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Acetylene from calcium carbide is an alternate feedstock route

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AN ALTERNATIVE to current coal-gasification schemes could be production of calcium carbide (Ca C_2) from coal and quicklime. Acetylene gas produced from the carbide could compete with ethylene as a chemical feedstock. Currently priced at 11¾¢/lb ethylene prices have been predicted to be as high as 16¢/lb by 1977.[1]

Pilot plants are being built. But lack of proven technology in coal gasification is stymieing design and construction of commercial-size plants.

Process for converting quicklime and carbon into calcium carbide is well known. Similar furnaces are also used for aluminum oxide and ferrosilicate. Furnace sizes range from 185 to 400 tons/day of calcium carbide.

Current prices are about 8½¢/lb. Calcium carbide produced contains impurities. These will be retained in the lime-ash residue after acetylene is produced.

Sulfur is not an important impurity. But iron and potassium are. Iron causes problems in furnace operation. Potassium forms phosphine gas in the acetylene.

Carbon monoxide (CO) from the furnace is generated in equal molar volumes to the acetylene gas generated. CO mixed with acetylene forms a synthesis gas for acrylic acid. This also dilutes the acetylene and reduces the danger of detonation.

Steam generated by cross exchanging the CO with water may be used for power and for acetylene generation with the calcium carbide when exhausted.

Earlier use. Until 1951, all acetylene produced in the U.S. was generated from calcium carbide. Since then, hydrocarbon feedstocks have been used. Calcium carbide technology in the U.S. came to a halt. Calcium carbide production peaked about 1956. Apparent consumption in 1968 was about 923,000 tons.

During the heyday of calcium carbide production, furnaces were available in 180, 250, and 400-ton/day carbide capacity. The 400-ton/day furnace used 50,000 kw of 75 to 250-v, three-phase power at 50,000 to 125,000 amp with power factors of 0.89 to 0.95. In North America, metallurgical coke has been the main source of carbon. In Russia, up to 75% of the furnace charge has been anthracite.[2]

In Europe, charcoal and mixtures of anthracite-coke have also been used.[3] Shale-tar coke graphitized at high temperature and lignite carbonized at 800° F. have been used as the carbon feed and to furnish part of the calcium otherwise provided by the lime.

Process description. Lime and carbon are heated to 1,800° C. (3,272° F.) in an electric-arc furnace. Lime is usually made by burning limestone in a kiln at the plant site.

Lime and carbon react in the furnace to form calcium carbide:

$$CaO + 3C \rightarrow CaC_2 + CO$$

Calcium carbide (CaC_2) reacts with water to form acetylene:

$$CaC_2 + H_2O \rightarrow C_2H_2 + CaO$$

A possibility does exist for recycling at least part of the lime found in the acetylene generation.

Raw materials. Impurities in the furnace charge remain in the calcium carbide. Furnace does not refire the product. It only heats the charge to reaction temperature, and melts the reaction products. The higher the temperature at which the furnace operates, the higher the calcium carbide purity.

Limestone for the process should be at least 97% $CaCO_3$. MgO and Al_2O_3 may be present. But they consume power as they pass through the furnace relatively unchanged. The limestone or lime should have a maximum of 0.5% MgO and Al_2O_3; 0.5% Fe_2O_3 and 0.004% P.

Phosphorous is a serious impurity. It will appear in the carbide. When the carbide is reacted into acetylene, poisonous phosphine (PH_3) is generated.

Silicates in both coal and lime feed may be a mixed blessing. Presence of silicates lowers the melting temperature and thus the heat losses while increasing the tonnage flow through the furnace. Lower temperature caused by silicates also reduces percentage of carbide in the product. Up to 3% sodium chloride in the charge seems to promote the carbide reaction by decreasing the activation energy for the transformation.

Lime should be fed to the furnace as directly from the limestone burning kiln as possible. Carbon from any source may be used, including charcoal, anthracite, and lignite.[4] Primary reason for using coke has been the high percentage of fixed carbon

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and low percentage of volatiles.

Pyrolysis of coal has been economically infeasible as a single step because of coke residue and/or ash problems. When coal pyrolysis is an integrated step in the total use of coal, it can become a valuable portion of the overall production.

Heat savings. Heat used in pyrolysis remains in coal fed to the furnace. This reduces furnace power requirements. By feeding the furnace charge to the furnace at 900° C. (1,652° F.), as much as 17% reduction in power requirement may be effected.

This just happens to be a good pyrolysis temperature. About 40% weight loss of the coal results. Gas composition is 52% H_2, 23% CH_4, 18% C_2-C_4, and 7% CO_2.

Fixed carbon in the charge goes from about 47% to about 85% in the resultant coke. Fuel gas of about 550 BTU/ft³ is produced. Heat in the offgas could be used to produce steam to feed an electrical generating plant, providing power for the furnace operation. Gas could then be burned in the power plant, sold for fuel, or sold for its potentially most-valuable use as a synthesis gas.

Coal could be both high in sulfur and in ash without creating appreciable problems, if the percentage of organic sulfur were a substantial fraction of the total sulfur present. Sulfur present in the form of iron pyrites does cause a problem due to its reaction with silicon in the furnace to form ferrosilicon.

In continuous tapping furnace, a hump of ferrosilicon forms on the furnace bottom. Furnace must be shut down about every 3 years for its removal. If iron pyrites are present in the coal, it is fairly easily removed by flotation and washing. But, this causes an otherwise unnecessary step.

Ash present in the coal should be as high in calcium and as low in Fe_2O_3 and Al_2O_3 as possible which infers carbonaceous shale and or lignite. Some subbituminous coals also have ashes high in calcium.

Particle size of the metallurgical coke normally used for furnace feed has been 80% ⅜ to ¾ in. and 99% ¼ to 1 in. Carbon fines have been mixed with a dry hydrated lime, briquetted, calcined, and mixed with the furnace charge. Rate of reaction is proportional to area of contact between the CaO and C. A high rate of reaction occurs with the briquette feed.

Recycling reactor sludge with carbon fines to form briquettes must be limited to avoid aggravating the impurities problems.

Furnace operation. Furnaces used for carbide manufacture are three phase. They operate on 75 to 250v with power factors of 0.80 to 0.95 and have three electrodes connected in a delta circuit.

Furnaces are two basic types, ingot casting and continuous tapping. In the ingot type, electrodes are lowered into a box containing the charge, reaction is completed, and the box is removed.

The continuous tapping furnace has tap holes, usually one opposite each electrode, from which molten carbide is removed. A separate tap hole may be provided for ferrosilicon. Withdrawal may be continuous or intermittent from all three tap holes.

Furnaces may be open or closed. In the open furnace, gases, primarily carbon monixide, are allowed to escape to the atmosphere. This is highly undesirable for reasons of safety and economy.

The closed furnace permits 1,475° F. gas to be used. Its fuel value represents a tremendous heat loss if not reclaimed.

A 150-ton/day furnace could be made of a steel shell 30 ft in diameter by 10 ft tall. The inside wall is protected by a firebrick lining. The bottom is covered with carbon blocks to a depth of 3 ft.

Tap holes for ferrosilicon are offset below the carbide tap holes. Furnace cover allows offgas to be collected. It rests in a sand-filled groove at the furnace top and is supported from above.

A toothed rack on the bottom is sometimes used to rotate the furnace at speeds of 1 revolution/18 hr to 1 revolution/5 days.

Electrodes enter the furnace from above, through the furnace top. In plain view, they form an equilateral triangle. Electrodes are completely encased in a thin (¼-in.) carbon-steel casing extended into the furnace. They are continuously formed in place by filling the new casing segments with paste made from carbon fines and baked by the furnace heat.

A pool of molten carbide is formed underneath the electrode tips. As the volume of the molten pool increases, the electric resistance between electrodes decreases. As resistance decreases, the electrodes must be raised to maintain operating rate, or the carbide tapped.

The higher the electrical resistance, the higher is the temperature that can be reached. With a higher furnace temperature, higher-purity carbide can be obtained. The melting point of pure carbide is 2,300° C. For 85% carbide, it is 1,800° C., and for 70% carbide, 1,780° C. Since commercial grade of carbide is 80%, furnace operating range is quite narrow. Fine control is required.

Economics. Material requirements vary, depending upon feed variations. Assuming 95% available CaO in the lime and a fixed percent in carbon-

Table [illegible]

Material and energy costs*

Furnace alone:	$/ton
Lime (2,100 lb/ton @ $25/ton)	26.25
Coke (1,200 lb/ton @ $35/ton)	21.00
Power (2,800 kw-hr/ton @ 2¢/kw-hr)	56.00
	103.25
Integrated complex:	
Lime (2,100 lb/ton @ $17.50/ton)	18.38
Coal (2,000 lb/ton @ $23/ton)	23.00
Power (2,350 kw-hr @ 1.2¢/kw-hr)	28.20
	69.58
By-product credit:	
Pyrolysis section gas (12.9 Mcf @ 500 BTU × $1.50/MMBTU	
– integrated complex only)	9.68
Furnace offgas (10 Mcf @ 280 BTU × $1.50/MMBTU)	4.20
	13.88
Net power & material costs	$55.70/ton

*150 ton/day, 80% calcium carbide. Capital investment [illegible] million. Capital [illegible] [illegible] million.

Table 2

Calcium carbide production costs*

	Costs, $/ton	
	Minimum plant	Integrated complex
Raw material & power	99.05	55.70
Labor @ 06/man-hr	1.00	2.40
Overhead 69% of labor	0.90	2.16
Maint. 3% of investment	4.57	14.28
Taxes % ins. 2% of invest.	3.05	9.38
Depreciation 5% year	7.62	23.81
	116.19	107.73

*150 ton/day, 80% calcium carbide.

bearing feed of 88%, cost of material and energy for 150 tons of 80% Calcium carbide/day is $103.25/ton (Table 1).

Furnace gas taken off of enclosed furnace will be 10,000 cu ft/ton. Exclusive of sensible heat, it will have a fuel value of about 280 BTU/ft³. At $1.50/MMBTU, this gives a credit of $4.20/ton and reduces effective cost to $99/ton.

Carbide plant could be a portion of an integrated complex. This complex would buy coal, operate a pyrolysis section, generate electricity, burn limestone to produce lime, and feed hot coke and limestone to the furnace. Capital investment for 150 tons/day of carbide would increase, but the material and power costs would reduce to $55.70/ton (Table 1).

For the two plant schemes, total production cost for calcium carbide would be $116.19/ton and $107.73/ton respectively (Table 2).

Current sales price of calcium carbide is $171.40/ton in carload lots of 600-lb drums. This in itself indicates such plants could have a significant impact on the market for calcium carbide. At 4.8 ft³ of acetylene/lb of 80% carbide, costs for acetylene is 17.8¢ and 16.49¢/lb.

If, as has been predicted, 16¢/lb ethylene is as close as 1977, investigation of this possible alternate should have begun 2 years ago.

References

1. Chemical Marketing Reporter, Jan. 5, 1976, p. 28.
2. Encyclopedia of Chemical Technology, Second Edition, Kirk-Othmer, 1963.
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Beam pump preventive maintenance yields multiple benefits

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CONCEPT of preventive maintenance (PM) is not new in production operations. However, most operating organizations incorporate PM and operations in one organization. The primary disadvantage of this setup is the secondary priority PM receives. Day-to-day operating problems normally receive first priority and PM work is done after the "emergencies" are handled.

A PM organization separate from the "operations" organization has been established in the southeastern New Mexico portion of Continental Oil Co.'s production department operations. The PM system has been in operation for 12 months and covers over 2,000 separate pieces of major surface equipment.

Only PM for beam pumping equipment is discussed here. However, the procedures followed in establishing the PM for the beam equipment are essentially the same for all pieces of equipment included in this project.

Although 12 months is a relatively short period of time for a program such as this to be fairly evaluated, several indicators of the effectiveness of the program are visible.

First a number of mechanical problems with the pumping units were corrected on the first inspection. These included structural bolts missing or loose, grease seals needing replacement, units misaligned, bearings needing repair, and units with improper or inadequate tie-downs. These were problems that had accumulated over a period of years.

Table 1

Pumping units PM checklist

Item	Inspection interval	Routine servicing for PM
1. Check oil level in gearbox	Monthly	[illegible]
2. Check for oil seal leaks	[illegible]	[illegible]
3. Inspect belts for wear	[illegible]	[illegible]
4. Look for foundation movement or cracks	[illegible]	[illegible]
5. Inspect stuffing box and polished rod	[illegible]	[illegible]
6. Clean equipment and location as needed	[illegible]	[illegible]
7. Lubricate wire line	[illegible]	[illegible]
8. Clean breather cap on gearbox	[illegible]	[illegible]
9. Check operation of shutdown switches	[illegible]	[illegible]
10. Inspect wellhead ground	[illegible]	[illegible]
11. Visual inspection of gearbox oil	Semiannually	[illegible]
12. Lubricate structural bearings	[illegible]	[illegible]
13. Check structural and foundation bolts	[illegible]	[illegible]
14. Check unit for proper alignment	[illegible]	[illegible]
15. Grease brake cable and adjust	[illegible]	[illegible]
16. Check counterbalance	[illegible]	[illegible]
17. Check V-belt drive for alignment and wear	[illegible]	[illegible]
18. Check ladder bolts and ladder condition	[illegible]	[illegible]
19. [illegible]	[illegible]	[illegible]
20. [illegible]	[illegible]	[illegible]

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