QUARTERLY TECHNICAL PROGRESS REPORT NO. 4

ARC-COAL ACETYLENE PROCESS
DEVELOPMENT PROGRAM

AVSD-0344-78-CR
DOE Contract EM-78-C-02-4507.A000

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Cost of Production (including ROI) of VCM & VAM
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Procurement Status - 1 Mw Arc-Coal Acetylene
Development Facility
I. DESCRIPTIVE TITLE OF WORK

Design, development, testing and evaluation of a chemical process to
produce acetylene from coal in an electric plasma arc reactor during the
Phase I segment of a 4-1/2 year program.

II. CONTRACT OBJECTIVES

The objectives of the Arc-Coal Acetylene Development Program are as
follows:

• To develop a 1 Mw (nominal) arc reactor producing a 30% yield
  of acetylene with SER (kwhr/lb C₂H₂) of approximately 4.
• To develop components and a subsystem to classify and segregate
  carbon-black at 99.5% purity from the particulate material in the
  process stream.
• To demonstrate the commercial attractiveness of this process to
  the petrochemical community with economic analyses and projections.

III. APPROACH

Design, develop, test and evaluate a 1 Mw arc reactor system suitable
for an Engineering Test Facility (ETF) based on scale-up of a previously
successful 200 kw arc-coal reactor. Design, develop, test and evaluate a
carbon-black segregation system. Combine the two subsystems in a develop-
ment test facility to be constructed by an engineering-construction firm.
Test, evaluate and report results.
IV. FINAL PRODUCT

The final products of this program are: (1) a proven design of the key subsystems for the 1 Mw Engineering Test Facility (ETF) to be designed, constructed, tested and evaluated in Phases 2 through 4 of the program and (2) economic evaluation of the process for the commercial chemical market.

V. PROGRESS SUMMARY

a. Technical

Data taken from the Avco 200 kw Arc Coal Reactor facility provides increasing optimism for this acetylene producing process. Continued improvements in the reactor design have been accomplished over the past three months. These improvements result in data which, when reduced and analyzed, yield SER's well below 5.0. Further, these SER values are an improvement over those of the comparable OCR program test data results under the same test conditions. The anode and cathode designed for this 200 kw Chemical Facility have performed well with no visible degradation after minor adjustments in the geometry and operating procedures. The data taken to date, both with and without quench, within this facility underline the importance of commencing work on the 1 Mw Arc Coal Acetylene PDU where SER values between 3.5 and 4.0 are a clear probability. With values of SER in this range, the arc coal process is economically attractive as a competitor to the ethylene process for manufacturing VCM and VAM. A summary of the 200 kw facility test results provided in Appendix A to this report is a synopsis of a Topical Technical Report submitted earlier this month.¹

A second topical report concerns the 1 Mw arc reactor design and development tests using an inert gas as a feedstock. This work was completed in June of 1978. A synopsis of this topical report is provided in Appendix B of this report.

b. Economics

During the quarter just completed economic analyses have been performed updating and expanding previous work. Near the conclusion of this quarter a dramatic increase in the price of oil dictated by the OPEC cartel once again underlined this country's dependence upon foreign crude. This recent OPEC price increase of 14.5% on oil underscores again the need for this country to become self-sufficient in energy. Thus, as one key element toward that self-sufficiency, it appears increasingly urgent to proceed aggressively with the Arc Coal Acetylene project to provide this country with a key chemical building block from coal, rather than oil. Further, the Arc Coal Acetylene process, which produces chemicals directly from coal is increasingly attractive economically when viewed in the context of the recent OPEC action. The OPEC action has a double impact on the process economics. On the one hand, it increases the by-product credit for carbon-black produced in the process as the cost-push price of this key rubber ingredient reflects the increase in feedstock cost for the dominant furnace-black in the United States. On the other hand, the price of ethylene which is now produced increasingly from petroleum and is the competitor to acetylene as a basic chemical building block, will increase steadily even with technological advances in its production somewhat offsetting its rise. While neither ethylene nor carbon-black increases are likely to be reflected immediately

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because of existing contractual relationships at lower prices within the petrochemical industry, the increase in price for both these commodities is inevitable as presaged by similar situations in Europe. Further OPEC increases in price can only accelerate the increasing attractiveness of arc-coal acetylene over ethylene since petrochemical economists agree that neither the price of coal nor of electric power (from either coal or nuclear plants) will increase at a rate approaching that of oil. Thus, it appears increasingly important that this program proceed now with construction of the 1 Mw Arc-Coal development facility so that the technology will be ready in the late 1980's when the need for this coal-based process will be all too clear.

Two major points reinforce the reality of this current situation which is summarized in graphical form as Figure 1.

1. At present, the cost of production of ethylene* from crude oil for a 15% DCF return is about 19¢/lb\(^1\). With the latest OPEC increase in crude oil price of 14.5%, the cost of production of (crude oil-based) ethylene can also be expected to increase by the same percentage (since raw material costs account for most of the production costs) to 22¢/lb. Using crude oil-derived ethylene as feedstock, the cost of producing VCM would be 19.5¢/lb and the cost of producing VAM would be 29.7¢/lb after the OPEC increase. (In Europe, where ethylene is derived mainly

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*Currently the pre-OPEC-action market price of ethylene in the U.S.A. is holding at about 13¢/lb since most of the ethylene produced is derived from natural gas liquids being purchased at regulated interstate prices. However, this depressed pricing situation cannot continue for long and the market price of ethylene is expected to increase sharply as:
(a) ethylene production becomes increasingly crude oil-based;
(b) interstate gas prices increase (due either to deregulation or to higher regulated prices);
(c) the current temporary over capacity in ethylene production disappears.

1. Donald C. MacInrye, Allied Chemical Corp., "Ethylene: Make It or Buy It?": Chemical Engineering Progress, December 1978.
Figure 1 COST OF PRODUCTION (INCLUDING ROI) OF VCM AND VAM COMPARING ARC-COAL ACETYLENE VERSUS ETHYLENE FEEDSTOCKS
from crude oil, ethylene costs 21¢/lb; VCM costs 20¢/lb; VAM costs 36¢/lb. In contrast, VCM made from arc-coal acetylene would only cost 15.3¢/lb and VAM from arc-coal acetylene would only cost 25.2¢/lb. Thus arc-coal acetylene is clearly more economical than crude oil-derived ethylene as a feedstock for both VCM and VAM.

2. Since VCM and VAM are manufactured in very large quantity in the U.S.A. (U.S. production in 1977: 5.8 billion lbs and 1/6 billion lbs respectively), the use of arc-coal acetylene instead of ethylene for the manufacture of these chemicals could help considerably towards reducing this country's dependence on foreign oil, and improving its balance of trade. An added advantage is that while producing acetylene, the arc-coal process manufactures carbon black - a large volume chemical with 1977 U.S. production of 3.5 billion lbs, which today is also largely derived oil. Thus savings in oil consumption can be simultaneously achieved in both the chemical and in the carbon black industries.

A summary of the current economics of the Arc Coal Acetylene process is provided as Appendix C to this report. This summary is a brief synopsis of a Topical Technical Report provided earlier this month.

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VI. SUPPORTING DATA

As indicated in previous monthly reports the milestone schedule portion of this document has been suspended until DOE defines and approves the construction option for the 1 Mw facility. Upon approval to proceed with the construction of the 1 Mw Arc Coal Acetylene facility, Avco will promptly prepare a milestone schedule for construction, testing and evaluating this facility.

Table 1 provides the procurement status of the 1 Mw Arc Coal Acetylene Development facility. With the exception of the Auxiliary Equipment Building, piping, welding, wiring, and installation and checkout are not included in the costs delineated in the table. Bid specifications for instrumentation and control, piping and valves, and the two development sections (the reactor subsystem and the char-black subsystem) also are not included. Work on these two development subsystems and their related instrumentation and control is continuing.

Three agreements, related to Phase II of the Arc Coal Acetylene program are in the final draft stage. These documents will be transmitted to Davy Powergas/A. G. McKee (the selected engineer-constructor), GAF Incorporated (the selected process user firm), and to Hoechst-Uhde (the HCN Oxamide process patent holder) for review and negotiation in late December and January. Engineering activity related to this proposal is currently underway with lead engineers and program managers assigned at each company. It is anticipated that activity will increase sharply upon conclusion of agreement negotiations.
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*Bids received 27 November 1978; DOE approval withheld to date*
APPENDIX A

200 KW ARC-COAL ACETYLENE
REACTOR TESTS AND EVALUATION
APPENDIX A

200 kw ARC-COAL ACETYLENE REACTOR TESTS AND EVALUATION

I. SUMMARY

The 200 kw Arc Coal Reactor Facility was assembled for the purpose of evaluating the arc-process for conversion of coal to acetylene at conditions not considered in a previous program funded by the Office of Coal Research, and for testing process modification on a small scale prior to inclusion in the 1 Mw scale facility. Test data generated in the 200 kw facility showed that when operating at the conditions employed in the OCR program (18-30 SCFM hydrogen flow, 40-80 lb coal/hr feed, 60-100 kw power input) the specific energy requirement (kw-hr/lb acetylene produced) were comparable. Subsequent tests at higher input conditions (110 lb coal/hr, 40 SCFM hydrogen flow, 126 kw power input) resulted in acetylene production at 5.1 kw-hr/lb acetylene; this is a significant decrease from a minimum of 5.5 kw-hr/lb acetylene observed in the previous work. Initial tests performed with the reactor products quenched by introduction of water produced a further decrease in the energy requirement to 4.6 kw-hr/lb acetylene. These results indicate that the chief economic goal of the process (i.e., acetylene production at a power consumption of 4.0 kw-hr/lb) is achievable in the 1 Mw power level facility and perhaps even in the 200 kw facility.

Developmental test programs have been conducted in the facility to determine the advantages of alternate system pressure control schemes, reactor stability with two classes of coal feeders, and qualitative investigations of reactor cleaning during operation. From the standpoint of both safety and
economy, the use of a throttling valve as the means of system pressure control was proven to be the superior control scheme. Screw auger and star valve devices for controlling coal feed to the reactor were tested in the facility and their effect on system operation observed. The auger device produced unstable reactor performance because of instabilities in the solid feed to the reactor, whereas with the star valve rotary feed the reactor stability was greatly enhanced (voltage fluctuations of \( \pm 3 \) percent of the mean value).

Analytical techniques have been developed to give a basic understanding of chemical and physical processes occurring within the reactor. Material and energy balances as well as thermodynamic relationships were developed as a means of evaluating the consistency of the test data from the 200 kw facility. All, analytical techniques were generated in a form which make them applicable to the 200 kw as well as the 1 Mw arc-coal facility.

The 200 kw reactor facility has been operated at various hydrogen and coal flow rates, and reactor power levels. Initial tests were conducted at the operating parameters employed in the previous OCR study. Comparison of the test data generated with the OCR results showed that the 200 kw facility operation was similar to the OCR facility. Experiments performed at higher throughputs and power levels than previously explored demonstrated successful operation at low energy requirement (5 kw-hr/lb acetylene) were feasible at high coal loading. Initial tests conducted with quenchant introduction resulted in a reduction in SER to 4.6 kw-hr/lb acetylene.

The 200 kw Arc Coal Reactor facility is being employed in conducting experiments to satisfy eight major test objectives. The 200 kw arc-coal
facility is expected to operate continuously on an intermittent mode even after most of the stated objectives are met in order to support the development of long-life reactor and to facilitate the 1 Mw reactor testing. The eight major testing areas are outlined below.

1. Throughput Maximization Study

One of the major findings in the operation of the 200 kw arc-coal reactor is that when the reactor power was increased and both the coal and hydrogen flows were increased in direct proportion, the SER's of the process appear to decrease even though the temperature and energy available for the gasification of coal should have remained the same. The observed effect may be due to (1) decreased heat loss to the reactor wall per unit mass of the reactants, and (2) enhanced heat and mass transfer between the gas and the solid particles. In this study, the input values of the primary process parameters, i.e., power, coal and hydrogen flows, will be increased to the maximum capacity of the facility. The results will be analyzed in view of the above hypothesis.

2. Reaction-Zone Characterization

To aid the theoretical understanding of the reaction mechanism and the development and selection of the optimum quench scheme, the reaction-zone of the arc-coal reactor will be quantized using several water-cooled sampling probes located at different distances from the arc zone. This will allow us to construct the production profile of acetylene under various operating conditions, which will be used to locate the optimum quench points and also to verify and/or modify some of the critical assumptions that are necessarily employed in the development of the analytical model of the arc-coal process.
3. Water or Steam Wash of Carbon Deposit on Reactor Wall

To date only water has been injected to the reactor to remove the carbon build-up on the reactor wall. In the OCR study steam was found to work as well, if not better. In this study both water and steam will be tested to compare their effectiveness in keeping the reactor wall clean. During the study the wash injection cycles and time will be varied to keep the wash time relative to the acetylene production time as short as possible, which is desired in view of the fact that during the wash no acetylene is produced and hence the power input is wasted.

4. Evaluation of Coal /H₂ and H₂O as Quench

Before starting the statistically designed experiments for minimizing the acetylene SER, we need to select the quench material between coal/H₂ and water. When the coal/H₂ mixture is used to quench, water may have to be injected as a secondary quenchant. If coal/H₂ quench does not produce any additional C₂H₂, and if H₂O does not noticeably decompose with C₂H₂ during quenching, then water will be used as the sole quench material in all subsequent tests.

5. Arc Characteristics

Physical characteristics of arc will be studied in all tests with the purpose of continual refinement of experimental and/or theoretical scaling laws for the arc-coal reactor.

6. Study of SER Minimization, with Quench

Owing to the new sets of experimental data from the 200 kw arc-coal reactors in addition to the OCR data and the previously discussed
theoretical considerations, we are able to limit our search to a fairly narrow region to find the minimum SER point. Although it seems possible to divide the region into regularly spaced grids and test each of them to find the minimum SER point without exerting too excessive effort, we decided to use the Box-Wilson composite rotatable design to conduct the experiments.

The following table shows the experimental design tailored according to the coded form. The center point has about 20 to 25\% greater input values than the OCR minimum SER point to reflect the current finding that the higher throughput of coal and hydrogen with a proportionally higher power input can result in lower SER's. The ranges of the three independent variables are set narrower than the OCR matrix study to reflect our better understanding of the process characteristics at this time.

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<th>$x_2$ (coal)</th>
<th>$x_3$ ($H_2$)</th>
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<td>83 kw</td>
<td>83 lb/hr</td>
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<tr>
<td>k</td>
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At the conclusion of tests a regression analysis is to be carried out to determine the coefficients of the response function, and then an analysis of variance to determine its significance. If it deems necessary, a new minimum SER point will be estimated from the study and another set of experiments will be conducted to find the minimum SER point and to develop a better response function.
7. Char/Carbon Black Separation

Although the separation tests can be carried out in parallel with other studies, it is more desirable to do so when the minimum SER operation point is more or less known. Because of the pioneering nature of the work, the separation study is expected to continue well after the minimum SER operating conditions are found.

8. Study of Effects of Secondary Process Parameters and Others

After the acetylene SER is minimized with respect to the primary process parameters, i.e., power input, coal and hydrogen flows, effects of other process parameters of secondary importance on the process performance will be studied with the objective of finely tuning the minimum SER operating conditions. The secondary parameters of interest are magnetic field strength, coal injection pattern, coal characteristics, particle size distribution, moisture content of coal, etc.
APPENDIX B

1 MW (INERT GAS FEED) ARC REACTOR
DESIGN AND TEST RESULTS.
APPENDIX B

1 MW (INERT GAS FEED) ARC REACTOR DESIGN AND TEST RESULTS

I. SUMMARY

The design and development test objectives of the 1 Mw Inert Reactor test facility have been achieved. The data indicate that for a given chamber pressure, mass flux, and working fluid the voltage gradient is independent of the reactor size. When switching from a nitrogen arc to an hydrogen arc in the 200 kw facility, the voltage increases by about a factor of three. However, if the reactor is maintained at a constant pressure while the coal is introduced, no change in the voltage is observed.

For the available DC power supplies to achieve a stable arc discharge, the arc voltage should be one-half or less of the open circuit voltage. For this reason, the design point for the 1 Mw facility was chosen at 1150 volt and 870 amps direct current.

Since the test results in the 200 kw facility show that the voltage gradient does not change when coal is added to the arc, the voltage gradients for a hydrogen arc can be applied to size the arc-coal reaction chamber. Using the projected voltage gradients and the design point (i.e., 1150V and 870A) the voltage gradient (dv/dx) is 300 V/in for a hydrogen mass flux of 8.710^{-2} lb/sec/ft^2 at 0.5 atm reactor pressure. Thus, for a 1-inch diameter cathode, the reactor diameter:

\[
D_R = 1 + \frac{2V}{dv/dx}
\]

\[
= 8.67 \text{ inch}
\]
The 1 Mw inert gas facility provided valuable information about the operating characteristic of a large reactor. Empirical scaling factors were established comparing the results of the 1 Mw inert and the 200 kw facility.

Components of the final 1 Mw Arc Coal Reactor have been designed and tested. This test program has been concluded except for the optimization of the arc initiation procedure.
APPENDIX C

ECONOMICS OF ARC-COAL ACETYLENE PROCESS
APPENDIX C
ECONOMICS OF ARC-COAL ACETYLENE PROCESS

I. SUMMARY

In order to assess the attractiveness of the Avco Arc-Coal Acetylene Process, it is necessary to evaluate, a) capital and operating costs associated with the process, and b) the economics of using the acetylene produced in the manufacture of vinyl chloride monomer (VCM) and vinyl acetate monomer (VAM) -- arc-coal acetylene produced estimated to be 17.5¢/lb in mid-1978, is low enough to be competitive with ethylene for the manufacture of VCM, and more competitive than ethylene for the manufacture of VAM. Since mid-1978, market prices for various grades of carbon black have increased. Using December 1978 prices, as published in "Chemical Marketing Reporter," the byproduct credit for carbon black produced increases from 4.49¢/lb acetylene to 5.33¢/lb acetylene resulting in a current acetylene transfer price of 16.6¢/lb.

Capital and operating costs for arc-coal plants of a range of capacities are developed herein. Transfer prices for the acetylene produced are calculated according to ERDA (now DOE) guidelines. The cost of manufacturing both VCM and VAM from arc-coal acetylene is evaluated and compared with the cost of producing these chemicals by the current ethylene-based processes. Projections of these costs are also made, based on two scenarios of future electricity, coal and crude oil prices.

An acetylene-based VCM plant of 725 million lbs/yr capacity (typical size) would require a 300 million lbs/year arc-coal plant to keep it
supplied with acetylene feedstock. The capital investment for a plant of this capacity is estimated at $94 million (mid-1978). Compressors and electrical equipment are the highest capital cost items, accounting for 23 percent and 21 percent, respectively, of the total plant investment. Electricity is the highest operating cost item, accounting for 48 percent of the total gross annual operating cost. By-product credits for carbon black, hydrogen cyanide and char, made in the process, help to reduce operating costs substantially.

For the mid-1978 time-frame, the price of VCM made from arc-coal acetylene is estimated at 15.3¢/lb; practically identical to the price calculated for VCM via ethylene of 15.1¢/lb (using ethylene at its current market price of 13¢/lb). A previous evaluation by Blaw-Knox Chemicals showed that for the 1971 time frame, ethylene-based VCM would have a cost 32 percent less than VCM made from arc-coal acetylene; thus the outlook for arc-coal acetylene as a feedstock for VCM has markedly improved over the intervening period. The transfer price of VAM made from arc-coal acetylene is estimated at 25.2¢/lb; 1¢/lb cheaper than if made from ethylene.

At smaller capacities, the transfer price of acetylene increases. For example, at 100 million lbs/year (50 MW) capacity, the transfer price is 23¢/lb; at 2 million lbs/year (10 MW) capacity, the transfer price is 38.7¢/lb with by-products credited at chemical value and 45¢/lb with by-products at fuel value. This price is lower than that for calcium carbide-based acetylene, which in large quantity sells for about 50¢/lb and, as cylinder gas sells for over 70¢/lb. Thus, acetylene from a 10 MW arc-coal plant would be economically attractive for use as cylinder gas, and for the manufacture
of chemicals such as 1, 4-butanediol, acrylate esters, acrylic acid and others, which today are largely made from acetylene.

Projections comparing arc-coal acetylene and ethylene for the manufacture of both, VCM and VAM are based on two scenarios of future prices for electricity, coal and crude oil. (The price of arc-coal acetylene will depend largely on electricity and coal costs, while the price of ethylene will depend largely on crude oil-derived feedstock costs.)

The first scenario is based on a study of comparative energy values to the year 1990 by Arthur D. Little, Inc. It shows rapid escalation over the next decade in the price of crude oil and crude oil-derived ethylene, but with far less pronounced increases in the prices of electricity and coal. As a result, by 1980, arc-coal acetylene appears clearly to be the more economical raw material for the manufacture of both VCM and VAM. By 1990, arc-coal acetylene appears to have a dominant advantage over ethylene.

The second scenario is based on a study published by EPRI in which SRI International presents marginal price forecasts for electricity, coal, and feedstock naphtha for the years 1985 and 2022. Here, the price of electricity is higher than in Scenario 1, but is shown actually to decline (in real price) between 1985 and 2000. Coal also declines in real price during this time period. However, the real price of feedstock naphtha steadily increases between 1985 and 2000. The results of Scenario 2 show that VCM made from ethylene stays marginally cheaper than VCM from arc-coal acetylene, until 1988. After that VCM made from arc-coal acetylene becomes noticeably cheaper. VAM based on arc-coal acetylene stays cheaper than VAM from ethylene throughout the period covered in this scenario.
In the future, the economic attractiveness of the arc-coal process could be even further enhanced with the commercialization of certain technologies that are currently under development. For example, if fuel cells are successfully introduced as on-site power sources for refineries and chemical plants, as seems possible, the arc-coal process would have a ready source of DC power in fuel cells; the need for expensive rectification equipment would be eliminated, resulting in considerable savings in capital cost. Moreover, savings in operating cost may also be realized because by-product fuel gas from the process could be used in the fuel cells. A second example is the development of metal hydride technology for the purification and compression of hydrogen gas. A large portion of the capital cost for an arc-coal plant consists of compressor costs; 60 percent (by volume) of the gas compressed consists of hydrogen. The separation and compression of the hydrogen using a metal hydride scheme could drastically reduce the compression duty for the remaining gas, resulting in large savings in compressor equipment and operating costs.

As a result of these analyses, the following conclusions are drawn:

1. The Total Plant Investment required for an arc-coal acetylene plant of capacity 300 million lbs/year is approximately $94 million (mid-1978).

2. The transfer price of acetylene from such a plant for a 12% DCF rate of return would be 17.5¢/lb (mid-1978).

3. The highest capital costs in the arc-coal plant are for "Gas Compressing and Cooling" and "Electrical Equipment," which together account for over 40% of the Total Plant Investment.
4. Electrical energy is the highest operating cost component. Consumption of electricity and high pressure steam accounts for over 60% of the Total Gross Annual Operating Cost.

5. Acetylene manufactured in "small-size" (10 Mw) arc-coal plants will be economically attractive for use as cylinder gas for welding and metal cutting, and also as feedstock for chemicals such as 1,4-butenediol which are presently made from acetylene.

6. The transfer price of VCM manufactured with arc-coal acetylene feedstock at 17.5¢/lb is 15.3¢/lb, while it is 15.1¢/lb when manufactured via the ethylene oxychlorination route, with ethylene purchased at its current market price of 13¢/lb. This indicates that arc-coal acetylene is competitive with ethylene as a feedstock for VCM.

7. The economic advantage of ethylene over arc acetylene as a feedstock for VCM has considerably lessened since 1971. Examination shows that this has been due mainly to price rises in ethylene that have far outpaced rises in electricity price (on which the transfer price of arc-coal acetylene is largely dependent) over the same period.

8. The transfer price of vinyl acetate monomer (VAM) is 25.2¢/lb when manufactured from arc-coal acetylene. It is 26.2¢/lb when manufactured from ethylene. Arc-coal acetylene is therefore the more economical feedstock for the manufacture of VAM.

9. According to the scenarios considered, the outlook for arc-coal acetylene as a feedstock for both VCM and VAM, improves with time, while the outlook for ethylene deteriorates.
10. Transfer price projections (in 1978 dollars) for Scenario 1 are as follows:

<table>
<thead>
<tr>
<th></th>
<th>1980</th>
<th>1985</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCM ex Arc-Acetylene, $/lb</td>
<td>16.0</td>
<td>16.4</td>
<td>16.3</td>
</tr>
<tr>
<td>VCM ex Ethylene, $/lb</td>
<td>18.0</td>
<td>22.1</td>
<td>23.3</td>
</tr>
<tr>
<td>VAM ex Arc-Acetylene, $/lb</td>
<td>25.7</td>
<td>25.9</td>
<td>25.8</td>
</tr>
<tr>
<td>VAM ex Ethylene, $/lb</td>
<td>28.4</td>
<td>31.6</td>
<td>32.5</td>
</tr>
</tbody>
</table>

11. Using Scenario 1 projections, by 1980, arc-coal acetylene is clearly more economical than ethylene as a feedstock for VCM. By 1990 this advantage becomes domimative. Its current advantage as a feedstock for VAM also increases in like manner.

12. Transfer price projections for Scenario 2 are as follows:

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VCM ex Arc-Acetylene, $/lb</td>
<td>18.5</td>
<td>18.5</td>
<td>18.4</td>
<td>18.2</td>
</tr>
<tr>
<td>VCM ex Ethylene, $/lb</td>
<td>19.3</td>
<td>19.8</td>
<td>20.8</td>
<td>20.4</td>
</tr>
<tr>
<td>VAM ex Arc-Acetylene, $/lb</td>
<td>27.4</td>
<td>27.4</td>
<td>27.4</td>
<td>27.2</td>
</tr>
<tr>
<td>VAM ex Ethylene, $/lb</td>
<td>28.7</td>
<td>29.1</td>
<td>29.7</td>
<td>30.2</td>
</tr>
</tbody>
</table>

13. With Scenario 2 projections, ethylene is marginally more attractive than arc-coal acetylene for the manufacture of VCM until 1987. After that time, arc-coal acetylene becomes the more favored feedstock. For VAM however, arc-coal acetylene is the more economical feedstock throughout the period covered.