PROJECT ADMINISTRATION DATA SHEET

project No. A-3663
project Director: Tom F. McGowan
Sponsor: Georgia Office of Energy Resources

Atlanta, GA
Type Agreement: Contract dated 10/1/83 - 44.23
award Period: From 9/1/83 To 12/31/84
This Change
Total to Date
Estimated: $100,000
Funded: $100,000
Cost Sharing Amount: $______
Cost Sharing No:
title: "Solid Fuel Extension Service"

ADMINISTRATIVE DATA
Sponsor Technical Contact: 
OCA Contact: John W. Burdette ext. 4820
2) Sponsor Admin/Contractual Matters:
Phil Whitlow
Georgia Office of Energy Resources
270 Washington St. S.W.
Suite 615
Atlanta, GA 30334

Defense Priority Rating: N/A
Military Security Classification: N/A
(or Company/Industrial Proprietary:

RESTRICTIONS

Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval - Contact OCA in each case. Domestic travel requires sponsor
approval where total will exceed greater of $500 or 125% of approved proposal budget category.

equipment: Title vests with None Proposed.

COMMENTS:

OPIES TO:
Project Director
Procurement/EES Supply Services
GTRI

Research Administrative Network
Research Security Services
Library

Research Property Management
Reports Coordinator (OCA)
Project File
accounting
Research Communications (2)

ORM OCA 4:383
Other NEWTON
Date April 25, 1985

Grant No. A-3663

Title Subproject No.(s) N/A

Principal Investigator(s) Tom T. McGowan

Office, Agency or Sponsor
Georgia Office of Energy Resources
"Solid Fuel Extension Service"

Closeout Completion Date: 12/31/84
(Performance) 12/31/84 (Reports)

Contract Closeout Actions Remaining:

☐ None
☒ Final Invoice or Final Fiscal Report
☐ Closing Documents
☐ Final Report of Inventions
☒ Govt. Property Inventory & Related Certificate—already sent out
☐ Classified Material Certificate
☐ Other

SPOKES Project No. Continued by Project No.

TO:
☒ Director
☒ Library
☒ GTRC
☒ Research Communications (2)
☒ Project File
☒ Other

Jones

Heyser

OCA 69.285
November 11, 1983

Mr. Phil Whitlow
Georgia OER
270 Washington Street
Suite 615
Atlanta, GA 30334

Dear Phil:

Enclosed is our first progress report on the Solid Fuel Extension Project. Our primary work to date is in the producing an inventory of companies which were past recipients of feasibility studies and starting to collect a list of new clients. Major planning will take place in November.

Please call me at 894-3636 if you have any questions.

Sincerely,

Thomas F. McGowan
Chief, Energy Technology Branch

TFM/pk

Enclosure
Progress Report
Solid Fuel Extension Service
Project A-3663

September and October 1983

The primary task for the two months was contacting past clients who had received wood energy feasibility studies and developing a preliminary list of new clients.

The recipients of the DOE funded feasibility studies were contacted by phone to update their current status. Of the 25 contacted, 12 are interested in or actively pursuing the installation wood or coal fired equipment. The remainder were not interested or could not be contacted (some are out of business).

A total of 6 new clients have been found as a result of a memo on the project sent to Georgia Tech's IEES Branch and EES field offices. The companies included manufacturers of tires, brick, furniture, and textiles.

As part of the liaison function of the project, Bill Bulpitt and Tom McGowan met with Markus Fritz of the University of Georgia. He is in charge of an international biomass conference scheduled for May 21-25, 1984 in Athens, Georgia. We reviewed his current plans, offered suggestions, and provided mailing lists of potential speakers and attendees.

Final planning for the project will take place in early November. Critical planning elements are prioritization of clients and preparation of materials for maximum efficiency to produce the greatest number of feasibility studies at minimum cost.

Current concepts include screening via phone calls to eliminate plants with small heat loads, insufficient operating hours per year, lack of fuel storage space, and lack of capital. Candidates which look promising will then be provided with a feasibility study of solid fuel use at their site. We plan to prepare a standard package and presentation for use with all clients, plus a brief study specific to their plant.

Personnel allocation and final budgeting and scheduling will also take place in November.
Budget

Expenditures for September and October 1983, total $7,380.07 or 7.4% of the total budget. Time expended is 2 months or 17%, hence we are currently under-spending our budget.
December 16, 1983

Mr. Phil Whitlow  
Georgia OER  
270 Washington Street  
Suite 615  
Atlanta, GA  30334

Subject: Project A-3663, Solid Fuel Extension Service

Dear Phil:

The November progress report for our project on Industrial Solid Fuels is enclosed. Planning continued to take place, as well as limited contact with industrial sponsors. We expect to complete planning in December and start field visits in January.

Sincerely,

Thomas F. McGowan  
Chief, Energy Technology Branch

TFM/pk

Enclosure
Several planning meetings were held to discuss past efforts in aiding industry to make the transition to solid fuel and apply these experiences to this project. Some of the topics discussed are listed below:

1. How to choose companies which will actually build a solid fuel fired plant.

2. Assembling an efficient package to allow a useful feasibility study to be produced at minimum cost.

3. Follow-up for companies that wish to pursue equipment installation based on the preliminary study.

4. Inventory of past work which is applicable.

5. Topics for newsletters, articles, possible use as public relations vehicle for finding possible feasibility study clients.

6. Personnel available for the project and allocation of time and budgets.

These discussions have strengthened the feeling that more pre-screening is needed to reduce the possibility that feasibility studies will be performed for companies which are unlikely to follow through on installation. Allocation of resources toward new clients, rather than past recipients of feasibility studies, was considered and may be worthwhile. We expect to make final decisions on these topics in December to allow for field work to start in January.
Some contact with clients was made this month. Bill Bulpitt and Tom McGowan met with Lanier Edwards and John Miller from Timberland Harvesters. They are considering financing and construction of stand alone wood fired power plants in South Georgia or North Florida. We have responded by supplying them with economic and financial information and lists of engineering firms and equipment vendors who specialize in this sector.

Bulpitt and McGowan plan to attend the December 14th opening of a wood fueled boiler plant built with State funds (through the Georgia Forestry Commission) at Walker Correctional Institute. They will also visit a new coal installation at Armstrong, Inc., financed by a "second party" arrangement, and will visit Desoto Falls Mills regarding their need for a feasibility study.

Budget

Expenditures in November were $2,212. Cumulative expenditures are $9,592, or 9.6% of the total budget vs. time expended of 3 months, or 25%. 
January 16, 1984

Mr. Phil Whitlow  
Georgia OER  
270 Washington Street  
Suite 615  
Atlanta, GA 30334

Subject: Project A-3663, Solid Fuel Extension Service

Dear Phil:

The December progress report for the Industrial Solid Fuel project is enclosed. Although the contract only calls for quarterly reports, I will be sending them on a monthly basis as an aid in planning and measuring our progress.

Sincerely,

Thomas F. McGowan  
Chief, Energy Technology Branch

TFM/pk  
Enclosure
Progress Report
Industrial Solid Fuel Extension Service
Project A-3663
December 1983

Two industrial clients were surveyed this month. Both have pressing needs to explore solid fueled equipment and can be served by a relatively brief report on cost and savings resulting from solid fuel.

The first company was Quality Furniture in Tallapoosa, Georgia. This company has its own wood waste which is being sold at a low price. Steam is needed for a dry kiln and space heating. Tom McGowan produced a report, dated 12/22, outlining the cost of a wood fired boiler system and projected savings. Also included was a list of kiln design consultants and boiler suppliers to allow the company to obtain alternate quotations. While the system is small (about 75 boiler hp), the economics look encouraging, with a payback period of 3.7 years. This is due to the low selling price of the fuel and the elimination of large receiving and storage facilities.

The second company is Desota Falls, a textile mill. Bill Bulpitt and Tom McGowan visited the home office in Dalton, Georgia and received data on the plant located just outside Atlanta. This company is primarily interested in wood, but coal may also be competitive. A site visit will be scheduled in January.

Bill Bulpitt and Tom McGowan visited the Walker Correctional Institute wood boiler demonstration. The Georgia Forestry Commission installed this system on State and TVA funds. While space heating systems of this size are rarely economical for commercial or industrial use, the use of inmate labor to reduce operating costs and for some of the construction resulted in a payback period of 5.5 years.

Bulpitt and McGowan also visited the Armstrong Company in Dalton. They have installed four 40,000 lb/hr coal fired steam boilers under a second-party financing arrangement. Armstrong will pay 90% of the cost of natural gas for the steam supplied by the system owner, "Pilot Engineering," located in
Tucker, Georgia. The boilers are "Coalmasters" made by Industrial Boiler Co. in Thomasville, Georgia. The plant should be in full operation the first quarter of 1984.

Work for next month includes conclusion of planning, production of a newsletter article, and continued industrial assistance.

Budget

Expenditures in December were $6,603. Cumulative expenditures are $16,195, or 16.2% of the total budget versus time expended at 4 months or 33%.
February 8, 1984

Mr. Phil Whitlow
Georgia OER
270 Washington Street
Suite 615
Atlanta, GA  30334

Subject: Project A-3663, Solid Fuel Extension Service

Dear Phil:

Our January progress report is attached for the Industrial Solid Fuel Project. Please call me at 894-3636 if you have any questions or suggestions.

Sincerely,

Thomas F. McGowan
Chief, Energy Technology Branch

TFM/pk

Attachment
Progress Report
Industrial Solid Fuel Extension Service
Project A-3663
January 1983

A newsletter article was written for inclusion in the next addition of the Conserver (IEES) newsletter and the OER newsletter. The article describes the program and gives a contact at Georgia Tech for clients wanting a pre-feasibility study.

Tom McGowan was a speaker on a panel of experts on energy futures. His topic was current and future use of wood fuel in the U.S. and Georgia. The meeting took place on January 24, on the Georgia Tech campus and was sponsored by Scientists and Engineers for Secure Energy, Inc. A meeting announcement is attached, as well as presentation materials on the use of wood fuel.

We have been contacted by the Georgia Tire Dealer's Association regarding a long standing problem--tire disposal. We will work with them (on a pre-feasibility study basis) to find cost effective ways to burn tires in an environmentally sound manner.

We have assigned Mike Brown to work on developing a questionnaire to screen clients requesting pre-feasibility studies. He will also do the update on the wood boiler installed at Integrated Products Company in Aragon, Georgia, and produce studies for industrial clients.

Plans are being made for the solid fuel conference, tentatively scheduled for this summer. An organizing meeting will be held Wednesday, February 22, 1984, to finalize details.

Work for next month includes finishing the questionnaire, developing or obtaining overview materials on coal systems, and continuing assistance to industry.

Budget

Expenditures in January were $7,867. Cumulative expenditures are $24,027, or 24% of the total budget, versus time expended at 5 months or 42%.
GEORGIA INSTITUTE OF TECHNOLOGY

Presents

A Community/Campus Energy Forum

ELECTRICAL ENGINEERING AUDITORIUM (EEA)
THE VAN LEER BUILDING
ATLANTIC AVENUE (Off 10th Street)

Tuesday, January 24, 1984 — 7:30 p.m.

1984 AND BEYOND:
IN SEARCH OF AN ENERGY FUTURE

A panel of nationally recognized energy experts will discuss issues and answer questions about the importance of energy in our nation’s future.

Presented by the Georgia Institute of Technology in cooperation with Scientists and Engineers for Secure Energy, Inc. (SE₂), a national non-profit education organization dedicated to the sensible development of energy resources and to the prudent use of technology.

ADMISSION FREE — COMMUNITY/UNIVERSITY INVITED
Featured Speakers

Robert L. San Martin is Deputy Assistant Secretary for Renewable Energy within the Office of Conservation and Renewable Energy of the U.S. Department of Energy. He received his B.S., M.S. and Ph.D. degrees in Mechanical Engineering from the University of Florida in 1963, 1964, and 1969, respectively. Following teaching assignments at the University of Florida and New Mexico State University, he was appointed Director, Energy Research and Development Institute at NMSU in 1974. Then, in 1976, he was named Director of the New Mexico Energy Institute, followed by appointment as Director of the New Mexico Solar Energy Institute in 1977. In 1978, he began his governmental services as Director, Division of Distributive Solar Technology in the Department of Energy; followed by appointment as Deputy Assistant Secretary for Solar Energy in 1980, followed by his current assignment in 1981. Dr. San Martin has vast oversight of the many facets of both research and application of the broadly classified renewable energy sources.

Philip S. Schmidt is a Professor in the Department of Mechanical Engineering and the Center for Energy Studies at the University of Texas at Austin. He received a B.S. in 1962 from M.I.T. M.S. and Ph.D. degrees from Stanford University in 1968 in the field of Thermal Sciences. His research has concentrated on the application of thermal sciences to the improvement of energy production in industrial processes; including, the study of advanced processes for industrial electrification and the application of thermal dynamics and economic evaluation of energy conservation and energy intensive industrial processes. He has extraordinary technical and economic perspective on electricity and industrial productivity.

Mr. Thomas F. McGowan is Chief of the Energy Technology Branch, which is within the Technology Applications Laboratory of the Engineering Experiment Station of Georgia Tech. He received both his B.A. and M.S. degrees in Chemical Engineering from Manhattan College, New York City. His area of expertise is biomass combustion and gasification. He has extensive research in the area of wood energy development and potential.

Dr. Raymond L. Murray received his doctorate in Physics from the University of Tennessee. He has been a faculty member at North Carolina State University since 1950, assisting in the establishment of the first nuclear engineering curriculum and the first university nuclear reactor. He served there as Burlington Professor of Phsyics, as head of the Nuclear Engineering Department, and currently is Professor Emeritus. He is a past member and chairman of the North Carolina Radiation Protection Commission. His current studies involve nuclear reactor analysis and public information on nuclear technology. His most recent textbooks are Nuclear Energy, 2nd. 1980, and Understanding Radioactive Waste, 1982.

Program Moderator
Dr. Henry C. Bourne, Jr.
Vice President for Academic Affairs
Georgia Institute of Technology

Director, Campus Energy Forums of SE2
Dr. R. Leslie Dugan
Scientists and Engineers for Secure Energy, Inc.
Presentation Material on Current and Future Wood Use in U.S. and Georgia
ENVIRONMENT

- STACK CLEANUP TO CONTROL ASH EMISSIONS
- RESIDENTIAL WOOD STOVE SMOKE - CATALYTIC AFTERBURNERS
- INCREASED USE OF TIMBERLAND - FOREST MANAGEMENT REQUIRED
INDUSTRIAL AND SMALL UTILITY SECTOR

- PULP AND PAPER INDUSTRY FOR STEAM AND POWER PRODUCTION: 50% SELF-SUFFICIENT; 3,400 MW TOTAL

- UTILITIES:
  - BURLINGTON, VT
  - KETTLE FALLS, WA
  - LAKE SUPERIOR, WI
  - FRENCH ISLAND, WI
  - EUGENE WATER AND ELECTRIC, OR

<table>
<thead>
<tr>
<th>Utility</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burlington, VT</td>
<td>50 MW</td>
</tr>
<tr>
<td>Kettle Falls, WA</td>
<td>40 MW</td>
</tr>
<tr>
<td>Lake Superior, WI</td>
<td>40 MW</td>
</tr>
<tr>
<td>French Island, WI</td>
<td>15 MW</td>
</tr>
<tr>
<td>Eugene Water and Electric, OR</td>
<td>25 MW</td>
</tr>
</tbody>
</table>

| UNDER CONSTRUCTION              | >100 MW  |
COMMERCIAL SECTOR

- LIMITED USE FOR SMALL MANUFACTURING OPERATIONS

- SOME USE IN AGRICULTURE
LONG TERM BENEFITS

- LOWER COSTS = HIGHER PRODUCTIVITY
- MORE EMPLOYMENT
- LOCAL BUSINESS DEVELOPMENT AND REVENUES
- REPLANTING OF IDLE TIMBERLAND
FOREST SERVICE DATA (1981)

- UNUSED WASTE WOOD = 600 MILLION DRY TONS/YEAR

- POTENTIAL FOR 8% OF U.S. ENERGY BUDGET IF ONLY HALF IS RECOVERED
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current industrial use</td>
<td>5 million TPY</td>
</tr>
<tr>
<td>Estimate of economic availability</td>
<td>22 million TPY</td>
</tr>
<tr>
<td>Maximum renewable resource</td>
<td>140 million TPY</td>
</tr>
</tbody>
</table>
GEORGIA'S WOOD ENERGY POTENTIAL

CURRENT INDUSTRIAL USE
5 MILLION TPY

ESTIMATE OF ECONOMIC AVAILABILITY
22 MILLION TPY

MAXIMUM RENEWABLE RESOURCE
140 MILLION TPY
WOOD CONSUMPTION DATA

<table>
<thead>
<tr>
<th>QUADS</th>
<th>U.S.</th>
<th>GEORGIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURRENT USE</td>
<td>2.5*</td>
<td>.08</td>
</tr>
<tr>
<td>PROJECTED USE</td>
<td>6.5</td>
<td>.20</td>
</tr>
</tbody>
</table>

* EQUALS 3% OF U.S. ENERGY USE
RESIDENTIAL USE

- APPROXIMATELY 5 MILLION HOUSEHOLDS USE WOOD AS PRIMARY HEAT SOURCE

- IN GEORGIA, HOMES CONSUME 1.7 MILLION CORDS PER YEAR OF WOOD FUEL
March 14, 1984

Mr. Phil Whitlow  
Georgia OER  
270 Washington Street  
Suite 615  
Atlanta, GA  30334  

Subject: Project A-3663, Solid Fuel Extension Service  

Dear Phil: 

The progress report for February is enclosed. The highlights were the conference organizing meeting and initiatives in the area of feasibility studies.  

Sincerely,  

Thomas F. McGowan  
Chief, Energy Technology Branch  

TFM/pk  
Attachment
Progress Report
Industrial Solid Fuel Extension Service
Project A-3663
February 1983

The press release on the solid fuels program is ready for March release in the Conserver. A copy is attached.

An organizing meeting for the solid fuel conference was held on February 22. Those attending included C. Aton, T. McGowan, and M. Smith with Georgia Tech, P. Whitlow and J. Wiseman with Georgia OER, F. Allen with GFC, and M. Fritz with UGA. A date has not been set for the meeting, but late July or early August is contemplated. Lists of speakers and topics are being generated.

Jim Walsh visited Desoto Falls textile mill near Atlanta to collect field data for our second feasibility study. Mike Brown has created a data sheet to be filled out by plant personnel. This is currently in review and will be used to screen candidates for feasibility studies. Mike Smith is working the Georgia Tire Dealers Association on waste tire disposal.

Budget

Expenditures in February were $7,938. Cumulative expenditures are $31,710 or 32% of the total budget, versus time expended at 6 months or 50%.
**INDUSTRIAL ENERGY CONSERVER**

Published by the Industrial Energy Extension Service of Georgia Tech

Funded by the Georgia Office of Energy Resources through a grant from the U.S. Department of Energy

March 1984

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**TECH BEGINS NEW SOLID FUELS PROGRAM**

Have you been considering converting from oil or gas to solid fuels? Does your plant produce combustible waste that holds promise for fuel substitution?

So, then you will be interested in hearing about a new outreach service at Georgia Tech, called the Solid Fuels Conversion Service. Through this program, industry interested in conversion from oil or gas to solid fuels can receive free technical assistance via a hot line from the Georgia Office of Energy Resources.

Feasibility studies for twenty projects will be performed by the service. This includes a site visit, analysis of fuel supply, a conceptual plant design, an estimate of equipment costs, and economic analysis. Participation is limited, candidates will be screened by project staff to identify the most likely companies benefit from fuel conversion. Two studies have already been undertaken, one for a furniture manufacturer and another for a textile mill.

Project Director Tom McGowan, of the Engineering Experiment Station at Tech, observes that candidates for fuel switching typically "have a two or three shift operation with steady load characteristics, and fired equipment that consumes more than 15 million Btu's per hour (400 boiler hp), which includes boilers, kilns, dryers, and calciners." Additionally, the plant must have sufficient room for fuel storage.

Other activities of the new program include:

- a conference scheduled for mid-1984
- technical aid and review for two existing wood demonstration sites
- liaison with industry and research groups working in the area of solid fuels.

If you're interested in more information, write to Tom McGowan at Georgia Tech EES/TAL, 215 O'Keefe Bldg., Atlanta, GA 30332.
Mr. Phil Whitlow  
Georgia OER  
270 Washington Street  
Suite 615  
Atlanta, GA 30334

Subject: Project A-3663, Solid Fuel Extension Service

Dear Phil:

Our March progress report is attached for the Industrial Solid Fuel project. Please call me at 894-3636 if you have any questions or suggestions.

Sincerely,

Thomas F. McGowan  
Chief, Energy Technology Branch

TFM/pk

Attachment
Progress Report
Project A-3663
INDUSTRIAL SOLID FUEL EXTENSION SERVICE
March 1984

Planning for the wood and coal conference continued this month. Wednesday, July 25, has been selected as the date and it will be held at the Sheraton on North Avenue and West Peachtree. The conference fee will be $60. A preliminary list of speakers and topics have been compiled. Speakers will be contacted in time for an April 18 deadline to prepare the brochure. Public relations for the conference are underway. A list of radio stations and papers have been contacted and sent a press release. One telephone interview has been compiled with a radio station in Rome, Georgia.

As a result of previous press releases, we have received two letters from prospective industrial firms. Our response letter and preliminary questionnaire are in final draft form (awaiting updated prices for boiler plants) and will be completed and mailed out in April to the two firms noted above, as well as firms which contacted us some time ago.

We are continuing our review of the Integrated Products Company, a successful demonstration installation under a past DOE contract. Company personnel have been very cooperative and we have received good data on maintenance problems, solutions, and costs. This data will aid manufacturers and users of wood fired boilers.

Budget

Expenditures in March were $11,311. Cumulative expenditures are $43,191, or 43% of the total budget, versus time expended at 7 months or 58%.
May 18, 1984

Mr. Phil Whitlow
Georgia OER
270 Washington Street
Suite 615
Atlanta, GA 30334

Subject: Project A-3663, Solid Fuel Extension Service

Dear Phil:

Our April progress report is attached for the Industrial Solid Fuel project. I look forward to meeting with you, Paul Burks, and Fred Allen on May 22 about the project.

Sincerely,

Thomas F. McGowan
Chief, Energy Technology Branch

TFM/pk
Attachment
Progress Report
Project A-3663
INDUSTRIAL SOLID FUEL EXTENSION SERVICE
April 1984

Details for the July coal and wood conference were finalized this month. All speakers were contacted and letters of confirmation mailed to them. A rough draft of the conference brochure has been produced and publicity is underway.

We have another plant study underway at a carpet mill in Dalton, and have discussed, but not yet started a study in South Georgia for a tire manufacturer. Two other plants are under consideration, a clothing manufacturer and a mining company.

The paper to be submitted to the Forest Products Journal on the boiler installation at the Integrated Products Co. (Aragon, GA) is 90% complete. We are awaiting final information on maintenance costs for the paper.

A partial draft was produced of a study on the combustion of used tires for a tire manufacturer’s association. It is hoped that this document will serve as a catalyst for several tire burning installations in Georgia.

Budget

Expenditures in March were $8,431. Cumulative expenditures are $51,635, or 52% of the total budget, versus time expended at 8 months or 67%.
June 8, 1984

Mr. Phil Whitlow
Georgia OER
270 Washington Street
Suite 615
Atlanta, GA 30334

Subject: Project A-3663, Solid Fuel Extension Service

Dear Phil:

Our May progress report is attached for the Industrial Solid Fuel project. I enjoyed meeting with you and Paul on May 22 about the project. We are getting a good response from industry and expect to a good turnout at the July conference.

Sincerely,

Thomas F. McGowan
Chief, Energy Technology Branch

TFM/pk
Attachment
The conference brochure was produced, typeset, printed, and will be ready to mail June 1. We will send extra copies to OER for your use in publicizing the July 25 conference.

We mailed out eight letters with questionnaires (a sample is attached) to plants which have expressed interest in studies. We expect to receive them in early June. We will then evaluate them, make recommendations by letter for plants which are poor candidates, and do field studies for those that show promise. Per our conversation, all company names will be kept confidential. We will send report copies referenced with a code number.

Work continued on a tire combustion study for a tire manufacturer's association. The economics of using them as fuel appear to be highly dependent on tipping fee for disposal. This cost of disposal may make them at attractive fuel in specific regions.

Budget

Expenditures in May were $8,732.98. Cumulative expenditures are $60,091.12, or 60% of the total budget, versus time expended at 9 months or 75%.
SOLID FUELS SURVEY FORM

Company Name ________________________________
Address _____________________________________
City, Zip _____________________________________
Company Contact _______________________________ Title ________________________________
Telephone ________________________________

BUSINESS INFORMATION

Major Business Sector __________________________ Major Products __________________________
SIC Code ______________________________________
Waste Materials ______________________________ Quantity (Tons/year) _______________________
Shifts Per Day __________________________________

BOILER CHARACTERISTICS

1. Number of Boilers _________________________

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Fuel Type</th>
<th>Approximate % Load</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>______ H.P. ( ) or lb/hr ( )</td>
<td>__________</td>
<td>__________</td>
<td>__________________</td>
</tr>
<tr>
<td>______ H.P. ( ) or lb/hr ( )</td>
<td>__________</td>
<td>__________</td>
<td>__________________</td>
</tr>
<tr>
<td>______ H.P. ( ) or lb/hr ( )</td>
<td>__________</td>
<td>__________</td>
<td>__________________</td>
</tr>
</tbody>
</table>

Do you plan to install any new boiler equipment either as replacement or for expansion in the near future?  ____ Yes  ____ No

If yes, when will it be installed? __________ What size will it be? __________
What fuel will be used? __________
3. For the boilers now operating, indicate your fuel cost as accurately as possible. This cost should be f.o.b. the plant. (Data will be maintained in confidence.)

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Unit Cost of Fuel ($)</th>
<th>Units Consumed Annually</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SYSTEM DESIGN

Solid fuel can be used either as a primary fuel or as a secondary (backup) fuel. Because gas/oil package boilers cannot be modified effectively to consume solid fuel, an existing package boiler may have to be shutdown when converting to solid fuel.

Shown below are the estimated capital costs for solid fuel boilers of several sizes. For comparison, the costs for gas package boilers are also presented. The solid fuel boiler costs are based on a turn-key installation not including building or foundation, but including limited fuel storage handling equipment.

<table>
<thead>
<tr>
<th>Capacity*</th>
<th>Solid Fuel Boiler</th>
<th>Gas Boiler</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,500 lbs/hr</td>
<td>$ 350,000</td>
<td>$ 25,000</td>
</tr>
<tr>
<td>10,350 lbs/hr</td>
<td>550,000</td>
<td>72,000</td>
</tr>
<tr>
<td>17,250 lbs/hr</td>
<td>750,000</td>
<td>120,000</td>
</tr>
<tr>
<td>35,000 lbs/hr</td>
<td>1,100,000</td>
<td>240,000</td>
</tr>
<tr>
<td>50,000 lbs/hr</td>
<td>1,600,000</td>
<td>250,000</td>
</tr>
<tr>
<td>100,000 lbs/hr</td>
<td>3,200,000</td>
<td>500,000</td>
</tr>
</tbody>
</table>

*Divide by 34.5 to obtain boiler horsepower.

. Are you interested in installing a solid fuel boiler either as a replacement for existing boilers or for future expansion? ___ Yes ___ No

. What type of solid fuel do you think would be most attractive at your plant site? __ Wood ___ Coal ___ Industrial Waste ___ Other ________________________________

. What value of return is usually required before a capital project of this scale and type can be approved? ____________________

How is it calculated?
___ Simple Payback ___ Internal Rate of Return ___ Net Present Value
7. Space may be required for fuel storage. The appropriate space required for a one month backup supply of wood fuel, for different boiler sizes, is given below:

<table>
<thead>
<tr>
<th>Boiler Size*</th>
<th>Storage Pile**</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,500 lbs/hr</td>
<td>3,500 ft²</td>
</tr>
<tr>
<td>35,000 lbs/hr</td>
<td>35,000 ft²</td>
</tr>
<tr>
<td>50,000 lbs/hr</td>
<td>50,000 ft²</td>
</tr>
<tr>
<td>100,000 lbs/hr</td>
<td>100,000 ft²</td>
</tr>
<tr>
<td>250,000 lbs/hr</td>
<td>250,000 ft²</td>
</tr>
</tbody>
</table>

*Divide by 34.5 to obtain boiler horsepower.

**Based on green wood, 12 ft pile height.

Based on the size of your boiler and fuel utilization requirements, how would you describe space for boiler and fuel storage at your location.

___ More Than Adequate ___ Adequate ___ Enough, But Very Tight ___ Insufficient

On the separate sheet of paper provided, sketch your existing steam plant layout and indicate space available for a solid fuel system including storage. Indicate approximate dimensions on the sketch.

8. Solid Fuel boilers are not as quick to react to load changes as are gas/oil package boilers. In some cases, this aspect influences boiler system design. For background information, how would you characterize your boiler load?

___ Steady Load ___ Fluctuating Load

[Approximate Load Change ____ lb/hr (minimum) to ____ lb/hr (maximum) in ____ mins.]

You may wish to provide typical steam flow charts if they are available.

9. This question is intended to provide information on plant access.

a. The plant location is: ____ Urban ____ Suburban ____ Rural

b. The plant is serviced by a major highway so truck fuel deliveries would be practical? ____ Yes ____ No

c. The plant has rail access? ____ Yes ____ No
May 22, 1984

Dear

Thank you for expressing interest in the Solid Fuels Extension Service offered by the Georgia Tech Engineering Experiment Station and sponsored by the Georgia Office of Energy Resources. The purpose of this service is to provide engineering assistance to plants which request help on switching to solid fuels. Enclosed is a survey form for you to complete. It will provide us with information to be used in establishing the preliminary feasibility of fuel switching at your location.

Before seriously considering the feasibility of switching to solid fuel, several fundamental parameters must be noted. Boiler systems which utilize solid fuel are typically much more expensive than gas/oil package boilers. This means a firm considering a solid fuel boiler must be in a position to commit a significant amount of capital up-front, even though this original investment can be recovered in 3 years or less. The savings on solid fuel boilers results from consuming a lower cost fuel. Therefore, solid fuel boilers must have high yearly operating hours and high utilization (load), since it is obviously inappropriate to invest a large sum in an asset that remains idle.

Two other factors that influence the feasibility of solid fuel boilers are plant space availability and access. Solid fuels but must be stored on site. Depending on the properties of the particular fuel selected and number of days of storage, a large area may be required. Additionally, since frequent deliveries of fuel by truck or rail may be necessary, reasonable access by road or rail must be available.

If preliminary examination of these factors produces favorable results, further investigation of fuel switching is warranted. The services under this grant are of a limited nature. If the results of the study are positive, further assistance can be obtained from Georgia Tech via a contract, or from qualified engineering firms. If you have any questions concerning the survey, I can be reached at (404) 894-3636.

Sincerely,

Thomas F. McGowan
Chief, Energy Technology Branch

cc: Mike Brown
    Grant Curtis
    Jim Walsh
Mr. Phil Whitlow  
Georgia OER  
270 Washington Street  
Suite 615  
Atlanta, GA  30334

Subject:  Project A-3663, Solid Fuel Extension Service

Dear Phil:

Our June progress report is attached for the Industrial Solid Fuel project. We are working hard on preparation for the July 25th conference including publicity, speaker arrangements, and publications.

Sincerely,

Thomas F. McGowan  
Chief, Energy Technology Branch

TFM/pk
Progress Report
Project A-3663
INDUSTRIAL SOLID FUEL EXTENSION SERVICE
June 1984

Conference brochures were mailed out in early June. As of the end of June, we had 13 people preregistered. We are keeping in contact with the speakers, reproducing papers, preparing the final agenda, and working on the myriad details organizing the conference.

Regarding the wood/coal preliminary feasibility studies, we have not received any of the completed questionnaires from the 8 companies that received them. We are following up by phone and will acquire as much data as possible via phone interview. The form may be more detailed than the plant engineers can handle. However, if a company does not have the information that we have requested, it will have a difficult time in making a decision on a boiler plant. We have some concern that we do not have a sufficient number of good candidates available for studies. We will attempt to locate more candidates at the July 25th conference and associated public relations spots.

The paper on the wood fired boiler plant at Aragon, Georgia (the Integrated Products Company) was completed this month and will be presented at the July 25th conference.

BUDGET

Expenditures in June were $10,129. Cumulative expenditures are $70,341, or 70% of the total budget, versus time expended at 10 months or 83%.
August 20, 1984

Mr. Phil Whitlow  
Georgia OER  
270 Washington Street  
Suite 615  
Atlanta, GA 30334  

Subject: Project A-3663, Solid Fuel Extension Service  

Dear Phil:  

Our July progress report is attached for the Industrial Solid Fuel project. The major undertaking for the month was the Wood and Coal for Industry's Needs conference which was a great success. The progress report contains more detail on this and other subjects.  

We are currently underspending our funds and would like to request a no cost extension of the project through October 31, 1984.  

Sincerely,  

Thomas F. McGowan  
Chief, Energy Technology Branch  

TFM/pk
Progress Report
Project A-3663
INDUSTRIAL SOLID FUEL EXTENSION SERVICE
July 1984

The "Wood and Coal for Industry's Needs" conference was held on July 25 at the Sheraton Hotel. It was a success, with 86 in attendance, 62 paid, and the remainder invited guests. The conference evaluations were very positive (summary attached) with good to excellent ratings predominating. In particular, our choice of keynote speaker, Bob Schwieger, editor of Power Magazine, repeatedly received praise. As a result of the conference, we have received several calls for prefeasibility studies and also for publications and information.

We are continuing to produce prefeasibility studies for industrial plants. At this time, we have five completed, two underway, and six prospects lined up.

BUDGET

Expenditures in July were $8,569. Cumulative expenditures are $79,080, or 79% of the total budget, versus time expended at 11 months or 92%.
20 August 1984

MEMORANDUM

TO: Tom McGowan
FROM: Carol Aton

SUBJECT: Report on "Wood and Coal for Industry's Energy Needs"

Georgia Tech held the wood and coal conference at the Sheraton-Atlanta Hotel on July 25, 1984, for 62 registrants and 24 guests. The conference was a success as evidenced by the positive comments on content and organization made to Georgia Tech personnel, as well as the positive tone of the written evaluations (see attached summary).

Based on 37 responses to the written questionnaire, two-thirds of the audience were experienced or very experienced with one-third of the audience classifying themselves as "new." An overwhelming percentage felt the time spent was worthwhile, and all respondents stated they would recommend the program to business associates.

Best-liked aspects of the program were diverse, indicating that we provided something of interest to everyone. Least-liked aspects centered primarily on length of the program, with many respondents requesting more time, more detail, or additional topics. This is consistent with the experience level of our audience. It also suggests that we have achieved our goal of making Georgia industry aware of solid fuels and should now concentrate on providing them with in-depth information and assistance on implementation.

CLA/pk
SUMMARY
(37 Responses)

EVALUATION

WOOD AND COAL FOR
INDUSTRY ENERGY NEEDS

July 25, 1984

1. What is your experience level? 12 new 19 experienced 5 very experienced
2. Was the time spent worthwhile? 35 yes 1 no
3. Would you recommend our program to business associates? 37 yes 2 no
4. The purpose of the program is to stimulate solid fuel usage in industry.
   (a) Do you plan to implement recommendations suggested? 24 yes 2 no
   (b) What did you like best about the program? see attachment
   (c) What did you like least about the program? see attachment
5. How would you evaluate the organization of the conference?
   excellent 16 good 19 fair 2 poor
   Comments: see attachment
6. How would you evaluate the helpfulness of the audio-visual materials?
   distracting, not helpful 14 moderately helpful 21 very helpful
   Comments: see attachment
7. How did you learn about this workshop?
   Brochure 17 (50%)
   IEES Conserver (Quarterly Newsletter) 1 (3%)
   Other publication (please specify) 6 (18%)
   Other source (please specify) 10 (29%)
   Record your overall feeling about this workshop by placing an "X" in the appropriate box.
   excellent 10 good 24 fair 2 poor
   Any further comments or suggestions you have are most welcome. Thank you. (Name, title, and company address are optional.)
   see attachment
SUMMARY OF COMMENTS
Wood and Coal for Industry's Energy Needs
July 25, 1984

4b. WHAT DID YOU LIKE BEST ABOUT THE PROGRAM?

- Well organized, covered subject well.
- Keynote lunch speaker was great.
- Wood side.
- Lunch.
- Learned a systematic approach to selecting solid fuel. Also liked "Materials Handling" section—would have liked more details.
- Financing and economics.
- Tough to answer. Total field well covered with time available.
- Materials for fuel.
- Financing alternatives.
- Enthusiasm.
- Very interesting subject matter.
- Well planned. (Could be 2 days.)
- Energy conservation.
- Coal aspects.
- Mr. Schweiger, Power Magazine.
- Diversity of lecturers.
- Present trend of industry.

4c. WHAT DID YOU LIKE LEAST ABOUT THE PROGRAM?

- More time should have been available for attendees to talk & exchange ideas & experiences.
- Schedule was so tightly packed that it was too rushed by mid-afternoon.
- Coal side.
- Technical detail & costs on pollution control & fuels handling is somewhat lacking.
- Length.
- Capital investment.
- Did not start on time.
- It was very broad.
- Turning off all lights so can’t follow paper as speaker talked.
- None.

5. COMMENTS ON ORGANIZATION?

- Would have been better to have coffee before the morning presentations started, in addition to the regular breaks.
- Moderator managed schedule very well.
- Excellent program—very professional, well planned & well executed.
- Keep on time.
- O.K.
6. COMMENTS ON AUDIO-VISUAL MATERIALS?

- So much darkness made it difficult to stay awake.
- Ask each speaker to repeat questions before he answers. Include speaker's address along with company.
- Would suggest even more slides to keep interest levels high (Jim Walsh could correct spelling of calorimeter on his slide--or did he mis-spell it on purpose just to see if we were really paying attention?).
- Some were too jumbled/small to read.
- Presentation on Integrated Products took too long.
- Some pretty good, others very poor.
- O.K.

7. HOW DID YOU LEARN ABOUT THIS WORKSHOP?

Other Publications: Trade publication (2)
Energy User News
Atlanta Constitution
NWEA
Newspaper

Other Sources: Radio
Personal reference
GT staff
Supervisor
GTMA
OER
Industrial Boiler
Letter
Rome field office
USMC Public Works Branch Continuing Education

9. FURTHER COMMENTS?

- Your agreement with the Sheraton Hotel for all participants to pay a $49 room rate was a disservice to Federal employees. We were charged $9 per room more than we would have had to pay without your agreement. Plus the Sheraton desk personnel were extremely rude when we just asked for an explanation of why....Make provisions in meeting room for non-smokers....Overall it was a good conference. You are to be commended for your quality and diversity of speakers.
- I think that the conference should be 2 days in length, organized into 3 day topic areas, i.e., boiler selection & design, material handling, pollution control & fuel specification and procurement. Vendors should be allowed to participate to the extent of setting up display tables during the evening of the first day of the conference.
- I'm running into a lot of people who know their boilers, but very few know anything about material handling equipment....Would have liked more detailed talk--especially concerning coal material handling. Discuss examples of what size silo handles, what angle of repose--(this type detail) screw conveyor vs. belt conveyor, types of bucket elevators, etc.
- Good balance of subject matter, appropriate level of detail for target
...Trade-show-to-go is effective transfer of vendor data.... Suggest you prepare & present a unit cost & system cookbook for plant engineers to conduct preliminary solid fuel feasibility study from a single source document.

- Total experience beneficial and much appreciated.
- Program well organized. Presented by well prepared and qualified professionals. Reasonable fee.
- Too long.
- A discussion of ash handling/storage systems should be included.
- Seminar was a very broad overview— From my standpoint it increased broad knowledge—but none of the topics were in depth— I looked for more material handling & boiler info. Need more case studies (design & operation).
- I certainly enjoyed the opportunity to be on the program and hope it was beneficial. We would certainly be happy to help out again on any future seminars.
- No discussion of wood mixed with coal, a process that is supposed to ameliorate many emission problems with coal. What about wood pellet use, availability, and future? More discussion needed on gasification— Is it viable? Is it better than straight wood boilers in all aspects including economics? Your experience at NW Georgia Regional Hospital and why system doesn’t work would be helpful.
- Wood Energy Case Study went overtime, was presented too elementary for audience, was too detailed for value of paper content. Very poor presentation.
- Workshop attempts to cover a little too much material in a very short period of time—possibly one less speaker but devote more time to other topics—technological aspects.
Mr. Phil Whitlow  
Georgia OER  
270 Washington Street  
Suite 615  
Atlanta, GA  30334

Subject: Project A-3663, Solid Fuel Extension Service

Dear Phil:

Our August progress report for the Industrial Solid Fuel project is attached. The major activity continues to be the preparation of solid fuel feasibility studies. The progress report contains more details on this subject.

We did receive notification of the no cost extension through October 31, 1984. Currently, our spending is on track. In addition, I want to bring your attention to the fact that I have assumed Tom McGowan's project director responsibilities for the remainder of the project. This was necessary because Tom has returned to college full-time and is only working half-time at Georgia Tech Research Institute (formerly the Engineering Experiment Station).

Sincerely,

Michael Brown

MLB/pk  
Attachments
Progress Report  
Project A-3663  
INDUSTRIAL SOLID FUEL EXTENSION SERVICE  
August 1984

The major activity for the month consisted of the preparation of solid fuel feasibility studies. A total of twelve companies have provided information for studies and six of these reports are in process. During August, four reports were sent out bringing the number completed to six. To date all of the studies underway are for new contacts. So far, the response from previously studied plants for update reports has been limited. A list of feasibility study plants including code number, industry, type contact, and date report sent is presented on the following page.

BUDGET

Expenditures in August were $7,347. Cumulative expenditures are $86,257, or 86% of the total budget, versus time expended at 11 months or 86%.
## FEASIBILITY STUDY STATUS

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<td>08/03/84</td>
<td>Carpet Processing</td>
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<td>07/23/84</td>
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</tr>
<tr>
<td>843005-MS</td>
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<td>Tire Retailers</td>
<td>New</td>
</tr>
<tr>
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</tr>
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<td>842212-JW</td>
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</tbody>
</table>
Mr. Phil Whitlow  
Georgia OER  
270 Washington Street  
Suite 615  
Atlanta, GA  30334

Subject: Project A-3663, Solid Fuel Extension Service

Dear Phil:

Our October progress report for the Industrial Solid Fuel project is attached. The last feasibility studies are almost complete and should be sent early in November. The remaining activity will be preparation of a final report.

Sincerely,

Michael Brown

MLB/bs

Attachments
The major activity for the month consisted of the preparation of solid fuel feasibility studies. A total of twenty companies have provided information for studies and five of these reports are in process. During October, four reports were sent out bringing the number completed to fifteen. Eighteen of the studies are for new contacts. A list of feasibility study plants including code number, industry, type contract, and date report sent is presented on the following page. The five reports not yet mailed are largely complete and should be sent in early November. The remaining activity will be preparation of a final report.

BUDGET

Expenditures in October were $4,046. Cumulative expenditures are $95,905 or 96% of the total budget. The extension of the project through December means the total length will be 15 months. As of the end of October 13 months or 87% of the time has been expended. This means spending is ahead of schedule but all that remains to be completed is the final report.
### FEASIBILITY STUDY STATUS

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FINAL REPORT

INDUSTRIAL SOLID FUEL EXTENSION SERVICE

Project Directors:
Thomas F. McGowan
Michael L. Brown

Project Contributors:
Carol Aton
Michael Smith
James Walsh

Sponsored by
THE GEORGIA OFFICE OF ENERGY RESOURCES

December 1984

GEORGIA INSTITUTE OF TECHNOLOGY
A Unit of the University System of Georgia
Atlanta, Georgia 30332

1984
Final Report
Industrial Solid Fuel Extension Service

Sponsored by
The Georgia Office of Energy Resources

Project Directors:
Thomas F. McGowan
Michael L. Brown

Project Contributors:
Carol Aton
Michael Smith
James Walsh

Georgia Tech Research Institute
Atlanta, Georgia

December 1984
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I. Introduction

II. Task Overviews
   1. Feasibility Studies
   2. Plant Follow-Up
   3. Fuel Analysis
   4. Newsletter Articles
   5. Solid Fuel Conference
   6. Coordinators

III. Conclusion

IV. Recommendations for Future Work

Appendices
I. INTRODUCTION

This final report covers activities performed under the contract for "A Solid Fuel Extension Service". This project, sponsored by the Georgia Office of Energy Resources, had the overall goal of providing local industry with technical and economic data on solid fuel boiler systems. Much of the interest in solid fuels is due to industrial dependence on natural gas which continues to increase in price, adversely impacting manufacturing costs. In many instances conversion to alternate fuels such as wood, coal or process waste can decrease the unit fuel costs and increase the competitiveness of the industry concerned.

Wood is increasingly becoming a vital source of energy to Georgia's industry because of its abundance. An earlier study disclosed that if all the wood suitable for fuel use was recovered it could supply up to 63% of the 1977 industrial energy consumption on an annual basis. While almost all of Georgia's natural gas is imported from other states wood is an indigenous resource. Since wood is not feasible for use in every industrial plant, coal was also evaluated as an energy option. Although little coal is mined within the state, Georgia is near coal producing regions in other states. As a result, good quality industrial grade coal can be purchased for reasonable prices. Finally, many industrial plants produce combustible waste as a manufacturing by-product. In the past this material has been considered at least a nuisance and at most a cost burden due to the price of disposal. Currently, however, more and more firms are evaluating the feasibility of incinerating their waste to provide part or all of their energy needs.

The purpose of the Solid Fuel Extension Service was to provide assistance to industries considering a conversion to one of these fuel sources. The assistance was composed of six different tasks:

- Feasibility studies
- Demonstration plant follow-up
- Fuel analysis
- Publication of newsletter articles
- Presentation of a solid fuel conference
o Coordinating extension activity with industrial trade associations

Each of these tasks was designed to provide industry with the information they needed to be able to make informed decisions about solid fuel conversions. A discussion of the results of each of the six tasks follows in the next section which also presents an estimate of the potential economic and energy savings possible as a result of this project. A final section is devoted to recommendations for future work in the solid fuels area based on insights gained from this initial year of research.
II. TASK OVERVIEWS

1. Feasibility Studies

One of the major elements of the Solid Fuel Extension Service was the provision for direct assistance to industrial plants. The assistance consisted of preparing a feasibility study on the economic and technical aspects of solid fuel utilization. Included in each study was a determination of the recommended fuel, brief conceptual design of the required equipment, equipment capital cost estimate and an estimate of the economic payback. A total of twenty studies were performed under this project.

A summary of pertinent data on the studies is shown in Table 1. The report code was developed to identify each of the reports yet maintain the confidentiality of the firms. The code is composed of three-two digit numbers and a set of initials. The first two digits refer to the year of production, the next two to the SIC code (standard industrial classification) of the industry and the final two to the report sequence number. The initials were that of the author. Solid Fuel was determined to be a viable alternative in all but five instances. In these cases solid fuel was not recommended due to the small size or limited operating hours of the facility. The high number of positive studies is in part due to pre-screening candidates, looking for high utilization and high capacity sites.

As Table 1 indicates, a wide diversity of industries were examined. The largest group represented was the textile industry with six studies (when carpet is included), followed by mineral processing with three and apparel, furniture, and asphalt roofing with two each. Primary metals, food products, pharmaceuticals and tire manufacturing each had one study. The remaining report was an investigation of methods and costs of waste tire incineration prepared for the Georgia Tire Retailers Association.

Of the twenty studies prepared only two were done for plants that had received a feasibility study under an earlier extension program. Although the contract had originally called for eight of the studies to be performed for locations that had received previous assistance, a telephone survey revealed that most of the thirty-three firms receiving feasibility studies in 1980 and 1981 had already made a decision and needed no further assistance. The survey
<table>
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<td>96,000</td>
<td>2.7 year payback</td>
</tr>
<tr>
<td>842208-MB</td>
<td>Textile</td>
<td>New</td>
<td>Boiler</td>
<td>27,600 lb/hr</td>
<td>Coal</td>
<td>216,000</td>
<td>2.0 year payback</td>
</tr>
<tr>
<td>842909-MB</td>
<td>Roofing Disposal</td>
<td>New</td>
<td>Boiler</td>
<td>10,000 lb/hr</td>
<td>Waste Roofing</td>
<td>98,000</td>
<td>3.3 - 8.0 year payback</td>
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<tr>
<td>842810-MB</td>
<td>Pharmaceutical</td>
<td>New</td>
<td>Boiler</td>
<td>30,000 lb/hr</td>
<td>Coal</td>
<td>144,000</td>
<td>7.9 year payback</td>
</tr>
<tr>
<td>842211-MB</td>
<td>Textile</td>
<td>New</td>
<td>Boiler</td>
<td>20,700 lb/hr</td>
<td>Coal</td>
<td>91,000</td>
<td>3.4 year payback</td>
</tr>
<tr>
<td>842212-JW</td>
<td>Textile</td>
<td>New</td>
<td>Boiler</td>
<td>-</td>
<td>Wood</td>
<td>-</td>
<td>Solid fuel not recommended</td>
</tr>
<tr>
<td>842013-MB</td>
<td>Food Products</td>
<td>New</td>
<td>Burner</td>
<td>3,000,000 Btu/hr</td>
<td>Peanut Skins</td>
<td>9,700</td>
<td>2.6 year payback</td>
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<tr>
<td>843214-TM</td>
<td>Mineral Processing</td>
<td>New</td>
<td>Gasifier</td>
<td>-</td>
<td>Wood</td>
<td>-</td>
<td>Concept prepared</td>
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<td>842515-MB</td>
<td>Furniture</td>
<td>New</td>
<td>Boiler</td>
<td>-</td>
<td>Wood</td>
<td>-</td>
<td>Solid fuel not recommended</td>
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<td>842216-MB</td>
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<td>Old</td>
<td>Boiler</td>
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<td>Coal</td>
<td>70,000</td>
<td>4.3 year payback</td>
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<td>Coal</td>
<td>-</td>
<td>Solid fuel not recommended</td>
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<tr>
<td>843219-MB</td>
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<td>30,000,000 Btu/hr</td>
<td>Coal</td>
<td>257,100</td>
<td>3.0 year payback</td>
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<tr>
<td>843320-MB</td>
<td>Primary Metals</td>
<td>New</td>
<td>Gasifier</td>
<td>-</td>
<td>Wood</td>
<td>-</td>
<td>Solid fuel not recommended</td>
</tr>
</tbody>
</table>

Total Displacement Potential, MMBtu/yr

*10^6 Btu/yr
of these recipients indicated that approximately 25% had already installed or had plans to install solid fuel equipment. Based on this feedback, a decision was made to devote most of the feasibility study effort to new firms that needed more help and were more likely to result in an installation.

Two reports, numbers 843005 and 843214, did not involve feasibility studies, per se, but involved the presentation of a new or underutilized concept. Report 843005 prepared for the Georgia Tire Retailers presented data on the availability, potential equipment requirements and cost benefits of waste tire incineration. Report 843214 introduced a program to investigate the application of wood gasification for mineral drying.

The remaining eighteen studies evaluated the technical and economic feasibility of solid fuel for an industrial operation. In five of these studies solid fuel was not recommended due to the marginal economic return afforded. In each of these instances small size and limited operating hours rendered solid fuel infeasible.

Thirteen studies determined that solid fuel was an acceptable alternative to conventional fuel. The simple payback period for this equipment was found to vary between approximately 2.0 - 4.0 years. Two cases were found to have paybacks significantly greater than four years. Report 842909 evaluated installation of a waste roofing incinerator to produce steam which could then be sold. The firm interested in the incinerator has no need for steam but does have a need to dispose of this waste material. The payback period for this arrangement varies between 3.3 and 8.0 years depending on the price steam can be sold for. Report 842810 studied the installation of a 30,000 lb/hr boiler at a pharmaceutical plant. A 7.9 year payback was calculated, but this was due to the fact that the boiler was oversized. Reducing the boiler size, even though it could not satisfy all the load swings, would make the economic payback more reasonable.

Table 1 also shows that most of the surveys, fourteen, were for boiler evaluations. There were also four gasifiers and one combustor assessed in these studies. Coal was the predominate fuel recommended with eleven sites, followed by wood with five and waste roofing with two. In addition, peanut skins and waste tires were the fuels examined at one site each. The impact on
conventional fuel consumption should all these solid fuel systems be installed would be quite large. The amount of calculated conventional fuel displacement from these systems is 3.2 trillion Btu per year. Copies of the feasibility studies with the name of the firm removed to protect confidentiality are included in Appendix A.

While installation of all of the feasible solid fuel plants could save 3.2 trillion Btu's of conventional fuel, in theory actual savings can be attained only if the systems are purchased and constructed. As a final element of determining the impact of the studies the plants were contacted after receiving the report to assess their reaction. In general the results were favorable. At least six of the firms had the recommendations under serious consideration. Two other firms were performing further evaluation before making a decision.

Preparation of the individual feasibility studies required collection of certain site specific data from each site. Particular data requirements included boiler size, fuel consumption and cost, operating schedule, acceptable economic returns, and accessibility of the site to rail and truck delivery. To simplify the data collection a Solid Fuel Survey Form was developed and mailed to all study candidates. The form (Appendix B) was designed to accommodate all required data plus an additional amount of supplementary information. Eighteen survey forms were mailed out. Additional surveys were completed over the telephone.

2. Demonstration Plants Follow-up

The second task of this project concerned following up on two wood energy demonstration plants installed during an earlier DOE alternate fuel program. The purpose of these installations was to demonstrate the feasibility of using wood fuel in non-forest related industries. Participation was encouraged by offering cost share funds provided as part of the DOE contract.

The two firms participating in the study included a textile mill and a food processing plant. A 400 HP (13,320 lb/hr) firetube boiler was installed at the textile mill. It was started in January, 1981. The food operation installed a 60,000 lb/hr water tube boiler designed to fire wood or agricultural residue including pecan shells and peanut hulls. This unit began operation in May 1981.
The purpose of this task was to perform an updated economic analysis after the units had operated three years and provide technical assistance on any problems that may have developed or to help expand system use.

Integrated Products, the textile mill located in Aragon, Georgia, which participated in the study, was visited during March, 1984. At the time of the visit, their wood boiler was operating satisfactorily and no major problems warranting technical assistance were noted. The economic analysis performed at the time of the installation projected a 3.5 year simple payback based on estimated fuel and maintenance costs and operating hours. The accurate records kept on fuel purchase, steam production, and maintenance permitted us to perform an updated economic analysis. Integrated products has increased the boiler utilization factor each year since its installation; therefore, no assistance to help expand system use was required.

The results of the Integrated Products wood boiler economic analysis are included in Appendix C. This paper, in similar form, was accepted for publication in the Forest Products Research Society Journal. Based on cost data provided by the plant, an actual 3.0 year simple payback was calculated. The updated analysis revealed a shorter payback than originally projected because of the exceptionally high utilization during 1983. Solid fuel systems generate incremental savings on each unit of fuel consumed, thus greater fuel consumption nets greater savings. The greater than anticipated fuel consumption during 1983 reduced the payback from that originally projected.

The 60,000 lb/hr solid fuel demonstration boiler is installed at Gold Kist Soy Products in Valdosta, Georgia. The economic analysis performed before start-up projected a 3.9 year simple payback period. No update of economic payback was possible because the company was sensitive about divulging operating and cost data. Apparently the system is working up to expectations because Gold Kist has decided to proceed with the installation of a steam turbine cogeneration system. The only major operational change is the conversion to almost exclusively wood fuel as opposed to wood/peanut hull mixtures. This is due to the high resale value of peanut hulls when used for animal feed and operating problems experienced with combustion of peanut hulls. A summary of the Gold Kist plant visit is presented in Appendix C.
3. Fuel Analysis

The Technology Applications Lab at Georgia Tech maintains a well-equipped laboratory for the analysis of solid fuels. Samples can be tested for heating value, moisture content, and ash content, proximate and ultimate analyses. These tests are useful for all types of solid fuels but during the course of this project were applied only to categorize waste fuels.

Three major fuel tests were conducted. A peanut blanching operation (involved in removing the skins from the nuts) was experiencing a disposal problem with removed skins. A fuel analysis was conducted to determine if these skins could be combusted and used as a source of energy. The energy content, which was found to be 9700 btu/1b, was determined to be high enough to offset the natural gas energy used for drying. The 9% moisture content and 3% ash content were measures useful in selecting an appropriate combustion system. For this situation a suspension burner was indicated. The proximate analysis results are presented in Table 2.

A second sample was evaluated for an alternate energy firm located in Augusta. The firm got its start reclaiming motor oil as a fuel but recently had started a solvent recovery operation that could also become a fuel source. Samples of recovered solvent were collected by Georgia Tech for analysis. The test revealed that the solvent was similar to #6 fuel oil and possessed a high carbon content and heating value of 17,800 Btu/lb. The sample apparently contained a significant amount of light volatiles, probably toluene, and determination of the moisture was inconclusive. However, given the high Btu value and low ash content the material could probably be combusted in a burner designed for #6 fuel oil.

The last fuel analyzed was carpet waste. The state of Georgia is a leading producer of carpet and as such has a rather large annual production of finished carpet and yarn waste. Two different forms of carpet waste found at a tufting plant were tested for energy content. The firm was considering a carpet waste fired boiler and needed heating value data to establish the energy content of their available resource. The test revealed a high ash content in the material as expected as well as a reasonable heating value. Further, more specific tests must be conducted to determine if corrosive substances such as chlorine or flourine are present before carpet waste can be fully utilized.
<table>
<thead>
<tr>
<th></th>
<th>Peanut Skins</th>
<th>Solvent</th>
<th>Burlap Backed Carpet Waste</th>
<th>Latex Backed Carpet Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moisture Content</strong></td>
<td>9%</td>
<td>-*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Volatile Content (dry basis)</strong></td>
<td>79%</td>
<td>-*</td>
<td>78</td>
<td>70</td>
</tr>
<tr>
<td><strong>Fixed Carbon (dry basis)</strong></td>
<td>18%</td>
<td>-*</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td><strong>Ash Content (dry basis)</strong></td>
<td>3%</td>
<td>0.2</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td><strong>Higher Heating Value (Btu/lb)</strong></td>
<td>9700</td>
<td>17,800</td>
<td>10,200</td>
<td>7,900</td>
</tr>
</tbody>
</table>

*Moisture test on solvent inconclusive.*
4. Newsletter Articles

One aspect of the Solid Fuel Extension Program technology transfer was the writing of articles for use in newsletter publications such as the IIEES conserver. The articles had the purpose of conveying information of a general nature on solid fuel technology and announcing the availability of cost free technical assistance through the program. An example of a newsletter article which appeared in the March 1984 Conserver is reproduced in appendix D. This article served a dual purpose because it also announced the upcoming solid fuel conference.

5. Solid Fuel Conference

The major technology transfer activity was a one day conference on wood and coal for industry. The conference was held on July 25, 1984 at the Sheraton-Atlanta Hotel. It attracted 62 registrants and 24 guests. The conference title was "Wood and Coal for Industry's Energy Needs," and it featured fourteen speakers addressing fuel supply and analysis, boiler systems, fuel handling, emissions, economics and financing. The luncheon keynote speaker was Robert Schweiger, Power magazine editor, who spoke on the future of wood and coal systems.

The initial planning meeting for the wood and coal conference was held on February 22, 1984. At this meeting conference logistics including date, location and fee, presentation topics and speakers, publicity and announcement brochure wording and design were developed. During March a press release describing the conference was mailed to 350 media outlets in the State of Georgia. Press releases were also sent to trade journals for inclusion in their calendars of events. We received clippings dated late March from several state newspapers that had run the article. An article describing technical assistance available under the program and giving the details of the conference was included in the March issue of the Conserver. The Conserver is a quarterly newsletter produced by Georgia Tech to help keep industry informed on energy conservation matters. It is mailed to over 6,000 manufacturing plants, commercial establishments, and government agencies within the state. Reminders of the conference date and location were included in the May-June Energy Update and the July 24 Atlanta Journal Business Section. Several radio
interviews were also done to reach a wider market. The brochure included in Appendix E was sent to names on a mailing list maintained by Georgia Tech. It contained information on topics to be discussed at the meeting and registration information.

Review of the conference evaluation forms indicated the program was a success. Positive comments were received on both content and organization. Based on 37 responses to the questionnaire, two-thirds of the audience was experienced and one-third classified themselves as inexperienced or "new" to the subject. An overwhelming percentage felt the time was worthwhile, and all respondents stated they would recommend the program to business associates.

When asked how they learned about the conference, eleven different sources were listed. The single largest information source was publications including newspapers and trade journals. Other sources of information listed included personal reference, vendor contact and OER.

The best-liked aspects of the program were diverse, indicating that we provided something of interest to everyone. Least-liked aspects centered primarily on length of the program, with many respondents requesting more time, more detail, or additional topics. This is consistent with the experience level of our audience. It also suggests that we have achieved our goal of making Georgia industry aware of solid fuels and should now concentrate on providing them with in-depth information and assistance on implementation.

6. Coordination with Industrial Trade Associations

Georgia Tech renewed contacts with trade associations developed during the original state wood energy program as a final part of the project. News releases detailing the availability of no-cost feasibility studies and the solid fuel conference were mailed to 20 locally oriented trade associations, the most prominent including:

- Georgia Textile Manufacturers Association
- Carpet and Rug Institute
- Georgia Poultry Federation
- Southeastern Lumber Manufacturers Association
In addition, Georgia Tech engineers wrote an article describing the solid fuel extension service for inclusion in a biomass newsletter published by the Institute of Natural Resources at the University of Georgia.

Close working relations were also maintained with the Georgia Forestry Commission. Representatives from the GFC participated in the solid fuel conference, and in at least one case they notified us of an industrial plant which wanted a feasibility study.

A final aspect of this liaison activity was the provision of fundamental technical data on solid fuel usage to clients not receiving a feasibility study. Much of the activity occurring under this heading involved the screening of candidates for formal studies. A number of firms did not require a detailed study since operational data including boiler size, operating hours or load factor indicated solid fuel would not be a viable alternative.

Several contacts were made with firms unable or uninterested in utilizing an on-site supply of wood or waste for fuel. These companies were willing to make their fuel source available to others considering solid fuel firing.
III. CONCLUSIONS

The Solid Fuel Extension Service conducted by Georgia Tech for OER achieved all of the goals set for the project. The primary objective of offering a readily available, unbiased source of technical information on industrial solid fuels was achieved by successful completion of the program's six tasks. Most prominent among these activities was the one day seminar on solid fuel technology and twenty feasibility studies developed for individual plants. Based on the favorable comments received both activities were useful to industry. Follow-up contact with the firms receiving studies disclosed at least seven recipients are seriously considering installation of a solid fuel system and further evaluation will occur. If each feasibility study location receiving a positive recommendation proceeded to install a solid fuel system approximately 3.2 trillion Btu per year of conventional energy resources would be displaced.
IV. RECOMMENDATIONS FOR FUTURE WORK

The success accomplished under the initial year of the Solid Fuel Extension Service has generated consideration of appropriate follow-on activity. Future work need not offer the diversity of activity conducted during the first year, but important, highly demanded extension work such as the feasibility studies and seminar would be well received. The feasibility studies meet a definite industrial need, as shown by the high demand and serious consideration afforded the reports. Since the demand for studies almost exactly equalled the contracted supply, an annual level of twenty studies should be maintained.

The solid fuel seminar which attracted almost 100 people obviously met a need that industries have for greater information on what is available in this area. This year's conference received a highly positive rating on content and delivery. Suggestions on topics to be included in future seminars were received on the review forms.

A final topical area not included in this year's contract would be a survey of industrial stack gas clean-up equipment. Serious environmental problems may result as more and more industries convert to solid fuel, especially if there is widespread conversion in an industry concentrated within a narrow geographic area. Much of the current expertise on solid fuel emissions reduction is restricted to very large size, utility scale systems. A task area to identify and evaluate potential low-cost emission control systems suited for industrial situations is proposed.
APPENDIX A

Feasibility Study Reports
December 22, 1983

Report Code No.: 842501-TM

Re: Project A-3663, Solid Fuel Extension Service

Dear

I have checked with equipment and engineering companies and have made up a list of firms (attached) which can give you alternate boiler quotes. Also included is a list of engineering companies which can do the steam system design on the dry kiln and space heating. Of special note is Steve Rice with Blue Ridge Dry Kiln. He is a private consultant and that may suit the scale of your job better than dealing with a large firm.

I have included a very brief analysis of the economic and technical aspects of your situation. A major question remains as to proper boiler sizing. Based on your average use for a peak month (February 1981), you need peak demand from kiln loading and space heating. I suspect that a safety factor of at least 2 is needed, resulting in the need for a 75 horsepower boiler. A design consultant would be better equipped to look at the specifics of your plant and calculate a more accurate figure. A secondary consideration is turn-down ratio; if the boiler is too large, improper operation could result during summer months.

In general, a "firebox" boiler with an underfeed stoker is normally used for the type of fuel you have available.

Please let us know if we can be of further help.

Sincerely,

Thomas F. McGowan
Chief, Energy Technology Branch

TFM/dk

Enclosures
Information for Evaluation of Wood Boiler System

- Steam operating pressure: 15 psi
- Fueled with wood shavings, sawdust, sander dust—10% moisture content (hardwood)
- Wood waste produced at rate of 25,000 lbs/week
- Excess wood waste sold @ $12/per truckload; 7 loads/week
- Kiln cycle_load one per day (3-5 day cycle)
- Number and size of kilns: 6 @ 8' x 16'
- Board feet cured per year: 1 million
- 20% double investment tax credit is available for wood fired equipment until 1985
- Use $75,000 as initial cost for wood-fired boiler and steam system

### Kiln and Heating System Fuel Consumption

<table>
<thead>
<tr>
<th>Month</th>
<th>Fuel Consumption (Therms)</th>
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</thead>
<tbody>
<tr>
<td>January</td>
<td>5,900</td>
</tr>
<tr>
<td>February</td>
<td>8,014 (maximum consumption)</td>
</tr>
<tr>
<td>March</td>
<td>5,389</td>
</tr>
<tr>
<td>April</td>
<td>3,925</td>
</tr>
<tr>
<td>May</td>
<td>2,343</td>
</tr>
<tr>
<td>June</td>
<td>2,073 (summer load (minimum))</td>
</tr>
<tr>
<td>July</td>
<td>1,595</td>
</tr>
<tr>
<td>August</td>
<td>2,110</td>
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<tr>
<td>September</td>
<td>2,833</td>
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<td>October</td>
<td>2,637</td>
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<tr>
<td>November</td>
<td>3,617</td>
</tr>
<tr>
<td>December</td>
<td>5,732</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>46,168</strong></td>
</tr>
</tbody>
</table>

Average consumption: 3,550 therms/month

Peak monthly consumption: February, 8014 therms

Average summer consumption: 2400 therms/month
Determination of Boiler Capacity
Required to Meet Maximum Load

Peak Month = \(8,014 \text{ therms} \times \frac{\text{month}}{\text{month}} \times \frac{28 \text{ days}}{28 \text{ days}} \times \frac{24 \text{ hours}}{24 \text{ hours}}\)

= 12.4 \text{ therms/hour}

Peak Month = 1.24 \text{ million Btus/hour}
Average Load
(continuous)

Max Load (actual) due to cycles, i.e., day vs night. Use factor of 2 for peak load, thus use \(2 \times 1.24 = 2.48 \times 10^6 \text{ Btu/hr}\)

Max Load (peak) = 2.48 \text{ million Btu/hr}

Boiler produces 34.5 lbs/hr (steam) per boiler horsepower

Then needed boiler capacity is determined as

\[
\text{Capacity} = \frac{2.48 \times 10^6 \text{ Btu/hr}}{34.5 \text{ lbs/hr} \times 1000 \text{ Btu/lb steam}}
\]

= 71.9 h.p., use 75 h.p.

\[
\text{Capacity} = 75 \text{ h.p.}
\]

Note: Consultant should check nameplate ratings on equipment and peak kiln use to arrive at proper peak capacity.
Economic Considerations

Gas Fuel Savings: Determined by cost for total gas consumption = 46,168 therms (assume cost of gas is $.50/therm).

Value of Gas Savings = \( \frac{46,168 \text{ therms} \times \$0.50}{\text{year} \times \text{therm}} \)

\[ \text{Value of Gas Savings} = \$23,100/\text{year} \]

Loss of Wood Sales: Determined from market value of wood wastes necessary to meet annual load.

annual load of \( = \frac{46,168 \text{ therms} \times 1000,000 \text{ Btu}}{\text{year} \times \text{therm}} \)

\( \text{wood needed} = \frac{7,650 \text{ Btu} \times 2000 \text{ lbs}}{\text{lb wood} \times \text{ton wood}} \times 0.75 \) (boiler efficiency)

\( = 402 \text{ tons wood} \)

\( \text{year} \)

From information given, revenue from wood waste sales is $12/load. Since there are approximately 7 loads per week, and a total of 25,000 lbs/week of wood waste produced, this translates to

value of \( = \frac{12 \times 7 \text{ loads/week} \times 2000 \text{ lbs/ton}}{25,000 \text{ lbs/week}} \)

\( \text{(wood waste value)} = \$6.72/\text{ton} \)

Thus, the total loss of wood sales for the year is \( 402 \times 6.7 = \$2,700/\text{year} \).

Payback of Initial Investment: This is determined by consideratin of time needed to recover the initial boiler system investment, as well as lost wood sales through the gas savings gained. If the initial system costs $75,000, then the fuel savings minus the lost wood sales will pay for this initial cost in approximately 3.7 years as shown below.

Payback Period = \( \frac{\text{Initial Cost}}{\text{gas savings - loss of wood sales}} \)

\( = \frac{75,000}{(23,100 - 2,700) \$/\text{year}} \)

\( = 3.7 \text{ years} \).

This payback period is representative of economic benefits from converting to a wood fired boiler. Actual benefits would depend upon actual system cost, and extra operating and maintenance costs. Economic benefits will be enhanced by a 20% double investment tax credit available for wood fired equipment until 1985.
Comparison of Wood Produced to Wood Supply Needed to Meet Boiler Wood Consumption Rate

Average Wood = Average Gas $\times \frac{.0087 \text{ tons wood}}{\text{Consumption}} \times \frac{\text{therm}}{\text{Consumption}}$

\[\text{Average Wood} = \frac{33.5 \text{ tons}}{\text{month}}\]

Peak Month Wood = Peak Month Gas $\times \frac{.0087 \text{ tons}}{\text{Consumption}} \times \frac{\text{therm}}{\text{Consumption}}$

\[\text{Peak Wood} = \frac{69.7 \text{ tons}}{\text{month}}\]

Wood Production Rate = $\frac{12.5 \text{ tons}}{\text{week}} \times \frac{30.4 \text{ days}}{\text{month}} \times \frac{7 \text{ days}}{\text{week}}$

\[\text{Wood Production Rate} = \frac{54.3 \text{ tons/month}}{}\]

The above numbers show that normal wood production would be sufficient to cover most normal operation, and that some storage would be needed to cover peak load needs.
Sources of Information and Assistance for Boiler and Kiln Design

1. James J. Brietzman
   Simons Eastern
   Box 1286
   Decatur, GA 30301
   Phone: 377-0711

2. Sandwell International, Inc.
   6640 Powers Ferry Road, NW
   Phone: 955-1250

3. Mr. Lee Handelman
   Paper Industry Engineers (Div. of Dravo)
   2310 Park Lake Drive, NE
   Atlanta, GA 30345
   Phone: 939-9002

4. Steve Rice (Consultant)
   Blue Ridge Dry Kiln Company
   Phone: (704) 254-6125

Boiler Suppliers

1. Industrial Boiler Company
   Mr. Welch Goggins
   P.O. Box 936
   Thomasville, GA 31792
   Phone: (912) 226-3024

2. Hurst Boiler Company
   P.O. Box 38
   Hwy 319
   Coolidge, GA 31738
   Phone: (912) 346-3443
1. **INTRODUCTION**

is a custom carpet dyeing firm located in Northwestern Georgia, and a large user of process steam currently generated exclusively from natural gas with #5 fuel oil serving as backup. The purpose of this study is to provide a preliminary examination of the feasibility of using solid fuel as an alternative to the existing energy supply. Because the plant does not have a significant amount of combustible solid waste nor a readily available supply of wood fuel, this analysis evaluated coal firing.

The plant currently has four boilers in place. The primary boiler is a 600 HP (20,700 lb/hr steam) Nebraska unit. It is base loaded and operates at or near full load constantly. The #2 boiler, which is heavily loaded most of the time, has an unknown rating because it is an HRT (horizontal return tubular) boiler that was converted from coal to gas firing. Based on plant energy consumption and boiler load profile, we assume that its output is between 12,000 and 20,000 lb/hr. The #3 boiler is a Scotch Marine unit rated at 250 HP. It is used in peak times of heavy load. The #4 boiler is rated at 400 HP, but it is rarely used. These boilers are capable of carrying the plant load at all times and no expansion of capacity is being contemplated.

The plant operates 24 hours per day utilizing two 12-hour shifts, 5-6 days per week, depending on product demand, and 50 weeks per year. The primary application of steam is for heating water in the 20 dye becks. While swings in steam demand are frequent during the first 12 hours after startup following the weekend, it is relatively steady during the ensuing operational period.
2. EQUIPMENT SELECTION

Using the operational and fuel consumption data provided, a calculation of the plant's average steam production based on a one-year period, and for a one-month period in each season was completed. The details of these calculations are included as Attachment 1. In the analysis, a boiler efficiency of 80%, average work week of 5½ days, and 1,000 Btu/lb steam heat content were used. A summary of this analysis is shown in Table 1 below.

<table>
<thead>
<tr>
<th>Time/Period</th>
<th>Average Steam Production (lb/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month/January '84</td>
<td>33,300</td>
</tr>
<tr>
<td>1 month/March '83</td>
<td>31,200</td>
</tr>
<tr>
<td>1 month/July '83</td>
<td>31,000</td>
</tr>
<tr>
<td>1 month/September '83</td>
<td>33,000</td>
</tr>
<tr>
<td>1 year/1983</td>
<td>33,100</td>
</tr>
</tbody>
</table>

This calculation indicated that there was not a significant variation in average steam production between seasons. There was a 7% increase in steam production in winter (January) as compared to summer (July), but this is relatively insignificant given the error possible in the data and the four monthly averages agree strongly with the yearly average. Based on these average steam production values, a 30,000 lb/hr (870 HP) boiler was selected as the size appropriate for analysis. A boiler of this size would be around 10% below the average plant steam demand which means natural gas backup would be necessary to meet the load swings, as well as a small degree of the base load. Undersizing the boiler guarantees that it is base loaded and does not have to
operate at low load conditions.

There are various package boilers in this size range that are capable of burning coal. For the purposes of comparison this study considered the application of a 30,000 lb/hr, three-pass, modified Scotch Marine, steam boiler (Figure 1). This unit has horizontal fire tubes and a wet back design. Coal stoking is accomplished with a chain grate and ash removal is automatic. The boiler has a standard design pressure of 150 psig, but higher pressure designs are available.

A chain grate stoker consists basically of an endless chain formed by small links on rods. The links are made of either cast iron or chromium bearing cast iron. The chain mat moves continuously into the furnace carrying a bed of coal leveled at an adjustable thickness by a guillotine door. The chain grate arrangement will handle most coals, other than anthracite and lignite, provided the ash content exceeds 5%. Below this level, the grate will tend to overheat. The upper limit of coal size recommended in 1\(\frac{1}{2}\) inches. Fuel in excess of this sizing will create blow holes in the coal bed resulting in inefficient combustion. Coal with the appropriate recommended characteristics are readily in your area as will be discussed in the Fuel Recommendation section of this report.

For fuel receiving, an underground bunker is recommended. Coal will be delivered in dump trucks which will unload into the pit. The pit is sized to handle a 20 ton truckload. A screw conveyor transfers fuel from the storage pit. From the fuel receiving area, coal is moved to the storage silo. For a 30,000 lb/hr boiler, a 400 ton silo is recommended. This size would yield approximately 11 days of storage if the boiler operates fully loaded 24 hours per day. A bucket elevator is used to lift fuel from the receiving pit to the storage silo. In the recommended design, the silo is arranged to accommodate both live and reserve storage. Live storage is held at the top of the silo, feeds the boiler directly, and is filled first by the bucket elevator. Once the live storage is filled, fuel falls to the reserve storage area. Reserve storage empties via gravity into the bucket elevator where it can be transferred to live storage. Using the silo as both live and reserve storage eliminates the need for a coal bunker at the boiler and also reduces the amount of handling equipment necessary to move fuel between live and reserve storage.
Figure 1. Modified Scotch Marine coal boiler
Total space requirements for this arrangement including receiving pit, silo, and boiler house is approximately 50 feet by 80 feet. This area is available on the southeast corner of the plant. Placed at this position, the boiler would have adequate road access for truck delivery.

3. FUEL RECOMMENDATION

Because of the proximity of the plant to the coal fields, Tennessee Bituminous coal is recommended. The most economical delivery method is by 20 ton dump truck. The delivered price of this fuel is $43-$47/ton. Important properties are presented in Table 2. The properties of this coal match closely those required by the boiler. Based on a coal price of $47/ton, the unit energy cost is $1.81 per million Btu's. The boiler would consume 2,885 pounds of coal per hour, fully loaded, or 35 tons per day. This is equivalent to 1-3/4 truckloads.

| TABLE 2 |
| PROPERTIES OF | TENNESSEE BITUMINOUS COAL |
| Moisture | - 4% |
| Ash | - 10% |
| Volatile Matter | - 29% |
| Fired Carbon | - 59% |
| Heat Content | - 13,000 Btu/lb |
| Sulfur | - 0.70% |
| Size | Stoker Coal |
| | 15% - 1/4" |
| Cost | $43-$47/ton |
4. **ECONOMIC ANALYSIS**

The economic justification for a solid fuel boiler relies on the lower unit fuel cost to offset the higher capital and operating costs. The estimated capital costs for the coal boiler system described earlier are shown in Table 3. All costs include installation. The prices presented in Table 3 are the minimum based on limited options and extras. Significant deviation from the configuration presented could increase the capital cost by as much as 50%. Final equipment selection will be dictated in part by individual plant operating requirements.

<table>
<thead>
<tr>
<th>TABLE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Boiler Installation Costs</td>
</tr>
<tr>
<td>Boiler (30,000 lb/hr three-pass, modified Scotch Marine steam boiler w/chain grate)</td>
</tr>
<tr>
<td>Fuel Receiving - 20 ton, underground pit</td>
</tr>
<tr>
<td>Fuel Storage - 400 ton silo</td>
</tr>
<tr>
<td>Fuel Handling</td>
</tr>
<tr>
<td>Ash Disposal - Submerged Drag Chain</td>
</tr>
<tr>
<td>Site Work and Boiler House</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
</tr>
</tbody>
</table>

Due to greater manpower, utility, and maintenance costs, coal and other solid fuel boilers have operating costs per unit of output that are 3-4 times those of similar gas boilers. Several factors cause this difference. First, coal boilers have more direct labor associated with their operation. While gas boiler installations often have assigned boiler operators each shift, they do not have to devote their full attention to the boiler as do coal boiler operators and can perform other activities in addition to boiler operation. Second, maintenance costs of solid fuel boilers are higher due to the large
number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the number of motors used in receiving and handling, and solid waste disposal. Our evaluation used an operating cost of $0.60/1,000 lb steam for solid fuel boilers and $0.15/1,000 lb steam for gas/oil boilers. When calculating the operating cost, an efficiency of 80% was used with both the coal and gas boilers to determine annual steam production.

The estimated annual costs of operating both the conventional and solid fuel boilers are summarized in Table 4. These costs are based on a fully loaded 30,000 lb/hr coal boiler replacing a fully loaded 30,000 lb/hr gas boiler. Both boilers are assumed to operate 6,600 hr/yr. An additional cost for the coal system is the amortization of the capital cost. A 20 year life and 12% interest rate were used to calculate the annual cost of capital. Based on these assumptions, a simple payback of 1.8 years was calculated. The analysis did not consider tax advantages such as depreciation, investment tax credits, or interest payment deductions which could decrease the payback period, or more expensive equipment expenditures which could increase the payback period.

<table>
<thead>
<tr>
<th></th>
<th>Conventional System</th>
<th>Coal System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>(existing)</td>
<td>$776,000</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>---</td>
<td>$104,000</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$ 30,000</td>
<td>$119,000</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>$1,080,000</td>
<td>$448,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$1,110,000</td>
<td>$671,000</td>
</tr>
</tbody>
</table>

Annual Cost Savings: $1,110,000 - $671,000 = $439,000
Approximate Payback Period: $776,000/$439,000 = 1.8 years
5. CONCLUSION

Due to the annual operating hours of your boilers and their associated load factor, the preliminary analysis indicates that a 30,000 lbs/hr coal boiler could offer a payback of less than 2 years. Based on the favorable result of this introductory study, a more detailed analysis is recommended.
1. Introduction

Company is a manufacturer of passenger car tires located in southwestern Georgia. The production of tires consumes large amounts of steam. Currently this steam is generated from natural gas. The purpose of this study is to provide a preliminary examination of the feasibility of using solid fuel as an alternative to the existing energy supply. This study will consider coal, agriculture residues such as peanut hulls which are plentiful in the area, and plant waste products which include scrap tires and wood pellets.

This plant currently has four boilers in place. Plant personnel related that three boilers are regularly used to supply steam with the fourth unit serving as back-up. All of the boilers are rated at 60,000 lb/hr, and they are estimated to produce 45,000-55,000 lb/hr of steam when operating. These existing boilers are capable of meeting plant steam demand, but the addition of a 20,000-30,000 lb/hr boiler to consume solid waste is planned for 1986. A 100,000 lb/hr boiler to burn solid fuel and replace the gas fired units would be considered if adequate economic benefits could be demonstrated.

The plant operates 24 hr/day approximately 350 day/year. Steam is used in various locations throughout the plant, but the load is relatively steady, remaining between 80,000 and 120,000 lb/hr. In addition to evaluating solid fuels like coal and agricultural residue the plant produces approximately 2,000 tons per year of solid waste which includes 1400 tons of tires and rubber, 300 tons of wood, and 300 tons of paper and cardboard that might be put to use as a supplemental energy source.
2. Equipment Selection

Using the operational and fuel consumption data provided, a calculation of your plant's average steam production based on a one-year period, and for a one-day period in several different months, was completed. The details of these calculations are included in Attachment 1. In the analysis a boiler efficiency of 80%, average work week of 7 days, and energy content of 1000 Btu/lb of steam were used. A summary of this analysis is shown in Table 1 below.

<table>
<thead>
<tr>
<th>Time/Period</th>
<th>Average Steam Production (lb/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year/1983</td>
<td>94,000</td>
</tr>
<tr>
<td>1 day/Dec., 1983</td>
<td>86,200</td>
</tr>
<tr>
<td>1 day/May, 1984</td>
<td>78,500</td>
</tr>
</tbody>
</table>

The average steam production for the year of 1983 was found to be higher than the average daily production during the months of December, 1983, and May, 1984. Some seasonal variation is to be expected, but this does not explain the large difference between the yearly and daily average steam demands. Consultation with plant energy personnel revealed that using a certain operational procedure referred to as steam filled water recovery reduces the daily steam demand by approximately 15,000 lb/hr. This coupled with differences in production rates can explain the discrepancy in steam demand. Based on steam demand rates a 100,000 lb/hr solid fuel boiler is the recommended size in this situation. This boiler is slightly above the average steam demand requirement and thus can respond to seasonal variations above the average. However, it is not greatly over-sized so as to be significantly under-loaded much of the time.

To gauge the size of the system you must first examine the amount of fuel that must be handled. Last year's gas consumption translates into an average coal usage of 105 tons per day. Since 100 ton railcars carry between 80-90 tons of payload, average daily usage would be just over 1 car. Handling capa-
city would need to be larger than 100 tons since delivery could be sporadic. The described system will be capable of handling a minimum of 50 tons/hr, which is as small as would be practical.

The unloading system will contain the following components:
- Car Puller
- Car Shaker
- Rail Support Beams
- Unloading Hopper and Grate
- Vibrating Feeder

The car puller is used to position the railcars for unloading. It will be of the double drum reversible type with a rope pull of 23,000 pounds provided by a 20 hp drive motor. The car shaker is used to assure fast and complete discharge of fuel during unloading. It will be of a lightweight construction swung from a hoist. The unloading hopper will be approximately 14' x 14' at the top and 9' deep fabricated from Type 304 stainless steel. The coal will be moved from the unloading hopper to a belt conveyor with a vibrating feeder. Coal from the vibrating feeder will be deposited on an inclined belt conveyor for transport to the storage silo. The boiler and storage silo will need to be located in the vicinity where the drum storage is now located. This area is located near the southeast corner of the plant adjacent to the existing boiler room and exhaust stack. Therefore, the length of the belt conveyor will need to be approximately 150 feet. The storage silo, constructed of concrete using jumpforms, will be designed to hold 800 tons, which is equivalent to one week's consumption at the maximum capacity of the boiler. Based on a bulk density of 50 lb/ft³, the required storage volume is 32,000 ft³. Since the entire volume of the silo will not be available for storage because the bottom must have conically sloping sides to assist unloading and coal has a 50° angle of repose, this will not occupy the top volume exactly. Installing a silo 30 feet in diameter and 55 feet tall will yield a total volume of 38,000 ft³, which is 20% oversized. Having all of the coal storage covered gives you greater control over it and eliminates environmental concerns such as dust particles becoming caught in the wind and carried away and rainwater falling into the pile and being contaminated. Discharge from the silo will be carried by another belt conveyor to the boiler house.
The boiler is to be a 100,000 lb/hr stoker coal, water tube boiler for production of 250 psi saturated steam. The coal will be delivered from covered storage to a surge bin in the boiler house. Coal exiting the surge bin will be weighed and then distributed to the stokers. The boiler will be a tube and tile, field erected design with an economizer for higher efficiency. For emission control a multi-clone dust collector and fabric filter baghouse are necessary. A new stack is not required since the exhaust can be ducted to the existing stack.

3. Fuel Recommendation

Due to the quantity of fuel required and the distance of the plant from the coalfields in Kentucky and Tennessee, rail delivery is preferred. Bottom unloading 100-ton capacity railcars are the recommended receiving method. Each car has a capacity of 80-90 tons, so about 8 cars will have to be unloaded each week. To be compatible with the boiler firing equipment, stoker coal, 1\(\frac{1}{4}\) x 4, with low fines should be used. This coal is more costly than nut and slack or run of mine coal but has low fines and more uniform size. The properties of the recommended fuel are presented in Table 2. Based on a fuel cost of $56/ton and a heating value of 13,000 Btu/lb, the unit energy cost is $2.15 per million Btu. Fully loaded, the boiler would consume 150 tons per day. This is equivalent to approximately 1-3/4 railcar loads per day. The use of scrap tires and other waste material will be evaluated separately in a report to follow.

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coal Properties</strong></td>
</tr>
<tr>
<td><strong>Size:</strong></td>
</tr>
<tr>
<td><strong>Energy Content:</strong></td>
</tr>
<tr>
<td><strong>Sulfur:</strong></td>
</tr>
<tr>
<td><strong>Fines:</strong></td>
</tr>
<tr>
<td><strong>Ash Fusion Temperature:</strong></td>
</tr>
<tr>
<td><strong>Coal Cost FOB Mine:</strong></td>
</tr>
<tr>
<td><strong>Freight Cost:</strong></td>
</tr>
</tbody>
</table>
4. **Economic Analysis**

The economic justification for a solid fuel boiler relies on the lower unit fuel cost to offset the higher capital and operating costs. The estimated capital costs for the coal boiler described earlier are shown in

**Table 3**

**Coal Boiler Installation Costs**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler (100,000 lb/hr, field erected water tube, spreader stoker with economizer, coal bunkers)</td>
<td>$2,000,000</td>
</tr>
<tr>
<td>Coal Handling (car puller, hopper, shaker, conveyors)</td>
<td>$ 450,000</td>
</tr>
<tr>
<td>Emission Control (multi-clone, baghouse)</td>
<td>$ 450,000</td>
</tr>
<tr>
<td>Coal Storage Silo (800 ton, concrete jump form construction)</td>
<td>$ 250,000</td>
</tr>
</tbody>
</table>

**Total** $3,150,000

10% Tax Credit $315,000

**Adjusted Capital Cost** $2,835,000

Table 3. The budget estimates have been inflated approximately 35% to cover equipment installation. The prices presented in Table 3 represent minimums based on limited equipment options and extras. Significant design variation could increase this cost by 25-30%. Final equipment selection will be dictated in part by individual plant operating requirements. Additionally, the construction of long-term, outdoor storage which would serve to protect the plant from coal strikes or other fuel disruptions has been left to your discretion.

Due to greater manpower, utility and maintenance costs, coal and other solid fuel boilers have operating costs per unit of output that are 3-5 times those of similar conventional fuel boilers. Several factors cause this difference. First, coal boilers have more direct labor associated with their
operation. While gas boiler installations often have assigned boiler operators each shift, they do not have to devote their full attention to the boiler as do coal boiler operators and can perform other activities in addition to boiler operation. Second, maintenance costs of solid fuel boilers are higher due to the large number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the number of motors used in receiving and handling, and solid waste disposal. Our evaluation used an operating cost of $0.50/1,000 lb steam for solid fuel boilers and $0.10/1,000 lb steam for gas/oil boilers. When calculating the operating cost, an efficiency of 80% was used with both the coal and gas boilers to determine annual steam production.

The estimated annual costs of operating both the conventional and solid fuel boilers are summarized in Table 4. These costs are based on a 100,000 lb/hr coal boiler replacing the existing three gas/oil boilers with both loaded an average of 94,000 lb/hr. A natural gas cost of $4.77/MCF or $4.63 per million Btu was used. A cost included with the coal boiler but not the gas boiler is the amortization of the capital cost. A 20-year life and 12% interest rate were used to calculate the annual cost of capital. Based on these assumptions, a simple payback of 1.7 years was calculated.

Table 4
Boiler Economic Analysis
Annual Costs

<table>
<thead>
<tr>
<th></th>
<th>Conventional System (existing)</th>
<th>Coal System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td></td>
<td>$2,835,000</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>--</td>
<td>$ 380,000</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$ 77,000</td>
<td>$ 383,000</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>$4,440,000</td>
<td>$2,060,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$4,517,000</td>
<td>$2,823,000</td>
</tr>
</tbody>
</table>

Annual Cost Savings: $4,517,000 - $2,823,000 = $1,694,000
Approximate Payback Period: $2,835,000/$1,694,000 = 1.7 years
While a 10% investment tax credit was deducted from the initial capital cost, other tax advantages such as depreciation and interest deductions which could further reduce the payback were not considered.

Conclusion
Due to the annual operating hours of your boilers and their associated load factor, the preliminary analysis indicates that a 100,000 lb/hr coal boiler could offer a payback of less than 2 years. Based on the favorable result of this introductory study, a more detailed analysis is recommended.
August 2, 1984

Dear

This letter is to follow up our phone conversation on July 12, 1984, regarding the feasibility of installing a solid fuel boiler at your plant. Currently there are two 200 HP gas fired boilers at your plant. They operate all the time the plant is in production, but at low fire much of the time. The production schedule at your plant was given as 24 hours/day, 5 days/week, approximately 48-50 weeks/year. This is equivalent to 5,760 operating hours.

A solid fuel boiler system is 5-10 times as expensive as a similarly sized gas package boiler. Solid fuel boilers must generate savings from the consumption of a lower cost fuel. Therefore, to be economically attractive, a solid fuel boiler must have a large number of operating hours each year and a high load factor during these hours. Your plant has a relatively large number of operating hours so that the critical factor becomes the boiler load.

The natural gas usage from May 18 to June 21, 1984, was analyzed to determine an average boiler load during this period. The data supplied was:

<table>
<thead>
<tr>
<th>Gas Usage</th>
<th>Energy Factor</th>
<th>Cost (30 Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,898,300 ft³</td>
<td>1,030 Btu/ft³</td>
<td>$26,600</td>
</tr>
</tbody>
</table>

Furthermore, not all of the natural gas is used by the boiler. Plant personnel estimated that a direct fired gas dryer used 40% of this total energy. The gas used by the boiler is:

\[3,898,300 \text{ ft}^3 \times 1,030 \text{ Btu/ft}^3 \times 0.6 = 2,410 \text{ MMBtu/yr}\]

where MM refers to millions of Btu's.

This energy can be converted to steam production by multiplying by boiler efficiency and dividing by steam energy content:

\[2,410 \times 10^6 \text{ Btu/mo} \times 0.82 \times 1 \text{ lb steam/1,000 Btu} = 1,980,000 \text{ lbs steam/mo.}\]
During this period, the plant operated about 520 hours yielding an average steam rate of:

\[1,980,000 \text{ lbs steam/mo} \times 1 \text{ mo/520 hrs} = 3,810 \text{ lbs steam/hr.}\]

This is the monthly average steam production rate and represents the starting point for sizing an appropriate boiler. If the plant load fluctuates frequently, a boiler significantly larger than 3,810 lbs/hr could be required.

Unfortunately, a steam load of 3,810 lbs/hr or 110 HP is below the size where solid fueled boilers are generally economical. This fact is illustrated by the enclosed boiler cost vs. boiler output figure developed at Georgia Tech. The unit boiler cost ($ per lb of steam output) escalates rapidly at sizes below 10,000 lbs/hr (290 HP) so that the cost of smaller boilers does not drop linearly. A boiler of the size needed at your plant would cost approximately $315,000. This is the installed cost for a 200 HP solid fuel boiler assuming no expenditure for fuel receiving as shown in Table 1. This means that if the installed solid fuel system operated for free, which it would not, and completely eliminated your natural gas requirement, the payback would still be 1 year.

Based on this reasoning, we recommend that you not consider a solid fuel boiler at this time. However, if your steam demand shows an increase in the future, such a system could become feasible.

Sincerely,

Michael Brown

MB/pk
Enclosure
Table 1

200 HP Solid Fuel Boiler

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler</td>
<td>$210,000</td>
</tr>
<tr>
<td>Fuel Receiving</td>
<td>---</td>
</tr>
<tr>
<td>Fuel Storage</td>
<td>$65,000</td>
</tr>
<tr>
<td>Fuel Handling</td>
<td>$20,000</td>
</tr>
<tr>
<td>Site Work</td>
<td>$20,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$315,000</td>
</tr>
</tbody>
</table>
USING SCRAP TIRES AS AN INDUSTRIAL ENERGY SOURCE

INTRODUCTION

The disposal of discarded or worn out tires by environmentally safe means is a topic that has received much attention during the last decade. Making a tire requires a substantial investment in raw materials and energy. Therefore, research dedicated to effective tire disposal has focused on identifying practical uses for discarded tires or recycling recoverable compounds into other applications. Many of these methods have proven their technical merit but few have demonstrated the economic viability necessary for acceptance by the industrial sector.

Of the 200 million tires scrapped in the United States in 1978, 72.5% were landfilled. Examination of Table 1 indicates that less than 28% of the discarded tires were recycled and less than 10% were processed for rubber or energy recovery.

Table 2 lists the uses of used tires in order of their economic attractiveness. Those alternatives that do not require additional processing head the list. Many of the alternatives listed require extensive processing with special equipment. More information can be obtained from Table 3. The technologies that appear to be most attractive in Table 2 are shown applicable only on a small scale and of negligible potential in alleviating the tire disposal problem. Of greater promise for large scale tire disposal are asphalt substitutes, combustion and pyrolysis.

Because it requires the least amount of tire processing, direct combustion of whole or shredded tires appears to be the most attractive means of tire disposal for the short term. This conclusion is drawn from the following facts:
<table>
<thead>
<tr>
<th>Disposal Option</th>
<th>Scrap Tires (million)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill</td>
<td>145</td>
<td>72.5</td>
</tr>
<tr>
<td>Retread</td>
<td>36</td>
<td>18</td>
</tr>
<tr>
<td>Reclaim</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Fuel</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
<td>100</td>
</tr>
</tbody>
</table>
### Table 2. Uses for Worn Tires[3]

<table>
<thead>
<tr>
<th></th>
<th>Whole</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Used Tire</td>
<td>Worth as much as retread</td>
</tr>
<tr>
<td>2.</td>
<td>Retread</td>
<td>For 30% of the energy required, for new tire production you get 80% of the wear. 30% truck tires retreaded. 70% bus tires retreaded. (17-18)% privately owned vehicle tires retreaded. Overall 20% retreaded.</td>
</tr>
<tr>
<td>3.</td>
<td>Artificial Reef, Highway Crash Barrier, highway base material, etc.</td>
<td>No processing costs. Presently less than 0.1% of waste tires.</td>
</tr>
<tr>
<td>5.</td>
<td>Ground or crumb rubber</td>
<td>Used in asphalt compounds in tires as filler, in molded rubber products &amp; in concrete.</td>
</tr>
<tr>
<td>6.</td>
<td>Rubber reclaim by chemical or thermal devulcanization</td>
<td>Chemical or thermal devulcanization requires more processing than ground or crumb rubber. Mixed with virgin rubber in new tires and other products.</td>
</tr>
<tr>
<td>7.</td>
<td>Reclamation of Rubber by Microwave Treatment</td>
<td>Material can be recycled more than once without detriment to physical properties.</td>
</tr>
<tr>
<td>Process</td>
<td>Comments</td>
<td>Plant(1) Scale</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Combustion of whole tires</td>
<td>Requires special furnace; replaces coal; 12,000 Btu per lb energy recovered</td>
<td>L</td>
</tr>
<tr>
<td>Combustion of shredded tires</td>
<td>Co-fire with coal in existing stoker furnace; replaces coal; 12,000 Btu per lb energy recovered</td>
<td>S</td>
</tr>
<tr>
<td>Pyrolysis (fuel products only)</td>
<td>Up to 12,000 Btu/1b petroleum replaced</td>
<td>L</td>
</tr>
<tr>
<td>Pyrolysis (recover fuel products and carbon black)</td>
<td>Cost $1.50; revenue $1.80/tire carbon black quality in dispute</td>
<td>L</td>
</tr>
<tr>
<td>Reclaim</td>
<td>Often considered an inferior product; use declining until recently</td>
<td>S</td>
</tr>
<tr>
<td>Biological degradation</td>
<td>Experimental; sulfur-carbon bonds attacked by microorganisms</td>
<td>S</td>
</tr>
<tr>
<td>Microwave devulcanization</td>
<td>Still experimental for tire rubber</td>
<td>S</td>
</tr>
<tr>
<td>Asphalt substitute</td>
<td>Most promising option. One pound of rubber could replace five pounds of asphalt.</td>
<td>S</td>
</tr>
</tbody>
</table>

(1) S = applicable on small scale; L = large scale only.

(2) A = could consume all scrap tires; P = could consume only part of supply.
o No special equipment or processes are required to prepare tires for burning. The shredding technology has already been proven and is in use in the U.S.

o Some locales already have dealers or "jockeys" who collect, process and sell scrap tires.

o Scrap tires exhibit heating values between 12,000 and 14,000 Btu per pound and can be purchased at a cost of $0.50 per tire or less. This makes scrap tires an inexpensive fuel source on a dollar per BTU basis (comparable to coal). In the short-term, users may be able to obtain tires from landfill operations at no cost.

o Burning of scrap tires has the potential to dispose of all the scrap tires generated in the U.S. every year.

o Enough research has been conducted in this area to establish operating parameters for fuel delivery, combustion and stack clean-up.

With about 95,000 tons of scrapped tires generated annually[3], the Georgia Environmental Protection Department (E.P.D.) and the State's retail tire dealers are facing an acute disposal problem. Two county landfills, Cobb and Dekalb have tire shredding equipment on site but Georgia industry is not actively involved in recycling or recovering energy from scrap tires. Interest is high however, and it is hoped that this report will be of assistance to those Georgia plants presently considering scrap tires as a fuel source.

This paper presents the results of a literature review conducted on burning tires for industrial thermal energy. The technical and economic factors involved for several technologies are summarized. These technologies include:
Co-firing with coal or wood waste in an existing solid fuel furnace;

Co-firing whole tires and coal in rotary kilns used in cement making;

Burning scrap tires in an industrial waste incinerator.

COMBUSTION CHARACTERISTICS OF SCRAP TIRES

A tire burns in two distinct stages. In the first or primary zone, the solids and liquids are partially oxidized driving off all the volatile matter. The volatile gases are burned along with any airborne particles in the second phase of combustion.

Agitation and temperature control are critical because of the behavior of the charge in both the primary and secondary zones. As a tire is thermally degraded in the first zone, it melts forming a high temperature slag. Agitation prevents the slag from forming and adhering to the grates. In addition the agitation exposes more of the slag to the flame and primary combustion air. Traditionally excess air has been used to maintain the primary zone temperature around 1800°F. One firm has used steam in place of combustion air to affect primary zone temperature control. It may be possible to use other gases as well.

Maintaining the temperature at this level will result in complete carbon burnout. Agitation is best supplied by mechanical means such as traveling grates; rotating hearth or an environment much like a rotary kiln. This action agitates the bottom of the bed preventing slag formation while minimizing velocities at the fuel bed surface.

In the secondary zone the temperature must be held in excess of 2000°F to insure complete combustion of all the volatile matter. Temperature control is again achieved by using excess air. The gases should be mixed with this secondary air quickly to facilitate fast burning and to avoid smoking.
The chemistry involved in tire making is quite complex. Organic rubber compounds and inorganic additives are combined to produce the finished product. Many of these additives require special attention when tires are burned. Table 4 lists the problems associated with these inorganics along with their contribution to the manufacturing process.

Table 5 presents a typical proximate and ultimate analysis of a passenger tire with the fabric and steel removed. The inorganics listed in Table 4 are contained in the ash according to Tables 5 and 6. As can be seen the quantities of these inorganics are small relative to the whole tire. Still caution must be exercised when burning tires to ensure that the ash removal system prevents the entrainment of the troublesome particles in the flue gas.

The technical problems associated with co-firing a solid fuel boiler with scrap tires appear to be minimal. Previous research in this area has indicated that the major concerns are:

- Pollution control, especially particulate emissions due to the carryover of zinc oxide into the flue gas;
- Excess ash due to the steel belts present in many of today's tires.

The presence of steel belts in most tires must be dealt with in the combustion chamber. When combusted, the steel oxidizes and becomes part of the ash robbing the tire of useable energy and resulting in higher maintenance costs. Perhaps the most serious problem results from increased particulate loading. Zinc oxide escapes the combustion chamber and is carried over into the stack. Most co-fired installations classified as boilers burning low percentages of scrap tires meet their emission standards. If classified as incinerators however, particulate emissions may prevent approval of the facility by a State's Environmental Protection Department. This has occurred at some installations such as Goodyear in Michigan[4,10]. Should additional cleanup equipment be necessary, the economic viability of burning tires becomes questionable.
<table>
<thead>
<tr>
<th>ADDITIVE</th>
<th>PURPOSE</th>
<th>POTENTIAL PROBLEMS WITH COMBUSTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Black</td>
<td>Used in all tired thread compounds</td>
<td>Residual carbon black &quot;floats&quot; in the ash</td>
</tr>
<tr>
<td>Zinc Oxide</td>
<td>Curing Activator/Pigment</td>
<td>Potential for particulate emission</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Vulcanizing Compound</td>
<td>Possible pollution hazard</td>
</tr>
<tr>
<td>Antimony &amp; Arsenic Compounds</td>
<td>Mold and Algae Retardants</td>
<td>Potential for particulate emission.</td>
</tr>
<tr>
<td>Cobalt &amp; Boron Compounds</td>
<td>Adhesion Enhancements</td>
<td>Potential for particulate emission.</td>
</tr>
<tr>
<td>Barium, Lead Copper, Cadmium, Calcium, Sodium, Potassium</td>
<td>Trace Elements</td>
<td>Potential for particulate emissions.</td>
</tr>
</tbody>
</table>
TABLE 5. ANALYSES OF TIRES[12]

<table>
<thead>
<tr>
<th></th>
<th>PT - 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proximate, percent:</strong></td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>0.5</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>62.3</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>31.5</td>
</tr>
<tr>
<td>Ash</td>
<td>5.7</td>
</tr>
</tbody>
</table>

| **Ultimate, percent:**   |        |
| Hydrogen                 | 7.1    |
| Carbon                   | 83.2   |
| Nitrogen                 | .3     |
| Oxygen                   | 2.5    |
| Sulfur                   | 1.2    |
| Ash                      | 5.7    |

*Bead and fabric free.*
TABLE 6. TYPICAL ANALYSES OF SCRAP TIRE ASH[9]*

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight %</th>
<th></th>
<th>Parts Per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample 1</td>
<td>Sample 2</td>
<td>Sample 1</td>
</tr>
<tr>
<td>Carbon (C)</td>
<td>81.81</td>
<td>83.23</td>
<td></td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>1.88</td>
<td>1.81</td>
<td></td>
</tr>
<tr>
<td>Barium (Ba)</td>
<td></td>
<td></td>
<td>47</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>24,400</td>
<td>26,660</td>
<td></td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>44</td>
<td>197</td>
<td></td>
</tr>
<tr>
<td>Boron (B)</td>
<td>3</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>50</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>21,410</td>
<td>1,538</td>
<td></td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>256</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>5,610</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>82</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>1,360</td>
<td>254</td>
<td></td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>442</td>
<td>205</td>
<td></td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Antimony (Sb)</td>
<td>132</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

*Moisture free and steel wire free basis.
Sulfur is usually not a problem in co-firing tires. The sulfur content is below that of coal resulting in a small reduction in sulfur oxide levels[4]. When fired with wood, the wood ash may help control sulfur related problems. Reports available in the literature claim that co-firing of coal with up to 15% scrap tires requires no boiler adjustments and no capital investment in burning or stack cleanup equipment[4]. Capital expenditures are confined to storage, handling and delivery systems.

BURNING SCRAP TIRES

Tire Collection, Delivery and Costs

Those scrap tires that are disposed of in an environmentally sound manner are usually landfilled. Deese, et al reported fees of $0.20 per tire to $5 per tire for landfilling at numerous landfills across the United States[2]. In Atlanta, a phone survey of four private landfills yielded a range of $4.50 per tire to $12 per tire. One firm refused to accept them. In contrast the Dekalb County Landfill accepts passenger tires at an approximate cost of $0.17 per tire. As a rule, private operations charge more for tire disposal than municipal dumps.

Many areas of the country have used tire dealers or "jockeys" who collect scrap tires from retail tire dealers for storage, landfill, processing or sale. These "jockeys" usually collect a "tipping" fee of $0.25 to $0.50 per tire from the tire generator. This is comparable to what many municipal landfills currently charge for tire disposal. Such an operation is not currently operating in Georgia.

Estimates of the number of scrap tires generated typically are based on a rate of 1 tire per person per year. Intenco, Inc. developed a computer model that relied on the parameters of tire production rate, mileage, tire life expectancy, and vehicle registration. Their result confirmed the validity of the rule-of-thumb with a generation rate of roughly one tire per person per year[3]. Therefore, plants considering burning tires should be located within or adjacent to large population centers.

In applications with energy demands of over 100,000 pounds of steam
per hour, tire supply may be a problem. Location adjacent to metropolitan areas will provide a source of scrap within a mileage radius from the plant that still allows a savings in energy cost to be realized. Large plants may choose to collect their own scrap tires or contract with a scrap tire dealer for a guaranteed supply. The former option will essentially put the large user in the scrap tire business; requiring the same equipment and operating expenses as the conventional scrap tire operation.

Consider Atlanta as an example. Scrap tire generation was estimated at 3 million tires annually[3]. A cement kiln wishing to satisfy 20% of its energy demand would burn 5000 tires per day. This corresponds to 1.8 million scrap tires annually or 60% of the total available. It is unlikely that this number of tires could be consistently collected and processed at a total cost less than the plant's conventional fuel source.

Some institutional resistance may be encountered in the near-term as scrap tire collection networks become established. Many scrap tire generators are used to disposing of their carcasses at costs less than the $0.20 to $0.50 per tire "tipping" fees discussed in this paper. They may view the "tipping" fee as an unwanted or undesirable expense. At the same time, the scrap tire dealer or the user must charge the fee to recover some of the costs incurred in collecting and processing scrap tires or the cost of burning tires will not be competitive with burning conventional fuels. Because of these supply limitation scrap tires cannot be considered a reliable source of fuel for large users.

The user may uncouple himself from the tire supply problem by purchasing his tire fuel from a "jockey". Processing costs and profit are recovered by the jockey from two sources: the tire operator and the scrap tire user. This allows him to price tire fuel at a level competitive with other industrial fuels.

As markets develop for scrap tires, more tire "jockeys" will begin operating in more localities. They will serve as middle men between scrap tires generators and users. Should the tires require any processing such as shredding, the jockey will perform it and recover the costs from both the tire generator and the user.

Reports in the literature indicate that mechanical shredding of
longer tires costs between $30 and $50 per ton. These estimates are
based on amortization of capital costs, annual operating expenses and
scrap tire throughput. Shredding costs are extremely sensitive to annual
throughput. Figures quoted by shredder vendors are typically design
sizes. But shredding operations rarely operate at their design point.
Making use of the available capacity increases shredding costs on a per
basis.

Deese, et. al., performed an economic analysis for the case of a tire
collection operation on a 150 mile radius and supplying a plant with
shredded tire fuel. They assumed a sale price of $0.25 per ton to the
other costs were charged to the generator in a "tipping" fee. The
results indicated that 75% of the processing costs were attributed to
transportation. Total processing cost was not sensitive to changes in
transporting costs for operations processing 30 tons per day or more of
shredded tire fuel.

It is likely that whole tires would be less expensive than shredded
tires since all shredding costs are avoided. In some cases, a prospec-
tor might secure landfilled tires from a local dump at no charge.
Another possibility would see the tire user picking up tires from the
stor for a "tipping" fee sufficient to recover his transportation and
ming costs, resulting in an essentially free energy source. In areas
where landfills will accept tires, the user could implement this plan
co-operation with local tire dealers.

Previous Demonstration Projects

Whole and shredded scrap tires have been burned successfully in
boilers. Tables 7 and 8 list those installations found in the
along with a short description of each project. Many of the
projects have been shut down for economic reasons although some operations
have faced problems with pollution. In many instances, no numerical data on
these cases was reported in the literature.

OF CO-FIRING TIRES IN SOLID FUEL FURNACES
<table>
<thead>
<tr>
<th>User and Location</th>
<th>Type of Combustor</th>
<th>Percent Tires Burned</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goodyear</td>
<td>Cyclonic, Rotary</td>
<td>10%</td>
<td>Unit operated for a year, 25% of the time at 150% rated capacity. Met emission standards of a coal-fired boiler. When reclassified an incinerator, it was shut down to avoid expense retrofit of pollution control equipment. Burned tires exclusively.</td>
</tr>
<tr>
<td>Jackson, Michigan</td>
<td>Hearth Furnace</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goodyear</td>
<td>Coal-fired, Wet bottom</td>
<td>10%</td>
<td>No technical problems reported. Classified as a utility boiler. Burned for disposal rather than energy recovery so no economics reported. Boiler retired from service due to age.</td>
</tr>
<tr>
<td>Akron, Ohio</td>
<td>Boiler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jersey City</td>
<td>Incinerator for</td>
<td>5%</td>
<td>Tires burned as part of a 12,000 lb. charge. Unit suitable for service. More underfire air ports proposed.</td>
</tr>
<tr>
<td>Incinerator</td>
<td>Bulky Refuse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User and Location</td>
<td>Type of Combustor</td>
<td>Percent Tires Burned</td>
<td>Project Description</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------------------</td>
<td>----------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Nihon Cement Co. &amp; Bridgestone Tire</td>
<td>Inclined Rotary Kiln in Cement Manufacture</td>
<td>Data not available</td>
<td>Whole tires co-fired with coal. Bridgestone holds U.S. patent on technology. Over 20 Japanese firms adopted technology. In 1981, this method disposed of 69,000 tons of tires. Sulfur and steel cords usable as cement raw materials. Capital expenditure of $200,000 to $300,000 necessary. However, problems with &quot;gumming up&quot; of pre-calciners have been encountered. Temperature control in kiln critical to preserve refractory.</td>
</tr>
</tbody>
</table>
Tires have a heat content comparable to coal on a Btu per pound basis. Values in the range of 12,000 to 14,000 Btu per pound are reported in the literature[9]. This high heating value and the potential low cost of worn out tire carcasses provide the economic incentive to displace coal, wood or natural gas as an industrial energy source. Table 9 compares many popular industrial fuels on a dollar per million Btu basis. As shown, scrap tires are the least expensive fuel source listed.

Tire characteristics vary as to size, weight, and method of construction. For this analysis, the scrap tire is assumed to be an unretreadable, 22 pound, steel-belted radial tire.

**Burning Shredded Tire Fuel**

Although co-firing low percentages of scrap tire fuel may not affect boiler costs, costs associated with the fuel system will be incurred. Listed below are the major cost components to be considered:

1. **Purchase and installation of equipment**
   - Storage space
   - Feed conveyor
   - Airlock at boiler

2. **Operating and maintenance of boiler/fuel system**
   - Auxiliary power consumption
     - By conveyor motors
     - By front end loader
   - Extra manpower for boiler crew
     - More frequent inspection and cleanout
     - Closer monitoring of combustion efficiency and contents of flue gas
   - Fuel cost
     - Cost of tires
     - Additional transportation and delivery fees
<table>
<thead>
<tr>
<th>FUEL</th>
<th>HEATING VALUE</th>
<th>UNIT COST</th>
<th>COST PER MILLION BTU'S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Wood</td>
<td>4,250 Btu/lb</td>
<td>$10/ton</td>
<td>$1.18</td>
</tr>
<tr>
<td>Coal</td>
<td>13,000 Btu/lb</td>
<td>$45/ton</td>
<td>$1.73</td>
</tr>
<tr>
<td>Gas</td>
<td>1,000 Btu/ft³</td>
<td>$6.50/Mcf</td>
<td>$6.50</td>
</tr>
<tr>
<td>#6 Oil</td>
<td>150,000 Btu/gal</td>
<td>$1.00/gal</td>
<td>$6.67</td>
</tr>
<tr>
<td>Scrap Tires</td>
<td>12,000 Btu/lb</td>
<td>$.25/tire</td>
<td>$0.95</td>
</tr>
</tbody>
</table>
Figure 1 compares the annual fuel costs for generating steam with waste wood, co-firing waste wood with 10% shredded tires, coal, co-firing coal and 10% shredded tire fuel and co-firing with 10% whole scrap tires as a function of steam output. Tires are assumed to cost $0.25 each. The savings appear to be small for small installations and increase as the rated steam capacity increases. Figure 2 illustrates the effect of tire cost on the annual fuel cost for a plant burning coal and 10% shredded tire fuel. The no-cost line is included for reference. It is unlikely that shredded tires would be available to the user for free. The $0.50 per tire line represents the approximate cost associated with collecting, shredding, and delivering scrap tires according to Deese, et. al. It also represents the maximum "tipping" fee paid by scrap tire generators to have their discarded carcasses landfilled in a municipal dump. It is assumed that the scrap tires are purchased from a tire "jockey". Tire cost is assumed to include all tipping fees, processing costs, associated overhead, profit and transportation costs. Examining the figure shows that potential savings from co-firing becomes significant as the tire price declines and rated steam capacity increases. Figure 3 provides the same type of information for co-firing with waste wood. It should be noted that the savings are greater in this case and for large installations such as paper mills, tire costs below $0.33 per tire could result in significant fuel savings.

Using the tables provided in the Appendix and the results illustrated in Figures 2 and 3, curves depicting steam generation costs for co-firing tires with coal or waste wood can be plotted. Figure 4 presents the results for coal. As can be seen, cost per million Btu of delivered steam energy declines as steam demand increases. The rate of decrease appears greatest at approximately 100,000 lb of steam per hour boiler capacity. This is the same trend exhibited when firing coal alone. Note that shredded tire fuel at $0.50 per tire costs more than firing 100% coal until the steam demand approximates 200,000 pounds of steam.

In Figure 5, the generated curves exhibit a hump in the 100,000 pound per hour range. This is due to the disproportional increase in wood boiler cost. A waste wood boiler of this capacity costs 211% more than one of 50,000 pound per hour size. As a comparison a 100,000 pound per hour
Figure 1. Annual Fuel Cost for Steam Generating Systems

LEGEND
1. 100% Coal
2. Coal & 10% Shredded Tires
3. 100% Waste Wood
4. Waste Wood & 10% Shredded Tires
5. 100% Shredded Tires

Boiler Rated Steam Capacity (pounds per hour)
Figure 2. Sensitivity of Annual Fuel Cost to Tire Price for Co-Firing 10% Shredded Tires With Coal

Million Dollars Per Year

$0.50 per tire
$0.25 per tire
No charge

Boiler Rated Steam Capacity (pounds per hour)
Figure 3. Sensitivity of Annual Fuel Cost to Tire Price for Co-Firing 10% Shredded Tires With Waste Wood

Million Dollars Per Year

$0.50 per tire

$0.25 per tire

No charge

Boiler Rated Steam Capacity (pounds per hour)
Figure 4. Steam Generation Cost and its Sensitivity to Tire Price for Coal

per MMBTU

LEGEND

1. Coal & 10% Tires @ $0.50 per tire
2. 100% Coal
3. Coal & 10% Tires @ $0.25 per tire
4. Coal & 10% Tires @ No Cost

Boiler Rated Steam Capacity (pounds per hour)
Figure 5. Steam Generation Cost and Its Sensitivity to the Price of Tires for Co-Firing with Waste Wood

LEGEND

1. Waste Wood & 10% Tires @ $0.50 per tire
2. 100% Waste Wood
3. Waste Wood & 10% Tires @ $0.25 per tire
4. Waste Wood @ 10% Tires @ No Cost

Boiler Rated Steam Capacity (pounds per hour)
coal boiler costs 83.33% more than its 50,000 pound per hour counterpart. Therefore, the lowest generating costs are obtained for the 200,000 pound per hour system. It appears that tires costing less than $0.33 a piece would result in lower generating costs than for 100% waste wood.
Burning Whole Tires

Co-firing whole scrap tires possesses several economic advantages over shredded tire fuel. The processing costs associated with shredding are avoided and the only costs incurred are due to transportation. By charging the waste tire generator a disposal or "tipping" fee, the user could recover all costs, ending up with a free source of energy.

Three different technologies have been employed for co-firing whole tires. They are:

- Wet bottom solid fuel boiler;
- Pre-calcined inclined rotary kilns used in the cement industry;
- Industrial waste incinerator.

Goodyear successfully co-fired 10% whole scrap tires in an old, wet bottom boiler at their Akron facility. No technical problems were reported and the unit burned tires until it was retired from service due to its age. The application is extremely limited, however, because of the equipment involved.

Injecting whole tire carcasses into precalcining, inclined rotary kilns offers some advantages to the cement industry. Not only can fuel costs be cut but the steel belts and sulfur present in the tires can be used as raw materials in the cement making process. This technology has been successfully demonstrated by the Japanese. The application has drawbacks, though. It requires precise combustion control to avoid ruining the refractory and/or the cement charge. Although savings in fuel costs are large, modifying an existing kiln is an expensive proposition. Costs in excess of $500,000 could be encountered. Co-firing small percentages of tires with coal does not appear to be economically attractive at this time. However, the energy savings become significant as the weight percent of tires in the fuel feedstock increases above 10%.

Because of the large number of tires required to satisfy the fuel demand of a cement kiln, securing a reliable, continuous supply source becomes extremely important. Two options are open to the plant; they may
collect their own scrap tires or purchase them from a tire "jockey". If an operation chooses to secure their own tires, they must have access to a large guaranteed source. For example, a cement kiln requiring 22.8 million scrap tires per year to be co-fired with coal will save money as long as their total tire cost remains below $0.34 per tire. If only transportation charges are considered ($0.0030 per tire per mile) then the plant can collect scrap tires within a 113 mile radius of the kiln site. Therefore, it is possible for the operation to save money provided enough scrap tires are generated within this radius that can be collected for burning. If the plant is able to collect a "tipping" or disposal fee from the tire generators the collection radius increases. Note that the collection radius depends on the necessary break-even cost and the total cost incurred in getting tires to the kiln. These figures will be different for each case analyzed.

The demand for scrap tires is so large for most kilns that plants collecting their own tires will essentially become scrap tire dealers.

This application is extremely limited in Georgia. The Atlanta Chapter of the Portland Cement Association claims there are only two kilns of this type currently operating in the State.

Incinerators are commercially available that provide complete burn of charges containing tires and other industrial wastes. Once combusted, the gases flow through a heat recovery boiler for manufacturing steam.

One modification for a user whose entire waste load cannot meet his steam demand might be a small incinerator located adjacent to a conventional boiler.

Basic Environmental Engineering, Inc. has provided two such incinerator/waste heat boiler systems to Firestone for burning tires and other industrial wastes. Each unit satisfies a percentage of the steam required by its respective plant. The incinerators are equipped with their own feed mechanisms. Equipment cost for the 28 million Btu per hour unit is approximately $1.25 million.

A further reduction in equipment cost could be utilized by burning waste in an incinerator and pipping the hot combustion gases directly into the existing boiler. Such a setup eliminates the need for a waste heat
recovery boiler as well as a separate stack for each combustor.

The equipment to accomplish this is commercially available. Energy savings should be comparable to an incinerator/waste heat boiler system of similar size.

Economics

Table 10 presents the yearly costs for generating 100,000 lb per hour of steam from a coal fired boiler and an industrial waste burning system. At $3.43 per million Btu of delivered steam energy, this option achieved the lowest steam generating cost of any alternative with an equal capacity. Figure 6 illustrates the comparison. In Figure 7, the savings in annual fuel costs for a plant displacing natural gas with a whole tire incinerator are illustrated. Again the steam capacity is 100,000 pounds per hour. The large savings are possible because of the relatively high cost of natural gas per million Btu. In this application the simple payback period would be slightly more than one year.

Conclusions

Disposing of scrap tire carcasses can be accomplished by burning them in conventional boilers, pre-calcining rotary kilns, or industrial waste incinerators. The technology has been tested and is in place to co-fire whole or shredded tires in these devices. The technical problems are minimal, focusing on combustion control and particulate emissions due to the zinc oxide present in tires.

The operating experience of users co-firing tires with coal indicates that a tire mix of 10 to 15 percent by volume in the fuel feed requires no adjustments of combustion controls and no extra pollution control equipment to acceptably burn the fuel.

Co-firing shredded tires in industrial solid fuel furnaces appears attractive for installations in the 200,000 pounds of steam per hour range. More savings are realized when co-fired with waste wood because of wood’s lower heat content compared to tires and the higher boiler costs when com-
<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Capital Cost - Boiler, Conveyors, Dumpers, etc.</td>
<td>$2,659,000</td>
</tr>
<tr>
<td>Total Incinerator Cost - Combuster, Conveyor, W.H. Boiler</td>
<td>$1,250,000</td>
</tr>
<tr>
<td><strong>10% Investment Tax Credit</strong></td>
<td><strong>$3,909,000</strong></td>
</tr>
<tr>
<td><strong>Total Financed</strong></td>
<td><strong>$3,518,000</strong></td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>$544,000</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$317,000</td>
</tr>
<tr>
<td>Maintenance Costs</td>
<td>$175,000</td>
</tr>
<tr>
<td>Tax and Insurance</td>
<td>$88,000</td>
</tr>
<tr>
<td>Total Annual Fuel Cost</td>
<td>$882,000</td>
</tr>
<tr>
<td><strong>Total Annual Costs</strong></td>
<td><strong>$2,006,000</strong></td>
</tr>
<tr>
<td>Annual Heat Delivered (in MMBtu)</td>
<td>585,000</td>
</tr>
<tr>
<td>Cost per Million Btu Delivered</td>
<td>$3.43</td>
</tr>
<tr>
<td>Cost per million Btu for a Coal Boiler Delivering 100,000 lb/hr of steam</td>
<td>$3.76</td>
</tr>
</tbody>
</table>
Figure 7. Annual Fuel Cost Comparison for an Industrial Waste Incinerator That Burns Tires

Cost in Millions of Dollars ($)

- 100% Natural Gas
- Natural Gas And Industrial Waste Incinerator

Steam Capacity of 100,000 lb/hr
pared to coal. Industries such as paper mills could benefit from burning shredded tire fuel, relying on their past experience with solid fuels to hold down equipment and operating costs. Co-firing 10% scrap tires in a 200,000 pound per hour wood waste boiler could burn over 1,300,000 tires per year. This means one paper mill could possibly dispose of 17% of the State's scrap tires.

Whole scrap tires may be burned in the pre-calcining rotary kilns used in cement making. The steel belts and sulfur present in a tire are actually used as raw materials in the cement making process. Energy savings are significant for feed mixtures of coal and over 10% tires by weight. Actual savings depend on the cost of tires. The large energy demand of these devices requires a large amount of scrap tires. Securing a reliable source may be a problem.

The most profitable alternative appears to be displacing natural gas by including an industrial waste incinerator as part of an industrial operation's steam plant. However, special considerations such as a "free" source of tires would generate significant savings even with coal or waste wood.

Burning scrap tires in an incinerator has other advantages:

- achieves the lowest steam generation cost of a given size steam plant for firing alongside a coal boiler
- the incinerator can burn other wastes besides tires
- scrap tires might be a "free" source of energy from landfills and tire retail outlets
- the combustion chamber of the incinerator is expressly designed for burning tires
- units are available commercially and include their own feed mechanism.

The option reviewed in this report could burn over 160,000 tires per year or 2.1% of the tires annually discarded in Georgia. If implemented on a wide scale, burning tire carcasses in industrial waste incinerators could eliminate the State's tire disposal problem.
The decision to burn scrap tires to displace conventional industrial fuel is an economic one. It is extremely sensitive to the cost of scrap tires which, in turn, is a function of transportation costs and to a lesser degree processing and shredding costs. Plants burning whole tires may have an advantage over those considering shredded carcasses for fuel. Shredded tires most likely will be purchased from a dealer. This dealer will charge the tire generator a disposal or "tipping" fee and will process the carcasses into a uniform fuel which will be sold to the end user. Burners of whole tires could collect their own fuel, recouping collection costs with their own "tipping" fee.

Tire cost will depend on processing costs including all transportation charges. The price to the end user will depend on the amount of the "tipping" fee collected from the tire generator for tire disposal. In cases where the user collects his own tires, the tires may become a free energy source. But middle men or "jockeys" must recover all transportation and processing costs plus make a profit. To seriously compete against conventional fuel sources, jockeys must provide scrap tire fuel to end users at a fixed price. This means that "tipping" fees will vary with distance from the jockey's operation. As long as these disposal fees compare favorably with the charge to landfill tires, a guaranteed source of tires should not a problem.

Plants requiring large amounts of scrap tires will be at a disadvantage in the near term. Until scrap dealers establish effective collection networks in more areas of the U.S., large users must collect their own tires. They will likely encounter these problems:

- Not enough scrap tires are generated within a distance from the plant that can be economically collected, processed, and burned;
- They will essentially become scrap tire dealers themselves;
- Institutional resistance to paying disposal fees.

The current scrap tire supply situation favors the small user. Since his demand is not so great, he is afforded more flexibility in his method
of scrap tire collection.

Co-firing scrap tires appears to be an ideal method of environmentally safe disposal for the near term. Widespread application could result in the disposal of all the scrap carcasses generated annually in Georgia. However, when considered as an energy conserving measure, the decision to burn tires is not so obvious. Steam plant size, tire cost, "tipping" fees, and the prices of the fuel being displaced will dictate the parameters used in the economic equation. Under certain conditions such as industrial waste incineration and large waste wood burning plants, the energy savings appear to be more than sufficient to ensure reduced energy expenditures and rapid return on investment dollars.
APPENDIX

Boiler System Data
### TABLE A.1 SYSTEMS COSTS - COAL BOILER SYSTEM

#### Firing with 100% coal

<table>
<thead>
<tr>
<th>Capacity (lbs/hr)</th>
<th>50,000</th>
<th>100,000</th>
<th>200,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel System</td>
<td>488,394</td>
<td>537,612</td>
<td>685,266</td>
</tr>
<tr>
<td>Boiler</td>
<td>1,514,400</td>
<td>2,776,400</td>
<td>5,048,000</td>
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<td>Total Capital Cost</td>
<td>2,002,794</td>
<td>3,314,012</td>
<td>5,733,266</td>
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<tr>
<td>Less Tax Credit</td>
<td>200,279</td>
<td>331,401</td>
<td>573,327</td>
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<td>Financed Cost</td>
<td>1,803,000</td>
<td>2,983,000</td>
<td>5,160,000</td>
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<td>Annual Cost of Capital</td>
<td>263,000</td>
<td>434,000</td>
<td>751,000</td>
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<tr>
<td>Operating Cost</td>
<td>240,000</td>
<td>298,000</td>
<td>344,000</td>
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<tr>
<td>Maintenance Cost</td>
<td>100,000</td>
<td>166,000</td>
<td>287,000</td>
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<tr>
<td>Tax &amp; Insurance</td>
<td>50,000</td>
<td>83,000</td>
<td>143,000</td>
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<td>Fuel Cost</td>
<td>609,000</td>
<td>1,221,000</td>
<td>2,441,000</td>
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<tr>
<td>Heat Delivered (106 Btu)</td>
<td>2,202,000</td>
<td>3,966,000</td>
<td>1,171,000</td>
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<tr>
<td>$/MMBtu</td>
<td>$4.32</td>
<td>$3.76</td>
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#### For Co-firing 10% Scrap Tires

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<thead>
<tr>
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<th>2,062,108</th>
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<th>5,819,082</th>
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<td>581,908</td>
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<td>Tax Credit</td>
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<p>| | | | |</p>
<table>
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<td>247,000</td>
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<td>Maintenance Cost</td>
<td>103,000</td>
<td>169,000</td>
<td>262,000</td>
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<td>Tax &amp; Insurance</td>
<td>52,000</td>
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<td>131,000</td>
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<tr>
<td>Fuel Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.0) $/tire</td>
<td>558,000</td>
<td>1,118,000</td>
<td>235,000</td>
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<tr>
<td>(0.25) $/tire</td>
<td>586,000</td>
<td>1,174,000</td>
<td>348,000</td>
</tr>
<tr>
<td>(0.50) $/tire</td>
<td>614,000</td>
<td>1,230,000</td>
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<td>Total Annual Cost</td>
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<td></td>
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<tr>
<td>(0.0)</td>
<td>1,230,000</td>
<td>2,119,000</td>
<td>705,000</td>
</tr>
<tr>
<td>(0.25)</td>
<td>1,258,000</td>
<td>2,175,000</td>
<td>818,000</td>
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<tr>
<td>(0.50)</td>
<td>1,286,000</td>
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<td>$/MMBtu (0.0)</td>
<td>$4.21</td>
<td>$3.62</td>
<td>$3.16</td>
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<td>(0.25)</td>
<td>4.31</td>
<td>3.72</td>
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<tr>
<td>(0.50)</td>
<td>4.40</td>
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<td>3.36</td>
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<tr>
<td>Capacity (lbs/hr)</td>
<td>Firing with 100% Wood Waste</td>
<td>For The Case of Co-firing 10% Scrap Tires</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------------</td>
<td>-----------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50,000</td>
<td>100,000</td>
<td>200,000</td>
</tr>
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<td>Fuel System</td>
<td>906,116</td>
<td>1,460,134</td>
<td>1,917,000</td>
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<tr>
<td>Boiler</td>
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<td>6,057,600</td>
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<td>Less Investment Tax Credit</td>
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<td>499,373</td>
<td>797,460</td>
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<tr>
<td>Financed Capital Cost</td>
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<td>4,494,361</td>
<td>7,177,140</td>
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<td>Annual Cost of Capital</td>
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<td>1,045,000</td>
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<tr>
<td>Operating Cost</td>
<td>245,000</td>
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<td>479,000</td>
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<td>Maintenance Cost</td>
<td>102,000</td>
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<td>Tax &amp; Insurance</td>
<td>51,000</td>
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<td>199,000</td>
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<td>Fuel Cost</td>
<td>529,000</td>
<td>1,060,000</td>
<td>2,119,000</td>
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<tr>
<td>Total Annual Cost</td>
<td>1,195,000</td>
<td>2,539,000</td>
<td>4,241,000</td>
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<tr>
<td>Annual Heat Delivered (10^6 Btu)</td>
<td>292,000</td>
<td>585,000</td>
<td>1,171,000</td>
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<tr>
<td>Cost per MMBtu Delivered</td>
<td>$4.09</td>
<td>$4.34</td>
<td>$3.62</td>
</tr>
</tbody>
</table>

Fuel System:
<table>
<thead>
<tr>
<th>Capacity (lbs/hr)</th>
<th>Firing with 100% Wood Waste</th>
<th>For The Case of Co-firing 10% Scrap Tires</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Fuel System</td>
<td>965,430</td>
<td>1,527,020</td>
</tr>
<tr>
<td>Boiler</td>
<td>1,135,800</td>
<td>3,533,600</td>
</tr>
<tr>
<td>Total Capital Cost</td>
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<td>5,060,620</td>
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<tr>
<td>Tax Credit</td>
<td>210,123</td>
<td>506,062</td>
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<tr>
<td>Financed Capital Cost</td>
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<td>Ann. Cost of Capital</td>
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<td>Operating Cost</td>
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<tr>
<td>Maintenance Cost</td>
<td>105,000</td>
<td>253,000</td>
</tr>
<tr>
<td>Tax &amp; Insurance</td>
<td>53,000</td>
<td>127,000</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td></td>
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</tr>
<tr>
<td>@ $0.00/Tire</td>
<td>412,000</td>
<td>826,000</td>
</tr>
<tr>
<td>@ $0.25/Tire</td>
<td>506,000</td>
<td>1,014,000</td>
</tr>
<tr>
<td>@ $0.50/Tire</td>
<td>600,000</td>
<td>1,202,000</td>
</tr>
<tr>
<td>Total Annual Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ $0.00/Tire</td>
<td>1,097,000</td>
<td>2,324,000</td>
</tr>
<tr>
<td>@ $0.25/Tire</td>
<td>1,191,000</td>
<td>2,512,000</td>
</tr>
<tr>
<td>@ $0.50/Tire</td>
<td>1,285,000</td>
<td>2,700,000</td>
</tr>
<tr>
<td>$/MMBTU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ $0.00/Tire</td>
<td>3.76</td>
<td>3.97</td>
</tr>
<tr>
<td>@ $0.25/Tire</td>
<td>4.08</td>
<td>4.29</td>
</tr>
<tr>
<td>@ $0.50/Tire</td>
<td>4.40</td>
<td>4.62</td>
</tr>
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</table>
TABLE A.2 SYSTEMS COSTS - WOOD WASTE BOILER SYSTEM

\[
\text{$/\text{MMBTU}} \\
\begin{array}{ccc}
@ \$0.00/\text{Tire} & 3.76 & 3.97 & 3.24 \\
@ \$0.25/\text{Tire} & 4.08 & 4.29 & 3.56 \\
@ \$0.50/\text{Tire} & 4.40 & 4.62 & 3.88 \\
\end{array}
\]

Sensitivity to Tire Cost: Wood Waste

\[
\begin{array}{ccc}
\text{AC:} & 686,000 & 1,498,000 & 2,145,000 \\
\text{FC:} & 600,000 & 1,202,000 & 2,404,000 \\
 & 412,000 & 826,000 & 1,652,000 \\
\text{TC:} & 1,285,000 & 2,700,000 & 4,549,000 \\
 & 1,097,000 & 2,324,000 & 3,797,000 \\
\$/\text{MMBTU} & \times 0.5 & 4.62 & 3.88 \\
 & \times 0.0 & 3.97 & 3.24 \\
\end{array}
\]


15. Private Conversation with Mr. Jerry Scott, ECON, Alexander City, Ala.
FINISHING DIVISION

1. Introduction

is a manufacturer of apparel, home furnishing, and industrial conveyor fabric. The corporation has three plants located in Thomaston and one in Griffin, Georgia. The Finishing Division located in Thomaston is responsible for the dyeing, bleaching, and finishing of goods produced at the other locations. Finishing operations consume large amounts of energy in the form of steam to heat dye baths, washers and dryers. Currently steam for the Finishing Division is produced from natural gas. The purpose of this study is to provide a preliminary examination of the feasibility of using solid fuel as an alternate source to the existing energy source. This study will devote primary attention to the use of coal as an alternate energy source.

The plant currently has two boilers in place, both of watertube design. The base loaded boiler has an output capacity of 80,000 lb/hr. Back-up capacity is provided by a 75,000 lb/hr unit. Average steam demand is estimated to be in the range of 80,000-100,000 lb/hr.

The plant operates 5½ days per week, 24 hours per day, and 50 weeks per year for an annual total of 6600 hr/yr. Steam is used for numerous tasks throughout the plant. The dye range is responsible for the greatest load swing at the plant since it has an instantaneous demand for 10,000-15,000 lb/hr of steam. Aside from the dye range, steam demand is relatively stable. Because the plant has a high, relatively stable steam demand and large number of annual operating hours it is a promising candidate for conversion to solid fuel firing.
2. **Equipment Selection**

Using the operational and fuel consumption data shown in Table 1, a calculation of your plant's average steam consumption was performed. The analysis used a boiler efficiency of 82% and energy content of 1000 Btu/lb steam. The derived steam consumption, 69,000 lb/hr based on 6600 operating hours per year, is lower than the actual boiler capacity needed because it is not corrected for start-up or other periods when production is low. Another

| Table 1 |
| Average Plant Steam Consumption |
| Energy Usage | 539,000 MCF |
| Fuel | Natural Gas |
| Energy Content | 1030 Btu/ft³ |
| Average Annual Steam Production | 69,000 lb steam/hr |

factor that would increase the required boiler capacity is load swings. Based on the average steam demand and known swings in load, a boiler size of 80,000 lb/hr is recommended. A boiler of this size is above the average steam demand and should be able to meet most of the plant load swings. It is not, however, greatly oversized since the average plant demand would represent a load of approximately 85%.

Specification of 80,000 lb/hr of boiler capacity can be met in at least two ways:

- Installation of a battery of approximately two solid fuel package boilers
- Installation of a single field erected solid fuel boiler

A battery of two solid fuel package boilers would offer the advantages of lower capital cost, reduced installation time, simplified emission control system, and greater turn-down ratio than a similar sized field erected unit.
The primary disadvantage of package boilers is their fire tube design, and although fire tube boilers have been built for operating pressures up to 250 psig, their high pressure operating experience is limited.

For this study, our analysis will be based on the installation of a 80,000 lb/hr field erected water tube boiler. This choice may be more costly than package units, but the ruggedness and durability it offers in the finishing plant environment will be worth the added investment.

The boiler will be a 80,000 lb/hr, field erected, water tube unit of tube and tile construction. It includes storage bunkers, rotary distributor valves, spreader stoker, and boiler economizer. For emission control a multi-clone dust collector and fabric filter baghouse are necessary. A new stack approximately 100 feet tall will be required to assure the system satisfies ground level emission criteria.

In addition to the boiler, the other major area is fuel unloading, handling and storage. Last year's gas consumption translates into an average coal usage of 75 tons per day. The fuel will need to be delivered by rail, and since 100 ton railcars carry between 80-90 tons of fuel, average daily usage would be approximately 3/4 of a car. Since deliveries can be sporadic, the handling system must be capable of handling much greater amounts than the 3.2 ton average requirement. The minimum capacity of typical small systems is 50 tons/hr.

The unloading system will contain the following components:
- Car Puller
- Car Shaker
- Rail Support Beams
- Unloading Hopper and Grate
- Vibrating Feeder

The car puller is used to position the railcars for unloading. It will be of the double drum reversible type with a rope pull of 23,000 pounds provided by a 20 hp drive motor. The car shaker is used to assure fast and complete discharge of fuel during unloading. It will be of a lightweight construction swung from a hoist. The unloading hopper will be approximately 14' x 14' at the top and 9' deep fabricated from Type 304 stainless steel. The coal will be moved from the unloading hopper to a belt conveyor with a vibrating feeder.
Coal from the vibrating feeder will be deposited on an inclined belt conveyor for transport to the storage silo. The storage silo will need to be located near the new boiler. Therefore, the length of the belt conveyor from receiving to storage will need to be approximately 200 yards. The storage silo, constructed of concrete using jumpforms, will be designed to hold 800 tons, which is equivalent to one week's consumption at the maximum capacity of the boiler. Based on a bulk density of 50 lb/ft$^3$, the required storage volume is 32,000 ft$^3$. Since the entire volume of the silo will not be available for storage because the bottom must have conically sloping sides to assist unloading and coal has a 50° angle of repose, this will not occupy the top volume exactly. Installing a silo 30 feet in diameter and 55 feet tall will yield a total volume of 38,000 ft$^3$, which is 20% oversized. Having all of the coal storage covered gives you greater control over it and eliminates environmental concerns such as dust particles becoming caught in the wind and carried away and rainwater falling into the pile and being contaminated. Discharge from the silo will be carried by another belt conveyor to the boiler house.

Coal from the vibrating feeder will be deposited on an inclined belt conveyor for transport to the storage silo. The storage silo will need to be located near the new boiler. Therefore, the length of the belt conveyor from receiving to storage will need to be approximately 200 yards. The storage silo, constructed of concrete using jumpforms, will be designed to hold 800 tons, which is equivalent to one week's consumption at the maximum capacity of the boiler. Based on a bulk density of 50 lb/ft$^3$, the required storage volume is 32,000 ft$^3$. Since the entire volume of the silo will not be available for storage because the bottom must have conically sloping sides to assist unloading and coal has a 50° angle of repose, this will not occupy the top volume exactly. Installing a silo 30 feet in diameter and 55 feet tall will yield a total volume of 38,000 ft$^3$, which is 20% oversized. Having all of the coal storage covered gives you greater control over it and eliminates environmental concerns such as dust particles becoming caught in the wind and carried away and rainwater falling into the pile and being contaminated. Discharge from the silo will be carried by another belt conveyor to the boiler house.

The boiler is to be a 80,000 lb/hr stoker coal, water tube boiler. The coal will be delivered from covered storage to a surge bin in the boiler
house. Coal exiting the surge bin will be weighed and then be distributed to
the stokers.

3. **Fuel Recommendation**

   Due to the quantity of fuel required and the distance of the plant from
   the coalfields in Kentucky and Tennessee, rail delivery is preferred. Bottom
   unloading 100-ton capacity railcars are the recommended receiving method.
   Each car has a capacity of 80-90 tons, so about 6 cars will have to be
   unloaded each week. To be compatible with the boiler firing equipment, stoker
   coal, 1\(\frac{1}{8}\) x \(\frac{1}{4}\), with low fines should be used. This coal is more costly than
   nut and slack or run of mine coal but has low fines and more uniform size.
   The properties of the recommended fuel are presented in Table 2. Based on a
   fuel cost of $56/ton and a heating value of 13,000 Btu/lb, the unit energy
   cost is $2.15 per million Btu. Fully loaded the boiler would consume 110 tons
   per day. This is equivalent to approximately 1\(\frac{1}{4}\) railcar loads per day.
Table 2
Coal Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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</thead>
<tbody>
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</tr>
<tr>
<td>Energy Content:</td>
<td>13,000 Btu/lb</td>
</tr>
<tr>
<td>Sulfur:</td>
<td>1%</td>
</tr>
<tr>
<td>Fines:</td>
<td>5-10%</td>
</tr>
<tr>
<td>Ash Fusion Temperature:</td>
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<tr>
<td>Coal Cost FOB Mine:</td>
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</tr>
<tr>
<td>Freight Cost:</td>
<td>$20/ton</td>
</tr>
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4. Economic Analysis

The economic justification for a solid fuel boiler relies on the lower unit fuel cost to offset the higher capital and operating costs. The estimated capital costs for the coal boiler described earlier are shown in Table 3. The budget estimates have been inflated approximately 35% to cover equipment installation. The prices presented in Table 3 represent minimums based on limited equipment options and extras. Significant design variation could increase this cost by 25-30%. Final equipment selection will be dictated in part by individual plant operating requirements. Additionally, the construction of long-term, outdoor storage which would serve to protect the plant from coal strikes or other fuel disruptions has been left to your discretion.

Due to greater manpower, utility and maintenance costs, coal and other solid fuel boilers have operating costs per unit of output that are 3-5 times those of similar conventional fuel boilers. Several factors cause this difference. First, coal boilers have more direct labor associated with their operation. While gas boiler installations often have assigned boiler operators each shift, they do not have to devote their full attention to the boiler as do coal boiler operators and can perform other activities in addition to
### Table 3

**Finishing Division**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler (80,000 lb/hr, field erected</td>
<td>$1,750,000</td>
</tr>
<tr>
<td>water tube, spreader stoker with</td>
<td></td>
</tr>
<tr>
<td>economizer, coal bunkers)</td>
<td></td>
</tr>
<tr>
<td>Coal Handling (car puller, hopper, shaker,</td>
<td>$ 600,000</td>
</tr>
<tr>
<td>conveyors)</td>
<td></td>
</tr>
<tr>
<td>Emission Control (multi-clone, baghouse)</td>
<td>$ 450,000</td>
</tr>
<tr>
<td>Coal Storage Silo (800 ton, concrete jump</td>
<td>$ 250,000</td>
</tr>
<tr>
<td>form construction)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$3,050,000</td>
</tr>
<tr>
<td><strong>10% Tax Credit</strong></td>
<td>- 305,000</td>
</tr>
<tr>
<td><strong>Adjusted Capital Cost</strong></td>
<td>$2,745,000</td>
</tr>
</tbody>
</table>

boiler operation. Second, maintenance costs of solid fuel boilers are higher due to the large number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the number of motors used in receiving and handling, and solid waste disposal. Our evaluation used an operating cost of $0.50/1,000 lb steam for solid fuel boilers and $0.10/1,000 lb steam for gas/oil boilers. When calculating the operating cost, an efficiency of 82% was used with both the coal and gas boilers to determine annual steam production and fuel consumption rates.

The estimated annual costs of operating both the conventional and solid fuel boilers are summarized in Table 4. These costs are based on a 80,000 lb/hr coal boiler replacing the existing two gas/oil boilers with both loaded an average of 69,000 lb/hr. A cost included with the coal boiler but not the gas boiler is the amortization of the capital cost. A 20-year life and 12% interest rate were used to calculate the annual cost of capital. Based on
these assumptions, a simple payback of 3.0 years was calculated. While a 10%

<table>
<thead>
<tr>
<th>Table 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler Economic Analysis</td>
</tr>
<tr>
<td>Annual Costs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conventional System</th>
<th>Coal System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost (existing)</td>
<td>$2,745,000</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>$365,000</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$228,000</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>$2,665,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$1,194,000</td>
</tr>
<tr>
<td>$2,711,000</td>
<td>$1,787,000</td>
</tr>
</tbody>
</table>

Annual Cost Savings: $2,711,000 - $1,787,000 = $924,000

Approximate Payback Period: $2,745,000/$924,000 = 3.0 years

investment tax credit was deducted from the initial capital cost, other tax advantages such as depreciation and interest deductions which could further reduce the payback were not considered.

If two 1200 HP (41,400 lb/hr) package fire tube boilers with chain grate stoker were substituted for the single field erected water tube unit, the lower capital cost of these boilers would reduce the expected payback to approximately 2.2 years. The specification of a field erected or package boiler can be resolved by consultation with a specialist who can help make the decision based on the particular needs of the plant.

Conclusion

Due to the annual operating hours of your boilers and their associated load factor, the preliminary analysis indicates that a 80,000 lb/hr coal boiler could offer a payback of around 3.0 years. Typical paybacks for solid fuel boilers are on the order of three years or less. Specification of the most appropriate equipment for this situation and the consequent economic payback will require more in-depth examination.
INTRODUCTION

Corporation is a manufacturer of asphalt building and roofing materials located in Savannah, Georgia. Steam is used primarily at this plant to heat trace pipes carrying asphalt. Natural gas is the primary fuel for steam generation with #2 fuel oil serving as back-up. The purpose of this study is to provide a preliminary examination of the feasibility of using solid fuel as an alternative to the existing energy supply. The plant has a significant amount of combustible waste that could provide a large portion of the energy with the remaining portion supplied by coal.

The plant has two boilers in place, but most of the steam is generated in a 40,000 lb/hr natural gas, #2 fuel oil fired unit. This unit is underloaded with a maximum steam demand equal to approximately 12,000 lb/hr. It is possible that the steam demand could increase by 5,000 lb/hr in the coming years. The boiler plant operates 24 hours a day, 7 days a week, 52 weeks a year. The two production operations at this plant run significantly less than this amount. The rolled roofing goods line operates one 8-hour shift per day, 5 days per week, and the asphalt shingle line operates three 8-hour shifts per day, 5 days per week. The weekly production schedule on the shingle line consists of 14 production shifts and one clean-up shift.

The waste material generated at this location consists of rejected roofing material and scraps produced during manufacturing. The annual production rate is equal to approximately 4,940 tons. The waste material has a heating value of about 8,000 Btu/lb, and an ash content of between 40% and 50%. Using this waste material as fuel would offer at least two advantages: (1) it would provide a large source of relatively free energy, and (2) it would eliminate the cost of disposal which is over $100,000 per year currently. The major disadvantage of this material may be the difficulty of handling it because of its flat, bulky nature. Also handling problems are increased in summer because it has a tendency to soften and stick together.
EQUIPMENT SELECTION

Using the operational and fuel consumption data provided, a calculation of the plant's average steam production based on a one-year period and for a one-month period during the winter and summer was completed. In the analysis, a boiler efficiency of 82%, annual operating hours of 8,740, and 1,000 Btu/lb heat content of steam were used. A summary of these calculations is shown in Table 1. The calculation indicates that the major variation in steam requirements is due to seasonal temperature differences. It was found that the winter maximum steam demand was close to the predicted 12,000 lb/hr.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Average Steam Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Year</td>
<td>9,000</td>
</tr>
<tr>
<td>Summer Month</td>
<td>7,640</td>
</tr>
<tr>
<td>Winter Month</td>
<td>10,840</td>
</tr>
</tbody>
</table>

Because the energy content of the waste can provide only approximately 86% of the total energy requirement, the boiler must be co-fired with another fuel. To combust the roofing waste, a fluidized bed boiler is recommended. It is able to accommodate fuel of nonuniform size and will yield effective control of sulfur in the asphalt through limestone absorption. Fluidized beds are able to handle fuels of high ash content, such as waste roofing material. Because the granules do not fluidize well, they will sink to the bottom of the bed for easy recovery.
Recovery can be accomplished by extracting material from the bottom of the bed and separating granules from bed material by sifting or gravity separation. In one fluid bed design examined, ash material sifts through the distributor plate where it is cooled to approximately 2500°F by incoming combustion air. After cooling, ash can be conveyed to the separation equipment. This study will consider a 10,000 lb/hr fluidized bed boiler which will consume all of the waste roofing material, recover the roofing granules, and provide 90% of the total annual steam requirement. The fluidized bed incinerator will have an efficiency of approximately 75% which is lower than that of conventional gas/oil boilers. To guarantee proper fluidization of the waste material it must be shredded in a hog or hammermill before being screwed into the boiler. While a system such as the one described appears feasible, one has never been commercially installed. Therefore, considerable research may be necessary to assure the success of this arrangement.

**FUEL RECOMMENDATION**

The primary fuel source for the fluidized bed incinerator will be waste asphalt roofing material. Disposing of the waste in this manner provides a free source of energy and saves $100,000 per year in landfill costs. A secondary benefit will be the reclaim of approximately 1,000 tons per year of roofing granules worth $100 a ton. Roofing waste contains approximately 2% sulfur, but the amount of limestone mixed with asphalt to form the coating is greater than that required for total absorption.

As a secondary source of fuel, waste wood such as sawdust is recommended. The fluidized bed boiler can accommodate low grade wood which can be purchased for approximately $15 per ton, delivered. Based on an energy content of 4,500 Btu/lb, this is a unit energy cost of $1.67 per million Btu. Unlike roofing tabs, wood is low in ash and sulfur. It is envisioned that the most important advantage of wood may be its action as a fuel conditioner. When shredded roofing material is blended with the correct amount of wood it will act as a sorbent to keep the asphalt from sticking together. Since the correct blending ratios are uncertain, this study will assume that the amount of wood necessary to provide approximately 15% of the annual energy demand is correct.
ECONOMIC ANALYSIS

The economic justification for a waste incinerator relies on the negligible unit fuel cost to offset the higher capital and operating costs. The budget cost of a 10,000 lb/hr fluidized bed coal boiler is $100 per pound of steam or $1,000,000. Since the system must also be able to blend waste wood with roofing material before combustion, a small amount of additional fuel handling will be required. Wood can be mixed with roofing waste after it has been hogged. The added cost to be able to co-fire wood and roofing waste is $100,000. This assumes handling the asphalt tabs manually with a front end loader and limited fuel storage. The total cost of the completed system should be approximately $1,100,000, but significant design changes or equipment additions could inflate this cost by 25% to 50%.

Due to greater manpower, utility and maintenance costs, solid fuel boilers and incinerators have unit operating costs that are 3 to 5 times those of conventional boilers. Several factors cause this difference. First, solid fuel boilers have more direct labor associated with their operation. Second, maintenance costs of solid fuel boilers are higher due to the large number of moving parts and greater system complexity. Lastly, utility costs are higher because of the number of motors used in receiving and handling, and ash disposal and air pollution control. Our evaluation used an operating cost of $0.60/1,000 lbs steam for the solid fuel case and $0.15/1,000 lbs steam for the gas/oil boiler.

The estimated annual costs of operating both the incinerator and conventional boilers are summarized in Table 2. These costs are based on the incinerator providing 90% of the annual steam demand with the other 10%, corresponding to peak demands above 10,000 lb/hr, provided by natural gas. The only fuel cost for the fluidized bed system is the wood purchased to blend with the roofing waste. Roofing material is capable of providing 86% of the plant's annual energy consumption. Assuming wood provides the remaining 14%, about 1500 tons of green wood per year will be required. An additional cost for the incinerator system is the amortization of the capital cost. A 20 year life and 12% cost of capital were used to calculate the annual cost of capital. The cost of the conventional system also includes $100,000 per year for solid waste disposal and $100,000 per year for purchase
TABLE 2
BOILER ECONOMIC ANALYSIS
ANNUAL COSTS

<table>
<thead>
<tr>
<th></th>
<th>Conventional System</th>
<th>Solid Fuel System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>Existing $1,100,000</td>
<td>$1,100,000</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>--- $147,000</td>
<td>$147,000</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$10,000</td>
<td>$41,000</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>$408,000</td>
<td>$21,900</td>
</tr>
<tr>
<td>Waste Disposal Costs</td>
<td>$100,000</td>
<td>$0</td>
</tr>
<tr>
<td>Granule Purchase</td>
<td>$100,000</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$618,000</strong></td>
<td><strong>$209,900</strong></td>
</tr>
</tbody>
</table>

Annual Cost Savings: $618,000 - $209,900 = $408,100
Approximate Payback Period: $1,100,000/$408,100 = 2.7 years

of 1,000 tons of granules that would not be necessary with the fluidized bed system. The incinerator has a net annual savings of $408,100 per year and simple payback of 2.7 years. This analysis did not consider tax advantages, such as depreciation, investment tax credits, or interest payment deductions, which could decrease the payback period or make the application of a solid fuel boiler appear feasible. While this preliminary examination shows that burning the

CONCLUSION

Despite the fact that the boiler has a relatively low average steam demand, the availability of "free" energy from plant waste and the elimination of waste disposal costs serve to make the application of a solid fuel boiler appear feasible. While this preliminary examination shows that burning the
plant waste is economical, further engineering evaluation is warranted to address the particular problems of the design and to better predict the capital cost of the system. Since a system such as the one described has not been utilized, significant amounts of further research will be necessary before it can be fully commercial.
Introduction

is a manufacturer of towels and infant diapers located in Griffin, Georgia. has several plants in the Griffin area, but this study will be concerned with steam production at the Lowell Bleachery. The purpose of this study is to provide a preliminary examination of the feasibility of using solid fuel as an alternative to the existing energy supply. Because the plant does not have a readily available supply of combustible waste, this analysis will evaluate coal firing.

The plant has four boilers in place. Two boilers are fired together in a battery on alternating weeks. During one week, a 28,500 lb/hr unit and a 50,000 lb/hr unit are fired together followed by another 28,500 lb/hr unit and an 80,000 lb/hr unit the next week. The alternate firing is done so no boiler has to sit unused for an excessive period of time. The primary fuel is natural gas with #6 fuel oil as backup. The load is relatively stable except during shift changes when some equipment is shut down temporarily.

The plant operates 24 hours per day, 6 days per week, 52 weeks per year. Steam is used to heat water used in washers and in process for drying in two loop dryers and various pressurized steam can dryers.

Equipment Selection

Using the operational and fuel consumption data provided, a calculation of the plant's average hourly steam production was completed. In the calculation, a boiler efficiency of 80%, annual operating hours of 7,488, and 1,000 Btu/lb steam heat content were used. The calculation revealed an average steam rate of 25,650 lb/hr. Based on this output, the tandem boilers used to produce plant steam are severely underloaded. As a substitute our analysis will consider the installation of an 800 HP (27,600 lb/hr) coal fired packed
boiler. A boiler of this size would be just slightly above the average steam load and because dyeing operations are prone to some degree of load fluctuation, one of the small gas fired boilers could be retained to carry the swings.

There are various package boilers in this size range that are capable of burning coal. For the purposes of comparison this study considered the application of a 27,600 lb/hr (800 HP), three-pass, modified Scotch Marine, steam boiler (Figure 1). This unit has horizontal fire tubes and a wet back design. Coal stoking is accomplished with a chain grate and ash removal is automatic. The boiler has a standard design pressure of 150 psig, but higher pressure designs are available.

A chain grate stoker consists basically of an endless chain formed by small links on rods. The links are made of either cast iron or chromium bearing cast iron. The chain mat moves continuously into the furnace carrying a bed of coal leveled at an adjustable thickness by a guillotine door. The chain grate arrangement will handle most coals, other than anthracite and lignite, provided the ash content exceeds 5%. Below this level, the grate will tend to overheat. The upper limit of coal size recommended is 1½ inches. Fuel in excess of this sizing will create blow holes in the coal bed resulting in inefficient combustion. Coal with the appropriate recommended characteristics are readily in your area as will be discussed in the Fuel Recommendation section of this report.

For fuel receiving, an underground bunker is recommended. Coal will be delivered in dump trucks which will unload into the pit. The pit is sized to handle a 20 ton truckload. A screw conveyor transfers fuel from the storage pit. From the fuel receiving area, coal is moved to the storage silo. For a 27,600 lb/hr boiler, a 400 ton silo is recommended. This size would yield over 12 days of storage if the boiler operated fully loaded 24 hours per day. A bucket elevator is used to lift fuel from the receiving pit to the storage silo. In the recommended design, the silo is arranged to accommodate both live and reserve storage. Live storage is held at the top of the silo, feeds the boiler directly, and is filled first by the bucket elevator. Once the live storage is filled, fuel falls to the reserve storage area. Reserve
storage empties via gravity into the bucket elevator where it can be transferred to live storage. Using the silo as both live and reserve storage eliminates the need for a coal bunker at the boiler and also reduces the amount of handling equipment necessary to move fuel between live and reserve storage.

This boiler is equipped with an automatic ash disposal system. It uses a drag chain submerged in water to collect the ash. The chain stoker deposits ash into the drag chain trench. When the ash strikes the water, it is cooled and converted to a slurry. The drag chain transfers the ash slurry to a collection vessel.

Total space requirements for this arrangement including receiving pit, silo, and boiler house is approximately 50 feet by 80 feet. The boiler could possibly be located in the parking area where the railroad track is now or adjacent to the chemical storage area near the boiler stack.

---

**TABLE 1**

**PROPERTIES OF TENNESSEE BITUMINOUS COAL**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>4%</td>
</tr>
<tr>
<td>Ash</td>
<td>10%</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>29%</td>
</tr>
<tr>
<td>Fired Carbon</td>
<td>59%</td>
</tr>
<tr>
<td>Heat Content</td>
<td>13,000 Btu/lb</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.70%</td>
</tr>
<tr>
<td>Size</td>
<td>Stoker Coal</td>
</tr>
<tr>
<td></td>
<td>15% - 1/4&quot;</td>
</tr>
<tr>
<td>Cost</td>
<td>$43-$47/ton</td>
</tr>
</tbody>
</table>

---

**Fuel Recommendation**

Because of the proximity of the plant to the coal fields, Tennessee Bituminous coal is recommended. The most economical delivery method is by 20 ton dump truck. The delivered price of this fuel is $43-$47/ton. Important
properties are presented in Table 1. The properties of this coal match closely those required by the boiler. Based on a coal price of $47/ton, the unit energy cost is $1.81 per million Btu's. The boiler would consume 2,640 pounds of coal per hour, fully loaded, or 32 tons per day. This is equivalent to 1.6 truckloads.

Economic Analysis

The economic justification for a solid fuel boiler relies on the lower unit fuel cost to offset the higher capital and operating costs. The estimated capital costs for the coal boiler system described earlier are shown in Table 2. All costs include installation. The prices presented in Table 3 are the minimum based on limited options and extras. Significant deviation from the configuration presented could increase the capital cost by as much as 50%. Final equipment selection will be dictated in part by individual plant operating requirements.

<table>
<thead>
<tr>
<th>TABLE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>COAL BOILER INSTALLATION COSTS</td>
</tr>
<tr>
<td>Boiler (27,600 lb/hr three-pass, modified Scotch Marine steam boiler w/chain grate)</td>
</tr>
<tr>
<td>Fuel Receiving - 20 ton, underground pit</td>
</tr>
<tr>
<td>Fuel Storage - 400 ton silo</td>
</tr>
<tr>
<td>Fuel Handling</td>
</tr>
<tr>
<td>Ash Disposal - Submerged Drag Chain</td>
</tr>
<tr>
<td>Site Work and Boiler House</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
</tbody>
</table>

Due to greater manpower, utility, and maintenance costs, coal and other solid fuel boilers have operating costs per unit of output that are 3-5 times those of similar gas boilers. Several factors cause this difference. First,
coal boilers have more direct labor associated with their operation. While gas boiler installations often have assigned boiler operators each shift, they do not have to devote their full attention to the boiler as do coal boiler operators, and can perform other activities in addition to boiler operation. Second, maintenance costs of solid fuel boilers are higher due to the large number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the number of motors used in receiving and handling, and solid waste disposal. Our evaluation used an operating cost of $0.60/1,000 lb steam for solid fuel boilers and $0.15/1,000 lb steam for gas/oil boilers. When calculating the operating cost, an efficiency of 80% was used with both the coal and gas boilers to determine annual steam production.

The estimated annual costs of operating both the conventional and solid fuel boilers are summarized in Table 3. These costs are based on a 27,600 lb/hr coal boiler replacing the existing gas boilers. The boilers are assumed

<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>BOILER ECONOMIC ANALYSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANNUAL COSTS</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Conventional System</th>
<th>Coal System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>(existing)</td>
<td>$757,000</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>---</td>
<td>$101,000</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$26,000</td>
<td>$104,000</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>$942,000</td>
<td>$391,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$968,000</td>
<td>$596,000</td>
</tr>
</tbody>
</table>

Annual Cost Savings: $968,000 - $596,000 = $372,000
Approximate Payback Period: $757,000/$372,000 = 2.0 years
to operate 7,488 hr/yr. Because the coal boiler size is closely matched to the average steam demand, it will not be able to pick up all the load swings when the steam demand exceeds the average. For this analysis, it will be assumed that the coal boiler will be able to supply 90% of the required steam with the remainder provided by natural gas. An additional cost for the coal system is the amortization of the capital cost. A 20 year life and 12% interest rate were used to calculate the annual cost of capital. Based on these assumptions, a simple payback of 2.0 years was calculated. The analysis did not consider tax advantages such as depreciation, investment tax credits, or interest payment deductions which could decrease the payback period, or more expensive equipment expenditures which could increase the payback period.

**Conclusion**

Due to the annual operating hours of your boilers and their associated load factor, the preliminary analysis indicates that a 27,600 lb/hr coal boiler could offer a payback of approximately 2 years. Based on the favorable result of this introductory study, a more detailed analysis is recommended.
INTRODUCTION

Located in Atlanta, is a distributor of roofing materials for both the residential and commercial markets. While the firm has no direct demand for steam, they are in the position of having access to a large amount of waste asphalt roofing material which could be burned. Additionally, the company has a fleet of trucks used to haul new roofing material that could also haul waste material to a site for incineration. The purpose of this study is to evaluate the feasibility of burning waste roofing material in an incinerator and selling the steam produced to a second party. The purchaser of the steam could be a small industrial or commercial client.

EQUIPMENT SELECTION

This study will evaluate a 10,000 lb/hr steam generator fired with roofing waste. It will be assumed that a customer with a steady steam demand 24 hours per day, 7 days per week, will be found. To minimize handling problems, waste material will be fed to the incinerator combustor with a front end loader. The loader deposits waste into the incinerator hopper where an electromechanical ram pushes it into the furnace. The grates, externally suspended from the furnace by cables, are referred to as a pulse hearth. The floor of the hearth is propelled at user-defined intervals by a system of inflating air bags. The hearth's shoveling motion causes noncombustibles to inch along the floor until they drop into a water quench tank. Sides of the hearth rise vertically in a staiartipe pattern, and combustion air is fed through horizontal jets in the floor steps. Hot gases produced in the combustion chamber transfer heat to a radiant watertube furnace, watertube convective boiler, and economizer, producing steam.

A big environmental concern is the sulfur contained in the roofing material which produces sulfur dioxide when burned. Effective control may be
attained, however, because one of the ingredients in roofing is calcium carbonate, which acts as an absorbent of sulfur dioxide. It is anticipated that the mixing action of the pulse furnace will promote absorption of sulfur emissions. Because of the high ash content of the waste material, land filling will still be necessary; however, incineration of the waste will reduce the weight of the material by one-half or greater.

While the boiler must supply a relatively constant amount of steam and consequently requires fuel continuously, fuel deliveries will not be continuous, occurring only during the weekday, daylight hours. Due to this discrepancy in supply, excess fuel must be stored on-site for night-time and weekend use. Typical designs include an inside tipping-floor and outdoor storage pile to hold reserve fuel supplies.

FUEL SPECIFICATION

The incinerator will be fired exclusively with roofing waste. Since approximately 2½ tons of waste can be recovered when re-roofing a small house, adequate supplies of material should be available. Waste roofing has a heating value of about 8,000 Btu/lb and an ash content of 40-50%. Current landfill charges are $8/ton to dispose of this roofing waste; hence it has a negative value at present.

ECONOMIC ANALYSIS

The economic justification for a solid fuel boiler relies on the lower unit fuel cost to offset the higher capital and operating cost. In the situation under consideration, material that would otherwise be waste and incur a significant disposal cost could be burned to reduce its mass and produce energy. While Heely Brown has no steam requirement, they would be able to sell it to someone else if they could guarantee a reliable supply of steam at a low delivered price.

The primary investment that must be made is the purchase of an incineration system. A reasonable estimate of this cost is $100 per pound of output steam or $1,000,000 for a 10,000 lb/hr system. Significant design variations could increase this cost by 25-50%.
Due to greater manpower, utility and maintenance costs, solid fuel boilers and incinerators have operating costs per unit of output that are 3-5 times those of similar conventional fuel boilers. Several factors cause this difference. First, solid fuel boilers have more direct labor associated with their operation. While gas boiler installations often have assigned boiler operators each shift, they do not have to devote their full attention to the boiler and can perform other activities, unlike solid fuel boiler operators. Second, maintenance costs of solid fuel boilers are higher due to the large number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the greater number of motors used in receiving, handling, solid waste disposal and air pollution control equipment. Our evaluation used an operating cost of $0.10/1000 lb steam for gas boilers and $0.50/1000 lb steam for the solid fuel incinerator. When calculating the operating cost, an efficiency of 80% was used for the equivalent gas boiler and 70% for the incineration system.

Table 1 presents the results of this economic analysis. In this case it has been assumed that a customer such as a hospital with a steady steam demand of 9,000 lb/hr has been located. This customer operates around the clock 8,740 hours per year, producing 78,660 thousand pounds of steam annually. Based on a gas price of $4.50 per million Btu, the steam cost would be $5.71 per 1000 pounds. The incinerator option would incur no fuel costs since it burns waste. The waste disposal cost is a net income of $51,000 (that is, $85,000 - $34,000) since incineration would reduce the weight of material to be disposed by 60%. It may be possible to sell the ash as a fill material and reduce the disposal cost, but this was not considered. The economic payback on the incineration system is a function of the price steam can be sold for.

A sensitivity analysis of economic payback for gas boiler steam costs of $3, $4 and $5 per 1000 pounds was performed. Since a gas boiler can generate steam for $5.71/1000 pounds, the price of $5/1000 pounds may be too high for anyone to take the chance on this system. However, the other prices are very reasonable. This analysis is very conservative since it did not include tax advantages such as depreciation and a possible tax rebate for displacing oil with waste fuel per the 44D tax code, which are significant. A 10% investment tax credit was included which reduced the capital investment to $900,000.
Based on the raw cash flow analysis, paybacks of 3.3-8.0 years were found. If non-cash flow items like depreciation and interest deductions are included the expected return on investment becomes more favorable. Furthermore, third party arrangements such as the one proposed offers increased tax advantages over conventional financing.

The paybacks shown in Table 2 were calculated by subtracting the incinerator operating cost for the revenue generated from steam sales to find the boiler income. The net income is found by adding the disposal cost which would be avoided with the incinerator to the boiler income. The simple payback is defined as the capital investment less tax credit divided by net income.

CONCLUSION

A preliminary feasibility analysis indicates that a waste roofing incinerator may be a good investment since it would help with solid waste disposal problems and generate significant cash flow if a dependable steam customer can be located. Further analysis to locate prospective customers and verify that the incinerator systems available operate reliably must be completed before proceeding further.
Table 1
OPERATING COST ANALYSIS

<table>
<thead>
<tr>
<th></th>
<th>Incinerator Option</th>
<th>Disposal Option</th>
<th>Gas Boiler Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>0</td>
<td>0</td>
<td>441,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>40,000</td>
<td>0</td>
<td>7,900</td>
</tr>
<tr>
<td>Waste Disposal</td>
<td>34,000</td>
<td>85,000</td>
<td>0</td>
</tr>
<tr>
<td>Capital (Annual Debt Service)</td>
<td>134,000</td>
<td>0</td>
<td>Existing</td>
</tr>
<tr>
<td><strong>TOTAL ANNUAL COST</strong></td>
<td><strong>208,000</strong></td>
<td><strong>85,000</strong></td>
<td><strong>448,900</strong></td>
</tr>
</tbody>
</table>

Steam production = 78,600 thousand pounds
Natural gas steam cost = $448,900/78,660 = $5.71/1000 pounds

Table 2
ECONOMIC ANALYSIS

<table>
<thead>
<tr>
<th>SENSITIVITY</th>
<th>Cost of Steam</th>
<th>Income ($)</th>
<th>Operating Cost</th>
<th>Income</th>
<th>Net Income ($)</th>
<th>Payback (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$3.00/1000 lb</td>
<td>236,000</td>
<td>208,000</td>
<td>28,000</td>
<td>113,000</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>$4.00/1000 lb</td>
<td>315,000</td>
<td>208,000</td>
<td>107,000</td>
<td>192,000</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>$5.00/1000 lb</td>
<td>393,000</td>
<td>208,000</td>
<td>185,000</td>
<td>270,000</td>
<td>3.3</td>
</tr>
</tbody>
</table>

$3.00/1000 lb: Simple payback = ($1,000,000 x .9)/113,000 = 8.0
$4.00/1000 lb: Simple payback = ($1,000,000 x .9)/192,000 = 4.7
$5.00/1000 lb: Simple payback = ($1,000,000 x .9)/270,000 = 3.3
INTRODUCTION

is a pharmaceutical firm located in central Georgia. The plant manufacturers hospital quality IV (intravenous) solutions in both plastic and glass bottles. A large amount of steam generated by natural gas is used in the solution sterilization process. The purpose of this study is to provide a preliminary examination of the feasibility of using solid fuel as an alternative to the existing energy supply. This study will consider the use of coal as a fuel source.

The plant currently has two boilers in place. The primary boiler is a 1500 HP package watertube unit. It operates 24 hours per day, 5.5 days per week, 50 weeks per year, providing process steam. The secondary boiler is a 1000 HP package watertube unit that supplies steam on weekends. It operates 24 hours per day, 1.5 days per week, 52 weeks per year. The annual operating hours for the boiler is 8,470.

The major problem confronting the application of a solid fuel boiler to this service is the rapid load fluctuations experienced during the charging of autoclaves. A primary focus of this study will be the determination of a solid fuel boiler can adequately meet these load variations.

EQUIPMENT SELECTION

Using the operational and fuel consumption data provided, a calculation of the plant's average hourly steam production was completed. In the calculation, a boiler efficiency of 80%, annual operating hours of 8,470, and steam heat content of 1000 Btu/lb were used. The calculation revealed an average steam rate of 15,100 lb/hr. Steam flow charts from a summer and a winter month were studied. They indicated that the steam demand is higher in winter
than summer. In the summer, the peak steam flow is 37,500 lb/hr, and in winter it is 40,000 lb/hr. These peaks are maintained only momentarily before the flow begins to decrease. The steam charts revealed that the steam flow exceeds 30,000 lb/hr less than 5% of the time in the summer and less than 10% of the time in the winter. This study will evaluate the installation of a 30,000 lb/hr boiler since the steam demand is less than this amount over 90% of the time.

The boiler considered for this application is a firetube, fire box boiler of three-pass construction for high thermal efficiency (see Figure 1). It has extended waterlegs that increase the volume of the furnace without excessive refractory. This unit can be equipped with chain grate or underfeed stoker. For this application, a boiler with dual underfeed stokers is recommended, since this will double the turndown to approximately 6:1. The boiler efficiency is guaranteed to be 78.5% on coal and over 80% on natural gas. In addition to coal, this boiler can burn gas or gas and coal in combination. This dual feed capability increases boiler flexibility. The gas burner option permits burning of gas alone at times when demand is extremely low, such as weekends. The coal stoker is designed to burn 2" nut-slack coal. Boilers are normally designed for 150 psi operation, but are available in 175, 200, 250 psi designs. The furnace is designed to sustain low gas velocities and produce low particulate emissions.

The firebox boiler with dual fuel, coal and gas, capability offers the load response and turndown ratio necessary for this application. Using two underfeed stokers allows boiler operation with one stoker turned off which increases the turndown from 3:1 to 6:1. The gas burner can be fired in conjunction with the coal stokers which gives the boiler load response similar to natural gas boiler. The gas burner can be used to catch rapid swings with the boiler reverting to coal when it can sustain the load. The fact that the load swings will be known 15-30 minutes before they occur, since the process is computer controlled, may allow the boiler control system to be programmed to begin feeding coal and building boiler pressure before the steam demand surges.

For fuel receiving, an underground bunker is recommended. Coal will be delivered in dump trucks which will unload into the pit. The pit is sized to
FIGURE 1

DRAFT CONTROL DAMPER
INDUCED DRAFT FAN

SOLID FUEL BED

AUBURN RAM TYPE STOKER

COMBINATION GAS/OIL BURNER

UNDERFIRE AIR FAN

OVERFIRE AIR FAN

OVERFIRE AIR JET ASSEMBLY
handle a 20 ton truckload. A screw conveyor transfers fuel from the storage pit. From the fuel receiving area, coal is moved to the storage silo. For a 30,000 lb/hr boiler, a 350 ton silo is recommended. This size would yield approximately 10 days of storage if the boilers operate fully loaded 24 hours per day. A bucket elevator is used to lift fuel from the receiving pit to the storage silo. In the recommended design, the silo is arranged to accommodate both live and reserve storage. Live storage is held at the top of the silo, feeds the boiler directly, and is filled first by the bucket elevator. Once the live storage is filled, fuel falls to the reserve storage area. Reserve storage empties via gravity into the bucket elevator where it can be transferred to live storage. Using the silo as both live and reserve storage eliminates the need for a coal bunker at the boiler and also reduces the amount of handling equipment necessary to move fuel between live and reserve storage.

This boiler is equipped with an automatic ash disposal system. To assure compliance with local emission regulations, a mechanical dust collector (multi-clone) has been included.

FUEL RECOMMENDATION

Because of the proximity of the plant to the coal fields, Tennessee Bituminous coal is recommended. The most economical delivery method is by 20 ton dump truck. The coal price at the mine is $38/ton. The plant is approximately 230 miles from the mine, and the cost of hauling is 7¢/ton/mile. This gives a delivery cost of $16.10 and a total coal price at the factory door of $54.10/ton. Important properties are presented in Table 1. The properties of this coal match closely those required by the boiler. Based on a coal price of $54.10/ton, the unit energy cost is $2.08 per million Btu's. The boiler would consume 2,940 pounds of coal per hour, fully loaded, or 35 tons per day. This is equivalent to approximately 3/4 truckload.

ECONOMIC ANALYSIS

The economic justification for a solid fuel boiler relies on the lower unit fuel cost to offset the higher capital and operating costs. The
### TABLE 1
Properties of Tennessee Bituminous Coal

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>4%</td>
</tr>
<tr>
<td>Ash</td>
<td>10%</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>29%</td>
</tr>
<tr>
<td>Fired Carbon</td>
<td>59%</td>
</tr>
<tr>
<td>Heat Content</td>
<td>13,000 Btu/lb</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.70%</td>
</tr>
<tr>
<td>Size</td>
<td>Stoker Coal</td>
</tr>
<tr>
<td></td>
<td>15% - 1/4&quot;</td>
</tr>
<tr>
<td>Cost</td>
<td>$54.10/ton</td>
</tr>
</tbody>
</table>

### TABLE 2
Coal Boiler Installation Costs

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler (30,000 lb/hr firebox boiler with underfed stoker)</td>
<td>$400,000</td>
</tr>
<tr>
<td>Dust Collector, I.D. Fan</td>
<td>$30,000</td>
</tr>
<tr>
<td>Storage Silo and Feeders</td>
<td>$190,000</td>
</tr>
<tr>
<td>Ash Handling</td>
<td>$100,000</td>
</tr>
<tr>
<td>Installation, Engineering</td>
<td>$480,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1,200,000</strong></td>
</tr>
</tbody>
</table>
estimated capital costs for the coal boiler system described earlier are shown in Table 2. Installation and engineering is shown as a separate item. The prices presented in Table 2 are the minimum based on limited options and extras. Significant deviation from the configuration presented could increase the capital cost by as much as 50%. Final equipment selection will be dictated in part by individual plant operating requirements.

Due to the greater manpower, utility, and maintenance costs, coal and other solid fuel boilers have operating costs that are 3 to 4 times those of similar gas boilers. Several factors account for this difference. First, coal boilers have more direct labor associated with their operation. While gas boiler installations often have assigned boiler operators each shift, they do not have to devote their full attention to the boiler as do coal boiler operators and can perform other activities in addition to boiler operation. Second, maintenance costs of solid fuel boilers are higher due to the large number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the number of motors used in receiving and handling and solid waste disposal. Our evaluation used an operating cost of $0.15/1,000 lb/steam for gas/oil boilers and $0.60/1,000 lb/steam for solid fuel boilers. When calculating the operating cost, an efficiency of 78.5% was used for coal firing and 80% for natural gas firing to determine annual steam production.

The estimated annual costs of operating both the conventional and solid fuel boilers are summarized in Table 3. These costs are based on an annual steam production of 128,000 thousand pounds which is equivalent to 160,000 million Btu's of energy usage. For the coal boiler it was assumed that 90% of the energy was provided by coal and the remainder with natural gas. This would require 5,640 tons of coal assuming an operating efficiency for 78.5% and 15,500 MCF of natural gas at 80% operating efficiency. An additional cost for the coal system is the amortization of the capital cost. A 20 year life and 12% interest rate were used to calculate the annual cost of capital. Based on these assumptions, a simple payback of 7.9 years was calculated. The calculation did include the investment tax credit which effectively reduced the capital cost by 10%. The analysis did not consider tax advantages such as depreciation or interest payment deductions which could decrease the payback
period. The primary reason for this protracted payback is the low load factor on the boiler (15,000 lbs/hr / 30,000 lbs/hr = 0.5). Installing a smaller solid fuel boiler closer to the average steam load will yield a more reasonable payback even though it requires greater steam production from natural gas.

---

**TABLE 3**

Boiler Economic Analysis

**Annual Costs**

<table>
<thead>
<tr>
<th></th>
<th>Conventional System</th>
<th>Coal System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>(existing)</td>
<td>$1,200,000</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>$ 19,200</td>
<td>$ 78,800</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$ 19,200</td>
<td>$ 78,800</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>$736,000</td>
<td>$ 378,700</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$755,200</td>
<td>$ 618,500</td>
</tr>
</tbody>
</table>

**Annual Cost Savings** = $755,200 - $618,500 = $136,700

**Approximate Payback Period** = ($1,200,000 x 0.9)/$136,700 = 7.9 years

---

**CONCLUSION**

The low load factor coupled with the relatively high cost of coal per Btu due largely to the increased transportation costs yielded an unacceptable payback. Further analysis could determine if a smaller boiler would yield a more reasonable payback.
INTRODUCTION

, located in Calhoun, Georgia, is a manufacturer of scatter rugs. The plant employs approximately 300 people. Steam used in the process is currently generated from natural gas, but #6 fuel oil and propane are available as back-up fuels. The purpose of this study is to provide a preliminary examination of the feasibility of using solid fuel as an alternative to the existing energy supply. Because the plant does not have a significant amount of combustible waste nor a readily available supply of wood fuel, this analysis evaluated coal firing.

The plant currently has two 600 HP (20,700 lb/hr) boilers in place. Both units are identical three-pass firebox boilers equipped to use either natural gas, #6 fuel oil, or propane fuel. The boilers satisfy a fluctuating steam load. Steam is used primarily in the dye house to heat dye becks and for steam drying. They operate an average of 4,320 hours per year. Based on a natural gas cost of $5.10/MCF ($4.95/MMBtu), annual fuel costs are $464,830. This corresponds to an equivalent annual fuel usage of 91,175 MMBtu's. These units are designed to utilize coal fuel if modified.

EQUIPMENT SELECTION

This study will evaluate the feasibility of retrofitting the existing natural gas boilers to coal firing. On initial installation, the boilers were set off the floor allowing adequate room to add a coal stoker and grates. Further equipment that will be needed are induced draft fans, mechanical dust collectors, ash removal, and coal handling storage and receiving systems.

The stoker will be a simple retort, side dump, hydraulically ram feed type. The stoker comes complete with grate. The waterleg design of the
boiler provides large furnace volume with a minimum of refractory. Ash removal will be accomplished in a "capped" trench placed across the front of the boiler. The stoker rating is based on firing nut-slack coal with a bulk density of 50 lb/ft$^3$ and heating value of 13,000 Btu/lb, but low fires stoker coal can also be used.

For fuel receiving, an underground bunker is recommended. Coal will be delivered in dump trucks which will unload into the pit. The pit is sized to handle a 20 ton truckload. A screw conveyor transfers fuel from the storage pit. From the fuel receiving area, coal is moved to the storage silo. For two 600 HP boilers, a 350 ton silo is recommended. This size would yield approximately 9 days of storage if the boilers operate fully loaded 24 hours per day. A bucket elevator is used to lift fuel from the receiving pit to the storage silo. In the recommended design, the silo is arranged to accommodate both live and reserve storage. Live storage is held at the top of the silo, feeds the boiler directly, and is filled first by the bucket elevator. Once the live storage is filled, fuel falls to the reserve storage area. Reserve storage empties via gravity into the bucket elevator where it can be transferred to live storage. Using the silo as both live and reserve storage eliminates the need for a coal bunker at the boiler and also reduces the amount of handling equipment necessary to move fuel between live and reserve storage. A small stoker hopper located at the boiler serves as a surge tank.

When the stoker is added, the boiler will be capable of burning coal, natural gas, and coal and gas in combination. Because of the rapid load swings experienced at this location, coal will not be able to provide all of the steam demanded, therefore, a certain percentage of natural gas co-firing will be necessary. To calculate the relative amounts of coal and natural gas used, a boiler efficiency of 78.5% on coal and 82% on natural gas will be used in the calculations.

**FUEL RECOMMENDATION**

Because of the proximity of the plant to the coal fields, Tennessee bituminous coal is recommended. The most economical delivery method is by 20 ton dump truck. The delivered price of this fuel is $43-$47/ton. Important
properties are presented in Table 1. The properties of this coal match closely those required by the boiler. Based on a coal price of $47/ton, the unit energy cost is $1.81 MMBtu's. Assuming 90% of the energy is supplied by coal, the boiler would consume 3,300 tons of coal per year, or 13.75 tons per day. This is equivalent to approximately 3/4 truckload.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties of</td>
</tr>
<tr>
<td>Tennessee Bituminous Coal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>4%</td>
</tr>
<tr>
<td>Ash</td>
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</tr>
<tr>
<td>Volatile Matter</td>
<td>29%</td>
</tr>
<tr>
<td>Fired Carbon</td>
<td>59%</td>
</tr>
<tr>
<td>Heat Content</td>
<td>13,000 Btu/1b</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.70%</td>
</tr>
<tr>
<td>Size</td>
<td>Stoker Coal</td>
</tr>
<tr>
<td></td>
<td>15% - 1/4&quot;</td>
</tr>
<tr>
<td>Cost</td>
<td>$43-$47/ton</td>
</tr>
</tbody>
</table>

**ECONOMIC ANALYSIS**

The economic justification for a solid fuel boiler relies on the lower unit fuel cost to offset the higher capital and operating costs. The estimated cost for the retrofit described earlier is $550,000.

Due to the greater manpower, utility, and maintenance costs, coal and other solid fuel boilers have operating costs that are 3 to 5 times those of similar gas boilers. Several factors account for this difference. First, coal boilers have more direct labor associated with their operation. While gas boiler installations often have assigned boiler operators each shift, they do not have to devote their full attention to the boiler as do coal boiler operators and can perform other activities in addition to boiler operation.
Second, maintenance costs of solid fuel boilers are higher due to the large number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the number of motors used in receiving and handling and solid waste disposal. Our evaluation used an operating cost of $0.15/1,000 lb/steam for gas boilers and $0.60/1,000 lb/steam for solid fuel boilers. Based on total energy consumption and a gas boiler efficiency of 82%, steam production was calculated to be 74,760 thousands of pounds per year.

As stated previously for the coal/natural gas case, 90% of the energy will be supplied by coal and 10% by gas. The annual energy requirement will be equivalent to 3,300 tons of coal and 8,850 MCF of natural gas. The total annual operating costs are summarized in Table 2. An additional cost for the coal boiler is the amortization of capital. A 20 year life and 12% interest rate were used to calculate the annual cost of capital. The analysis yields a simple payback of 3.4 years.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Boiler Economic Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Costs</td>
<td>Gas</td>
</tr>
<tr>
<td>Operation</td>
<td>Operation</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>(existing)</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>---</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$11,200</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>$455,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$466,200</td>
</tr>
</tbody>
</table>

Annual Cost Savings = $466,200 - $318,800 = $147,400  
Approximate Payback Period = $550,000 x 0.9/$147,400 = 3.4 years
A 10% investment tax credit was deducted from the capital investment. The analysis did not consider other tax advantages such as depreciation or interest deductions which could reduce the payback period.

CONCLUSION

The availability of coal, high boiler utilization, and low capital investment make the conversion to coal firing attractive. A simple payback of approximately 3.4 years was found for conversion to coal firing.
MEMORANDUM

Date: August 22, 1984
To: Tom McGowan, Mike Brown
From: Jim Walsh
Subject: Audit of Project A-3663

On Thursday, March 1, 1984, I conducted an audit of the subject plant. I might note that I had extreme difficulty contacting the company to set up the audit. I met the plant manager, and Bill Bulpitt and Tom McGowan visited their office in Dalton, Georgia.

The major findings are as follows:

- Single Cleaver Brooks 200 HP Boiler
- Produces 150 psig Steam
- Plant Works 6 Days per Week, 3 Shifts
- Boiler Operates at About a 60% Load Factor
- A 100' x 100' Concrete Pad within 50' of Current Boiler
- No Natural Gas Curtailment in 8 Years
- Fuel Type in 20'H x 10'D Tank is Unknown

The plant agreed to provide data on fuel use, but as of this date, no data has been received. There appears to be little interest by the company in pursuing this, and the system size is small, indicating a low probability of economic feasibility.

Based on these facts, I have decided to close out this audit. All the data received from the company is attached for file purposes.

JLW/dk
Attachment
INTRODUCTION

is a food industry located in south central Georgia. The primary operation at this plant is blanching, or the removal of the red outer skins from peanuts. A major use of natural gas at this plant is as a fuel for the peanut dryer. The nuts are dried to 4.5-4.75% moisture content. Most of the nuts processed are dried at 210°F, but a small percentage are roasted at 300°F. Uniform drying aids the removal of the peanut skins. The purpose of this study is to provide a preliminary examination of the feasibility of using peanut skin residue as an alternative to natural gas for heating the dryer.

The peanut dryer consumes approximately 11,000 million Btu of natural gas annually. The dryer operates 16 hours per day, 5 days per week, 52 weeks per year, for a total of 4160 hours per year. This yields an average annual energy consumption for the dryer of approximately 2.6 million Btu per hour. This study will consider replacing natural gas with peanut skins. Dry peanut skins are biomass material with a reasonably high energy content and low sulfur and ash content. The specific properties of peanut skins were determined in the Georgia Tech Solid Fuel Lab and are reported in the Fuel Specification section later. Besides providing a free source of energy, burning peanut skins will resolve the problem of disposing of them.

EQUIPMENT SELECTION

A calculation of the average energy consumption by the dryer was found to be 2.6 million Btu per hour. This agrees with the maximum expected consumption of 3.4 million Btu per hour found by multiplying the rating of each of the dryer's burners, 430,000 Btu per hour, by the number of burners, eight.
Based on the properties of the peanut skins, a suspension burning system would be recommended. The cyclone furnace or suspension burner has enjoyed widespread use for burning pulverized coal in utility size boilers. The fuel is very finely ground and blown into the furnace almost as a gas and, as a result, the combustion process is complete and efficient. Variations on the cyclonic furnace concept have been developed for burning biomass material, but the fuel used must satisfy certain criteria. The biomass material must be dry (usually less than 10% moisture content on a wet basis), and it must be ground to a fine particle size.

This study will evaluate the installation of a 3 million Btu/hr capacity suspension burner capable of operating on dry fuel. The budget price estimate includes the burner, hammermill for size reduction, fuel metering equipment, and controls. All that must be added are storage, handling and hot gas distribution.

The flame temperatures generated when burning dry material are very high, usually in the 2500°F - 3000°F range. Since gas temperatures of 200°F - 300°F are required in the dryer, extensive dilution of the combustion products is necessary. Once the gas has been blended with dilution air to reduce the temperature, it can be distributed via ducting to the eight heating zones in the dryer. Only limited fuel storage will be necessary since the burner will consume the waste peanut skins almost as quickly as they are produced. Since there are not enough peanut skins to completely provide the plant's energy needs, supplemental energy will be provided by dry wood waste—fodder example, planar shavings or sander dust. To minimize cost, the shavings should be received by dumptruck and stored under an open shed. The dry wood can be fed into the hog or hammermill with a small front end loader. While receiving wood in dumptrucks will increase the delivered cost of wood fuel, and manual handling using a front end loader will increase the labor costs, both of these serve to reduce the initial capital investment required. Note also that since this area has a heavy concentration of peanut processors, it may be possible to obtain peanut skins from another local source if transportation can be arranged. Peanut skins may be preferred since the system is designed to use them as the primary fuel, and their only associated cost would be delivery.
FUEL RECOMMENDATION

Peanut skins are the suggested fuel for this situation. Currently the plant produces 500 tons annually, or enough to provide 88% of the plant's thermal energy demand or drying. Samples of peanut skins were tested in the Georgia Tech Fuels Lab, and the average values for three tests are presented in Table 1. The complete test results are included as an attachment. The

<table>
<thead>
<tr>
<th>Moisture Content</th>
<th>9% (wet basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatile Content</td>
<td>79% (dry basis)</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>18% (dry basis)</td>
</tr>
<tr>
<td>Ash Content</td>
<td>3% (dry basis)</td>
</tr>
<tr>
<td>Higher Heating Value</td>
<td>9700 Btu/lb</td>
</tr>
</tbody>
</table>

fuel is dry and has a heating value consistent with other dry biomass products.

Since in-house production of peanut skins is not sufficient to meet the entire plant energy demand, supplemental fuel must be procured. For the purposes of this study, waste wood is considered as a secondary fuel. Wood is plentiful in this area of the state and should be available. For use in the suspension burner, wood fuel must be dry (<10% moisture content), which limits the type of wood suitable to sander dust, planer shavings or similar material. Dry wood fuel can be purchased for approximately $25 per ton (or less), or about $1.47 per million Btu. An even better fuel would be waste peanut skins from another processor in the vicinity. If they can be found, it would eliminate any problems with handling two different fuels. In either case, most of the fuel cost can be attributed to transportation.
ECONOMIC ANALYSIS

The economic justification for solid fuel firing relies on the lower unit fuel cost to offset the higher capital and operating costs. The estimated capital costs for the combustion system described earlier are presented in Table 2. The prices in this table are the minimum based on limited options and extras. Significant deviations from the configuration presented could increase the capital cost by 25-50%. Final equipment selection will be dictated in part by individual plant operating requirements.

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solid Fuel Burner Installation Costs</strong></td>
</tr>
<tr>
<td>Suspension Burner</td>
</tr>
<tr>
<td>(3 million Btu/hr, includes hammermill, fuel metering, controls and installation)</td>
</tr>
<tr>
<td>Front End Loader</td>
</tr>
<tr>
<td>Wood Shed</td>
</tr>
<tr>
<td>Dilution Air Fan</td>
</tr>
<tr>
<td>Pneumatic Conveying for Peanut Skins and Warm Air Ducting to Dryer</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

Due to greater manpower, utility, and maintenance costs, solid fuel combustors have operating costs per unit of output that are 3-4 times those of similar gas burners. Several factors cause this difference. First, solid fuel combustors have more direct labor associated with their operation. While gas installations often have assigned operators each shift, they do not have to devote as much of their attention to the burner as do solid fuel combustor operators. Second, maintenance costs of solid fuel systems are higher due to the large number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the number of motors used in receiving,
handling, and size reduction. Our evaluation used an operating cost of $0.60/MMBtu input for the solid fuel combustor and $0.15/MMBtu input for the gas combustor.

The estimated annual costs of operating both the conventional and solid fuel boilers are summarized in Table 3. These costs are based on an energy requirement of 11,000 million Btu/yr. In this analysis, peanut skins were assumed to provide 88% of the total, with dry wood supplying the remainder. A natural gas cost of $5.58/million Btu was used. An additional cost for the solid fuel system is the amortization of the capital cost. A 20-year life and 12% interest rate were used to calculate the annual cost of capital. Based on these assumptions, a simple payback of 2.6 years was calculated. The analysis did not consider tax advantages such as depreciation, investment tax credits, or interest payment deductions which could decrease the payback period, or more expensive equipment expenditures which could increase the payback period.

<table>
<thead>
<tr>
<th></th>
<th>Natural Gas</th>
<th>Solid Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>(existing)</td>
<td>104,000</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>--</td>
<td>13,900</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>1,650</td>
<td>6,600</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>61,400</td>
<td>1,900</td>
</tr>
<tr>
<td></td>
<td>63,050</td>
<td>22,400</td>
</tr>
</tbody>
</table>

Annual Cost Savings: $63,050 - 22,400 = $40,650

Approximate Payback Period: $104,000/$40,650 = 2.6 years
CONCLUSION

The presence of a large amount of combustible waste makes the installation of a solid fuel combustor for dryer heating appear feasible. A simple payback of 2.6 years was calculated for such a system. Before purchasing the recommended system, a supplemental source of fuel, either wood or peanut skins, and complete combustion tests must be conducted.
MEMORANDUM

Date: September 6, 1984
To: Mike Brown
From: Jim Walsh
Subject: Fuels Analysis of Peanut Skins

The following are the results of the fuels analysis of the peanut skins:

<table>
<thead>
<tr>
<th></th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Content, Percent Wet Basis</td>
<td>9.08</td>
<td>9.09</td>
<td>9.09</td>
</tr>
<tr>
<td>Volatile Content, Percent Dry Basis</td>
<td>81.78</td>
<td>76.18</td>
<td>79.29</td>
</tr>
<tr>
<td>Fixed Carbon Content, Percent Dry Basis</td>
<td>15.71</td>
<td>21.24</td>
<td>18.48</td>
</tr>
<tr>
<td>Ash Content, Percent Dry Basis</td>
<td>2.51</td>
<td>2.58</td>
<td>2.55</td>
</tr>
<tr>
<td>Higher Heating Value, Btu/1b Dry Bsis</td>
<td>9997</td>
<td>9432</td>
<td>9715</td>
</tr>
</tbody>
</table>

I'm not sure why there is a large variation in the volatile content, but I don't think the difference is significant.

JLW/dk

cc: T. McGowan
CONCEPT PAPER
ON PRODUCT QUALITY TESTING FOR
COMPANY
Tom McGowan, GTRI, 9/24/84

INTRODUCTION

The Company is considering the installation of wood gasification equipment to supply heat to full scale industrial spray dryers. The prime concern is product quality. Ash or unburned carbon can darken the product and reduce its worth and marketability. Georgia Tech proposes to study this problem in order to assess the probability of product contamination.

OUTLINE OF PROPOSED PROJECT

Phase 1: Visit plant site, obtain data on the spray dryer, current combustion system, product quality specifications, and test standards. Obtain information from gasification vendors (and/or literature sources) on particulate loading downstream of low Btu gas burner. Assess the effectiveness of particulate control technology in reducing particulate to an acceptable level.

Phase 2: Design test program to utilize an existing ( ) Niro Utility spray dryer to test the effect of particulates on product quality. Estimate the cost and time involved to accomplish this test work and evaluation.

Phase 3: If the cost and duration of the test program are acceptable, proceed with final design, construction, and testing. will supply the spray dryer, dryer operating personnel, and perform product quality tests. Georgia Tech personnel will handle the remainder of the hardware and testing programs. The final evaluation will be performed jointly.
This plant is a wood products industry which manufactures chairs and wood furniture. The plant is located in the metro-Atlanta area and employs approximately 70 people. Currently the plant uses a natural gas hot water boiler to supply space heat and heat used in curing. The purpose of this study was to determine if wood residue from the manufacturing operation could be used in the hot water boiler.

Plant personnel indicated that the volume of wood residue produced daily is approximately 1000 ft\(^3\). This material is dry wood waste composed of sawdust, sauder dust, and wood scraps. With a bulk density of 11.5 lb/ft\(^3\) this is equivalent to 11,500 lb/day of waste or 5-3/4 tons. At an energy content of 7000 Btu/lb the available energy would be equal to 80 MMBtu/day. This is more than the current daily energy consumption of natural gas. The dry wood residue can be fired in a suspension burner. Large pieces of material would need to be screened out so they could subsequently be hogged or disposed of. Burning residue would offer the additional benefit of saving the landfill costs.

While initial investigation indicated a high potential for success since they were both a demand for and source of energy further investigation revealed that such an option was unworkable. The plant is located in a non-attainment zone for particulate. This means that no new sources of atmospheric particulate are allowed in this area unless a emission source of equal or greater magnitude is removed. This non-attainment condition rendered the installation of a wood system infeasible and the only remaining option would be to sell the fuel to a user outside the zone.
INTRODUCTION

is a major textile firm with plants in many separate locations. This study will focus on a carpet yarn plant located in West Central Georgia. Currently, energy for steam generation is provided by natural gas. The purpose of this study is to provide a preliminary examination of the feasibility of using solid fuel as an alternative. Because the plant does not have a significant amount of combustible waste nor a readily available supply of wood fuel, this analysis evaluated coal firing.

The plant has two 10,000 lbs/hr package boilers in place. Steam generation is required 24 hours per day, 6 days per week, for 50 weeks per year, or a total of 7200 hours per year. A single boiler is sufficient to carry the load in summer, but both are required during winter. Steam is used primarily in the heat setting process.

EQUIPMENT SELECTION

Using the operational and fuel consumption data provided, a calculation of the plant's average steam production was made. In the calculation, a boiler efficiency of 80%, operating time of 7200 hours per year, and steam energy content of 1000 Btu/lb were used. The calculation indicated an average steam rate of 8600 lbs/hr. This agrees well with the data from plant personnel who indicated that the summer load is 6-7,000 lbs/hr, and the winter load which lasts only 4 months is 12-14,000 lbs/hr.

Based on this data, a 300 HP (10,350 lbs/hr) boiler was selected as appropriate for this application. This will yield a yearly average boiler load of about 85%. In winter, co-firing with a natural gas boiler will be necessary to meet the required steam demand. This is only for a short period,
however. Therefore, the coal system should be able to provide 90% of the necessary steam.

There are various package boilers in this size range that are capable of burning coal. For the purposes of comparison, this study considered the application of a three-pass, modified Scotch Marine, steam boiler (Figure 1). This unit has horizontal fire tubes and a wet back design. Coal stoking is accomplished with a chain grate and ash removal is automatic. The boiler has a standard design pressure of 150 psig, but higher pressure designs are available.

A chain grate stoker consists basically of an endless chain formed by small links on rods. The links are made of either cast iron or chromium bearing cast iron. The chain mat moves continuously into the furnace carrying a bed of coal leveled at an adjustable thickness by a guillotine door. The chain grate arrangement will handle most coals, other than anthracite and lignite, provided the ash content exceeds 5%. Below this level, the grate will tend to overheat. The upper limit of coal size recommended is 1¼ inches. Fuel in excess of this sizing will create blow holes in the coal bed resulting in inefficient combustion. Coal with the appropriate recommended characteristics are readily in your area as will be discussed in the Fuel Recommendation section of this report.

For fuel receiving, an underground bunker is recommended. Coal will be delivered in dump trucks which will unload into the pit. The pit is sized to handle a 20 ton truckload. A screw conveyor transfers fuel from the storage pit. From the fuel receiving area, coal is moved to the storage silo. For a 10,000 lbs/hr boiler, a 150 ton silo is recommended. This size would yield approximately 12 days of storage if the boiler operates fully loaded 24 hours per day. A bucket elevator is used to lift fuel from the receiving pit to the storage silo. In the recommended design, the silo is arranged to accommodate both live and reserve storage. Live storage is held at the top of the silo, feeds the boiler directly, and is filled first by the bucket elevator. Once the live storage is filled, fuel falls to the reserve storage area. Reserve storage empties via gravity into the bucket elevator where it can be transferred to live storage. Using the silo as both live and reserve storage eliminates the need for a coal bunker at the boiler and also reduces the amount of
Figure 1. Firetube Boiler Schematic
handling equipment necessary to move fuel between live and reserve storage.

This boiler is equipped with an automatic ash disposal system. It uses a drag chain submerged in water to collect the ash. The chain stoker deposits ash into the drag chain trench. When the ash strikes the water, it is cooled and converted to a slurry. The drag chain transfers the ash slurry to a collection vessel.

**FUEL RECOMMENDATION**

Because of the proximity of the plant to the coal fields, Tennessee bituminous coal is recommended. The most economical delivery method is by 20 ton dump truck. The delivered price of this fuel is $43-$47/ton. Important properties are presented in Table 1. The properties of this coal match closely those required by the boiler. Based on a coal price of $47/ton, the unit energy cost is $1.81 per million Btu's. The boiler would consume 1,080 pounds of coal per hour, fully loaded, or 13 tons per day. This is equivalent to 2/3 of a truckload.

---

**TABLE 1**

**PROPERTIES OF TENNESSEE BITUMINOUS COAL**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>4%</td>
</tr>
<tr>
<td>Ash</td>
<td>10%</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>29%</td>
</tr>
<tr>
<td>Fired Carbon</td>
<td>59%</td>
</tr>
<tr>
<td>Heat Content</td>
<td>13,000 Btu/lb</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.70%</td>
</tr>
<tr>
<td>Size</td>
<td>Stoker Coal</td>
</tr>
<tr>
<td></td>
<td>15% - 1/4&quot;</td>
</tr>
<tr>
<td>Cost</td>
<td>$43-$47/ton</td>
</tr>
</tbody>
</table>
ECONOMIC ANALYSIS

The economic justification for a solid fuel boiler relies on the lower unit fuel cost to offset the higher capital and operating costs. The estimated capital costs for the coal boiler system described earlier are shown in Table 2. All costs include installation. The prices presented in Table 2 are the minimum based on limited options and extras. Significant deviation from the configuration presented could increase the capital cost by as much as 50%. Final equipment selection will be dictated in part by individual plant operating requirements.

| TABLE 2 |
|---|---|
| **COAL BOILER INSTALLATION COSTS** | |
| Boiler (10,000 lbs/hr three-pass, modified Scotch Marine steam boiler w/chain grate) | $256,000 |
| Fuel Receiving - 20 ton, underground pit | $ 20,000 |
| Fuel Storage - 150 ton silo | $ 50,000 |
| Fuel Handling | $ 30,000 |
| Ash Disposal - submerged drag chain | $ 10,000 |
| Site Work and Boiler House | $ 20,000 |
| **TOTAL** | **$386,000** |

Due to greater manpower, utility, and maintenance costs, coal and other solid fuel boilers have operating costs per unit of output that are 3-4 times those of similar gas boilers. Several factors cause this difference. First, coal boilers have more direct labor associated with their operation. While gas boiler installations often have assigned boiler operators each shift, they do not have to devote their full attention to the boiler as do coal boiler operators, but can perform other activities in addition to boiler operation. Second, maintenance costs of solid fuel boilers are higher due to the large
number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the number of motors used in receiving and handling, and solid waste disposal. Our evaluation used an operating cost of $0.60/1,000 lbs/steam for solid fuel boilers and $0.15/1,000 lbs/steam for gas/oil boilers. When calculating the operating cost, an efficiency of 80% was used with both the coal and gas boilers to determine annual steam production.

The estimated annual costs of operating both the conventional and solid fuel boilers are summarized in Table 3. These costs are based on providing 90% of the annual steam demand or 55,700 thousand pounds with coal. The remaining 10% of the steam is produced with natural gas. The coal boiler will consume 2,680 tons of coal to provide 90% of the plant steam, and the peak loaded natural gas boiler will consume 7,500 MCF of gas to produce the remaining 10%. An additional cost for the coal system is the amortization of

<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>BOILER ECONOMIC ANALYSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ANNUAL COSTS</td>
</tr>
<tr>
<td></td>
<td>Conventional System</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>(existing)</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>$ ---</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$ 8,400</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>$314,300</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$322,700</td>
</tr>
</tbody>
</table>

Annual Cost Savings: $322,700 - $242,400 = $80,300
Approximate Payback Period: ($386,000 x .9)/$80,300 = 4.3 years
the capital cost. A 20 year life and 12% interest rate were used to calculate the annual cost of capital. Based on these assumptions, a simple payback of 4.3 years was calculated. An investment tax credit of 10% was included. The analysis did not consider additional tax advantages such as depreciation or interest payment deductions which could decrease the payback period, or more expensive equipment expenditures which could increase the payback period. The payback period is strongly dependent on fuel costs and a high coal cost of $47/ton was used in these calculations. If coal can be purchased at a lower cost, the payback can be further reduced.

CONCLUSION

A preliminary analysis evaluating a 10,000 lbs/hr coal boiler indicated an approximate simple payback of 4.3 years. This outcome resulted primarily from the current relatively low cost of natural gas ($4.06/MMBtu) and the high price of coal ($47/ton) considered. Given that natural gas prices will continue to rise at a greater rate than coal, the payback period should continue to improve.
INTRODUCTION

, located in east central Georgia, is a processor of Fuller's earth. Total employment is approximately 175 persons, and the plant operates 24 hours per day, 7 days per week, 50 weeks per year. The major energy source is natural gas, and the primary use of gas is to fire a nominal 60 MMBtu/hr rotary kiln. Earlier Georgia Tech performed a study on the feasibility of replacing natural gas with wood chips. This study will examine the feasibility of using a coal gasifier to provide low Btu gas.

EQUIPMENT SELECTION

During the 1920s, there were approximately 11,000 small gasifiers in operation in the United States converting coal into low Btu gas. The advent of natural gas pipelines with high quality, readily available natural gas spelled the end for most of these systems. Today, however, the rising price of natural gas while coal remains stable has renewed interest in these early systems. This study will consider the application of a fixed bed, atmospheric pressure gasifier to your plant.

A schematic of the gasifier is presented in Figure 1. A two compartment fuel bin forms the top of the unit. The upper most section serves as a storage bin. Fuel is fed to the lower bin through disc valves. From the lower bin coal flows through feed pipes to the fire chamber. The gas producing chamber is completely water jacketed. Waste heat in the water jacket generates steam required to make gas. Feeding the combustion zone with less than the stoichiometric amount of air results in the production of fuel gas with an energy content of 150 Btu/ft³. Coal in the reaction zone is supported on
Figure 1. Gasifier Schematic

ZONES
7 DRYING
6 PREHEAT
5 DISTILLATION
4 SECONDARY REDUCTION
3 PRIMARY REDUCTION
2 COMBUSTION
1 ASH
revolving steel plate rings. The grates are oriented eccentrically with respect to the centerline of the gasifier vessel. As the space between the grate and the vessel increases, it fills with ash which is forced over the inner edge of the grate platforms into a cone-shaped ash hopper. The constituents of the fuel gas are shown in Table 1.

<table>
<thead>
<tr>
<th>Volume Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide  CO     25.00%</td>
</tr>
<tr>
<td>Methane          CH₄       2.27%</td>
</tr>
<tr>
<td>Illuminants      ---       .87%</td>
</tr>
<tr>
<td>Hydrogen         H₂        14.49%</td>
</tr>
<tr>
<td>Carbon Dioxide   CO₂       4.69%</td>
</tr>
<tr>
<td>Nitrogen         N₂        52.68%</td>
</tr>
</tbody>
</table>

In addition to coal, the other feed materials required are steam and air. They are introduced through the bottom of the bed. The thermal efficiency of the gasifier is affected by the properties of the coal and by the proportions and amounts of air and steam. Average efficiencies are in the 70%-90% range. The gasification plant is complicated by the fact that clean gas is required. Raw producer gas from the gasifier must be subjected to particulate removal, tar removal, and, if significant sulfur is present, sulfur removal in successive stages. These operations convert the hot raw gas into cold, clean gas.

Included with the gasifier is equipment for coal handling and storage, ash disposal, and tar removal and conditioning. Coal will be received by rail. Bottom dump cars will be positioned over a receiving hopper with a car puller. An unloading conveyor transports the coal to an outdoor conical storage pile. It is then deposited into an elevator for transport to the feed bin on top of the gasifier. The gasifier is constructed so that the conical
shaped ash hopper is sufficiently elevated above ground level to allow truck access.

Raw gas particulate clean-up is achieved in a cyclone which removes approximately 85% of the entrained coal and ash particles. Hot gas exiting the cyclone is quenched with a water stream in a quench tower, and the temperature is reduced to 135°F. This temperature reduction condenses out many of the tars and oils and much of the remaining particulate is removed. Quench water is pumped to a heat exchanger for cooling and then to a tar separator. The gas leaving the quench tower is cooled further in a gas cooler. Additional tars and water are removed and flow by gravity to the tar separtor. Any remaining fine particulates or tar mists are removed in an electrostatic precipitator.

In the tar separator, tars settle out and are pumped to a storage tank for holding. It can be either delivered to secondary purchases or returned to the gasifier for destruction. Water from the tar separator contains dissolved and suspended organics and must be treated before discharge.

**FUEL RECOMMENDATION**

Due to the quantity of fuel required and the distance of the plant from the coalfields in Kentucky and Tennessee, rail delivery is preferred. Bottom unloading 100-ton capacity railcars are the recommended receiving method. Each car has a capacity of 80-90 tons, so about 4½ cars will have to be unloaded each week. To be compatible with the gasifier equipment, nut-slack coal, 2 x 0, or equivalent should be used. This coal is less costly than stoker coal. The properties of the recommended fuel are presented in Table 2. Based on a fuel cost of $45/ton and a heating value of 13,000 Btu/lb, the unit energy cost is $1.73 per million Btu. At full output, the gasifier would consume 65 tons per day. This is equivalent to approximately 3/4 railcar loads per day.
TABLE 2
COAL PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Nut- Slack, 2 x 0</td>
</tr>
<tr>
<td>Energy Content</td>
<td>13,000 Btu/lb</td>
</tr>
<tr>
<td>Sulfur</td>
<td>1%</td>
</tr>
<tr>
<td>Ash Fusion Temperature</td>
<td>2700°F</td>
</tr>
<tr>
<td>Coal Cost FOB Mine</td>
<td>$25/ton</td>
</tr>
<tr>
<td>Freight Cost</td>
<td>$20/ton</td>
</tr>
</tbody>
</table>

ECONOMIC ANALYSIS

The economic justification for solid fuel utilization relies on the lower unit fuel cost to offset the higher capital and operating costs. The estimated capital cost of the gasification system, including fuel handling and effluent disposal, is $2,000,000 for 60 MMBtu/hr output size. This is a budget cost estimate and significant deviations could occur.

Due to the greater manpower, utility, and maintenance costs, coal and other solid fuel systems have operating costs that are 3-4 times higher than similar natural gas systems. Several factors account for this difference. First, coal systems have more direct labor associated with their operation. Second, mainenance costs of solid fuel systems are higher due to the larger number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the motors used in receiving, handling, and waste disposal and the cost of water treatment. Our evaluation used an operating cost of $0.60/MMBtu output from the coal gasifier and $0.15/MMBtu output for the natural gas system. When evaluating the operating cost, an efficiency of 85% was used for the coal system.
The estimated annual costs of operating both the conventional and solid fuel systems are summarized in Table 3. The costs are based on a thermal energy output of 411,000 MMBtu/yr. This is equivalent to 420,000 MCF of natural gas and 18,600 tons of coal. A natural gas cost of $4.25/MMBtu was used. An additional cost for the coal system is the amortization of the capital cost. A 20 year life and 12% interest rate were used to calculate the annual cost of capital. Based on these assumptions, a simple payback of 3.3 years was found. The analysis did consider the application of a 10% investment tax credit to the system capital cost. Other tax advantages, such as depreciation and interest deductions which could decrease the payback period, were not considered.

<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>GASIFIER ECONOMIC ANALYSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANNUAL COSTS</td>
<td></td>
</tr>
<tr>
<td>Conventional System</td>
<td>Coal System</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>(existing)</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>$ ---</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>$ 62,000</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>$1,840,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$1,902,000</td>
</tr>
</tbody>
</table>

CONCLUSION

Due to the large number of annual operating hours and high load factor, the preliminary analysis indicates that a coal gasifier could yield a payback of 3.3 years. Based on this result, further detailed analysis to better establish equipment requirements and capital costs is recommended.
INTRODUCTION

is an apparel firm located west of metro-Atlanta near the Alabama border. Major products are men's suits and coats and women's coats. Employment is about 800. The plant has two gas boilers for process steam production. The purpose of this study is to provide a preliminary examination of the feasibility of using solid fuel as an alternative to the existing energy supply.

The boilers in place are a 2,760 lb/hr (80 HP) unit and a 1,380 lb/hr (40 HP) unit. Both are package units designed for 150 psig service. The plant operates on a 9 hour day, 5 days per week, 52 weeks per year schedule for a total of 2,340 hours. Natural gas consumption for a typical year is 11,400 MMBtu's. Based on a boiler conversion efficiency of 75% and steam heat content of 1,000 Btu/lb, the average steam production is 3,600 lb/hr. The steam consumption by the process fluctuates very little. Based on the average steam production, the boiler load is over 85%. The delivered cost of natural gas is $4.31 per million Btu's yielding an annual fuel bill of $49,100.

SOLID FUEL FEASIBILITY

Coal is the preferred alternate fuel for this location. At a sister plant nearby, coal is the primary fuel with gas and oil providing back-up. Coal is purchased from Alabama due to its close proximity. The delivered price is $56/ton or $2.15 per million Btu's.

While a readily available supply of coal has been found, the plant steam load and operating schedule limit the feasibility of a solid fuel system. As shown in Figure 1, the cost of coal boilers in dollars per pound increases rapidly as the size is reduced. A 100 HP boiler, just slightly smaller than
your average steam load, would cost somewhere in the $250,000-$300,000 range. This is 5-6 times your annual fuel cost, or put another way, if the coal system completely eliminated your fuel bills, it would take 5 years to pay for itself. This is a result of the limited operating schedule at the plant. The feasibility of solid fuel systems increases with the annual plant operating hours. If the plant operated 24 hours per day instead of 9, the natural gas fuel bill would almost triple to near the $150,000/year level. The fuel cost savings from using coal would increase to approximately $100,000/year and yield a 2.5-3 year simple payback.

CONCLUSION

Due to the small steam load and low annual operating hours, coal does not appear to be a viable option for your plant at this time. Increases in the steam demand or operating hours could favorably alter this outcome.
Introduction

is a producer of both common and jumbo brick located in central Georgia. Total employment is approximately 135 people. The kilns at the plant operate 24 hours per day, 7 days per week, 50 weeks per year or a total of 8400 hours per year. The kiln is fired with natural gas. Several years ago a pulverized coal firing system was installed but operational problems resulted in a return to natural gas. The purpose of this study is to examine the feasibility of firing the kiln with low Btu coal gas from a gasification system.

Equipment Selection

Coal is a more economical fuel per Btu than conventional natural gas, but it has not received widespread industrial acceptance due to concerns over equipment costs, pollution control and fuel handling and storage. A pulverized coal burner system was installed at Cherokee several years ago but serious problems with ash build-up in the kiln and caused it to be shut down. This study will examine the feasibility of firing the kiln with low Btu coal gas. Coal gas offers the advantages of being relatively clean (thus it should present no ash build-up problems) and easy to distribute. This study will assume that the existing coal receiving system and storage silo can be adapted to a gasifier. The major capital equipment that will have to be purchased will be the gasifier vessel and its associated ancillary equipment.

During the 1920s, there were approximately 11,000 gasifiers in operation in the United States converting coal into low Btu gas. The arrival of natural gas pipelines with high quality, readily available natural gas spelled the end for most of these systems. Today, however, the high price of natural gas low price of coal has renewed interest in these early systems. This study will consider the application of a fixed bed,
atmospheric pressure gasifier to your plant. While there are several designs of gasifiers, this study will be based on a particular commercial unit that has successfully been applied to brick making. An attachment provides further background information on coal and wood gasifiers.
A schematic of the gasifier is presented in Figure 1. A two compartment fuel bin forms the top of the unit. The upper most section serves as a storage bin. Fuel is fed to the lower bin through disc valves. From the lower bin, coal flows through feed pipes to the fire chamber. The gas producing chamber is completely water jacketed. Waste heat in the water jacket generates steam required to make gas. Feeding the combustion zone with less than the stoichiometric amount of air results in the production of fuel gas with an energy content of 170 Btu/ft. Coal in the reaction zone is supported on revolving steel plate rings. The grates are oriented eccentrically with respect to the centerline of the gasifier vessel. As the space between the grate and the vessel increases, it fills with ash which is forced over the inner edge of the grate platforms into a cone-shaped ash hopper. The constituents of the fuel gas are shown in Table 1.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPOSITION OF LOW BTU FUEL GAS</td>
</tr>
<tr>
<td>Volume Analysis</td>
</tr>
<tr>
<td>Carbon Monoxide CO 25.00%</td>
</tr>
<tr>
<td>Methane                   CH 2.27%</td>
</tr>
<tr>
<td>Illuminants               --- .87%</td>
</tr>
<tr>
<td>Hydrogen                  H 14.49%</td>
</tr>
<tr>
<td>Carbon Dioxide CO 4.69%</td>
</tr>
<tr>
<td>Nitrogen                  N 52.68%</td>
</tr>
</tbody>
</table>

In addition to coal, the other feed materials required are steam and air. They are introduced through the bottom of the bed. The thermal efficiency of the gasifier is affected by the properties of the coal and by the proportions and amounts of air and steam. Average efficiencies are in the 70%-90% range. Raw producer gas from the gasifier will pass through a cyclone for particulate removal then on to the kiln.
Figure 1. Gasifier Schematic
Existing coal receiving, handling and storage equipment can be used with the gasifier. Included with the gasifier is a coal elevator (for loading the storage bin), dust cyclone, structural steel, controls and instrumentation, and start-up assistance. The gasifier vessel recommended for this application is 10' in diameter and has a maximum capacity of 75 million Btu/hr. The storage bin on top of the gasifier generally has a one day capacity.

In some situations special burners to accommodat the low Btu gas need not be purchased. Because of the differing heat content of natural gas and producer gas in some cases burners can be modified to accept low Btu gas by simply switching the air and the gas lines. Further consultation with the burner manufacturer will determine if this is feasible. If, indeed, producer and natural gas can be burned interchangeably your fuel flexibility will be greatly advanced.

Because the gas will be in a raw form it is imperative that the temperature of the gas not be allowed to decrease significantly or tars will begin to condense. The gas piping must be adequately insulated to reduce condensation.

**FUEL RECOMMENDATION**

Due to the quantity of fuel required and the distance of the plant from the coalfields in Kentucky and Tennessee, rail delivery is preferred. Bottom unloading 100-ton capacity railcars are the recommended receiving method. Each car has a capacity of 80-90 tons, so about 4½ cars will have to be unloaded each week. To be compatible with the gasifier equipment, nut-slag coal, 2 x 0, or equivalent should be used. This coal is less costly than stoker coal. The properties of the recommended fuel are presented in Table 2. Based on fuel cost of $45/ton and a heating value of 13,000 Btu/lb, the unit energy cost is $1.73 per million Btu. At full output, the gasifier would consume 65 tons per day. This is equivalent to approximately 3/4 railcar loads per day.
TABLE 2
COAL PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Nut- Slack, 2 x 0</td>
</tr>
<tr>
<td>Energy Content</td>
<td>13,000 Btu/lb</td>
</tr>
<tr>
<td>Sulfur</td>
<td>1%</td>
</tr>
<tr>
<td>Ash Fusion Temperature</td>
<td>2700 F</td>
</tr>
<tr>
<td>Coal Cost FOB Mine</td>
<td>$25/ton</td>
</tr>
<tr>
<td>Freight Cost</td>
<td>$20/ton</td>
</tr>
</tbody>
</table>

ECONOMIC ANALYSIS

The economic justification for solid fuel utilization relies on the lower unit fuel cost to offset the higher capital and operating costs. The estimated capital cost of the gasification system is $1,300,000 for a 10’ diameter vessel. This is a budget cost estimate and significant deviations could occur.

Due to the greater manpower, utility, and maintenance costs, coal and other solid fuel systems have operating costs that are 3-4 times higher than similar natural gas systems. Several factors account for this difference. First, coal systems have more direct labor associated with their operation. Second, maintenance costs of solid fuel systems are higher due to the larger number of moving parts and greater system complexity. Lastly, the utility costs are higher because of the motors used in receiving, handling, and waste disposal, and the cost of water treatment. Our evaluation used an operating cost of $0.60/MMBtu output from the coal gasifier and $0.15/MMBtu output for the natural gas system. When evaluating the operating cost, an efficiency of 90% was used for the coal system.

The estimated annual costs of operating both the conventional and solid fuel systems are summarized in Table 3. The costs are based on a thermal energy output of 257,100 million Btu/yr. This is equivalent to 250,000 MCF of natural gas or 10,800 tons of coal. A natural gas cost of $4.50/MMBtu was used. An additional cost for the coal system is the amortization of the
the capital cost. A 20 year life and 12% interest rate were used to calculate the annual cost of capital. Based on these assumptions, a simple payback of 3.0 years was found. The analysis did consider the application of a 10% investment tax credit to the system capital cost. Other tax advantages, such as depreciation and interest deductions which could decrease the payback period were not considered.

| TABLE 3 |
| GASIFIER ECONOMIC ANALYSIS |
| ANNUAL COST |

<table>
<thead>
<tr>
<th></th>
<th>Conventional System</th>
<th>Coal System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>(existing)</td>
<td>$1,300,000</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>---</td>
<td>174,000</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>$ 38,000</td>
<td>$ 151,000</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>$1,157,000</td>
<td>$ 484,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$1,195,000</td>
<td>$ 809,000</td>
</tr>
</tbody>
</table>

Annual Cost Savings = $1,195,000 - $809,000 = $386,000
Approximate Payback Period = ($1,300,000 x .9)/$386,000
= 3.0 years

CONCLUSION

Due to the large number of annual operating hours and high load factor, the preliminary analysis indicates that a coal gasifier could yield a payback of 3.0 years. Based on this result, further detailed analysis to better establish equipment requirements and capital costs is recommended.
Dear

This letter is in response to our phone conversation on October 29, 1984. I agree with your assessment of wood gasification as being an unnecessary step when the ultimate goal is to produce high pressure steam for electrical power generation. Gasification may be the preferred approach when you want to convert an existing gas-fired boiler to wood or you have an application that requires a "clean" fuel. Wood gasifiers are usually of a size smaller than would be necessary for your application. As you can see from the attached report on gasification, fixed bed gasifiers are generally no larger than 60 million Btu/hr. If greater outputs are needed, gasifiers must be operated in "batteries." This creates operational and maintenance problems due to the duplication of equipment and coordination required.

I have enclosed some information on coal and wood gasification as an attachment. Given the situation with a higher cost for competing fuel and smaller total energy requirement, gasification could become a viable alternative. If you need further help now or in the future, I can be reached at 894-3412.

Sincerely,

Michael Brown

MB/1mk
APPENDIX B

Solid Fuel Survey Form
SOLID FUELS SURVEY FORM

**COMPANY INFORMATION**

Company Name ____________________________________________
Address ________________________________________________
City, Zip ________________________________________________
Company Contact ___________________________ Title ________________
Telefone ________________________________

**BUSINESS INFORMATION**

Major Business Sector __________________________ Major Products _______________________
C Code ______________________________________________
Waste Materials __________________________ Quantity (Tons/year) ________________
Shifts Per Day __________________________

**BOILER CHARACTERISTICS**

Number of Boilers ________________

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Fuel Type</th>
<th>Approximate % Load</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>_____ H.P. ( ) or lb/hr ( )</td>
<td>_______</td>
<td>_________</td>
<td>hr/day ___ day/wk ___ wk/yr</td>
</tr>
<tr>
<td>_____ H.P. ( ) or lb/hr ( )</td>
<td>_______</td>
<td>_________</td>
<td>hr/day ___ day/wk ___ wk/yr</td>
</tr>
<tr>
<td>_____ H.P. ( ) or lb/hr ( )</td>
<td>_______</td>
<td>_________</td>
<td>hr/day ___ day/wk ___ wk/yr</td>
</tr>
</tbody>
</table>

Do you plan to install any new boiler equipment either as replacement or for expansion in the near future?  ____ Yes  ____ No

If yes, when will it be installed? _______ What size will it be? _______
What fuel will be used? _______
For the boilers now operating, indicate your fuel cost as accurately as possible. This cost should be f.o.b. the plant. (Data will be maintained in confidence.)

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Unit Cost of Fuel ($)</th>
<th>Units Consumed Annually</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SYSTEM DESIGN

Solid fuel can be used either as a primary fuel or as a secondary (backup) fuel. Because gas/oil package boilers cannot be modified effectively to consume solid fuel, an existing package boiler may have to be shutdown when converting to solid fuel.

Shown below are the estimated capital costs for solid fuel boilers of several sizes. For comparison, the costs for gas package boilers are also presented. The solid fuel boiler costs are based on a turn-key installation not including building or foundation, and including limited fuel storage handling equipment.

<table>
<thead>
<tr>
<th>Capacity*</th>
<th>Solid Fuel Boiler</th>
<th>Gas Boiler</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,500 lbs/hr</td>
<td>$350,000</td>
<td>$25,000</td>
</tr>
<tr>
<td>10,350 lbs/hr</td>
<td>550,000</td>
<td>72,000</td>
</tr>
<tr>
<td>17,250 lbs/hr</td>
<td>750,000</td>
<td>120,000</td>
</tr>
<tr>
<td>35,000 lbs/hr</td>
<td>1,100,000</td>
<td>240,000</td>
</tr>
<tr>
<td>50,000 lbs/hr</td>
<td>1,600,000</td>
<td>250,000</td>
</tr>
<tr>
<td>100,000 lbs/hr</td>
<td>3,200,000</td>
<td>500,000</td>
</tr>
</tbody>
</table>

*Divide by 34.5 to obtain boiler horsepower.

Are you interested in installing a solid fuel boiler either as a replacement for existing boilers or for future expansion? ___ Yes ___ No

What type of solid fuel do you think would be most attractive at your plant site?
Wood ___ Coal ___ Industrial Waste ___ Other ____________________________

What value of return is usually required before a capital project of this scale and type can be approved? __________

How is it calculated?
___ Simple Payback ___ Internal Rate of Return ___ Net Present Value
Space may be required for fuel storage. The appropriate space required for a one month backup supply of wood fuel, for different boiler sizes, is given below:

<table>
<thead>
<tr>
<th>Boiler Size*</th>
<th>Storage Pile**</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,500 lbs/hr</td>
<td>3,500 ft²</td>
</tr>
<tr>
<td>35,000 lbs/hr</td>
<td>35,000 ft²</td>
</tr>
<tr>
<td>50,000 lbs/hr</td>
<td>50,000 ft²</td>
</tr>
<tr>
<td>100,000 lbs/hr</td>
<td>100,000 ft²</td>
</tr>
<tr>
<td>250,000 lbs/hr</td>
<td>250,000 ft²</td>
</tr>
</tbody>
</table>

*Divide by 34.5 to obtain boiler horsepower.
**Based on green wood, 12 ft pile height.

Based on the size of your boiler and fuel utilization requirements, how would you describe space for boiler and fuel storage at your location.

___ More Than Adequate ___ Adequate ___ Enough, But Very Tight ___ Insufficient

On the separate sheet of paper provided, sketch your existing steam plant layout and indicate space available for a solid fuel system including storage. Indicate approximate dimensions on the sketch.

Solid Fuel boilers are not as quick to react to load changes as are gas/oil package boilers. In some cases, this aspect influences boiler system design. For background information, how would you characterize your boiler load?

___ Steady Load ___ Fluctuating Load

[Approximate Load Change ____ lb/hr (minimum) to ____ lb/hr (maximum) in ____ mins.]

You may wish to provide typical steam flow charts if they are available.

This question is intended to provide information on plant access.

a. The plant location is: ___ Urban ___ Suburban ___ Rural

b. The plant is serviced by a major highway so truck fuel deliveries would be practical? ___ Yes ___ No

c. The plant has rail access? ___ Yes ___ No
APPENDIX C

Demonstration Follow-up Reports
CASE STUDY IN WOOD ENERGY:
THE INTEGRATED PRODUCTS CO.

by

Michael L. Brown
Research Engineer
Energy Conservation Branch
Georgia Institute of Technology

presented at

WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1994
Atlanta, Georgia
I. INTRODUCTION

Integrated Products, Inc., a textile firm headquartered in Rome, Georgia, manufacturers yarn for the carpet industry from plants located in Rome, Villa Rica, and Aragon, Georgia. The processing of yarn consumes large quantities of steam for "heat setting," (providing a permanent twist to the yarn), and drying. In April 1980, Integrated Products agreed to participate in a program being conducted by the Georgia Tech Engineering Experiment Station to investigate the utilization of wood waste as an energy source in non-forest product industries. The program, sponsored by the Department of Energy, offered matching funds in an amount of up to $146,000 to help offset the capital costs of installing a wood energy system. The purpose of the program was to demonstrate the feasibility of using wood as a source of energy in non-forest product related industries.

Integrated Products agreed to participate in the program as a means to reduce the energy and, consequently, product costs at the Aragon plant. While the cost of wood fuel is unquestionably less than conventional fuels, other concerns such as fuel availability, fuel cost escalation, fuel delivery and storage method, equipment operating procedures and maintenance required, and load carrying capabilities are different from those for natural gas and presented significant uncertainties to the firm. This paper is a review of the first three years' operating experience with a wood boiler in a textile plant and an examination of the pre-installation economic analysis to determine if the system achieved desired operational levels and projected payback.
II. WOOD BOILER SYSTEM DESCRIPTION

The existing steam system at Integrated Products consisted of two gas-oil package boilers rated at 350 and 200 hp, respectively. Following the decision to install a wood boiler, planning began on developing an appropriate system design. The initial activity centered on determining what capacity boiler would be appropriate. In sizing the boiler, the existing energy consumption, size, and utilization of the current gas fired boilers, characteristics of steam consuming equipment, and future plans of the company were taken into consideration. The wood boiler selected was to be able to supply all of the plant process heating and space heating requirements with no backup by fossil fuel boilers except in emergencies. Based on these considerations, a 400 hp wood fired boiler was judged to be adequate by engineers at Integrated Products and Georgia Tech.

The wood boiler selected was a horizontal return tube (HRT) boiler designed to produced 13,320 lb/hr of saturated steam (approximately 400 hp) at 150 psi from feedwater at 212°F. It is a firetube boiler, designed to burn sawdust, bark, and chips with a moisture content of up to 50% (wet basis). The boiler has pinhole type fixed grates.

The fuel is fed into the furnace from the metering bin by means of air swept feeders and a variable speed drive unit. Steam pressure sensing controls vary the speed and operation of the metering bin screw conveyor.

A combustion air fan and air duct system supplies combustion air both under and above the grates. Flyash collected under the boiler in a dropout hopper is reinjected to the furnace by a pneumatic system. The boiler is equipped with an induced draft fan and a stack. Particulate emission levels are maintained within allowable levels by two multiclone particulate collectors in series. Particles collected in the primary collector are fed back into the furnace, while those removed by the secondary collector are collected in a drum for disposal.

Other important components of any wood energy system are the fuel handling and storage. Based on a typical wood boiler efficiency of 65% and energy consumption data from previous years, it was calculated that the system
would require approximately 40 tons or 2 truckloads of green wood waste per day. Because of the high cost associated with a hydraulic truck dump and the low use factor, a self-unloading tractor-trailer was selected as the most cost effective delivery method. Wood waste in the form of sawdust and chips is collected at the supplier and transported to the plant. Upon arrival the wood fuel is either unloaded at the open storage area or at the fuel staging area located near the silo. Most of the time the trailer unloads the wood fuel in the fuel staging area.

The fuel staging area is essentially a covered storage shed, with floor dimensions of 55 ft x 35 ft. It can accommodate approximately four truckloads of wood fuel after allowing room for the movement of the front end loader. Trailer unloading time is approximately 15 minutes.

The wood in the fuel staging area is transferred to the receiving hopper by means of a small front end loader. The receiving hopper is approximately 4 ft wide, 8 ft long, and 6.5 ft high, and the fuel received in this hopper is transferred to the storage silo by means of a screw conveyor and bucket elevator. Fuel fed from the silo to the metering bin and from the metering bin to the stokers is accomplished by means of screw conveyors.

Oversized pieces of wood are separated by a vibrating screen located on the top of the receiving hopper. It takes approximately 1 to 1-1/2 hours to transfer one truckload of wood fuel into the silo.

A poured concrete silo, 24 ft diameter x 48 ft high, is used for covered storage. The usable storage capacity of this silo is 14,464 cubic feet which is sufficient fuel for approximately 72 hours of continuous operation when the boiler is at 70% load. An unloading system installed at the bottom of the silo includes revolving chains to prevent bridging of the wood fuel inside the silo.

For long term storage, an open (uncovered) storage area of approximately 6,000 ft$^2$ of concrete floor is provided. This is sufficient to store wood for approximately 15 days. Long term storage is located at a distance of approximately 200 ft from the boiler house and, therefore, is used only in case of emergency.

The layout of the wood boiler site is shown in Figure 1. The boiler was erected adjacent to the factory outside the existing boiler room. The fuel
staging area, fuel silo, and boiler house were arranged to fit into a "U" shaped space formed by the main factory, connecting rampway, and warehouse. Space limitations prevented the open storage area from being situated near the boiler house. It was located as close as possible in an open space 200 feet from the boiler.

**SYSTEM OPERATION**

From the time of startup to the present, the wood boiler has been monitored with respect to its operational aspects including the ability to supply steam under varying conditions of load and fuel quality. Steam is used for process heating in the heat setting of yarn and for space heating in winter, but heat setting is the primary use for steam at the plant. Two different types of equipment with different steam requirements are used for heat setting. The oldest equipment used are autoclaves which are a batch operation. Autoclaves are loaded with yarn, filled with steam, and held for a short period, then exhausted. A newer type of machine known as a continuous heat setter gives constant production of yarn and has a steady steam demand of 1,400 lb/hr. The plant has three autoclaves and six continuous heat setters. The boiler capacity rating is 13,320 lb/hr of steam at 150 psig. The only critical production variable is steam pressure. The continuous heat setters require steam at approximately 110 psig and an alarm goes off when the pressure drops to 95 psig. Due to the variability of the steam load, an operator is assigned to the boiler full-time to make sure steam pressure is maintained above 95 psig and also to attend to various maintenance duties. The utilization factor for the wood boiler, defined as actual steam production ratioed to maximum possible steam production (13,320 lb/hr x annual operating hours), is presented in Table 1 for the first three years of operation. As can be seen from these figures, the wood system has been integrated very effectively into the plant's production process reaching a high utilization of 62% in 1983. This increased utilization corresponds to an upswing in demand for carpet products.

Because of the difficulty in starting and the lag time involved in building up steam pressure, the wood boiler is operated 24 hours per day. If plant production is curtailed, the number of days per week the plant operates
### TABLE 1

**UTILIZATION OF WOOD BOILER**

<table>
<thead>
<tr>
<th>Year</th>
<th>Operating Hours</th>
<th>Measured Steam Production (lb/yr)</th>
<th>% of Maximum Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>6530</td>
<td>24,170,000</td>
<td>28</td>
</tr>
<tr>
<td>1982</td>
<td>6670</td>
<td>41,620,000</td>
<td>47</td>
</tr>
<tr>
<td>1983</td>
<td>7560</td>
<td>62,750,000</td>
<td>62</td>
</tr>
</tbody>
</table>

### TABLE 2

**FRONT END LOADER OPERATING ACTIVITY**

<table>
<thead>
<tr>
<th>Year</th>
<th>Loader Operation (hrs)</th>
<th>Days</th>
<th>Average Operation (hrs/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>952</td>
<td>278</td>
<td>3.4</td>
</tr>
<tr>
<td>1983</td>
<td>1583</td>
<td>325</td>
<td>5.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2535</td>
<td>593</td>
<td>4.3</td>
</tr>
</tbody>
</table>
is reduced, but not the number of shifts. In a typical week, the boiler is fired at 6 p.m. on Sunday evening and steam is ready for delivery in approximately 5 hours or by the time the 11 p.m. shift commences. In addition to making sure the boiler maintains the proper pressure, the operators on each shift are responsible for various maintenance activities on the boiler and support equipment.

An operator is required to operate the front end loader and transfer wood from the fuel staging area to the receiving hopper and to maintain the level of wood chips in the silo. The boiler consumes approximately 40 tons of fuel in a 24 hour period. Each day this requires between 4-6 hours of front end loader operating time distributed among all three shifts to transfer fuel from the receiving area to the silo. As a record of loader activity, the engine operating hours have been logged monthly for the past two years. Table 2 presents this data for 1982 and 1983. The average daily operating hours increased from 1982 to 1983, but the overall average for both years was just over 4 hours per day. This increase in 1983 is not unexpected since the boiler utilization rose from 47% to 62% with a subsequent increase in the daily fuel requirement.

Once each shift, the operator is responsible for raking ash from the boiler furnace. The normal procedure is to turn off the bidirectional screw that feeds fuel into the furnace and allow the fuel pile to burn down. The operator can then open the furnace door and rake out as much ash as possible while being careful not to remove glowing char necessary for restarted. Since the furnace is divided into two sides by separate furnace doors usually, this procedure is performed twice per shift with only one side of the furnace being cleaned at a time. To prevent the fire from going out, the grates must be raked quickly, therefore, the entire procedure to clean one side of the furnace requires less than 10 minutes. Following the last shift of the week, the furnace and firetubes are cleaned. The furnace is completely raked out and the firetubes are brushed. This task requires two men and takes about 4 hours.

The operator is responsible for other miscellaneous activities that require 2-4 hours per day. Daily attention items include lubricating fuel handling conveyors, the front end loader, and wood trailer, dumping the flyash
barrels, changing steam flow and pressure charts, and generally inspecting the fuel handling conveyors for breakage, material build-up, and blockage. Additional attention may be necessary for proper operation of the boiler if complicating factors, such as excessively wet fuel or fuel with a large percentage of oversize pieces is received. It is estimated that the above factors coupled with the requirement to maintain 95 psi steam pressure to the continuous heat settlers requires the equivalent of from 12-15 hours of operator attention in a 24 hour shift.

PROBLEMS ENCOUNTERED

The boiler has effectively supplied steam at the pressures required by processes at the plant under varying conditions of load and fuel quality; however, some boiler related problems have been encountered. The most commonly encountered operational problems are attributable to the non-uniformity of the fuel. Boiler operation has been reported to be stable with fuel moisture contents of 50% on a wet basis. Fuel moisture contents of 55% or greater lead to unstable combustion and ultimately to shutdown, as was discovered during the initial phases of operation. In addition to very high moisture content fuel yielding unstable combustion, it can also result in feed system shutdown. The boiler operates with an air swept spreader-stoker where fuel is dropped on a chute to slide into the furnace. Moist fuel has greater resistance to sliding than does dry fuel. This sometimes causes wet fuel to back-up and overload the bidirectional screw which feeds fuel into the stoker. Occasionally, this back-up can severely overload the screw feeder, tripping the circuit breaker and shutting the system down.

If the temperature drops to around 0°F and the fuel is moist, freezing can result in the feeding system. When this has happened in the past, freezing occurred in the rotary unloading valve at the bottom of the silo. With the valve frozen, fuel cannot be unloaded from the silo and operation ceases. To maintain boiler operation, the rotary valve must be thawed by applying heat.

Because of blockages and jams caused by oversize pieces of wood, Integrated Products' engineers designed a vibrating screen add-on to the receiving hopper. The purpose of this screen is to remove any oversize pieces
which could potentially lock up the feeding system. A fuel analysis disclosed
that oversize pieces constitute approximately 2% of the fuel weight. The
1-1/2 inch mesh screen added to the receiving hopper before startup greatly
reduced jamming problems and helped protect feed system components, however,
an unacceptable level of handling system shutdowns and repairs were still
occurring. In January 1983, following two years of operation, the original
screen was replaced with a 1-1/4 inch mesh one. This modification reduced
fuel handling system blockages to an acceptable level.

A final characteristic of fuel which influences boiler operation is wood
species. All hardwood species have been found to combust acceptably, but pine
was found to yield a rosin-like residue in the furnace and boiler tubes.
Following the early deposition problems experienced with pine, plant personnel
decided to restrict boiler fuel to hardwood. This does not, however, repre-
sent a severe limitation since pine is usually not available as a fuel source
because of the significant consumption by paper mills and related industries.

Oversize pieces of fuel in the handling system resulting in jamming,
blockage, and ultimately breakage of components was the most common mainte-
nance item during the first three years of operation. Table 3 is a list of
those fuel system items that required attention. The most serious operational
problem with the boilers occurred in mid-1983. During this period the boiler
was operating continuously 7 days per week. Without a weekly shutdown period
during which the firetubes could be brushed, the boiler experienced a buildup
of flyash in the tubes. This resulted in a decrease in the flue gas velocity
with an accompanying increase in the temperature of the firetubes. After
several weeks, the tubes became overheated, expanded, and broke some of the
welds between the tube and tube sheet. This allowed boiler water to leak into
the fireside of the tube increasing the ash buildup problem and interfering
with combustion. Eventually, the boiler was shut down so the tubes could be
rolled. To prevent future occurrences of this problem, it was decided to shut
down the boiler weekly for firetube brushing even during periods of continuous
plant operation. The boiler is unavailable for steam production approximately
4 hours each week while the tubes are being cleaned. Back up steam is
supplied by a gas fired boiler during this period.
TABLE 3
FUEL HANDLING SYSTEM
Components Replaced

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ITEM</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>Bidirectional Screw Shaft</td>
<td>$100</td>
</tr>
<tr>
<td>1982</td>
<td>Metering Bin Screw Gearbox</td>
<td>$1000</td>
</tr>
<tr>
<td>1983</td>
<td>Metering Bin Shear Pins Sheared</td>
<td>minimal</td>
</tr>
<tr>
<td>1983</td>
<td>Section of Inclined Screw Flights Worn Out</td>
<td>$500</td>
</tr>
<tr>
<td>1983</td>
<td>Metering Bin Shear Pins Sheared</td>
<td>minimal</td>
</tr>
<tr>
<td>1983</td>
<td>Replace Kicker Screen</td>
<td>$250</td>
</tr>
</tbody>
</table>
ECONOMIC EVALUATION

Just as important as establishing the technical feasibility of the wood fired system was the determination of economic feasibility. Before the project was initiated, economic evaluations were conducted to assure that it offered positive net benefit. The preconstruction analysis yielded a projected payback before taxes of between 2 and 3 years. Given that the system has now been installed and operating for over 3 years, a more accurate calculation of economic benefit is possible using actual operating data.

The most important element of the analysis is the determination of fuel costs. Any potential for savings with a solid fuel boiler must come from the reduction of fuel costs. During the period the wood boiler has been operational, accurate records of fuel consumption on a weekly, monthly, and yearly basis have been maintained. Table 4 is a summation of this data. This table also illustrates the associated cost of the wood during the 1981-83 time period. The wood fuel has experienced a slight price rise, but this can be attributed mainly to increases in the cost of delivery. The wood system is compared with a conventional natural gas boiler. The amount of natural gas that would be equivalent to the actual wood used can be calculated from the energy content of the two fuels and the efficiency of the associated boiler systems. In this analysis an efficiency of 65% was used for the wood boiler and 82% for the gas boiler. During the period under consideration, the gas cost rose at a much greater rate than wood which helped to improve the economic payback of the wood system. From the values shown in Table 4, an average annual fuel cost was found.

The next cost considered was labor. As stated earlier, the wood boiler required approximately 15 hours of labor for each 24 hours of operation. Conversely, a gas boiler is more automated and requires much less operator attention when it is operating. It was estimated that 3 hours of direct labor would be necessary during every 24 hours of operation. Since the operating hours of the wood boiler was known, the amount of labor required could be calculated. The cost of boiler operating personnel used was $12/hour. Table 5 shows the cost of labor during the first 3 years of operation.

Also shown in Table 5 are two other operating costs, that for a front end loader and for maintenance. The front end loader is used to move wood
# TABLE 4

## FUEL CONSUMPTION AND COST

<table>
<thead>
<tr>
<th>YEAR</th>
<th>WOOD USED* (tons)</th>
<th>UNIT COST ($/ton)</th>
<th>TOTAL COST ($)</th>
<th>EQUIVALENT GAS** USAGE (MCF)</th>
<th>UNIT COST ($)/MCF</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>8,809</td>
<td>7.00</td>
<td>61,600</td>
<td>61,050</td>
<td>3.45</td>
<td>210,650</td>
</tr>
<tr>
<td>1982</td>
<td>10,147</td>
<td>8.00</td>
<td>81,180</td>
<td>70,320</td>
<td>3.91</td>
<td>275,000</td>
</tr>
<tr>
<td>1983</td>
<td>14,500</td>
<td>8.60</td>
<td>124,700</td>
<td>100,485</td>
<td>4.38</td>
<td>440,100</td>
</tr>
</tbody>
</table>

Average Consumption  
89,180  
308,600

*Energy Content = 4500 Btu/lb  
**Energy Content = 1030 Btu/ft³
<table>
<thead>
<tr>
<th>YEAR</th>
<th>LABOR HOURS</th>
<th>LABOR COST</th>
<th>FRONT END LOADER COST</th>
<th>MAINTENANCE COSTS</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>4080</td>
<td>48,960</td>
<td>1,650</td>
<td>250</td>
<td>$50,860</td>
</tr>
<tr>
<td>1982</td>
<td>4170</td>
<td>50,040</td>
<td>1,900</td>
<td>1,250</td>
<td>$53,190</td>
</tr>
<tr>
<td>1983</td>
<td>4725</td>
<td>56,700</td>
<td>3,170</td>
<td>6,000</td>
<td>$65,870</td>
</tr>
</tbody>
</table>

Average = $56,640

<table>
<thead>
<tr>
<th>YEAR</th>
<th>LABOR HOURS</th>
<th>LABOR COST</th>
<th>FRONT END LOADER COST</th>
<th>MAINTENANCE COSTS</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>815</td>
<td>9,790</td>
<td>-</td>
<td>300</td>
<td>$10,090</td>
</tr>
<tr>
<td>1982</td>
<td>833</td>
<td>10,000</td>
<td>-</td>
<td>300</td>
<td>$10,300</td>
</tr>
<tr>
<td>1983</td>
<td>945</td>
<td>11,340</td>
<td>-</td>
<td>300</td>
<td>$11,640</td>
</tr>
</tbody>
</table>

Average = $10,680
unloaded from a delivery truck to the receiving hopper and then to the storage silo. The labor cost associated with operating the loader was determined earlier. The loader manufacturer estimated that the operating cost for the loader used by Integrated Products is approximately $2/hour. This cost item represents the fuel, tires, oil, and maintenance required to keep the loader operating. The hours of operation were determined by recording readings on the engine clock.

The final item included in the operating costs was maintenance. For the wood boiler, maintenance costs were found by summing up the dollar amounts spent on replacement parts. The labor costs associated with maintenance were accounted for earlier. The maintenance all consist of small items in the fuel handling and boiler control system which were replaced, except for the third year which shows a large increase due to the tube leak repair. Consultation with a vendor for gas boiler sales and service revealed the average expected parts cost for conventional boilers. This lower value reflects the more simple design of gas package boilers. Taking the average of the values presented in Table 5 yields an annual operating cost of $10,680 for gas boilers and $56,640 for wood boilers. Since the wood boiler is purchased new and assumed to be competing with an already existing gas boiler, a cost for capital must be included with the wood system. The equipment cost for the wood boiler system was $460,000. At the time of installation, the company received a 10% investment tax credit and a 10% energy tax credit. These credits served to reduce the system cost by 20%. Using an interest rate of 12% and equipment life of 20 years, the annual cost of capital is $49,530. The final cost item included was insurance and property taxes. Although the wood system has many more electric motors than a gas boiler and should consume more electrical energy, the electrical cost associated with each arrangement was not included since no quantitative data was available. The electrical cost differential between the systems was assumed to be insignificant since little change in the plant's electric bills was noted after the installation.

A summary of the average annual operating costs for the wood and gas boilers is presented in Table 6. The most significant item for both boilers is the cost of the fuel consumed. Since this analysis is based on measured fuel consumption, it reflects the actual load on the boiler. The high boiler
TABLE 6
WOOD BOILER SYSTEM FINANCIAL ANALYSIS

Annual Costs based on Average of three years

<table>
<thead>
<tr>
<th>COST COMPONENT</th>
<th>WOOD SYSTEM</th>
<th>CONVENTIONAL SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Cost of Capital Amortization</td>
<td>$ 49,530</td>
<td>$ -</td>
</tr>
<tr>
<td>Fuel</td>
<td>89,180</td>
<td>308,590</td>
</tr>
<tr>
<td>Labor, Maintenance parts and Front End Loader operation</td>
<td>56,640</td>
<td>10,680</td>
</tr>
<tr>
<td>Insurance and Taxes</td>
<td>4,500</td>
<td>4,000</td>
</tr>
<tr>
<td>Annual Costs</td>
<td>$199,850</td>
<td>$323,270</td>
</tr>
</tbody>
</table>

Annual Savings = $323,270 - $199,850 = $123,420

Simple Payback = 370,000/123,420

= 3.0 years
utilization factor coupled with the ever widening cost gap between wood and natural gas yielded average annual fuel savings of almost $220,000. Accounting for all costs, the wood boiler had a savings of $123,420 per year over the natural gas boiler. This is equivalent to a before tax simple payback of 3.0 years. Thus, the high boiler utilization over the initial 3 years of operating generated sufficient fuel savings to yield an economic payback equal to the one calculated on pre-installation projections.

CONCLUSION

In non-forest related industries which have high, relatively steady steam demands, a large number of annual operating hours, and reliable access to wood fuel, a wood boiler system can in many cases satisfy all the technical requirements of a conventional boiler at a lower economic cost. This analysis revealed that the wood system responded adequately to variations in steam demand, operated adequately on fuels of various qualities, and was reliable and simple to operate. The post-installation economic analysis demonstrated that the boiler could achieve the projected levels of savings and yield a favorable economic payback.
I visited the Gold Kist Plant on 11/2/83, site of the wood/peanut hull fired boiler. I called Jack Gilden at corporate headquarters to discuss the OER project and the possibility of Georgia Tech aiding in upgrading their plant. We quickly disposed of cogeneration possibilities—the 1.5 MW turbogenerator has proven to be uneconomical (too small, even with used equipment, due to relatively low electric rates and higher operating costs due to need for on site engineer).

A better area is reliability for the boiler. Outages and higher than expected maintenance costs have reduced the rate of return on the project. Gilden has recently evaluated the return on offset for the last 2 years. Results are good, but due to lower than projected natural gas costs, plus maintenance/outages, it is not as high as might be possible. (Gilden's report may help us in an update analysis of the plant.)

I talked to Greg Biggers, Plant Manager, and Craig Dyer, in charge of the boiler plant, at the Gold Kist Valdosta site. They are enthusiastic about us helping them on reliability. I went over their past and current problems. They are listed below with possible areas to investigate for solutions:

   a = Problem  b = Possible Solution for Investigation
1.a Silos become lined with a thick solid layer of wood requiring expensive removal and shutdown once a year.
   b Silos appear too tall for their diameter which may cause packing. Suggest running them empty (perhaps once a week); do not fill them all the way up; add height, if necessary to Flying Dutchman, run it when empty to scrape out buildup.

2.a I.D. Fan (250 HP) D.C. drive has excessive brush wear and downtime.
   b This may have already been fixed. However, evaluation of the dust filtering system which directly cools the motor and brushes may be worthwhile. A 250 HP mechanical drive steam turbine substitute might be an interesting possibility. A motor of this size will use about $60,000/yr in electricity.

3.a The bag house has had repeated problems. Much of this has been solved via ash conveyor modifications, however, bag life is shorter than expected.
   b Check back data on bag life and operating conditions. Perform ash analysis and locate possible markets. Check overall design for improvements.

4.a The boiler will not put out full capacity with fuel over 40% m.c.
   b Implement storage strategies to reduce water pickup. Consider fuel price penalties for high m.c. loads.

5.a Other minor areas for investigation may be feed water pump seals (perhaps fixed) desuperheater valve packing (not solved yet).
   b Investigate appropriate engineering solutions.

A final note of interest is related to fuels. They no longer burn peanut hulls since they get more money per ton selling them as animal feed. In retrospect, and for future candidates, the possibility of using radically different solid fuels should be approached
with caution. The extra cost of providing complete dual fuel capability may be costly, blending fuels before storage or at the final infeed to the combustor may prove less costly and more prudent.
APPENDIX D

Conserver Article
“ENERGY STING” AND HOW TO AVOID IT
Deborah Lockman

What can you do when the complex plant’s fuel consumption in half an hour doesn’t work as the vendor indicated it should?

What happens when you try to call the dealer who sold you the plant an unbreakable system and he’s uncooperative?

Here do you turn when you’ve been victim of an “energy sting”?

The following steps are ways you can take to protect yourself from an energy sting.

At the state level, there is only one consumer and assistance source available to consumers, and it is for the benefit of residential consumers.

Where can the industrial community seek advice and assistance in areas of energy conservation and consumer protection?

Section For Industry Assistance comes from the federal government in the form of the Federal Trade Commission (FTC). While the FTC is a multi-faceted organization responsible for the actions of its agencies, a branch of the commission, the Bureau of Consumer Protection, seeks to keep the public free from fraudulent practice in areas of advertising, credit, service industry, and marketing.

Atlanta Regional Office of the serving eight southern states, receives 100-120 calls per day and 700 letters. The calls and letters are the most common form of complaints in a variety of industries.

Although the FTC usually can’t resolve individual consumer’s problems, the calls and letters may help the commission decide whether a violation of the law is occurring. If indeed a violation is discovered, the commission may investigate a particular industry, business, or business practice and seek voluntary compliance. If voluntary compliance is rejected, the commission may take legal action against the violator. However, legal action taken by the FTC is on behalf of the American public, not on behalf of the individual consumer.

In addition, the FTC has established a federal energy fraud clearinghouse primarily to exchange information with state attorneys general about fraudulent claims for energy-related products. This office accepts complaints and releases information on actions already taken, but is prohibited from divulging details about matters currently under investigation.

“LET THE BUYER BEWARE”

There is no quick or easy solution to the shortage of energy resources, although there are a myriad of devices, gadgets, and systems which dealers claim can offer simple solutions to your energy problems. The fraudulent ones are usually of two varieties: those without any scientific basis and those which are misapplications of legitimate devices. These can be foisted upon the consumer by dishonest dealers, misinformed sales and technical representatives, or unknowledgeable service staff.

Devices and gadgets with no technical basis that, in reality, offer no decrease in energy consumption, are relatively easy to spot. In other words, if it seems too good to be true, it probably is. Beware of the sales representative that claims wondrous results from an inexpensive product. The representative should be able to explain in more detail how the product works and what benefits it will provide.

RETROFIT BOILER DEVICE EVALUATED

Manufacturers claim that retrofit boiler draft control devices save 15% to 30% or more in fuel consumption. These exhaust flow restriction devices range from an orifice in a flat plate to a fully automatic, solenoid-actuated device that modulates with the firing rate of a boiler, a water heater, or a furnace. The Naval Energy and Environmental Support Agency (NEESA) evaluated one of these devices to provide utilities managers with updated technology.

The flow restrictor tested consists of an orifice that reduces cross-sectional stack area by 40%. The reduction in area decreases the flow of combustion gases through the heating unit. The configuration is claimed to increase heat retention.

A natural-gas-fired, firetube, low-pressure steam boiler with 5.6 MBtu/hr output capacity was used for the evaluation. The boiler is equipped with a forced-draft fan and modulating air-fuel controls connected by mechanical linkages.

Boiler efficiency was measured using the heat loss method. Tests were conducted as found, after a boiler tuneup, after installation of the restrictor, and after final adjustment by the manufacturer’s representatives.

The boiler tuneup increased efficiency by 4.2%. Installation of the restrictor increased efficiency by 0.5%. This value is within expected measurement error and is therefore considered negligible. Final adjustments by manufacturer’s representatives decreased efficiency by 3.2%. Test results (from May 12-26, 1982) are shown below.

<table>
<thead>
<tr>
<th>Percent Load</th>
<th>Existing</th>
<th>After Tuneup</th>
<th>After Installation</th>
<th>Final Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>77.35/43.46</td>
<td>80.58/9.36</td>
<td>80.98/6.38</td>
<td>78.40/51.18</td>
</tr>
</tbody>
</table>

The most effective efficiency improvement was achieved by adjusting the air/fuel ratio without adding peripheral devices. (From “Information Bulletin,” August 1982, a publication of the Naval Energy and Environmental Support Activity.)
O MEASUREMENT OR BOILERS

Mike Brown

As discussed in the September issue of the *Conservor*, the excess air required for efficient operation of industrial boilers should be maintained at the lowest possible level consistent with safety precautions. While oxygen trim systems yield substantial reductions in excess air, control manufacturers agree that the most accurate method of excess air control is measurement of carbon monoxide (CO).

Excess as Control Variable
Carbon monoxide is a good control variable because, as shown in the accompanying figure, it has an exponential rise as excess air is decreased below optimum levels. However, it can be economically used for control of boilers producing steam above 000 lb/hr.

Since the minimum amount of excess air is not a constant value but a function of boiler load, fuel type, and burner design, oxygen trim does not guarantee minimum excess air and peak efficiency. With CO control, excess air level can be reduced further on the appearance of carbon monoxide and combustibles in the flue gas indicates an incipient rise in unburned losses. A control system monitors carbon monoxide is programmed to reduce combustion air until readings of 100 parts per million (ppm) from the usual background level of 10 to 15 ppm for natural gas.

Combustion Efficiency and Measurement
Combustion air control based on the appearance of CO can yield a 0.5% to 1% efficiency increase in a well-run boiler with 02 trim. Improving the combustion efficiency 0.8% on a 500 lb/hr boiler via high resolution control would not a payback period of approximately one year.

Three options for measuring CO and combustibles vary. Simple portable analyzers give measurement for one spot period of time. Unlike permanent instruments which yield a continuous flow of concentration, portable analyzers provide a spot check of CO and other carryover gases.

Analyzer Method
The most commonly applied technique for control using carbon monoxide measurement is infrared absorption. A source unit mounted beside the stack emits a dual beam of infrared radiation, some of which is absorbed by the flue gas through which it passes. On the opposite side of the stack is a receiver unit. A light detector in the receiver senses the difference in intensity between the beam traveling through the stack and the control beam which does not. The difference is related to the carbon monoxide concentration.

Infrared Analyzer Equipment
Infrared analyzers mounted directly on the stack are referred to as in-situ models. Extractive models, in which the sample is removed from the flue and then conditioned, are also available. In-situ analyzers yield an almost instantaneous response time. Extractive analyzers respond with a 90% level of the reading within 5 seconds.

Infrared analyzers are very accurate devices, typically producing a response that is within 20 ppm or ±3% of actual, whichever is greater. Calibration of these instruments can be accomplished by using a bottle of CO gas of known concentration or by using an internal infrared source as a reference to compare with the measurement channels. Infrared analyzers for carbon monoxide detection cost an average of $15,000 plus installation, but installation is typically simple and should not exceed $2,000.

Catalytic Analyzer Method
Another instrument which is widely applied for diagnostic measurements is the catalytic analyzer. Catalytic sensors for combustible detection sense both carbon monoxide and hydrogen in combination but do not give a specific indication of their relative proportions. The catalytic measurement principle can only be applied with flue gas samples containing some oxygen. The sensor consists of a ceramic base coated with a platinum catalyst which causes the combustion of carbon monoxide and hydrocarbons to occur at low temperatures on the sensor surface. The increase in temperature is accompanied by a change in electrical resistance of the sensor, which is compared to that of a passive element not exposed to the flue gas. This difference in resistance, read as a current difference, is calibrated to combustibles in the flue gas.

Diagnostic Usefulness of Catalytic Analyzers
Catalytic analyzers yield readings accurate to within ±5% of the measured value. They have a minimum sensitivity of 0.01% combustibles (100 ppm) which is useful as a diagnostic tool, but is insufficient for use as a control signal. A response corresponding to 90% of the combustibles present can be made in 10 to 15 seconds. This is slower than the response of in-situ infrared analyzers.

Though they are not as sensitive as infrared analyzers, the selling price for catalytic analyzers is much lower, ranging from $1,500 to $3,000. Installation costs are typically not quoted since catalytic combustible monitors are sold in conjunction with oxygen analyzers.

Catalytic sensors can be utilized in hostile flue gas environments because they are not sensitive to dirt. Under most conditions, catalytic sensor elements are responsive for about 2 years, and the cost of replacement is $300.
CH BEGINS NEW SOLID FUELS PROGRAM

Have you been considering converting from oil or gas to solid fuels? Is your plant produce combustible waste that holds promise for fuel utilization?

So, then you will be interested in hearing about a new outreach service at Georgia Tech, called the Solid Fuel Conversion Service. Through this program, industry interested in conversion of oil and gas to solid fuels can receive free technical assistance via a call from the Georgia Office of Energy Resources. Feasibility studies for twenty selected firms will be performed by the service. This includes a site visit, an analysis of fuel supply, a conceptual system design, an estimate of equipment costs, and economic analysis. The participation is limited, candidates will be screened by project staff to identify the most likely companies benefit from fuel conversion. Two studies have already been undertaken, one for a furniture manufacturer and another for a textile mill.

Project Director Tom McGowan, of the Engineering Experiment Station at Tech, observes that candidates for fuel switching typically have a two or three shift operation with steady load characteristics, and fired equipment that consumes more than 15 million Btu’s per hour (400 boiler hp), which includes boilers, kilns, dryers, and calciners. Additionally, the plant must have sufficient room for fuel storage.

Other activities of the new program include:

- a conference scheduled for mid-1984
- technical aid and review for two existing wood demonstration sites
- liaison with industry and research groups working in the area of solid fuels.

If you’re interested in more information, write to Tom McGowan at Georgia Tech EES/TAL, 215 O’Keefe Bldg., Atlanta, GA 30332.

ENERGY INSTRUMENTATION SCHEDULED FOR MAY 16

Suppose your plant’s adding a new piece of steam-heated equipment. And suppose it consumes 3000 lbs/hr at 100 psig. Would you know how to measure the current steam load of your boiler to see if it can accommodate the increased load? And would you know how to minimize the resulting increase in your utility bill?

The next IEES seminar is designed to help you answer questions like these. Energy Measurement Instrumentation and Techniques is scheduled for Wednesday, May 16, at the Howard Johnson’s Midtown Hotel in Atlanta. First offered last spring, this presentation has been revised and updated. The focus here is on equipment: what’s available, how it’s used, and how it works.

For more information, contact Hank Jackson at 404/694-3412 or write to the Energy Conservation Branch, EES-TAL, Georgia Tech, Atlanta, GA 30332.

CONSERVATION, Continued

One of the terms how the energy savings can be achieved.

Before You Buy

It’s a good idea to test the energy-saving device in your own plant to demonstrate its effectiveness (see next article, “Retrofit Boiler Device Evaluation”). However, make sure you retain complete control of the test and assume no financial risk. Make certain that you have accurate data on the energy consumption of your equipment both before and after the test. In order to know the effect on energy consumption for device being demonstrated, be aware that the only thing that has occurred during the test is the installation of the device.

In some instances, testing expensive hardware just isn’t feasible, but all efforts should be made to ensure protection from The FTC recommends that the consumer find out something about the reputation of the dealer, with previous customers, and how the unit will work.

“Energy sting” and how to avoid it, Continued

Most importantly, when you buy, be sure to record the transaction. No matter how much evidence the dealer has to back up his claims of wondrous results, consumer satisfaction, and a money-back guarantee, the consumer should thoroughly check the dealer’s credentials. A money-back guarantee means nothing if the dealer can’t be located when a problem arises.

A “Common Sense” Approach

Don’t let your guard down once you’ve convinced yourself that an energy-saving device will be installed. After the appearance of a solar energy system dealer, investigation of a complaint revealed that technicians had incorrectly installed the device. In case it was impossible to determine if a faulty system was sold, or if the system failed because it was improperly installed.

Common sense should help you avoid the energy sting and by calling the FTC, consumers can receive sound advice and learn what questions to ask about product reliability and a dealer’s sales practices. If you have already been the victim of an energy sting, the Commission can receive your complaint and outline options you may follow.

FOR FURTHER INFORMATION

Georgia Office of Consumer Affairs ........................................... 800/282-5808
FTC Energy Fraud Clearinghouse ............................................ 202/724-0726
Federal Trade Commission, Atlanta Office .............................. 404/881-4836

ONSERVATION AS RESOURSE SUBSTITUTION

Fred Rossini, Technology Policy & Assessment Center, Georgia Tech

One way to view conservation is as a substitution of resources. Our dependence upon gas and electricity, at current cost, continues to rise, has led to an examination of alternative sources such as solar and wind energy. However, there is no known energy source that is totally problem-free, environmentally sound, or the best for every situation. Consequently, we must conclude that direct substitution of one energy source for another is at best a partial answer to the energy problem.

The Lessons of Japan

The question then becomes: Where can we look for the answer? Here, lessons of other industrialized nations such as Japan may provide some insight. Like Georgia, Japan is almost totally dependent on energy from outside its geographical borders. It has become an important industrial power in the world, Japan has substituted advanced technology and management techniques for rich resources in energy and materials. This substitution is a form of conservation since it diminishes the reliance on scarce fuels through the application of knowledge and organization.

Knowledge is One Resource

Knowledge can be applied in a variety of ways. One is to consider the efficiency of devices when specifying industrial systems. More efficient devices, although their initial cost may be higher, can save energy in the long run. Such devices are often substantially cheaper, considering the total cost of operation over their entire life (a calculation referred to as “life cycle costing”).

Other energy conservation possibilities relate to making new buildings as energy efficient as possible or to retrofitting existing facilities in order to minimize energy consumption. Passive design techniques such as insulation, site orientation, and interior design features may effectively achieve energy savings. Here, too, the potential financial gains are realized over the life of the facility with reduced energy costs offsetting the initial expense.

Organization is Another Resource

Organization may affect energy consumption through the grouping and sequencing of industrial tasks. Significant energy savings can often be achieved through the rearrangement of process lines in a plant. Another possibility can be found in the administrative areas of the plant. Excess for efficient lighting techniques, office functions are not usually thought to hold potential for energy conservation. However, to be thorough in analyzing options for energy conservation, no operations should be exempted. Efficient space requirements and the efficient use and placement of office machinery should be investigated when seeking conservation opportunities.

Meeting Georgia’s Increased Demand

The main message of the Georgia-Japan analogy lies in planning for the future of industry in our state. The demand for energy will increase as a result of industrial development. Without parallel increases in the efficiency of our energy usage, development will outstrip our limited energy supplies. This will create additional burdens for the utilities as well as the consumers.

One reason why Pittsburgh, Pennsylvania, was so many years ahead of the steel production in the U.S. was its proximity to the energy and material resources used in making steel. By analogy, it can be argued that without endless resources, Georgia’s future industrial development should stress processes that are not overly energy intensive. Firms seeking to diversify and develop new opportunities may be wise to use low energy requirements as one of the criteria for selection. Indeed, minimizing energy usage appears to be an important component in the overall development of Georgia’s industries in keeping with our limited energy resources.

The Need for On-Going Education

Such an approach to industrial development requires an on-going commitment to learning—not exclusively in the classroom sense, but rather in the real life sense of knowing the times and uncovering the opportunities that are present. This strategy entails on-going education for persons at every level in industry. The frightening lessons now being driven home in our industrial heartland are that what does not progressively change does not survive, and that flexibility in production and marketing is critical in times of rapid change such as today.

Most of Georgia’s Industry has

(Continued on Page 3)
APPENDIX E
Workshop Agenda
DO YOU KNOW THAT...

Scrap wood worth 300 trillion Btu's goes wasted every year in Georgia.

The United States possesses nearly 1/3 of the proven coal reserves in the world.

Its abundance of coal and wood, at prices 1/3 to those of oil and natural gas, makes solid fuel economically attractive option for industry's energy needs.

Backs of 2 to 3 years mean high returns on small capital investments. Less dependence on foreign fuel sources means a more stable business outlook if overseas supplies are curtailed. In some cases, solid fuel equipment can also handle waste products such as peanut hulls and pet feeds.

Industries in Georgia, a state that imports all of its oil and gas, should certainly consider the benefits of solid fuel as a source of energy for steam generation and process heating.

DO YOU HAVE QUESTIONS SUCH AS...

- When is conversion to solid fuels justified?
- What is the fuel supply outlook for Georgia industry? How do you know what energy value you are getting?
- What are the types of coal and wood fuels available? What are the important decision criteria in evaluating those types?
- How do you handle and store solid fuels?
- How do you select the equipment that meets your specific needs? How does your current equipment fit into the system?
- What technologies are available to reduce emissions?
- What is the best way to finance the capital investment?
- Who else has converted to solid fuels and what were their results?

These and other questions will be answered at WOOD AND COAL FOR INDUSTRY'S ENERGY NEEDS. Georgia Tech and the Georgia Forestry Commission have invited professionals from key areas of the solid fuels industry to present the results of their experience and knowledge.

You'll learn enough about the fuels and equipment available to make sound comparisons and choices among different types of systems on the market. You'll talk with suppliers of fuel and manufacturers of equipment. You'll ask questions and get straight answers about applications and installations.

Most importantly, you'll feel more confident about dealing with the wide range of options in solid fuels.
CONFERENCE PROGRAM

Georgia's Wood Resource
Tommy Loggins, Associate Chief, Forest Research
Georgia Forestry Commission

Wood Fuel Brokering
Larry W. Scott, Engineer
CON Company

Industrial Coal Supply
Dennis Duffy, District Sales Manager, Southeast
Consolidation Coal Company

Solid Fuel Analysis and Standards
James L. Walsh, Jr., P.E., Senior Research Engineer
Georgia Tech Engineering Experiment Station

Modular Coal and Wood Boilers
Indren Rigby, Manager, Plant System Products
Industrial Boiler Company, Inc.

Field-Erected Coal and Wood Boilers and Incinerators
Ben T. Kaskey, Business Development Manager
Energy Systems, Inc.

Wood and Coal Handling Systems
J. Breitzman, Department Manager, Wood Products Division
Pennington, Assistant Manager, Wood Products Division
Cons-Eastern Company

Economics of Solid Fuel Systems
Thomas F. McGowan, P.E., Chief, Energy Technology Branch
Georgia Tech Engineering Experiment Station

Funding Alternatives
Fred W. Swann, Jr., Senior Group Vice-President
Wholesale Banking, Bank South

Pollution Control
Raymond M. Warren, Jr., President and Owner
Warren Engineering, Inc.

Advanced Coal Systems
William L. Calhoun, Associate Consulting Engineer
Peeco Coal Operations, Atlanta

Case Study in Wood Energy — The Integrated Products Company
Michael L. Brown, Research Engineer
Georgia Tech Engineering Experiment Station

Case Study in Coal Energy — The Liggett & Myers Tobacco Company
Ben T. Kaskey, Business Development Manager
Energy Systems, Inc.

KEYNOTE LUNCHEON SPEAKER
Robert G. Schwieger
Editor-in-Chief, POWER magazine

Bob Schwieger, a licensed engineer, has received widespread recognition for his work with POWER, which includes award-winning reports on the use of wood fuels.

Through close association with scientific advancements and industrial developments in the solid-fuels field, Schwieger has become one of the foremost spokesmen on the current state of solid-fuels usage — particularly solid- and waste-fueled boilers, fluidized beds, wood-fueled systems, and coal combustion.

Prior to joining POWER in 1969, Schwieger's experience included operating power plants, and, for Westinghouse Corporation, work on advanced energy systems.
CONFERENCE LOGISTICS

WHO SHOULD ATTEND?

This conference is designed for plant managers, financial officers, and engineering personnel who are responsible for evaluating alternate fuel sources and equipment needs.

ACCOMMODATIONS

The conference will be held at the Sheraton-Atlanta Hotel, located at 590 W. Peachtree Street. A block of rooms has been reserved for participants needing overnight accommodations. Participants should make and confirm their reservations by completing the hotel reservation acknowledgment or by calling (404) 881-6000. Mention Georgia Tech and the name of the conference to receive the special $49 room rate.

REGISTRATION

Registration begins at 8:00 a.m. at the Sheraton-Atlanta Hotel on the morning of the conference. The registration program runs from 8:30 a.m. to 5:00 p.m. To secure a place in the conference, fill out and return the attached registration form. The $60 registration fee covers coffee breaks, lunch, and conference materials.

SPECIAL FEATURE

Each participant will receive a directory containing descriptive brochures of solid fuel equipment manufacturers and suppliers. This directory has been compiled by the National Wood Energy Association.

CONTINUING EDUCATION UNITS

Continuing Education Units (CEUs) are awarded for this conference. As required by Standard Nine of the Southern Association of Colleges and Schools, one CEU is equal to 10 contact hours. An official transcript of CEU's earned at Georgia Tech may be obtained from the Registrar's Office.

TAX DEDUCTION FOR EDUCATIONAL EXPENSES

Treasury regulation 1.162.5 permits an income tax deduction for educational expenses (registration fees and cost of travel, meals, and lodging) undertaken to:

1. Maintain or improve skills required in one's employment or other trade or business, or
2. Meet express requirements of an employer or a law imposed as a condition to retention of employment, rate status, or rate of compensation.

Consult your tax advisor for details.

FOR MORE INFORMATION

Contact: Tom McGowan
EES/TAL
O'Keefe Building, Room 216
Georgia Tech
Atlanta, GA 30332

WOOD AND COAL FOR INDUSTRY'S ENERGY NEEDS

JULY 25, 1984
Registration Form
COURSE FEE — $60

NOTE — A LATE REGISTRATION FEE OF $15 WILL BE ADDED FOR PARTICIPANTS REGISTERING AFTER JULY 18.

NAME ____________________________
TITLE ____________________________
OFFICE PHONE ( ) ____________
COMPANY __________________________
COMPANY ADDRESS __________________________
CITY __________________________ STATE __________ ZIP CODE __________
COUNTY OF RESIDENCE (IF IN GEORGIA) __________
*SOCIAL SECURITY NUMBER __________
*RACE: Black ☐ White ☐ Other ☐ *SEX: Female ☐ Male ☐ *Age Classification: under 22 ☐ 22-35 ☐ 36-55 ☐ over 55 ☐
*Information voluntarily supplied by the participant so that the Institute can comply with various reporting guidelines.

MAKE CHECK PAYABLE TO GEORGIA INSTITUTE OF TECHNOLOGY AND MAIL, BY JULY 18, WITH THIS FORM TO:
Department of Continuing Education-R
Georgia Institute of Technology
Atlanta, Georgia 30332
Telephone: (404) 894-2400

REFUNDS ARE AVAILABLE IF THE CONTINUING EDUCATION DEPARTMENT IS NOTIFIED 48 HOURS IN ADVANCE OF THE WORKSHOP.
# WOOD and COAL for INDUSTRY’S ENERGY NEEDS

**JULY 25, 1984**

**ATLANTA, GEORGIA**

<table>
<thead>
<tr>
<th>Time</th>
<th>Subject</th>
<th>Speaker/Organization</th>
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| 8:30  | Opening Remarks                        | Thomas F. McGowan  
Georgia Institute of Technology  
Engineering Experiment Station |
| 8:45  | Georgia's Wood Resources                | Tommy Loggins  
Georgia Forestry Commission                                      |
| 9:05  | Wood Fuel Brokering                    | Jerry W. Scott  
ECON Company                                                       |
| 9:30  | Industrial Coal Supply                  | Dennis Duffy  
Consolidation Coal Company                                         |
| 10:00 | BREAK                                  |                                                                |
| 10:25 | Solid Fuels Analysis                   | James L. Walsh, Jr.  
Georgia Institute of Technology  
Engineering Experiment Station                                     |
| 10:45 | Modular Coal and Wood Boilers           | Fondren Rigsby  
Industrial Boiler Co., Inc.                                         |
| 11:15 | Field Erected Coal and Wood Boilers and Incinerators | Doug W. Kindred  
Energy Systems, Inc.                                                   |
| 11:45 | LUNCH  
Keynote Address: The Future of Wood and Coal Systems | Robert G. Schwieger  
Power Magazine                                                        |
| 1:15  | Wood and Coal Handling Systems          | J.J. Breitzman  
Simons-Eastern Company                                               |
| 1:45  | Economics of Solid Fuel Systems         | Thomas F. McGowan  
Georgia Institute of Technology  
Engineering Experiment Station                                     |
| 2:15  | Financing Alternatives                 | Alfred W. Swann, Jr.  
Wholesale Banking, Bank South                                         |
| 2:40  | Air Pollution Control                  | Raymond M. Warren, Jr.  
Warren Engineering, Inc.                                             |
| 3:10  | BREAK                                  |                                                                |
| 3:40  | Case Study in Wood Energy:  
The Integrated Products Company  | Michael L. Brown  
Georgia Institute of Technology  
Engineering Experiment Station                                     |
| 4:05  | Case Study in Coal Energy:  
The Liggett & Myers Tobacco Company  | Doug W. Kindred  
Energy Systems, Inc.                                                   |
| 4:30  | Advanced Coal Systems                  | William L. Calhoun  
Ebasco Coal Operations                                                 |
| 5:00  | Adjourn                                |                                                                |
WOOD AND COAL FOR INDUSTRY'S ENERGY NEEDS

July 25, 1984 Atlanta, Georgia

Sponsored by
Georgia Forestry Commission and
Georgia Office of Energy Resources

Conducted by
Engineering Experiment Station
Georgia Institute of Technology
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GEORGIA'S TIMBER RESOURCES

by

Tommy J. Loggins
Associate Chief
Forest Research & Wood Energy
Georgia Forestry Commission

presented at

WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
GEORGIA'S TIMBER RESOURCES

By
Tommy J. Loggins
Associate Chief
Forest Research & Wood Energy
Georgia Forestry Commission

Based upon an analysis and inventory of the state's forest by the U. S. Forest Service beginning with the field inventory in May 1980 and completed in January 1983, the following description of the state's timber supply is presented. Data is also included from the Georgia Forestry Commission's Wood-Using Industries in Georgia, 1981.

Georgia encompasses some 37.2 million acres of land area, of which 65 percent is classed as forest. Forests occur in a diversity of geographic conditions across the state. Forests occupy as much as 75 percent of the land in mountainous North Georgia and as little as 47 percent in agricultural southwest Georgia.

While estimates of growing stock and sawtimber volume are the customary measures of timber inventory, the total quantity of wood and bark is emerging as an important inventory item. Estimates of growing stock exclude a considerable amount of wood suitable only for low-value products such as fuel. The advent of whole-tree chipping, the manufacture of products from chips, and increased fuelwood use (both domestic and industrial) make these non-growing-stock volumes an increasingly important resource.

The 1982 inventory measured an additional 1.8 billion cubic feet of timber in trees failing to qualify as growing stock because of species, poor form, or excessive internal rot. Hardwoods accounted for 95 percent of this additional volume. Inclusion of the volume in stumps, in tops and limbs, and in saplings added another 12.8 billion cubic feet to the inventory. This total volume represents a 41 percent increase over the conventional value
of all trees and 49 percent more value than growing stock. In terms of green weight of wood and bark, this total inventory is equivalent to 1.7 billion tons of forest biomass, an average of 70 tons per acre of commercial forest.

The feasibility of utilizing the total inventory in variable, depending on tree size, stand conditions, and a host of other factors—primarily economic ones. From a silvicultural standpoint, much more of the total biomass in stands should be removed than has been removed in conventional harvests. Harvested stands are left with an average of 23 tons per acre of standing pine plantations to 46 tons per acre for harvested lowland hardwood stands.

Annual removals of growing stock for 1981 totaled nearly 1.4 billion cubic feet. Softwood removals accounted for 1.1 billion cubic feet, or 79 percent of the total. Softwood removals currently equal 91 percent of softwood net growth, compared with 68 percent in 1971. Softwood removals have increased by 39 percent since 1971. Hardwood removals have increased by 20 percent and currently equal 50 percent of hardwood net growth.

Timber products accounted for nearly 1.1 billion cubic feet, or 80 percent of the total removals from growing stock in 1981. Over 141 million cubic feet, or 10 percent, were left in the woods as logging residues.

The 1981 output data indicate that the established trend of declining fuelwood output in Georgia has reversed. Output of roundwood for domestic fuel increased more than three-fold for 1971 to 1981, going from 11.3 to 38.2 million cubic feet. Roundwood accounted for 97 percent of the total volume of 39.4 million cubic feet used for household fuel; plant by products such as slabs and edgings made up the remainder.

Substantial values of wood were also used as industrial fuel. Georgia is a leader in this area. The 1980 industry canvass revealed that 53.6 million cubic feet of plant by products were used for industrial fuel. This volume represents a six-fold increase since 1971.
Primary wood-using plants in Georgia generated an estimated 211 million cubic feet of wood residue in 1981, excluding bark. About 71 percent of this material was converted to by products or sold for litter or mulch, and another 25 percent was used for industrial fuel. Only 4 percent of plant wood residues remained unused.

In addition to wood residues, 93 million cubic feet of bark residues were generated. About 86 percent of this material was used for industrial fuel, and 6 percent for other miscellaneous uses, which 8 percent was not used.

Bibliography


2. Unpublished data from manuscript by Noel D. Cost, USDA Forest Service, Southeastern Forest Experiment Station, Asheville, 1984.

WOOD FUEL BROKERING

by

Jerry W. Scott
HCON Company

presented at

WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
WOOD FUEL BROKERING

Jerry W. Scott
ECON Company

ABSTRACT

Wood is perhaps the most complicated of all fuels currently being utilized to any extent. It is the wood fuel broker's job to match a suitable wood fuel with a designed combustion and fuel handling system at sufficient quantities and an economical cost. The variables comprised in a ton of wood fuel oftentimes make this a not-so-easy task.

WHY A BROKER?

The reason for using a wood fuel broker is the same as for using a stock broker—he can save you money! The good wood broker has a myriad of information available to help determine the best supply system available. It is a naive Plant Manager or Engineer who, when considering the installation of a wood-fired system, calls a few local producers of wood residue to get a budget price. Then when he gets the price from a broker and finds it to be higher decides that he can buy wood fuel himself. Just as in the stock market, a new self-investor may get lucky and make some good purchases but he will make some mistakes also. In the wood business, however, mistakes have a lasting effect. Each error perpetuates itself until the guaranteed price that he turned down from the broker looks pretty good.

WOOD FUEL PRICING

The most important question that is on everyone's mind is "How much is wood fuel going to cost me?". The answer to this question depends on two basic factors: the location and the specifications required by the consumer.

The price of a ton of wood fuel is composed of two parts: the basic fiber cost and transportation costs. The location of the boiler affects both of these parts by the laws of supply and demand. If a boiler is located in an area where wood is scarce then the transportation cost will be higher than where wood can be readily obtained. The factor that best controls the transportation cost is "wood density", which is simply the amount of wood available for fuel in a given area expressed in tons/year/square mile. If the wood density is constant for a given supply area, then the average haul distance can be computed using the formula

\[ H = \left( \frac{T}{6.28 \times wd} \right)^{1/2} \]
where

\[ H = \text{average haul distance} \]
\[ T = \text{annual tonnage required} \]
\[ wd = \text{wood density} \]

Careful analysis of this relationship shows that doubling the annual wood usage or cutting the wood density in half only results in a 41% increase in the average transportation cost. Several graphs are included showing the effect of wood density.

Location also has a great deal of influence on the fiber cost most of which is determined directly by the amount of competition in the area. In areas where there is intense competition for wood fuel, the basic fiber cost can be double or triple what it may be in a non-competitive area. When installing a fuel supply system in a competitive area, the most difficult part of determining what the final cost will be to the consumer is figuring out what counter measures the competition will take. Most of the time it will be impossible to determine exactly what the final delivered price will be before actual delivery has been underway for some length of time. The price that the broker gives to the prospective customer must take these factors into consideration.

Specifications have the biggest influence on the final delivered price of the wood fuel. The primary fact to remember is FEWER SPECS=LOWER COST. Specs are necessary, however, to insure proper boiler and fuel handling performance and to guarantee that you are getting the proper fuel that you pay for. Too many specs can make the price of wood fuel uneconomical. For instance, specifying that the wood be delivered in self-unloading trailers can add as much as $1.50 per ton of fuel. The table below illustrates how different specs can affect price.

**TABLE 1- SPEC EFFECTS ON 40,000 TPY SUPPLY**

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>$/TON INCREASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-unloading trailers</td>
<td>$ 1.50</td>
</tr>
<tr>
<td>Particle size &lt; 3&quot;</td>
<td>$ 2.23</td>
</tr>
<tr>
<td>Particle size &gt; 1/4&quot;</td>
<td>$ 2.56</td>
</tr>
<tr>
<td>Moisture content &lt; 50%</td>
<td>$  .62</td>
</tr>
<tr>
<td>Moisture content &lt; 25%</td>
<td>$14.87</td>
</tr>
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</table>

(Note: The above price increases are not additive. For example, the first 3 specs combined would be +$ 3.06)

Other factors that affect the price of wood fuel are:

INVENTORY - Two factors make wood fuel inventory a necessity: the weather and the economy. When purchasing wood
from a given number of suppliers, the amount of wood produced will vary seasonally. The average deliveries at an existing boiler for a three year period is illustrated in the WEEKLY FUEL DELIVERIES included herein. The total average monthly output from these mills may vary as much as 50% from high to low due to these factors. In a lot of cases, the steam demand will be the highest when the residue output is the lowest. A typical supply situation is described in the DELIVERY PROJECTIONS graph at the end of this report. If your particular plant site lacks space for a sizeable inventory area, it might be required for the broker to maintain a suitable inventory at a remote location. This is costly to you in that it involves double unloading of the fuel.

RESTRICTED DELIVERY HOURS OR PURCHASE ORDER DELIVERIES - By only accepting fuel during certain hours of the day or by requiring that deliveries be on notification only, the broker is forced to stockpile fuel at a remote location. Again the double unloading and loading factor is costly.

MOISTURE CONTENT - Nature produces wood fuel green or at about 50% M.C. If wood is required at a moisture content lower than this, it must be dried. Various manufacturing processes produce wood residue at different moisture levels. Basically if the wood has been air-dried it will be around 20% M.C. and kiln dried material will be about 7%.

The amount of water that is contained in the fuel affects the amount of heat available in the wood in two ways. First, there is a proportionate amount of BTU's in a ton of wood. For example a pound of wood may have 9,000 BTUs in its bone dry state and only 4,500 BTUs at 50% M.C. The second effect that water in the fuel has is that some of the BTUs in the wood will be required to evaporate the water. The RELATIVE VALUE OF WOOD FUEL graph at the paper's end illustrates this point by allowing comparisons of different moisture contents to a base of either bone dry or at 50% M.C.

The moisture content in a given supply of wood will vary seasonally as depicted in the MONTHLY MOISTURE VARIATION graph. This data represents the actual average moisture variations over a three year period and may be used in conjunction with the relative value graph to determine the seasonal fuel costs. Let's assume that 50% MC wood is valued at $10 per ton. The wood delivered in January at 49% MC is worth 1.029 times more or $10.29. The wood delivered in August is worth 1.261 times more or $12.61 per ton. The reciprocal of the worth value multiplied times the annual tonnage required at 50% MC will give the tonnage required at the new MC.

The broker's transportation charge per ton is increased when the fuel he transports becomes drier if he continues to haul the same volume. His transportation costs remain about the same and the amount of tonnage that he hauls goes down.

FUEL SUPPLY OPTIMIZATION

The first thing that should be done when one is considering the installation of a wood-fired boiler is to contact a broker to
have a fuel survey performed. The cost of this service will vary with location but usually runs about $1000 per 20,000 tons of annual fuel required (@ 50% MC). At ECON we perform wood fuel surveys at our cost, reimbursing this money if the survey results in our obtaining a wood fuel contract.

The wood fuel survey should contain information about the various wood residues available in the area and about what price to expect for them. There is usually at least a two year period between the time of the initial survey and the time of first delivery of fuel so a close estimate is all that can be expected at first. The broker should also be furnished with information regarding the annual steam load that will be obtained from wood. A typical survey for a 360 MM lb/yr might resemble the following:

**WOOD FUEL SURVEY**

**XYZ COMPANY**

**360 MM LB/YR**

**60,000 TONS @ 50%MC**

<table>
<thead>
<tr>
<th>RANGE</th>
<th>DESCRIPTION</th>
<th>TONNAGE</th>
<th>2%MC</th>
<th>&lt;1/4&quot;</th>
<th>1/2&quot;</th>
<th>&gt;3&quot;</th>
<th>&gt;24&quot;</th>
<th>COST</th>
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<tr>
<td>0-25mi</td>
<td>Wholetree chips</td>
<td>6400</td>
<td>45</td>
<td>10%</td>
<td>70%</td>
<td>1%</td>
<td>0%</td>
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<tr>
<td></td>
<td>Sawmill residue</td>
<td>14125</td>
<td>43</td>
<td>31%</td>
<td>53%</td>
<td>15%</td>
<td>2%</td>
<td>$9.23</td>
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<tr>
<td></td>
<td>Shavings</td>
<td>1250</td>
<td>12</td>
<td>16%</td>
<td>69%</td>
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<td>0%</td>
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<tr>
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<td>Sanderdust</td>
<td>400</td>
<td>7</td>
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<td>0%</td>
<td>0%</td>
<td>0%</td>
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<td>Pole peelings</td>
<td>5200</td>
<td>46</td>
<td>8%</td>
<td>80%</td>
<td>12%</td>
<td>0%</td>
<td>$10.15</td>
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<td></td>
<td>Pulpwood</td>
<td>1875</td>
<td>47</td>
<td>0%</td>
<td>100%</td>
<td>100%</td>
<td>99%</td>
<td>$16.80</td>
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<td>Totals</td>
<td>29250</td>
<td>42</td>
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<td>64%</td>
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<td>7%</td>
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</tr>
</tbody>
</table>

| 25-50mi| Wholetree chips | 15100  | 45   | 11%   | 69%  | 1%  | 0%   | $18.63|
|        | Sawmill residue | 43331  | 43   | 31%   | 53%  | 11% | 2%   | $11.71|
|        | Shavings        | 4550   | 12   | 12%   | 72%  | 0%  | 0%   | $17.34|
|        | Sanderdust      | 6675   | 7    | 98%   | 0%   | 0%  | 0%   | $27.49|
|        | Trim blocks     | 5200   | 7    | 0%    | 100% | 60% | 1%   | $14.40|
|        | Pulpwood        | 12000  | 46   | 0%    | 100% | 100%| 99%  | $17.40|
|        | Totals          | 86856  | 37   | 26%   | 51%  | 23% | 15%  | $15.37|

**COMBINED TOTALS**  

<table>
<thead>
<tr>
<th>TONNAGE</th>
<th>2%MC</th>
<th>&lt;1/4&quot;</th>
<th>1/2&quot;</th>
<th>&gt;3&quot;</th>
<th>&gt;24&quot;</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>116106</td>
<td>38</td>
<td>25%</td>
<td>54%</td>
<td>21%</td>
<td>13%</td>
<td>$14.54</td>
</tr>
</tbody>
</table>

Once you have the fuel survey then the boiler contractors should be contacted to get prices on the various equipment required. The fuel should be selected before you have decided on a boiler. It can be very dangerous and costly to build a boiler and then try to find fuel to burn in it.

The survey should be carefully studied and the various groupings should be converted to equivalent tons at 50%MC. For instance in the above survey there are 57,456 tons of sawmill residue available at 43% MC which is equivalent to 69,120 tons at 0% MC. The average delivered price for the initial 60,000 tons quoted to 50% MC would be $9.15.

**SUMMARY**

Careful planning in the initial stages of the boiler design
but careful selection of the fuel is equally or more important. A trained broker can save you money in the purchase and acquisition of wood fuels. Once you have been given a price by a broker, make sure you know what that price includes.

COST BREAKDOWN PER TON OF FUEL
@ 60000 TON/yr & 6.5 RES.DENSITY

FIGURE 1. BROKER’S PRICE BREAKDOWN PER TON OF WOOD FUEL
Figure 2 - Quantity variations on fuel and overhead

Figure 3 - Residue density effect on quantity and cost
WEEKLY FUEL DELIVERIES

FIGURE 4 - 3 YEAR AVERAGE WEEKLY FUEL DELIVERIES

DELIVERY PROJECTIONS
ALL SUPPLIERS

FIGURE 5 - DELIVERY, CONSUMPTION AND INVENTORY AT TYPICAL PLANT
MONTHLY MOISTURE VARIATION

MONTH

% MOISTURE CONTENT

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

AVERAGE MOISTURE

FIGURE 6 - 3 YEAR AVERAGE MONTHLY MOISTURE VARIATION

RELATIVE VALUE OF WOOD FUEL

BONE DRY & 50% M.C.

RELATIVE VALUE

0 10 20 30 40 50 60 70 80 90 100

MOISTURE CONTENT

BONE DRY & 50% M.C.

FIGURE 7 - RELATIVE VALUES AT 0% & 50% MOISTURE CONTENTS
INDUSTRIAL COAL SUPPLY

Dennis Duffy
District Sales Manager
Southeast Consolidation Coal Company

presented at
WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
SOLID FUELS ANALYSIS AND STANDARDS

by

James L. Walsh, Jr., P.E.
Senior Research Engineer
Energy Technology Branch
Georgia Institute of Technology

presented at

WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
SOLID FUELS ANALYSIS AND STANDARDS

Introduction

Gas and liquid fuels and the equipment required to burn them are relatively simple to specify and purchase. A plant manager simply calls the local gas company to connect his plant to the gas line, or the local burner/boiler supplier to get a new unit. The quality of the fuel delivered does not vary more than a few percent in heating value, and thus the combustion equipment does not vary in design from unit to unit. Petroleum can be a little more complicated to supply if high sulfur fuels are sold in the area, but even these are not complicated.

Solid fuels and combustion equipment are not as easily specified or purchased, as there are many variations in properties for the same generic fuel type. Close attention must be paid to the specification of the solid fuel being purchased, or the combustion equipment at the plant may be incapable of burning the fuel.

In order to establish the quality of the solid fuel, an analysis must be conducted. To insure the accuracy of the results, approved standardized test procedures must be utilized. This paper will discuss the analyses that are conducted on solid fuels and describe the standardized tests used to conduct these analyses. The emphasis will be on tests for coal and wood, but procedures applicable to other solid fuels will be identified.

Organizations Involved in Approving Standards

There are a number of organizations in the United States and throughout the world that are actively involved in writing and approving standardized test procedures, classifications and specifications. All of these documents will be referred to as standards in the balance of this paper. These organizations include the American Society of Automotive Engineers (ASAE), the American Petroleum Institute (API), and the American Society for Testing and Materials (ASTM). Of all of these organizations, ASTM is the most active in the development of solid fuel standards.

The ASTM standards approval process assures the review of documents by a large number of diverse interests. Approval requires a review by a 50-member
subcommittee of specialists responsible for initial writing of the document, a 200-member committee composed of individuals familiar with the general subject area, and finally the entire 26,000 members of ASTM. The system is set up such that a single person with a valid technical objection to the document can stop the approval of a proposed standard. However, it is also designed such that a single person or persons who object to the document for political or other non-technical reasons cannot stop approval. The approval system is time-consuming, but it assures that only quality standards are approved by ASTM.

Solid Fuel Analysis

The analysis of solid fuels requires conducting a number of different tests. A brief description of these tests will be presented in the following sections:

Heat of Combustion - The heat of combustion is determined by using a bomb calorimeter. A weighed sample of the fuel is ignited in a metal container (bomb) filled with oxygen at a pressure of 30 atmospheres. The temperature rise of a precisely measured amount of water in which the bomb is placed is measured; corrections are made for the heat of formation of nitric and sulfuric acid and for the combustion of the ignition wire; and the heating value in Btu per pound is computed.

The heat of combustion, determined with a bomb calorimeter, is the higher heat value (HHV) of the fuel and is usually reported on a dry basis. The significance of the basis for reporting results will be discussed later. The heat of combustion of a fuel may also be reported on a lower heating value (LHV) or net heating value (NHV) basis; however, these values require data from additional tests. Computation of LHV and NHV will be discussed later.

The heat of combustion is perhaps the most important analysis as this determines the type of combustion equipment required and the quantity of fuel that must be purchased.

Proximate Analysis - The proximate analysis determines the combustion characteristics of the fuel. The analysis determines the moisture, volatile, ash and fixed carbon content of the fuel.

- Moisture content is determined by heating the fuel at a temperature
slightly above the boiling point of water to drive off all moisture.

- Volatile content is determined by heating the fuel at a temperature of approximately 1742°F in the absence of air to drive off additional water and that portion of the combustible material that can be easily vaporized.

- Ash content is determined by heating the fuel at a slow rate to a temperature of 1100°F to burn all combustibles and drive off all moisture.

- Fixed carbon content is determined "by difference," i.e., determining the percentages of moisture, volatile and ash and subtracting from 100 percent.

The proximate analysis provides a number of important pieces of information. The moisture content determines the type of combustion system required and the quantity of fuel that must be purchased. If the moisture content of a fuel is too high it may be impossible to burn. Moisture content may also serve as a basis for fuel pricing. The ash content affects the combustion equipment selection, the capacity and type of equipment required for its removal from the boiler, and selection of air pollution control systems. The volatile and fixed carbon content affect the combustion equipment design and, in particular, the ratio of overfire to underfire air. Southern pine bark, for example, has approximately 73 percent volatiles and 24 percent fixed carbon, and thus more overfire air is needed. Medium volatile bituminous coal has approximately 24 percent volatiles and 64 percent fixed carbon and thus more underfire air is needed.

The moisture content and the HHV of the fuel must both be specified for a given boiler efficiency. For example, a boiler may have an efficiency of 69 percent with a wood fuel having a dry basis HHV of 8500 Btu/lb and a moisture content of 50 percent. All three values—efficiency, moisture content and higher heating value—are interdependent; a change in one variable will change the others.

**Ultimate Analysis** - The ultimate analysis determines the percent by weight of the chemical elements in the fuel. These elements include oxygen, hydrogen, carbon, nitrogen and sulfur. The tests for these elements are somewhat involved and will not be described here. It should be noted that the
ASTM procedures determine oxygen "by difference."

Most of the data obtained in an ultimate analysis affects the initial design of the combustion equipment and thus is not used on a daily basis by the plant engineer. However, the sulfur content is extremely important, as a batch of fuel with a high sulfur content could cause environmental problems.

The determination of the moisture content (MC), the higher heating value (HHV) and the hydrogen content (HC) permit the determination of the lower heating value (LHV) from the following formula:

\[
LHV = HHV_{\text{dry basis}} - (9460 \times HC) - (1059 \times MC)
\]

The lower heating value accounts for the energy losses required to vaporize the water in the fuel and the water formed from the hydrogen in the fuel and the oxygen in the combustion air. The efficiency based on LHV is higher than based on HHV for the same fuel and boiler. Foreign manufacturers often quote efficiency based on LHV, and thus care must be taken to be sure the proper terminology is used.

**Other Analyses** - A number of other analyses are conducted on solid fuels, particularly when initially specifying the combustion equipment. Some of these analyses are as follows.

- **Size Distribution** - Sieves and a Ro-Tap are used to determine the distribution by weight of fuel particle sizes.

- **Ash Fusion** - The temperatures at which ash initially begins to soften and finally turns into a liquid.

- **Ash Content** - The major, minor and trace chemical compounds in ash (oxides of non-combustibles) are determined on a weight percentage basis.

- **Durability and Dustiness** - The durability of wood pellets and the dustiness of coal can have a significant impact on the fuel handling system.

**Basis for Reporting Results** - The terminology used to report the results of the analyses can have a significant impact on the design of a solid fuel combustion system. The heating value of the fuel is often reported on an "as received" basis or the condition of raw sample including moisture. Moisture may be reported on a wet or dry basis. The wet basis is generally preferred for engineering work. Proximate analysis is usually reported on an "as
received" basis, but ultimate analysis usually reported on a dry basis. Some results are reported on an "ash-free" basis to eliminate the effects of non-combustibles.

Standard Classifications

The use of standard test procedures to classify a fuel into a standard category simplifies the specification of combustion equipment and the purchase of fuel. An example of such a classification is ASTM D388-82, "Standard Classification of Coal by Rank." This standard classifies coal according to fixed carbon content, volatile content, heating value and agglomerating character. This standard is used to establish coals as anthracitic, bituminous, subbituminous and lignitic.

At the present time, similar classifications do not exist for other solid fuels. However, ASTM Subcommittee E44.12 on Biomass Conversion Systems is working with the Fiber Fuels Institute of Minneapolis, Minnesota, to develop classifications for biomass fuels.

Standard Test Methods

Table 1 shows the ASTM standard test procedures for conducting the analyses discussed in the preceding sections. The coal standards are under the jurisdiction of ASTM Committee D5 on Coal and Coke; the biomass standards are under the jurisdiction of ASTM Committee E44 on Solar Energy Conversion, Subcommittee E44.12 on Biomass Conversion Systems; and the Refuse Derived Fuel standards are under the jurisdiction of ASTM Committee E38 on Resource Recovery, Subcommittee E38.1 on Energy. The standards represent the primary tests used for analysis; however, some laboratories use internal procedures. An exact statement on the test procedure used is needed to accurately compare results from two different laboratories.

Copies of these standards can be purchased from ASTM at the following address and telephone number:

ASTM
1916 Race Street
Philadelphia, PA 19103
(215) 299-5400
<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Biomass</th>
<th>Refuse Derived Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat of Combustion</td>
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<td>E711</td>
<td>E711</td>
</tr>
<tr>
<td>Moisture</td>
<td>D3173</td>
<td>E871</td>
<td>E790</td>
</tr>
<tr>
<td>Volatiles</td>
<td>D3175</td>
<td>E872</td>
<td>E897</td>
</tr>
<tr>
<td>Ash</td>
<td>D3174</td>
<td>D1102</td>
<td>E830</td>
</tr>
<tr>
<td>Fixed Carbon Difference</td>
<td></td>
<td>Difference</td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>D3178</td>
<td>E777</td>
<td>E777</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>D3178</td>
<td>E777</td>
<td>E777</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>D3179</td>
<td>E778</td>
<td>E778</td>
</tr>
<tr>
<td>Sulfur</td>
<td>D3177</td>
<td>E775</td>
<td>E775</td>
</tr>
<tr>
<td>Oxygen Difference</td>
<td></td>
<td>Difference</td>
<td></td>
</tr>
<tr>
<td>Conversion of Bases</td>
<td>D3180</td>
<td>E791</td>
<td>E791</td>
</tr>
<tr>
<td>Ash Fusion</td>
<td>D1857</td>
<td>D1857</td>
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<tr>
<td>Size</td>
<td>D410</td>
<td>E828</td>
<td>E828</td>
</tr>
</tbody>
</table>
What the Plant Engineer Needs to Know

The plant engineer will probably not need to know the intricate details of every fuel analysis and test procedure. However, there are a number of critical aspects that the plant engineer must be aware of.

1. **The analysis must be conducted using identified, approved standards.**

   If an equipment manufacturer does not know how the data was generated, the results can be misinterpreted. Approved standards are suggested as these provide a common basis for comparison of data. However, draft or internal laboratory procedures may have to be used if an approved procedure does not exist. In such cases a copy of the procedure used should be supplied with the data.

2. **The basis for the results reported and efficiencies stated must be known.**

   An "as received" versus dry basis result can have a significant effect on equipment. Both dry basis higher heating value and moisture content must be specified along with boiler efficiency.

3. **Equipment suppliers and architects/engineers are given accurate analyses of the proposed fuel.**

   Improper analysis of the fuel could result in the purchase of equipment that does not perform as required or may not work at all.

4. **Fuel analysis may be a requirement of fuel purchase contracts.**

   Wood fuel is often purchased at a price based on moisture content. Coal can be purchased on a Btu basis, and the price may be adjusted for sulfur content.

Technology Applications Laboratory Fuel Testing Service

The Technology Applications Laboratory (TAL) has conducted analyses of many different types of solid and liquid fuels. In particular, TAL specializes in the analysis of waste fuels. Some of the testing is done in-house, and other tests such as ash fusion and ultimate analysis are conducted at commercial laboratories. The TAL service is not intended to be a mass production operation, and clients with multiple tests are referred to outside laboratories. The primary objective of the service is to give the client an interpretation of the significance of the data.
Tests of solid fuels are conducted free of charge during the current State of Georgia Office of Energy Resources Project. At the end of this project, the test can be conducted at a nominal charge to cover expenses. The charge depends on the number of tests required. Contact Jim Walsh at 404-894-3636 for details.

Summary

Solid fuels require more analysis than fuels such as gas or oil. Accurate analysis of a solid fuel is important for the proper operation of the combustion system. This analysis must be conducted using approved standard procedures such as those developed by ASTM. The plant engineer needs to have a basic knowledge of the analysis and tests involved and must insure that the program is properly carried out. The entire process is relatively simple and should not discourage a plant from converting to solid fuels. The economic advantages of solid fuels far outweigh the minor additional work involved for analysis.
MODULAR COAL AND WOOD BOILERS

Fondren Rigsby
Manager, Plant System Products
Industrial Boiler Company, Inc.

presented at
WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
MODULAR COAL & WOOD FIRED BOILERS

In recent years past American industry has seen a revitalization of the solid fuel technology which once played an important role in providing process steam for our industrial sector and heating demands for institutional applications. Rising gas and oil prices combined with conditional uncertainties of a constant fuel supply have been the major factors to enhance the resurgence of coal and wood fired boiler systems.

One of the major concerns facing the boiler industry was to develop total systems to supply small to medium sized industry with an affordable alternate energy system that would offer paybacks of less than three years. Hence, the growing interest in modular units to eliminate as much as possible the cost intensive field erection required by larger energy systems. For the purposes of our discussion, we will be dealing with firetube boilers only. Due mainly to physical size, freight limitations, construction techniques etc., modular boiler systems are available up to 40,000 PSHP on coal and wood in single units, and unlimited capacity in battery settings. Pressures in firetube units are commonly available up to 300 PSIG design.

For any solid fuel project there are 5 basic areas to consider when looking at a total system. These areas are:

1. Fuel Receiving & Preparation
2. Fuel Storage
3. Boiler Equipment
4. Pollution Control
5. Peripheral Support Equipment
Each of the above areas must function together smoothly and efficiently to provide a total system. The selection of the right equipment will be dictated by specific job conditions.

To explore in more detail let us look at several factors associated with the selection of solid fuel boiler systems. Probably the most important and first decision required is to select the proper fuel. In some installations wood will be the logical choice, in others coal would make more sense.

This decision is generally based on economic considerations, availability of fuel, air pollution requirements, and capital cost of various systems. In some situations one or more factors may dictate that one fuel has distinct advantages over the other while other situations may not be as clear-cut and both fuels should be considered until enough information is developed to make a selection of the fuel which will offer the most economic advantage to your specific application.

Once a preliminary selection of wood or coal is made, you can begin the process of equipment selection. We will discuss briefly each of the five areas of equipment with emphasis on the modular or packaged boiler equipment. The other areas will be highlighted by speakers in today's program.

1a. Wood Receiving & Preparation

If wood is selected as the best alternate fuel, you should already be comfortable that there is an abundant quantity available to you for your needs. Generally, if the fuel is not produced in-house, you would have several suppliers to further insure the constant availability of wood residues.
The first major consideration is how the fuel will be delivered to the job site. This is important so that you can select the proper system to unload or receive the fuel once it is delivered to the site. If self-unloading trucks are available, this is fine; however, with several suppliers, this is not often the case and most deliveries will come in standard chip trailers.

Next, consider the number of trucks you will be required to unload a day based on fuel requirements for your particular process and select a system that will handle this tonnage in a time frame acceptable to you and one compatible with your budget. Acceptable systems include:

1. Self-unloading trucks
2. Truck dumps
3. Front end loader
4. Scoop-veyor
5. Vacuum systems

Fuel type (i.e. dry vs. green, hogged vs. unhogged) and the degree of automation will also affect the selection of this equipment.

Once the unloading system is selected, next consider fuel preparation. Screening is considered a basic necessity in wood systems and will eliminate many problems in the fuel handling system downstream of the screen.

If the percentage of oversized pieces of wood or bark in your fuel supply is high, a hog may need to be considered but should only be sized large enough for the anticipated amount of overs from the screen. Proper fuel specifications to prospective suppliers should help eliminate excessive quantities of overs.
The screened or hogged material must then be conveyed to the storage system. Acceptable equipment would include mechanical conveyors such as screw conveyors, drag chains, vibrating conveyors, and bucket elevators or pneumatic systems. Again, fuel type, and quantity will dictate the selection of this equipment.

1b. Coal Receiving & Preparation

Coal can generally be controlled better than wood as to the consistency of the size and type of coal delivered. Proper coal specifications should eliminate some of the problems associated with wood such as screening and sizing of material prior to storage.

Most coal will be delivered in dump trucks or by rail and unloading is performed by mechanical or pneumatic means as the specific situation may dictate. Here again system capacity, degree of automation and weather conditions will also contribute to the selection of coal receiving and prep. systems. The simplest system would include a fuel staging area where the coal trucks could dump on grade and the coal could be maneuvered by front end loader to the inlet hopper of a bucket elevator which would convey the coal to a height sufficient to feed an overhead bunker or feed directly to the stokers.

A more advanced system but requiring less man hours to operate would include an inground bunker with a vibrating grizzly which would receive the discharge of an entire coal truck and convey the coal automatically, by means of mechanical or pneumatic systems to reserve or active storage, either in a silo or overhead bunkers or both.
2. Fuel Storage

Fuel storage capacity for both coal and wood systems is based on several factors including size of the boiler system or actual fuel usage for process steam requirements and anticipated delivery schedules.

Several acceptable storage mediums can be used including storage silos, covered concrete storage slabs, and live bottom floors or bins.

Weather conditions, required reserve storage, type of fuel and again degree of automation required dictate the type of storage facilities best suited for a particular application.

One of the most convenient and accepted methods for storage of coal and wood are silos. Silos may be constructed of concrete, steel or glass/epoxy lined metal.

Storage silos for wood must be equipped with mechanical unloaders due to the bridging nature of most wood residue fuels, while coal silos, due to the more free flowing nature of coal, may only require sloped floors and rely on gravity discharge to feed the boiler systems. Coal silos are often equipped with two sloped shelves within the silo when mechanical means are incorporated to feed the boilers. This allows for active and active reserve storage within the silo. Silos with pneumatic conveying systems to feed the coal boilers generally only have one sloped floor in the bottom of the silo.

Intermediate overhead bunkers are generally used to store a days supply of coal directly above the boilers. This practice is not used with wood fired boilers due to the non-free flowing nature of wood fuels.
3a. Wood Fired Boilers

HRT boilers have long been associated with wood fired systems. The HRT boilers have many advantages including, reliability, durability and flexibility which are all important when working with a fuel as inconsistent as wood residues.

The HRT or Horizontal Return Tubular boiler incorporates an overhead suspension design which allows for flexibility of setting height and furnace design depending on the type of fuel to be burned. HRT boilers with induced draft are sized for a nominal rating of 6.0 to 6.5 sq. ft. of heating surface per boiler horsepower. This is a conservative rating and insures durability and long life of the boiler unit.

Dry fuels less than 20% M.C. content can generally be combusted in a standard set furnace with a setting height of 8-12 ft. depending on the size of the unit. Green fuels (up to 50% M.C.) generally require the same setting height but require either an extended "prefurnace" arrangement or a combustion air preheater to insure maximum efficiency and good combustion as you approach the higher moisture content levels.

Setting height is determined by the required combustion volume within the furnace and is generally designed around a heat release of 25,000-30,000 BTU/HR/cubic of furnace volume.

Most HRT applications include a fixed manually cleaned grate system. The grates are constructed of either cast iron or refractory and designed with either tapered pin holes or spaces between the individual grates to allow for under grate combustion air to reach the fuel bed. Grate composition is determined by
fuel type. Cast iron grates are generally used with high moisture fuels and refractory type grates with low moisture fuels or when an air preheater is used in the application. Grate size is determined by using a design heat release figure of 450,000 BTU/sq. ft. of grate area.

The furnace built below the suspended HRT pressure vessel is constructed of structurally reinforced steel plate with refractory anchors for securing the refractories within the furnace. The refractories consist of a layer of fiberglass blanket and 9 to 12 inches of rammed plastic refractory to form a monolithic structure. Additional refractories used include castable, firebrick, arch, and blowdown protection tile.

A bridgewall is generally constructed at the rear of the grate area and below the boiler drum. The bridge wall increases combustion dwell time within the furnace, forces the hot products of combustion along the complete belly of the pressure vessel and causes a natural pressure drop which permits larger particles of unburned carbon and flyash to fall out into the rear collection hopper where they are reinjected into the furnace for further combustion.

Undergrate and overgrate combustion air is supplied by the combustion air fan through structurally reinforced duct work. The pressure is controlled to maintain a static pressure through the grates of .1 - .2 inches of W.C. and the volume of air is regulated by means of dampers responding to varying fuel rates as dictated by load demands.
The furnace pressure above the grates is maintained at a slightly negative pressure as the hot gases are drawn through the boiler pollution equipment, interconnecting breeching and pre-heater (if required) and pushed through the stack.

Fuel feed to the boiler furnace is controlled by a metering bin equipped with a live bottom discharge and a variable speed drive. A pressure control panel senses minute changes in boiler pressure and relays this signal to the master combustion control panel which in turn sends a signal to vary the discharge of the metering bin. The fuel discharge from the metering bin is conveyed into the boiler furnace either mechanically for high moisture fuel or pneumatically for lighter lower moisture fuels. The fuel is spread evenly over the grates for maximum combustion efficiency. This type of combustion is known as controlled pile burning, in where a portion of the smaller particle injected into the furnace burn in suspension while the balance falls to the grate and is burned in a 50% excess air environment.

Recently and more frequently in smaller scale applications, 3-pass wet back firebox boilers with extended water legs are being used. The purpose of this is to eliminate costly field labor and in turn reduce overall cost. This technique can be effectively applied to units up to 300 HP or approximately 10,000 PPH of steam. Pressures are available up to 200 PSIG design and operation and performance is basically identical to the HRT boilers as we previously discussed.
In addition, "hybrid" boilers or a combination of firetube boilers with extended water-tubes "chapels" have been introduced to the market place and are proving to have certain merits. I am certain that we will see more applications of this type in the future. These units offer the combination of packageability, the capture of radiant heat within the furnace and ability to bulk feed materials into the furnace. These units are generally induced draft only and combustion is controlled by feed rate and draft created across the fuel bed.

3b. Coal Fired Boilers

The recent resurge of interest in coal fired boilers has brought many new ideas to the American boiler market. One of these is the combination of a packaged three pass wet back boiler complete with an integral chain grate stoker (or stokers). Units up to 20,000 lbs. of steam per hour are generally outfitted with one chain grate stoker while the larger units which are available up to 40,000 PPH in complete package units are outfitted with dual stokers. On the dual stoker arrangements the boilers may be built with split rear turnarounds so the stokers may operate independently and increase the turndown ratio to 5 or 6 to 1.

A major feature of the chain grate stoker is the deashing process which offers continuous and automatic deashing while the boiler is operating. There is no need to shut down the boiler for the deashing process. While ash residue from wood is generally less than a percentage or two, ash contents in coal may range much higher. In fact, a minimum of 5% ash is required in the coal to maintain the cool temperature of the grate and keep
the cast links from overheating. The stoker is sized as not to exceed a burn rate of more than 35-40 lbs. of coal per square/ft. per hour.

The coal is fed from an overhead hopper to the inlet of the stoker by gravity. An adjustable guillotine gate is installed to regulate a bed depth generally between 5-7 inches. Coal falling down onto the stoker grate is leveled by the present guillotine gate and travels under a refractory ignition arch which radiates heat down onto the coal bed and ignites the incoming coal as it passes underneath the arch. Combustion is controlled by modulating the speed of the stoker thus the amount of coal being burned in a given period. As with the wood boilers, a pressure control panel senses minute changes in steam pressure and transmits a signal to the combustion controller which in turn relays the proper signal to the stokers to modulate the speed.

Combustion air is supplied up through the chain grate by separate combustion air fans for each stoker. Combustion air volume is controlled by automatic dampers and responds in ratio to fuel input and stoker speed. Directional vanes distribute the combustion evenly under the coal bed on the stoker.

Combustion of the coal is completed as it reaches the rear of the stoker. At the rear of the stoker the coal ash is dropped into dropout tubes and through the boiler shell to the ash removal system selected for the particular application.
The hot gases of combustion are pulled by the induced draft fan through the remaining two passes of the boiler, through the pollution control equipment and interconnecting duct work and discharged into the stack. Exhaust gas temperatures leaving the boiler should be in the range 425-450°F on 100 psi operating boilers. The packaged coal fired units also operate on a negative draft from the coal bed to induced draft fan.

Several other configurations of the packaged 3-pass wet back scotch boilers are available including fixed grate models, underfeed models and low ram type models. Generally more common for smaller applications, these units do not normally feature automatic ash removal. Additionally for smaller applications, 3-pass firebox design boilers are available with underfeed and ram type stokers.

4. Pollution Control Equipment

Coal and wood fired boilers generally require some type of particulate removal equipment to insure compliance with State and Federal regulatory agencies. In addition coal fired boilers face the possibility of the need to control sulfur emissions. This depends on sulphur content of the coal, tonnage consumed annually and current regulations for a specific location.

Unfortunately, not all pollution equipment is suitable for both fuels. A mechanical multitube collector(s) is the primary step in reducing particulate emissions in both coal and wood fired applications. However, they offer no control of sulfur emissions. High efficiency mechanical collectors with partial
recirculation offer slightly better control than straight mechanical collectors but again offer no help with sulfur emissions. More stringent regulations may require the use of baghouses which are more acceptable on coal fired units and rarely used on wood fired applications. Baghouses also are used for particulate control only.

Wet scrubbers offer control of both particulate and sulfur and can be used on either coal or wood fired applications. Wet scrubbers and baghouses offer the most thorough particulate removal and generally meet the most stringent requirements for boilers of the size we are discussing.

It is very important to have the boiler and pollution control equipment operate in conjunction with each other in order to meet the necessary pollution requirements.

5. Peripheral Equipment

In addition to the basic system components, auxiliary support equipment is required to give a fully functional system. Some equipment may be existing in your plant and may be capable servicing your conversion to solid fuels. Other equipment is associated directly with either the coal or wood systems and needs to be included where required.

This equipment includes the following:

1. Deaerators or vented feedwater systems. Some code states require an alternate method to put water into solid fuel boilers other than electrical. Steam turbine driven pumps or steam injectors may be required.
2. Water softeners, chemical feed systems, and blowdown separators may be required for proper boiler operation and increased operating life.

3. Ash removal systems from the discharge of the chain grate stoker(s). The simplest and cheapest method is by ash cart(s) which are positioned under the ash drop chute(s) and manually removed and dumped when filled. This is not practical in larger size units and both pneumatic and mechanical systems are available to receive the ash discharge and transport to the receptacle outside of the boiler room.

4. Steam flow meters and recorders should be considered as optional equipment but are very useful in tracking and calculating steam production and cost savings.

5. Soot blowing systems for both coal and wood fired units should be considered strongly as options. They are generally available in both steam air operated models and will reduce maintenance down time when used properly.

6. Economizers are available to be used in conjunction with solid fuel boilers to recover additional heat from the exhaust gases after leaving the boiler. In some cases, economizers may be required on systems utilizing baghouses to buffer the exhaust gas temperature down to a point acceptable to the fabric filter median. Care should be exercised to make sure that the economizers are compatible with the type of fuel you are burning. Coal and wood generally require specific economizers for the application.
In summary, solid fuel applications can offer fuel savings up to 50% over traditional fossil fuels. However, the selection and application of equipment is very critical and offers quite a challenge to those unfamiliar with solid fuel combustion. Thorough research and education on the subject will greatly enhance ones ability to make a competent selection of the right fuel and the proper equipment for receiving, storing, burning, and cleaning up this selection of fuels.
FIELD-ERECTED COAL AND WOOD BOILERS AND INCINERATORS

William L. Reeves
Vice-President
Southeast Operations
ESI/PDS Engineers and Constructors

presented at
WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
WOOD and COAL
For Industry’s Energy Needs

Field-Erected Coal and Wood Boilers and Incinerators

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FIELD ERECTED COAL AND WOOD

BOILERS & INCINERATORS

PRESENTED TO: Seminar for Wood & Coal
For Industry's Energy Needs

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INTRODUCTION

Prior to the oil embargo of the early 1970's, industrial steam production costs were generally a minor portion of total product cost. Therefore, industrial steam users placed little emphasis on capital cost spending programs designed to aggressively minimize those costs through increased steam plant efficiencies or use of alternative fuels. However, since the mid 1970's, plant and utility engineers, plant managers and all levels of management including top management have been sensitive to the ever increasing cost of energy and its affects on manufacturing costs, thereby affecting one's ability to compete in the market place. Consequently, in their search for solutions to the high cost of energy, industrial steam users have been constantly bombarded with a steady barrage of material illustrating the various forms of technology, equipment and expertise available in the marketplace designed to solve these problems. Being relatively unfamiliar with most of this equipment, plant and utility engineers find themselves in a relentless search for information that will answer questions which generally come to mind when considering a new coal or wood fired boiler system. These questions deal with subjects relating to the following:

1. Type of boiler and firing equipment to install.
2. Current process steam requirement compatibility.
3. Availability and relative cost of fuels.
4. Operating and maintenance requirements.
5. Typical system availability and redundancy requirements.
6. On site fuel storage requirements.
7. Pollution control requirements.
8. Ash disposal.
9. Space requirements.
10. Economic feasibility.
11 Cogeneration feasibility.

This paper will attempt to give some preliminary answers to some of these questions to make the coal or wood fired boiler feasibility issue a little more clear.
EQUIPMENT SELECTION AND COMPATABILITY

The enclosed Table I lists different types of coal and wood firing equipment and types of boiler construction. Most industrial field erected boilers which are below 175,000-200,000 pph utilize some type of stoker for firing equipment. Even though the capital costs are higher for pulverized coal fired systems, at a utilization capacity of 175,000-200,000 pph, the increased efficiency and much lower coal costs, along with the excellent load response and good turn down capability, make a pulverized coal system more advantageous in this size range or larger. Stokers which are used below 175,000-200,000 pph are available in various types as follows:

1. Traveling grate spreader. (Exhibit III)
2. Traveling or chain grate. (Exhibit II)
3. Watercooled vibrating grate.
4. Single or multiple retort underfeed. (Exhibit I)
5. Reciprocating grate.
6. Watercooled pin hole grate spreader.

The application of one of these types of stokers in a particular industrial situation is dependent upon the following factors:

1. Type of fuel to be burned.
2. Boiler size.
3. Load response requirement.
4. Turn down requirement.

The reciprocating grate stoker is generally exclusively used in the refuse derived fuel applications for industrial or municipal solid waste incinerator/boiler installations. This stoker requires essentially no initial preparation of the refuse prior to incineration. The watercooled pinhole grate stoker is generally used exclusively for wood waste or prepared plant waste applications. The fuel is introduced in this stoker generally through pneumatic spreader feeders and therefore requires initial preparation to properly size the material. Traveling chain grates, watercooled vibragrates, and underfeed stokers are all mass burning type stokers. The traveling grate spreader stoker is a suspension burning stoker and is the type of stoker most predominately used in the industrial marketplace. This is because it
has a better load response capability than the mass burning type units. Because a coal fired spreader stoker boiler responds almost as well as gas/oil fired units, there is very little concern about adverse affects upon process steam requirements. The major disadvantage with a traveling grate spreader stoker is its limited turn down capability. The real dilemma for an industrial client in stoker selection comes when both good turn down and load response capabilities are required. Generally, unless the fuel savings potential can be captured during the periods of low load operation, the new solid fuel fired system economics become marginal. Therefore, extensive analyses is required to determine if mass burning type stokers which can satisfy the required turn down will yield sufficient enough load response so that the pressure fluctuations are tolerable and within process requirement guidelines. Regardless of the application, there is rarely a case when a coal or wood fired boiler installation cannot deliver the quantity and quality of steam on a continuous reliable basis to satisfy the requirements of an industrial user.

The reason that suspension fired stokers have much better load response capability is that approximately 50% to 60% of the fuel is burned in suspension with the larger heavier pieces falling to the grate and being burned in a thin active fuel bed. It is for this reason that the suspension fired stokers generally result in a higher particulate loading to the gas clean-up equipment resulting in higher capital and maintenance costs. Mass burning stokers have lower particulate emission rates because of generally less disturbance in the fuel bed.

**AVAILABILITY AND RELATIVE COST OF FUELS**

Purchasers of industrial stoker coal pay a slight premium for coal to be fired on mass burning stokers because of the requirements to have a lower free swelling index (tendency of the coal to swell when heated), higher ash fusion temperatures and fewer fines. Spreader stokers can generally handle slightly more fines than mass burning stokers and are not as sensitive to a higher free swelling index or lower ash fusion temperatures. Pulverized coal fired boilers use very inexpensive run of mine coal which requires virtually no processing. In contrast, most stokers require a double screened product with some percentage of fines blended back into the coal prior to shipping. The availability and relative cost of fuels will not be discussed in this paper since it is a separate topic to be discussed by others in this seminar.

**OPERATING AND MAINTENANCE REQUIREMENTS**

Referring again to Table I, some of the differences are listed between tube and tile verses welded wall construction and baffled versus single pass boiler construction. Tube and tile furnace construction is generally used in the lower capacity units.
because of the approximate 30% lower first cost for the boiler equipment. Because of the flat projected exposure of the refractory tile between the tubes to the furnace, tube and tile construction generally increases turn down capability due to the resultant higher furnace temperatures. Subsequently, tube and tile construction is generally used for fuels which have high moisture content such as wet wood and selected plant waste. Welded wall furnace construction is generally used in larger boiler installations and results in lower overall maintenance because of the absence of the refractory tile. It does, however, decrease the turn down capability because of the cooler furnace at lower loads.

Baffled boiler construction is generally used in the smaller boiler size range because of its lower capital cost. A single pass boiler is more expensive because of a necessity to supply much more boiler bank heating surface to result in the same boiler exit gas temperature. However, the single pass boiler does result in lower overall maintenance since there are no baffles to maintain.

Prospective industrial purchasers of field erected coal and wood fired boiler systems are always concerned with what kind of operator input is required above and beyond existing gas/oil boiler equipment requirements. Unlike many gas/oil fired boiler plants, which generally require no full time operator attendants, it is generally common practice and in many cases requirement by code or local laws that full time operators be in attendance for solid fuel fired operations. Most industrial power plants operate with anywhere from 1 to 2 full time operators per shift. The small industrial steam plants, which utilize equipment such as underfeed stokers are generally capable of being operated with one full time operator who can perform all the duties including semi-automatic ash handling and coal handling supervision. The larger more sophisticated plants can require up to 2 full time operators per shift to handle all of these duties. The mass burning stoker fired installations require somewhat more operator input than suspension fired systems requiring occasional manual adjustments to be made to feed gates or dampers to improve fuel/air distribution throughout the entire load range.

Although there may be some differences which affect the relative cost of maintenance between different coal or wood fired stoker systems, one thing for certain is that the overall maintenance costs of solid fuel fired systems is greater than gas and oil fired systems. Most coal fired systems generally have increased operating and maintenance costs, above and beyond those costs already attributed to gas and oil fired systems, of approximately 2% to 3% per year of the system capital cost. Because of the severe duty requirement of burning a non-homogeneous fuel, reciprocating grate stoker fired units generally have the highest maintenance and operating costs. Also, systems which fire wood
with the more extensive and sophisticated handling equipment, generally have higher maintenance and operating costs than coal fired systems. Suspension coal fired stokers generally have slightly higher maintenance than the mass burning systems because of the higher particulate carry over.

SYSTEM AVAILABILITY AND DESIGN REDUNDANCY

Unscheduled, forced outages are generally a rare occurrence in most properly designed and maintained industrial solid fuel fired steam plant facilities. Although total system availability does vary somewhat with the size and level of sophistication, system availability generally runs in excess of 99 percent for the balance of the year exclusive of a one to two week scheduled annual shut down for maintenance and inspection. Most engineering firms and design/build firms with extensive experience in industrial solid fuel fired boiler plant design are aware of the areas of particularly high maintenance and service requirements and are able to incorporate more ruggedly designed equipment in specific areas where it is warranted to ensure this kind of reliability.

There is a general tendency for most industrial steam users considering new coal or wood fired steam plants to initially insist on redundancy in many areas to ensure system availability. This redundancy generally causes substantial increases in the capital cost requirements, often times resulting in marginal economic feasibility for the project. Because utility availability is critical for production continuity for industrial steam users, this insistence upon having redundant capability is very justified. The majority of new coal or wood fired steam plants which are installed consist of replacement capacity for existing gas/oil fired units which are still in serviceable condition. The existence of currently serviceable gas/oil fired equipment should not be ignored as being that potential redundant capacity. Therefore, keeping this thought in mind, by installing a well designed system with the minimum amount of equipment, the capital cost and maintenance costs are quickly reduced making these projects economically very attractive.

ON SITE FUEL STORAGE REQUIREMENTS

Typically, in the design of new coal and wood fired steam plant facilities, required on-site fuel storage requirements becomes an issue. Here again, because of the critical nature of utilities, industrial users are inclined to want extensive on-site storage to ensure reliability and independence from fuel suppliers and transportation interruptions. However here again, since these new systems are merely replacement capacity, most industrial users have in inventory a fair amount of oil storage capacity which was always sufficient to make them feel comfortable about market or transportation interruptions in the past. Another
determining factor is the tremendous volumetric requirements of storing large energy reserves in solid fuels. Therefore, most new solid fuel fired installations lean towards 10 to 20 days of on site storage of solid fuels at the full rated boiler capacity. Normally the coal is stored in silos thereby providing a very clean installation and eliminating redundant coal handling which enhances degradation. It also improves the overall operation by eliminating the infiltration of moisture into the coal handling systems.

POLLUTION CONTROL REQUIREMENTS

Another topic which is always of concern when considering a solid fuel fired installation is the air pollution control requirements. Under current law, whenever a new source has the potential to emit over 250 tons per year of any pollutant, it is subjected to Federal regulation as well as State regulation. In coal fired operations, sulfur dioxide emissions are the pollutant which usually are the greatest. In simple terms, burning 1% sulfur coal, any proposed facility with a continued average load in excess of 30,000 pph for more than 8,000 hours a year would exceed the 250 ton per year limit.

Typically, for systems below 30,000 pph, permits can be obtained using multicyclone mechanical collectors only. Systems larger than 30,000 pph require sidestream mechanical collector/baghouse combinations or full size baghouses for particulate emission control. Sulfur dioxide emissions are normally controlled with the use of compliance low sulfur coal for most boiler installations below 100,000 pph. Above 100,000 pph in geographic locations such as the Midwest where high sulfur coal is readily available at a much reduced cost over low sulfur coal, dry flue gas desulfurization systems are currently being installed. Most of the coal fired stoker systems now being considered comply with all nitrogen oxide emission requirements. Visible emissions and corresponding neighborhood public relations are always a concern of industrial users when considering new solid fuel fired steam plants. The combustion technology of all the solid fuel fired systems discussed in this paper have been improved upon in the last few years to the point where visible emissions are not a problem as long as the equipment is operated as the manufacturers dictate.

ASH DISPOSAL

Ash disposal is another area which becomes of concern during the proposal phases of these projects. The majority of the industrial solid fuel fired steam plant facilities utilize pneumatic ash handling systems which are virtually automatic and allow dust free unloading into trucks for haul-away. The smaller installations utilize various forms of mechanical material handling equipment which is generally semi-automatic. If a
client has to pay to have ash hauled away and land filled, this is very rarely a substantial economic factor to be considered in the total project economics. Often times, markets can be found for the basically inert ash such as concrete block manufacturers, road building or land filling operations. When this is the case, the ash is often disposed of at no charge or the client even paid a minimal fee to provide the ash to these end users.

SPACE REQUIREMENTS

Another common misconception for prospective new industrial users of solid fuel fired steam plant facilities is that these facilities require a considerable amount of space. There is no question that these systems do require more space than gas/oil fired systems because of the more elaborate material handling systems, flue gas clean-up systems and sheer size of the equipment. However, there are usually many options available in the engineering layout phase of a project which makes their feasibility from a space requirement standpoint almost without exception. These systems can sometimes be partially installed in existing building facilities or retrofitted into adjacent space to utilize many of the existing facilities already in place. If space is not readily available in close proximity to the existing steam plant, the necessity to build a complete stand alone remote located steam plant with lengthy tie-ins rarely decays the economics to the point of creating a marginal project.

ECONOMIC FEASIBILITY

Total installed system capital costs for new coal and wood fired boiler systems are primarily dependent upon the following criteria:

1. Fuels to be burned.
2. Desired system redundancy
3. Air pollution control requirements.
4. Fuel storage requirements.
5. Requirement for future cogeneration.

Table I illustrates the wide range of capital costs associated with the different types of coal and wood fired boiler systems being discussed. When considering capital cost dollars per pound of installed capacity, the lower end of the range is generally attributed to the larger capacity units and visa versa. The pulverized coal fired systems are slightly higher than stoker fired systems because of the increased equipment requirements of
boiler management systems, coal pulverizers and primary air heaters. As mentioned earlier, the much lower coal costs and higher efficiencies generally make pulverized coal systems very attractive in the 175,000 - 200,000 pph and above range. Traveling grate, chain grate and vibrigrate stokers are generally slightly less expensive than traveling grate spreader stoker systems, because of the slightly lower cost of the stoker and the capability of using a smaller baghouse system with a larger air to cloth ratio due to the lower particulate emission rates. Underfeed stoker systems appear to be higher from a first cost, dollars per pound basis, however this is because these systems are not afforded the economic benefits attributed to escalation of size. Generally, underfeed coal fired stoker systems can be installed with mechanical multicyclones only for particulate clean-up in lieu of baghouse requirements which are generally accepted for the larger systems. Wood fired systems are inherently more expensive because of the normally required more sophisticated and extensive material handling requirements and the large volume of material to be stored and handled. Plant waste and other refuse derived fuel systems are generally the highest cost because of the very rugged design of the equipment, due to the extremely heterogenous fuel burned. In general, unless an the industrial consumer is faced with unusual circumstances such as stringent air pollution control requirements or very high alternate solid fuel costs due to geographic location, an average steam flow requirement of 15,000 pph for not less than 6000 hours per year results in an after tax payback of less than 3 years. The attached Table II gives some examples of typical proposed coal and wood fired boiler systems and their respective capital costs. This Table includes identification of some factors which affect total project cost and illustrates some typical industrial applications and the economic feasibility of those installations.

COGENERATION FEASIBILITY

Virtually, every new prospective industrial client wants to look at the feasibility of adding cogeneration to these projects, either initially or at some future point in time. It is for this reason that the majority of boilers currently being installed above 30,000 pph are of high pressure design for initial low pressure operation with the possibility of being retrofitted to operate at higher pressures for cogeneration in the future.

Because of the widely varying affect of many determining factors, cogeneration feasibility analysis is very site specific. The following trends enhance the feasibility of cogeneration:

1. Higher average steam flow rate requirements. (Greater than 40-50,000 pph)
2. Minimum deviation between maximum and minimum steam flow requirements from that of the average flow requirement. (Less than 25-35%)

3. Higher purchase power and buy back power electrical rates. (Greater than 5-6%/KWH)

4. Lower process saturated steam pressure requirements. (Less than 175 psig)

5. Maximum utilization of the system in hours per year. (8000 hour per year or more)

INSTALLATION

Total system delivery for new design/build steam plant facilities generally range from 9 to 12 months for the smaller systems and from 14 to 16 months for the larger systems. The most critical item in the project schedule critical path is the delivery of the boiler and firing equipment. The delivery of these components usually range from 6 to 10 months. Prior to their arrival most of the design work is generally completed and all of the foundations have been put into place. Since concrete and foundation work is very sensitive to cold weather conditions, particularly in the northern climates, the timing of new field erected boiler projects can be very critical especially if the schedule is substantially accelerated. One method used to circumvent potential problems with concrete and foundation work construction falling in the severe winter months is the preliminary release of projects to begin environmental permitting work and engineering so that this work can be done immediately upon complete release of the project prior to the onset of bad weather conditions.

SUMMARY

In summary, it is obvious that there is a general trend in the marketplace among industrial steam users to seek alternative fuels such as coal, wood and plant waste to serve their energy needs. Any industrial steam user with more than 15,000 pph average load for more than 6,000 hours per year probably has a feasible application for the installation of a new coal and/or wood fired boiler system. These low risk projects have economics that meet the investment hurdle rates of most industrial users. The technology is available in the marketplace to enable the installation of systems which will give clean reliable and safe operations. The uncertainty of environmental regulations has been erased during the past few years so that prospective installers of these systems need no longer be afraid of ever changing environmental regulations. Many small, privately owned as well as large major corporations in textiles, chemicals, agriculture, food processing, rubber, etc. have already made these conversions or are in the process of installing these systems to
reduce their production costs and increase their competitiveness in the marketplace.
<table>
<thead>
<tr>
<th>Type of Equipment</th>
<th>Typical Sizes (KPH)</th>
<th>Load Response</th>
<th>Typical Turn Down</th>
<th>Particulate Emissions to Air Pollution Equipment</th>
<th>Typical Fuels *3</th>
<th>Operator Input Requirement</th>
<th>Relative Cost</th>
<th>System Capital Cost $/Lb.</th>
<th>System Maintenance &amp; Operating Cost</th>
<th>Typical System Efficiencies *2</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Firing Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Pulverized Burners</td>
<td>Greater than 175</td>
<td>Excellent</td>
<td>6:1</td>
<td>Very High</td>
<td>Coal</td>
<td>Lower</td>
<td>Very Low</td>
<td>$35-$45</td>
<td>Highest</td>
<td>85-87%</td>
</tr>
<tr>
<td>B. Traveling Grate Spread Stoker</td>
<td>30-200</td>
<td>Good</td>
<td>3:1</td>
<td>High</td>
<td>Coal</td>
<td>Avg.</td>
<td>Lower</td>
<td>(C)$30-$55 ($)40-$60 ($)40-$60</td>
<td>Higher</td>
<td>(C)-83-84% (W)-65-75% (RDF)-65-70%</td>
</tr>
<tr>
<td>C. Traveling or Chain Grate Stoker</td>
<td>35-150</td>
<td>Fair</td>
<td>6:1</td>
<td>Low</td>
<td>Coal</td>
<td>Higher</td>
<td>Avg.</td>
<td>$27-$50</td>
<td>Avg.</td>
<td>83-84%</td>
</tr>
<tr>
<td>D. Water Cooled Vibrating Stoker</td>
<td>35-150</td>
<td>Fair</td>
<td>6:1</td>
<td>Medium</td>
<td>Coal</td>
<td>Higher</td>
<td>Avg.</td>
<td>$27-$50</td>
<td>Avg. to Lower</td>
<td>83-84%</td>
</tr>
<tr>
<td>E. Underfeed Stoker</td>
<td>Less than 30</td>
<td>Fair</td>
<td>3:1</td>
<td>Low</td>
<td>Coal</td>
<td>Higher</td>
<td>Avg. to Higher</td>
<td>$35-$60</td>
<td>Avg.</td>
<td>83-84%</td>
</tr>
<tr>
<td>F. Reciprocating Grate Stoker</td>
<td>30-120</td>
<td>Fair to Poor</td>
<td>3:1</td>
<td>Medium</td>
<td>RDF</td>
<td>Avg.</td>
<td></td>
<td>$50-$80</td>
<td>Highest</td>
<td>65-70%</td>
</tr>
<tr>
<td>G. Watercooled Pinhole Grate Spreader Stoker</td>
<td>30-175</td>
<td>Good</td>
<td>3-6:1</td>
<td>High</td>
<td>Wood RDF</td>
<td>Avg.</td>
<td></td>
<td>$40-$60</td>
<td>Highest</td>
<td>65-75%</td>
</tr>
<tr>
<td>II. Type Boiler Construction</td>
<td>0-150</td>
<td>--</td>
<td>Increases</td>
<td>Coal Wet Wood</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>A. Tube &amp; Tile Furnace</td>
<td>Greater than 100</td>
<td>--</td>
<td>Decreases</td>
<td>Coal RDF Dry Wood</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Higher</td>
<td>--</td>
</tr>
<tr>
<td>B. Welded Wall Furnace</td>
<td>0-150</td>
<td>--</td>
<td>Decreases</td>
<td>Coal Wood</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Lower</td>
<td>--</td>
</tr>
<tr>
<td>C. Baffled Boiler</td>
<td>Greater than 100</td>
<td>--</td>
<td>--</td>
<td>Coal RDF Dry Wood</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Higher</td>
<td>--</td>
</tr>
<tr>
<td>D. Single Pass Boiler</td>
<td>Greater than 100</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Higher</td>
<td>--</td>
</tr>
</tbody>
</table>

Notes:
1. These costs vary considerably with size and scope. Generally, the lowest price per pound of steam corresponds to the larger capacity unit and vice versa.
2. System efficiencies vary directly with fuel, particularly moisture. All assume flue gas recovery through use of economizer and/or air preheater.
3. All of these boilers can be installed with full or partial capacity gas and/or #2-#6 oil burners.
### TABLE-2

**TYPICAL SOLID FUEL SYSTEMS AND SYSTEM ECONOMICS**

<table>
<thead>
<tr>
<th>Size (PPH)</th>
<th>Avg. Steam Load (PPH)</th>
<th>Design Operating Pressure (PSIG)</th>
<th>Fuel Types Equipment</th>
<th>Fuel # Silos # Days Capacity</th>
<th>Fuel Winterside Auxiliaries</th>
<th>Construction Labor Location</th>
<th>Air Pollution Equipment</th>
<th>Capital Cost ($Million)</th>
<th>After tax Payback (Yrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30,000</td>
<td>21000</td>
<td>250 125</td>
<td>Coal Underfed Stoker</td>
<td>1/11 600</td>
<td>No</td>
<td>Non-Union N. Carolina</td>
<td>Multicycle</td>
<td>1.100</td>
<td>2.7</td>
</tr>
<tr>
<td>45,000</td>
<td>32000</td>
<td>450 400</td>
<td>Coal/Waste Spreader Stoker</td>
<td>1/8.5 500</td>
<td>No</td>
<td>Non-Union N. Carolina</td>
<td>Pulse Jet Baghouse</td>
<td>2.250</td>
<td>3.1</td>
</tr>
<tr>
<td>50,000</td>
<td>38000</td>
<td>250 150</td>
<td>Coal Chain Grate Stoker</td>
<td>1/10 100</td>
<td>No</td>
<td>Non-Union Georgia</td>
<td>Pulse Jet Baghouse</td>
<td>1.950</td>
<td>2.4</td>
</tr>
<tr>
<td>90,000</td>
<td>36000</td>
<td>750 180</td>
<td>Coal Chain Grate Stoker</td>
<td>2/12 350</td>
<td>Yes</td>
<td>Non-Union N. Carolina</td>
<td>Multicycle &amp; Sidestream Baghouse</td>
<td>2.950</td>
<td>2.8</td>
</tr>
<tr>
<td>100,000</td>
<td>72000</td>
<td>350 285</td>
<td>Coal Spreader Stoker</td>
<td>2/10 200</td>
<td>No</td>
<td>Non-Union Alabama</td>
<td>Pulse Jet Baghouse</td>
<td>3.40</td>
<td>2.0</td>
</tr>
<tr>
<td>100,000</td>
<td>80000</td>
<td>750 650/750°F</td>
<td>Plant Refuse Reciprocating Grate Stoker</td>
<td>N/A 100</td>
<td>Yes</td>
<td>Non-Union N. Carolina</td>
<td>Multicycle &amp; Baghouse</td>
<td>6.975 (Note 1)</td>
<td>3.3</td>
</tr>
<tr>
<td>150,000</td>
<td>101000</td>
<td>750 150</td>
<td>Coal Gas/Oil Spreader Stoker</td>
<td>2/10 300</td>
<td>Yes</td>
<td>Non-Union Alabama</td>
<td>Pulse Jet Baghouse</td>
<td>4.450</td>
<td>2.0</td>
</tr>
<tr>
<td>200,000</td>
<td>200000</td>
<td>700 650</td>
<td>Coal Gas/Oil Spreader Stoker</td>
<td>1/8 150</td>
<td>No</td>
<td>Merit Shop West Virginia</td>
<td>Pulse Jet Baghouse</td>
<td>5.875</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Note:** 1. This system is a full cogeneration project with a 2800 KW synchronous generator and back pressure turbine.
WOOD AND COAL HANDLING SYSTEMS

Bill Pennington
Assistant Manager
Wood Products Division
Simons-Eastern Company

presented at
WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
COAL AND WOOD ENERGY SYSTEMS
ECONOMIC ANALYSES

by

Thomas F. McGowan
Dr. B.S. Dixit
Senior Research Engineers
Wood Energy Systems Branch
Georgia Institute of Technology

presented at

WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
WOOD ENERGY SYSTEMS
ECONOMIC ANALYSIS

INTRODUCTION

Wood and coal systems are receiving widespread attention for industrial use. In Georgia, wood has been used most widely in many forest product industries where wood waste is available as a by-product. Coal use, on the other hand, was nearly abandoned until recently. However, rising conventional fuel costs have made wood and coal strong candidates for replacing conventional natural gas and oil in many industries.

The factors that enter into the economics of installation of wood and coal (hereafter referred to as solid fuels) systems are varied and complex. Important factors include costs of solid fuels, conventional fuel to be replaced, and capital cost of the equipment. Previous studies indicate that solid fuel systems are capital intensive but the overall savings, based on current fuel prices, can be significant.

In this paper the economic feasibility of using a solid fuel fired system will be illustrated by performing an economic analysis on a typical system for installation in an existing plant—a case study example. Specifically, the analysis will focus on items such as the expected savings in fuel costs, payback period, and possible accumulated savings over the life of the equipment.

Important factors that enter into the economic analysis and the effects of their variations on cost savings and payback will be discussed.

ECONOMIC CONSIDERATIONS

The economic feasibility of a solid fuel system depends heavily on the following factors:

- Present and future costs of solid fuels and conventional fuels
- Capital costs
- Availability of solid fuels
Availability of space for fuel storage
- Extent of energy utilization
- Type of conventional fuel (oil or gas)

These factors are interrelated and vary in importance. An analysis of costs indicates that fuel costs constitute a major item of the annual costs of both the solid fuel and the conventional systems. The savings resulting from the use of solid fuels depends on the relative costs of solid fuels and conventional fuels, the size of the system, and its utilization. Figure 1 shows the relative costs of the gas, oil, coal and wood fuel per MCF (thousand cubic feet) of steam delivered for various selling prices taking into account conversion efficiencies.

Also, another important factor for the consideration of solid fuel systems is the availability of space. Solid fuel systems occupy a large amount of space for the boiler and storage. This requirement places a constraint on the design and cost of the system. Other considerations are included in the discussion below on various costs.

**Fuel Costs**

The prices of solid fuels and conventional fuels and the availability of solid fuels depend on site specific conditions. Wood fuel is usually available in the form of sawdust, bark, planer shavings, whole tree chips, or wood pellets with varying moisture content and density. The type of wood and its moisture content affect the efficiency and selection of the appropriate combustion unit.

Coal also varies in properties. However, for small to medium size industrial plants, low sulfur coal sized to conform to stoker requirements is the norm, and pricing is competitive.

Similarly, the costs of conventional fuels per unit of energy delivered depend on the selling price and efficiencies of the associated systems. Whether the existing fuel is oil, gas, or both gas and oil used in various proportions during the year significantly affect the economics.
Figure 1

UNIT FUEL COST vs. COST OF HEAT

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Heat Value</th>
<th>Boiler Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 2 Oil</td>
<td>140,000 Btu/gal</td>
<td>80%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1,000 Btu/ft²</td>
<td>80%</td>
</tr>
<tr>
<td>Coal</td>
<td>12,000 Btu/lb</td>
<td>80%</td>
</tr>
<tr>
<td>Wood Chips (50% Moisture)</td>
<td>4,000 Btu/lb</td>
<td>-65%</td>
</tr>
</tbody>
</table>

OIL $/GAL 0.70 0.80 0.90 1.00 1.10 1.20
GAS $/MCF 3.00 3.80 4.60 5.40 6.20 7.00
WOOD $/TON 5.0 10.0 15.0 20.0 25.0 30.0
COAL $/TON 20.0 35.0 50.0 65.0 80.0 95.0

UNIT FUEL COST TO DELIVER 1,000 LBS OF STEAM vs. UNIT FUEL COST
Capital Costs

The capital costs depend on the size and type of solid fuel systems and include the costs of the boiler or other combustion unit, the fuel handling equipment and storage, and buildings. The cost also depends on site specific conditions such as the use of existing buildings, stack, and boiler feed pumps. In some instances, the use of in-house engineering staff and labor during the design and installation phases of the project might reduce the cost of the system. In general, the costs of solid fuel systems vary with the size of the system, and they are sensitive to economies of scale.

In arriving at the investment costs for a given plant, federal energy tax credits should be taken into account since they reduce the investment costs and payback period considerably. Currently, a 10% credit is available for all capital investments, and an extra 10% is available for systems utilizing biomass.

Operating and Maintenance Costs

The operating and maintenance costs for the solid fuel system include the cost of electricity for running the electric motors for pumps, fuel handling equipment, fans, and emission control equipment. These costs depend on the type and size of the plant and its utilization. Labor costs depend on the degree of automation provided within the equipment and on the size of the equipment. It is difficult to determine the exact amount of labor that should be charged to any boiler plant because a maintenance technician or boiler attendant would frequently be doing other jobs in addition. Based on visits to plants and discussions with plant managers, a six hour equivalent per shift is used as a basis for labor costs for this case study. Maintenance and repair costs usually range from 1% to 5% of the capital costs of the equipment and may increase slightly with the age of the equipment. In general, these costs are relatively higher than those associated with conventional systems.
Taxes

Taxes include property taxes and insurance. In many industries, these taxes are based on the value of the entire industrial plant. In general, they constitute a small percentage of the capital costs. Federal and state income taxes influence the payback period but they depend on the internal accounting procedure that exists within an organization.

CASE STUDY--ECONOMIC ANALYSIS

There are three types of cases that influence the economic analyses of solid fuel systems:

1) Installation of a new solid fuel system rather than a new conventional system
2) Replacement of an existing conventional system with a new solid fuel system
3) Conversion of an existing system to solid fuel burning by a modification of the existing boiler or other process heating system

The economics associated with each one of these cases would vary because the costs involved would be different. In the following case study example, a Type 2 case is considered.

An industrial firm using steam from its existing boilers for process and space heating is chosen for this study. For performing the analysis, the following data has to be collected:

- Description of existing boilers--size, capacity, pressure, temperature, efficiency, and other information on the related components
- Steam demand--hourly, daily, monthly, seasonal, cyclical or other patterns
- Energy consumption figures
- Types of fuel and costs
o System efficiency
o Operating and maintenance costs
o Labor costs
o Solid fuel availability and cost--type and quantity available in the area
o Plot plan--space availability for the system
o Future plans for expansion
o Environmental restrictions

This information will be used to design the system and calculate the various costs.

Solid Fuel System

The designed solid fuel system (Figure 2) for this study consists of the following components:

800 hp (27,600 lbs/hr steam) boiler for medium pressure saturated steam, with all necessary auxiliaries and emission control, storage silo with fuel infeed-outfeed and unloading arrangement, conveyor to boiler, fuel receiving platform or pit, receiving hopper and front end loader.

Estimated cost of the complete system:

Annual costs: The computed annual costs of the solid fuel systems are based on the following conditions:
<table>
<thead>
<tr>
<th></th>
<th>Wood</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Cost System:</td>
<td>$800,000</td>
<td>$750,000</td>
</tr>
<tr>
<td>Adjusted Capital Cost of the System:</td>
<td>640,000</td>
<td>675,000</td>
</tr>
<tr>
<td>(allowing for federal tax credits - 20% for wood, 10% for coal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest Rate:</td>
<td>14%</td>
<td>14%</td>
</tr>
<tr>
<td>Life:</td>
<td>20 years</td>
<td>20 years</td>
</tr>
<tr>
<td>Fuel:</td>
<td>Sawdust, bark, whole tree chips</td>
<td>Low sulfur coal</td>
</tr>
<tr>
<td>Fuel Cost:</td>
<td>$10/ton (@ 50% moisture)</td>
<td>$45/ton</td>
</tr>
<tr>
<td>Moisture Content:</td>
<td>50%</td>
<td>N/A</td>
</tr>
<tr>
<td>Heat Value:</td>
<td>4,000 Btu/lb</td>
<td>12,000 Btu/lb</td>
</tr>
<tr>
<td>Bulk Density:</td>
<td>20-24 lb/cu-ft</td>
<td>45-60 lb/cu-ft</td>
</tr>
<tr>
<td>System Eff.:</td>
<td>65%</td>
<td>80%</td>
</tr>
<tr>
<td>Capacity:</td>
<td>800 hp</td>
<td>800 hp</td>
</tr>
<tr>
<td>Load Factor:</td>
<td>75%</td>
<td>75%</td>
</tr>
<tr>
<td>Hours of operation:</td>
<td>7200 hrs/yr</td>
<td>7200 hrs/yr</td>
</tr>
</tbody>
</table>
TYPICAL SOLID FUEL BOILER PLANT LAYOUT

Figure 2
Existing System

Capital: No amortization (capital is completely paid)
Conventional fuel usage: 85% natural gas, 15% No. 2 fuel oil
Average efficiency: 80%
Heat value of No. 2 oil: 140,000 Btu/gal
Heat value of natural gas: 1,000 Btu/ft³
Fuel prices: Natural gas @ $5.00/1,000 ft³
No. 2 oil @ $0.90/gal

Using these conditions, the various costs were calculated and are shown in Table 1. Based on the costs listed in Table 1, the payback period after allowing for amortization, is about 2 years when solid fuel is used to replace 85% gas and 15% oil in the existing system at current prices ($0.90/gallon of oil, and $5.00/MCF of gas). The various costs were calculated for a given set of conditions, data and assumptions used in the analysis. However, some of these costs can vary and would influence the savings.

The capital cost of the equipment was based on current equipment costs provided by manufacturers and can vary depending on the system design, additional equipment or other options, instrumentation and other site specific conditions. Similarly, the operating costs (which include the costs of electricity, labor, maintenance, and repair) can vary to some extent within a region and across the nation. But when the system is operating at or near full capacity, these costs do not influence the savings to a great extent.

By far the greatest influence on the expected savings is exerted by the fuel costs—conventional and solid fuels. For instance, a 25% increase in the price of solid fuel would reduce the savings by about 15% for the given systems, other conditions being the same. On the other hand, a 25% increase in the cost of conventional fuels—gas and oil being used under the same proportions and other conditions remaining the same—would increase the expected savings by about 50%.

The effects of the cost of coal, wood, oil and gas, and percent utili-
TABLE 1
ANNUAL COAL, WOOD, AND EXISTING SYSTEM COSTS

<table>
<thead>
<tr>
<th></th>
<th>Coal Fired System</th>
<th>Wood Fired System</th>
<th>Existing System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Cost of Capital</td>
<td>$101,900</td>
<td>$96,600</td>
<td>$</td>
</tr>
<tr>
<td>(Amortization)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Electricity, gasoline for front end loader, etc.)</td>
<td>27,400</td>
<td>29,200</td>
<td>16,300</td>
</tr>
<tr>
<td>Labor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Maintenance, front end loader, etc.)</td>
<td>33,200</td>
<td>35,400</td>
<td>11,700</td>
</tr>
<tr>
<td>Maintenance &amp; Repair, Water Treatment</td>
<td>19,900</td>
<td>21,200</td>
<td>15,600</td>
</tr>
<tr>
<td>Property Taxes &amp; Insurance</td>
<td>7,400</td>
<td>7,800</td>
<td>7,000</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>349,300</td>
<td>286,600</td>
<td>971,500</td>
</tr>
<tr>
<td>TOTAL ANNUAL COSTS</td>
<td>$539,100</td>
<td>$476,800</td>
<td>$1,022,100</td>
</tr>
</tbody>
</table>

Coal Savings/year = $1,022,100 - $539,100 = $483,000

Wood Savings/year = $1,022,100 - $476,800 = $545,300
<table>
<thead>
<tr>
<th>Results</th>
<th>COAL</th>
<th>WOOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) a) net annual savings after allowing for amortization</td>
<td>$483,000</td>
<td>$545,300</td>
</tr>
<tr>
<td>b) Payback period (approximate)</td>
<td>2 years</td>
<td>2 years</td>
</tr>
<tr>
<td>c) Present worth of savings over the life of the equipment</td>
<td>$3,200,000</td>
<td>$3,600,000</td>
</tr>
<tr>
<td>2) Fuel Requirements =</td>
<td>7,760 tons/year</td>
<td>28,650 tons/year</td>
</tr>
<tr>
<td>=</td>
<td>20-35 tons/day</td>
<td>80-130 ton/day</td>
</tr>
<tr>
<td>=</td>
<td>1-2 truckloads</td>
<td>4-6 truckloads</td>
</tr>
<tr>
<td></td>
<td>day</td>
<td>day</td>
</tr>
</tbody>
</table>
zation on the payback period, the total costs and savings can be observed in Figure 3 and 4. The data for these curves are based on the calculations and assumptions for the 800 hp system. In Figure 4, the operation costs are assumed to be directly proportional to utilization and specific cases may depart slightly from this model. Figures 3 and 4 emphasize that the economics of solid fuel systems are enhanced by higher conventional fuel prices and increased percent utilization (and load factor), whereas rising solid fuel prices would have adverse affects.

Summary

The analysis presented here is not comprehensive and does not include the effects of all variables and conditions. An 800 hp system was used as an example for this study. However, a few general conclusions can be drawn here and they would be valid for other systems also.

a) Solid fuel systems are economically feasible at current gas, oil, wood and coal fuel prices
b) The prospects of feasibility are greatly enhanced if the energy consumption by the plant is intensive
c) Its feasibility in any given location should be examined by a consideration of all of the factors and site specific conditions before a decision is taken to install a solid fuel system
Figure 3

PAYBACK PERIOD SENSITIVITY TO FUEL COST

NOTES:
* BEFORE TAX
* ASSUMES $5.00/MCF
  NATURAL GAS PRICE

UNIT FUEL COST ($/TON)
Figure 4

SENSITIVITY OF ANNUAL COSTS TO UTILIZATION

TOTAL ANNUAL COST, $1000

TOTAL COST - GAS BOILER SYSTEM

TOTAL COST - SOLID FUEL SYSTEM

FUEL COST

COAL $45/TON

WOOD $10/TON

FIXED COST

OPERATING COST

PERCENT UTILIZATION
FINANCING ALTERNATIVES

Alfred W. Swann, Jr.
Senior Group Vice-President
Wholesale Banking
Bank South

presented at
WOOD AND COAL FOR
INDUSTRY’S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
FINANCING ALTERNATIVES

I. CONVENTIONAL

II. INDUSTRIAL DEVELOPMENT BOND

III. LEASING
CONVENTIONAL LOAN

- Most common method of borrowing
- Usually requires 20% downpayment
- Term of loan structured in accordance with the life of the equipment
- Liquidity is reduced by amount of downpayment
- Increases fixed assets
- Increases short term & long-term debt
- Investment tax credit
- Interest & depreciation are recorded in the expense section of the income statement
- Interest rate is prime & above
- Fixed rate may be quoted, depending on value of collateral, amount of downpayment, and financial strength of borrower
### BEFORE PURCHASE OF EQUIPMENT

**BALANCE SHEET**

<table>
<thead>
<tr>
<th>Account</th>
<th>Amount</th>
<th>Account</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASH</td>
<td>350</td>
<td>NOTES PAYABLE</td>
<td>1500</td>
</tr>
<tr>
<td>RECEIVABLES AND INVENTORY</td>
<td>5000</td>
<td>ACCOUNTS PAYABLE</td>
<td>1900</td>
</tr>
<tr>
<td>CURRENT ASSETS</td>
<td>5350</td>
<td>CURRENT PORTION OF LTD</td>
<td>350</td>
</tr>
<tr>
<td>FIXED ASSETS</td>
<td>5000</td>
<td>ACCRUALS</td>
<td>650</td>
</tr>
<tr>
<td>TOTAL ASSETS</td>
<td>10350</td>
<td>CURRENT LIABILITIES</td>
<td>4400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LONG-TERM DEBT</td>
<td>2500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TOTAL LIABILITIES</td>
<td>6900</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EQUITY</td>
<td>3450</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TOTAL LIABILITIES &amp; EQUITY</td>
<td>10350</td>
</tr>
</tbody>
</table>

**NOTES:** Figures in Thousands  
Debt/Worth 2:1  
Working Capital 950  
Interest is 15%  
Depreciation is 10%
ASSUME $2000 PURCHASE OF EQUIPMENT
100% FINANCING OVER 10 YEAR TERM

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BALANCE SHEET</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CASH</td>
<td>350</td>
<td>NOTES PAYABLE</td>
</tr>
<tr>
<td>RECEIVABLES AND</td>
<td></td>
<td>ACCOUNTS PAYABLE</td>
</tr>
<tr>
<td>INVENTORY</td>
<td>5000</td>
<td><strong>CURRENT PORTION OF</strong></td>
</tr>
<tr>
<td>CURRENT ASSETS</td>
<td>5350</td>
<td>LTD</td>
</tr>
<tr>
<td>*FIXED ASSETS</td>
<td>7000</td>
<td>ACCRUALS</td>
</tr>
<tr>
<td>TOTAL ASSETS</td>
<td>12350</td>
<td>CURRENT LIABILITIES</td>
</tr>
<tr>
<td><strong>LONG-TERM DEBT</strong></td>
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<td></td>
</tr>
<tr>
<td>TOTAL LIABILITIES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EQUITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL LIABILITIES &amp;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EQUITY</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:** Figures in Thousands
Debt/Worth 2.6:1
Working Capital 750
### BEFORE PURCHASE OF EQUIPMENT

#### INCOME STATEMENT

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SALES:</strong></td>
<td>40000</td>
<td>100%</td>
</tr>
<tr>
<td>Cost of Sales</td>
<td>32000</td>
<td>80%</td>
</tr>
<tr>
<td>Gross Profit</td>
<td>8000</td>
<td>20%</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXPENSES:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General and Administrative</td>
<td>3650</td>
<td></td>
</tr>
<tr>
<td>Depreciation</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Interest</td>
<td>650</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL EXPENSES</strong></td>
<td>4800</td>
<td>12%</td>
</tr>
<tr>
<td><strong>PRE-TAX PROFIT</strong></td>
<td>3200</td>
<td>8%</td>
</tr>
</tbody>
</table>
ONE YEAR AFTER PURCHASE OF EQUIPMENT
ASSUME NO OTHER CHANGES

SALES:
- Cost of Sales: 32000 (80%)
- Gross Profit: 8000 (20%)

EXPENSES:
- General and Administrative: 3650 (9%)
- Depreciation: 700 (2%)
- Interest: 934 (2%)

TOTAL EXPENSES: 5284
PRE-TAX PROFIT: 2716

DOES THE MACHINERY JUSTIFY THE EXPENSE?

NOTES: Figures in Thousands
$2,000 for 10 years @15%
IDB FINANCING

- Industrial development bonds are usually unrated issues backed by the credit of a company that is not known in the public markets.

- Banks analyze and administer IDBs as term loans.

- Most banks require an equity contribution of between 10% and 30%.

- Because of the high cost of issuance, IDBs are rarely used to finance projects smaller than $500,000.

- Issuance expenses cease to be a major cost factor in projects exceeding $1,000,000.

- Most banks require the project assets be pledged as collateral for the bonds.

- As in most long-term loan agreements, various financial covenants such as debt to worth, minimum net worth, and current ratio minimums may be specified.

- Most IDB issues are in the seven to ten year range.

- Most IDBs are done as floating rate issues in the general range between 70% and 80% of prime.

- Many banks will charge an up-front fee to offset the bank's expense in arranging to purchase the bond.

- The financial statements do not differ from the Conventional Loan example.

- The 1984 tax law has restricted the availability of IDB financing.
LEASING ALTERNATIVES

WHO CAN LEASE?

Any individual, partnership, corporation, subchapter S corporation or trust may be a lessee under a lease agreement. The user of the equipment is the lessee.

WHAT TYPES OF EQUIPMENT QUALIFY?

All "Section 38 property" - which is to say most depreciable property classified as recovery property; having a useful life of three years or more such as:

- Machine tools and other industrial equipment
- Construction equipment
- Trucks, tractors and trailers
- Marine and fishing vessels
TYPES OF LEASES

- Operating Lease
- Capital Lease
- Leveraged Lease
- Finance Lease
OPERATING LEASE

- An Operating Lease is the simplest type of lease to account for since a lessee only has to expense the rentals.
- Tax benefits of ownership lessor only.
- Impact on user is rental expense.
- The equipment is footnoted in the asset portion of the balance sheet.
### OPERATING LEASE

<table>
<thead>
<tr>
<th>INCOME STATEMENT (Before)</th>
<th>o</th>
<th>INCOME STATEMENT (After)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SALES:</strong></td>
<td></td>
<td><strong>SALES:</strong></td>
</tr>
<tr>
<td>Sales</td>
<td>40000</td>
<td>Cost of Sales</td>
</tr>
<tr>
<td>Cost of Sales</td>
<td>32000</td>
<td>Cost of Sales</td>
</tr>
<tr>
<td>Gross Profit</td>
<td>8000</td>
<td>Gross Profit</td>
</tr>
</tbody>
</table>

<table>
<thead>
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CAPITAL LEASE

A Capital Lease must have one or more of the following characteristics:

(1) A bargain purchase option

(2) Transfer of ownership of the property to the Lessee by the end of the lease term

(3) A term equal to 75% or more of the estimated economic life of the property

(4) 90% or more recovery of the fair value of the property through the present valuation of minimum lease payments

In a Capital Lease, the lessee records the asset on his books as though it were purchased. A corresponding liability, equal to the present value of the lease payments, is also recorded.

Each month, the asset is amortized in accordance with the Lessee's normal depreciation procedure and the liability is reduced and expensed according to the "interest method." In other words, it's as though the asset were bought and financed with debt.

For tax purposes, there is no balance sheet consideration, and monthly rentals are fully expensed.
LEVERAGED LEASE

A Leveraged Lease is one in which the lessor borrows money from one or more separate lenders to purchase the asset. Under IRS guidelines, the lessor's minimum investment must be 20% of the asset cost.

- From user's perspective same as an operating lease.
- Three parties involved in a leveraged lease:
  1. Lessee
  2. Equity Participant (at least 20%)
  3. Debt Participant
- Substantial tax benefits to the equity participant.
- Legally complex = expense. Usually used for large transactions.
FINANCE LEASE

The Finance Lease was created to allow for greater flexibility on the part of lessees and lessors in determining what equipment can be leased and how it may be purchased at the end of the lease period. This will be a significant benefit to many firms especially those that need the cash flow benefits of leasing, but want to eventually own the equipment for a pre-determined price.

- A Finance Lease may be done for special use, "limited use" equipment.

- A Finance Lease may contain a fixed price purchase option as low as 10% of equipment cost.

- A Finance Lease may be initiated anytime up to 90 days after equipment goes into service.
Most Industrial Development Bonds are unrated issues backed by the credit of a company that is not known in the public markets; they are not handled as investments by the banks that are purchasing the bonds. Most IDB's are analyzed and administered as term loans. Just like any loan, the terms and structure are negotiated between the bank and the customer. While there are many aspects to the term and structure of the loan, there are some features which are typically found in IDB's as a result of the nature of the obligation or through legal requirement.

The amount to be financed may be as high as 100% of the cost of the project, although most banks will require an equity contribution of between 10% and 30%. In addition to the cost of the depreciable assets, the cost of the issuance of the bond may also be financed. The size of this issuance cost is an important consideration in determining the economic feasibility of using IDB financing for a particular project. Because of the high cost of issuance, IDB's are rarely used to finance projects smaller than $500,000. If the documentation can be kept fairly simple, projects between $500,000 and $1,000,000 can normally be cost justified. Issuance expenses cease to be a major cost factor in projects exceeding $1,000,000.

Most banks require the project assets be pledged as collateral for the bonds. Depending on the nature of the project and the creditworthiness of the borrower, additional collateral may be required. In the case of a closely held company, personal guarantees may be required. As in most long term loan agreements, various financial covenants such as debt to worth, minimum net worth, and current ratio minimums will be specified.

Because of the credit risk and rate risk inherent in longer term obligations, banks usually try to minimize the term of IDB's. Most issues are in the seven to ten year
range. Various techniques can be employed to stretch the average maturity of the obligation. One technique is to employ a 15 to 20 year amortization schedule with a balloon payment of the remaining principal at year ten. Another technique which has seen wider application in recent years is the use of what is commonly referred to as a "call". This mechanism, more accurately referred to as a "put", enables the bank to require the customer to buy back the bond at some interim point in the life of the bond. This put is exercised at the bank's discretion. A typical use of this mechanism might be to provide for a call at year five on a ten-year bond. Thus, if at year five, the creditworthiness of the borrower had deteriorated, if interest rates had moved against the bank, or if the customer had failed to maintain a broadly-based relationship with the bank, then the bank could require the customer to buy the bond back. As a practical matter, the borrower would find another bank willing to purchase the bond, maintaining its status as a tax-free obligation.

Pricing is a critical aspect of the IDB structure. In years past, most banks were willing to provide fixed rate financing under IDB's. As bank's cost of funds have generally escalated and fluctuated widely from time to time, fixed rate lending has been discouraged. Most IDB's are now done as floating rate issues which are priced at a percent of prime. The present general range is between 70% and 80% of prime. (Beware of lower rates with greater fees or points.) Some interest rate protection may be afforded in the form of "caps and floors" or maximum and minimum rates that will be charged over the life of the bond. Many banks will charge an up-front fee to offset the bank's expense in arranging to purchase the bond. These fees range between a quarter of a percent and one percent of the total issue.
LEASING ALTERNATIVES

WHO CAN LEASE

Any individual, partnership, corporation, subchapter S corporation or trust may be a lessee under a lease agreement. The user of the equipment is the lessee. He leases from the lessor.

WHAT TYPES OF EQUIPMENT QUALIFY

All "Section 38 property"—which is to say most depreciable property classified as recovery property; having a useful life of three years or more such as:

* machine tools and other industrial equipment
* construction equipment
* trucks, tractors, and trailers
* marine and fishing vessels

Special use, or "limited use," property is not eligible under the IRS guidelines.

TAX-ORIENTED LEASE

A tax-oriented (or "true") lease transfers the use of investment tax credits (ITC) and depreciation from the user of the equipment (lessee) to the owner (lessor) in return for lower payments.

Many companies cannot use all or part of the tax benefits they would earn by purchasing equipment. For them, a tax-oriented lease makes surplus tax benefits on new and used equipment usable by allowing them to be claimed by a lessor in return for lower monthly rentals.

NON-TAX ORIENTED LEASE

If a lease is non-tax-oriented the tax benefits are not transferred, i.e. the user of the equipment may use the ITC and depreciation to reduce his taxes, but may not deduct the entire rental payment (only the "interest portion"). On a lessee's tax return a non-tax-oriented lease is treated like a loan, and consequently the payments are usually higher than in a tax-oriented lease.

On the other hand, a non-tax-oriented lease does not pretend to be a lease for tax purposes, and so does not need to comply with IRS guidelines. Naturally, this allows for much greater
flexibility in structuring such a transaction. For example, a non-tax-oriented lease may contain a nominal purchase option price.

KINDS OF TAX-ORIENTED LEASES

A tax-oriented lease—one in which the lessor is allowed to use the tax benefits—may be either a capital lease or an operating lease for book reporting purposes as defined in the FASB Statement No. 13 published by the Financial Accounting Standards Board.

According to FASB 13, a capital lease must have one or more of the following characteristics:

1. a bargain purchase option
2. transfer of ownership of the property to the lessee by the end of the lease term
3. a term equal to 75% or more of the estimated economic life of the property
4. 90% or more recovery of the fair value of the property through the present valuation of minimum lease payments

A lease which does not exhibit any of these characteristics is an operating lease.

OPERATING LEASE

An operating lease is the simplest type of lease to account for since a lessee only has to expense the rentals. There is no necessity to add the asset to the balance sheet (other than footnoting the amount of firm lease rental obligations in the notes to the financial statements).

CAPITAL LEASE

In a capital lease, the lessee records the asset on his books as though it were purchased. A corresponding liability, equal to the present value of the lease payments, is also recorded.

Each month, the asset is amortized in accordance with the lessee's normal depreciation procedure and the liability is reduced and expensed according to the "interest method". In other words, it's as though the asset were bought and financed with debt.

For tax purposes, of course, there is no balance sheet consideration, and monthly rentals are fully expensed.
LEVERAGED LEASE

A leveraged lease is one in which the lessor borrows money from one or more separate lenders to purchase the asset. Under IRS guidelines, the lessor's minimum investment must be 20% of the asset cost.

While leveraging the potential return to the lessor and perhaps providing lower rentals to the lessee, a leveraged lease is usually a very complex transaction involving several parties, the establishment of multiple trusts, high legal expense, and substantial documentation. As a result, it is generally used only for very large transactions.

FINANCE LEASE

The tax code allows a new type of leasing to take place after 1/1/84. A Finance lease generally contains the same restrictions as a Guideline lease, with the exceptions that:

1. A Finance lease may be done for special use, or "limited use," equipment.
2. A Finance lease may contain a fixed price purchase option as low as 10% of equipment cost.
3. A Finance lease may be initiated anytime up to 90 days after equipment goes into service.

The Finance lease was created to allow for greater flexibility on the part of lessees and lessors in determining what equipment can be leased and how it may be purchased at the end of the lease period. This will be a significant benefit to many firms especially those that need the cash flow benefits of leasing, but want to eventually own the equipment for a predetermined price.

CASH FLOW

"Cash flow" is the normal flow of cash in and out of your business. Increasing cash flow may simply mean reducing payments. A lease can help do just that because the payments (or "rentals") are usually less than normal debt financing payments.

Whether a lease has fixed monthly payments or payments that are tied to an interest rate index, its overall effective rate should be less than current loan rates if tax benefits are properly utilized. This represents a real cash savings on a monthly basis.
Often leasing companies assume that the equipment will have a residual resale value at the end of the lease, and reduce the monthly payments accordingly.

**A COMPANY'S TAX STATUS AFFECTS THE LEASE-BUY DECISION**

Companies in capital intensive industries or industries where depletion or similar tax reduction benefits are prevalent often find that all of the tax benefits resulting from equipment purchases cannot be used. For such companies leasing makes sense. On the other hand, if a company does not have sufficient deductions to apply against its income and is in a high tax bracket, a non-tax-oriented lease, where the lessee keeps the tax benefits or loan financing should be considered.

Consider your company's ability to use all of its tax benefits in the future. Forecast your operating income as well as your capital expenditures to determine whether your best choice is to keep and use your tax benefits, or to use them to reduce financing costs through leasing.

**BALANCE SHEET CONSIDERATIONS AFFECT THE LEASE-BUY DECISION**

The lease-buy decision is affected by the financial position of your business. Some companies need to reduce their balance sheet debt and improve their financial ratios to preserve overall borrowing capacity, while others have loan covenants prohibiting additional debt. The debt-to-equity level is closely monitored by banks in determining credit worthiness and the cost of credit.

An Operating lease reduces your balance sheet debt, compared with debt financing, because you do not report the lease obligation as a liability. This is similar to the rent paid for office space.

At the very least an operating lease with a leasing company represents an additional source of capital and preserves credit lines at your primary bank.

**ITC**

The Investment Tax Credit (ITC) is a direct credit against federal income taxes ranging from 6% to 10% of the cost of the new equipment.

Because of inflation and the time value of money, ITC that must be carried forward (used in future years) is worth less than it would be if it saved this year's tax dollars. A lease agreement which gives such credits to the lessor not only sidesteps the diminishing value problem but can result in substantial cash savings via lower monthly lease payments—a direct impact in today's dollars.
LEASE PAYMENTS

Lease payments may be fixed or floating, paid in advance or in arrears, and even occur at irregular intervals.

Most leases are written with regular monthly or quarterly payments, although this is not a requirement.

Floating rate leases may be structured a variety of ways, from payments that fluctuate monthly, quarterly, or annually to fixed payments with periodic adjustments.

A lease may provide for payments to change at predetermined intervals. The lessee, however, is generally required to expense uneven lease payments including advance rental payments for tax purposes as though the lease were written with level payments. This is referred to as "normalizing" rents.

The IRS guidelines do restrict the amount that lease payments may vary from one year to the next. Basically, a 10% spread is allowed above and below the average rental payment. This "uneven rent test" should be checked before entering into a lease agreement.

Leasing is usually 100% financing, with the leasing company purchasing 100% of the asset and leasing it to the lessee with no down payment.

Lessees with limited credit ratings may find that if no down payment is made, additional security is required. Additional security can take the form of advance rentals, a pledge of assets or a bank letter of credit.

Some industries experience predictable seasonable slowdowns due to weather conditions, market conditions or a variety of other reasons. The construction industry is an example. For such business, leases may be arranged with payments due at irregular times, such as monthly from April to November only, in concert with the productive use of equipment.

Take care in calculating the effective rate when irregular payments are involved. Each payment should be discounted the exact number of calendar months it occurs after the start of the lease. Also take into consideration the federal income tax impact of uneven rentals, which must be expensed on an even or "normalized" basis.
ADVANTAGES OF LEASING

1. Frees working capital for more productive uses since leasing provides up to 100% financing.

2. May cost less than other financing alternatives

3. May provide faster tax write-off

4. Avoids restrictions often contained in loan agreements

5. Permits 100% financing (including tax, freight and installation) vs. 75-80% through other methods

6. May not appear as a liability on the lessee's balance sheet thus provided "off balance sheet" financing

7. Does not disturb present bank credit lines

8. Provides a hedge against inflation (equipment is paid for in "cheaper" dollars)

9. Is more flexible in meeting the lessee's needs than conventional financing (longer terms, etc.)

10. Does not dilute ownership or control (as would a sale of common stock or bringing in a new partner to provide necessary funds)

11. Provides a new credit source

12. Book earnings may be higher with a lease

13. Provides fixed rate financing

14. Overcomes capital budget restrictions (lease payments may be expensed in the operating budget)
DISADVANTAGES OF LEASING

1. May be more expensive
2. May provide less attractive tax deductions
3. Gives the residual value of the equipment to the lessor
4. May reduce flexibility to dispose of obsolete equipment
5. Creates a fixed obligation the lessee must meet
6. Lessee loses "pride of ownership" in the equipment
AIR POLLUTION CONTROL

Raymond M. Warren, Jr.
President and Owner
Warren Engineering, Inc.

presented at
WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
AIR POLLUTION CONTROL

INDUSTRIAL COAL AND WOOD FIRED BOILERS

Since the Federal 1967 Clean Air Act, air pollution control of emissions from coal and wood fired boilers has made major advances in both the techniques of operation and the technology of design of air pollution control equipment. Even though there is still need for further advances, we can now select system equipment with almost certain assurance of results and can almost predict capital, maintenance and operational costs. The purpose of this paper is to present an overview of the current state of the art for air pollution control of industrial coal and wood fired boilers.

Air pollutants from coal and wood fired boilers are shown in Figure 1 along with their major cause.

Opacity is usually associated with poor combustion and can be best controlled by the three T's of combustion--Time, Temperature and Turbulence; in other words, the fuel and the air properly mixed in a furnace of sufficient size and held at combustion temperature for a sufficient time to complete combustion prior to the gases entering the colder regions of the boiler unit.

Particulate (fly ash) is caused by many factors, the principle of which includes the ash content of the fuel being fired, the rise velocity of the gases within the furnace and the method of firing or stoking. An underfeed type of stoker will cause less fly ash to be carried out of the furnace and hence out of the boiler unit than a spreader type of stoker unit--a spreader less than suspension burning.

The size of the particulate particles generated within the furnace is a function of the size of the inorganic ash associated with the fuel and greatly effects the cleaning of the contaminated exhaust gases of this particulate. Wood waste firing will generate a bi-modal sized distribution of fly ash. One mode will be the unburned wood particles known as bark char while the other mode will be the dirt or sand contaminating the wood waste. These two modes have difference specific gravities (.22 and 2.2, respectively) and demand special attention in air pollution control equipment selection. Coal firing particulate varies in size distribution with the method of firing.

Sulfur dioxides are directly proportional to the sulfur content of the fuel. It is usually assumed that all of the sulfur within the fuel is converted to sulfur oxides unless some attempt is made to combine the sulfur with a capturing chemical within the initial burning zone. Examples of this technology are the fluid bed burning system with limestone additives.

Nitrous oxides are formed in the high temperature combustion zone of the furnace and are a function of the nitrogen bound content of the fuel, the moisture content of the fuel, the combustion air temperature and the amount of excess air in the combustion zone. The design for control of nitrous oxides is generally placed with the stoker and the boiler manufacturer who use certain techniques of air distribution and staged combustion to minimize their formation.
Some coal and wood waste may be contaminated with organic chemicals which have been added for various reasons and which will cause hydrocarbon emissions from the boiler unit if the hydrogen and carbon is not properly oxidized within the combustion process. Southern pine bark and wood contains resins which will produce hydrocarbons without proper combustion within the boiler furnace.

It is common practice to utilize a solid fuel fired industrial boiler as an incinerator to destroy undesirable industrial waste products. Caution should be taken as to what these waste products might produce within the combustion process and what effect they may have on the boiler outlet emissions and the performance of the air pollution control equipment.

The best available control technology for boiler pollutants is shown in Figure 2.

The selection of a premium fuel, one with low ash, sulfur and nitrogen content, is best but must be considered with economic justification. Wood waste fired boiler fuel selection seldom has the opportunity to select premium fuel and must be content with what is generated or what is available.

The selection of stoker, furnace and combustion control equipment is extremely important in containing the fuel producing pollutants within the burning zone and reducing the quantity of pollutants to the air pollution control equipment. The temperature and turbulence of combustion is extremely important in the selection of the combustion air quantity, quality and location.

Good operation is simply a function of a conscientious and trained boiler operator provided with sufficient combustion controls and instrumentation to do his job.

The best of well engineered boiler units cannot perform unless properly maintained.

Air pollution control equipment has now reached a state of the art where we can predict fairly comfortably performance. Air pollution controls for particulate emission control has advanced much more rapidly than those for sulfur oxide emission control.

For sulfur dioxide emission control, industry currently uses five techniques as listed in Figure 3.

The purchase of low sulfur coal limits sulfur dioxide emissions but must be tempered with the availability, economics and possibility that ground level concentrations will steel meet EPA limits.

Modeling studies of the plant site often allow higher sulfur dioxide emissions by increasing stack height for dispersion of the pollutants. Taller stacks have the advantage of a one-time cost with little operational and maintenance yearly costs.

Wet scrubbers/absorbers must either have chemical additives or a once through source of neutralizing water available. Sometimes the transfer of the sulfur to the water poses a water pollution problem.
Dry scrubbers are currently being utilized but are, in this writer's opinion, still in the development stage for reliability and cost effective consideration unless no other alternative exists.

Fluidized bed combustion with a chemical additive is in the early development stages for industrial boiler applications but will certainly become a viable alternative in the very near future for some applications.

Nitrous oxide emission control techniques are shown in Figure 4.

By a combination of selecting the distribution of combustion air holding excess air to a minimum, the boiler/stoker manufacturer can stage combustion, minimize combustion temperature and, therefore, control the emission of nitrous oxides.

In considering particulate emission control, there are some differences between air pollution control equipment selection for wood waste fired boilers as compared to coal fired boilers. Figures 5 and 6 describe the most common selections of air pollution control equipment for each type of firing with possible operational and capital dollar costs and possible outlet emission capabilities. Combination wood/coal fired boiler emissions can be controlled with similar equipment.

Pressure drops are average but will vary somewhat with the quality of fuel and the method of fuel stoking or combustion.

The energy per 10,000 cfm is a close estimate of electrical energy stated in horsepower of the induced draft fan and the auxiliaries of the air pollution control equipment system.

Emissions are stated in lbs/million btu which are achievable with proper selection of both boiler/stoker equipment and air pollution control equipment, and good operation.

The relative costs are "ball park" installed costs for the air pollution control system equipment with ash handling and chemical additive equipment where applicable.

The use of data within these charts is to be tempered with specific job site and fuel conditions and should not be taken as absolute for any given specific application. The intent of the charts is to present current state of the art potentials and to present the alternatives for consideration.

Planning suggestions for your specific need are indicated in Figure 6. All of them are valuable for making correct decisions and each should be utilized to their fullest for Best Available Control Technology at the most economical capital and operating cost.
## AIR POLLUTANTS FROM
### COAL AND WOOD FIRED BOILERS

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<td>FINE PARTICULATES</td>
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<tr>
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<td>MANY FACTORS</td>
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<tr>
<td>SULFUR OXIDES</td>
<td>SULFUR CONTENT OF FUEL</td>
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<td>NITROUS OXIDES</td>
<td>HIGH TEMPERATURE COMBUSTION</td>
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<td></td>
<td>NITROGEN CONTENT OF FUEL</td>
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<td>HYDRO CARBONS</td>
<td>CONTAMINATED FUEL</td>
</tr>
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</table>

**FIGURE 1**
BEST AVAILABLE CONTROL
TECHNOLOGY (BACT) FOR BOILER POLLUTANTS

PREMIUM FUEL - LOW ASH CONTENT
LOW SULFUR CONTENT
LOW NITROGEN CONTENT

EQUIPMENT PROPERLY SIZED - FURNACE VOLUME
GRATE AREA
COMBUSTION AIR DISTRIBUTION

GOOD OPERATION - TRAINED OPERATOR
SUFFICIENT INSTRUMENTS

MAINTAIN SYSTEM - CONTROLS CALIBRATED
AUXILIARIES IN CONDITION

AIR POLLUTION CONTROLS - SELECTION CORRECT
SIZE CORRENT

FIGURE 2
COAL FIRED BOILER
SULFUR DIOXIDE EMISSION CONTROL

PURCHASE LOW SULFUR COAL
INCREASE STACK HEIGHT FOR DISPERSION
WET SCRUBBER/ABSORBER
DRY SCRUBBER WITH CHEMICAL ADDITIVE
FLUIDIZED BED COMBUSTION WITH CHEMICAL ADDITIVE

FIGURE 3

COAL OR WOOD WASTE FIRED BOILER
NITROUS OXIDE EMISSION CONTROL

PURCHASE LOW NITROGEN FUEL
PROPER COMBUSTION AIR DISTRIBUTION
LOWEST POSSIBLE EXCESS AIR
MINIMUM POSSIBLE COMBUSTION TEMPERATURE

FIGURE 4
### Coal Fired Boiler

#### Particulate Emission Control

<table>
<thead>
<tr>
<th>Air Pollution Controls</th>
<th>Pressure Drop (I.W.G.)</th>
<th>Energy/10,000 CFM (HP)</th>
<th>Emission (LB/MM BTU)</th>
<th>Relative Cost</th>
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<td>One Centrifugal Collector</td>
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<td>7</td>
<td>.3</td>
<td>X</td>
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<td>Two Collectors in Series</td>
<td>3+3</td>
<td>14</td>
<td>.2</td>
<td>2X</td>
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<tr>
<td>Collector Plus Scrubber</td>
<td>3+12</td>
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<tr>
<td>Fabric Filter</td>
<td>6</td>
<td>16</td>
<td>.05</td>
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<td>Collector With Side Stream</td>
<td>3+.2(8)</td>
<td>13</td>
<td>.15</td>
<td>5X</td>
</tr>
<tr>
<td>Collector Plus Gravel Bed</td>
<td>3+5</td>
<td>21</td>
<td>.1</td>
<td>8X</td>
</tr>
<tr>
<td>Precipitator</td>
<td>1</td>
<td>5</td>
<td>.05</td>
<td>8X</td>
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<tr>
<td>Electric Assist Scrubber</td>
<td>4</td>
<td>10</td>
<td>.03</td>
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**Figure 5**
WOOD WASTE FIRED BOILER

PARTICULATE EMISSION CONTROL

<table>
<thead>
<tr>
<th>AIR POLLUTION CONTROLS</th>
<th>PRESSURE DROP</th>
<th>ENERGY/10,000 CFM</th>
<th>EMISSION LB/MM BTU</th>
<th>RELATIVE COST</th>
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<tr>
<td></td>
<td>I.W.G.</td>
<td>HP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ONE CENTRIFUGAL COLLECTOR</td>
<td>3</td>
<td>7</td>
<td>.4</td>
<td>X</td>
</tr>
<tr>
<td>TWO COLLECTORS IN SERIES</td>
<td>3+3</td>
<td>14</td>
<td>.3</td>
<td>2X</td>
</tr>
<tr>
<td>COLLECTOR PLUS SCRUBBER</td>
<td>3+6</td>
<td>26</td>
<td>.1</td>
<td>4X</td>
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<tr>
<td>COLLECTOR PLUS FABRIC FILTER</td>
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<td>COLLECTOR WITH SIDE STREAM</td>
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<td>5X</td>
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<tr>
<td>COLLECTOR PLUS GRAVEL BED</td>
<td>3+5</td>
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<td>12</td>
<td>.05</td>
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FIGURE 6
PLANNING SUGGESTIONS

CONSULT STATE AND LOCAL ENVIRONMENTAL PROTECTION AGENCIES
MAKE SURVEY OF YOUR REGION AND INDUSTRY SUCCESSFUL INSTALLATIONS
REQUEST TECHNICAL AND COST INFORMATION FROM EQUIPMENT VENDORS
RETAIN SERVICES OF A QUALIFIED CONSULTING ENGINEER
CONSIDER EXPERIENCED ENGINEER/CONTRACTORS

FIGURE 7
CASE STUDY IN WOOD ENERGY:
THE INTEGRATED PRODUCTS CO.

by

Michael L. Brown
Research Engineer
Energy Conservation Branch
Georgia Institute of Technology

presented at

WOOD AND COAL FOR
INDUSTRY' ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
I. INTRODUCTION

Integrated Products, Inc., a textile firm headquartered in Rome, Georgia, manufacturers yarn for the carpet industry from plants located in Rome, Villa Rica, and Aragon, Georgia. The processing of yarn consumes large quantities of steam for "heat setting," (providing a permanent twist to the yarn), and drying. In April 1980, Integrated Products agreed to participate in a program being conducted by the Georgia Tech Engineering Experiment Station to investigate the utilization of wood waste as an energy source in non-forest product industries. The program, sponsored by the Department of Energy, offered matching funds in an amount of up to $146,000 to help off-set the capital costs of installing a wood energy system. The purpose of the program was to demonstrate the feasibility of using wood as a source of energy in non-forest product related industries.

Integrated Products agreed to participate in the program as a means to reduce the energy and, consequently, product costs at the Aragon plant. While the cost of wood fuel is unquestionably less than conventional fuels, other concerns such as fuel availability, fuel cost escalation, fuel delivery and storage method, equipment operating procedures and maintenance required, and load carrying capabilities are different from those for natural gas and presented significant uncertainties to the firm. This paper is a review of the first three years' operating experience with a wood boiler in a textile plant and an examination of the pre-installation economic analysis to determine if the system achieved desired operational levels and projected payback.
II. WOOD BOILER SYSTEM DESCRIPTION

The existing steam system at Integrated Products consisted of two gas-oil package boilers rated at 350 and 200 hp, respectively. Following the decision to install a wood boiler, planning began on developing an appropriate system design. The initial activity centered on determining what capacity boiler would be appropriate. In sizing the boiler, the existing energy consumption, size, and utilization of the current gas fired boilers, characteristics of steam consuming equipment, and future plans of the company were taken into consideration. The wood boiler selected was to be able to supply all of the plant process heating and space heating requirements with no backup by fossil fuel boilers except in emergencies. Based on these considerations, a 400 hp wood fired boiler was judged to be adequate by engineers at Integrated Products and Georgia Tech.

The wood boiler selected was a horizontal return tube (HRT) boiler designed to produce 13,320 lb/hr of saturated steam (approximately 400 hp) at 150 psi from feedwater at 212°F. It is a firetube boiler, designed to burn sawdust, bark, and chips with a moisture content of up to 50% (wet basis). The boiler has pinhole type fixed grates.

The fuel is fed into the furnace from the metering bin by means of air swept feeders and a variable speed drive unit. Steam pressure sensing controls vary the speed and operation of the metering bin screw conveyor.

A combustion air fan and air duct system supplies combustion air both under and above the grates. Flyash collected under the boiler in a dropout hopper is reinjected to the furnace by a pneumatic system. The boiler is equipped with an induced draft fan and a stack. Particulate emission levels are maintained within allowable levels by two multiclone particulate collectors in series. Particles collected in the primary collector are fed back into the furnace, while those removed by the secondary collector are collected in a drum for disposal.

Other important components of any wood energy system are the fuel handling and storage. Based on a typical wood boiler efficiency of 65% and energy consumption data from previous years, it was calculated that the system
would require approximately 40 tons or 2 truckloads of green wood waste per day. Because of the high cost associated with a hydraulic truck dump and the low use factor, a self-unloading tractor-trailer was selected as the most cost effective delivery method. Wood waste in the form of sawdust and chips is collected at the supplier and transported to the plant. Upon arrival the wood fuel is either unloaded at the open storage area or at the fuel staging area located near the silo. Most of the time the trailer unloads the wood fuel in the fuel staging area.

The fuel staging area is essentially a covered storage shed, with floor dimensions of 55 ft x 35 ft. It can accommodate approximately four truckloads of wood fuel after allowing room for the movement of the front end loader. Trailer unloading time is approximately 15 minutes.

The wood in the fuel staging area is transferred to the receiving hopper by means of a small front end loader. The receiving hopper is approximately 4 ft wide, 8 ft long, and 6.5 ft high, and the fuel received in this hopper is transferred to the storage silo by means of a screw conveyor and bucket elevator. Fuel fed from the silo to the metering bin and from the metering bin to the stokers is accomplished by means of screw conveyors.

Oversized pieces of wood are separated by a vibrating screen located on the top of the receiving hopper. It takes approximately 1 to 1-1/2 hours to transfer one truckload of wood fuel into the silo.

A poured concrete silo, 24 ft diameter x 48 ft high, is used for covered storage. The usable storage capacity of this silo is 14,464 cubic feet which is sufficient fuel for approximately 72 hours of continuous operation when the boiler is at 70% load. An unloading system installed at the bottom of the silo includes revolving chains to prevent bridging of the wood fuel inside the silo.

For long term storage, an open (uncovered) storage area of approximately 6,000 ft\(^2\) of concrete floor is provided. This is sufficient to store wood for approximately 15 days. Long term storage is located at a distance of approximately 200 ft from the boiler house and, therefore, is used only in case of emergency.

The layout of the wood boiler site is shown in Figure 1. The boiler was erected adjacent to the factory outside the existing boiler room. The fuel
Figure 1

INTEGRATED PRODUCTS INC.
Wood-Fired Boiler Plant
staging area, fuel silo, and boiler house were arranged to fit into a "U" shaped space formed by the main factory, connecting rampway, and warehouse. Space limitations prevented the open storage area from being situated near the boiler house. It was located as close as possible in an open space 200 feet from the boiler.

**SYSTEM OPERATION**

From the time of startup to the present, the wood boiler has been monitored with respect to its operational aspects including the ability to supply steam under varying conditions of load and fuel quality. Steam is used for process heating in the heat setting of yarn and for space heating in winter, but heat setting is the primary use for steam at the plant. Two different types of equipment with different steam requirements are used for heat setting. The oldest equipment used are autoclaves which are a batch operation. Autoclaves are loaded with yarn, filled with steam, and held for a short period, then exhausted. A newer type of machine known as a continuous heat setter gives constant production of yarn and has a steady steam demand of 1,400 lb/hr. The plant has three autoclaves and six continuous heat setters. The boiler capacity rating is 13,320 lb/hr of steam at 150 psig. The only critical production variable is steam pressure. The continuous heat setters require steam at approximately 110 psig and an alarm goes off when the pressure drops to 95 psig. Due to the variability of the steam load, an operator is assigned to the boiler full-time to make sure steam pressure is maintained above 95 psig and also to attend to various maintenance duties. The utilization factor for the wood boiler, defined as actual steam production ratioed to maximum possible steam production (13,320 lb/hr x annual operating hours), is presented in Table 1 for the first three years of operation. As can be seen from these figures, the wood system has been integrated very effectively into the plant's production process reaching a high utilization of 62% in 1983. This increased utilization corresponds to an upswing in demand for carpet products.

Because of the difficulty in starting and the lag time involved in building up steam pressure, the wood boiler is operated 24 hours per day. If plant production is curtailed, the number of days per week the plant operates
### TABLE 1

**UTILIZATION OF WOOD BOILER**

<table>
<thead>
<tr>
<th>Year</th>
<th>Operating Hours</th>
<th>Measured Steam Production (lb/yr)</th>
<th>% of Maximum Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>6530</td>
<td>24,170,000</td>
<td>28</td>
</tr>
<tr>
<td>1982</td>
<td>6670</td>
<td>41,620,000</td>
<td>47</td>
</tr>
<tr>
<td>1983</td>
<td>7560</td>
<td>62,750,000</td>
<td>62</td>
</tr>
</tbody>
</table>

### TABLE 2

**FRONT END LOADER OPERATING ACTIVITY**

<table>
<thead>
<tr>
<th>Year</th>
<th>Loader Operation (hrs)</th>
<th>Days</th>
<th>Average Operation (hrs/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>952</td>
<td>278</td>
<td>3.4</td>
</tr>
<tr>
<td>1983</td>
<td>1583</td>
<td>325</td>
<td>5.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2535</td>
<td>593</td>
<td>4.3</td>
</tr>
</tbody>
</table>
is reduced, but not the number of shifts. In a typical week, the boiler is fired at 6 p.m. on Sunday evening and steam is ready for delivery in approximately 5 hours or by the time the 11 p.m. shift commences. In addition to making sure the boiler maintains the proper pressure, the operators on each shift are responsible for various maintenance activities on the boiler and support equipment.

An operator is required to operate the front end loader and transfer wood from the fuel staging area to the receiving hopper and to maintain the level of wood chips in the silo. The boiler consumes approximately 40 tons of fuel in a 24 hour period. Each day this requires between 4-6 hours of front end loader operating time distributed among all three shifts to transfer fuel from the receiving area to the silo. As a record of loader activity, the engine operating hours have been logged monthly for the past two years. Table 2 presents this data for 1982 and 1983. The average daily operating hours increased from 1982 to 1983, but the overall average for both years was just over 4 hours per day. This increase in 1983 is not unexpected since the boiler utilization rose from 47% to 62% with a subsequent increase in the daily fuel requirement.

Once each shift, the operator is responsible for raking ash from the boiler furnace. The normal procedure is to turn off the bidirectional screw that feeds fuel into the furnace and allow the fuel pile to burn down. The operator can then open the furnace door and rake out as much ash as possible while being careful not to remove glowing char necessary for restarting. Since the furnace is divided into two sides by separate furnace doors usually, this procedure is performed twice per shift with only one side of the furnace being cleaned at a time. To prevent the fire from going out, the grates must be raked quickly, therefore, the entire procedure to clean one side of the furnace requires less than 10 minutes. Following the last shift of the week, the furnace and firetubes are cleaned. The furnace is completely raked out and the firetubes are brushed. This task requires two men and takes about 4 hours.

The operator is responsible for other miscellaneous activities that require 2-4 hours per day. Daily attention items include lubricating fuel handling conveyors, the front end loader, and wood trailer, dumping the flyash
barrels, changing steam flow and pressure charts, and generally inspecting the fuel handling conveyors for breakage, material build-up, and blockage. Additional attention may be necessary for proper operation of the boiler if complicating factors, such as excessively wet fuel or fuel with a large percentage of oversize pieces is received. It is estimated that the above factors coupled with the requirement to maintain 95 psi steam pressure to the continous heat setters requires the equivalent of from 12-15 hours of operator attention in a 24 hour shift.

PROBLEMS ENCOUNTERED

The boiler has effectively supplied steam at the pressures required by processes at the plant under varying conditions of load and fuel quality; however, some boiler related problems have been encountered. The most commonly encountered operational problems are attributable to the non-uniformity of the fuel. Boiler operation has been reported to be stable with fuel moisture contents of 50% on a wet basis. Fuel moisture contents of 55% or greater lead to unstable combustion and ultimately to shutdown, as was discovered during the initial phases of operation. In addition to very high moisture content fuel yielding unstable combustion, it can also result in feed system shutdown. The boiler operates with an air swept spreader stoker where fuel is dropped on a chute to slide into the furnace. Moist fuel has greater resistance to sliding than does dry fuel. This sometimes causes wet fuel to back-up and overload the bidirectional screw which feeds fuel into the stoker. Occasionally, this back-up can severely overload the screw feeder, tripping the circuit breaker and shutting the system down.

If the temperature drops to around 0°F and the fuel is moist, freezing can result in the feeding system. When this has happened in the past, freezing occurred in the rotary unloading valve at the bottom of the silo. With the valve frozen, fuel cannot be unloaded from the silo and operation ceases. To maintain boiler operation, the rotary valve must be thawed by applying heat.

Because of blockages and jams caused by oversize pieces of wood, Integrated Products' engineers designed a vibrating screen add-on to the receiving hopper. The purpose of this screen is to remove any oversize pieces
which could potentially lock up the feeding system. A fuel analysis disclosed that oversize pieces constitute approximately 2% of the fuel weight. The 1-1/2 inch mesh screen added to the receiving hopper before startup greatly reduced jamming problems and helped protect feed system components, however, an unacceptable level of handling system shutdowns and repairs were still occurring. In January 1983, following two years of operation, the original screen was replaced with a 1-1/4 inch mesh one. This modification reduced fuel handling system blockages to an acceptable level.

A final characteristic of fuel which influences boiler operation is wood species. All hardwood species have been found to combust acceptably, but pine was found to yield a rosin-like residue in the furnace and boiler tubes. Following the early deposition problems experienced with pine, plant personnel decided to restrict boiler fuel to hardwood. This does not, however, represent a severe limitation since pine is usually not available as a fuel source because of the significant consumption by paper mills and related industries.

Oversize pieces of fuel in the handling system resulting in jamming, blockage, and ultimately breakage of components was the most common maintenance item during the first three years of operation. Table 3 is a list of those fuel system items that required attention. The most serious operational problem with the boilers occurred in mid-1983. During this period the boiler was operating continuously 7 days per week. Without a weekly shutdown period during which the firetubes could be brushed, the boiler experienced a buildup of flyash in the tubes. This resulted in a decrease in the flue gas velocity with an accompanying increase in the temperature of the firetubes. After several weeks, the tubes became overheated, expanded, and broke some of the welds between the tube and tube sheet. This allowed boiler water to leak into the fireside of the tube increasing the ash buildup problem and interfering with combustion. Eventually, the boiler was shut down so the tubes could be rolled. To prevent future occurrences of this problem, it was decided to shut down the boiler weekly for firetube brushing even during periods of continuous plant operation. The boiler is unavailable for steam production approximately 4 hours each week while the tubes are being cleaned. Back up steam is supplied by a gas fired boiler during this period.
TABLE 3
FUEL HANDLING SYSTEM
Components Replaced

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ITEM</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>Bidirectional Screw Shaft</td>
<td>$100</td>
</tr>
<tr>
<td>1982</td>
<td>Metering Bin Screw Gearbox</td>
<td>$1000</td>
</tr>
<tr>
<td>1983</td>
<td>Metering Bin Shear Pins Sheared</td>
<td>minimal</td>
</tr>
<tr>
<td>1983</td>
<td>Section of Inclined Screw Flights Worn Out</td>
<td>$500</td>
</tr>
<tr>
<td>1983</td>
<td>Metering Bin Shear Pins Sheared</td>
<td>minimal</td>
</tr>
<tr>
<td>1983</td>
<td>Replace Kicker Screen</td>
<td>$250</td>
</tr>
</tbody>
</table>
ECONOMIC EVALUATION

Just as important as establishing the technical feasibility of the wood fired system was the determination of economic feasibility. Before the project was initiated, economic evaluations were conducted to assure that it offered positive net benefit. The preconstruction analysis yielded a projected payback before taxes of between 2 and 3 years. Given that the system has now been installed and operating for over 3 years, a more accurate calculation of economic benefit is possible using actual operating data.

The most important element of the analysis is the determination of fuel costs. Any potential for savings with a solid fuel boiler must come from the reduction of fuel costs. During the period the wood boiler has been operational, accurate records of fuel consumption on a weekly, monthly, and yearly basis have been maintained. Table 4 is a summation of this data. This table also illustrates the associated cost of the wood during the 1981-83 time period. The wood fuel has experienced a slight price rise, but this can be attributed mainly to increases in the cost of delivery. The wood system is compared with a conventional natural gas boiler. The amount of natural gas that would be equivalent to the actual wood used can be calculated from the energy content of the two fuels and the efficiency of the associated boiler systems. In this analysis an efficiency of 65% was used for the wood boiler and 82% for the gas boiler. During the period under consideration, the gas cost rose at a much greater rate than wood which helped to improve the economic payback of the wood system. From the values shown in Table 4, an average annual fuel cost was found.

The next cost considered was labor. As stated earlier, the wood boiler required approximately 15 hours of labor for each 24 hours of operation. Conversely, a gas boiler is more automated and requires much less operator attention when it is operating. It was estimated that 3 hours of direct labor would be necessary during every 24 hours of operation. Since the operating hours of the wood boiler was known, the amount of labor required could be calculated. The cost of boiler operating personnel used was $12/hour. Table 5 shows the cost of labor during the first 3 years of operation.

Also shown in Table 5 are two other operating costs, that for a front end loader and for maintenance. The front end loader is used to move wood
<table>
<thead>
<tr>
<th>YEAR</th>
<th>WOOD USED* (tons)</th>
<th>UNIT COST ($/ton)</th>
<th>TOTAL COST ($)</th>
<th>EQUIVALENT GAS** USAGE (MCF)</th>
<th>UNIT COST ($/MCF)</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>8,809</td>
<td>7.00</td>
<td>61,600</td>
<td>61,050</td>
<td>3.45</td>
<td>210,550</td>
</tr>
<tr>
<td>1982</td>
<td>10,147</td>
<td>8.00</td>
<td>81,180</td>
<td>70,320</td>
<td>3.91</td>
<td>275,000</td>
</tr>
<tr>
<td>1983</td>
<td>14,500</td>
<td>8.60</td>
<td>124,700</td>
<td>100,485</td>
<td>4.38</td>
<td>440,100</td>
</tr>
<tr>
<td></td>
<td><strong>Average</strong></td>
<td></td>
<td><strong>89,180</strong></td>
<td></td>
<td></td>
<td><strong>308,600</strong></td>
</tr>
</tbody>
</table>

*Energy Content = 4500 Btu/lb
**Energy Content = 1030 Btu/ft³
<table>
<thead>
<tr>
<th>YEAR</th>
<th>LABOR HOURS</th>
<th>LABOR COST</th>
<th>FRONT END LOADER COST</th>
<th>MAINTENANCE COSTS</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>4080</td>
<td>48,960</td>
<td>1,650</td>
<td>250</td>
<td>$50,860</td>
</tr>
<tr>
<td>1982</td>
<td>4170</td>
<td>50,040</td>
<td>1,900</td>
<td>1,250</td>
<td>$53,190</td>
</tr>
<tr>
<td>1983</td>
<td>4725</td>
<td>56,700</td>
<td>3,170</td>
<td>6,000</td>
<td>$65,870</td>
</tr>
</tbody>
</table>

**Average = $56,640**

**GAS BOILER**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>LABOR HOURS</th>
<th>LABOR COST</th>
<th>FRONT END LOADER COST</th>
<th>MAINTENANCE COSTS</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>815</td>
<td>9,790</td>
<td>-</td>
<td>300</td>
<td>$10,090</td>
</tr>
<tr>
<td>1982</td>
<td>833</td>
<td>10,000</td>
<td>-</td>
<td>300</td>
<td>$10,300</td>
</tr>
<tr>
<td>1983</td>
<td>945</td>
<td>11,340</td>
<td>-</td>
<td>300</td>
<td>$11,640</td>
</tr>
</tbody>
</table>

**Average = $10,680**

**TABLE 5**

OPERATING COSTS

WOOD BOILER
unloaded from a delivery truck to the receiving hopper and then to the storage silo. The labor cost associated with operating the loader was determined earlier. The loader manufacturer estimated that the operating cost for the loader used by Integrated Products is approximately $2/hour. This cost item represents the fuel, tires, oil, and maintenance required to keep the loader operating. The hours of operation were determined by recording readings on the engine clock.

The final item included in the operating costs was maintenance. For the wood boiler, maintenance costs were found by summing up the dollar amounts spent on replacement parts. The labor costs associated with maintenance were accounted for earlier. The maintenance all consist of small items in the fuel handling and boiler control system which were replaced, except for the third year which shows a large increase due to the tube leak repair. Consultation with a vendor for gas boiler sales and service revealed the average expected parts cost for conventional boilers. This lower value reflects the more simple design of gas package boilers. Taking the average of the values presented in Table 5 yields an annual operating cost of $10,680 for gas boilers and $56,640 for wood boilers. Since the wood boiler is purchased new and assumed to be competing with an already existing gas boiler, a cost for capital must be included with the wood system. The equipment cost for the wood boiler system was $460,000. At the time of installation, the company received a 10% investment tax credit and a 10% energy tax credit. These credits served to reduce the system cost by 20%. Using an interest rate of 12% and equipment life of 20 years, the annual cost of capital is $49,530. The final cost item included was insurance and property taxes. Although the wood system has many more electric motors than a gas boiler and should consume more electrical energy, the electrical cost associated with each arrangement was not included since no quantitative data was available. The electrical cost differential between the systems was assumed to be insignificant since little change in the plant's electric bills was noted after the installation.

A summary of the average annual operating costs for the wood and gas boilers is presented in Table 6. The most significant item for both boilers is the cost of the fuel consumed. Since this analysis is based on measured fuel consumption, it reflects the actual load on the boiler. The high boiler
TABLE 6
WOOD BOILER SYSTEM FINANCIAL ANALYSIS

Annual Costs based on Average of three years

<table>
<thead>
<tr>
<th>COST COMPONENT</th>
<th>WOOD SYSTEM</th>
<th>CONVENTIONAL SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Cost of Capital Amortization</td>
<td>$ 49,530</td>
<td>$ -</td>
</tr>
<tr>
<td>Fuel</td>
<td>89,180</td>
<td>308,590</td>
</tr>
<tr>
<td>Labor, Maintenance parts and Front End Loader operation</td>
<td>56,640</td>
<td>10,680</td>
</tr>
<tr>
<td>Insurance and Taxes</td>
<td>4,500</td>
<td>4,000</td>
</tr>
<tr>
<td>Annual Costs</td>
<td>$199,850</td>
<td>$323,270</td>
</tr>
</tbody>
</table>

Annual Savings = $323,270 - $199,850 = $123,420
Simple Payback = 370,000/123,420
= 3.0 years
utilization factor coupled with the ever widening cost gap between wood and natural gas yielded average annual fuel savings of almost $220,000. Accounting for all costs, the wood boiler had a savings of $123,420 per year over the natural gas boiler. This is equivalent to a before tax simple payback of 3.0 years. Thus, the high boiler utilization over the initial 3 years of operating generated sufficient fuel savings to yield an economic payback equal to the one calculated on pre-installation projections.

CONCLUSION

In non-forest related industries which have high, relatively steady steam demands, a large number of annual operating hours, and reliable access to wood fuel, a wood boiler system can in many cases satisfy all the technical requirements of a conventional boiler at a lower economic cost. This analysis revealed that the wood system responded adequately to variations in steam demand, operated adequately on fuels of various qualities, and was reliable and simple to operate. The post-installation economic analysis demonstrated that the boiler could achieve the projected levels of savings and yield a favorable economic payback.
CASE STUDY IN COAL ENERGY
THE LIGGETT & MYERS TOBACCO COMPANY

William L. Reeves
Vice-President
Southeast Operations
ESI/PDS Engineers and Constructors

presented at
WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
WOOD and COAL
For Industry's Energy Needs

Field-Erected Coal and Wood Boilers and Incinerators

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FIELD ERRECTED COAL AND WOOD
BOILERS & INCINERATORS

PRESENTED TO: Seminar for Wood & Coal
For Industry's Energy Needs

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INTRODUCTION

Prior to the oil embargo of the early 1970's, industrial steam production costs were generally a minor portion of total product cost. Therefore, industrial steam users placed little emphasis on capital cost spending programs designed to aggressively minimize those costs through increased steam plant efficiencies or use of alternative fuels. However, since the mid 1970's, plant and utility engineers, plant managers and all levels of management including top management have been sensitive to the ever increasing cost of energy and its affects on manufacturing costs, thereby affecting one's ability to compete in the market place. Consequently, in their search for solutions to the high cost of energy, industrial steam users have been constantly bombarded with a steady barrage of material illustrating the various forms of technology, equipment and expertise available in the marketplace designed to solve these problems. Being relatively unfamiliar with most of this equipment, plant and utility engineers find themselves in a relentless search for information that will answer questions which generally come to mind when considering a new coal or wood fired boiler system. These questions deal with subjects relating to the following:

1. Type of boiler and firing equipment to install.
2. Current process steam requirement compatibility.
3. Availability and relative cost of fuels.
4. Operating and maintenance requirements.
5. Typical system availability and redundancy requirements.
6. On site fuel storage requirements.
7. Pollution control requirements.
8. Ash disposal.
9. Space requirements.
10. Economic feasibility.
11. Cogeneration feasibility.

This paper will attempt to give some preliminary answers to some of these questions to make the coal or wood fired boiler feasibility issue a little more clear.
EQUIPMENT SELECTION AND COMPATABILITY

The enclosed Table I lists different types of coal and wood firing equipment and types of boiler construction. Most industrial field erected boilers which are below 175,000-200,000 pph utilize some type of stoker for firing equipment. Even though the capital costs are higher for pulverized coal fired systems, at a utilization capacity of 175,000-200,000 pph, the increased efficiency and much lower coal costs, along with the excellent load response and good turn down capability, make a pulverized coal system more advantageous in this size range or larger. Stokers which are used below 175,000-200,000 pph are available in various types as follows:

1. Traveling grate spreader. (Exhibit III)
2. Traveling or chain grate. (Exhibit II)
3. Watercooled vibrating grate.
4. Single or multiple retort underfeed. (Exhibit I)
5. Reciprocating grate.
6. Watercooled pin hole grate spreader.

The application of one of these types of stokers in a particular industrial situation is dependent upon the following factors:

1. Type of fuel to be burned.
2. Boiler size.
3. Load response requirement.
4. Turn down requirement.

The reciprocating grate stoker is generally exclusively used in the refuse derived fuel applications for industrial or municipal solid waste incinerator/boiler installations. This stoker requires essentially no initial preparation of the refuse prior to incineration. The watercooled pinhole grate stoker is generally used exclusively for wood waste or prepared plant waste applications. The fuel is introduced in this stoker generally through pneumatic spreader feeders and therefore requires initial preparation to properly size the material. Traveling chain grates, watercooled vibragrates, and underfeed stokers are all mass burning type stokers. The traveling grate spreader stoker is a suspension burning stoker and is the type of stoker most predominately used in the industrial marketplace. This is because it
has a better load response capability than the mass burning type units. Because a coal fired spreader stoker boiler responds almost as well as gas/oil fired units, there is very little concern about adverse affects upon process steam requirements. The major disadvantage with a traveling grate spreader stoker is its limited turn down capability. The real dilemma for an industrial client in stoker selection comes when both good turn down and load response capabilities are required. Generally, unless the fuel savings potential can be captured during the periods of low load operation, the new solid fuel fired system economics become marginal. Therefore, extensive analyses is required to determine if mass burning type stokers which can satisfy the required turn down will yield sufficient enough load response so that the pressure fluctuations are tolerable and within process requirement guidelines. Regardless of the application, there is rarely a case when a coal or wood fired boiler installation cannot deliver the quantity and quality of steam on a continuous reliable basis to satisfy the requirements of an industrial user.

The reason that suspension fired stokers have much better load response capability is that approximately 50% to 60% of the fuel is burned in suspension with the larger heavier pieces falling to the grate and being burned in a thin active fuel bed. It is for this reason that the suspension fired stokers generally result in a higher particulate loading to the gas clean-up equipment resulting in higher capital and maintenance costs. Mass burning stokers have lower particulate emission rates because of generally less disturbance in the fuel bed.

AVAILABILITY AND RELATIVE COST OF FUELS

Purchasers of industrial stoker coal pay a slight premium for coal to be fired on mass burning stokers because of the requirements to have a lower free swelling index (tendency of the coal to swell when heated), higher ash fusion temperatures and fewer fines. Spreader stokers can generally handle slightly more fines than mass burning stokers and are not as sensitive to a higher free swelling index or lower ash fusion temperatures. Pulverized coal fired boilers use very inexpensive run of mine coal which requires virtually no processing. In contrast, most stokers require a double screened product with some percentage of fines blended back into the coal prior to shipping. The availability and relative cost of fuels will not be discussed in this paper since it is a separate topic to be discussed by others in this seminar.

OPERATING AND MAINTENANCE REQUIREMENTS

Referring again to Table I, some of the differences are listed between tube and tile verses welded wall construction and baffled versus single pass boiler construction. Tube and tile furnace construction is generally used in the lower capacity units
because of the approximate 30% lower first cost for the boiler equipment. Because of the flat projected exposure of the refractory tile between the tubes to the furnace, tube and tile construction generally increases turn down capability due to the resultant higher furnace temperatures. Subsequently, tube and tile construction is generally used for fuels which have high moisture content such as wet wood and selected plant waste. Welded wall furnace construction is generally used in larger boiler installations and results in lower overall maintenance because of the absence of the refractory tile. It does, however, decrease the turn down capability because of the cooler furnace at lower loads.

Baffled boiler construction is generally used in the smaller boiler size range because of its lower capital cost. A single pass boiler is more expensive because of a necessity to supply much more boiler bank heating surface to result in the same boiler exit gas temperature. However, the single pass boiler does result in lower overall maintenance since there are no baffles to maintain.

Prospective industrial purchasers of field erected coal and wood fired boiler systems are always concerned with what kind of operator input is required above and beyond existing gas/oil boiler equipment requirements. Unlike many gas/oil fired boiler plants, which generally require no full time operator attendants, it is generally common practice and in many cases requirement by code or local laws that full time operators be in attendance for solid fuel fired operations. Most industrial power plants operate with anywhere from 1 to 2 full time operators per shift. The small industrial steam plants, which utilize equipment such as underfeed stokers are generally capable of being operated with one full time operator who can perform all the duties including semi-automatic ash handling and coal handling supervision. The larger more sophisticated plants can require up to 2 full time operators per shift to handle all of these duties. The mass burning stoker fired installations require somewhat more operator input than suspension fired systems requiring occasional manual adjustments to be made to feed gates or dampers to improve fuel/air distribution throughout the entire load range.

Although there may be some differences which affect the relative cost of maintenance between different coal or wood fired stoker systems, one thing for certain is that the overall maintenance costs of solid fuel fired systems is greater than gas and oil fired systems. Most coal fired systems generally have increased operating and maintenance costs, above and beyond those costs already attributed to gas and oil fired systems, of approximately 2% to 3% per year of the system capital cost. Because of the severe duty requirement of burning a non-homogeneous fuel, reciprocating grate stoker fired units generally have the highest maintenance and operating costs. Also, systems which fire wood
with the more extensive and sophisticated handling equipment, generally have higher maintenance and operating costs than coal fired systems. Suspension coal fired stokers generally have slightly higher maintenance than the mass burning systems because of the higher particulate carry over.

SYSTEM AVAILABILITY AND DESIGN REDUNDANCY

Unscheduled, forced outages are generally a rare occurrence in most properly designed and maintained industrial solid fuel fired steam plant facilities. Although total system availability does vary somewhat with the size and level of sophistication, system availability generally runs in excess of 99 percent for the balance of the year exclusive of a one to two week scheduled annual shut down for maintenance and inspection. Most engineering firms and design/build firms with extensive experience in industrial solid fuel fired boiler plant design are aware of the areas of particularly high maintenance and service requirements and are able to incorporate more ruggedly designed equipment in specific areas where it is warranted to ensure this kind of reliability.

There is a general tendency for most industrial steam users considering new coal or wood fired steam plants to initially insist on redundancy in many areas to ensure system availability. This redundancy generally causes substantial increases in the capital cost requirements, often times resulting in marginal economic feasibility for the project. Because utility availability is critical for production continuity for industrial steam users, this insistence upon having redundant capability is very justified. The majority of new coal or wood fired steam plants which are installed consist of replacement capacity for existing gas/oil fired units which are still in serviceable condition. The existence of currently serviceable gas/oil fired equipment should not be ignored as being that potential redundant capacity. Therefore, keeping this thought in mind, by installing a well designed system with the minimum amount of equipment, the capital cost and maintenance costs are quickly reduced making these projects economically very attractive.

ON SITE FUEL STORAGE REQUIREMENTS

Typically, in the design of new coal and wood fired steam plant facilities, required on-site fuel storage requirements becomes an issue. Here again, because of the critical nature of utilities, industrial users are inclined to want extensive on-site storage to ensure reliability and independence from fuel suppliers and transportation interruptions. However here again, since these new systems are merely replacement capacity, most industrial users have in inventory a fair amount of oil storage capacity which was always sufficient to make them feel comfortable about market or transportation interruptions in the past. Another
determining factor is the tremendous volumetric requirements of storing large energy reserves in solid fuels. Therefore, most new solid fuel fired installations lean towards 10 to 20 days of on site storage of solid fuels at the full rated boiler capacity. Normally the coal is stored in silos thereby providing a very clean installation and eliminating redundant coal handling which enhances degradation. It also improves the overall operation by eliminating the infiltration of moisture into the coal handling systems.

POLLUTION CONTROL REQUIREMENTS

Another topic which is always of concern when considering a solid fuel fired installation is the air pollution control requirements. Under current law, whenever a new source has the potential to emit over 250 tons per year of any pollutant, it is subjected to Federal regulation as well as State regulation. In coal fired operations, sulfur dioxide emissions are the pollutant which usually are the greatest. In simple terms, burning 1% sulfur coal, any proposed facility with a continued average load in excess of 30,000 pph for more than 8,000 hours a year would exceed the 250 ton per year limit.

Typically, for systems below 30,000 pph, permits can be obtained using multicyclone mechanical collectors only. Systems larger than 30,000 pph require sidestream mechanical collector/ baghouse combinations or full size baghouses for particulate emission control. Sulfur dioxide emissions are normally controlled with the use of compliance low sulfur coal for most boiler installations below 100,000 pph. Above 100,000 pph in geographic locations such as the Midwest where high sulfur coal is readily available at a much reduced cost over low sulfur coal, dry flue gas desulfurization systems are currently being installed. Most of the coal fired stoker systems now being considered comply with all nitrogen oxide emission requirements. Visible emissions and corresponding neighborhood public relations are always a concern of industrial users when considering new solid fuel fired steam plants. The combustion technology of all the solid fuel fired systems discussed in this paper have been improved upon in the last few years to the point where visible emissions are not a problem as long as the equipment is operated as the manufacturers dictate.

ASH DISPOSAL

Ash disposal is another area which becomes of concern during the proposal phases of these projects. The majority of the industrial solid fuel fired steam plant facilities utilize pneumatic ash handling systems which are virtually automatic and allow dust free unloading into trucks for haul-away. The smaller installations utilize various forms of mechanical material handling equipment which is generally semi-automatic. If a
client has to pay to have ash hauled away and land filled, this is very rarely a substantial economic factor to be considered in the total project economics. Often times, markets can be found for the basically inert ash such as concrete block manufacturers, road building or land filling operations. When this is the case, the ash is often disposed of at no charge or the client even paid a minimal fee to provide the ash to these end users.

SPACE REQUIREMENTS

Another common misconception for prospective new industrial users of solid fuel fired steam plant facilities is that these facilities require a considerable amount of space. There is no question that these systems do require more space than gas/oil fired systems because of the more elaborate material handling systems, flue gas clean-up systems and sheer size of the equipment. However, there are usually many options available in the engineering layout phase of a project which makes their feasibility from a space requirement standpoint almost without exception. These systems can sometimes be partially installed in existing building facilities or retrofitted into adjacent space to utilize many of the existing facilities already in place. If space is not readily available in close proximity to the existing steam plant, the necessity to build a complete stand alone remote located steam plant with lengthy tie-ins rarely decays the economics to the point of creating a marginal project.

ECONOMIC FEASIBILITY

Total installed system capital costs for new coal and wood fired boiler systems are primarily dependent upon the following criteria:

1. Fuels to be burned.
2. Desired system redundancy
3. Air pollution control requirements.
4. Fuel storage requirements.
5. Requirement for future cogeneration.

Table I illustrates the wide range of capital costs associated with the the different types of coal and wood fired boiler systems being discussed. When considering capital cost dollars per pound of installed capacity, the lower end of the range is generally attributed to the larger capacity units and visa versa. The pulverized coal fired systems are slightly higher than stoker fired systems because of the increased equipment requirements of
boiler management systems, coal pulverizers and primary air heaters. As mentioned earlier, the much lower coal costs and higher efficiencies generally make pulverized coal systems very attractive in the 175,000 - 200,000 pph and above range. Traveling grate, chain grate and vibragrate stokers are generally slightly less expensive than traveling grate spreader stoker systems, because of the slightly lower cost of the stoker and the capability of using a smaller baghouse system with a larger air to cloth ratio due to the lower particulate emission rates. Underfeed stoker systems appear to be higher from a first cost, dollars per pound basis, however this is because these systems are not afforded the economic benefits attributed to escalation of size. Generally, underfeed coal fired stoker systems can be installed with mechanical multicyclones only for particulate clean-up in lieu of baghouse requirements which are generally accepted for the larger systems. Wood fired systems are inherently more expensive because of the normally required more sophisticated and extensive material handling requirements and the large volume of material to be stored and handled. Plant waste and other refuse derived fuel systems are generally the highest cost because of the very rugged design of the equipment, due to the extremely heterogenous fuel burned. In general, unless an the industrial consumer is faced with unusual circumstances such as stringent air pollution control requirements or very high alternate solid fuel costs due to geographic location, an average steam flow requirement of 15,000 pph for not less than 6000 hours per year results in an after tax payback of less than 3 years. The attached Table II gives some examples of typical proposed coal and wood fired boiler systems and their respective capital costs. This Table includes identification of some factors which affect total project cost and illustrates some typical industrial applications and the economic feasibility of those installations.

COGENERATION FEASIBILITY

Virtually, every new prospective industrial client wants to look at the feasibility of adding cogeneration to these projects, either initially or at some future point in time. It is for this reason that the majority of boilers currently being installed above 30,000 pph are of high pressure design for initial low pressure operation with the possibility of being retrofitted to operate at higher pressures for cogeneration in the future.

Because of the widely varying affect of many determining factors, cogeneration feasibility analysis is very site specific. The following trends enhance the feasibility of cogeneration:

1. Higher average steam flow rate requirements. (Greater than 40-50,000 pph)
2. Minimum deviation between maximum and minimum steam flow requirements from that of the average flow requirement. (Less than 25-35%)

3. Higher purchase power and buy back power electrical rates. (Greater than 5-6¢/KWH)

4. Lower process saturated steam pressure requirements. (Less than 175 psig)

5. Maximum utilization of the system in hours per year. (8000 hour per year or more)

INSTALLATION

Total system delivery for new design/build steam plant facilities generally range from 9 to 12 months for the smaller systems and from 14 to 16 months for the larger systems. The most critical item in the project schedule critical path is the delivery of the boiler and firing equipment. The delivery of these components usually range from 6 to 10 months. Prior to their arrival most of the design work is generally completed and all of the foundations have been put into place. Since concrete and foundation work is very sensitive to cold weather conditions, particularly in the northern climates, the timing of new field erected boiler projects can be very critical especially if the schedule is substantially accelerated. One method used to circumvent potential problems with concrete and foundation work construction falling in the severe winter months is the preliminary release of projects to begin environmental permitting work and engineering so that this work can be done immediately upon complete release of the project prior to the onset of bad weather conditions.

SUMMARY

In summary, it is obvious that there is a general trend in the marketplace among industrial steam users to seek alternative fuels such as coal, wood and plant waste to serve their energy needs. Any industrial steam user with more than 15,000 pph average load for more than 6,000 hours per year probably has a feasible application for the installation of a new coal and/or wood fired boiler system. These low risk projects have economics that meet the investment hurdle rates of most industrial users. The technology is available in the marketplace to enable the installation of systems which will give clean reliable and safe operations. The uncertainty of environmental regulations has been erased during the past few years so that prospective installers of these systems need no longer be afraid of ever changing environmental regulations. Many small, privately owned as well as large major corporations in textiles, chemicals, agriculture, food processing, rubber, etc. have already made these conversions or are in the process of installing these systems to
reduce their production costs and increase their competitiveness in the marketplace.
<table>
<thead>
<tr>
<th></th>
<th>System Maintenance &amp; Operating Cost</th>
<th>Typical System Efficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Firing Equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Pulverized Burners</td>
<td>45 Highest</td>
<td>86-87%</td>
</tr>
<tr>
<td>B. Traveling Grate</td>
<td>-$55 Higher</td>
<td>(C)-83-84%</td>
</tr>
<tr>
<td>Spreade r Stoker</td>
<td>-$60 Higher</td>
<td>(W)-65-75%</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>(RDF)-65-70%</td>
</tr>
<tr>
<td>C. Traveling or Chain</td>
<td>50 Avg.</td>
<td>83-84%</td>
</tr>
<tr>
<td>Grate Stoker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Water Cooled</td>
<td>50 Avg. to Lower</td>
<td>83-84%</td>
</tr>
<tr>
<td>Vibragrate Stoker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Underfeed Stoker</td>
<td>60 Avg.</td>
<td>82-84%</td>
</tr>
<tr>
<td>F. Reciprocating Grate</td>
<td>80 Highest</td>
<td>65-70%</td>
</tr>
<tr>
<td>Stoker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. Watercooled Pinhole</td>
<td>60 Highest</td>
<td>65-75%</td>
</tr>
<tr>
<td>Grate Spreader Stoker</td>
<td></td>
<td></td>
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<tr>
<td>II. Type Boiler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Tube &amp; Tile Furnace</td>
<td>Higher</td>
<td></td>
</tr>
<tr>
<td>B. Welded Wall Furnace</td>
<td>Lower</td>
<td></td>
</tr>
<tr>
<td>C. Baffled Boiler</td>
<td>Higher</td>
<td></td>
</tr>
<tr>
<td>D. Single Pass Boiler</td>
<td>Lower</td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. These costs vary depending on the larger capacity unit and type.
2. System efficiency varies with the use of economizer and/or air preheater.
3. All of these boilers are designed for different applications.
<table>
<thead>
<tr>
<th>Size (PPH)</th>
<th>Avg. Steam Load (PPH)</th>
<th>Illution Equipment</th>
<th>Capital Cost ($Million)</th>
<th>After tax Payback (Yrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30,000</td>
<td>$21000 &lt;br&gt;6200</td>
<td>cyclone</td>
<td>1.100</td>
<td>2.7</td>
</tr>
<tr>
<td>45,000</td>
<td>$32000 &lt;br&gt;6000</td>
<td>Jet use</td>
<td>2.250</td>
<td>3.1</td>
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<tr>
<td>50,000</td>
<td>$38000 &lt;br&gt;6600</td>
<td>Jet use</td>
<td>1.950</td>
<td>2.4</td>
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<td>90,000</td>
<td>$36000 &lt;br&gt;8400</td>
<td>cyclone &amp; steam use</td>
<td>2.950</td>
<td>2.8</td>
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<tr>
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<td>2.0</td>
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<td>6.975 &lt;br&gt;Note 1</td>
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<tr>
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<tr>
<td>200,000</td>
<td>$200000 &lt;br&gt;8400</td>
<td>Jet use</td>
<td>5.875</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Note: 1. This system is a bine.
ADVANCED COAL SYSTEMS

William L. Calhoun
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presented at

WOOD AND COAL FOR
INDUSTRY'S ENERGY NEEDS
July 25, 1984
Atlanta, Georgia
COAL WATER MIXTURES for INDUSTRIAL APPLICATIONS

By:
John K. Alderman
Ebasco Services Incorporated
Atlanta, Georgia

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WOOD AND COAL FOR INDUSTRY'S ENERGY NEEDS,
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INTRODUCTION

Over the past five years, Coal Water Mixture (CWM) has evolved from primarily a research and development activity, to a fuel technology on the threshold of commercial application. The most important aspect of CWM fuels is that the delivered cost to industrial consumers will be from 10% to 50% below the cost of No. 6 fuel oil and other competing fuels, depending upon the specific situation. However, CWM is only partially known by many potential users and it is often confused with Coal Water Slurry (CWS), such as that proposed by ETSI and Coalstream.

Coal Water Mixtures will not be an economically viable alternative for every oil burning industry. Successful application of CWM is contingent upon many factors, including the user's site, boiler design, and environmental requirements; the CWM producer's plant location and process design; the coal supplier's location, methods of mining and processing, and most important, the chemical and physical characteristics of the feedstock coal. Therefore, the intent of the following information is to familiarize the potential user or coal supplier with the major technical and economic properties of CWM and to identify those variables which have the greatest impact on the cost and characteristics of CWM.

CHARACTERISTICS OF COAL WATER MIXTURES

As shown in Figure 1, coal water mixture consists of approximately 70% coal, 30% water, and less than 1% chemical additives. CWM's are pumpable, directly fired (containing the 30% water), and are essentially non-setting.

CWM is not to be confused with Coal Water Slurry (CWS), a mixture of 50% coal and 50% water which is proposed for long distance pipeline transportation of coal, such as promoted by Coalstream in the East and ETSI in the West. CWS is also pumpable, but must be dewatered prior to firing and will readily settle out of suspension in the absence of mechanical agitation.

Commercially available coal water mixtures are estimated to cost from less than three dollars per million BTU to about $4.00 per MBTU. No. 6 fuel oil currently costs approximately $4.50 to $5.00 per MBTU. While the heating value of CWM is significantly lower than No. 6 fuel oil (approximately 10,500 BTU/1b vs 18,000 BTU/1b) the effective viscosities of the two fuels are both in the range of 1000 centipoise, depending upon formulation, temperature, and other factors. A comparison of CWM and No. 6 fuel oil is shown in Figure 2. The relatively low viscosity of CWM is a major factor in its capability to be substituted for fuel oil.

Normally, fine coal containing 30% moisture would resemble a stiff paste; however, by blending the correct combination of particle sizes and application of a small quantity of chemical dispersant, a fluid mixture which flows like motor oil can be attained. Correct particle size distribution permits the system of coal particles to pack as closely as possible in order to create a CWM with solids loadings of 70% and higher.
As shown in Figure 3 the smaller particles in the size distribution not only fill-in the interstitial spaces, thereby providing maximum density, but in addition, the fine particles interact with the chemicals and water to provide a fluid medium through which the coarser particles may easily "slip" past one another, in a low viscosity solid/liquid system. In effect, the finest size particles are an integral part of the fluid carrier media.

PARTICLE SIZE DISTRIBUTION

A number of theories have been developed to project the ideal particle size distribution for efficient particle packing and stable, low-viscosity CWM. One of the weaknesses of the theory-based projections is that the fundamental mathematical models have been developed from the packing behavior of spherical particles, while fine coal is characterized by irregular-shaped particles ranging from plates and slivers to cubic shaped particles. Future research may focus upon the packing behavior of heterogeneous shapes in the particle size distributions. Although strict adherence to a given size distribution may be critical at the limit of solids loading for an acceptable CWM (approximately 80% solids), at solids loadings in the range of 70%, a reasonably wide tolerance exists. Figure 4 shows histogram plots of particle size distributions for CWMs produced by three process developers. Note that while a great deal of similarity exists, the size distributions are not identical, a fact which is due not only to processing differences, but also to differences in the feedstock coals utilized. It should also be noted that all of these size distributions cover a much wider range of particle sizes and are more evenly distributed than is the case of a "typical" dry pulverized coal commonly used by utilities.

CWM RHEOLOGY

The rheology, or fluid behavior of CWM is contingent upon a variety of factors including the solids loading, the particle size distribution, and the types and quantities of chemical surfactants utilized in the specific formulation. For the purpose of comparison, Figure 5 shows three types of behavior found in fluids, namely, dilatant, Newtonian, and pseudoplastic. As can be seen, a dilatant fluid increases in viscosity as the shear rate applied increases, Newtonian fluids maintain a constant viscosity under conditions of increasing shear rate, and a pseudoplastic fluid decreases in viscosity as shear rate increases. A pseudoplastic fluid is generally desirable for its behavior during pumping, although mild dilatancy can be acceptable. A number of CWM process developers claim pseudoplastic properties for their fuels and have presented supporting data from lab-scale studies. Other data, from third party investigations, have shown that CWM's from a variety of processers and feedstock coals generally are characterized by some degree of dilatancy. Four of these CWMs, shown in Figure 6, while not ideal, proved to be readily pumpable, good quality fuels.
For a given CWM formulation, viscosity can be expected to decrease as solids loading decreases, and this relationship is shown in Figure 7. The stability of a CWM is the capacity of the coal water suspension to resist settling over time and stability is effected by both viscosity and solids loading. A thixotropic CWM forms a stable gel-like structure when the fluid is at rest, but the structure is easily broken-up by the application of agitation or shear. Minor amounts of settling commonly occur in CWMS when they are stored under static conditions for a period of weeks or months. If properly formulated, the settled particles will form a "soft pack" which can be resuspended by applying mild agitation. When substantial settling occurs, such as shown in Figure 8, a "hard pack" forms which is dilatant and very difficult to resuspend.

CHEMISTRY

Chemical additives are utilized to reduce viscosity and to increase the stability of CWMS. Dispersants are believed to interact with fine particles and cause them to repel each other, a behavior which reduces the viscosity of the system. Stabilizers, as their name implies, promote the formations of gel structures in CWMS which retard settling. Control of pH in CWM can be effectively utilized to reduce viscosity through enhancement of the effects of the dispersing agent, as shown in Figure 9. Viscosity of CWM may increase with the presence of certain divalent and trivalent cations such as Ca⁺⁺ and Fe⁺⁺⁺. Because a number of harmful cation species can occur due to oxidation of mineral matter, which is naturally present in coal, screening of potential feedstock coals should account for this type of problem.

Overall, the chemical packages and their synergism with a given coal have a major impact upon CWM rheology. The effect of differences in CWM chemistry on viscosity, among the major process developers, is illustrated in Figure 10. Note that although CWM "A" has a very high solids content, its viscosity is the lowest of the group.

COMBUSTION OF CWM

While it has been well established for a number of years that CWM's containing as much as 40% water can be successfully burned in utility and industrial boilers, firing CWM requires attention to details not encountered when firing No. 6 fuel oil. Depending upon furnace design, boiler deratings ranging from 15% to 35% can be expected when switching from No. 6 to CWM firing. The higher ash level of CWM, as compared to No. 6 fuel oil, will require modifications to furnace design, and the addition of bottom ash and fly ash collection equipment. Firing CWM will also require increased levels of furnace/boiler maintenance.

The parameters that determine the combustion quality of CWM are interrelated to some extent. Two of the most important factors are the volatile matter content of the parent coal and the atomization quality of the CWM fuel. Conventional wisdom has indicated that the volatile matter content of the feedstock coal should be 30 percent, and preferably higher, in order to support stable combustion. Studies conducted over the last 2
to 3 years have shown that CWM's with feedstock volatile matter content of less than 30% can be fired effectively provided that the CWM has good atomization qualities, i.e., atomization results in a spray consisting of very small individual droplets. Atomization quality is a function of CWM characteristics, such as particle size distribution, viscosity, and chemical additives used, and can also be greatly enhanced by the burner/spray-atomizer design.

An additional aspect of combustion which is particularly important to consider, is the amount of ash-forming constituents in the fuel, and the chemical composition of the ash. Ash can provide problems in three areas:

1. Ash collection and handling
2. Furnace/boiler tube erosion due to ash abrasiveness

For most CWM's bottom ash handling equipment and a baghouse for flyash equipment will be required for installation on converted boilers. Expenditures for these items can be reduced by selecting coal feedstocks with a low-ash content. Typically, low-ash coals are obtained through mechanical "cleaning", which separates the combustible organic material from ash-forming minerals. CWM's with low-ash contents will also cause less erosion within the furnace, but even with low-ash CWM's, protection of critical areas with abrasion resistant materials is advisable. If the coal ash contains relatively high amounts of certain trace elements, severe slagging and/or fouling of furnaces surfaces can occur. The presence of significant amounts of sodium in the coal ash is responsible for fouling; some of the dispersants and pH modifiers used for CWM contribute sufficient additional sodium to produce severe fouling potential for the coal ash. Selection of chemicals for CWM should therefore be based upon the ash chemistry of the feedstock coal.

CWM ECONOMICS

In order to evaluate CWM economics, it is necessary to begin with the current price of No. 6 fuel oil, which, for the purpose of this discussion, is approximately $5.50 delivered to Atlanta. Subtract from this figure the cost of capital charges for boiler retrofit and costs for higher G&M requirements, about $1.50 combined, and there remains $4.00 to mine the coal, clean it, process it into CWM, transport it to the user's site, and derive a return on investment.

To see how this $4.00 ceiling breaks-down, consider the information presented in Figure 11 based upon delivery of CWM to Atlanta. Taking into account the range of costs for feedstock coal, CWM processing, and transportation costs, the estimated costs for CWM delivered to Atlanta range from $2.20 to $3.50 per million BTU. Going back to the benchmark price of $4.00 per MBTU, the residual for return on investment ranges from $0.50 to $1.80 per million BTU.

- 4 -
THE CASE FOR SYSTEM OPTIMIZATION

Coal water mixture technology is a multidisciplinary field of engineering which involves the integration of geology, mining, coal preparation, CWM processing, transportation, material handling, and combustion. The objective of a coal water mixture program should be to maximize economic benefits to the coal supplier, the CWM processor, and the CWM user, concurrently. Ebasco's approach has been to accomplish this through a systems optimization program. Although it may appear that the range of $2.20 to $3.50 per MBTU, presented for delivery of CWM to Atlanta, is a rather broad range, in fact, the prices could be either significantly lower, or higher, while maintaining comparable profit margins for both the coal supplier and the CWM processor. The reasons for this variability is best explained by examining the individual cost components of CWM.

COAL

Coal will normally be the largest cost component in CWM. Costs of mining and cleaning the coal determine the suppliers' profit margin, but the selling price of coal, that is, the cost to the user, is determined by prevailing free market prices for coal or fuel products of comparable quality.

TRANSPORTATION

Transportation cost is a key to determining what the supplier can sell his coal for and what the user must pay for coal. The map in Figure 12 shows the location of major coal reserves in the U.S. Comparable quality coal is produced in both western Pennsylvania and Alabama, but because the coal fields of Alabama are closer to Atlanta than those of Pennsylvania, Alabama producer's should enjoy a transportation cost advantage in the Atlanta market. If mining and preparation costs are similar, the Alabama producer could realize higher profits and the Atlanta user lower costs as compared to purchasing coal from Pennsylvania.

CWM PROCESSING

Processing costs for coal water mixtures not only depend on the fundamental design of the process developer, but more importantly they depend upon the characteristics of the feedstock coal. Figures 13 shows typical flow diagrams for the production of CWM. Generally, the less complex the plant, the lower the associated processing costs. Both flow diagrams incorporate froth flotation, a method of reducing the ash content of the parent. The relative value of froth flotation must be determined on a case by case basis. The flow diagrams shown in Figure 14 are simpler and should provide lower processing costs although they may require more expensive feedstock coal to produce CWM's with comparable levels of ash to those produced in plants with flotation.
The CWM processes consist of grinding, cleaning (possibly), and mixing. If the feedstock coal utilized is relatively "soft" then grinding costs (capital and operating) will be lower than for a "hard" coal. The chemical characteristics of the coal surface can increase or decrease costs for chemical additives. Finally, the size distribution of the feedstock coal can have a major impact on grinding costs. In Figure 15 particle size distributions are shown for a "typical" CWM feedstock, an optimized CWM feedstock developed by Ebasco, and for a generic CWM product. The finer size distribution of the optimized feedstock is expected to result in a reduction of grinding requirements by approximately 70%.

PROGRAM FOR SYSTEM OPTIMIZATION

For an industrial user of No. 6 fuel oil considering conversion to CWM, the following program should be undertaken:

1) Inspection of the boiler to determine coal/CWM quality requirements and boiler retrofit requirements.

2) Identification of perspective CWM processors and costs.

3) Identification of coal suppliers and costs for the specified quality.

4) Selection of the low cost CWM processor/coal supplier.

5) Economic analysis of CWM conversion.

6) Trial CWM burn.

7) Retrofit boiler and convert to CWM.

PROSPECTS FOR CWM

Within the next year or year-and-a-half, there is a good probability that coal water mixtures will be available in Georgia, South Carolina, Alabama, and Tennessee for $3.00 per million BTU or less. As with any new technology, there is uncertainty associated with initial applications; however, by carefully optimizing the system of coal supplier, CWM processor, and industrial users, substantial savings in fuel costs will be realized by industrial users of coal water mixture.

REFERENCES:


FIGURE 1
CHARACTERISTICS OF COAL WATER MIXTURE

DIRECTLY FIRABLE - NO DEWATERING
PUMPABLE
NON-SETTLING

~30% H₂O
~70% COAL
<table>
<thead>
<tr>
<th></th>
<th>NO. 6 FUEL OIL</th>
<th>COAL-WATER MIXTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEATING VALUE (BTU/lb)</td>
<td>18,000</td>
<td>10,000 - 11,000</td>
</tr>
<tr>
<td>VISCOSITY (cP)</td>
<td>1,000 - 10,000</td>
<td>&lt;2,000</td>
</tr>
<tr>
<td>COST ($/MBTU)</td>
<td>$5.00 - $5.73</td>
<td>$3.00 - $3.50</td>
</tr>
<tr>
<td>POUNDS SO₂/MBTU</td>
<td>2.8</td>
<td>&lt;1.2</td>
</tr>
</tbody>
</table>
FIGURE 3
PARTICLE PACKING

NARROW SIZE DISTRIBUTION

BROAD SIZE DISTRIBUTION
FIGURE 5
FLUID CHARACTERISTICS

INCREASING VISCOSITY

\[ \text{Dilatant} \]

\[ \text{Newtonian} \]

\[ \text{Pseudoplastic} \]

INCREASING SHEAR RATE
FIGURE 6
VISCOSITY VS. SHEAR RATE FOR SELECTED CWM's

![Graph showing viscosity vs. shear rate for selected CWM's](image)

- A
- B
- C
- D

Viscosity, cP
Shear Rate, 1/sec.
FIGURE 7
SOLIDS CONTENT VS. VISCOSITY

PERCENT SOLIDS

0 500 1000 1500 2000 2500
VISCOSITY, CP
FIGURE 9
pH VS. VISCOSITY
FIGURE 10
VISCOSITY OF SELECTED CWM's

PERCENT SOLIDS

VISCOSITY, CP
**FIGURE 11**

**COST RANGE FOR CWM DELIVERED TO ATLANTA**

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal, Cleaned - FOB</td>
<td>$1.20</td>
<td>$1.50</td>
</tr>
<tr>
<td>CWM Processing Cost</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td>CWM Total Delivered Cost</td>
<td>$2.20</td>
<td>3.50</td>
</tr>
<tr>
<td>Saving vs. No. 6</td>
<td>$1.80</td>
<td>$0.50</td>
</tr>
</tbody>
</table>