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ARGONNE NATIONAL LABORATORY
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ANL/CNSV-TM-42

INDUSTRIAL COGENERATION CASE STUDY #3:
MEAD CORPORATION PAPER MILL,
KINGSPORT, TENNESSEE

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Energy and Environmental Systems Division
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PREFACE

The project reported here was directed and conducted by James H. McElroy. Nirmal Kotamraju worked and consulted on many aspects of the project and provided particularly valuable service in his organization and management of the data development. Richard Peppin contributed to and participated in the early stages of project development; Barbara Coates performed much of the data manipulation; and Esther Kane and Carol Kulski typed the manuscript drafts. Thanks are due Charles Leatham of Gilbert Commonwealth Engineers for his expert consultation on many of the technical aspects of cogeneration and Jack G. Faucett for his consultation on the intricacies and complexities of interest, capital depreciation, inflation, and investment decision making.

Special thanks go to the people of the Mead Corporation -- at headquarters in Dayton, Ohio, to Mr. Ralph Bernstein who coordinated and arranged the authorization for the case study; and at Kingsport to William Gory, energy coordinator, who integrated JFA's onsite activities, and to Carl Weed, utility superintendent, who answered numerous detailed questions about the cogeneration operation and its history and evolution.

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TABLE OF CONTENTS

	<u>Page</u>
PREFACE	iii
1 INTRODUCTION AND BACKGROUND	1
1.1 Project Objective	1
1.2 Site Selection Methodology and Criteria	2
1.2.1 Size of Electric Generation Plant	2
1.2.2 Facility Location	3
1.2.3 Facility Fuel Use	3
1.2.4 Prime Mover Technology	4
1.2.5 Motive Power Cogeneration	4
1.2.6 Varied Institutional Environment in Which the Cogeneration Plants Existed.	4
1.3 Selection of the Mead Paper Kingsport Plant.	5
1.4 Report Overview	6
2 THE MEAD CORPORATION'S KINGSFORT MILL.	7
2.1 Mead-Kingsport Energy Operations	8
2.2 Onsite Electric Generation Evolution	8
3 COGENERATION AT MEAD	11
3.1 Cogeneration Equipment, Processes and Outputs	11
3.1.1 Description of Equipment.	11
3.1.2 Description of the Cogeneration Process	14
3.2 Performance and Reliability of the Cogeneration System	15
4 THE ECONOMIC AND ENERGY EFFICIENCY OF COGENERATION AT MEAD	17
4.1 Onsite Electric Generation.	17
4.1.1 Onsite Electric Generation Fuel Consumption	17
4.1.2 Onsite Electric Generation Costs.	19
4.2 Purchased Power Alternative	21
4.2.1 Purchased Power Alternative Fuel Consumption	21
4.2.2 Purchased Power Alternative Costs to Mead	23

TABLE OF CONTENTS (cont'd)

	<u>Page</u>
4.3 Comparison of Onsite Generation with the Purchased Power Alternative	25
4.3.1 Energy Consumption of Onsite Generation Compared with the Purchased Power Alternative	25
4.3.2 Comparison of the Costs of Onsite Generation with the Purchased Power Alternative	26
4.4 Comparison of the Costs of Onsite Generation at a Hypothetical New Facility with the Purchased Power Alternative	26

LIST OF FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
3.1	Schematic of the Cogeneration System at Mead.	

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
3.1	Characteristics of Boilers at Mead	13
3.2	Characteristics of Turbine Generators at Mead.	13
4.1	Mead Onsite Electric Generation Fuel Consumption	29
4.2	Mead Steam Production and Onsite Electric Generation	29
4.3	Mead Onsite Electrical Generation Total Costs	30
4.4	Onsite Electrical Generation Fuel Costs.	30
4.5	Onsite Electric Generation Operating and Maintenance Costs	31
4.6	Onsite Electrical Generation Capital Costs	31
4.7	Purchased Power Alternative Fuel Consumption	32
4.8	Purchased Power Alternative Costs.	32
4.9	Fuel Consumption Comparison of Mead Onsite Generation vs Kingsport Power Company Purchased Power Alternative.	33
4.10	Cost Comparison of Mead Onsite Generation vs Kingsport Power Company Purchased Power Alternative.	33
4.11	Rate of Return of Onsite Generation.	34
4.12	Mead Onsite Electrical Generation Total Costs with Capital Costs for a New Facility	34
4.13	Cost Comparison of Mead New Facility Onsite Generation vs Kingsport Power Company Purchased Power Alternative	35
4.14	Rate of Return of Onsite Generation at New Facility.	35

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1 INTRODUCTION AND BACKGROUND

Argonne National Laboratory, under the sponsorship of the Department of Energy's Office of Industrial Programs, has financed a project to do case studies of cogeneration at five industrial establishments. Six reports, one on each of the five individual case studies and a summary synthesis report, document the total case study project. This report covers the case study of the cogeneration operation at the Mead Corporation Paper Mill in Kingsport, Tennessee.

This chapter describes the objective of the project, the general methodology of site selection, and the selection of the subject Mead plant in particular. The chapter concludes with a brief discussion of the case study methodology employed and the report organization used for documenting the results.

1.1 PROJECT OBJECTIVE

The Industrial Cogeneration Case Study Project, which this report partially documents, is part of an effort by the Department of Energy (DOE) to improve understanding of cogeneration.

Much has recently been written and said about the energy-saving potential of co-locating facilities that generate electric power with facilities that consume large quantities of lower grade process heat. Thereby much of the by-product heat of electric generation that is traditionally thrown away (often as a thermal pollutant) can be used productively. If properly designed and operated such cogeneration can save large amounts of fuel and capital. (Capital savings come from eliminating the boilers that otherwise would be needed to convert additional fuel into the heat energy that is thrown away.) While the theoretical potential of cogeneration is well known, generally, little is known about the actual operation of functioning cogeneration facilities at establishments.

To fill this knowledge gap, DOE/Argonne National Laboratory have commissioned two sets of cogeneration case studies. The earlier series of case studies explored cogeneration that takes place at a number of nonindustrial facilities in the Midwest and Eastern United States. The case studies of this project explore cogeneration that takes place at five large industrial establishments located in five widely separated U.S. locations.

The earlier case studies were of relatively small scale cogeneration operations that primarily provided electricity and space conditioning energy for mostly commercial, residential, and service sector establishments. With one exception, the operations studied had electric power capacities of 5000 kW or less, and most used diesel prime mover technology and had requirements for relatively very low grade by-product heat. They all operated on oil or natural gas and were of fairly recent (since 1960) vintage. In addition, most at best, were only marginal economic and energy-saving successes, and, at worst, total failures in both aspects.

In contrast the case studies of this project are of much larger scale operations, 12,000-29,000 kW of electric generating capacity with large additional amounts of motive power cogenerated in some cases. The industrial cogeneration operations serve process heat requirements that are much more diverse. For example, steam is frequently needed at more than three different enthalpies (temperature and pressure) and the process heat usually needed must be of a much higher grade than is typical for space conditioning. In some instances fairly high grade heat (400 psi superheated steam) is required.

The five establishments of this project all use steam turbine prime mover technology. Fuel use, on the other hand, is very diverse. All of the electric generation is 30 years of age, or more, with most dating back to the first two decades of this century. The cogeneration operations studied are the result of long histories of incremental plant changes, additions, and refinements. Only one of the facilities even remotely resembles the originally designed and installed cogeneration operation; the others have grown and evolved into operations quite different from those initially installed.

1.2 SITE SELECTION METHODOLOGY AND CRITERIA

For this case study project the Department of Energy was interested in cogeneration in five industries -- (1) textiles, (2) chemicals, (3) pulp and paper, (4) oil refining, and (5) food processing. In selecting sites for study, Jack Faucett Associates (JFA) used a cogeneration data base they developed that identifies and categorizes most establishments where cogeneration takes place. From this array, JFA selected some from each industry category and began requesting their participation and cooperation in this project.

In general, sites ultimately selected were those that would provide the widest possible variety of information about the actual practice of industrial cogeneration in the U.S., particularly on those factors near the economic margin that can make the difference between successful and unsuccessful cogeneration operations. The case study candidates were not selected according to any scientific sampling principles. Rather, JFA's experience and knowledge gained in doing other case studies, especially one on cogeneration, and in developing and analyzing its cogeneration data base were used as bases for selection. A number of specific considerations and factors, in addition to industry classification, influenced the selection of candidate establishments that were contacted for possible participation in this project. Some of these are discussed below.

1.2.1 Size of Electric Generation Plant

A prime objective of this study was to investigate the economics of operating cogeneration plants. In that regard, the most interesting plants are those with electric generation in the 10,000-30,000 kW range. As cogeneration candidates in the future, the smaller operations are less numerous and in general are expected to be less attractive; whereas the larger operations, being major beneficiaries of the economies of scale available from electric generation technology, are expected to be more certain cogeneration

winners. As to the very large operations, however, the number of industrial applications where they are practical is small. For example, there are no large (greater than 30,000 kW) cogeneration plants in the food and textile industries. The five industries studied constitute the bulk of U.S. manufacturing capacity and thus the bulk of the market for cogeneration, which lies in such medium-to-large-sized plants as those selected for study.

1.2.2 Facility Location

Facility location was an important choice criterion for two reasons:

1. The overall project's usefulness is enhanced by case study experience provided from a large variety of geographical locations.
2. Selected individual establishments should be in locations that are generally attractive to industry -- out of the way locations were avoided. For example, pulp and paper mills in remote and isolated locations in the States of Maine, Oregon, and Washington were not contacted. The participation of paper mills closer to the industrial heart of the country was preferred.

Additionally, it was desired to have sites located in as many different states and in as many different regulatory environments as possible. Facilities selected are in five states -- New Jersey, South Carolina, Tennessee, Illinois, and California.

1.2.3 Facility Fuel Use

Case study candidates were chosen with major consideration given to the type of fuel used. The widest possible variety of fuel was sought; the sites selected use petroleum, natural gas, coal, oil refinery by-product oil and gas, and paper mill by-product black liquor. An aspect related to fuel used by these studied sites is the fuel-use mix of the electric utility that serves them.

In effect, onsite electric generation competes in part with the local electric utility, since industrial plant managers typically have the choice of making power onsite or buying it from the utility. To varying degrees, this decision has been made based on the comparative economies involved. Because a large and growing share of the cost of purchased power (as well as onsite generated power) goes for fuel purchase, the kind of fuel used to generate utility-produced power is an important consideration. If the onsite cogeneration uses expensive oil and gas fuels and the electric utility uses the same, onsite cogeneration can be expected to be much more cost competitive with the purchased power option than would be the case if the relatively inexpensive coal and nuclear fuel generated the utility provided power.

With regard to the sites selected for the case study project:

1. The Mead Paper, Tennessee, onsite generating facility uses purchased coal and by-product black liquor and competes with Appalachian Power Company whose 1978 baseload electric generation was nearly 100% coal fueled.
2. The Celanese, South Carolina, onsite generating facility uses coal and competes with Duke Power Company whose baseload generation in 1978 was 66% coal and 33% nuclear fueled.
3. The American Cyanamid in New Jersey, onsite generating facility uses oil and natural gas and competes with the Public Service Gas and Electric Company whose 1978 baseload electric generation was about 50% oil, 25% nuclear, and 25% coal fueled.
4. The AMOCO, Illinois, onsite generating facility uses natural gas, refinery gas, by-product fuel oil, and residual fuel oil and competes with the Illinois Power Company whose 1978 baseload electric generation was more than 90% coal fueled.
5. The C&H Sugar, California, onsite generating facility uses oil and gas and competes with the Pacific Gas and Electric Company whose 1978 baseload electric generation was 48% natural gas and 49% oil fueled, with the remaining 3% provided by geothermal energy.

1.2.4 Prime Mover Technology

Case study candidates were chosen with consideration given to the type of engine used as the prime mover. Analysis, however, of JFA's cogeneration data base revealed that not much variety existed in the kind of technology used for large cogeneration prime movers. One listing of large industrial cogeneration facilities showed that out of 380 facilities, 349 were powered by steam turbine, 17 by internal combustion (diesel), and fewer than 20% by gas turbine. The fact that all of the sites selected use steam-turbine technology is due to limitations in the number of case studies performed plus the greater importance of other site-selection criteria.

1.2.5 Motive Power Cogeneration

The most common perception of cogenerated power is of electric power. Technologically, however, there is no reason to accept that limitation. A more general and proper notion of cogeneration conceives of power in both mechanical and electrical terms. In selecting sites for this study the primary focus was onsite electric generation with recovery and use of by-product heat, but sites were also sought for the project where there was significant motive power generation so that the relationship between motive power and electric power cogeneration could be explored. It turned out that all the sites have some motive power generation.

1.2.6 Varied Institutional Environment in Which the Cogeneration Plants Existed

An initial criterion for case study site selection was varied institutional arrangements in which cogeneration existed. Sites of particular interest were those where cogenerators:

1. Sold excess electricity to the electric utility that serves their area;
2. Bought additional power above and beyond that they produced;
3. Wheeled onsite generated power over electric utility lines to remotely located consumers; and
4. Are provided back-up demand capacity without a requirement for a minimum purchase of electricity.

While this objective of studying a variety of institutional arrangements in which cogeneration occurs was pursued, contacts with industrial cogeneration managers revealed that all the candidate sites reviewed were similar in that they had connections with their local electric utility to import additional power. None of the sites contacted were isolated from the grid; all purchased electricity in addition to making it; none had excess power they wanted to sell to the electric utility or wheel over the electric utility's lines. Consequently, all the sites selected buy power as well as make it. While other institutional arrangements do sometimes exist, a finding of this project's site-selection process was that other arrangements or (historically) the need for them is rare.

1.3 SELECTION OF THE MEAD PAPER KINGSPORT PLANT

The Mead mill was selected as the paper industry plant for this study. The Mead plant has 25,000 kW of normally used onsite electric generating capacity. It also has another 2,500 kW of generating capacity that is old, less efficient, and almost never used. Among the characteristics that recommended the Kingsport plant were:

1. Its geographically central location;
2. The fact that it is fueled almost exclusively with coal and that the electrical utility that serves Kingsport is also fueled almost exclusively with coal; (The Mead facility is the only one of the five sites studied where coal-fueled cogeneration was competing with exclusively coal-fueled utility generated power, and such a case was considered essential to a well-balanced set of case studies.)
3. The moderate size of its electric generating plant -- some paper plants have very large electric generating

facilities, but, as discussed earlier, moderate-sized plants were preferred in the studies for this project.

1.4 REPORT OVERVIEW

In the three chapters remaining, Chapter 2 describes the Mead plant and discusses the evolution of its onsite electric generation to its current state; Chapter 3 describes and discusses the cogeneration plant at Mead mill; and Chapter 4 provides an evaluation of the energy use characteristics and economics of the cogeneration operation. The evaluation is performed by comparing the economics and energy use characteristics of onsite cogenerated electric power with those of electric utility provided power that would be required in the absence of onsite generation.

2 THE MEAD CORPORATION'S KINGSFORT MILL

The Mead Corporation is a large paper, fiber, and wood products manufacturing company. The firm also distributes paper and paper products and is, through acquisition of other companies, entering other fields. Its subsidiaries distribute piping; valves, fittings, and industrial electrical supplies; manufacture furniture; process fabrics into consumer products; manufacture castings and rubber products; and mine coal. In 1978 Mead had sales of over \$2.5 billion with paper and wood products accounting for over 65% of total sales.

Of the 30 paper, fiber, and wood products corporations among the Fortune 500 largest industrial companies, Mead was the seventh largest and ranked 127th in terms of sales. It has pulp, paper, wood, and wood products mills in British Columbia and Quebec in Canada, and in the States of Wisconsin, Michigan, New York, Massachusetts, Ohio, Virginia, Tennessee, and Georgia. It has paper product fabricating plants in many other states, and sales and distribution facilities around the world. The Mead Corporation is an outgrowth of a business founded by the Mead family in 1846. In 1930, many of its numerous separate ventures were consolidated into the single Mead Corporation.

Kingsport, Tennessee, is located in northeastern Tennessee near the borders of Virginia and North Carolina and about 70 miles northeast of Knoxville. The Mead Plant is located inside Kingsport on about 60 of 125 acres Mead owns. The buildings in the Kingsport complex are closely spaced with many separated by common walls.

The original plant was built about 1916 to produce pulp from by-product wood chips left over from a tannin extract-producing operation. The City of Kingsport grew up around the extract and pulp businesses and incorporated in 1917. A Mead engineering firm took over operation of the Kingsport pulp mill in 1919 in order to improve its engineering operation. In 1920 Mead Fibers another part of the Mead enterprises, purchased the Kingsport Pulp Company and that facility has been part of the Mead complex ever since.

In 1923 Mead installed the plant's first paper machine. A second paper machine was installed in 1928, a third in 1937, a fourth in 1938, and the fifth and last machine, in 1966. In 1970 paper machine No. 1 was removed and No. 2 ceased operation; consequently units 3, 4, and 5 are all that currently operate.

The Mead-Kingsport complex is one of about 350* U.S. paper mills.¹ While the Kingsport facility is not a giant in the paper industry, it is nevertheless among the 32 largest U.S. paper mills in terms of employment. The plant produces almost 200,000 tons per year of high quality printing, copying, and cigarette paper, accounting for about 2/3 of one percent of all U.S. paper production, which in 1978 was about 28 million tons.

*If pulp and paperboard mills were included this number would be nearly 700.

2.1 MEAD-KINGSPORT ENERGY OPERATIONS

The energy needs of the mill are supplied primarily by purchased coal, by-product black liquor,* and purchased electricity. Small quantities of No. 6 fuel oil and natural gas are also used in the combustion of black liquor and in a lime kiln used to provide paper-making chemicals. Oil and natural gas typically supply less than 5% of its fuel needs and never provide more than 10%.

The coal fuel comes by rail from Virginia and West Virginia mines and is unloaded directly from rail cars onto conveyors for delivery to the pulverizers and boilers. Fuel is consumed at a rate of between 400 and 630 tons per day. A back-up supply of coal is maintained in a 12,000-ton pile that under normal circumstances is not used.

The mill purchases nearly 40% of its electricity from the Kingsport Power Company, a local distribution company for the Appalachian Power Company that generates the power Mead-Kingsport buys.

The mill has one tie to Kingsport Power Company through a 34.5 kV bus. The Power is then split and stepped down and feeds two electrical systems that serve the mill. The older electrical system is a 4160-V system and the newer electrical one is a 13,800-V system. Both electrical systems are also supplied by onsite generated power that is paralleled with the utility supply.

Mead's onsite energy needs are supplied primarily by steam produced in three 900-psi boilers (three older, small 400-psi boilers are also used occasionally). The 900-psi steam is expanded through two (a 12,500- and a 7,500-kW) turbine generators to make electricity to run the electric-drive paper machine, the electric portion of the steam driven paper machines, and for other purposes. The 400-psi steam is extracted from the turbine for the 12,500-kW generator and expanded through the turbine drives for two paper machines, one turbine generator (a 5000-kW unit) and through the turbine drives for boiler-house auxiliaries.

The 150-psi steam is extracted from the turbines for the 7500- and 5000-kW generators to drive additional boiler-house auxiliaries and supply some process heat. The turbines for the 12,500- and 5,000-kW generators exhaust to the 40-psi steam system that supplies most of the process steam for the mill. The turbine drives of some of the boiler-house auxiliaries exhaust to a 5-psi steam system that supplies heat for feed water for both boilers. Some boiler feed water is condensate from the turbine for the 7500-kW generator but most feed water is make-up feed.

2.2 ONSITE ELECTRIC GENERATION EVOLUTION

The Kingsport mill is the smaller of two Mead paper mills that produce electricity onsite. Mead-Kingsport cogenerated an average of 123.5 million

*Black liquor is a residue left when the pulp fibers are removed from wood that has been chemically treated and liquefied. The Black Liquor residue is composed of combustible wood organic matter, water, and chemicals.

kWh per year for the 1975 to 1978 period and met about 65% of their total electrical requirements. This electrical production amounts to about 1% of all the onsite power produced by paper mills in the U.S. Mead-Kingsport purchases of power account for about 1/4 of one percent of all electrical power purchased by paper mills.

Over the years up to 1970, Mead-Kingsport purchased very little power even though it appears that they had a tie with the Kingsport Power Company at least since the 1930s. In 1970, with the removal from service of paper machine Nos. 1 and 2, requirements for low-pressure process steam diminished greatly. Additionally, the reduction in steam consumption due to the energy conservation measures that accompanied higher fuel prices in the 1970s has reduced the amount of electricity that can be economically produced through cogeneration. Consequently, nearly 40% of Mead's electricity is now supplied from purchased power.

Before 1937 Mead-Kingsport operated on 150-psi steam, which powered both steam driven turbine generators and steam driven paper machines. Mead had two turbine generators during this early period and both probably had extraction points at 40-psi that exhausted to condensers.

In 1937 a new 400-psi steam system was installed, consisting of three new 400-psi boilers and two turbine generators, which increased the plant's electric generating capacity by 7500-kW. Mead also added two new paper machines, one electric drive and one steam drive, which greatly increased their productive capacity. With this mix of electric generation capacity and steam- and electric-drive paper machines, Mead was able to maintain an appropriate balance between these needs so as to take advantage of cogeneration.

Between 1938 and 1948 their needs for electricity grew and the old 150-psi boilers became less and less efficient relative to the higher pressure and temperature steam boiler equipment that was becoming available. The decreasing supply of chemicals used in papermaking made it increasingly economical to burn black liquor and recover the chemicals dissolved in it as well as to capture the heat it contained. In 1948 a black liquor boiler that operated at 900-psi was installed. During this period Mead-Kingsport also tried to install an additional turbine generator set they already owned but could not use elsewhere. Because of technical problems that arose, however, the unit was ultimately removed from the Kingsport mill.

In 1952 another 900 psi-boiler was installed, followed shortly by the installation in 1954 of a new 7500-kW turbine generator that operated at inlet pressure of 900-psi. At this time fuel was cheap and it was still economical for Mead to make electricity even when sizeable amounts of condensing was required. Therefore, the new 7500-kW turbine generator exhausted to a condenser and extracted as well at 150-psi (the pressure at which the old boilers produced steam). At this time 150-psi steam was in great demand to drive the three steam driven paper machines then in service.

The new 900-psi steam system enabled Mead to reduce usage of the old inefficient 150-psi boilers and old 150-psi inlet turbine generator sets while increasing power generation efficiency.

In the early 1960s the production capacity at the Kingsport operation was increased again. At that time the plant was producing about 320 tons of paper per day. It was decided to add a large new 200-ton-per-day paper machine and it was determined that given the existing electrical requirements plus its electrical and steam requirements, the best approach would be to add a new large 900-psi steam generator, a new 12,500-kW noncondensing turbine generator, and a steam turbine drive paper machine with a steam turbine drive vacuum pump. In addition, a new electrical system (13.8 kV) was needed for the new paper machine and new turbine generator. In 1965 and 1966 all of this new equipment was installed, and the plant was able to continue to operate with a relatively good balance between steam and electrical needs so that little power had to be purchased.

In 1970 Mead stopped using its oldest paper machines and instead increased usage of its newest machines. Since the new machines were much more energy efficient, requirements for process steam declined. This decline plus rapidly increasing fuel prices made it uneconomical to make electricity using the condensing stages of the two remaining turbine generators that had condensers. Thus, beginning in 1970 the plant began purchasing more electricity than it ever had in the past.

In the future it is likely that the plant will continue to increase its purchase of power. This will happen as Mead further reduces, through conservation, its process steam usage and as ways are found to reduce the usage of the 7500-kW condensing turbine that is used a great deal and has such a detrimental effect on the economics of its electric generation operation.

This trend could be reduced by going to a higher pressure steam system and electric generators and, possibly, to gas turbines if Mead found it economical to use them in their electric generation equipment mix. It is unlikely, however, that gas turbines with their requirement for expensive liquid and gas fuels would ever be economical at Kingsport without sharply higher coal prices or perhaps an environmental restriction that increased the cost of using coal so as to make oil and gas fuels more cost competitive with coal.

3 COGENERATION AT MEAD

There are three outputs of the cogeneration system at Mead. These are: (1) process steam generated to meet the thermal requirements of the mill's different paper making processes; (2) mechanical power used directly to drive paper machines and powerhouse auxiliaries; and (3) onsite generated electricity. (Approximately 63% of total electrical requirements are met through onsite electrical generation with the other 37% being met through purchases from the Kingsport Power Company.)

Cogeneration at Mead is discussed in two sections: The first, provides a description of the equipment used and the manner by which process steam, mechanical power and electricity are generated. The relationship among the outputs is also discussed. The second, describes the performance and reliability of cogeneration in providing these outputs.

3.1 COGENERATION EQUIPMENT, PROCESSES AND OUTPUTS

3.1.1 Description of Equipment

A schematic of the cogeneration system is shown in Fig. 3.1.*. The major components of the system are: boilers, steam turbine generators (TGs) for electricity, and steam turbine drives for paper machines and powerhouse auxiliaries.

The system consists of six boilers (five of which burn coal and by-product black liquor), four turbine-generator sets (only two are heavily used), and steam driven paper machines and auxiliaries. Boiler capacity is 790,000 lb/hr and the total electrical generating capacity is 27,500-kW. The steam drives for the paper machines have a total rated output of about 5,000 hp.**

Three of the boilers generate steam at 900-psi with the black liquor boiler generating steam at 750°F and boilers No. 6 and 7 at 800 and 850°F, respectively. Boilers No. 3, 4, and 5 generate 400-psi steam at 625°F and are very rarely used (see Fig. 3.1). The technical specifications of the boilers are provided in Table 3.1.*

Turbine generators No. 6 and No. 7 are driven by the 900-psi steam generated by the No. 6, No. 7, and recovery boilers and extract steam at 150 and 400-psi, respectively. Turbine generator No. 6 exhausts into a condenser and TG No. 7 exhausts at 40-psi. Turbine generator No. 4 is driven by 400-psi steam, extracts at 150, and exhausts at 40. Turbine generator No. 3 is driven by 400-psi steam, extracts at 40, and exhausts to a condenser (see Fig. 3.1). The characteristics of the TGs are listed in Table 3.2.

For paper machines Nos. 3 and 5 (see Fig. 3.1), the steam drives are driven by the 400-psi steam and exhaust into the 40-psi header; for the

*This does not include the powerhouse auxiliaries that have a total rated output of about 3000 hp for normally running machines. Additional auxiliaries exist to provide back-up capacity.

Fig. 3.1 Schematic of the Cogeneration System at Mead

Table 3.1 Characteristics of Boilers at Mead

Boiler No.	No. 3	No. 4	No. 5	No. 6	No. 7	Recovery
Manufacturer	Babcox & Wilcox	Babcox & Wilcox	Babcox & Wilcox	Babcox & Wilcox	Combustion Engineering	Babcox & Wilcox
Capacity ((lb/hr)	75,000	75,000	75,000	150,000	300,000	115,000
Pressure (psi)	400	400	400	900	900	900
Temperature (^o F)	625	625	625	800	850	750
Feedwater Temp. (^o F)	275	275	275	350	350	285
Fuel Type	Pulverized Coal	Pulverized Coal	Pulverized Coal	Pulverized Coal	Pulverized Coal	Black Liquor
Date of First Use	1937	1937	1937	1952	1966	1948
	Rarely Used	Rarely Used	Rarely Used			

Table 3.2 Characteristics of Turbine Generators at Mead

Turbine Generator No.	No. 3	No. 4	No. 6	No. 7
Manufacturer	General Electric	General Electric	General Electric	Westinghouse
Capacity (kW)	2,500	5,000	7,500	12,500
Date of First Use	1938	1937	1954	1966
<u>Steam Inlet</u>				
Temperature (^o F)	650	650	800	800
Pressure (psi)	400	400	900	900
Flow Rate (lb/hr) ^a	Uncertain	200,000	160,000	530,000
<u>Steam Extraction</u>				
Temperature (^o F)	Uncertain	520	520	650
Pressure (psi)	40	150	150	400
Flow Rate (lb/hr) ^a	Uncertain	180,000	140,000	518,000
<u>Steam Exhaust</u>				
Temperature (^o F)	80	350	80	350
Pressure (psi)	Condensing	40	Condensing	40
Flow Rate (lb/hr) ^a	Uncertain	75,000	60,000	168,000

^a Maximum

powerhouse auxiliaries, the steam drives driven by 400-psi steam, exhaust into the 150- and 40-psi headers and those driven by 150-psi steam, exhaust into the 40- and 5-psi headers (see Fig. 3.1).

3.1.2 Description of the Cogeneration Process

The cogeneration system at Mead is designed to meet the thermal demands of the industrial process, the mechanical power requirements of the steam driven paper machines and boilerhouse auxiliaries, and a portion of the plant's electrical requirements. The generation of process steam is described first, followed by a description of the generation of mechanical power and electricity.

Process Steam: Process steam for the paper mill is provided at 400, 150, and 40 psi. (Five-psi steam is also provided and used in the boilerhouse to heat feed water.) Steam is provided at 400 psi from the extraction point of TG No. 7 and at 150 psi from the extraction points of TGs No. 4 and No. 6. Steam is provided at 40 psi from the exhausts of TGs No. 4 and 7, the paper machine steam drives, and the powerhouse auxiliaries (see Fig. 3.1). When the 900-psi steam generated by the boilers is passed through the TG sets, its pressure is reduced and it is extracted/exhausted at 400, 150 and 40 psi. Similarly, steam entering the paper machine steam drives and powerhouse auxiliaries has its pressure reduced to 40 and 5 psi. The steam driven machines and TGs serve as pressure-reducing stations in the supply of process steam.

Mechanical Power: Mechanical power is required to drive two of the mill's four paper machines. The other paper machines are electrically powered. Steam from the 400-psi header drives the steam driven paper machines and exhausts at 40 psi (see Fig. 3.1). Steam exhausted from these machines provides a portion of the steam required for the heat-consuming paper making processes.

Electricity: The factors governing the production of electricity are more complex than those governing the production of process steam and mechanical power. There are two separate electrical systems at Mead -- one at 13,800 and the other at 4160 volts. Turbine generator No. 7 generates electricity for the 13,800-volt system, and TGs Nos. 4 and 6 generate electricity for the 4160-volt system. All of the 400-psi steam and part of the 40-psi steam (the exhausts of the steam driven paper machines and auxiliaries plus the exhaust of TG No. 4 provide the remainder of the 40-psi steam) is provided by the extraction and exhaust points of TG No. 7. Electricity is generated when the pressure of the steam produced by the 900-psi boilers is reduced to process requirement levels of 400, 150 and 40 psi. The remainder of the electricity required at 13,800 volts is obtained by stepping down the 34,500-volt supply from the utility to 13,800 volts. On the other hand, because of capacity limitations in the 34,500- to 4160-volt transformer, a large portion of the 4160-volt electricity supply must be generated by TG No. 6. Since a limited amount of electricity can be generated when the pressure of the steam at 900-psi is reduced to the 150-psi level required for process, the remaining required 4160-volt electricity has to be generated through condensing. Turbine generator No. 4 is operated when the steam requirements

at 40 psi exceed those that can be provided by the exhaust of TG No. 7 and the exhausts of the steam driven machines (see Fig. 3.1).

3.2 PERFORMANCE AND RELIABILITY OF THE COGENERATION SYSTEM

In this section, a discussion of the performance and the reliability of Mead's cogeneration system is presented. The supply of process steam is discussed first, followed by a discussion of the generation of mechanical power and electricity.

Process Steam: Process steam is required at 400, 150, and 40 psi. Steam is generated by the boilers and expanded through the turbine generator (TG), paper machine, and auxiliary drives to provide needed process steam. The reliability of supply of process steam therefore depends in turn on the operation reliability of the boilers, TGs and other steam drivers. However, even if this equipment were not available, pressure reducing desuperheating stations would be used to supply the required lower pressure steam.

- Boilers: There are six boilers at Mead with a total generating capacity of 790,000 lb/hr. Currently, only three of the boilers (total generating capacity of 565,000 lb/hr at 900-psi) are in use. Peak demand for process steam usually never exceeds 500,000 lb/hr and if one of the boilers at 900 psi is out of commission the 400-psi boilers would have to be put into service (see Fig. 3.1).
- Turbine Generators: There are four turbine generators (TGs) at Mead, one of them (unit No. 4) being only partially used and another (unit No. 3), nearly never used. If TG No. 7 is out of commission, the 400-psi steam has to be provided directly by the 400-psi boilers (see Fig. 3.1), and process steam needs at 40-psi would then have to be provided by the exhaust of No. 4. If TG No. 6 is out of commission, the 150-psi steam would have to be provided from the extraction of No. 4. Since No. 4 is used to back up the 40-psi steam supply of No. 7, its operation can be essential to insure a sufficient supply of 40-psi steam.
- Steam Driven Machines: Part of the process steam requirements are met by the exhausts of the steam driven machines. These steam drives are individually much smaller than the turbine generator drives and do not pose a serious threat to steam supply reliability.

Mechanical Power: Mechanical power is generated at Mead to drive the paper machines and the powerhouse auxiliaries. Steam turbine drives are very reliable and seldom go out of service without plenty of warning, being generally considered more reliable than electrical drives.

Electricity: Onsite electric generation provides approximately 60% of the total electrical requirements of Mead, the remaining 40% being met through electricity purchases from the Kingsport Power Company.

There are three generally used turbine generators at Mead with individual generating capacities of 5000, 7500, and 12,500 kW, providing a generating capacity of 25,000 kW. In addition, up to 15,000 kW of capacity can be purchased from the Kingsport Power Company. Thus, a maximum of 40,000 kW can be provided to the plant; and since peak electrical demand usually never exceeds 26,000 kW, an ample supply of electricity is readily available. The onsite generating capacity of 25,000 kW cannot, in itself, meet the peak electric demand. In the event of an outage of the tie-line from the utility, certain plant operations would usually have to be curtailed to reduce demand.

Because there are two separate systems -- 13,800 and 4160 volts -- electrical supply to two systems must be assured. Supply at 13,800 volts comes from two sources -- from TG No. 7 and from the utility (through a transformer). The 4160-volt supply is provided by TGs Nos. 6 and 4, and through a transformer from Kingsport Power, but because of transformer-capacity limitations on the utility tie, more power is often generated by TG No. 6 (through condensing) than would be desirable if it were possible to purchase more. However, because of the expense to Mead of having Kingsport Power add additional transformer capacity, no action has been taken to increase Mead's ability to purchase 4160-volt power.

4 THE ECONOMIC AND ENERGY EFFICIENCY OF COGENERATION AT MEAD

In this chapter, the economic and energy efficiency characteristics of Mead-Kingsport are evaluated by comparing the dollar costs and fuel usage of electric generation onsite at Mead with those of a hypothetical alternative in which all the power they use is purchased from the Kingsport Power Company.

The evaluation was performed by determining the actual costs and associated fuel usage of both onsite generation and purchased power for the four-year period 1975 through 1978. The evaluation is presented in four sections:

- The first section shows the costs and fuel consumption associated with onsite electric generation.
- The second, presents the costs and fuel consumption associated with the purchased power alternative.
- The third, compares the costs and fuel consumption of onsite generation with those of purchased power.
- The fourth, makes a second comparison between the costs and fuel consumption of onsite generation with those of purchased power. This second comparison uses capital costs that have been adjusted to reflect the costs that would have to be charged to onsite generation if the capital equipment required for electric generation had been purchased in 1973. (This was done in order to provide an estimate of the costs of onsite generation that are reflective of more recent capital equipment costs, allowing for more timely comparisons.)

4.1 ONSITE ELECTRIC GENERATION

The costs and the fuel consumption associated with onsite electricity generation are presented in this subsection.

Detailed monthly data were obtained from the accounting records of Mead, from which monthly costs and fuel consumption of onsite generation were computed. The costs were aggregated to yield annual totals for the years 1975 through 1978.

4.1.1 Onsite Electric Generation Fuel Consumption

Fuel consumption for onsite generation was calculated in the following manner* (see Table 4.1).

*Tables appear consecutively at the end of this section.

- First, the quantity of electricity generated (in kWh), by each of the three turbine generators (TGs), in each of the years 1975 through 1978, was obtained from the Mead records.
- Second, the fuel-to-electricity heat rate in Btu/kWh, (the quantity of fuel required to generate one kWh of electricity) was determined for each TG.
- Third, the quantity of electricity generated (in kWh) by each TG was multiplied by the corresponding heat rate (in Btu/kWh) to yield the fuel consumed (in Btu) by each TG.
- Fourth, the fuel consumption of the TGs was summed to yield the total fuel consumption for electric generation.

The onsite electrical generation system at Mead consists of two non-condensing and one condensing TG.* The heat rates of the noncondensing generators were estimated to be 4330 Btu/kWh (based upon boiler efficiencies of 83% and TG efficiencies of 95%). The average heat rate of the condensing TG (#6) varied annually, depending upon the quantity of electricity generated using condensing and averaged about 11,400 Btu/kWh. The composite heat rate for the onsite generation system averaged approximately 7032 Btu/kWh (see Table 4.1). (It must be noted at this point, that electricity can be generated onsite for 4330 Btu/kWh only when noncondensing TGs are used.). Thus, the use of a condensing TG results in an average additional fuel consumption of 2702 Btu for each kWh generated, which is an increase of 60% over the fuel consumption of a system that consists of only noncondensing TGs. This additional fuel consumption results in large additional fuel costs, which are discussed below.

The data on fuel consumption shows that:

- Between 1975 and 1978, fuel consumption for onsite electric generation amounted to almost 3474 billion Btu, with consumption averaging 869 billion Btu annually (see Table 4.1).
- Yearly fuel consumption for onsite electric generation varied little between 1975 and 1978 (Table 4.1).
- The decline in the quantity of electricity generated is primarily a result of the reduction in the quantity of steam generated, which in turn is a result of the reduction in demand for process steam (see Table 4.2). The reduction in process steam demand is a consequence of the energy-conservation program at Mead.

*Another old turbine generator is installed but is never used.

4.1.2 Onsite Electric Generation Costs

The costs of onsite electrical generation are provided in this section. An overview of the total costs will be presented first, followed by a detailed discussion of the three components of total costs: fuel costs, operating and maintenance costs, and capital costs.

A review of onsite generation costs shows that:

- Onsite electric generation cost Mead an average of 12.1 mills/kWh (see Table 4.3) or \$1,498,000 per year. Of this amount \$909,000 (61%) was for fuel, \$433,000 (29%) was for operation and maintenance of the electrical generating equipment, and \$156,000 (10%) was estimated for capital payments.
- The unit cost of generating electricity decreased from 12.6 mills/kWh in 1975 to 10.5 in 1976, and then increased to 13.7 in 1978 (see Table 4.3). This variation in the unit cost of electricity was primarily due to fluctuating coal costs (Table 4.3).

4.1.2.1 Onsite Electric Generation Fuel Costs

Fuel costs account for approximately 60% of the total costs of onsite electric generation. Fuel costs and methodology of determining fuel costs are described in this subsection.

Fuel costs were calculated in the following manner (data are given in Table 4.4):

- First, the fuel consumption (in Btu) was calculated for electric generation (see Section 4.1).
- Second, the unit cost of coal (in dollars per Btu) was obtained from the accounting records of Mead.
- Third, the fuel consumption (in Btu) was multiplied by the unit cost of coal (in dollars per Btu) to yield the fuel cost of onsite electric generation.

A review of the fuel costs reveals that:

- Fuel expenditures were 61% of the costs of onsite generation and averaged approximately \$909,000 over the studied four-year period (Tables 4.3 and 4.4).
- Fuel costs consumed 7.4 mills of the 12.1 mills/kWh cost generated onsite (Tables 4.3 and 4.4).

- Fuel costs decreased from \$983,000 in 1975 to \$754,000 in 1976, and then increased to \$1,005,000 in 1978. The variation in fuel costs is a result of fluctuating coal prices during the years immediately following the Arab oil embargo and large OPEC price increases.

A large portion (about 37%) of the total fuel cost comes from generating electricity through condensing. If noncondensing TGs had been employed exclusively, the fuel costs would have been greatly reduced.

4.1.2.2 Onsite Electric Generation Operation and Maintenance Costs

The operating and maintenance costs for onsite electrical generation provided in this section accounted for approximately 29% of its total cost.

The data on operating and maintenance costs obtained from the accounting records of Mead showed considerable monthly variation. These fluctuations were attributable to accounting procedures and large periodic maintenance expenditures. Since the benefit of large maintenance operations extend into periods other than those in which they were performed, operation and maintenance costs were averaged over the entire four-year period studied with variations in cost attributable only to inflation.

Annual expenditures for the labor and materials required for the operation and maintenance of the electric equipment were deflated to a common base (1975 dollars) through the application of GNP deflators. The annual expenditures (in constant 1975 dollars) were then summed to yield a total expenditure for the four-year period under consideration, from which an average annual expenditure was then obtained. These expenditures were then inflated (using GNP inflators) to yield a current dollar yearly expenditure for the years 1975 through 1978.

The data on operating and maintenance cost show that:

- Operating and maintenance costs account for 29% of the expenses for onsite generation and averaged approximately \$433,000 per year. Of the 12.1 mills/kWh spent for onsite generation, 3.6 were spent on equipment operation and maintenance. (See Tables 4.3 and 4.5).
- Of the 433,000 spent on the operation and maintenance of the electric generating equipment each year, \$243,000 (56%) was spent on equipment operation and the remaining 44% on equipment maintenance (see Table 4.5).

4.1.2.3 Onsite Electric Generation Capital Costs

Capital costs are the third cost element of onsite generation and account for 10% of total costs. Capital costs are low because the equipment used was for the most part acquired many years ago and has been almost fully depreciated.

Annual capital costs were calculated in the following manner:

- First, capital costs were estimated, by engineering consultants* to this project, for a facility with an onsite generation capability equivalent to that of Mead's Kingsport plant at \$8,758,000 in 1980 dollars (the incremental cost of the electric generation plant).
- Second, capital expenditures were determined as if the facility had been constructed in 1957, based on the actual age and cost of the different parts of the plant. The 1957 (current dollar) construction cost was obtained by deflating the costs (in 1980 dollars) to 1957 by applying dollar deflators obtained from the U.S. Department of Commerce, and was estimated to be about \$3,293,000.
- Third, annual capital costs for 1975 through 1978 were determined using an interest rate of 4% and an annual rate of depreciation of 3-1/3%. (The equipment was assumed to have a useful life of 30 years and was depreciated on a straight-line basis). The 4% interest rate is approximately what Mead paid for bond money in the 1950s.

The results are given in Table 4.6. The data show that capital costs account for only about 10% of the costs of onsite electric generation and averaged about \$156,000 per year. Of the 12.1 mills/kWh average cost for onsite electric generation, 1.3 were for capital changes (see Tables 4.3 and 4.6).

4.2 PURCHASED POWER ALTERNATIVE

The preceding section shows the costs and energy consumption associated with onsite electrical generation. In order to evaluate the energy-saving and economic advantages of onsite generation, these costs must be compared with the alternative under which electricity is purchased from the local utility. In this section, the energy consumption and costs associated with purchasing electricity under the hypothetical situation, hereafter referred to as the purchased power alternative, are presented. In the next section the economic and energy saving aspects of onsite generation are compared with that alternative.

4.2.1 Purchased Power Alternative Fuel Consumption

Fuel consumption under the purchased power alternative is discussed in this subsection. Data on fuel consumption, shown in Table 4.7, were determined in the following manner:

*The engineering consultants were Gilbert Commonwealth Associates of Jackson, Michigan.

- First, the quantity of electricity generated at Mead (in kWh) in each of the years 1975 through 1978 was obtained (see Section 4.1.1). Under the purchased power alternative, equivalent amounts are purchased from the Kingsport Power Company.
- Second, the heat rate in Btu/kWh (the quantity in Btu of fuel required to generate one kWh of electricity using baseload equipment) was calculated from data obtained from the annual reports submitted to FERC by the Appalachian Power Company.* The method of calculating the heat rate is discussed below.
- Third, the heat rate (in Btu/kWh) was multiplied by the quantity of electricity generated (in kWh) onsite, to yield the fuel (in Btu) that would have been consumed by the utility in replacing the electricity generated onsite.
- Fourth, the energy consumed for electric generation was apportioned by fuel type, based upon the fuel consumption profile of Appalachian Power Company's baseloaded plants. The method of apportionment is discussed below.

The heat rate and fuel distribution were calculated as follows:

- The plants of the Appalachian Power Company that were base-loaded are identified.
- Their heat rates (in Btu/kWh) and fuel consumption by type (in Btu) are identified.
- A weighted average of the heat rate (in Btu/kWh) is then obtained.
- The fuel consumption (in Btu) under the purchased power alternative is determined by simply multiplying the heat rate (in Btu/kWh) by the quantity of electricity generated (in kWh).
- The fuel distribution is obtained by apportioning energy consumption according to the actual fuel usage of the baseloaded plants.

The heat rates for baseloaded plants were selected because Mead's demand profile from the Kingsport Power Company (and Appalachian Power Company) would have been relatively flat, and, consequently, it was assumed the Mead demand would have been served from baseloaded facilities that would essentially have been dedicated to Mead. Heat rates were adjusted to reflect line losses of 8%.

*The Kingsport Power Company has no generation facilities of its own. It purchases the electricity it sells from the Appalachian Power Company, whose fuel consumption profile is therefore used.

The data on energy consumption of the purchased power alternative show that:

- Between 1975 and 1978, fuel consumption by Appalachian Power for generation of Mead's electricity would have amounted to 5747 billion Btu, with consumption averaging 1449 annually (see Table 4.7). By contrast, energy consumption for onsite generation averaged about 869 billion Btu annually. (A comparison between onsite generation and the purchased power alternative is made in the next section).
- The average annual heat rate for the purchased power alternative would have been 11,735 Btu/kWh. On the other hand, the average annual heat rate for onsite generation was 7032, which is only 60% of the purchased power alternative. Thus, it readily can be seen that onsite generation is significantly more energy efficient (Tables 4.1 and 4.7).
- Of the average 1449 billion Btu consumed by the utility each year for Mead's power under the purchased power alternative, 1437 (99%) are from coal, and 13 billion Btu (1%) are from fuel oil (Table 4.7).

4.2.2 Purchased Power Alternative Costs to Mead

In order to evaluate the economics of onsite generation, its cost must be compared with the cost of electricity under the purchased power alternative. The method of obtaining this cost is described first and results, next. The economic comparison is made in the next section. It is important to realize that the cost to Mead is based on purchased power prices rather than utility costs. Since the Kingsport Power Company and Appalachian Power Company do not price electricity based on marginal costs, Mead's costs are not the economic costs of the power.

Mead normally meets its electricity requirements partly through onsite generation and partly through purchases from the Kingsport Power Company. Under the purchased power alternative, Mead would purchase all of its electricity from Kingsport Power Company. Therefore, the incremental cost of the purchased power alternative -- the cost of purchasing an amount equivalent to the quantity of electricity generated onsite -- is the difference between the cost of meeting total electricity consumption and the cost of electricity currently being purchased. The cost of electricity under the purchased power alternative was calculated as follows (data is shown in Table 4.8):

1. An electric bill for purchasing all electricity used was calculated, as described later.
2. The cost of electricity currently purchased was obtained from the accounting records of Mead.

3. The incremental cost of electricity under the purchased power alternative was obtained by subtracting the cost of electricity currently purchased from the bill that was calculated as if all power used were purchased.

The electric bill for Mead's total consumption was calculated with the aid of rate schedules obtained from the Kingsport Power Company.

There are four separate charges for purchases of electricity under the billing system of the Kingsport Power Company. These are demand, energy, fuel adjustment, and facilities charges.

The demand charges are based on the maximum rate of flow of electricity (i.e., maximum kilowatt draw on the line) at any time; the energy charges on the total consumption (kilowatt-hours) of electricity; and the fuel adjustment charge, upon actual fuel cost deviation from expected fuel costs.

The demand charge is effectively the charge for the peak electrical consumption at Mead. Based on conversations with plant engineers at Mead, it was determined that the actual peak draw of the Mead Mill is about 26,000 kW, which has been relatively constant for the four years studied. The demand and energy charges were then calculated through the application of the demand and energy rates obtained from the rate schedules of the Kingsport Power Company for the years 1975-1978.

The fuel adjustment charges were calculated by simply multiplying the fuel adjustment rate by the total kilowatt hour consumption for each of the 48 studied months.

The facilities charge was a credit since Mead owns all of the equipment required for purchase of electricity.

The demand and energy, fuel adjustment, and facilities charges were summed to yield a total charge for electrical consumption at Mead.

An examination of the incremental costs of electricity under the purchased power alternative show that:

- Between 1975 and 1978, Mead would have purchased electricity under the hypothetical alternative for an average annual unit cost of 19.3 mills/kWh (see Table 4.8). During the same period Mead actually generated electricity at a cost of 12.2 mills/kWh. (A detailed economic comparison between onsite generation and the purchased power alternative is shown in the next section.)
- The unit cost of purchased electricity rose from 16.5 mills/kWh in 1975 to 23.5 mills/kWh in 1978, an increase of 42% (see Table 4.8).
- Between 1975 and 1978, Mead would have had to pay a total of \$9.5 million for 494 million kWh, or about \$2.4 million annually.

4.3 COMPARISON OF ONSITE GENERATION WITH THE PURCHASED POWER ALTERNATIVE

An evaluation of the cost and energy-saving effectiveness of onsite generation is made in this section. The actual costs and energy consumption associated with onsite generation are compared with those under the hypothetical situation where electricity is purchased from the Kingsport Power Company. Both of these situations were discussed individually in the preceding sections. Energy consumption and costs are compared below.

4.3.1 Energy Consumption of Onsite Generation Compared with the Purchased Power Alternative

A comparison of the energy consumption associated with onsite electrical generation with energy consumption under the purchased power alternative shows:

- Fuel consumption (in Btu) for electric generation under the alternative is more than one and a half times that of onsite generation. Mead consumed an average of 869 billion Btu each year to generate 123.5 million kWh and purchasing power would have resulted in 1449 billion Btu to generate an equivalent quantity of electricity (see Table 4.9).
- The difference in energy consumption between onsite generation and the purchased power alternative is a result of the difference between their respective heat rates. Electricity was generated at Mead for 7,032 Btu/kWh. Utility generated electricity had an average heat rate of 11,735 Btu/kWh (see Tables 4.1 and 4.7). The difference in heat rates arises from the fact that the utility generates its electricity through condensing, which results in the latent heat of vaporization in the steam being discarded. Onsite generation, by contrast, uses much of the latent heat of vaporization for process purposes, with some latent heat being discarded when electricity is generated through condensing. (It must be noted here that despite the considerable energy savings being realized through onsite generation (4703 Btu/kWh), its full energy-saving potential is not realized at Mead. The plant could realize savings of 7400 Btu/kWh if no heat was thrown away through condensing; however, fewer kWh would have to be generated.
- For the four years studied, onsite generation resulted in savings of 568 billion Btu of coal fuel, and 13 billion of oil, for a total cogeneration savings of 580 billion.

4.3.2 Comparison of the Costs of Onsite Generation with the Purchased Power Alternative

A comparison of these costs shows that:

- Under the purchased power alternative, Mead would have had to pay an average of about 7.2 mills/kWh more for electricity. Between 1975 and 1978 Mead generated electricity onsite for about 12.1 mills/kWh. If it had purchased the electricity from the Kingsport Power Company, it would have had to pay about 19.3 mills/kWh, a 60% higher cost (see Table 4.10).
- Between 1975 and 1978, the annual savings of onsite electric generation increased from 3.9 mills/kWh in 1975 to 9.8 in 1978. The increase in the savings on onsite generation is probably a result of the increased cost of coal to the utility generator. Since utility generated electricity is more fuel intensive than cogenerated electricity, its cost for power is more sensitive to the cost of fuel.
- The constant dollar rate of return of onsite electric generation increased from 18% in 1975 to 51% in 1978 (see Table 4.11). The rapid rise and the magnitude of the rate of return is a result of the vintage of the electric generating equipment. The book value of the equipment is small, and the return is relatively high. Moreover, as the equipment approaches the end of its life, debt service approaches zero rapidly.

It is evident that the onsite generation of electricity has proved to be economical for Mead. A major reason for its present attractiveness lies in the fact that the capital costs are very small because of the vintage of the generating equipment. In order to examine its economic effectiveness today, the costs incurred by a relatively newer facility must be analyzed and compared with the costs of purchasing electricity. The cost of generating electricity at a hypothetical new (1973) facility is analyzed in the next section.

4.4 COMPARISON OF THE COSTS OF ONSITE GENERATION AT A HYPOTHETICAL NEW FACILITY WITH THE PURCHASED POWER ALTERNATIVE

In this section, the estimated costs associated with onsite electric generation for a new (1975 start-up) facility are compared with the costs under the hypothetical purchased power alternative. The method of determining the capital costs are discussed first, followed by a comparison of total costs.

The capital costs of onsite generation were determined in the following manner:

1. The cost estimates (in 1980 dollars) of onsite electric generation equipment (referred to earlier), were deflated to 1973 by applying deflators obtained from the U.S. Department of Commerce.*
2. An annual rate of depreciation of three and one-third percent (equipment life of 30 years) was assigned to the equipment.
3. A rate of interest of 7.5% was assigned to the cost of borrowing the capital required for the construction of the facility. The rate of interest is based upon an examination of the rates of interest that Mead pays for the retirement of their long-term debt (obtained from Moody's Industrial Manual).

Capital costs were then added to the fuel, operating, and maintenance costs to yield the cost of onsite generation for a new facility. The results are presented in Table 4.12.

An analysis of the capital costs show that:

- If Mead had installed new electric generating equipment in 1973, electricity would have cost an average of 14.1 mills/kWh for the four-year period (1975 through 1978), a cost that is 17% higher than the current cost of 12.1 mills/kWh (see Tables 4.3 and 4.12).
- Capital costs for a new facility average approximately \$416,000 each year. On the other hand, capital costs for the current facility average about \$156,000 per year (see Tables 4.6 and 4.12).

A comparison of the costs for onsite electric generation with the costs of the purchased power alternative show that:

- Under the alternative, Mead would have to pay an average of 5.1 mills/kWh more each year for electricity. Between 1975 and 1978, Mead would have generated electricity onsite at a new facility for an average annual cost of about 14.2 mills/kWh. If it had purchased the electricity from the Kingsport Power Company, it would have had to pay an average of 19.3 mills/kWh, at a 36% higher cost (see Table 4.13).
- The constant dollar rate of return of newly provided onsite electrical generation ranged from 4-19% between 1975 and 1978. This rate of return, while still positive, is not as high as the rate of return (18-51%)

*U.S. Department of Commerce, Industry and Trade Administration, Construction Review; Table E-1. - Construction Cost Indexes, column entitled "Electric Light and Power," May, 1979.

on the actual capital investment (with equipment age centroid of 17-21 years) at Mead because of the relatively recent acquisition of the equipment (Tables 4.11 and 4.14).

From the above, it is evident that three factors -- fuel, capital, and purchased electricity costs -- play a major role in the economics of onsite electrical generation. All three can be expected to rise in the future, but the manner in which they rise relative to each other will determine the relative economics of onsite generation.

Table 4.1 Mead Onsite Electric Generation Fuel Consumption

Year	On-Site Generation	Fuel-to-Electricity Heat Rate	Fuel Consumption	
	(kWh, thousands)	(Btu/kWh)	(Btu, billions)	(Tons of Coal)
1975	122,162	7187	878	36,583
1976	126,658	6868	870	36,250
1977	125,993	7065	890	37,083
1978	119,195	7016	836	34,833
Total 1975-1978	494,008	7032	3,474	144,750
Annual Average	123,502	7032	869	36,188

Table 4.2 Mead Steam Production and Onsite Electric Generation

Year	<u>On-Site Generation</u>	<u>Steam Production</u>
	(kWh, thousands)	(Pounds, millions)
1975	122,162	3,676
1976	126,658	3,946
1977	125,993	3,863
1978	119,195	3,802
Total 1975-1978	494,008	15,287
Annual Average	123,502	3,057

Table 4.3 Mead Onsite Electrical Generation Total Costs

Year	<u>On-Site Generation</u> (kWh, thousands)	<u>On-Site Electric Generation - Costs</u>				<u>Costs per unit of Electricity Generated</u> (mills/kWh)
		<u>Fuel</u> (dollars, thousands)	<u>Operation and Maintenance</u> (dollars, thousands)	<u>Capital</u> (dollars, thousands)	<u>Total</u> (dollars, thousands)	
1975	122,162	983	397	162	1,542	12.6
1976	126,658	754	418	158	1,330	10.5
1977	125,993	892	443	153	1,488	11.8
1978	119,195	1,005	475	149	1,629	13.7
Totals 1975-1978	494,008	3,634	1,733	622	5,989	12.1
Annual Average	123,502	909	433	156	1,498	12.1

Table 4.4 Onsite Electrical Generation
Fuel Costs

Year	<u>On-Site Generation</u> (kWh, thousands)	<u>Energy Consumption</u> (Btu, Billions)	<u>Unit Cost of Fuel</u> (\$ per Million Btu)	<u>Fuel Cost</u> (dollars, thousands)	<u>Fuel Cost per Unit of Electricity</u> (mills/kWh)
1975	122,162	878	1.119	983	8.0
1976	126,658	870	.867	754	6.0
1977	125,993	890	1.002	892	7.1
1978	119,195	836	1.201	1,005	8.4
Total 1975-1978	494,008	3,474	1.046	3,634	7.4
Annual Average	123,502	869	1.046	909	7.4

Table 4.5 Onsite Electric Generation Operating and Maintenance Costs

Year	<u>On-Site Generation</u>	<u>Operating Costs</u>		<u>Maintenance Costs</u>		<u>Total Costs</u>	<u>Unit Cost</u>
	(kWh, thousands)	Labor	Materials	Labor	Materials	(dollars, thousands)	(mills/kWh)
		(dollars, thousands)		(dollars, thousands)			
1975	122,162	207	16	131	44	397	3.2
1976	126,658	218	16	137	46	418	3.3
1977	125,993	231	17	146	49	443	3.5
1978	119,195	248	19	156	52	475	4.0
Total 1975-1978	494,008	904	68	570	191	1,773	3.6
Annual Average	123,502	226	17	143	48	433	3.6

Table 4.6 Onsite Electrical Generation Capital Costs

Year	<u>On-Site Generation</u>	<u>Capital Costs</u>			<u>Capital Costs Per Unit of Electricity</u>
	(kWh, thousands)	Annual Depreciation	Annual Interest	Total	(mills/kWh)
		(dollars, thousands)			
1975	122,162	110	52	162	1.3
1976	126,658	110	48	158	1.2
1977	125,993	110	43	153	1.2
1978	119,195	110	39	149	1.3
Total 1975-1978	494,008	440	182	622	1.3
Annual Average	123,502	110	46	156	1.3

Table 4.7 Purchased Power Alternative Fuel Consumption

Year	<u>On-Site Generation</u>	<u>Fuel-to- Electricity Heat Rate</u>	<u>Fuel Consumption</u>	<u>Fuel Type</u>	
	(kWh, thousands)	(Btu, kWh)	(Btu, billions)	Coal (Btu, billions)	Oil (Btu, billions)
1975	122,162	11,589	1,416	1,406	10
1976	126,658	11,589	1,468	1,459	9
1977	125,993	11,742	1,479	1,467	12
1978	119,195	12,029	1,434	1,415	19
Total 1975-1978	494,008	11,735	5,797	5,747	50
Annual Average	123,502	11,735	1,449	1,437	13

Table 4.8 Purchased Power Alternative Costs

Year	<u>Electric Consumption</u>			<u>Purchased Power Cost</u>	<u>Cost Of Electricity</u>	<u>Purchased Power Alternative Cost</u>	
	<u>On-Site Generation</u>	<u>Purchased</u>	<u>Total</u>	<u>Of Total Electricity</u>	<u>Actually Purchased</u>	<u>Total Cost</u>	<u>Unit Cost</u>
	(kWh, thousands)	(kWh, thousands)	(kWh, thousands)	(dollars, thousands)	(dollars, thousands)	(dollars, thousands)	(mills/kWh)
1975	122,162	50,232	172,394	2,928	915	2,014	16.5
1976	126,658	66,884	193,542	3,325	1,224	2,101	16.6
1977	125,993	69,912	195,905	4,198	1,584	2,614	20.7
1978	119,195	77,810	196,805	4,711	1,903	2,803	23.5
Total 1975-1978	494,008	264,638	758,646	15,162	5,631	9,532	19.3
Annual Average	123,502	66,160	189,662	3,791	1,403	2,383	19.3

Table 4.9 Fuel Consumption Comparison of Mead Onsite Generation vs Kingsport Power Company Purchased Power Alternative

Year	<u>Electricity Produced</u> (kWh, thousands)	<u>On-Site Generation Fuel Use</u> Coal (Btu, billions)	<u>Purchased Power Alternative Fuel Use</u>			<u>Cogeneration Savings</u>		
			Coal	Oil	Total	Coal	Oil	Total
			(Btu, billions)			(Btu, billions)		
1975	122,162	878	1,406	10	1,416	528	10	538
1976	126,658	870	1,459	9	1,468	589	9	598
1977	125,993	890	1,467	12	1,479	577	12	589
1978	119,195	836	1,415	19	1,434	579	19	598
Total 1975-1978	494,008	3,474	5,747	50	5,797	2,273	50	2,323
Annual Average	123,502	869	1,437	13	1,449	568	13	580

Table 4.10 Cost Comparison of Mead Onsite Generation vs Kingsport Power Company Purchased Power Alternative

Year	<u>Electricity</u>	<u>On-Site Generation</u>		<u>Purchased Power</u>		<u>Cogeneration Savings</u>	
	<u>Produced</u>		<u>Cost</u>	<u>Alternative Cost</u>			
		Total Cost	Unit Cost	Total Cost	Unit Cost	Total Savings	Unit Savings
	(kWh, thousands)	(dollars, thousands)	(mills/ kWh)	(dollars, thousands)	(mills/ kWh)	(dollars, thousands)	(mills/ kWh)
1975	122,162	1,542	12.6	2,014	16.5	472	3.9
1976	126,658	1,330	10.5	2,101	16.6	771	6.1
1977	125,993	1,488	11.8	2,614	20.7	1,126	8.9
1978	119,195	1,629	13.7	2,803	23.5	1,174	9.8
Total 1975-1978	494,008	5,989	12.1	9,532	19.3	3,543	7.2
Annual Average	123,502	1,498	12.1	2,383	19.3	889	7.2

Table 4.11 Rate of Return of Onsite Generation

Year	<u>Book Value</u> <u>of Capital</u>	<u>Savings Due To</u> <u>On-Site Electric</u> <u>Generation</u>	<u>Constant Dollar</u> <u>Rate Of Return</u>
	(thousands of 1957 dollars)	(thousands of 1957 dollars)	(percent)
1975	1,320	241	18
1976	1,210	375	31
1977	1,100	517	47
1978	990	502	51

Table 4.12 Mead Onsite Electrical Generation Total Costs with Capital Costs for a New Facility

Year	<u>On-Site</u> <u>Generation</u>	<u>On-Site Electric Generation - Costs</u>				<u>Costs Per Unit of</u> <u>Electricity Generated</u>
	(kWh, thousands)	Fuel	Operation and Maintenance	Capital	Total	(mills/kWh)
		(dollars, thousands)	(dollars, thousands)	(dollars, thousands)	(dollars, thousands)	
1975	122,162	983	397	431	1,811	14.8
1976	126,658	754	418	421	1,593	12.6
1977	125,993	892	443	410	1,745	13.8
1978	119,195	1,005	475	400	1,880	15.8
Totals 1975-1978	494,008	3,634	1,733	1,662	7,029	14.2
Annual Average	123,502	909	433	416	1,758	14.2

Table 4.13 Cost Comparison of Mead New Facility
Onsite Generation vs Kingsport Power
Company Purchased Power Alternative

Year	<u>Electricity</u>	<u>On-Site Generation</u>		<u>Purchased Power</u>		<u>Cogeneration Savings</u>	
	<u>Produced</u>	<u>Cost</u>		<u>Alternative Cost</u>			
	(kWh, thousands)	Total Cost (dollars, thousands)	Unit Cost (mills/ kWh)	Total Cost (dollars, thousands)	Unit Cost (mills/ kWh)	Total Savings (dollars, thousands)	Unit Savings (mills/ kWh)
1975	122,162	1,811	14.8	2,014	16.5	203	1.7
1976	126,658	1,593	12.6	2,101	16.6	508	4.0
1977	125,993	1,745	13.8	2,614	20.7	869	6.9
1978	119,195	1,880	15.8	2,803	23.5	923	7.7
Total 1975-1978	494,008	7,029	14.2	9,532	19.3	2,503	5.1
Annual Average	123,502	1,758	14.2	2,383	19.3	626	5.1

^aCapital costs are for a hypothetical facility comparable to Mead's with a centroid of construction in 1973 and whose first year of operation is 1975.

Table 4.14 Rate of Return of Onsite Generation
at New Facility

Year	<u>Value of</u>	<u>Savings Due To</u>	<u>Constant Dollar</u>
	<u>Capital</u>	<u>On-Site Electric</u>	<u>Rate Of Return</u>
	(thousands of 1973 dollars)	(thousands of 1973 dollars)	(percent)
1975	3,808	169	4
1976	3,672	402	11
1977	3,536	649	18
1978	3,400	642	19