Industrial Fuel Gas Demonstration Plant Program

DOE/ET/13046--T15

FINAL REPORT

PLANS FOR USE AND DISPOSITION
OF BY-PRODUCTS

This book was prepared as an account
Neither the United States Government

Prepared For
The Department of Energy
Under Contract ET-77-C-01-2582

MEMPHIS LIGHT, GAS AND WATER DIVISION
P.O. BOX 430, MEMPHIS, TENNESSEE 38101

In Association with
FOSTER WHEELER ENERGY CORPORATION
INSTITUTE OF GAS TECHNOLOGY
DELTA REFINING COMPANY

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

PM079-2974

DOE/ET/13046--T15

FINAL REPORT

PLANS FOR USE AND DISPOSITION
OF BY-PRODUCTS

MASTER

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Submitted to: Memphis Light, Gas and Water Division
Industrial Fuel Gas Demonstration Plant
Contract No. ET-77-C-01-2582

Submitted by: Delta Refining Company
November 14, 1979

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *tb*

MEMPHIS INDUSTRIAL FUEL GAS
DEMONSTRATION PLANT PROJECT

PLANS FOR USE AND DISPOSITION OF PRODUCTS
(Deliverable #29)

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use or the results of such use of any information, apparatus, product or process disclosed in this report, or represents that its use by such third party would not infringe privately owned rights.

MEMPHIS LIGHT, GAS & WATER DIVISION
P.O. Box 430
MEMPHIS, TENNESSEE 38101

PREPARED FOR THE
U. S. DEPARTMENT OF ENERGY
ASSISTANT SECRETARY OF FOSSIL ENERGY

UNDER CONTRACT DE-AC02-77ET13406
(FORMERLY CONTRACT ET-77-C-01-2582)

FINAL REPORT

PLANS FOR USE AND DISPOSITION OF BY-PRODUCTS

Memphis Industrial Fuel Gas Demonstration Plant
Contract No. ET-77-C-01-2582

The purpose of this report is to summarize Phase I efforts for marketing by-products from the Industrial Fuel Gas Demonstration Plant (IFGDP). The scope of inquiry over the last year was not intended to be intensive, but rather to conduct a thorough preliminary investigation to define the marketing parameters and potential revenue available from the sale of plant by-products.

This report consists of several sections, the first of which discusses the impact of by-product revenue on plant economics and potential for local area development. Each succeeding section will discuss a particular by-product, its intended market, and economic calculations for potential yearly revenue. Three generic by-products have been identified; recovered liquid sulfur, ash agglomerates, and industrial gases.

The sale of IFGDP by-products has the potential for significant impact in several ways. First, the revenue generated can significantly lower operating costs and thereby reduce IFG gas cost. It is estimated that a one million dollar reduction in operating costs will reduce the gas price by .06 per MMBtu. Second, by-products can stimulate the local economy by increasing the availability of certain raw materials and offering a lower than existing market price for these materials and, third,

availability of certain by-products in large volumes may induce new business to locate in the Memphis/Mid-South area.

In order to assess the local market, a scoping type market survey was conducted. In March of 1977, the Memphis Area Chamber of Commerce surveyed the local use of industrial gases and sulfuric acid (major product of recovered sulfur) within the Memphis marketing area. Over one hundred companies who were potential users of these by-products were contacted. They were asked to provide quantities of yearly use as well as delivered prices. Examples of letters and forms used are attached at Inclosure 1. This survey was not intended to be a definitive market analysis - that type of analysis will be conducted during Phase II. A summary tabulation of the survey returns follows:

Table 1

Summary of Chamber of Commerce Survey

<u>By-Product</u>	<u>Source Within Plant</u>	<u>Potential Production/Yr.</u>	<u>Market Survey Usage/Year</u>
Sulfur	Claus Unit	30,000 L Tons	8,000 Tons*
Nitrogen	Air Separation Unit	Up to 150,000 Tons***	16,000 Tons
Argon	Air Separation Unit	To be defined	3.9MM Ft. ³
Carbon Dioxide	Selexol/Beavon-Stretford Units	150,000 Tons***	100,000 Tons

*One ton of sulfur makes approximately three tons of sulfuric acid. Acid is normally the end use, not sulfur.

**Depends on final configuration of air separation facility.

***Quantity can be increased if market requirements exist.

NOTE: Since ash agglomerates are a new substance, a survey on this material was not feasible.

The results of this survey show that by-product volumes will be significantly greater than the market usage. The difference can be made up two ways. First, by having industries relocate in the Memphis area and take additional volumes of the by-products, and second, to transport these by-products to other areas of the Mid-South. Of course, it will be preferable to have maximum utilization in the Memphis area.

The extent of a definitive market analysis in Phase II is unknown at this time. If MLGW decides to act as the marketing agent for any or all of the by-products, this will require hiring a sales force. When hired, these sales persons could conduct the definitive market analysis. However, if MLGW decides to enter over-the-fence supply agreements with an industrial gas and chemical company, these companies can then be expected to conduct their own market analysis and even expend effort to develop the existing market.

SULFUR

Sulfur compounds in the Industrial Fuel Gas must be removed. The Demonstration Plant will have Claus and Beavon/Stretford Units to recover sulfur in liquid form. It has been decided that liquid sulfur recovery units are easier to operate and keep operating, especially when considering storage limitations, rather than converting the sulfur directly to sulfuric acid. Although the manufacturing process for sulfuric acid is not complex, the expertise for marketing sulfuric acid is with the major chemical companies. It is expected that MLGW will sell the recovered liquid sulfur directly to a major chemical company for conversion

into acid. It is not inconceivable that a major chemical company would build a sulfuric acid plant near the IFGDP site if additional quantities of sulfur are available locally.

As stated above, by-product sulfur will likely be sold in liquid form. High energy costs are currently limiting the availability of Frasch recovered sulfur, especially, in the Gulf Coast area. Because of this limited availability, shortages of recovered sulfur have been predicted for the early 80's. This factor alone suggests that recovered liquid sulfur will have a very strong market potential in the early to mid-1980's. Over the past year, contacts were made with several large chemical companies who are potential purchasers of liquid recovered sulfur. The following is a list of those companies contacted:

- Ashland Chemical Company
- W. R. Grace and Company
- Olin Chemical Company
- Allied Chemical Company
- Monsanto Chemical Company
- Stauffer Chemical Company

At Inclosure 2, copies of correspondence are included to substantiate the contacts made. In October, letters of intent to purchase sulfur were sent to these companies for their approval. The letter of intent was developed as an agreement to enter negotiations if the Industrial Fuel Gas Demonstration Plant proceeds into Phase II. Letters of intent returned as of this date are included in Inclosure 3.

There are several potential new market applications for liquid recovered sulfur. These applications are now under development and are expected to result in accepted use over the next few years. The Asphalt Institute has been conducting studies on the use of sulfur mixed with asphalt as an asphalt extender. Results to date have been encouraging. Also being studied is the use of sulfur with cement as a cement extender. Others have been studying the use of sulfur as coating on bricks and cinder blocks, foamed sulfur for insulation purposes, and sulfur impregnation in concrete to increase strength and resistance to wear. Sulfur is also widely recognized as the fourth important plant nutrient and can be used by a large agricultural chemical company in the Memphis area. By-product revenue calculations follow:

Range of sulfur production: 67-90 Long Tons/Day

Range of sulfur netback (F.O.B.): \$70-\$90/Long Ton

Operating Days = 330 days/yr.

Range of revenue expected:

- a) Low: $67 \times 330 \times 70 = \$1,547,700/\text{yr}$
- b) High: $90 \times 330 \times 90 = \$2,673,000/\text{yr}.$

Ash Agglomerates

The IFGDP will produce approximately 100,000 tons per year of ash agglomerates using washed coal. If unwashed coal is used as a feedstock, the tonnage could increase to 150,000 tons per year. This material is 90-95% ash and includes high proportions of iron, silicon, and aluminum. Their size can vary anywhere

from small sand-like particles to 1/8" round spheres. Since ash agglomerates are a new material, it was necessary to test and evaluate the material in order to determine potential use.

One very important aspect of the evaluation for sale of ash agglomerates was leaching potential. Leaching tests were conducted in 1979 by Energy Impact Associates and Oak Ridge National Laboratories using standard ASTM procedures to determine the expected extent of leaching. Both organizations were able to report that the ash agglomerates are not expected to present any serious leaching problems.

In April, 1979, Peabody Testing Company in Memphis was retained to determine the structural properties of ash agglomerates and to evaluate their use as an aggregate with concrete. Initial tests were conducted to show physical properties. A structural mix was developed, several cylinders were poured, and then tested for load bearing strength. It is emphasized that since this particular ash has never been mixed with concrete, the proportion of ash to other materials was quite difficult to determine. Initial test results were not encouraging, however, further testing was done using the ash in varying ratios as a replacement for local aggregate (sand). The results of this testing indicated that ash could replace up to one-third of the locally available sand in the mixture.

Additional mixtures were made up to determine the extent of cement that can be reduced in a particular mix design while retaining a given minimum structural strength. The results of this testing indicated that either the amount of cement can be

reduced while retaining minimum strength levels or a higher level of confidence in meeting structural strengths can be achieved with the same amount of cement. This result confirms that the minimum value of the ash agglomerates is comparable to locally available sand (\$5/yd³).

The use of ash in a block mix design was also investigated. Certain properties of the ash are helpful in this type mix design, especially water retention. Several cylinders were made up and tested and it appears that ash can be used in a block mix design which will meet the applicable ASTM standards. Peabody Testing has concluded that the ash can be marketed for use in concrete, either structural or block mix and that the majority of the ash produced in the IFGDP can be sold for this purpose. Inclosure 4 contains a copy of each engineering report issued by Peabody Testing Company.

A minimal investigation was also conducted into another potential use of the ash agglomerates - as a soil conditioner. This use has two particular applications; 1) for farming and, 2) for home use. Discussions with state agricultural persons indicated that use in farming applications (spreading) depends critically on the economics involved and may require merely "giving away" the ash to farmers for incorporation into soils. The use of the ash for a soil conditioner for shrubbery beds and lawns around the home also has potential benefits, since soil conditioners are definitely needed for the heavy clay soils in the Memphis/Mid-South area. In this application, the ash can be packaged and sold in 50 lb. bags. The Tennessee Department

of Agriculture indicated that no particular marketing problems existed for the ash unless specific claims were made for its intended use.

Other potential uses of the ash agglomerates yet to be investigated are use as an asphalt aggregate, road cinders, architectural faces for non-structural concrete, pea gravel for roofing, crushing and coloring for use on asphalt shingles, spray coating on commercial and industrial walls since the agglomerates are expected to have insulating and fire retardancy properties, or the possibility of recovering metals from the ash using some of the new processes currently under development in the United States.

The following calculations show the potential revenue expected for sale of ash agglomerates from the IFGDP. Obviously, the more exotic uses feasible and "small package" sale applications used, the greater the yearly revenue. The following calculations are based on use as a replacement for local sand in concrete:

Range of Ash Agglomerate Production: 100-150,000 Tons/Yr.

Range of Ash Agglomerate Netback (F.O.B.): \$3.50-\$7.00/Ton

Range of Revenue Expected:

a) Low: $100,000 \times \$3.50 = \$ 350,000/\text{yr.}$

b) High: $150,000 \times \$7.00 = \$1,050,000/\text{Yr.}$

Industrial Gases

Industrial gases are the third major by-product available from the IFGDP. The air separation process, while making the required oxygen, also liberates large quantities of nitrogen and can be designed to separate argon and other rare gases. The production and marketing of industrial gases in the United States is concentrated within a few large companies. In nearly all cases, these companies construct, own, and operate the facilities and provide the marketing organization necessary to sell these products.

It is emphasized that certain process and hardware modifications can be made in order to improve the liquid recovery and purity of these gases. A decision on liquid production and purity requirements will be made early in Phase II and will depend upon the negotiated agreements for marketing and potential revenue when evaluated against the additional capital cost of such changes. Five large industrial gas production and marketing companies were contacted over the last year and asked about their interest in marketing gas liquids from the IFGDP. These include; Union Carbide-Linde, Air Liquide, Air Products, Airco, and Big Three Industries. Their responses ranged from "not interested" to "very interested". Two companies have submitted proposals to MLGW for marketing of the gas liquids in the Memphis/Mid-South area. Future discussions and negotiations with these companies and others are expected.

At this time, three gas liquids have been identified for potential marketing. They include nitrogen/oxygen, carbon dioxide and argon. The nitrogen and oxygen requirements are not separately identified at this time. Nitrogen is commonly used as a blanketing

medium in either a process plant, metals, or electronics manufacturing, or can be used for freeze-drying in the food processing industry. Carbon dioxide is used in the Memphis area for freezing and shipping foods and beverage carbonation. Argon is used primarily for welding and is in quite short supply throughout the country.

From the data presented in Table 1, the conclusion reached is that there are significantly greater volumes of by-product gas available than can be marketed in the Memphis area. While the impact of sale for just part of the production will be significant, the major impact will result when all of the by-product gases can be sold. Development of this market will require a commitment and resources that do not appear to be feasible for MLGW at this time. For this reason, and the results of the economic studies, it was determined that MLGW will most likely own and operate the air separation facility and contract with a major industrial gas company to market the expected by-product gas liquids and provide netbacks to the IFGDP to offset operating costs.

Perhaps the biggest impact of offering by-product industrial gases in the Memphis area is the potential for attracting new industries. One industrial gas company has indicated that they would provide the necessary marketing services to attract new industries. They have indicated that companies which use large volumes of these gases, especially nitrogen and carbon dioxide, usually locate near the production facilities in order to lower their purchased liquids cost. Of particular interest would be

a meat packer that freeze-dries meats or a beverage bottling company.

The following calculations are based upon a proposal submitted by one industrial gas company to MLGW and reflects their expectation of net revenue available from the sale of by-product gases. It is emphasized that costly modifications to the air separation plant will be required to produce the liquid gas volumes indicated. The extent of the modifications and its effect on potential revenue are still subject to extensive negotiation in Phase II.

Expected Liquids Production:*

- a) Oxygen-nitrogen 300 Tons/Day
- b) Argon 63 Tons/Day
- c) Carbon Dioxide 300 Tons/Day

Expected Netbacks (F.O.B.)

- a) Oxygen-nitrogen \$25-30/Ton
- b) Argon \$50-\$75/Ton
- c) Carbon Dioxide (Raw) \$2-5.00/Ton

Operating Days = 330 Days/Year.

Range of Revenue Expected:

- a) Low: $(300(25) + 63(50) + 300(2)) \times 330 = \$3,712,500/\text{Yr.}$
- b) High: $(300(30) + 63(75) + 300(5)) \times 330 = \$5,024,250/\text{Yr.}$

In summary, the preliminary work accomplished to date indicates that sale of all the IFGDP by-products is feasible. The entire quantity of sulfur will be marketed without any difficulty. Assuming the acceptance of ash agglomerates as a aggregate replacement and

*Current projections of volumes that can be sold in area.

other uses, the entire volume of ash agglomerates should be sold. Yet to be decided and which has a revenue impact for IFGDP are the process modifications and cost for the air separation facility. The following table summarizes by-product revenue expectations and assumes the required modifications are made:

Table 2
Summary of By-Product Sale Revenue

<u>By-Product</u>	<u>Low</u>	<u>High</u>	<u>Average</u>
Sulfur	1,547,700	2,673,000	2,110,350
Ash Agglomerates	350,000	1,050,000	700,000
Industrial Gases	<u>3,712,500</u>	<u>5,024,250</u>	<u>4,368,375</u>
Totals	5,610,200	8,747,250	7,178,725

Hopefully, a long-term agreement will be reached for marketing the ash agglomerates and liquid recovered sulfur. It is expected that an agreement will be reached with the air separation plant supplier to market certain volumes of the by-product gas liquids. By allowing other companies to conduct the marketing, shipping, and billing for the by-products, the plant owner and operator will not have to contend with any unnecessary difficulties with by-product sales and can therefore concentrate efforts on successful plant operation.

The ultimate benefit of having these by-products available in the Memphis area is that they can contribute to the future economic development of the city. Pidgeon Industrial Park, located adjacent to the IFGDP site, has 4,000 + acres of industrial land ready for development. With the construction and operation of the Coal Gas Plant, enough energy will be available (electrical from TVA and gas from the IFGDP) so that industries will find it attractive to move into the Memphis area. The Pidgeon Industrial site is also adjacent to the Mississippi River and will be a source of transportation for large, heavy industries. Sufficient water resources, land, labor, surface transportation, and other factors already exist within the city of Memphis to make it an attractive area for new business. The local Chamber of Commerce is already working with industries in the United States, Japan, and Germany and hopes to have several industries locate in the Memphis area in the near future. The construction of the Industrial Fuel Gas Demonstration Plant and eventual availability of by-products will be a positive influence on the economic health and growth of the Memphis/Mid-South area.

INCLOSURE 1

MEMPHIS AREA CHAMBER OF COMMERCE SURVEY

Form and Letter

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Memphis Area Chamber of Commerce

February 9, 1979

Dear :

The availability of natural gas and alternate fuel sources are important for the attraction of new industry and for the continued operations of local industry. To insure the availability of these fuels, MLG&W has contracted with the Department of Energy to design, build, and operate a coal gasification plant that will produce a medium BTU gas for industrial use. Several by-products have been identified which MLG&W expects to market in this area. If successful with the design, MLG&W will start construction of the plant in 1980 and produce industrial fuel gas and by-products in 1984.

The information requested in the enclosed questionnaire is necessary to establish a final price for the industrial fuel gas. Since MLG&W is a municipal utility, the gas cost can be significantly reduced by income generated from by-product sales. Because MLG&W will market these by-products to cover costs and not for profit, local industries will have the opportunity to reduce their raw material costs.

The Memphis Area Chamber of Commerce has been asked to assist in this project for the purpose of protecting those companies furnishing information. If your company uses any of the raw materials listed on the questionnaire, we would be most appreciative if you would complete the information and mail the questionnaire to the appropriate address by March 2, 1979. The information you supply will be held in strict confidence and will be used only in compiling composite statistical tables. None of the information will be identified by company name.

We appreciate your assistance in this matter. If you have any questions or need further explanations of this project, please feel free to contact us at any time.

Sincerely,

C. Keith LeMar
Research Coordinator

CKL:fh
Enclosure

Memphis Area Chamber of Commerce

QUESTIONNAIRE

COMPANY NAME _____ ADDRESS _____

1) Does your company use any of the following raw materials?

	YES	NO
a) Carbon Dioxide	()	()
b) Nitrogen	()	()
c) Argon	()	()
d) Sulfuric Acid	()	()
e) Oxygen	()	()

2) If you answered "yes" to any of the above, please fill in the following data:

<u>MATERIAL</u>	<u>PURITY/ GRADE*</u>	<u>APPROXIMATE YEARLY QUANTITY REQUIRED</u>	<u>APPROXIMATE COST FOB SUPPLIER</u>	<u>DELIVERED COST</u>
Carbon Dioxide	_____	_____	per _____	per _____
Nitrogen	_____	_____	per _____	per _____
Argon	_____	_____	per _____	per _____
Sulfuric Acid	_____	_____	per _____	per _____
Oxygen	_____	_____	per _____	per _____

3) Do you expect your requirements for the above materials to increase in the next few years? () YES () NO

If yes, explain _____

*If more than one, please indicate.

Name of Person Providing Information

Title

PLEASE SEND COMPLETED QUESTIONNAIRE TO:

C. Keith LeMar
Memphis Area Chamber of Commerce
P. O. Box 224
Memphis, Tennessee 38101

INCLOSURE 2

SALE OF RECOVERED LIQUID SULFUR

Sample of Correspondence (1978-79)

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

REFINING COMPANY 543 west mallory • p. o. box 9097 • memphis tennessee 38109 • 901-774-3100

October 15, 1979

Mr. Bill Sleichter
Monsanto Chemical Company
800 N. Lindberg Blvd.
St. Louis, Missouri 63166

Dear Mr. Sleichter:

Since we last talked, our coal gasification project has progressed smoothly and is now nearing completion of Phase I. As we have discussed, the final Phase I report to the Department of Energy will include a section on sale of by-product sulfur and its economic consequences to the project.

Attached is a letter of intent that outlines, what we feel, is a reasonable commitment for your company at this time. Please note that the only obligation is to enter negotiations. We intend to use this letter of intent as a supporting exhibit in our Phase I report.

Please have an appropriate official of your company sign the inclosed document. I would appreciate receiving the executed copy by November 2, 1979. If you have any questions regarding this letter of intent or any facet of the project, please call me at your convenience.

Sincerely yours,

Peter J. Vanderzee
Project Manager
Synthetic Fuels

PJV:gh

Incl.

cc: Mr. R. W. Gray, Program Manager
Coal Gasification Department
Memphis Light, Gas and Water Division

REFINING COMPANY 543 west mallory • p. o. box 9097 • memphis tennessee 38109 • 901-774-310

May 9, 1979

Mr. Bill Hunter
Business Manager
Industrial Chemicals
Allied Chemical Corporation
Morristown, New Jersey 07960

Dear Mr. Hunter:

It has been a number of months since we last spoke regarding Allied's interest in purchasing by-product sulfur from a coal gasification facility planned for Memphis, Tennessee. Our project team will be finished with Phase I, a definitive cost estimate, by December 1, 1979. In early 1980, the decision on construction and operation will be made.

At this time, we want to confirm Allied's interest in purchasing recovered liquid sulfur. If Allied remains interested, we would like to develop an "intent to negotiate" agreement that we can include in our report due December 1, 1979. This agreement would define our mutual interests and declare our intent to negotiate a final purchase agreement during Phase II, plant construction.

As another option, has Allied considered building an acid plant in the Memphis area? An acid plant would take an over-the-fence stream of H_2S from our coal gas plant for direct conversion, thereby saving both parties capital and operating expense.

I would like to meet with you to discuss these proposals at your convenience. Please feel free to call me at any time.

Very truly yours,

Peter J. Vanderzee
Project Manager
Synthetic Fuels

PJV:gh

Olin CHEMICALS GROUP
120 LONG RIDGE RD., STAMFORD, CONN. 06904

June 28, 1978

Delta Refining Company
543 West Mallory
Memphis, TN 38109

Attention: Mr. Peter Vanderzee

Dear Pete:

Per our conversation of 6/27/78, Olin Corporation would probably be interested in purchasing recovered liquid sulfur from your planned coal gasification unit that you expect to have on stream late 1982 to early 1983. Expected volume is 65-90 Long Tons per day, and Olin can probably use it at our sulfuric acid plant in North Little Rock, Arkansas. Based on current plant economics and sulfur availability, a competitive delivered price would have to be in the low \$50's (\$50-\$55/Long Ton).

Please keep me informed as to the progress on this project. As discussed, Olin might also be interested in any sulfur coming from your refining operation.

Very truly yours,

L. T. Flower
Senior Purchasing Agent

LTF/dz

cc: H. Chubb

Ashland Chemical Company

DIVISION OF ASHLAND OIL, INC.

5200 PAUL G. BLAZER MEMORIAL PARKWAY, DUBLIN, OHIO 43017 • (614) 889-3333

REPLY TO:
P.O. Box 2219
Columbus, Ohio 43216

May 24, 1978

Mr. Pete Vanderzee
Delta Refining Company
P. O. Box 9097
Memphis, Tennessee 38109

Dear Mr. Vanderzee:

This will confirm our recent conversations concerning potential molten sulphur production by Delta Refining Company. It is my understanding that you are currently evaluating your options with regard to sulphur recovery some time in 1982 at a level of about 75 to 100 tons per day.

As indicated, Ashland would be very interested in marketing your sulphur production. We presently market sulphur recovered in our own refineries as well as acting as a reseller for outside production sources. I have initiated the necessary action to investigate the potential which you have presented. Upon completion of our analysis relating to markets and netbacks, I will be in a better position to discuss this further. A review of these areas will also enable us to be more specific in developing a purchase proposal.

During the interim, should you develop any additional information, I would appreciate hearing from you. I look forward to exploring this with you in the future and am hopeful that we might develop a mutually satisfactory arrangement between our companies.

Sincerely,

ASHLAND CHEMICAL COMPANY

A handwritten signature in cursive script, reading "S. Keith Payne".

S. Keith Payne
Manager, Supply & Distribution
Petrochemical Division

SKP:rae

INCLOSURE 3

SALE OF RECOVERED LIQUID SULFUR

Letters of Intent to Negotiate

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

November 2, 1979

Memphis Light, Gas and Water Division
P. O. Box 430
Memphis, TN 38101

Re: Intent to Purchase Sulfur

Gentlemen:

This letter confirms the intent of W. R. Grace & Co.
(Company)

to enter negotiations with the Memphis Light, Gas and Water Division of the City of Memphis for the purchase of recovered liquid sulfur, subject to the following terms, conditions, and understandings:

1. The liquid sulfur will be recovered from a coal gasification demonstration plant to be constructed in Memphis and funded jointly by the MLGW Division, City of Memphis, and the Department of Energy (DOE).
2. In accordance with the current schedule, the recovered liquid sulfur will become available in limited quantities in 1984 and full production quantities in 1985. This schedule is subject to change.
3. Full production quantities of recovered liquid sulfur are expected to be between 75-100 long tons per day.
4. The purity of the recovered liquid sulfur will meet the requirements for its intended use. The undersigned is under no obligation to negotiate if the recovered liquid sulfur does not meet the purity requirements for its intended use.
5. The undersigned will be responsible for all shipping and delivery arrangements. The recovered liquid sulfur will be available for truck loading at the coal gasification demonstration plant site.
6. The final negotiated price and terms of contract will be agreed upon within two years from the commencement of Phase II of the program, Demonstration Plant Final Design and Construction. The undersigned will be notified by the MLGW Division, City of Memphis, upon entry into Phase II.

7. The successful purchaser will have first right of refusal for any additional quantities of recovered liquid sulfur made available by plant expansion or other means. However, any additional quantities may be sold under a separate agreement.
8. The undersigned is under no obligation to MLGW Division, City of Memphis, or the Department of Energy (DOE) if this program, for any reason, does not enter into Phase II, now expected to be March 1, 1980.

This letter of intent shall be valid through December, 1982.

Company: W. R. Grace & Co.
Agricultural Chemicals Group

By:
F. J. Ronan

Vice President

Title: Sales Services

INCLOSURE 4

SALE OF ASH AGGLOMERATES

Engineering Evaluation Reports

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

PROJECT: ASH AGGLOMERATES TEST RESULTS

FOR: DELTA-REFINING COMPANY, INC.
543 MALLORY
MEMPHIS, TENNESSEE 38106

ORDER NO.: L ATTN: PETER VANDERZEE

REPORTING:
NO. OF COPIES
(1) Delta-Refining Company, Inc.
543 Mallory
Memphis, TN 38106

()

()

()

LAB. NUMBER: RRE-006
DATE: 5/3/79

Peabody Testing Services, Inc.

May 3, 1979

Delta-Refining Company, Inc.
543 Mallory
Memphis, Tennessee 38106

ATTN: Peter Vanderzee

RE: Ash Agglomerates Test Results

Peabody Testing

Ash agglomerates (ash) were tested in regards to ASTM C-33. This specification includes the test run on the ash. ASTM C-33 is basic to aggregate that may be used for a building material. Test results are presented later in this report.

ASTM C-29 indicates the unit weight of the ash as being a very light weight material. As a comparison the unit weights of sand and gravel are given.

ASTM C-128 the absorption obtain (22.8%) indicates a very porous material. This absorption of water would cause harmful results on concrete. The volume of water and cement would greatly be increased causing an obvious cost and strength problem.

The specific gravity also indicates the light weightness of the ash. As a comparison both sand and gravel are shown.

ASTM C-88 the sodium soundness results show a compatible material.

✓ ASTM C-136 and C-117 indicated a poorly graded material. This gradation does not conform to ASTM Specifications. The ash contains a high amount of material passing numbers 3/8, 4, 8 and 16 sieves. This indicates material size restrictions due the manufacturing process.

ASTM C-131 The L. A. Abrasion test was not run due to the size and fragile condition of the ash. Again this is a result of its formation processes.

✓ ASTM C-289 the potential reactivity results indicate no deleterious reaction with building materials.

ASTM C-109 was performed in lue of the mix design required. The cubes are a common comparison test used in the building industry. The test clearly show the weakness of the ash. The cement content in mixes A, B, and C was equal to a 6-bag mix of cement.

CONCLUSION

Based on the test results presented, the ash material does not conform to building requirements as per the ASTM. The formation of the ash greatly enhances the voids indicated by the percent absorption and the light weightness of the material.

Compatability to building materials as indicated by sodium soundness and potential reactivity is good. No harmful affects are indicated.

The structural values of the ash in a mix design is very poor. Compressive test indicate the weakness of the material. Also, if used in concrete the absorption, gradation and unit weight indicate a great increase in cost to any user to make the material acceptable. Therefore, it is not recommended as a structural material.

Possible uses are still being investigated at present. The use as a loose fill is indicated. Use as a sand blasting material is being investigated as is the possibility of an insulating material.

We will continue investigating the possibilities and inquire with our customers. The cubes for display will be cut and prepared for your usage early next week.

Thank you for this unique opportunity. I look forward to hearing from you.

Sincerely,

PEABODY TESTING SERVICES, INC.

Billy C. Smith
Laboratory Supervisor

BCS:pf

P. S. I will call about other possibilities including the sand blasting.

Peabody Testing Services, Inc.

Memphis, Tennessee

May 3, 1979

REPORT OF ASH AGGLOMERATES TESTS

FOR Delta-Refining Company, Inc.

JOB _____

SAMPLE FROM _____

SOURCE OF MATERIAL _____

Selected test were performed on the ash agglomerates. The results are as follows:

PHYSICAL TEST:

ASTM - C - 29 - UNIT WEIGHT - (PCF)

Condition	Results	
	Loose	Rodded
as is	59.3	64.8
dry	57.7	62.0
wet	62.8	67.7

As a comparison:	sand	Pea gravel
	107.3 (PCF)	91.3 (PCF)

<u>ASTM - C 128</u>	Specific gravity & absorption	specific gravity
Ash	Sand	Pea Gravel
2.09	2.60	2.52
% absorption	22.8%	

REMARKS:

COPIES TO:

LABORATORY NO.

(PAGE 1 OF 3)

RRE-006

4-6

Peabody Testing Services, Inc.

Memphis, Tennessee

May 3, 1979

REPORT OF ASH AGGLOMERATES TESTS

FOR Delta-Refining Company, Inc.

JOB _____

SAMPLE FROM _____

SOURCE OF MATERIAL _____

ASTM C - 88

Sodium Soundness

1.40

ASTM - C 136 / C - 117

Sieve Analysis / Fined than # 200 sieve

% Passing

SIEVE SIZE	ASH	LOCAL SAND	LOCAL PEA GRAVEL
3/8	100.0	100.0	100.0
#4	99.6	96.7	30.3
#8	95.2	79.0	1.2
#16	53.1	66.4	0.6
#30	1.1	50.1	0.4
#50	0.4	9.6	0.1
#100	0.2	0.2	
#200	0.1		

ASTM - C 131

Los Angeles Abrasion - Not run

CHEMICAL TEST:

ASTM - C - 289

Potential Reactivity

Dissolved silica, millimoles/liter 48

reduction in alkalinity, millimoles/liter 92

ASTM - C - 109

Compressive Test 2x2x2 cubes

Volumetric mix by parts.

REMARKS:

IES TO:

Peabody Testing Services, Inc.

Memphis, Tennessee

May 3, 1979

REPORT OF ASH AGGLOMERATES TESTS

FOR Delta-Refining Company, Inc.

JOB _____

SAMPLE FROM _____

SOURCE OF MATERIAL _____

MIX:

	CEMENT	ASH	PEA GRAVEL
A	1	2	3
	CEMENT	SAND	PEA GRAVEL
B	1	2	3
	CEMENT	SAND	PEA GRAVEL
C	1	2	2

COMPRESSIVE TEST RESULTS (PSI)

	3 DAY	7 DAY	28 DAY
A	625/600	875/1000	1925/1700
B	1875/1925	2475/2750	4325/4500
C	700/675	1025/1100	2050/2125

REMARKS:

Memphis, Tennessee

April 20, 1979

REPORT OF SOUNDNESS TEST

FOR Delta Refining Company, Inc.

JOB

SAMPLE FROM

SOURCE OF MATERIAL Slag

5

CYCLE

Sodium

SULFATE

Sieve Size		Grading of Original Sample, %	Wt. of Test Fractions Before Test, %	Percentage Passing Finer Sieve After Test (Actual Percentage Loss)	Weighted Average (Corrected Percentage Loss)
Passing	Retained on				

SOUNDNESS TEST OF FINE AGGREGATE

#100 (149-micron)		0.2			
#50 (297-micron)	#100 (149-micron)	0.2			
#30 (590-micron)	#50 (297-micron)	0.7		0.0	0.0
#16 (1190-micron)	#30 (590-micron)	52.0	100	0.0	0.0
#8 (2380-micron)	#16 (1190-micron)	42.1	100	3.0	1.26
#4 (4760-micron)	#8 (2380-micron)	4.4		3.0	.13
3/8"	#4 (4760-micron)	.4		3.0	.01
TOTALS		100.0			1.40

SOUNDNESS TEST OF COARSE AGGREGATE

2-1/2"	1-1/2"				
1-1/2"	3/4"				
3/4"	3/8"				
3/8"	#4 (4760-micron)				
TOTALS					

REMARKS:

COPIES TO:

LABORATORY NO.

SCJ 3819

4-9

Peabody Testing Services, Inc.

Memphis, Tennessee

May 11, 1979

REPORT OF _____

FOR Delta Refining Company, Inc., 543 Mallory, Memphis, Tennessee 38106

JOB Special Testing of Ash Agglomerate

SAMPLE FROM _____

SOURCE OF MATERIAL Delta Refining Company, Inc.

SOLID VOLUME MIXES - 2" x 2" x 2" cubes

Materials - Type I Portland Cement - 6.0 sacks

Local Sand - As described in previous letter

Ash Agglomerate -

Basic Mixes #1 cement - 564# sand - 2042# - Ash 655#
Water - 50 gallons

#2 cement - 564# sand - 1755# - Ash 890#
Water - 50 gallons

#3 cement - 564# sand - 1472# - Ash 1124#
Water - 50 gallons

REMARKS:

NOTE: #1 - mix - 28.0% ash
#2 - mix 38.0% ash
#3 - mix 48.0% ash

COPIES TO: 1-Delta-Refining Company, Inc.

LABORATORY NO.

(SHEET #1 OF 2)

Peabody Testing Services, Inc.

Memphis, Tennessee

May 11, 1979

REPORT OF _____

FOR Delta Refining Company, Inc., 543 Mallory, Memphis, Tennessee 38106

JOB Special Testing of Ash Agglomerate

SAMPLE FROM _____

SOURCE OF MATERIAL Delta Refining Company, Inc.

COMPRESSION TEST (PSI) 2" x 2" x 2" Cubes

Mix #1	3 day	-	1125#
	7 day	-	1850#
	28 day	-	3025
#2	7 day	-	1175#
	28 day	-	2200 - porous cube 2625
#3	7 day	1275#	2250
	28 day	-	2125

REMARKS:

ES TO: 1-Delta Refining

LABORATORY NO. (SHEET #2 OF 2)

PROJECT:

EVALUATION OF PRIOR SUBMITTED ASH AGGLOMERATES
TEST RESULTS AND PROPOSED RECOMMENDATIONS FOR
ADDITIONAL TESTING (FINAL REPORT)

FOR:

Delta-Refining Company, Inc.
543 Mallory
Memphis, Tennessee 38106

ORDER NO. :

ATTN: Peter Vanderzee

REPORTING:

NO. OF COPIES

(1)

Delta-Refining Company, Inc.
543 Mallory
Memphis, Tennessee 38106

(1)

Hans Vanders

DATE:

August 7, 1979

Peabody Testing Services, Inc.

We enjoyed our meeting last Friday with you and appreciate the clarifications we received from you. We now have a background on which to base certain recommendations.

As brought out by you, data with regard to specific sintering temperatures in your process are not exactly defined at this time (1600 - 2300° F?) Two types of ashes were produced in your pilot plant operation; ash formed at higher temperature in the form of small balls and ash collected at a lower temperature in the form of aggregate particles.

The sample sent to our laboratory was the lighter, low temperature aggregate type ash. Your question was if this ash agglomerate could be sold as Lightweight aggregate to the concrete industry.

Based upon your comments in our meeting of last Friday, the material tested by us might not be a representative sample of the material to be obtained from the plant in Memphis, Tennessee. The final product will have in all probability better quality characteristics, according to you.

You expect a total ash agglomerate of 300 - 450 tons per day; based upon the difference of \$5.00 plus per ton for disposal and a possible initial \$5.00 per ton for a salable product, you are looking at estimated extra revenues of approximately \$900,000.00 per year, based upon 300 tons per day, 300 working days and a \$10.00 differential in costs per ton of ash.

Peabody Testing tested the material sent by you to us accordingly to A. S. T. M. specifications. The applicable A. S. T. M. designations and obtained test data were given to you in our letter of May 3, 1979.

In our conclusion of May 3, 1979, we had to state that the material at present does not meet certain A. S. T. M. requirements for aggregate application in the building industry.

Based upon the unit weights obtained, the material has to be classified as a lightweight material and as such could be compared with Arkalite which is produced in West Memphis as a Lightweight Aggregate.

Your material showed a water absorption of 22.8%; Arkalite has shown water absorption in this range.

The gradation of your material is accordingly to A. S. T. M. C 136 and C. 117 poor. The gradation obtained put it somewhere between fine and coarse aggregate.

Certain modifications to mix designs for concrete (Ready Mix and block) might be able to produce acceptable compressive strength results, although we still might be outside the scope of certain A. S. T. M. designations.

We might overcome this set back by splitting the aggregate into a coarse

and fine material, which has been done before in the industry and is an inexpensive operation.

Whereas this material is produced from Kentucky #9 coal, we do expect a low alkali and sulphur content. This was confirmed in our tests (A. S. T. M. C.88) and indicates that this material can be used, where applicable in concrete mix design. The test run accordingly to A. S. T. M. C-289 confirms the previous statement.

We know that the material is formed as a kind of fly ash and will have to take a closer look at its hydraulic characteristics.

Our suggestions based upon our preceeding evaluation is:

A. Compare your material with Arkalite

1. Make a 5 and 6 bag of cement/cu. yard of concrete; test for strength and evaluate for comparison

B. Your Material Only

1. Design concrete mixes based upon the specific gradation of your material; obtain the necessary test results and evaluate these results.
2. Split your material in a coarse and fine portion and proportion mix designs. We might now be able with a certain portion to meet A. S. T. M. requirements.

We advise to undertake section A and B at the same time on account of the time requirements. If you want to delete any part of these two sections we suggest to delete section A because section B is pertinent to your material and section A is for comparison.

C. Feasibility study for other possible application

Design typical mix designs for non-structural application-to be used for Lightweight panels or fill in accoustical and thermal applications. Of course, only testing will determine if these goals can be accomplished.

The costs for this suggested program are:

Section A \$ 1250.00

Section B \$ 3250.00
 (B-1 : \$ 1750.00)
 (B-2 : \$ 1500.00)

Section C No price estimate because this will be a feasibility study and the cost will be determined by your specific - to be outlined - goals.

We advise to start our program not later than August 13, 1979, in order to meet your deadline of September 30, 1979.

Looking forward to hearing from you.

Sincerely,

PEABODY TESTING SERVICES, INC.

Hans A. Vanders

HAS:pf

REPORT OF:

Testing report on ash agglomerates
Section A

FOR:

Delta-Refining Company, Inc.
543 Mallory
Memphis, TN 38106
ATTN: Peter Vanderzee

REPORTING:

NO. OF COPIES

(1)

Delta-Refining Company, Inc.
543 Mallory
Memphis, TN 38106

()

DATE:

September 4, 1979

Peabody Testing Services, Inc.

In accordance with our proposed testing program for the evaluation of your ash, we made different concrete mix designs.

We started off with a 5 bag and 6 bag Arkalite mix design, which designs were to serve as reference mixes.

The Arkalite lightweight aggregate had a water saturated weight of 46.54 lbs/cu. ft. The sand used had a weight of 105.4 lbs/cu. ft. on a surface dry weight basis.

Reference mix designs

The mix design developed as reference mixes are as follows:

5 bag design

Mix #1

Arkalite	;	369. lbs.	(18 2/3 cu. ft.)
Sand	;	1370. lbs.	(13 cu. ft.)
Cement	;	470. lbs.	(5 bags)
Water	;	237. lbs.	(28.49 gallons)

Admixtures

Pozz 3 oz. per 100 lbs of cement.

Air (Master Builders) 2.5 oz. per cu. yard.

This mix design yielded a concrete mix with the following characteristics:

Slump	;	4 1/2
Air	;	4.7%
Unit weight	;	109.0 lbs./cu. ft.
Yield	;	27.02 cu. ft./cu. yard of concrete

6 bag design

Mix #2

Arkalite	;	869. lbs.	(18 2/3 cu. ft.)
Sand	;	1299. lbs.	(12 1/3 cu. ft.)
Cement	;	564. lbs.	(6 bags)
Water	;	254	(30.5 gallons)

Admixtures

Pozz 3 oz. per 100 lbs. of cement

Air (M.B.) 2.5 oz. per cu. yard

The mix design yielded a concrete mix with the following characteristics:

Slump: 4 3/4"

Air: 4.8%

Unit weight: 110.8 lbs./cu.ft.

Yield: 26.95 cu. ft./cu.yd.

The sand used in these concrete mixes is of local origin and has the following characteristics:

<u>Sieve</u>	<u>Retained %</u>	<u>Passing %</u>
3/8	0.0	100.0
4	1.9	98.1
8	13.5	86.5
16	22.2	77.8
30	34.7	65.3
50	87.2	12.8
100	99.6	0.4 f.m.:2.59

Voids: 35.3%

Moisture absorption: 0.84%

This sand is defective from the 30# to 50#, a gap of 52.5% (!), but it is locally used.

The arkalite had the following characteristics:

<u>Sieve</u>	<u>Retained %</u>	<u>Passing %</u>
3/4	0.0	100.0
1/2	11.6	88.4
3/8	34.3	65.7

#4	82.1	17.9
#8	90.5	9.5
Pan	100.0	0.0

Moisture absorption: 22.2%
 Dry weight: 36.45 lbs/cu.ft.

Trial Mix Designs

We decided to duplicate the 6 bag mix design first and test the "ash" as a lightweight aggregate, although the gradation of this material doesn't conform with a course aggregate. However, mixing characteristics had to be established for further evaluation.

The dry weight of the "ash" was 57.0 lbs./cu.ft.. This represented no change with the previously established dry weight; no change was expected because the material had been stored in a closed drum.

The trial mix was designed with the Arkalite reference design mix in mind.

The following mix design was developed:

	6 bag design	Mix #3
"Ash"	1054 lbs (dry, 18½ cu. ft.)	
Sand	1299 lbs. (12 1/3 cu. ft.)	
Cement	564 lbs. (6 bags)	
Water	To be determined during actual mixing procedure	

Assuming a 20% moisture absorption by the "ash" and being further equal to the Arkalite reference mix design, a total water demand of 465 lbs. or 55.8 gallons was to be expected.

Admixtures: Pozz: 3 oz. per 100 lbs of cement.

Air (M.B.) 2.5 oz. per cu. yard.

During the mixing of the materials we established the slump of the concrete mix at different intervals.

After the addition of water equivalent to 55 gallons cu. yard the slump was 1". The addition of an amount of water equivalent to 5 gallons cu. yard raised the slump to 1 3/4" ; the addition of more water, equivalent to 6.8 gallons cu. yard raised the slump to 3".

Our total water addition accounted to 66.8 gallons of water of which we could attribute approximately 25.3 gallons to the water absorption of the dry ash.

It leaves $66.8 - 25.3 = 41.5$ gallons for mixing purposes. In the Arkalite reference we used a total of 30.5# gallons of water; therefore we have an increase of 36% in water demand, while the slump is only 3".

We did not continue the water addition to the mix because the concrete mix was bleeding - taking a slump cone, the water and cement was bleeding out excessively.

The following characteristics was obtained for this mix design:

Slump:	3"
Bleeding	(!)
Air:	4.2%
Unit weight:	125.8 lbs/cu.ft.
Yield:	27.6 cu. ft./cu. yd.

Because of the excessive water requirements and the profound bleeding which was observed, we took a closer look at the "ash" water characteristics.

The following test was done:

200 grams of ash was spread out on a plate and water added to the material. Up to 90 ml of water addition didn't show any visible excess water. By tilting the plate (60° angel), the water drained

out rapidly - a total of 58 ml. was collected in 20 seconds. The Ash material didn't slide! By adding again 48 ml. of water, no visible water could be detected; however, the same 48 ml. water could be drained off again within seconds by tilting the plate. The observation made during the mixing of the material in a concrete mix design and the particular water characteristic behavior of the ash necessitated a re-approval of the next mix design. In stead of a 5 bag mix design which on account of the water demand could not yield any strength, the best approach at this time was to combine the "ash" with and Arkalite and sand, in a 6 bag mix design.

The following design mix was set-up:

	<u>6 bag design</u>	<u>Mix #4</u>
Cement	564 lbs. (6 bags)	
Arkalite	842 lbs. (18½ cu. ft/ (wet)	
Sand	690 lbs. (6½ cu. ft.)	
Ash	380 lbs. (6 2/3 cu. ft.)	
Water	To be determined	
Admixtures:	Pozz	3 oz. per 100 lbs of cement.
	Air (m.b.)	2½ oz. per cu. yard.

Of the water to be added, we can assume that the ash will absorb approximately 78 lbs or 9.4 gallons.

Water addition was as follows:	31.5 gallons	slump 1"
Water addition:	36.35 gallons	slump 1½"
Water addition:	42.2 gallons	slump 3¼"

Mix characteristics:

Slump:	3¼"
Air:	difficult to measure estimated at 4%
Unit weight:	105.5 lbs./cu.ft.
Yield:	26.8 cu. ft./cu. yard

We stopped the water addition at 42.2 gallons because the mix started to bleed excessively.

Compared to the reference 6 bag Arkalite mix we arrive at the following:

Arkalite/Ash mix	42.2 gallons
Absorbed by ash approximately	9.4 gallons
mixing water	32.8 gallons

or 107.5% of the water demand by the plain Arkalite mix. This water demand is better in line with the reference mix (mix #2)

The compressive strength data obtained are:

<u>Reference mixes</u>	3 days	7 days
#1 (5 bag)	1840 ; 1880 psi	2370 ; 2400 psi
# 2 (6 bag)	2440 ; 2400 psi	3540 ; 3400 psi

<u>Trial mixes</u>	3 days	7 days
# 3 (6 bags, ash, sand)	920 ; 884 psi	1340 ; 1420 psi
# 4 (6 bags, arkalite, ash, sand)	1770 ; 1800 psi	2720 ; 2760 psi

28 days compressive strength will follow.

Evaluation

Arkalite Reference Design

Mix #1 (5 bag)	Most likely to meet 3000 psi in 28 days
Mix #2 (6 bag)	Most likely to meet 4000 psi in 28 days

Ash Mixes

Mix #3 (No Arkalite)	No strength
Mix #4 (part sand)	Likely to meet 3000 psi in 28 days

DISCUSSION AND RECOMMENDATIONS

The test results obtained indicate that mix #4 - in which part of the sand was replaced by your ash - shows compressive strength figures which could warrant further testing.

Mix #3 - in which the ash replaced the Arkalite had a high water consumption and the cylinders which were broken at 3 and 7 days showed this excessive water.

In both mixes, but especially in Mix #3, we observed shrinkage in the cylinder molds.

Our recommendation is to continue with a mix #4, changing the cement content and the percentage of sand to be replaced by ash. Sand replaced by ash will lower the weight of the concrete per cubic foot, which can apply to certain applications. It can make the ash a salable product. Suggested at this time: A 5½ bag mix design with 25%, 50% and 100% replacement of the sand by ash. The water demand will determine the next step. It might rule out a high replacement % of the sand, in which case the mix design with high sand replacement have to be abandoned.

As a fourth mix, we will change from Arkalite to regular gravel for the mix which proved most promising with the Arkalite.

Shrinkage will be measured of these mix designs as well as freeze & thaw characteristics.

These recommendations fit in with the 2nd phase of our testing program.

Whereas the mix showed in mix #3 a particular characteristic with regard to slump (slump very slow increasing with water addition) we can consider for the 3rd phase a block mix design with necessary modifications to accomodate your sand. We suggest that this block mix design is run at the same time we are running the concrete mixes as outlined, before, although this test would be part of our third phase with regard to testing (section B-2); a split in fine and coarse material as previously outlined doesn't seem applicable at this time.

Sincerely,

PEABODY TESTING SERVICES, INC.

Hans A. Vanders.

HAS:pf

September 25, 1979

Delta Refining Company
543 Mallory
Memphis, Tennessee 38106

Attn: Mr. Vanderzee

Follow up on our report of September 4, 1979. The following 28 day's compressive strength data were obtained today:

	<u>28 days strength</u>	
Mix # 1 (5bags Ref. Mix)	3360 psi 3430 psi	Av. 3395 psi
Mix #2 (6 bags Ref. mix)	4320 psi 4030 psi	Av. 4175 psi
Mix #3 (6 Bags No Arkalite)	2090 psi 2020 psi	AV. 2055 psi
Mix #4 (6 Bags Ark. Sand, Ash)	4070 psi 3540 psi	AV.. 3805 psi

We discussed the overall characteristics in our discussion in our report of September 4, 1979. These results fit in with the results obtained in section B of our testing program and we refer to the discussion in that report.

Sincerely,

PEABODY TESTING SERVICES, INC.

Hans Vanders

REPORT OF:

Ash Agglomerates, Section B

PROJECT:

Delta Refining Company, Inc.

FOR:

Delta Refining Company, Inc.
543 Mallory
Memphis, Tennessee 38106

REPORTING:

NO. OF COPIES

(3)

Delta Refining Company, Inc.
543 Mallory
Memphis, Tennessee 38106

()

()

()

DATE:

September 25, 1979

4-27

Peabody Testing Services, Inc.

Following up on our recommendations as outlined in section A of our testing program, we tested different mixes (3 mixes) in which part of the sand was replaced by ash and Arkalite as Lightweight aggregate was used.

A fourth (4th) mix design was developed in which the Arkalite was replaced by gravel and 1/3 (one third) of the sand was replaced by ash.

Basic Mix Design

We selected a mix design with a cement content of 5.7 bags of cement per cubic yard of concrete. This amount of cement (536 lbs.) per cubic yard of concrete will produce with the local materials a 3000 psi plus concrete.

The same materials were used as for the mixes tested in section A of our testing program - our report of September 4, 1979. We did run all gradations curves, unit weight and absorption tests again, but found no differences with regard to our previously obtained data.

A review of these data is as follows:

The sand used in these concrete mixes is of local origin and has the following characteristics:

<u>Sieve</u>	<u>Retained %</u>	<u>Passing %</u>
3/8	0.0	100.0
4	1.9	98.1
8	13.5	86.5
16	22.2	77.8
30	34.7	65.3
50	87.2	12.8
100	99.6	0.4 f.m:2.59

Voids: 35.3%

Moisture absorption 0.84%

This sand is defective from the 30# to 50#, a gap of 52.5% (!), but it is locally used.

The arkalite had the following characteristics:

<u>Sieve</u>	<u>Retained %</u>	<u>Passing %</u>
3/4	0.0	100.0
1/2	11.6	88.4
3/8	34.3	65.7
#4	82.1	17.9
#8	90.5	9.5
Pan	100.0	0.0

Moisture absorption: 22.2%
Dry weight: 36.45 lbs/cu.ft.

The mix design developed is as follows: per cu. yard of concrete.

Cement: 5.7 bags or 536 lbs.
Arkalite: 18½ cu.ft. (water saturated).
Sand & Ash: 13¼ cu. ft.

Sand: S.S.D.
Ash: As is

Water: To be determined

Admixtures

Pozz: 4 oz. per 100 lbs. of cement

Air: 4 oz. per cubic yard of concrete

In mix #1, $\frac{1}{4}$ part of the sand was replaced by ash.

In mix #2, $\frac{1}{2}$ part of the sand was replaced by ash.

In mix #3, $\frac{3}{4}$ part of the sand was replaced by ash.

Some variations in yield were expected; we found these variations to be minor!

Test observations

per cubic yard of concrete

Mix #1

Cement: 536 lbs. (T.X.I. Cement)
Arkalite: 868 lbs.
Sand: 1100 lbs.
Ash: 203 lbs.

(marked as mix #5)

Water addition: 267 lbs. (32.4 gals.)

Admixtures: 4 oz. of pozz per 100
lbs. of cement

4 oz. of air per cu. yd.
of concrete

Theoretical Wet Weight: 110.14 lbs./cu. ft.

Data obtained:

Slump: $3\frac{1}{2}$ inches
Air: 4%
Wet weight: 109.9 lbs./cu. ft.
Yield: 27.06 cubic ft./cubic yard of concrete

No specific problems were encountered during the mixing cycle.

Mix #2

More sand replaced by ash

(marked as mix #6)

per cubic yard of concrete

Mix design

Cement: 536 lbs.
Arkalite: 868 lbs.
Sand: 745 lbs.
Ash: 381 lbs.

Admixtures: 4 oz. of Pozz per 100 lbs.
of cement.

4 oz. of Air per cu. yd.
of concrete

Water: 323 lbs. (38.8 gallons)

Theoretical wet weight: 105.6 lbs./cu. ft. of concrete

Data obtained:

Slump $3\frac{1}{4}$ inches, mix workable

Air: 3 $\frac{3}{4}$ %

Wet weight: 106.0 lbs. per cu. ft. of concrete

Yield: 26.9 cu. ft./per cubic yard of concrete

Specific problems encountered during the mixing cycle were slump and
air. We tried to bring up the air content, but did not succeed!

We could not add more water because mix started to bleed!

Mix #3

per cubic yard of concrete

(marked as mix #7)

Cement: 536 lbs.

Arkalite: 868 lbs.

Sand: 378 lbs.

Ash: 605 lbs.

Admixtures: 4 oz. of Pozz. per 100 lbs.
concrete

6 oz. of air per cu. yd of
concrete

Water addition: 340 lbs. (44.8 gallons)

Theoretical Wet Weight: 102.2 lbs./cu. ft. of concrete

Data obtained:

Slump: at 40.8 gallons of water addition: 1"
at 42.8 gallons of water addition: $1\frac{1}{4}$ "
at 44.8 gallons of water addition: $1\frac{1}{4}$ "

Air : 3% with a question mark! Stiff mix.

Wet weight: 104.0 lbs. per cu. ft. of concrete

Yield: 26.5 cu. ft./cu. yard of concrete.

Problems encountered in water addition and slump; mix stays up! and started to bleed.

The fourth (4th) trial mix designed included the elimination of Arkalite - to be replaced by gravel - and the partial replacement of sand by ash.

In order not to deviate from current mix designs in the industry, we selected the following mix design:

	<u>Per cu. yard.</u>
Cement:	536 lbs. (5.7 bags of cement)
Gravel:	1875 lbs. S.S.D.
Sand:	1350 lbs. S.S.D.
Admixtures:	3 oz. of pozz. per 100 lbs. of concrete.
	4 oz. of air per cu. yard of concrete

and made the following change:

Mix #4 (marked as Mix #8)	<u>Per cu. yard.</u>
Cement:	536 lbs. cement (same)
Gravel:	1875 lbs. (same)
Sand:	900 lbs. (S.S.D.)
Ash:	252 lbs. (as is)
Water:	250 lbs. (30 gallons)
Admixtures:	No change

Theoretical wet weight: 142.1 lbs./cu.ft. of concrete.

Data obtained:

Slump: 3 3/4" inches
We tried to increase the slump: Mix started to Bleed
It was a workable mix!

Air: 3 1/2 - 4%

Wet weight: 142.57 lbs./cu. ft. of concrete

Yield: 26.9 cu. ft./cu. yard of concrete

The following compressive strength test data have been obtained:

<u>Mix #</u>	<u>Slump</u>	<u>Arkalite</u>	<u>Gravel</u>	<u>Sand</u>	<u>Ash</u>	<u>7 days compressive strength</u>
1	3½"	X	-	75%	25%	2480 psi 2860 psi Avg. 2670 psi
2	3½"	X	-	50%	50%	2970 psi 2650 psi Avg. 2810 psi
3	1½"	X	-	25%	75%	2690 psi 2440 psi Avg. 2565 psi
4	3 3/4"	-	X	66%	34%	4210 psi 4140 psi Avg. 4175 psi

Discussion:

Mix #1, #2 and #3 all should reach 3000 psi compressive strength in 28 days.

Mix #4 showed a remarkable performance. The 7 days strength is in excess of 4000 psi. The wet unit weight was only 142.5 lbs. per cu. ft. of concrete.

Shrinkage observed in all samples was within acceptable tolerances.

However, mix #3 was very hard to place in cylinder mold - showed voids

in the concrete and consequently cannot stand freeze-thaw cycles in field operations.

The 7 days' compressive strength figures indicate that ash sales might be feasible as part of sand replacement in concrete mixes under certain conditions. The gravel mix performance definitely enhances this approach.

The other characteristics observed indicate try-outs for block mix designs and stiff mixes (Featherlite, pipe plants, etc.), which would be a year-round sale. These try-outs will bring us into the third part of our testing program.

Sincerely,

PEABODY TESTING SERVICES, INC.

Hans A. Vanders

HAV:pf

PROJECT:

Ash Agglomerates, Section B, (2nd part)
Delta Refining Company, Inc.

FOR:

Delta Refining Company, Inc.
543 Mallory Avenue
Memphis, Tennessee 38109

ATTN: Mr. P. Vanderzee

REPORTING:

NO. OF COPIES

(5)

Above

Peabody Testing Services, Inc.

DATE:

November 12, 1979

INTRODUCTION

This report discusses the results of the 2nd phase of a two part testing program designed to assess the feasibility of utilizing ash agglomerates in concrete.

Following up on our discussion with you with regard to the results obtained in certain concrete mixes with your ash replacing part of the sand, we extended the testing program to establish a compressive strength pattern with different amounts of cement and to include an evaluation of a potential block mix design.

In order to maintain consistency with prior tests, we used the same materials sources as incorporated in our mix designs #1 through #8 - see our previous reports.

The following mix designs were developed:

- Mix #9 A mix with 470 lbs. of cement per cubic yard of concrete (5 bag)
Mix #10 A mix with 493 lbs. of cement per cubic yard of concrete (5½ bag)
Mix #11 A mix with 517 lbs. of cement per cubic yard of concrete (5½ bag)
Mix #12 A typical block mix design.

The following actual designs were put up in which 1/3 volume part of the sand was replaced by ash:

	Mix #9	Mix #10	Mix #11
Cement	5 bag	5½ bag	5½ bag
Sand	470 lbs.	493 lbs.	517 lbs.
Ash	925 lbs.	905 lbs.	885 lbs.
Gravel	<u>1825 lbs.</u>	<u>1825 lbs.</u>	<u>1825 lbs.</u>

Sand and gravel both surface dry. Corrections to be made in batch weight content.

Water addition to mixes:

Mix #9	31 gallons
Mix #10	31 gallons
Mix #11	31.3 gallons

Total weight of Mixes:

	Mix #9	Mix #10	Mix #11
Dry materials	3475 lbs.	3480 lbs.	3477 lbs.
Water	258 lbs.	258 lbs.	260 lbs.
Total weight	3733 lbs.	3738 lbs.	3737 lbs.
 Theoretical weight per cubic foot of wet concrete	 138.3 lbs.	 138.5 lbs.	 138.5 lbs.

Admixtures to mix #9, #10 and #11

Air entraining agent: 5 oz. per cubic yard

Water reducing agent: 4 oz. per 100 lbs. of cement

Data Obtained:

	Mix #9	Mix #10	Mix #11
Wet weight of concrete per cu. yd.	138.65 lbs.	138.85 lbs.	138.60 lbs.
 Yield obtained cu. ft/cu. yard	 26.93	 26.93	 26.98
 Air	 3½%	 4%	 4½%
Slump	3"	4"	5"

The slump for the different mixes varied, because we did not want any bleeding in the concrete and we were looking for a good workability.

Mix #9 obtained a good workability at 3" slump. Mix #10 obtained with the same amount of water a slump of 4" The difference between 3" and 4" slump is minor, because an addition of ¼ gallon of water to the concrete mix can cause an increase of 1" to 2" in the slump.

Mix #11 had approximately the same amount of water, but an higher cement

content. Because of more fines in the concrete mix, the air was better retained, which resulted in an increase in slump.

The following compressive strength data have been obtained:

	3 days	Average	7 days	Average	28 days	Average
Mix #9	2190 2300	2255 psi	3080 3180	3130 psi	4030 3930	3980 psi
Mix #10	2400 2260	2330 psi	3400 3570	3485 psi	4240 4420	4330 psi
Mix #11	2830 2860	2845 psi	3900 3610	3755 psi	5090 4880	4985 psi

We made four (4) 3" cubes from the 5½ bag mix design for your display use.

Our next step was to incorporate the ash into a block mix design. A trill table is available in the laboratory on which we can simulate the action of a block machine. The top pressure has to be applied by hand. Consequently, compaction of our mix is less than under actual conditions. Increased compaction will promote higher strength characteristics.

The cement consumption in a typical block mix is generally in the 11 - 15% range by total weight of the mix design.

Because we wanted to obtain an indication on cement consumption and on ash incorporation into the mix, we decided on

11% of cement by weight
and 50% replacement of sand by ash.

The original mix design was

Mix A: 700 lbs. of cement (10.94% by total weight)
 3300 lbs. of sand
 2400 lbs. of gravel, passing 3/8" sieve.

By incorporating ash, the new mix design was as follows:

Mix B: 700 lbs. of cement
 2400 lbs. of gravel, passing 3/8" sieve
 1650 lbs. of sand (50% of original sand amount)
 1100 lbs. of ash

The unit weight of a block for mix B is 9% less than the unit weight of a block made from Unit A. This is encouraging because it will make handling easier. We tested this block mix for a 7 days' compressive strength and obtained a strength of 2166 psi on a cylinder of 3 x 6 inches. The solid area of a block is approximately 36.8% of the total gross area of a block; therefore, we obtained a comparative block strength of 800 psi. The A.S.T.M. (C-90) sets a minimum of 700 psi for above grade and 1000 psi below grade. We expect the 28 days strength to improve, so both strength specifications will be met. At the same time, we only simulated a block machine action and therefore do expect strength figures approximately 30% lower than to be found with a typical production block machine.

The industry steam cures its block, because it is felt that proper steam curing of only 8 hours will result in a 7-14 days compressive strength characteristic of the typical block mix. Therefore, the 7 days compressive strength obtained in the laboratory indicates the minimum strength obtained after 24 hours if steam curing had been applied.

Our experience is that the 7 days compressive strength equals 80-90% of the compressive strength obtained within 24 hours with steam curing. The 28 days' compressive strength is 980 psi, which indicates that ASTM-C-90 specifications in all probability will be met for above and below grade application.

Discussion

The mix designs (#9, #10, #11) showed the following 28 days strength:

		Average psi
#9	3930 4030	3980
#10	4240 4420	4330
#11	5090 4080	4985

Therefore, we can recommend the following:

5 bag design	3000 psi design strength
5½ bag design	3000 psi design strength
5½ bag design	4000 psi design strength

The compressive strength obtained with the different mix designs is indeed good and compares very favorable with other mix designs used in this area.

As a matter of fact, the compressive strength found with the ash addition indicates that cement savings can be achieved by the concrete manufacturers. Whereas cement will be priced at \$60.00/ton in 1980, the savings of to cut the cement by only 25 lbs. per cubic yard of concrete amounts already to 75 cents per cubic yard of concrete for the concrete manufacturer.

However, we have to state that we have to be careful with water additions to these mixes, because of low slump and consequent bleeding problems.

The block mix came up to a good 7 days strength figure and incorporation into a block mix appears possible! We do suggest more testing on it for lower cement factors - important to the manufacturers - as well as tests to be done on concrete mixes with 1" - 2" slump for possible marketing

with manufactures who place low slump concrete - panels made on trill tables, pipe manufacturing, etc.

Marketing

We have established that in tested concrete mixes part of the sand can be replaced by ash. (approx. 33 1/3% by volume). Larger replacement volumes may be possible, depending on ash characteristics from the actual plant.

The addition of ash at the concrete plant will require additional storage and handling. Depending upon the set-up of a concrete plant, this storage and handling system can be easy or cumbersome, however we have to recognize the fact that sand is hard to come by in the Memphis area in the months of February through May because of the high water level of the Mississippi River and frequent rains. These factors affect the mining of sand and the ash could become a soughtafter replacement for part of the sand during these months.

Once introduced, it might become a permanent replacement, although seasonal factors always will play a role.

By introducing the ash material to pipe, block and other related mix design plants, a permanent year round market is envisioned. However, as outlined in this report, additional testing and development has to be done. In principle, block plant manufacturers are definitely willing to discuss the ash addition. I specifically refer you to Mr. Allen from Allen Materials, Inc., in Memphis.

In my conversations with you, we focused on specific energy savings in the building materials and the rising price of cement and its limited

supply in times of high building activity.

The product most suitable to save energy in general, not to be dependent upon cement production and to show a real good earning potential all over the country, is sand lime brick and its related lightweight product. For your information, I have added an outline on these products.

The possible price to be obtained for your material is subject to different factors:

1. Will your material be used by the concrete manufacturer when sand is in short supply? In this case, a price equivalent to the price of sand could be charged.
2. Or will you have to compete with sand supplier, in which case the price for your ash during the first one or two years should be approximately \$1.00 - 2.00 per yard below the price of sand in order to penetrate the market.
3. Will your material become a standard raw material for block and other related manufacturers?

The typical observations we have made, do indicate a good market for this type of application. It would be a year round application and the price of your material could be in the same price range as sand. For all practical purposes, I would set the price of sand for the coming year at approximately \$5.00/yard. We feel that with the proper marketing approaches and not limiting the use of the material initially only to the Memphis area, it is likely that a yearly production of approximately 100,000 tons of ash can be sold.

If we looked only to the Memphis area and could sell the entire output of the plant in the Memphis area and since a yard of ash will replace a yard of sand, and given the weight difference of 2700 lbs./yard for sand vs. 1539 lbs/yd. for ash, the ash material should be priced at between \$3.00/and \$4.00/yd. for 1980. This would equal to a yearly possible

revenue of \$390,000 to \$520,000. Different uses, or other more exotic uses such as a home soil conditioner will likely increase revenues. However, as outlined, more specific testing and data development is necessary before certain costs and marketing commitments can be made.

Sincerely,

PEABODY TESTING SERVICES, INC.

Hans A. Vanders

HAV:pf