafter, however, annual growth rates are expected to be significantly lower than in past decades. Cumulative real net effective investment over the next five years will be higher than in the past five years. An increasing capital intensity, however, will make each additional real dollar of investment somewhat less effective in terms of raising capacity. Utilization rates will gradually rise over the 1976-85 era, but should not reach 'crunch' levels. A slowdown in the growth of demand during the post-1985 period should then push utilization rates below historical average levels. Overall, the trend forecast calls for more orderly growth and a better balance between supply and demand than has been the case during the past 20 years. The cycle simulation (Table 6.13) indicates that the long-range forecast is not extremely sensitive to plausible changes in the underlying macro assumptions. Nevertheless, should the current recovery be somewhat stronger than expected, then some strains in capacity could develop during the next two years. Current profitability and prospects for price increases indicate that the industry should not be strapped for capital funds.

Product Forecasts (Basic Chemicals)

Forecasts for the important chemicals used as raw materials by the synthetics of interest to this study are given in Table 6.14. The forecasting equations for chlorine (Eq. 1), ethylene (Eq. 2), and benzene (Eq. 3) are given in Appendix 6-C.

Chlorine: It takes .54 lbs of chlorine plus .46 lbs of ethylene to make one pound of vinyl chloride monomer. Commitments to chlorine capacity expansion have been fairly heavy and present announced capacity additions alone would keep operating rates below 90 % of rated capacity through 1977 and around 95 % by 1980.²⁹ Sufficient additional capacity should be derived through debottlenecking and "rounding out" operations between now and 1980 to keep operating rates well below 73-74 levels. The availability of electricity has become a crucial plant expansion and location factor in recent years.

Table 6.13

CHEMICALS AND ALLIED PRODUCTS (SIC28)

'TREND' Production, Capacity and Capacity Utilization

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>		<u>2000</u> [*]
Production (1975 = 1.0)	1.05	1.08	1.00	1.16	1.25	1.36	1.47	1.58	2.20	2.93	- - - - -	4.91
Capacity (1975 = 1.0)	.87	.93	1.00	1.07	1.14	1.23	1.31	1.39	1.86	2.53	- - - - -	4.27
Capacity Utiliz. (%)	97	93	80	87	87	88	89	90	94	92	- - - - -	92
Capacity Margin (%)	-06	-2	14	5	5	4	3	2	-2	0	- - - - -	0

'TREND' Cumulative Real (1958 \$) Investment

	<u>1971-75</u>	<u>1976-80</u>	<u>Y</u> <u>1981-85</u>	<u>E</u> <u>1986-90</u>	<u>A</u> <u>1991-2000</u> [*]
Gross	14.78	18.99	21.45	29.14	62.55
Net	8.35	10.97	11.40	16.84	32.10
Net Effective	7.42	10.10	10.54	16.05	30.60

'CYCLE' Production and Capacity Utilization

	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>
Production (1975 = 1.0)	1.00	1.13	1.13	1.22	1.37	1.48	2.27	2.77
Capacity Utiliz. (1975 = 1.0)	80	87	88	85	85	92	98	91

* Production for the year 2000 is a function of GNP58. Corresponding capacity index indicates capacity required (not projected) to maintain indicated utilization rate. The latter has been set equal to its average historical (1958-75) level. Corresponding investment required between 1991-2000 is derived from 1986-90 marginal capital stock/capacity ratio.

Table 6.14

BASIC CHEMICALS

<u>Chlorine</u>											
	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	1.15	1.18	1.00	1.21	1.37	1.46	1.57	1.68	2.34	2.90	- - - - 3.99
Capacity (1975 = 1.0):											
Required	.98	.98	1.00	1.12	1.26	1.35	1.44	1.55	2.15	2.65	- - - - 3.67
Announced	.98	.98	1.00	1.05	1.40	1.57					
Capacity Utiliz. (%)	97	99	83	95	81	77					

<u>Ethylene</u>											
	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	1.13	1.21	1.00	1.22	1.42	1.59	1.71	1.84	2.82	3.76	- - - - 5.39
Capacity (1975 = 1.0):											
Required	.97	.99	1.00	1.12	1.30	1.46	1.57	1.69	2.59	3.45	- - - - 4.94
Announced	.97	.99	1.00	1.20	1.31	1.44					
Capacity Utiliz. (%)	90	95	78	79	84	86					

<u>Benzene</u>											
	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	1.39	1.45	1.00	1.24	1.36	1.48	1.58	1.68	2.31	2.77	- - - - 3.82
Capacity (1975 = 1.0):											
Required	.97	.97	1.00	.82	.91	.98	1.05	1.11	1.54	1.84	- - - - 2.54
Announced	.97	.97	1.00	-	-	-					
Capacity Utiliz. (%)	81	84	56	70	77	83					

Ethylene: This chemical is the most important of the building blocks and finds its way directly or indirectly into virtually all synthetics. It is especially critical to the production of polyethylene, polyvinyl chloride, polystyrene, and phenolics. Demand between 1975 and 1980 is expected to increase by 84%, and capacity requirements (based on an 85% target operating rate) by 69 %. Announced expansions (as of May 1976) add up to about 60 % over the same period.³⁰ These figures, however, do not include anticipated expansions from joint ventures now under consideration by Monsanto and Continental Oil, and Union Carbide, Société Financière Européenne, or from a number of plants in the feasibility stage.³¹ Add to this a conservative 5 % capacity expansion between 75-80 attributed to debottlenecking, and utilization rates should stay within the 85-90 % (i. e., far below the 1974 utilization rate of 94 %).

Much of the new ethylene capacity will be using the heavier feeds (naptha or gas oil). Both propylene and butadiene will be produced as co-products in very substantial quantities. Propylene can be upgraded from refinery to chemical grade, or to polymer grade (i.e., suitable for polypropylene), depending primarily on the price advantage of propylene vis-à-vis ethylene. Given that it takes a pound of propylene to make a pound of polypropylene, our forecast of the latter's growth rate indicates that the demand for polymer-grade propylene will more than double between now and 1979. Current announcements (as of February 1976) indicate at least a 70% expansion in polymer grade capacity.³² This does not include a projected debottlenecking effort by Exxon that would quadruple its Baytown, Texas plant's capacity.³³ All told, monomer support for polypropylene should be just about adequate over the next five years. Given the slowdown in demand projected for synthetic rubber, the long-run outlook for butadiene is one of excess supply.³⁴ The current (1976) butadiene capacity includes three billion pounds of devoted refinery capacity and anywhere from 1.5 to three million pounds that could be co-produced at olefin plants (depending on plant design, feedstock mix, and operating rates).³⁵ Projected requirements through 1977 could probably be satisfied without expanding current butadiene capacity.

Benzene: This aromatic is produced primarily (70%) by the oil refineries, and finds its major end uses (via styrene, cumene/phenol, and cyclohexane) in a variety of plastics, fabrics and rubber products. The United States has been a net importer of benzene since 1971. The supply of this aromatic is, to a great extent, dependent upon its price relative to the price of the toluene used in the hydrodealkylation process. If the benzene price is less than 25% higher, it may be more profitable to use toluene as a high octane gasoline blending component.³⁶ The present (end of 75) capacity of 1,850 million gallons would be adequate, under our forecast, to meet demands through 1979 without additional plant capacity. Projections of an additional 10-14% capacity expansions by 1978 would indicate that benzene will be in ample supply for the remainder of the decade.³⁷

Product Forecasts (Plastics and Resin Materials)

Forecasts for the various resins are given in Table 6.15. The econometric equations for polyethylene (Eq. 4), polypropylene (Eq. 5), polyvinyl chloride (Eq. 6), and phenolic resins (Eq. 7) are given in Appendix 6-C. Post-1980 forecasts generated by these equations have been modified to incorporate substitutions and innovations projected by industry sources.³⁸ The major end-markets for resins (in approximate order of importance) are packaging, construction, houseware, electrical, transportation, and appliances.

Polyethylene (low and high density): Demand for this important polymer is expected to nearly double between 1975-1980. Thereafter, its uses will continue to grow in wire and cable, extrusion coatings, and in various household products (trash bags, etc.) at a rate only slightly below historical (1965-75 levels). The substantial price increases of the 1973-74 era held up well during the recession, and the industry expects further increases during the next two years. Capacity will have to expand 62 % over 1975 levels if a target utilization rate of 85 % is to be achieved in 1980. Announced plant expansions of 26 % by 1977 would put utilization rates around 90% in the latter year; still far below 1973-74 crunch levels, but doubtless corresponding to extended delivery times.³⁹ Thereafter, plant expansions currently

Table 6.15

PLASTICS AND RESIN MATERIAL

Polyethylene

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	1.17	1.23	1.00	1.30	1.54	1.75	1.85	1.97	2.87	3.66	- - - - 5.42
Capacity (1975 = 1.0):											
Required	.88	.94	1.00	1.07	1.27	1.44	1.52	1.62	2.36	3.01	- - - - 4.46
Announced	.88	.94	1.00	1.10	1.26	1.31					
Capacity Utiliz. (%)	97	95	73	86	91	95					

Polypropylene

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	1.14	1.18	1.00	1.37	1.65	2.13	2.78	3.05	5.70	8.09	- - - - 17.87
Capacity (1975 = 1.0):											
Required	.74	.84	1.00	1.03	1.23	1.60	2.08	2.48	4.28	6.07	- - - - 13.41
Announced	.74	.84	1.00	1.10	1.23	1.56					
Capacity Utiliz. (%)	103	93	67	83	89	95					

Polyvinyl Chloride

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	1.25	1.33	1.00	1.38	1.52	1.66	1.84	2.03	3.19	4.59	- - - - 6.18
Capacity (1975 = 1.0):											
Required			1.00	.90	.99	1.08	1.19	1.32	2.07	2.99	- - - - 4.02
Announced			1.00	1.00	1.05	1.05					
Capacity Utiliz. (%)	95	91	59	76	80	87					

Table 6.15 (continued)

	<u>Phenolic</u>								<u>1985</u>	<u>1990</u>	<u>2000</u>
	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>			
Production (1975 = 1.0)	1.32	1.27	1.00	1.22	1.33	1.40	1.49	1.58	2.08	2.53 - - - -	3.81
Capacity (1975 = 1.0):											
Required	.91	.91	1.00	.86	.94	.99	1.05	1.11	1.46	1.78 - - - -	2.68
Announced	.91	.91	1.00	-	-	-					
Capacity Utiliz. (%)	87	84	60	73	79	84					

in the planning stage and debottlenecking should add sufficient capacity to keep operating rates in the comfortable 85-90 % range. Monomer support (ethylene), as noted earlier, is considered adequate over the forecast interval.

Polypropylene: Demand for this resin in 1980 will exceed 1975 levels by a factor of three. By the year 2000, polypropylene will have displaced low-density polyethylene as the highest volume resin. This growth rate is predicated upon the large supplies of propylene that will be extracted as a co-product from the new (heavier feed) ethylene plants, and the consequent price advantage that will accrue to polypropylene vis-à-vis polyethylene and styrene. Given announced expansion (and a 100 million pound debottlenecking effort scheduled to be completed by 1977), capacity might be just adequate through 1977, but will almost certainly fall far behind the 248% expansion required by 1980.⁴⁰ In the following decade, however, demand growth slows down and capacity will have a chance to catch up.

Polyvinyl Chloride: EPA restrictions will severely curtail the use of PVC in food-related markets. This loss, however, will be more than compensated for by rapidly increasing consumption of PVC by the construction-related industries. PVC plants were operating at 50 % capacity through most of 1975, and, while demand is expected to make healthy gains, the current capacity margins, plus announced expansions, should keep PVC operating rates around the 85% target range for the remainder of the decade.⁴¹ Vinyl chloride monomer support, however, is likely to impose a constraint on PVC production by 1977. Currently, only one new VCM plant has been announced (to start up in late 1976), and it probably won't add significantly to capacity until late in 1977.⁴² Current EPA emission standards are being met. There is industry concern, however, over the escalating cost of compliance and, while the dire predictions as to mass plant shutdowns made at the inception of EPA standards have not materialized, the uncertainty about future standards (and their costs) is probably inhibiting investment.

Phenolic Resins (including molding compounds): Historically, phenolic sales have been concentrated in the construction-related markets. Future growth in phenolic consumption, however, is likely to be highest on the automotive and appliance markets. Total demand for phenolics will grow very moderately relative to the other resins, and current capacity should be adequate out to 1979. No expansions have been announced and, given present overcapacity, very few plant additions can be expected during the remainder of the decade. Phenol and its benzene precursor should also be in adequate supply.

Other Resins: The styrenics are expected to grow at about the same rate as PVC over the next 25 years, and their prices are expected to outpace all other resin prices. Domestic capacity has increased by more than 40% since 1971, and industry sources see few supply problems ahead.⁴³ Demand growth for the epoxy resins has slowed in the past five years and current capacity should be adequate through 1977. The outlook is less certain for the fast-growing, unsaturated polyesters. Sales of the latter product should reach 1973 levels this year. Current capacity margins, plus announced expansions of both polyester and maleic anhydride (the former's petrochemical precursor) plant capacity, however, should prevent severe shortages from developing during the next two years.⁴⁴ EPA standards and energy problems have forced the shutdown of several sodium carbonate plants (according to the BOM), and this, coupled with inadequate growth in methane supply, could constrain supplies of silicone resins.

Product Forecasts (Synthetic Rubber)

The forecast for synthetic rubber is given in Table 6.16. The econometric equation (Eq. 8) used to generate this forecast can be found in Appendix 6-C. The forecast generated by this equation has been modified to incorporate the growing negative impact that radial tires are having on the tire replacement market.⁴⁵ The products included in this group consist of styrene-butadiene rubber (SBR), polybutadiene, butyl, polyisoprene, ethylene-propylene rubber, neoprene, nitrile, and other minor products. SBR accounts for about 50% of sales on a tonnage basis.

Table 6.16

ALLIED CHEMICAL PRODUCTS

Synthetic Rubber

		<u>Y E A R</u>											
		<u>73</u>	<u>74</u>	<u>75</u>	<u>76</u>	<u>77</u>	<u>78</u>	<u>79</u>	<u>80</u>	<u>85</u>	<u>90</u>	---	<u>2000</u>
Production (1975 = 1.0)													
		1.35	1.30	1.00	1.28	1.35	1.41	1.45	1.50	1.75	2.00		2.44
Capacity (1975 = 1.0)													
Required	NA	1.00	1.00	.95	1.00	1.05	1.08	1.11	1.30	1.48			1.81
Announced	NA	1.00	1.00	-	-	-							
Capacity Utiliz. (%)													
	NA	87	67	85	90	94							

Paints (SIC 285)*

													<u>Y E A R</u>											
													<u>73</u>	<u>74</u>	<u>75</u>	<u>76</u>	<u>77</u>	<u>78</u>	<u>79</u>	<u>80</u>	<u>85</u>	<u>90</u>	---	<u>2000</u>
Production (1975 = 1.0)													1.00	1.06	1.00	1.19	1.24	1.24	1.24	1.25	1.45	1.58		1.83

*Data Resources, Inc. projection from 1975-90; thereafter the series is extrapolated.

As of 1974, about 56% of all synthetic rubber sales were related to the auto market. The remaining 44% went into such products as belts, hoses, sponge products, and wire and cable.⁴⁶ Growth in consumption of synthetic rubber (SR) has been moderate (5% per year) over the past ten years. Increasing competition from natural rubber and the depressing effect that the longer-lasting radials are having on the replacement tire market have (and will continue to) restrain demand for SBR and other synthetic rubber products that depend on the auto market.

Inadequate supplies of styrene and butadiene, rather than capacity, were the binding constraints on SR production during 1973 and early 1974. As noted earlier, these petrochemicals should be in adequate supply over the forecast period. The forecasted SR demand through 1980 is a little on the high side of that expected by the Rubber Manufacturers Association.⁴⁷ Even so, current capacity could handle projected 1979 production, and no SR industry observer has suggested the possibility of a capacity shortage in the foreseeable future.

Product Forecasts (Miscellaneous Chemicals and Allied Products)

Monsanto, the only U. S. producer of polychlorinated biphenyls (PCBs) has announced that it will stop making PCB "eventually."⁴⁸ Pressure is growing for a complete ban on their use in capacitors, transformers, lubricating fluids, and 'carbonless' carbon paper. DRI's demand forecast for Paints, Varnishes, and Allied Products (Table 6.16) indicates that 1980 demand for these products will only be 19% higher than 1975 levels. Capacity for this amorphous collection of products is impossible to ascertain, but several plant expansions, including additions to DeSoto's Garland, Texas coating plant⁴⁹ and expansion of lucite production capacity at a Parkersburg, West Virginia plant,⁵⁰ are scheduled for completion this year. Zinc phosphate, a very specialized adhesion-promoting material, is expected to experience fairly rapid demand growth and may be constrained by inadequate supplies of zinc oxide (see "Primary Nonferrous Metals: Zinc"). The ready availability of iron phosphate as a substitute, however, should prevent serious problems from developing for zinc phosphate users.

Silicon carbide, boric acid, and copper salts all appear to have adequate resource bases, and no capacity problems have been reported. Sodium fluoride processing capacity is reported to be adequate, but domestic production of fluorspar at 15 mines has been declining for five years. U. S. fluorine consumers, however, have traditionally been dependent on imports (81% of consumption according to the BOM), and world supplies are considered adequate. Alumina and beryllium users are import dependent. Supply lines are stable, however, and forecasted demand growth is moderate (2% a year to 1980, according to the BOM).

Potential Shortage Evaluation

1976-80: Polypropylene, polyvinyl chloride (PVC), and polychlorinated biphenyls (PCBs) fall into the "shortage" category between 1977-80. No shortages are expected in 1976. Zinc phosphate (1976-80), insulating oil (76-80, due to history of transitory shortages for this low-profit, specialized product), polyethylene, polyester, epoxy, silicon, and chlorosulfanated polyethylene (CH, RSLF) resins fall into the "marginal" category (1977-78). All other SIC 28 products, as indicated in Table 6.3, fall into the "no shortage" category.

1981-85: Polypropylene and PVC fall back to "marginal." All other resins except silicones (which stay in the "marginal" category) fall back to "no shortage." All other products maintain their 1976-80 ratings.

1986-90: Polypropylene falls back to "no shortage." All other products maintain their 1981-85 ratings. Thus, only PCB (scheduled to eventually go out of existence by EPA fiat) remains in the "shortage" category over the entire (1976-2000) forecast interval.

- Lumber (SIC 24)

Background

Five categories of products may be derived from harvested timber: (1) structural wood, (2) fiber products (pulp, paper, etc.), (3) extractive materials (oils, drugs, etc.), (4) chemicals from woody tissue, and (5) energy. Presently, 63% of all U. S. raw wood production

is converted into structural wood products, 35% into fiber products, and the rest into products contained in the remaining three categories.⁵¹

This section is concerned primarily with the first category (structural wood products), but covers also the cutting of pulpwood timber. The major industry group is SIC 24 which includes: (a) logging camps, (b) sawmills and planing mills, (c) millwork, veneer, plywood, and prefabricated structural wood products, (d) wooden containers, (e) wood preserving, and (f) a small "miscellaneous" category.

Category E (wood preserving) contains the utility poles and crossarm products of special interest to this study. Processing at this stage is quite simple, consisting primarily of bark removal and impregnation with preservative chemicals. The major portion of raw timber supplies, however, is sawed or shaped into lumber, or fabricated into veneer, particles, flakes, strands, or fibers for still further processing into plywood and similar products. The ultimate end-market for most lumber and plywood is the residential and nonresidential (particularly the former) construction industries.

Most (over 80%) lumber products used today are made from softwood timber. The market for softwood lumber is extremely competitive; with about 7300 sawmills being operated by approximately 1000 companies (the top 100 of which account for only 60 percent of output).⁵² Dependence on the residential construction market makes the demand and the price for softwood lumber quite volatile.

Traditionally, softwood timber has also been preferred for pulpwood. Technological improvements in pulping, however, have, in recent decades, stimulated increasing use of hardwoods and (given the favorable supply outlook for hardwoods relative to softwoods) this trend is likely to continue.⁵³ The demand for pulpwood is, of course, primarily a function of the demand for woodpulp by paper manufacturers and is considerably less cyclical than lumber demand. Spruce and pine, because of their uniform long fibers and purity, are the preferred softwoods for making the pulp used in electrical-grade paper. Interviews with industry

experts indicate, however, that the species of tree is not of great importance; the pulp process can be modified (at some cost) to accomodate any tree.⁵⁴

Acute shortages of virtually all softwood (and, to a much lesser extent, hardwood) timber products occurred in 1972-73.⁵⁵ Superficially, these shortages resulted primarily from an unanticipated spurt in housing construction that quickly depleted available stocks of softwood lumber. Supply-side constraints, however, were structural rather than transitory, and deserve further comment. First, despite large potential forest reserves, poor utilization has resulted in the United States being a net importer (average: 11% of consumption) of all forest products since 1914. The largest import item is Douglas fir from Canada and, as one observer has noted: "The United States is currently so dependent upon Canada ... that any major restriction in price or volume could create a major materials supply problem for this country."⁵⁶ During peak demand periods, such as 1973, imports can account for almost one-quarter of softwood lumber consumption.

Secondly, the U. S. transportation system results in certain supply anomalies. The West Coast is, for example, a net exporter of logs (primarily to Japan), while the East Coast is a net importer of lumber and pulp products. This situation results from an antiquated U. S. rail system that discourages long-haul transport and from the Jones Act; which requires that ships carrying goods between U. S. ports fly the U. S. flag.⁵⁷ During 1973, a shortage of rail boxcars contributed significantly to regional shortages.⁵⁸

Finally, and most important, inadequate management and a new interpretation of the "multiple-use" doctrine have greatly restricted the amount of harvestable timber on the 18% of domestic commercial forest land that is located in our national forests and parks.⁵⁹ Overmature inventories and slow reforestation have reduced yields from U. S. national forests and, in general, Federal forest management appears inferior to that practiced in Scandanavian countries. A potentially more severe

constraint on future supply lies in the current propensity to give higher priority to nontimber uses of the national forests. If certain restrictions on timber cutting now being applied in eastern forests are extended to the western states, the U. S. national forest lands could cease, for all practical purposes, to be significant timber suppliers.⁶⁰

Industry Forecast (SIC 24)

Table 6.17 presents the industry demand forecast and repeats Task 3 forecasts for wood preserving (poles, crossarms) products. The aforementioned industry projection implies that domestic lumber production would have to increase by a factor of 2.6 from 1975 to the year 2000. Using a lumber demand forecast that is somewhat lower, the Forest Service has calculated that, with 1970 levels of forest management, an equating of supply and demand for saw timber over the same time interval would require substantial increases in the price of lumber relative to the general price level, and that these price increases would induce a substantial increase in net imports as a percent of consumption.⁶¹ Recent land use trends make it even more likely that net imports will have to satisfy an increasing share of timber requirements. On the positive side, new techniques for substituting hardwood for softwood in the production of certain pulp-paper and structural plywood products hold forth promise that better use will be made of the world's current excess supply of hardwood timber. As illustrated by the cycle forecast in Table 6.17, the lumber industry is sensitive to the business cycle. A conclusion of approximate supply-demand balance under a steady growth (trend) demand forecast implies, therefore, a high probability that acute but transitory and regional shortages will continue to materialize whenever short-run demand deviates sharply from its long-run growth path.

Product Forecast (Wood Preserving)

Future pole and crossarm production will be primarily for the replacement market. Alternative pole materials (flyash, concrete) have only limited regional applications and are not expected to be supplying

Table 6.17

LUMBER (SIC 24) AND WOOD PRESERVING (SIC 2491)

'TREND' Production for SIC 24

	<u>Y e a r</u>											
	<u>73</u>	<u>74</u>	<u>75</u>	<u>76</u>	<u>77</u>	<u>78</u>	<u>79</u>	<u>80</u>	<u>85</u>	<u>90</u>	...	<u>2000</u>
Production (1975 = 1.0)	1.17	1.10	1.00	1.15	1.22	1.27	1.30	1.33	1.70	1.91	...	2.55

'CYCLE' Production for SIC 24

Production (1975 = 1.0)	1.17	1.10	1.00	1.14	1.09	1.13	1.27	1.27	1.72	1.88	...	-
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BASE CASE FORECAST FOR
POLES AND CROSSARMS

Production (1975 = 1.0)	-	-	1.00	1.00	1.01	1.01	1.02	1.02	1.04	1.06	...	1.07
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a substantial percent of future national distribution system requirements. Demand for wood pole and crossarms will, therefore, increase, but at a very slow rate. These products are generally supplied by very small, local operations whose profitability is intimately related to market (price) conditions over which they have little control. Data from the Annual Survey of Manufacturers indicate that gross investment by firms primary to the wood preserving (SIC 2491) rose substantially in the late 60s and then stayed at these high levels through 1973 (the latest information available).⁶² Past constraints on production have been very transitory and related to poor timber harvesting conditions and transportation problems. Future peak timber demand periods are likely to produce similar transitory and localized tight markets, but the long-term national availability of these products is fairly secure.

Potential Shortage Evaluation

Under the assumptions of steady demand growth, ideal harvesting weather, adequate transportation facilities, current forest management expertise, and secure foreign supply lines, lumber and pumpwood supplies would be just adequate over the forecast period. Transitory deviations from these ideal conditions, however, are almost certain to occur. Consequently, the various lumber products required by the distribution system have been placed in the "marginal" category over the entire forecast period (Table 6.3).

- Paper and Allied Products (SIC 26)

Background

This industry includes pulp mills, paper mills, paperboard mills, converted paper products, paperboard containers and boxes, and building board mills. Although printing and writing paper is the most important product, the industry also produces a wide variety of other fibrous products (including the electrical-grade paper, vulcanized fiber, strings, and wood flour fillers of interest to the distribution equipment manufacturers) from pulp and recycled fibers. The bulk of the industry is

presently comprised of 350 companies operating 750 paper mills, with the top 18 firms controlling about 50% of the market.⁶³ Net imports of paper and paperboard products have constituted a fairly stable 8% of (apparent) consumption in recent years, and this percentage is expected to hold in the future.

The major paper companies, such as Hammerhill, Weyerhaeuser, Georgia-Pacific, and International Paper are integrated to pulp mills, and most have sizable timber holdings. The United States has been a net exporter of pulpwood and recent years have witnessed a sharp increase in exports (primarily to Japan). At the same time, however, market (purchased) pulp has constituted better than 20% of U. S. bleached paper pulp consumption, and more than 50% of this market pulp has been imported from Canada. Moreover, concerns over future world timber availability have caused paper companies to seek guaranteed fiber supply before building a new pulp mill.⁶⁴ The trend in pulp processing, however, toward greater utilization of the ample world supplies of hardwoods, and the gleaning of higher yields from lower quality pulps, promises, on balance, to make the paper industry somewhat less vulnerable to the vagaries of the softwood pulp market.

The pulp and paper industry consumes large quantities of energy, but is not particularly energy intensive (in terms of energy-per-ton-of-product) relative to other large energy consumers (aluminum, glass, and plastics, for example). Moreover, the industry now supplies more than 40 % of its total energy requirements from its own process wastes, and its energy conservation will continue to improve.⁶⁵ Bleached pulp mills with new chemical recovery systems can, for example, provide better than 80% of their energy needs and recover virtually all chemicals from their waste.⁶⁶ Some of these energy-efficiency gains have been associated with the industry's large expenditures on pollution abatement. The industry is apparently in compliance with current EPA pollution standards and, unless these standards are significantly elevated (a distinct possibility), real net investment in abatement equipment

over the next five years should be substantially less than in the previous five years.

The pulp and paper mills were operating at capacity during 1973 in response to what, in retrospect, appears to have been a combination of an artificial build-up of customer inventories during price controls, a "legitimate" peaking of world demand, and panic hoarding.⁶⁷ Those paper mills not integrated to on-site pulp mills also were constrained by a shortage of bleached pulp, which, in turn, resulted from a combination of capacity constraints, short supplies of bleaching chemicals (caustic soda and chlorine), and rail strikes.⁶⁸

Both prices and profits took great leaps forward during the shortage, and net investment held up well during the subsequent recession. Capacity is estimated to have expanded by 9% between the fourth quarters of 1973 and 1975, and this, coupled with lower production levels, left the paper industry with a sizable capacity margin going into 1976.

Industry Forecast (SIC 26)

The trend forecast has production recovering its 1974 level by 1977 (Table 6.18). These projections are, however, sensitive to the assumed GNP growth rate, and early 1976 data indicate that the industry is recovering at a somewhat faster rate. Even so, capacity expansions (primarily in the form of addition and modifications of existing plant) should be sufficient to keep operating rates below their historical average for the next three to four years. Operating rates will move above the historical average level for a year or two in the early 1980s, but will not reach the crunch levels of 1973. Thereafter, capacity expansion, responding to demand growth in the late 70s, will begin to outpace production and utilization rates will again fall below their average historical level.

Given the aforementioned projections concerning closer ties between pulp mills and fiber support, better utilization of pulp waste and hardwood reserves, and forecasted availability of chlorine (see "Chemicals") and caustic soda,⁶⁹ the industry should not be severely constrained by raw materials or energy.

Table 6.18

PAPER AND PRODUCTS (SIC26)

'TREND' Production, Capacity and Capacity Utilization

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u> [*]
Production (1975 = 1.0)	1.21	1.19	1.00	1.13	1.20	1.32	1.46	1.58	2.08	2.23 - - - - -	2.75
Capacity (1975 = 1.0)	.92	.96	1.00	1.05	1.11	1.16	1.23	1.32	1.85	2.12 - - - - -	2.34
Capacity Utiliz. (%)	99	94	78	84	84	88	93	95	85	83 - - - - -	92
Capacity Margin (%)	-7	-2	18	10	10	5	-1	-3	8	11 - - - - -	0

'TREND' Cumulative Real (1958 \$) Investment

	<u>1971-75</u>	<u>1976-80</u>	<u>Y</u> <u>1981-85</u>	<u>E</u> <u>1986-90</u>	<u>A</u> <u>1991-2000</u> [*]
Gross	6.19	9.89	14.64	10.06	22.91
Net	3.81	6.77	10.78	5.30	10.80
Net Effective	2.88	6.34	10.34	4.87	10.00

'CYCLE' Production and Capacity Utilization

	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>
Production (1975 = 1.0)	1.00	1.15	1.19	1.29	1.46	1.57	2.08	2.20
Capacity Utiliz. (%)	78	84	82	85	92	94	87	81

* Production for the year 2000 is a function of GNP58. Corresponding capacity index indicates capacity required (not projected) to maintain indicated utilization rate. The latter has been set equal to its average historical (1958-75) level. Corresponding investment required between 1991-2000 is derived from 1986-90 marginal capital stock/capacity ratio.

Product Forecast (Electrical-grade Paper)

Electrical paper is made from northern softwood, unbleached sulfate pulp, and used in capacitors, transformers, and cables.⁷⁰ Pulp in this product is supplied primarily by one Canadian pulp mill and one Swedish mill. The pulp is generally produced from spruce and pine because they possess the desired uniform long fibers and purity. As noted earlier, however, (see "Lumber") the pulp process can be modified, at some cost, to accommodate other species of trees.

The paper is very specialized, and demand for the product will increase faster than the demand for total paper products (see Table 6.18). Similarly, prices for electrical paper should rise at least as fast as the average of all other paper prices. Given projected capacity for the paper industry and the prospect for continuing high returns in the industry, therefore, this paper should not be in serious short supply in future years.

Potential Shortage Evaluation

All paper and wood fiber products consumed by the distribution system equipment manufacturers have been placed in the "No Shortage" category over the entire forecast period (Table 6.3).

- Stone, Clay, Glass, and Concrete Products (SIC 32)

Background

This industry includes establishments primarily engaged in the production of cement, concrete, structural clay products, glass, and other non-metallic mineral products made principally from stone, clay, and sand. Products of special interest to this study include portland cement, specialty porcelain, and various glass products. Cement, concrete, and glass products account for about 70 % of this industry's value-added, and also dominate the industry's investment statistics. These latter products are characterized by relatively low-technology production processes that consume large amounts of energy per unit of output.

The cement industry consists of one state-controlled firm and 57 private companies operating 175 plants, with the ten largest companies accounting for 47 % of 1975 clinker production capacity (BOM estimates). About 66 % of cement production is used as a binding agent in ready-mix concrete; the remainder is for similar purposes in block and precast concrete products. Portland cement typically accounts for 85 % of total cement produced and is manufactured by 164 plants having an annual capacity (1975) of 99.5 million tons. Net imports have averaged about 7 % of domestic (apparent) consumption in recent years, with Canada supplying more than 40 percent of total imports.

Demand for portland cement, which follows the construction cycle, began to rise sharply in 1972, and when it peaked in 1973, the industry was operating at 98 % of rated capacity (as opposed to an average operating rate of 75 % during the 1960s). Regional shortages, particularly in the Southeast, were acute and imports increased dramatically. Since 1973, however, capacity has expanded by 19 % (in response to improved earnings) and operating rates dropped below 70 % during 1975. The industry has made substantial progress in shifting from natural gas to coal, but is still vulnerable to natural gas curtailments.

The glass industry is broadly sub-divided into the flat glass (SIC 3211) and the pressed and blown glass (SIC 3229) sectors. The former produces principally for the auto and housing markets, while the latter is oriented toward the food container market. The latter sector also produces the glass products of primary interest to this study (glass meter covers, and various glass fibers and fillers used as high temperature insulation or as filler and reinforcement for plastics).

Glass (in the form of beads, bubbles, flakes, and other forms, excluding fiber) is used as a plastic filler (along with many potential substitutes) and (in its fiber form) is the favorite reinforcement material for plastic products. The advent of injection molding of reinforced thermoset resins and the desire to cut processing costs and improve the performance of the various plastics has created a new and expanding market for glass fillers and reinforcement material. PPG Industries and Owens-

Corning Fiberglas appear to be the major glass filler and fiber producers for the plastics market, but no information is available on precise market shares. Glass used in meter covers can be produced by any of the primary pressed and blown glass plants.

Growth in primary pressed and blown glass consumption has been moderate (about four percent a year) over the past three decades and has slowed down considerably during the past five years due, primarily, to increased competition from plastics and aluminum in the containers market. Natural gas shortages have periodically cut production at various plants, and transitory shortages of certain specialty containers (particularly canning jars) have occurred, but there is no evidence to suggest that primary glass capacity has been severely tested in recent years.

Unprecedented resin demand, by contrast, placed strong demands on glass fiber capacity during 1973, and natural gas shortages joined with capacity to impose constraints on the supply of glass fibers. Shipments of glass reinforcement material have dropped at least 15 %, and several new fiber plants have come on-line since 1973.⁷¹

Specialty porcelain used in the electrical distribution system is a small but distinct sub-sector of the total ceramics industry. The two major electrical equipment manufacturers (General Electric and Westinghouse) have captive plants that supply the various porcelain pieces used in transformers, lightning arresters, insulators, fuses, and various other electrical products. Industry sources indicate that most production lines were operating at maximum practical capacity in 1973, when an estimated 45 thousand tons of specialty porcelain were consumed in the production of distribution equipment.⁷² Since then, only one minor brick and mortar plant expansion (by McGraw-Edison) has taken place. Some (unspecified) additional capacity, however, has been achieved through technical improvements in the processing of several porcelain products.⁷³ Production declined so quickly after 1973 that most lines were operating at less than 50 % capacity by the middle of 1975; with an average estimated utilization rate of .62 % for the year.

Industry Forecast (SIC 32)

A forecasted 13 percent increase in SIC 32 production during 1976 (Table 6.19), coupled with a mere one percent increase in capacity, will eliminate most of the 1975 excess capacity. Thereafter, demand grows slowly, but capacity expansion is even slower and operating rates stay above historical levels for the remainder of the forecast interval. The industry's capital intensity, already high, is expected to increase, while annual net real investment stays virtually constant. Construction and/or auto activity substantially above (and below) the trend forecast for any period after 1976 will lead to substantial deviation from the trend SIC 32 forecast (see the cycle forecast in Table 6.19), and capacity margins in the latter industry will be insufficient to handle such variability.

Product Forecast (Portland Cement)

The forecast of portland cement shipments is given in Table 6.20. The econometric equation (Eq. 9) used to generate this forecast specifies shipments (in short tons) as a function of real investment in construction and a time trend, and is located in Appendix 6-C. Portland cement shipments (used as a proxy for production) under the trend projection are not expected to get back to 1973 levels until 1981. Given present capacity, plus a planned expansion of three percent over the next three years,⁷⁴ there should be ample national cement capacity for the remainder of the decade. The upper limit on the standard forecast error for construction activity, however, is high enough to allow for the possibility of cement demand reaching its previous peak as early as 1977. Moreover, markets for cement are localized and future natural gas shortages will continue to cause transitory and regionalized tight markets for cement and concrete. Future expansion may well be contingent upon receiving guarantees of sufficient energy.

Product Forecast (Glass)

A forecast of the FRB production index for "Pressed and Blown Glass" (SIC 322) is given in Table 6.20. The equation (Eq. 10) used to generate this forecast is in Appendix 6-C. Pressed glass production, on

Table 6.19

STONE, CLAY, GLASS, AND CONCRETE (SIC32)

'TREND' Production, Capacity and Capacity Utilization

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>Y</u> <u>1976</u>	<u>E</u> <u>1977</u>	<u>A</u> <u>1978</u>	<u>R</u> <u>1979</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>		<u>2000</u> [*]
Production (1975 = 1.0)	1.19	1.16	1.00	1.13	1.21	1.23	1.25	1.25	1.44	1.53	- - - -	2.01
Capacity (1975 = 1.0)	.97	.99	1.00	1.01	1.03	1.05	1.07	1.10	1.18	1.23	- - - -	1.79
Capacity Utiliz. (%)	99	93	79	88	93	93	92	90	97	97	- - - -	89
Capacity Margin (%)	-10	-4	13	1	-4	-4	-3	-1	-8	-8	- - - -	0

'TREND' Cumulative Real (1958 \$) Investment

	<u>1971-75</u>	<u>Y</u> <u>1976-80</u>	<u>E</u> <u>1981-85</u>	<u>R</u> <u>1986-90</u>	<u>1991-2000</u> [*]
Gross	4.19	4.91	5.06	5.12	11.98
Net	2.17	2.56	2.40	2.18	6.23
Net Effective	1.83	2.39	2.27	2.09	5.42

'CYCLE' Production and Capacity Utilization

	<u>1975</u>	<u>Y</u> <u>1976</u>	<u>E</u> <u>1977</u>	<u>A</u> <u>1978</u>	<u>R</u> <u>1979</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>
Production (1975 = 1.0)	1.00	1.12	1.09	1.08	1.19	1.18	1.47	1.42
Capacity Utiliz. (%)	79	87	84	84	91	90	100	94

* See Table 6.11, footnote.

Table 6.20

CEMENT, GLASS AND PORCELAIN PRODUCTS

Portland Cement

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	1.27	1.14	1.00	1.13	1.18	1.22	1.26	1.27	1.48	1.60 - - - -	2.02
Capacity (1975 = 1.0):											
Required	.84	.95	1.00	.91	.95	.98	1.01	1.01	1.19	1.29 - - - -	1.63
Announced	.84	.95	1.00	1.00	1.00	1.03					
Capacity Utiliz. (%)	98	82	69	77	81	81					

Pressed and Blown Glass (SIC322)

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	.96	1.00	1.00	1.08	1.12	1.16	1.21	1.25	1.57	1.82 - - - -	2.10

Glass Fiber

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Consumption (1975 = 1.0)	1.27	1.17	1.00	1.15	1.31	1.47	1.64	1.80	2.62	3.45 - - - -	5.18

Specialty Porcelain

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Consumption (1975 = 1.0)	1.61	1.60	1.00	1.12	1.24	1.36	1.48	1.62	1.91	1.95 - - - -	2.11

a plateau for the past three years, is projected to increase by 25 between 1975 and 1980. Growth will be orderly and is not expected to strain primary glass production capacity.⁷⁵ The glass industry, however, is still susceptible to gas and oil curtailments and periodic plant shut-downs due to inadequate fuel supplies can be expected to cause transitory delivery delays.

A forecast of glass fiber consumption in plastics (Table 6.20) has been derived from our resin forecast (see "Chemicals and Allied Products") and outside forecasts of future trends in the production of reinforced plastics.⁷⁶ Consumption of glass fiber in reinforced plastics should reach 1974 levels by 1977 and peak 1973 levels by 1978. Glass fiber prices held up well during 1975, and the industry expects earnings from these products to continue to improve. There have been several announced expansions of glass fiber plants in the past two years, but at least one company expects the market to be tight by 1977.⁷⁷

The consumption of glass fillers can also be expected to increase. Since, however, glass is just one of many conceivable plastic filler materials, shortages of glass filler would not impose a constraint on plastics production. Consequently, no explicit forecast of glass filler material is given. We do, however, expect the various glass beads, flakes, and spheres to be generally available.

Product Forecast (Specialty Porcelain)

The forecast of porcelain consumption in electrical equipment (Table 6.20) has been taken (unaltered) from Task 3. The captive porcelain firms have, in the past, managed to keep sufficient capacity on hand to meet the trend growth in electrical equipment porcelain requirements, and are expected to continue to do so. There are presently no announced plans to expand industry capacity. Current capacity, however, is sufficient to handle forecasted demand through 1980 for most product lines. Recent data indicate, however, that certain porcelain products may experience delivery delays during 1977, when the distribution equipment manufacturers make their expected full recovery from the recession.⁷⁸

Potential Shortage Evaluation

Cement-concrete, and glass fiber for use in reinforced plastics, have been placed in the "Marginal" category over the entire forecast interval. Specialty porcelain products are in the "Marginal" category during 77-78 and in the "No Shortage" category thereafter. Glass for use as meter covers has been placed in the "No Shortage" category for all years (Table 6.3).

- Primary Iron and Steel (SIC 331)

Background

This industry is defined to include establishments primarily engaged in the following activities: (a) coke production (including by-products), (b) reduction of iron ore (by blast furnace or other processes) to pig iron, (c) conversion of iron to steel, (d) rolling or drawing (to billet, strip, bar, wire, or other forms), (e) processing to furnished steel products (pickling, tinning, galvanizing, etc.). The domestic steel industry is presently composed of about 200 firms operating as many as 400 plants. One company (United States Steel Corporation) typically accounts for 22-24 % (and the top eight companies usually account for at least 70 %) of all U. S. steel production. The larger companies are integrated back through raw material preparation (pelletizing and beneficiation) to the mining of iron ore and coal; the latter two basic materials being in ample domestic supply. Primary steel is the most capital intensive of all industries considered by this study (see Table 6.7). It is also one of the most energy intensive; with coal being the principal Btu source.

U. S. demand for steel mill products (carbon, high-alloy, and stainless) by the major markets (transportation, construction, durables, and containers) grew at a trend annual rate of about 2.4 % a year between 1965 and 1974. Domestic production, by contrast, grew by only one-half percent per year over the same period; with the result being that U. S. steel buyers became increasingly dependent upon imports.

The U. S. steel industry's major investment effort over this period was directed toward the substitution of basic oxygen furnaces (BOF) and electric furnaces for the obsolete open hearth. This modernization program, coupled with relatively faster growth in raw material and labor costs in foreign countries, produced a domestic steel industry that, by 1974, could be reasonably competitive in the world market. This investment, however, did not expand capacity, and when United States and world demand peaked in late 1973, American buyers found that not only was the domestic industry incapable of supplying their needs, but also that the foreign supplies on which they had previously depended were no longer readily available. Consequently, domestic and foreign steel prices rose sharply, and there was a severe supply shortfall in most product lines that carried well into the following year.

These shortages were especially acute in the plate, tubular, and stainless steel product lines.⁷⁹ Consumers of the latter product had been dependent on foreign suppliers for about 25 % of their stainless requirements, and were particularly affected by the world-wide tight steel market. Producers of another specialty item - oriented electrical steel (OES) - were operating at 93 % of rated capacity during 1974, and delivery lead-times to electrical equipment producers were significantly extended.

Three factors, pollution abatement expenditures, low returns on investment, and fear of import penetration, are mentioned most frequently when steel industry executives explain past reluctance to expand capacity. The pollution problem is still with the industry, but returns have shown marked improvement and fear of foreign competition has lessened since 1973. Simultaneously, the industry has embarked on a major capacity expansion program that, between 1973 and 75, netted a 3 % increase in raw steel capacity. As in other industries, the recession brought a sharp drop in steel demand, so that annual utilization rates, according to our capacity equations, fell from 92 percent in 1973 to 70% in 1975.

Industry Forecast (SIC 331)

The trend forecast (Table 6.21) has primary steel demand rising by better than 40 % between 1975 and 1980. Cumulative real gross investment over the same period will total \$7.93 billion, up by more than \$2 billion over the previous five years. About 72 % of this gross investment, however, will go for replacement, and 13 % of this non-productive pollution control equipment; leaving 15 % (\$1.16 billion) devoted to expanding capacity by 9 % over the average 1975 level. The large 1975 capacity margin will disappear by 1977, and utilization rates will be back to 73-74 levels by the end of the decade. Thereafter, the demand-driven production forecast continues to outstrip capacity expansion and utilization rates begin to rise substantially above previous peaks during the mid-1980s.

It is instructive to compare these econometric projections with current "planned" expansion of raw steel capacity between 1975 and 1980. The American Iron and Steel Institute estimates that the average of beginning and ending domestic raw steel capacity during 1975 was 157 million tons and that shipments totaled 79.9 million tons.⁸⁰ Using the historical average shipment/ingot ratio of 70.5 %, we estimate raw steel production for 1975 to be 113 million tons. Capacity utilization for 1975 is, therefore, estimated to be 72 % (as compared to the 70 % estimated by the econometric approach).

A company-by-company survey of raw steel capacity expansion plans conducted during 1975 for the U. S. Bureau of Domestic Commerce indicated that the industry had made fairly firm commitments to have 23 million tons of additional capacity on hand by 1980.⁸¹ This 15 % capacity expansion, joined with our production forecast, would yield a capacity utilization rate of 89% during 1980. The latter operating rate would be high relative to its historical average but still far below the 1973 operating rate of 97 %.

Table 6.21

PRIMARY STEEL (SIC331)

'TREND' Production, Capacity and Capacity Utilization

	<u>Y E A R</u>											
	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>		<u>2000*</u>
Production (1975 = 1.0)	1.30	1.28	1.00	1.10	1.26	1.31	1.36	1.42	1.70	2.06	- - - - -	2.57
Capacity (1975 = 1.0)	.98	.99	1.00	1.03	1.05	1.07	1.08	1.09	1.24	1.40	- - - - -	2.17
Capacity Utiliz. (%)	92	90	70	74	84	85	88	91	95	99	- - - - -	83
Capacity Margin (%)	-10	-8	19	12	-1	-2	-6	-9	-13	-16	- - - - -	0

'TREND' Cumulative Real (1958 \$) Investment

	<u>Y E A R</u>					
	<u>1971-75</u>	<u>1976-80</u>	<u>1981-85</u>	<u>1986-90</u>	<u>1991-2000*</u>	
Gross	5.56	7.93	10.08	11.42	20.98	
Net	0.06	2.17	3.80	4.34	9.63	
Net Effective	-0.32	1.16	2.85	3.48	7.72	

'CYCLE' Production and Capacity Utilization

	<u>Y E A R</u>							
	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>
Production (1975 = 1.0)	1.00	1.10	1.04	1.02	1.22	1.34	1.86	1.97
Capacity Utiliz. (%)	70	77	88	80	80	94	94	95

* Production for the year 2000 is a function of GNP58. Corresponding capacity index indicates capacity required (not projected) to maintain indicated utilization rate. The latter has been set equal to its average historical (1958-75) level. Corresponding investment required between 1991-2000 is derived from 1986-90 marginal capital stock/capacity ratio.

There are several reasons, however, for doubting that the industry will expand capacity by the planned amount. First, all of this expansion appears to be coming from a "rounding out" of existing plants, rather than from large "green field" new plants, and at least one industry expert feels that limits to the expansion of existing sites would require the industry to build at least one new fully integrated facility if it is to meet its capacity objective.⁸² Secondly, required capital expenditures for these small rounding-out operations will be substantially larger than any plausible estimate of future cash flow; thereby requiring the steel industry to seek funds in the market. Past returns on steel investment have been far below the average for all manufacturing, and some analysts believe that the projected steel investments will not do much (if any) better.⁸³ This means: (a) that the market may not supply the necessary capital funds, and/or (b) the industry may stop seeking the required funds if it suddenly realizes that the investments will not further their expressed desire to earn an (all manufacturing) "average" return.

Third, even if the planned expansion does materialize, the consensus seems to be that it will not be enough to prevent shortages from developing during peak-demand years. The industry's cyclical behavior, for example, is such that production forecasted for 1979 could easily be required as early as 1977; in which case supply would be very tight. Finally, an expected rapid growth in world steel demand, coupled with growing U. S. import restrictions, suggests that imports will contribute proportionately less to U. S. steel supply than has been the case in past years.

Product Forecast (Stainless Steel)

The forecast equation (Eq. 11) for stainless steel shipments (000 St/yr) is given in Appendix 6-C. The forecast itself is contained in Table 6.22. Stainless steel consumption dropped by an estimated 50 % during 1975, and it should take at least three years to get

Table 6.22

STAINLESS AND ELECTRICAL STEEL PRODUCTS

<u>Stainless Steel</u>											
	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	1.63	2.06	1.00	1.53	1.97	2.02	2.06	2.13	2.52	2.71 - - -	3.27
<u>Oriented Electrical Steel</u>											
	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	1.44	1.54	1.00	1.23	1.45	1.54	1.65	1.75	2.31	2.69 - - -	3.08
Capacity (1975 = 1.0):											
Required	1.00	1.00	1.00	.87	1.03	1.09	1.17	1.24	1.63	1.91 - - -	2.18
Announced	1.00	1.00	1.00	1.00	1.00	1.00					
Capacity Utiliz. (%)	87	93	60	74	88	93					
<u>Non-Oriented Electrical Steel</u>											
	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Y</u> <u>1977</u>	<u>E</u> <u>1978</u>	<u>A</u> <u>1979</u>	<u>R</u> <u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
Production (1975 = 1.0)	1.62	1.41	1.00	1.18	1.28	1.37	1.50	1.67	2.32	2.96 - - -	3.88
Capacity (1975 = 1.0):											
Required	1.00	1.00	1.00	.88	.96	1.02	1.12	1.24	1.73	2.21 - - -	2.89
Announced	1.00	1.00	1.00	1.00	1.00	1.00					
Capacity Utiliz. (%)	100	89	63	81	87	95					

back to 1974 levels. Given the recently imposed restrictions on stainless imports, domestic shipments will have to recover much faster, however, and should be back to 1974 levels by 1977. There is no evidence to suggest that domestic stainless capacity has expanded significantly since 1974, and it is generally recognized that the specialty steel sector is in no mood to modernize (much less expand) its antiquated plant at the present time. Unless import restrictions eased, therefore, we would expect domestic supplies of stainless steel to be grossly inadequate by late 1977. Stainless sheet, in which imports have traditionally accounted for about 40 % of consumption should be particularly tight. Given the absence of an embargo against either Rhodesia or South Africa, chromium supplies should be adequate. The decline in domestic ferrochrome capacity (less than half its 1965 level), however, has made the United States increasingly dependent upon South African-produced ferrochrome and, therefore, increasingly vulnerable to politically-induced disruptions of our chromite-chromium supply lines. The second most important alloy-nickel should post no supply problems over the next five years.⁸⁴

Product Forecast (Electrical Steel)

Demands for oriented (OES) and non-oriented electrical steel (NOES) have been generated by Equations 12 and 13, respectively (Appendix 6-C). Corresponding production forecasts (Table 6.22) are derived by using the current industry assumption that imports as a percent of consumption will average 5 % for OES and 10% for NOES over the forecast interval.⁸⁵ Two companies, Armco and Allegheny-Ludlum, share a domestic OES capacity of 432,000 tons per year and a NOES capacity of 310,000-390,000 tons per year.⁸⁶ The capacity range given for the latter product is indicative of a tendency to give higher priority to OES during periods of high demand. There have been no announcements of planned additions to existing plant and, as a consequence, we expect total electric steel production to be at capacity levels by 1978. Thereafter, either a significant expansion of domestic capacity or a sharp increase in imports above assumed levels will be required if forecasted demand is to be satisfied.

Potential Shortage Evaluation

The various carbon steel products consumed by the electrical distribution equipment producers have been placed in the "marginal" category from 1977-1979 and in the "shortage" (1981-85) or "marginal" (1986-2000) category thereafter. Stainless products have been placed in the "marginal" category for 1977 and "shortage" thereafter (contingent upon current import restrictions). Finally, non-oriented electrical steel has been placed in the "marginal" category for 1978 and both oriented and non-oriented electrical steel fall into the "marginal" category for 1979. Thereafter, both fall into the "shortage" through 1985 and into the "marginal" category from 1986 to 2000.

- Primary Non-ferrous Metals (SIC 333)

Background

This major industry group includes establishments primarily engaged in the smelting of nonferrous metals from their respective ores and the subsequent refining of the metals by any of a number of processes. The four major non-ferrous metals (in order of tonnage consumed) are aluminum, copper, zinc, and lead. A large number of other metallic minerals, including precious metals, are also included in this group. These metals, particularly copper and aluminum, often compete in common markets, and have a tendency to have extremely energy-intensive production processes. These production processes have also been the target of very stringent anti-pollution standards which have required the installation of radically new production processes. Expenditures on these new controls and processes have constituted 17 % of total gross investment during the past five years. In terms of market structure and historical consumption growth rates, however, the four major non-ferrous metals exhibit marked differences, and a separate discussion of each is required.

The U. S. aluminum industry consists of 12 companies operating 31 primary aluminum reduction plants. The latter plants produce aluminum metal via electrolytic reduction of alumina; which, in turn, has been

extracted from bauxite ore. The United States has about one-third of the world's aluminum smelting capacity, and three companies (Alcoa, Kaiser, and Reynolds) control (by BOM estimate) 67 % of U. S. capacity. The major markets for aluminum include construction (21 % by BOM estimate), transportation (19 %), electrical (14 %), and packaging (18 %). Supply is augmented by purchased scrap (one-fifth of apparent consumption) and a relatively small amount of imported primary aluminum from Canada (73 %) and other countries.

Over the past 20 years, aluminum has made significant inroads into markets previously served by steel and copper. These marketing victories were due in no small part to a policy of keeping aluminum prices extremely low relative to competing materials. Low prices, in turn, were made possible by the existence of cheap hydroelectric power on the North American Continent and low prices for bauxite. Rapid growth, however, has forced the industry to turn to more expensive fossil fuel-based electric energy, and Jamaican taxes have dramatically raised the purchase price of bauxite during the past five years. Consumption growth, moreover, is beginning to slow down in markets (such as electrical equipment) where the easiest substitutions have already been made.⁸⁷

Overexpansion during the late 60s and a sharp drop in demand during 1970 led to a cutback in North American smelter capacity during the early 70s. Demand began to rise sharply in 1973, however, and by early 1974 North American smelters were operating at capacity. As in the case of paper, much of this demand resulted from desire on the part of consumers to build up inventories prior to expected price increases.⁸⁸

Excess demand for aluminum was largely satiated, however, by a virtually complete exhaustion of U. S. Government aluminum stockpiles. By late 1974, demand made a sharp about-face and the industry passed through 1975 operating at less than 76 % of capacity. North American capacity was expanded by about 3% between 1973 and 1975.

The U. S. primary copper industry consists of eight companies operating 16 smelters and 11 companies operating 20 refineries.

The production process consists of the beneficiation of copper ore to produce copper concentrates, the smelting of the concentrates to yield a copper metal containing impurities, and the subsequent removal of those impurities via electrolytic refining. The major immediate consumers of this refined copper are the wire and brass mills. Products from these mills then end up in electrical (53% by BOM 1975 estimate), construction (17%), and other industries. About one-quarter of the total copper supply is typically derived from secondary sources (old scrap). The United States is essentially self-sufficient in copper ore and maintains a rough balance between imports and exports of refined copper.

The world copper market has been characterized by sharp year-to-year demand variations around a 2% growth trend, and by a very responsive world price that acts quickly to choke off excess demand. The U. S. producer price, while considerably less volatile, is forced by arbitrage to maintain rough parity with the world price. Capacity expansion has been moderate but sufficient to meet trend demand growth, and financial performance by U. S. copper producers has been generally superior to that of the aluminum companies.

Sharp price increases, coupled with knowledge that U. S. capacity had not increased in two years, served notice early in 1973 that copper would be tight during the remainder of the year. By the end of 1973, the world-wide economic boom augmented by a speculative "flight-from-currency," had pushed world prices to such heights that copper took on the aura of a precious metal. Simultaneously, price controls exacerbated the domestic problem by inducing the export of copper scrap into the higher priced world market, and this drain then imposed a constraint on the scrap-dependent brass mills. By the end of the first quarter of 1974, however, U. S. Government stockpile releases and a leveling of demand had alleviated excess demand. U. S. production declined by 13 % and capacity expanded by 9% between 1973 and 1975; thereby leaving the industry with a substantial capacity margin and a large inventory going into 1976.

Zinc and lead, often found together in nature, share the fate of being unrecognizable in many of their important end uses. Both, moreover, share the distinction of being severely affected by EPA pollution standards. While U. S. zinc consumption has been increasing at about 2% a year since 1965, domestic zinc smelter capacity has declined by more than 50% and imports must now support more than 40% of slab zinc consumption during normal demand periods. The major reason for this decline is slab zinc capacity has been the industry's decision to eliminate horizontal retort smelters in response to State and Federal restrictions on the level of sulfur dioxide emissions. Lead, on the other hand, feels the effect of EPA regulations primarily on the demand side, where restrictions on the use of lead as an antiknock additive in gasoline have brought a sharp reduction in its already moderate growth rate. Lead imports, which have been declining in recent years, represented 22% of consumption during 1975. Secondary supply is usually equal to, and often exceeds, the primary supply of lead.

Industry Forecast (SIC 333)

The demand for non-ferrous metals is an exaggerated image of the U. S. business cycle; with the level of inventories and rest-of-world economic activity contributing significantly to yearly variation in production levels. Consequently, the production forecast contained in Table 6.23 must be viewed as falling within rather wide confidence intervals. Given the excessive inventories at the beginning of the year, production does not have to increase by much to satisfy recovering demand during 1976. During 1977, however, the trend forecast calls for a sharp increase in production and operating rates followed by more gradual gains in both variables out to 1980. Demand growth in the late 70s stimulates a sharp increase in net investment during the early 80s and consequent overexpansion (as the model mimics the past behavior of the aluminum industry) of capacity during the next five years. This is then likely to be followed by a virtual halt to capacity expansion during the 80s

Table 6.23

PRIMARY NONFERROUS METALS (SIC333)

'TREND' Production, Capacity and Capacity Utilization

				Y	E	A	R						
	1973	1974	1975	1976	1977	1978	1979	1980	1985	1990			2000*
Production (1975 = 1.0)	1.21	1.21	1.00	1.09	1.23	1.30	1.37	1.45	1.95	2.50	-	-	3.09
Capacity (1975 = 1.0)	.91	.96	1.00	1.03	1.07	1.11	1.16	1.24	1.77	2.51	-	-	2.51
Capacity Utiliz. (%)	89	85	67	70	77	78	79	79	74	67	-	-	83
Capacity Margin (%)	-3	1	28	23	12	10	9	9	16	28	-	-	4

'TREND' Cumulative Real (1958 \$) Investment

			Y	E	A	R			
	1971-75	1976-80			1981-85		1986-90	1991-2000*	
Gross	4.94	7.12			12.55		18.38	9.82	
Net	3.91	4.10			8.39		12.29	0.63	
Net Effective	2.35	3.84			8.04		11.95	0.00	

'CYCLE' Production and Capacity Utilization

		Y	E	A	R				
	1975	1976	1977	1978	1979	1980	1985	1990	
Production (1975 = 1.0)	1.00	1.09	1.11	1.12	1.25	1.35	1.93	2.25	
Capacity Utiliz. (%)	67	70	70	68	77	81	77	62	

* Production forecast for year 2000 is a function of GNP58. Capacity index has been arbitrarily held at its 1990 level. Marginal capacity to capital stock ratio (1986-90) and depreciation rates are then used to derive the investment figures for the 1991-2000 time interval.

and a subsequent rise in operating rates during the following decade. As indicated by the cycle simulation (Table 6.23), the trend production and utilization forecasts for any given year are quite sensitive to the underlying macro assumptions. In both simulations, however, utilization rates are projected to stay far below historical levels.

Product Forecast (Aluminum)

Production and capacity projections for aluminum (Table 6.24) are made on a North American (United States plus Canada) basis rather than a domestic basis in recognition of Canada's role in supplying U. S. aluminum needs. Equation 14 (Appendix 6-C), after modification to allow for inventory carry-over from the recession, is used to forecast North American production out to 1980; thereafter, advance information from the soon-to-be published 1975 Mineral Facts and Problems (BOM) and other outside sources have been used to modify equation 14's base-line forecast.⁸⁹

Information compiled by the Spector Report indicates that current plans imply a 5% increase in North American primary capacity by 1978 (an additional 3% presently in the "uncertain" category could be forthcoming).⁹⁰ This capacity expansion coupled with our production forecast implies that North American capacity will be operating at its 1974 crunch-level of 97 %, and that net imports will have to supply a significant portion of U. S. demands during 1977-78. This, however, does not imply a shortage. Rest-of-world demand will be increasing at a somewhat lower rate, and (as indicated in Table 6.22) world capacity (much of it State-financed) will expand by a full 16% over the same period; implying that excess capacity will be available to use in supplying the North American market.⁹¹ Capacity deferred during the recession and presently categorized as "uncertain" should then be available to ease domestic and world aluminum markets through the remainder of the decade. Thereafter, improved financial performance, the high utilization rates of the late 70s, and significant governmental assistance could very well create another period of overexpansion that has characterized the past world and domestic aluminum industry behavior. All future plant expansions and choices of plant location, however, will be

Table 6.24

NORTH AMERICAN & WORLD ALUMINUM SUPPLY

ALUMINUM

(U. S. and Canada)

	<u>Y e a r</u>										
	<u>73</u>	<u>74</u>	<u>75</u>	<u>76</u>	<u>77</u>	<u>78</u>	<u>79</u>	<u>80</u>	<u>85</u>	<u>90</u>	... <u>2000</u>
Production (1975 = 1.0)	1.16	1.26	1.00	1.10	1.29	1.34	1.41	1.48	1.91	2.44	3.97
Capacity (1975 = 1.0):											
Required	.97	.98	1.00	.99	1.16	1.20	1.27	1.33	1.72	2.19	3.57
Announced*	.97	.98	1.00	1.01	1.03	1.05					
Capacity Utiliz.	91	97	76	83	96	97					

REST-OF-FREE

WORLD ALUMINUM INGOT CAPACITY*

	<u>Y e a r</u>					
	<u>75</u>	<u>76</u>	<u>77</u>	<u>78</u>	<u>79</u>	<u>80</u>
Capacity Announced and Projected (1975 = 1.0)	1.00	1.05	1.10	1.16	1.21	1.26

* The Spector Report, Oppenheimer & Co., Inc., February 10, 1976

highly contingent upon the availability of energy.

Product Forecast (Copper)

Forecasts of copper consumption have been derived from Equation 15 (Appendix 6-C). Translation of forecasted consumption into the projection of U. S. production given in Table 6.25 was accomplished by using information from the aforementioned 1975 Mineral Facts and Problems and other sources as detailed in Reference 89. After an inventory adjustment in 1976, production of refined copper (from primary and secondary sources) should parallel consumption. Current capacity plus planned additions should be sufficient to keep domestic operating rates below historical levels for most of the decade. Current financial performance, expected moderate demand growth, and past industry behavior suggest that the long-run availability of refined copper is relatively secure.

Product Forecast (Lead and Zinc)

The forecasts of lead and zinc production and consumption contained in Table 6.25 are based on Equations 16 and 17, respectively. Lead consumption is expected to grow at an extremely slow rate for the rest of the decade (and well into the next), as it continues to lose ground in its petro, paint, and other end uses. Should a heavy demand for residential storage batteries materialize during the next decade, the growth of lead consumption would accelerate somewhat for a number of years.⁹² Since, however, the lead in a battery is recovered at the end of the battery's service life, the battery segment of the lead market would become, to a large extent, self-supporting after a period of time. In sum, we feel that capacity will not be a problem in this industry.

Zinc, on the other hand, faces a fairly healthy projected demand growth. As noted earlier, U. S. capacity and production has been declining and there are no current plans for expanding smelter capacity. Surveys of world smelter construction, moreover, indicate that world capacity expansions is not likely to keep up with projected demand.⁹³ Consequently, zinc could be in very short supply as early as 1977.

Table 6.25

COPPER, LEAD AND ZINC

CopperY e a r

	<u>73</u>	<u>74</u>	<u>75</u>	<u>76</u>	<u>77</u>	<u>78</u>	<u>79</u>	<u>80</u>	<u>85</u>	<u>90</u> ... <u>2000</u>
Production (1975 = 1.0)	1.27	1.17	1.00	1.08	1.39	1.42	1.45	1.46	1.78	2.11 2.98
Capacity (1975 = 1.0):										
Required *	.92	.95	1.00	.78	.99	1.02	1.04	1.05	1.27	1.51 2.14
Announced *	.92	.95	1.00	1.03	1.06	1.09				
Capacity Utiliz.	84	75	61	64	80	79				

LeadY e a r

	<u>73</u>	<u>74</u>	<u>75</u>	<u>76</u>	<u>77</u>	<u>78</u>	<u>79</u>	<u>80</u>	<u>85</u>	<u>90</u> ... <u>2000</u>
Production (1975 = 1.0)	1.10	1.05	1.00	1.15	1.24	1.27	1.29	1.32	1.47	1.57 1.77
Capacity (1975 = 1.0):										
Required	1.00	1.00	1.00	.97	1.04	1.07	1.08	1.11	1.24	1.32 1.49
Announced	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
Capacity Utiliz.	79	81	71	82	89	91	92	94		

ZincY e a r

	<u>73</u>	<u>74</u>	<u>75</u>	<u>76</u>	<u>77</u>	<u>78</u>	<u>79</u>	<u>80</u>	<u>85</u>	<u>90</u> ... <u>2000</u>
Consumption (1975 = 1.0)	1.58	1.36	1.00	1.21	1.49	1.64	1.71	1.77	2.13	2.48 3.11
Capacity (1975 = 1.0)	1.13	1.07	1.00	1.00	1.00	1.00				
Consumption/ Capacity (%)	155	141	111	141	166	182				

* Derived from Phelps Dodge Corporation projections as published in Fortune, May, 1976, p. 279.

Further, given the low profitability of the industry and the significant environmental hurdles that it faces, it would appear that the domestic zinc slab industry will continue to shrink.

Product Forecast (Miscellaneous)

The following information is derived primarily from the BOM.

Silver: Demand exceeded new supply last year, and EPA emission controls have limited U. S. smelter output. Given moderate demand and large imports from Mexico and Canada, however, supply should be adequate.

Tin: Demand is projected to grow at less than 1% a year. United States, however, is dependent upon foreign sources for almost all of its tin.

Cadmium: Increasing dependence on imports and continuing pollution problems suggest that it will join zinc on the shortage list. Tungsten: A high (6-7%) growth rate is projected. Domestic shortfalls are expected to be made up by imports. Ninety percent of world tungsten reserves are outside the United States. Cobalt: Demand growth should be moderate. Nickel-cobalt refineries were operating at 30% of capacity by the end of 1975.

Potential Shortage Evaluation

Primary aluminum has been placed in the "marginal" category for 1977-78; thereafter; aluminum goes into the "no shortage" class. Primary copper and lead are placed into the "no shortage" category for the entire forecast period. Slab zinc has been assigned to the "shortage" category for all years. The supply-status of each of the aforementioned and all remaining nonferrous metals is summarized in Table 6.3.

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- (9) The negative coefficient for the time trend in two of the industries (SIC 32 and 333) indicates a secular decline in capital productivity. Those equations exhibiting an insignificant constant term were re-estimated with the constant suppressed. Both the production and capital stock indexes had base-year values of 1975 = 1.0.

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CHAPTER 7

TASK 6 - IDENTIFY POTENTIAL MATERIAL SUBSTITUTIONS

7.1 Task Description

Task 6 is concerned with identifying material substitutions and changes in material usage that would alleviate material shortages identified in the previous tasks.

7.2 Results

7.2.1 Substitution Candidates for Materials in Probable Shortage Category

In this section, we discuss substitution candidates for materials that have been identified as having a high probability of being in short supply between 1976 and 2000. This probable shortage category is composed of

Steel

Stainless Steel

Electrical Steel

Zinc, Cadmium

Polypropylene

Polyvinylchloride

P C B (displaced for environmental reasons)

The equipment categories that would be primarily affected are listed with each material. For a complete listing of affected equipment, the reader is referred to Table 4.1 in Chapter 4.

STEEL - Used in most distribution equipment. Steel is used primarily as a structural material in most distribution equipment. In some applications (such as cabinets and containers), it could be replaced by other metals, such as aluminum, by organics, such as reinforced plastics,

or by inorganics, such as special concretes or glass-ceramics. Replacement of steel in cables would require a high tensile material with electrical conductivity, and in concrete pole reinforcement would require a material with high tensile strength.

STAINLESS STEEL - Used in most distribution equipment.

A shortage in stainless steels would be a problem for switchgear. These materials are used for parts subjected to wear, in applications which require good corrosion resistance. A suitable alternative does not exist and should be developed.

ELECTRICAL STEEL - Transformers. Ferrites and the relatively new amorphous magnetic alloys have been considered as transformer core materials. The advantages of both these types of materials are very high electrical resistivity compared to iron and possible low core losses and improved transformer efficiencies. The main problem with both materials is low saturation compared to iron. This is particularly true for oxide materials (ferrites), where saturation values approaching iron do not appear to be possible. Saturation values on the order of 90% of iron are possible for amorphous metals, and they could eventually find some application if they can be produced in large quantities at low cost.

ZINC, CADMIUM - Transformers, meters, cables. In cables, zinc is used as galvanized steel in cable coverings, and this coated steel could possibly be replaced by an organic, such as crosslinked polyethylene.

POLYPROPYLENE - Capacitors. A shortage of this material would necessitate a return to the special papers previously used as dielectrics. Polypropylene films now used in capacitors could be replaced in the future by a more thermally stable material with high dielectric constant and low dissipation factor to allow smaller or fewer capacitors and to reduce power losses to 0.01% from the present 0.05%.

POLYETHYLENE,
POLYVINYLCHLORIDE,
ETHYLENE PROPYLENE RUBBER,
CHLOROSULFONATED POLYETHYLENE,
BUTYL RUBBER,
NEOPRENE,
MISCELLANEOUS INSULATION

} - Cables.

Of the above materials, polyvinylchloride is the only one in the probable shortage category. These materials as used in cable insulation are used alone and in combination in order to build the required properties into the final cable. Although a shortage of a few of these materials might still allow suitable cables to be made, a general shortage of organic elastomers would severely limit cable production. A restriction in these materials is that only virgin (not re-processed) material may be used.

P C B - Capacitors, transformers. Within a year or so, PCB is expected to be replaced in capacitors because of environmental restrictions. It will be replaced by an assortment of aromatic hydrocarbons (perhaps halogenated) or silicone fluids. Because a significant fraction of all capacitors are used indoors, there is a strong desire for the liquid to be non-flammable. Of the materials being considered for this application, many will be used initially; however, of the few which turn out to be the best, probably none will prove to be an ideal replacement for PCB. Therefore, development of a suitable impregnating fluid is recommended for the near future.

Replacement of PCB in small power transformers will extend over a longer time (perhaps 3-5 years), but the change is inevitable. Fluids available for substitution include silicones and halogenated hydrocarbons.

7.2.2 Substitution Candidates for Materials in the Marginal Category

In this section, we discuss substitution candidates for materials in the marginal availability category. Included in this category are:

<u>Marginal</u>	<u>Availability</u>
Aluminum	Polyester
Silver	Epoxy
Tungsten	Silicone
Zinc Phosphate	Miscellaneous
Concrete	Plastics
Porcelain	Polyethylene
Glass	Poles
	Crossarms
	Lumber

ALUMINUM - Used in most distribution equipment. In the distribution industry, aluminum is used primarily where electrical conductivity is required. The alternative at the present time is copper. Sodium has been investigated, but offers no particular advantages other than perhaps cost. Thus, if aluminum and copper prices were to increase substantially, sodium conductors could become economically attractive.

SILVER - Transformers, switchgear, fuses. Silver is used primarily for contacts and for current limiting fuses. Silver could be replaced in contact applications by the use of copper; in this case, however, the contact would have to operate in the absence of oxygen (air).

To replace silver in current limiting fuses, it is possible that solid state devices could be developed. This would greatly reduce the silver requirement.

TUNGSTEN - Transformers and switchgear. Tungsten, used with silver in contacts, could be replaced by copper if the contacts were to operate in the absence of oxygen (air).

ZINC PHOSPHATE - Used in most distribution equipment. In general, zinc phosphate and iron phosphate are used almost interchangeably as metal pretreatments. The trend is from the zinc form to the iron form because of a cost advantage. Since corrosion protection is down-graded by such a step, there may be resistance to such a change for distribution equipment for outdoor use.

CONCRETE - Poles. Concrete has been used in lieu of wood poles in locations where wood poles have a short life. Concrete poles require heavier installation equipment and local manufacturing sites are required (because of transportation).

PORCELAIN - Used in most distribution equipment. Porcelain bushings on capacitors could be replaced by plastics, concrete, or other insulating materials if there were any advantage in doing so. In the extreme, if losses can be sufficiently reduced, an insulating case could be used, eliminating the need for bushings.

Shortages of particular ingredients in porcelain compounds should be no problem because contingency plans are already available for substitution of alternate recipes in case a particular component becomes critical.

GLASS - Used in most distribution equipment. Glass used as meter covers could be replaced by polycarbonate plastics. Most of the remaining glass requirements are for fibrous forms, either as high temperature insulation or as reinforcement for plastics parts. In most cases, organic or inorganic fibers or reinforcement would serve as replacements.

POLYESTER, EPOXY - Transformers, switchgear, fuses, meters. These resins are used primarily for structural insulation. In some cases, extensive design changes would allow replacement by materials such as vulcanized fiber or cold-molded plastics. For bushings, epoxies could be replaced by glass ceramics or special concrete formulations.

Because of their versatility, use of epoxies would be expected to increase. If material supplies are adequate, epoxies may increasingly replace porcelain bushings. Availability of specific curing agents could be a problem from time to time. Suitable fire retardants have also been scarce at times.

SILICONES - Transformers, switchgear. Silicones used as high temperature gaskets and seals could be replaced by other high temperature elastomers at a higher cost. The possibility of increased usage of silicones is discussed earlier in the section on PCB.

MISCELLANEOUS PLASTICS - Used in most distribution equipment. Miscellaneous plastics include all the various plastics which are selected by the equipment manufacturers for their own designs and requirements. In many cases, a shortage of a particular plastic could be solved by direct replacement by another plastic. A shortage of all plastics would necessitate design changes to permit the use of other materials, which could include metals, ceramics, paper, etc.

An increase in the usage of polytetrafluoroethylene plastics is probable with increased use of sulfur hexafluoride in switchgear and transformers.

INSULATING OIL - Transformers, reclosers. Parafinic oils are already replacing the less available naphthenics. For reclosers, there is already a trend toward vacuum units, and these plus gas-insulated units will eventually replace the present oil-insulated equipment.

WOOD POLES - Poles. Although a substantial amount of new circuit installation is underground, pole requirements for new installations and for replacements will continue. As distribution voltage increases, pole heights must increase, creating a more severe demand for suitable poles. Suitability of wood poles is also dependent on availability of chemicals and solvents as preservatives. Alternatives are available from concrete, plastics, and steel, the last two of which are significantly more expensive.

CROSSARMS - Crossarms. Crossarms made from plastics or steel are suitable replacements for wood, except that they are more expensive. Requirements for crossarms could decrease because there will be greater use of armless construction of poles and greater use of underground installations.

LUMBER - Used in most distribution equipment. Lumber used for packaging and transportation of equipment could be replaced by structural foamed plastics, metals, and specialty packaging at a substantial cost increase. Salvage and re-use of packaging would be a preferable alternative.

About four million board feet of hardwood (primarily maple) is used for items such as wedges in transformer construction. Alternatives would include reinforced phenolic resins.

7.2.3 Substitution Candidates for Materials in the No Shortage Category

For completeness, we discuss in this section substitutes for the materials for which we forecast a low probability of experiencing restricted availability. Some of these substitutions may take place for functional or economic (cost savings) reasons.

COPPER - Used in most distribution equipment. Copper is used where good electrical conductivity is required. The present alternative is aluminum. See the section of Aluminum for other potential replacements.

LEAD - Transformers, meters, cables. Lead used as armoring on cables could be replaced by steel, and, as confidence grows in organic coverings, eventually could be replaced by them.

ALNICO, BaFe - Meters. Alnico magnets and barium ferrite magnets can be used interchangeably (with design modifications). Rare earth magnets are a possibility for future application.

NICKEL, CHROME - Switchgear. These metals are used for plating on surfaces subject to wear. Replacement would require extensive testing and/or design changes.

SILICON CARBIDE - Arresters. Use of zinc oxide to replace silicon carbide will start in about five years.

BORIC ACID - Fuses. Boric acid is the optimum material for current limiting fuses. A shortage of this material would necessitate a renewed search and evaluation program for other materials or an extensive redesign of the fuses.

COPPER SALTS - Poles. Copper salts are used as preservatives for wood poles. Alternative are impregnants such as penta, or use of poles other than wood. Use of these salts will continue to be used in about the same proportions as reported for 1973.

GASKET MATERIALS - Used in most distribution equipment. Changes in equipment design will probably not eliminate the need for gaskets. Although the mix of materials selected for gaskets may change, a range of materials will continue to be used.

PAPER, FIBER - Used in most distribution equipment. In many cases, natural organic fibers used as paper, string, vulcanized fiber, plastics reinforcement, etc., could be replaced by synthetic fibers. However, there are no changes anticipated that will change substantially the amount used. Small quantities of high purity paper will be required as a dielectric in capacitors.

PHENOLIC RESIN - Meters and other equipment. Other plastics could be substituted for phenolics, but a shortage of phenolic resins implies a shortage of other plastics as well. A change to inorganic insulation would necessitate extensive design changes.

BUTYL RUBBER - Instrument transformers. Since epoxy insulated units are used competitively with butyl rubber units, these materials could be considered as alternates. In many applications, property requirements are not severe and other encapsulants might be considered.

SOLVENTS, CREOSOTE, PENTA - Poles. Solvent and preservative requirements for pole treatment would be reduced or eliminated only by the use of poles made from materials other than wood. The ratio of creosote to penta could vary as one or the other becomes scarce. Otherwise, usage would not be expected to change.

GOLD - Meters. In present circuit board technology, contact fingers are gold plated for reliable conductivity. This technique will undoubtedly be used until some other highly reliable system has been proved in long-term service. Estimations of the amount of gold required yielded 16×10^{-5} pounds per meter.

7.2.4 Alteration in Equipment Designs to Alleviate Potential Material Shortages

With the exception of electrical steel and perhaps insulating oil, the usage of materials for distribution equipment neither significantly creates nor alleviates any shortage. Thus, more efficient use of material in distribution equipment does not, in general, constitute a basic long-term solution to an availability problem. Such changes would, however, alleviate the severity of shortages and could be made for cost reduction reasons. In the following paragraphs, design changes are discussed that would decrease the requirements for some of the materials in the probable shortage or marginal availability categories.

ELECTRICAL STEEL - In the case of electrical steel, increased magnetic saturation in a steel core can be achieved by incorporating various elements into the alloy. This approach would result in a decreased requirement for electrical steel for transformers.

ALUMINUM - Increased thermal loading of underground cable would allow the aluminum requirements for this application to be reduced. Such an approach would require developments for improved insulations and would also decrease the efficiency of underground distribution.

SILVER - The amount of silver used as contact material in switchgear equipment could be significantly reduced by redesign. In fact, one can expect that significant price increases for silver will cause these design changes to be undertaken for economic reasons.

The amount of silver used in current limiting fuses could be substantially reduced by using films of silver fabricated on inorganic substrates.

INSULATING OIL and PCB - The requirement for insulating oil and PCB (and its substitute) for transformers can be drastically reduced by design changes that include the use of dry type transformers, insulating materials, such as hexafluoroethene, resin-cast coils (requiring no steel tanks), or vapor-cooled units, using fluorocarbon refrigerants and oil.

7.3 Methodology

For each of the materials in the probable shortage and marginal availability categories, an analysis was made of their functional characteristics, i.e., the prime characteristics that cause the materials to be used in their present applications. Once these characteristics were determined, a stepwise approach was taken to determine viable approaches for reducing the requirements for each of the materials with forecasted restricted availability.

Among the approaches considered for alleviating shortages were:

1. Substitution of an alternative material that is expected to be readily available and would not significantly increase product cost.
2. Improvement in certain prime characteristics of the material that would allow a smaller amount to be used.

3. Development of a new material to serve as a substitute.
(This approach usually requires substantial development.)
4. Consideration of production from alternative sources
when the restricted availability is caused by a raw
material input shortage.
5. Consideration of equipment design changes.
6. Consideration of altering the manner in which the equip-
ment is operated (e.g., higher thermal loading of
underground cable).

CHAPTER 8

TASK 7 - R&D AND POLICY RECOMMENDATIONS

7.1 Task Description

Task 7 is concerned with developing r&d and policy recommendations that are directed toward relieving the potential material availability problems identified in the previous tasks. These recommendations are based on a need to maintain the present level of technology, allow planned technological improvements to be implemented, or make possible the introduction of innovative changes.

7.2 R&D Recommendations for Alleviating Potential Material Shortages

The recommendations are grouped into six major categories.

1. Recommendations for Alleviating Shortages of Metals
2. Recommendations Associated with Replacement of PCB
3. Recommendations to Alleviate Problems Associated with
Natural Gas and Crude Oil Shortages.
4. Recommendations for Developing Substitutes for Wood Poles
5. Recommendations for Improved Electrical Load Analysis
6. Recommendations Indirectly Related to Material Availability

7.2.1 Recommendations for Alleviating Shortages of Metals

Electrical steel is expected to be in short supply. Aluminum and copper are forecasted to be in the marginal supply category (see Chapter 6, Section 6.4). These three materials are used to a significant extent in the manufacture of distribution equipment (see Table 4.4) and, hence, any shortages would have a large impact on equipment availability and price. The following recommendations are directed toward alleviating the severity of these potential shortages.

Improved Core Materials to Alleviate Electrical Steel Shortages

RECOMMENDATION 1 - One of the best opportunities for improving the distribution system efficiency is the transformer core. It is recommended the work be done in the core steel area that

1. Evaluates the trade-offs between higher resistivity versus lower saturation steels.
2. Develops manufacturing techniques for making lower loss core steels.
3. Develops electrical steels with higher permeability and higher saturation levels.

RECOMMENDATION 2 - Amorphous magnetic alloys are long-term candidates as substitutes for electrical steel as transformer core material. It is recommended that 1) the properties and benefits in using these alloys as transformer core material be studied; 2) a commercially feasible process be developed to produce these amorphous materials with desirable properties in stable form.

Developments to Reduce Copper and Aluminum Usage

RECOMMENDATION 3 - The use of high conductivity graphite intercalation compounds as conductor material in place of aluminum and copper would greatly improve the efficiency of the distribution (and transmission) system. However, the preparation techniques, structure, and properties of these compounds are not well understood. It is, therefore, recommended that basic research be conducted in this area aimed at:

1. Determining the feasibility and benefits of using these compounds as conductor material in distribution equipment.
2. Developing economic processes for fabricating these materials as conductor wires.

RECOMMENDATION 4 - Greater thermal loading of cable could significantly reduce the amount of material required for cable.[†]

[†]Higher thermal loading will decrease efficiency. A careful analysis should be made of the proper trade-off between aluminum usage and efficiency. This latter consideration could be an independent study.

(In addition, higher distribution voltages are expected to reduce material requirements.) However, in order to achieve satisfactory performance at higher temperatures, it will be necessary to improve the performance of insulating materials. Recommended research objectives include:

1. Improved heat resistance of cable insulations.
2. Corona resistant organic materials.
3. Development of synthetic mica compositions.
4. Study of the causes of voids in insulation.*
5. Development of void-free insulation systems.*
6. Studies of treeing in cables.*

7.2.2 Recommendations Associated with Replacement of PCB

The use of PCB in capacitors and transformers will be eliminated shortly for environmental reasons. The following recommendations are concerned with developing suitable substitutes and altering designs in order to provide a satisfactory solution to the PCB problem.

RECOMMENDATION 5 - Although various materials have been proposed as replacements for polychlorinated biphenyls in capacitors and transformers, none appears to be a completely satisfactory substitute. Research is recommended to:

1. Determine the performance and long-term environmental impact of present substitutes for PCB.
2. Determine the importance of flammability for each application and determine if multiple substitutes with different flammability properties would be appropriate.
3. Investigate biological approaches for decomposing or minimizing the environmental impact of PCB substitutes.
4. Develop a completely satisfactory substitute or substitutes for PCBs if none are found to presently exist.

* EPRI is currently sponsoring research in these areas.

RECOMMENDATION 6 - Replacement of PCB, shortages of insulating oil, and higher distribution voltages suggest the need for alternative transformer design. R&D objectives should include:

1. Development of insulating gases and gas mixtures for vapor-cooled units.
2. Development of compatible insulations for use in such systems.

RECOMMENDATION 7 - The replacement of PCB in capacitors may require the development of films that are compatible with the substitute material. At the same time, an effort should be made to develop a lower loss material that could reduce power losses by as much as 80% and, more importantly, reduce the size and quantity of capacitors required. It is, therefore, recommended that a program be undertaken to develop a cost-effective film, compatible with PCB substitutes, with improved thermal stability, high dielectric constant and strength, and low dissipation factor.

7.2.3 Recommendations to Alleviate Problems Associated with Natural Gas and Crude Oil Shortages

It is generally accepted that natural gas will be in short supply (particularly for industrial users) and that over the long term crude oil will have a similar problem. Under such circumstances, the prices of these fuels is expected to increase and specialized products with low volume may be discontinued. Porcelain requires a significant amount of natural gas to produce, and thus its cost can be expected to increase. Insulating oil is a low-volume, specialized product that will continue to suffer periodic restricted availability. The following two r&d recommendations are directed at alleviating these problems.

RECOMMENDATION 8 - Shortage of crude oil, particularly naphthenic-based crude, will pose a threat to the availability of insulating oils used in transformers and circuit breakers. Its relative insignificance among other refinery products increases the severity of

the problem. Methods should be developed for reducing the amount required.

Objectives include:

1. Develop synthetic fluids to replace napthenic-based oil.
2. Reduce the amount required by
 - Developing insulation systems with higher dielectric strength to decrease spacing, and greater thermal stability for operating at higher temperatures.
 - Designing transformers to better utilize internal volume, e.g., use round sections.
 - Developing inorganic fillers to reduce volume of dielectric.
3. Develop additives that allow insulating oils to be produced from non-napthenic based crude.
4. Develop oil diluents and recycling procedures.
5. Improve solid-state insulation and related heat transfer technologies to provide economical high voltage transformers with oil-filled transformer performance characteristics (ultimate objective).

RECOMMENDATION 9 - The production of porcelain uses a large amount of natural gas (relative to its overall input costs), and the use of epoxies to replace porcelain in bushings will eventually have to be tempered by the relative shortage of organic materials. It is recommended that the following areas be investigated.

1. Design improvements to reduce size of bushings.
2. Continued development of materials (such as concrete) to replace materials presently used.

7.2.4 Recommendations for Developing Substitutes for Wood Poles

RECOMMENDATION 10 - Since the trend toward higher distribution voltages means increased height of potentially scarce wood poles and since these poles require extensive pre-treatment and re-treatment with organic solvents that also can be in short supply, further development of alternative pole materials should be encouraged. Appropriate actions include:

1. Continued development on the use of flyash.
2. Development of low density concrete structures.
3. Development of cost effective concepts in other materials such as metals, wood composites, and plastics.

Improved pre-treatment and re-treatment materials and techniques are also very worthwhile objectives since they greatly reduce the replacement need for poles.

7.2.5 Recommendations for Improved Electrical Load Analysis

Current work in the area of electrical forecasting has revealed a need for methodology for directly estimating and forecasting peak load requirements. Many recent studies have concentrated on electrical energy forecasting. These energy forecasts are then aggregated and a parameter called load factor is used to relate energy to peak load. However, this conversion is almost always performed at an aggregate level, usually including the entire system kw-hrs or, at most, disaggregated by major class of service. Such an approach makes it difficult to accurately determine the impact of new loads, energy storage, pricing, etc. More specific information on individual end-use loads must be developed to adequately analyze the impacts of load management options and solar electric applications.

A methodology should be developed for representing the time profiles of each load over a daily, monthly, and yearly period. The approach should also consider the regional variations of each type load,

especially those of a weather sensitive nature. Extensive field data should be collected to verify the methodology.

Once reliable estimates of individual load profiles are available, additional methods need to be developed for statistically aggregating these profiles to obtain distribution and transmission system loads. Again, extensive field data should be used to verify the methodology.

Thus, in order to better forecast the load profile for individual distribution and transmission systems and have more accurately forecast capacity and equipment requirements, the following two studies are recommended.

RECOMMENDATION 11 - It is proposed that a load profile analysis program be developed in two phases: Phase I would be concerned with 1) the appropriateness of load data already available and collected by the majority of electric utilities, 2) additional data collection required, and 3) the methodology for analyzing the peak loads. Phase II would involve one or more studies with cooperating electric utilities to further develop the methodology in Phase I and to check the validity of the techniques against specific utility applications.

RECOMMENDATION 12 - It is further proposed that a follow-on study be conducted using the methods proposed in Recommendation 11 to determine the distribution equipment ramifications of load management options and several proposed solar heating and cooling and photovoltaic systems. The photovoltaic study should carefully consider the utility-customer interface and the role of storage.

7.2.6 Recommendations Indirectly Related to Material Availability

In the course of this study, several r&d areas were suggested that are not related to material availability. These areas are discussed in the following paragraphs.

RECOMMENDATION 13 - Zinc oxide has been shown to possess voltage-limiting characteristics desirable for application as voltage surge protectors. Other nonlinear electrical materials can be used as current limiting devices. It is recommended that research be funded that is directed toward a better understanding of the conduction mechanisms for such nonlinear electrical materials for both current limiting and voltage limiting applications. The successful development of such protection devices could significantly reduce the material used in other distribution equipment, particularly transformers.

RECOMMENDATION 14 - Although silver and tungsten have been identified as being in the marginal short supply category and, hence, are candidates for substitution, it is difficult to justify substantial efforts directed at eliminating their use as contact material. The price of silver and tungsten could increase substantially without having a severe impact on the cost of distribution equipment (except fuses).

Cadmium oxide is a satisfactory second component with silver in low-current contacts and refractory materials, such as metallic carbides, are potential substitutes for tungsten in high-current arcing environments. It is recommended, in conjunction with any funded effort that involves the redesign of equipment, that alternative contact materials be investigated, particularly in cases where the working medium is being changed as part of the redesign.

RECOMMENDATION 15 - The sand-filled fuse consisting of a silver or other metal element in the form of wire or ribbon is one of the two basic types of power fuses currently used in distribution substations, distribution feeders for fault sectionalizing, and distribution transformers. A new film-type fuse technology has been developing, on a laboratory scale over the last several years, that offers the following significant advantages over the conventional fuses:

- a) Improved low- and high-fault current-interrupting ability.
- b) Greater applicability to higher voltage and higher current systems.

- c) Higher current ratings due to heat extraction through the substrate and from the element surface.
- d) Lower costs, specially for the more intricately shaped elements.

It is recommended that 1) the basic scientific and technical phenomena related to film-type fuses for distribution voltage current-limiting applications be studied; 2) a fabrication technology for these films be developed.

7.3 General Policy Recommendations

It has been shown that, with few exceptions, the materials used for electrical distribution equipment are not particularly unique and, in fact, the distribution usage is a small part of the overall demand. Thus, the distribution usage neither creates nor alleviates any shortages to a significant extent.

Thus, the following policy recommendations are general in nature and are not specifically directed toward guaranteeing the availability of inputs for the manufacture of electrical distribution equipment at the expense of other potential users.

National Energy Policies. Many of the supplying sectors and the distribution equipment manufacturers themselves use significant amounts of natural gas. Policies that encourage a smooth transition of industry from natural gas to other fuels would drastically reduce the probability of periodic shortages of distribution equipment.

Environmental Policies. Several supplying sectors, particularly metal and paper producers, appear to be postponing capacity additions due to uncertainty regarding environmental issues. Thus, the resolution of these issues would tend to lead to a more orderly expansion of capacity to meet projected demands.

Steel Import Quotas. The capacity for steel production, including electrical steels, is forecasted to be insufficient. Thus, policies that restrict imports decrease the supply of steel to domestic users. (However, it can also be argued that import quotas over the long term encourage domestic producers to add capacity.) From an availability of steels for distribution equipment viewpoint, policies that eliminate import restrictions will decrease the severity of the impact of forecasted shortages of domestic steel and, hence, the probability of equipment shortages.

Specialty Materials. Since distribution equipment uses a small part of the total demand for most of its inputs, the industry has very little leverage on suppliers in general. (Electrical steel is a notable exception.) The use of specialty materials with low volume accentuates the problem since suppliers tend to drop low volume specialty lines when capacity is tight. Thus, ERDA, EPRI, and other funding agencies should encourage the use of commonly available materials where possible in new equipment designs. If specialized materials are required, then an effort should be made to assure their availability.