

# PROCESS ECONOMICS PROGRAM

SRI INTERNATIONAL  
Menlo Park, California  
94025

## Abstract

Process Economics Report No. 16A

### ACETYLENE

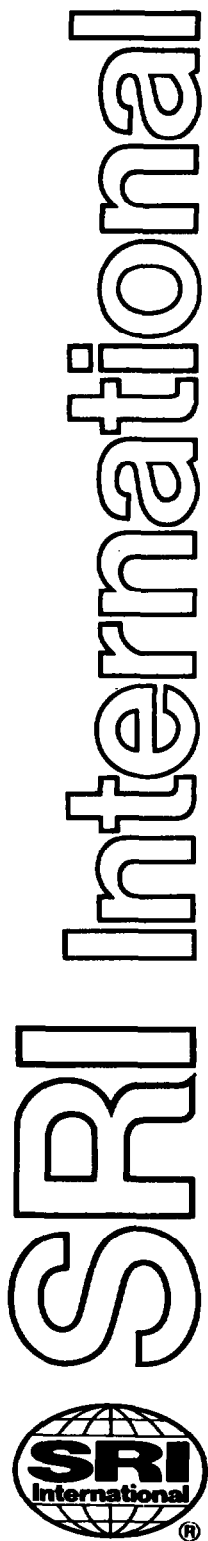
(November 1981)

Three processes for making acetylene are evaluated in detail: the manufacture of calcium carbide in an electric furnace, and its hydration to acetylene; the partial oxidation of natural gas or naphtha; and the electric arc process using natural gas or C-4 gas. The manufacture of calcium carbide by the thermal process and the recovery of heat in the partial oxidation process are also covered. At present costs, the partial oxidation of natural gas with heat recovery is the most economical. But as the price of gas is likely to increase faster than the price of electricity, the arc process and the carbide process will probably become more economical.

The arc process using coal dust feed and the submerged flame process using heavy residue have economic advantages, but are not yet commercialized. The thermal cracking process, once widely used, is no longer economic. The recovery of acetylene in an ethylene plant is economically attractive, but the quantity of acetylene produced is limited. The Kureha/UCC process for producing both ethylene and acetylene, may become economical once the ethylene price is out of its present depressed state.

The report also compares the competitive position of acetylene with those of ethylene and propylene as a chemical feedstock.

PEP'81 YCY



Report No. 16A

# **ACETYLENE**

SUPPLEMENT A

by YEN-CHEN YEN

November 1981

A private report by the  
**PROCESS ECONOMICS PROGRAM**

Menlo Park, California 94025

For detailed marketing data and information, the reader is referred to one of the SRI programs specializing in marketing research. The CHEMICAL ECONOMICS HANDBOOK Program covers most major chemicals and chemical products produced in the United States and the WORLD PETROCHEMICALS Program covers major hydrocarbons and their derivatives on a worldwide basis. In addition, the SRI DIRECTORY OF CHEMICAL PRODUCERS services provide detailed lists of chemical producers by company, product, and plant for the United States and Western Europe.

## CONTENTS

1	INTRODUCTION . . . . .	1
2	SUMMARY . . . . .	3
	General Aspects . . . . .	3
	Technical Aspects . . . . .	7
	Calcium Carbide Manufacture in Electric Furnaces . . . . .	7
	Acetylene from Calcium Carbide in a "Dry" Generator . . . . .	9
	Acetylene by Partial Oxidation, without Heat Recovery . . . . .	9
	Acetylene by Partial Oxidation, with Heat Recovery . . . . .	9
	Acetylene by a Submerged Flame Process . . . . .	10
	Acetylene from Natural Gas by the Arc Process . . . . .	10
	Acetylene from Coal by the Arc Process . . . . .	11
	Recovery of Acetylene in an Ethylene Plant . . . . .	12
3	INDUSTRY STATUS . . . . .	13
4	CALCIUM CARBIDE . . . . .	19
	Chemistry . . . . .	19
	Raw Materials . . . . .	22
	Lime . . . . .	22
	Carbon . . . . .	23
	Electrothermal Process for Making Calcium Carbide . . . . .	24
	Furnace . . . . .	24
	Handling of Calcium Carbide . . . . .	28
	Effluents from Carbide Furnaces . . . . .	31
	Other Processes for Making Calcium Carbide . . . . .	31
	Evaluation of an Electrothermal Process for Making Calcium Carbide . . . . .	37
	Process Description . . . . .	37
	Process Discussion . . . . .	43
	Cost Estimates . . . . .	44
	A Brief Evaluation of an Oxythermal Process for Making Calcium Carbide . . . . .	53
	Process Description . . . . .	53
	Process Discussion . . . . .	55
	Cost Estimates . . . . .	55
	A Brief Evaluation of a Thermal Process Using CO as a Heating Medium for Making Calcium Carbide . . . . .	60
	Process Description . . . . .	60
	Process Discussion . . . . .	61
	Cost Estimates . . . . .	61

## CONTENTS

5	<b>ACETYLENE FROM CALCIUM CARBIDE . . . . .</b>	67
	<b>Evaluation of a Process for Producing Acetylene from Calcium Carbide . . . . .</b>	78
	Process Description . . . . .	78
	Process Discussion . . . . .	83
	Cost Estimates . . . . .	83
	<b>Integrated Production of Acetylene from Calcium Carbide Made by Electrothermal Process . . . . .</b>	89
	<b>Recycle of Carbide Lime . . . . .</b>	89
	<b>Integrated Production of Acetylene from Calcium Carbide Made by Oxythermal Process . . . . .</b>	95
6	<b>REVIEW OF PROCESSES FOR PRODUCING ACETYLENE FROM HYDROCARBONS . . . . .</b>	99
	Cracking by Partial Oxidation . . . . .	99
	Arc Processes Using a Gaseous Feed . . . . .	104
	Arc Processes Using Liquid or Solid Feed . . . . .	113
	Heat by Combined Effect of Electric Discharge and Combustion . . . . .	113
	Thermal Cracking by a Combustion Gas . . . . .	118
	Thermal Cracking Through Indirect Heat Transfer . . . . .	118
	Recovery of the Products . . . . .	118
	Removal of Carbon Black . . . . .	124
	Removal of Heavier Acetylenes and Higher Hydrocarbons . . . . .	124
	Removal of CO <sub>2</sub> , H <sub>2</sub> S, and H <sub>2</sub> O . . . . .	137
	Recovery of Acetylene . . . . .	137
	Acetylene Purification . . . . .	138
	Acetylene in Ethylene Industry . . . . .	138
7	<b>ACETYLENE BY PARTIAL OXIDATION OF HYDROCARBONS . . . . .</b>	141
	<b>Acetylene from Natural Gas by a Partial Oxidation Process Based on BASF Technology . . . . .</b>	141
	Process Description . . . . .	141
	Process Discussion . . . . .	153
	Cost Estimates . . . . .	153
	<b>Variation of the Preceding Process with Recovery of Heat . . . . .</b>	159
	Process Description . . . . .	159
	Process Discussion . . . . .	164
	Cost Estimates . . . . .	164
	Acetylene from Naphtha by Partial Oxidation . . . . .	168
	Acetylene by Submerged Flame Process . . . . .	172

## CONTENTS

8	ACETYLENE BY THE ELECTRIC ARC PROCESS . . . . .	177
	Acetylene by an Arc Process Based on Huels Technology . . . . .	177
	Process Description . . . . .	177
	Process Discussion . . . . .	189
	Cost Estimates . . . . .	189
	Use of Other Feedstocks . . . . .	194
	Possible Improvements in the Process . . . . .	196
	Arc Process with Simplified Recovery Procedures . . . . .	196
	Acetylene from Coal by the Avco Arc Process . . . . .	197
9	ACETYLENE BY THERMAL CRACKING . . . . .	203
10	ACETYLENE AS A BY-PRODUCT IN ETHYLENE PRODUCTION . . . . .	207
	Recovery of Acetylene in an Ethylene Plant . . . . .	207
	Ethylene and Acetylene from Crude Oil by the Kureha/UCC Process . . . . .	216
11	COMPETITIVE POSITION OF ACETYLENE AS A CHEMICAL FEEDSTOCK . . . . .	219
	Competitive Position of Acetylene as Against Ethylene or Propylene . . . . .	219
	The Effect of Oil Price . . . . .	223
APPENDIX A	DESIGN AND COST BASIS . . . . .	231
APPENDIX B	PHYSICAL PROPERTIES . . . . .	233
APPENDIX C	ESTIMATING INVESTMENT FOR INCREMENTAL UTILITIES . . . . .	237
CITED REFERENCES	. . . . .	239
PATENT REFERENCES BY COMPANY	. . . . .	261

## ILLUSTRATIONS

4.1	Zones in an Electric Oven . . . . .	26
4.2	Calcium Carbide by Electrothermal Process Flow Sheet . . . . .	267
4.3	Calcium Carbide by Electrothermal Process Effect of Operating Level and Plant Capacity on Production Cost and Product Value . . . . .	52
4.4	Reactors in the Oxythermal Process for Making Calcium Carbide . . . . .	54
4.5	Reactors in the Thermal Process Using CO as Heating Medium for Making Calcium Carbide . . . . .	65
5.1	Acetylene from Calcium Carbide Flow Sheet . . . . .	269
5.2	Acetylene from Calcium Chloride Integrated Production Effect of Operating Level and Plant Capacity on Production Cost and Product Value . . . . .	93
5.3	Effect of Recycle of Carbide Lime on Product Value of Acetylene . . . . .	97
7.1	Acetylene by Partial Oxidation of Natural Gas Flow Sheet . . . . .	271
7.2	Route of the By-Produced Gas . . . . .	145
7.3	Acetylene by Partial Oxidation of Natural Gas Effect of Operating Level and Plant Capacity on Production Cost and Product Value . . . . .	158
7.4	Acetylene from Natural Gas Partial Oxidation Process Using Oil Quenching for Heat Recovery, Reaction Section Flow Sheet . . . . .	275
8.1	Acetylene from Natural Gas by Arc Process Flow Sheet . . . . .	277
8.2	Acetylene from Natural Gas by Arc Process Effect of Operating Level and Plant Capacity on Production Cost and Product Value . . . . .	193

## ILLUSTRATIONS

10.1	Acetylene Recovery in Ethylene Plant Flow Sheet . . . . .	283
11.1	Competitive Position of Acetylene as Against Ethylene or Propylene . . . . .	222
11.2	Competitive Position of Acetylene for VC Manufacture Against Ethylene from Ethane . . . . .	226
11.3	Competitive Position of Acetylene for VA Manufacture Against Ethylene from Ethanol . . . . .	227
11.4	Competitive Position of Acetylene for Acrylic Acid Manufacture . . . . .	229
B.1	Bunsen Solubility Coefficients for Gases in M-Pyrol <sup>®</sup> Solvent . . . . .	236



## TABLES

2.1	Cost Features of Commercial Acetylene Processes . . . . .	4
2.2	Cost Features of Potential Acetylene Processes . . . . .	6
2.3	Acetylene as By-Product of Ethylene . . . . .	8
3.1	Producers of Acetylene for Chemical Synthesis . . . . .	14
3.2	Estimated World Production of Acetylene in 1979 . . . . .	17
3.3	Historical and Projected Acetylene Consumption in the United States . . . . .	18
4.1	Calcium Carbide by Electrothermal Process Patent Summary . . . . .	29
4.2	Calcium Carbide by Processes Other Than the Conventional Electrothermal Process Patent Summary . . . . .	33
4.3	Calcium Carbide by Electrothermal Process Design Bases and Assumptions . . . . .	37
4.4	Calcium Carbide by Electrothermal Process Stream Flows . . . . .	40
4.5	Calcium Carbide by Electrothermal Process Major Equipment . . . . .	41
4.6	Calcium Carbide by Electrothermal Process Utilities Summary . . . . .	42
4.7	Calcium Carbide by Electrothermal Process Capital Investment . . . . .	46
4.8	Calcium Carbide by Electrothermal Process Capital Investment by Section . . . . .	47
4.9	Calcium Carbide by Electrothermal Process Production Costs . . . . .	48
4.10	Calcium Carbide by Electrothermal Process Direct Operating Costs by Section . . . . .	50
4.11	Calcium Carbide by Electrothermal Process Cost Effects of Adopting a Variable Operating Schedule . . . . .	51
4.12	Calcium Carbide by Oxythermal Process Design Bases and Assumptions . . . . .	53

## TABLES

4.13	Calcium Carbide by Oxythermal Process Capital Investment . . . . .	56
4.14	Calcium Carbide by Oxythermal Process Production Costs . . . . .	57
4.15	Calcium Carbide Processes Production of Cost Comparisons . . . . .	59
4.16	Calcium Carbide by Thermal Process Using CO as Heating Medium Design Bases and Assumptions . . . . .	60
4.17	Calcium Carbide by Thermal Process Using CO as Heating Medium Capital Investment . . . . .	62
4.18	Calcium Carbide by Thermal Process Using CO as Heating Medium Production Costs . . . . .	63
5.1	Acetylene Generators Patent Summary . . . . .	68
5.2	Utilization of Waste Streams from Acetylene Generation Patent Summary . . . . .	72
5.3	Purification of Acetylene Made from Carbide Patent Summary . . . . .	74
5.4	Other Processes for Making Acetylene from Carbide Patent Summary . . . . .	77
5.5	Acetylene from Calcium Carbide Design Bases and Assumptions . . . . .	78
5.6	Acetylene from Calcium Carbide Stream Flows . . . . .	80
5.7	Acetylene from Calcium Carbide Major Equipment . . . . .	81
5.8	Acetylene from Calcium Carbide Utilities Summary . . . . .	82
5.9	Acetylene from Calcium Carbide Capital Investment . . . . .	84
5.10	Acetylene from Calcium Carbide Capital Investment by Section . . . . .	85

TABLES

5.11	Acetylene from Calcium Carbide Production Costs . . . . .	86
5.12	Acetylene from Calcium Carbide Direct Operating Costs by Section . . . . .	88
5.13	Acetylene via Calcium Carbide Integrated Production Capital Investment . . . . .	90
5.14	Acetylene via Calcium Carbide Integrated Production Production Costs . . . . .	91
5.15	Effect of Recycle of Carbide Lime to Electrolytic Furnace on the Costs of Acetylene . . . . .	96
5.16	Integrated Production of Acetylene from Calcium Carbide Made by the Oxythermal Process . . . . .	96
6.1	Reactors for Producing Acetylene by Partial Oxidation Patent Summary . . . . .	100
6.2	Acetylene by Partial Oxidation or by Cracking in a Combustion Gas Patent Summary . . . . .	105
6.3	Submerged Combustion Process Patent Summary . . . . .	106
6.4	Acetylene by Electric Arc Process Patent Summary . . . . .	107
6.5	Acetylene from Coal or Liquid Hydrocarbon by Electric Processes Patent Summary . . . . .	114
6.6	Acetylene by Combined Combustion and Electric Discharge Patent Summary . . . . .	117
6.7	Reactors for Producing Acetylene by Cracking in a Combustion Gas Patent Summary . . . . .	119
6.8	Acetylene by Thermal Cracking with Indirect Heat Transfer Patent Summary . . . . .	121
6.9	Composition of Cracked Gas from Various Processes . . . . .	123
6.10	Purification and Separation of Cracked Gas Patent Summary . . . . .	125

TABLES

7.1	Acetylene by Partial Oxidation of Natural Gas Design Bases and Assumptions . . . . .	142
7.2	Acetylene by Partial Oxidation of Natural Gas (Without Heat Recovery) Stream Flows . . . . .	148
7.3	Acetylene by Partial Oxidation of Natural Gas (Without Heat Recovery) Major Equipment . . . . .	150
7.4	Acetylene by Partial Oxidation of Natural Gas (Without Heat Recovery) Utilities Summary . . . . .	152
7.5	Acetylene by Partial Oxidation of Natural Gas (Without Heat Recovery) Capital Investment . . . . .	154
7.6	Acetylene by Partial Oxidation of Natural Gas (Without Heat Recovery) Production Costs . . . . .	155
7.7	Acetylene by Partial Oxidation of Natural Gas (With Heat Recovery) Stream Flows . . . . .	160
7.8	Acetylene by Partial Oxidation of Natural Gas (With Heat Recovery) Major Equipment of Reaction Section . . . . .	161
7.9	Acetylene by Partial Oxidation of Natural Gas (With Heat Recovery) Utilities Summary . . . . .	162
7.10	Acetylene by Partial Oxidation of Natural Gas (With Heat Recovery) Capital Investment . . . . .	165
7.11	Acetylene by Partial Oxidation of Natural Gas (With Heat Recovery) Production Costs . . . . .	166
7.12	Acetylene by Partial Oxidation of Naphtha Capital Investment . . . . .	169
7.13	Acetylene by Partial Oxidation of Naphtha Production Costs . . . . .	170
7.14	Acetylene from Residual Oil by Submerged Flame Process Production Costs . . . . .	174

## TABLES

8.1	Acetylene from Natural Gas by Arc Process Design Bases and Assumptions . . . . .	178
8.2	Acetylene from Natural Gas by Arc Process Stream Flows . . . . .	179
8.3	Acetylene from Natural Gas by Arc Process Major Equipment . . . . .	181
8.4	Acetylene from Natural Gas by Arc Process Utilities Summary . . . . .	183
8.5	Acetylene from Natural Gas by Arc Process Capital Investment . . . . .	190
8.6	Acetylene from Natural Gas by Arc Process Production Costs . . . . .	191
8.7	Comparison of SRI's Evaluation with Huels Data . . . . .	195
8.8	Acetylene from Coal by Arc Process Using Water Quenching Production Costs . . . . .	199
8.9	Acetylene from Coal by Arc Process Using Hydrocarbon Quenching Production Costs . . . . .	201
9.1	Acetylene from Ethane by the Wulff Process Production Costs . . . . .	204
10.1	Hydrogenation of Acetylene Major Equipment . . . . .	208
10.2	Hydrogenation of Acetylene Utilities Summary . . . . .	209
10.3	Acetylene Recovery in Ethylene Plant Major Equipment . . . . .	211
10.4	Acetylene Recovery in Ethylene Plant Utilities Summary . . . . .	211
10.5	Acetylene in Ethylene Plant Capital Investment . . . . .	212
10.6	Acetylene By-Produced in Ethylene Production Production Costs . . . . .	214
10.7	Ethylene by Kureha/UCC Process with Acetylene By-Production Production Costs . . . . .	217

TABLES

11.1	Manufacture of Vinyl Chloride, Vinyl Acetate, Acrylic Acid by Acetylene Process and Competing Processes . . . . .	220
11.2	Price Required for Acetylene to Make it Competitive with Ethylene and Propylene . . . . .	221
11.3	Percentage of Oil-Related Items in Product Value of Acetylene and Ethylene . . . . .	223