



Figure 1. Typical Fluor Solvent Process flow diagram.

## Improved Economics In Synthesis Gas Plants

Fluor's Solvent Process has graduated from the natural gas area and is being used in the field of hydrogen and synthesis gas production.

T. P. Cook, and R. N. Tennyson, The Fluor Corp., Ltd., Los Angeles, Calif.

THE FLUOR SOLVENT PROCESS, INTRODUCED IN 1960, has since been proved in plants designed to purify natural gas. This process is now being introduced into the field of hydrogen and synthesis gas production through a combination of two well established technologies; the latest ammonia plant design, and the Fluor Solvent Process for carbon dioxide removal.

The Fluor Solvent Process, based on pure physical absorption of carbon dioxide from the gas stream, is well suited for use in high pressure synthesis gas purification systems when combined with steam reformers which operate at 400 to 500 psig, or with partial oxidation gas generation units, which operate at 1,500 to 2,000 psig.

### Process development

In 1960 Fluor discovered that a number of organic solvents have a large capacity for absorbing carbon dioxide and that the acid gas—solvent mixtures could be separated by simply flashing to low pressure, without the addition of heat. The process was developed in a pilot plant constructed in a west Texas gas field. The successful operation of the pilot plant was followed by the construction of the first commercial

unit, built for the El Paso Natural Gas Co. This facility was designed to treat 220 million scfd natural gas containing 54% carbon dioxide to produce a sales gas containing 2% carbon dioxide, meeting pipeline specifications. The success of this installation led to the construction of several additional plants, all of which are operating successfully. They include:

1. A 10 million scfd natural gas treating plant, constructed for the Standard Oil Co. of California at Lost Hills, California.

2. A 20 million scfd plant to remove carbon dioxide from a natural gas stream for Sinclair Oil and Gas Co. in Grand County, Utah.

3. A Fluor Solvent unit supplied as part of an ammonia synthesis plant for Union Chimique Chimische Bedrijven, in Belgium. This plant, started in November, 1965, includes a partial oxidation unit, sulfur removal and shift conversion ahead of the carbon dioxide removal unit. This is the first application of the Fluor Solvent Process in a synthesis gas plant.

4. A plant designed and constructed for Wintershall A.G. near Barnstorf, West Germany to remove hydrogen sulfide and carbon dioxide from a natural gas stream with a wide range of feed gas compositions. The plant was put on stream in July, 1968 and has

**Table 1. Comparison of manufacturing costs for 1,000 MT/D ammonia and 700 MT/D urea using Fluor Solvent or Activated Potassium Carbonate Systems for CO<sub>2</sub> removal in NH<sub>3</sub> plant using naphtha feed.**

	Using Fluor Solvent	Using Activated Potassium Carbonate
<b>Capital Requirements</b>		
Capital Investment, Including Royalty .....	\$24,000,000.....	\$24,000,000
Initial Catalyst and Chemical Charge .....	800,000.....	650,000
<b>Total Depreciable Capital</b> .....	<b>24,800,000.....</b>	<b>24,650,000</b>
<b>Operating Costs</b>		
<u>Raw Material and Utilities</u>		
Naphtha Feed and Fuel @ \$0.59/million BTU .....	6,750,000.....	6,980,000
Electric Power @ 1.0¢/kwh .....	554,000.....	618,000
<b>Sub-Total</b> .....	<b>7,304,000.....</b>	<b>7,598,000</b>
<u>Operating Labor</u>		
Foreman @ \$5.00/hr. ....	40,000.....	40,000
Operators @ \$3.50/hr. ....	168,000.....	168,000
Labor Burden @ 22% .....	46,000.....	46,000
<b>Sub-Total</b> .....	<b>254,000.....</b>	<b>254,000</b>
Chemicals, Catalysts, Operating Supplies .....	155,000.....	170,000
Maintenance (3.4/3.5% of Plant Invest.) .....	815,000.....	840,000
Plant General (40% of Total Labor) .....	297,000.....	309,000
<b>Sub-Total</b> .....	<b>1,267,000.....</b>	<b>1,319,000</b>
<b>Total Operating Costs</b> .....	<b>8,825,000.....</b>	<b>9,171,000</b>
<b>Fixed Charges</b>		
Interest @ 3.5% Avg. (7%) .....	868,000.....	863,000
Taxes & Insurance (2.5% of Total Capital) .....	620,000.....	617,000
Depreciation (10% of Total Capital) .....	2,480,000.....	2,465,000
<b>Total Fixed Charges</b> .....	<b>3,968,000.....</b>	<b>3,945,000</b>
<b>Total Manufacturing Costs</b> .....	<b>12,793,000.....</b>	<b>13,116,000</b>
Payout on Incremental Investment .....	0.46 years	

operated successfully since that time.

5. An additional plant to remove carbon dioxide from a natural gas stream in Terrell County, Texas. This is an expansion of the original Fluor Solvent facility constructed for the El Paso Natural Gas Co. This unit, which was recently put on stream, is operating quite satisfactorily.

6. A plant designed to treat 80 million scfd natural gas in Pecos County, Texas is nearing start up for the El Paso Natural Gas Co.

7. A Fluor Solvent unit being designed as part of a large hydrogen plant soon to be constructed for Standard Oil Co., a division of Chevron Oil Co., at Pascagoula, Mississippi. This unit is equivalent in carbon dioxide removal capacity to a 1,450 T/SD ammonia plant; and will be the second Fluor Solvent Process unit to be installed in a synthesis gas plant.

As mentioned, the process relies upon the physical absorption of the carbon dioxide in certain organic solvents. All of the plants now in operation, or being designed, use propylene carbonate, which exhibits all of the desirable characteristics for such a solvent. The usual process scheme for acid gas removal with the Fluor Solvent Process is illustrated in Figure 1. The process involves the physical absorption of carbon dioxide in the substantially anhydrous organic solvent. The acid gas is desorbed simply by the release of

pressure without the application of heat. A portion of the hydrogen in the synthesis gas is absorbed in the solvent. An intermediate pressure flash is included in the process flow to preferentially flash these materials from the solvent to permit their recovery. The hydrogen-rich gases, which also contain a very small part of the absorbed carbon dioxide, are compressed and returned to the absorber for recovery. The lean solvent from the stripper is returned to the absorber to complete the cycle. Hydraulic turbines are used to recover power to minimize the process' energy requirements.

Because the solvent used is a physical absorbent, its carbon dioxide carrying capacity is approximately proportional to the partial pressure of carbon dioxide in the feed gas. For this reason, the process works to best advantage purifying gas streams containing high concentrations of carbon dioxide, or when purifying gas streams at relatively high pressure. All of the applications to-date follow this pattern. In each case, the final acid gas removal from the solvent is accomplished in a flash drum.

### New design techniques

Fluor recently developed new design techniques using stripping, which enable the process to be used economically in plants where the partial pressure of

**Table 2. Comparison of manufacturing costs for 1,000 MT/D ammonia and 700 MT/D urea using Fluor Solvent or Activated Potassium Carbonate Systems for CO<sub>2</sub> removal in NH<sub>3</sub> plant using a natural gas feed.**

	Using Fluor Solvent	Using Activated Potassium Carbonate
<b>Capital Requirements</b>		
Capital Investment, Including Royalty .....	\$22,850,000.....	\$22,850,000
Initial Catalyst and Chemical Charge .....	700,000.....	600,000
Total Depreciable Capital .....	23,550,000.....	23,450,000
<b>Operating Costs</b>		
<u>Raw Material and Utilities</u>		
Natural Gas Feed & Fuel @ \$0.35/million BTU .....	3,900,000.....	4,000,000
Electric Power @ 1.0¢/kwh .....	458,000.....	535,000
Sub-Total .....	4,358,000.....	4,535,000
<u>Operating Labor</u>		
Foreman @ \$5.00/hr. ....	40,000.....	40,000
Operators @ \$3.50/hr. ....	168,000.....	168,000
Labor Burden @ 22% .....	46,000.....	46,000
Sub-Total .....	254,000.....	254,000
Chemicals, Catalysts, Operating Supplies .....	155,000.....	170,000
Maintenance (3.4/3.5% of Plant Invest.) .....	777,000.....	800,000
Plant General (40% of Total Labor) .....	288,000.....	294,000
Sub-Total .....	1,220,000.....	1,264,000
Total Operating Costs .....	5,832,000.....	6,053,000
<b>Fixed Charges</b>		
Interest @ 3.5% Avg. (7%) .....	824,000.....	821,000
Taxes & Insurance (2.5% of Total Capital) .....	589,000.....	586,000
Depreciation (10% of Total Capital) .....	2,355,000.....	2,345,000
Total Fixed Charges .....	3,768,000.....	3,752,000
Total Manufacturing Cost .....	9,600,000.....	9,805,000
Payout on Incremental Investment .....	0.49 years	

carbon dioxide in the outlet gas is very low. The process can produce a gas stream with a carbon dioxide concentration in the range normally used in hydrogen and ammonia plant methanators. Because the Fluor Solvent Process does not require any heat to regenerate the solution, thermal energy, which is normally required for regenerating the solution in systems using chemical solvents, is released for other uses. Fluor has developed techniques which take full advantage of this available energy.

Another advantage of the Fluor Solvent Process is its high reliability when compared with carbon dioxide removal processes which involve chemical reaction of the solvent with the carbon dioxide. The Fluor process has lower maintenance costs, operates essentially without water, and the solvent does not attack ordinary carbon steel. Corrosion, caused either by wet carbon dioxide or directly by the solvent, is negligible.

To illustrate the value of the Fluor Solvent Process in synthesis gas plants, comparative economics were prepared for a number of cases using the Fluor Solvent Process vs. an activated potassium carbonate process for carbon dioxide removal. The studies indicate that the Fluor process has only a slight cost advantage over an activated potassium carbonate process for a project involving only an ammonia plant

using steam reforming. In this case, the lower operating cost of the Fluor Solvent unit is offset by higher capital investment. However, efforts to reduce the capital cost while maintaining the reduced operating requirements are continuing. For ammonia plants in which the synthesis gas is generated in a partial oxidation unit, the Fluor Solvent Process exhibits both reduced capital investment and lower operating cost when compared with an activated potassium carbonate system.

When the plant includes facilities to convert the ammonia to urea, there are substantial advantages to using the Fluor Solvent Process for acid gas removal. By flashing the carbon dioxide from the solvent at above atmospheric pressure, urea plant compression requirements are reduced. This is accomplished very simply because propylene carbonate is a pure, dry physical solvent, which does not require any heat to desorb the carbon dioxide, and because the carbon dioxide is cool and dry as it leaves the flash drum.

### Cost advantages

Table 1 illustrates the relative cost of producing 1,000 MT/D of ammonia and 700 MT/D of urea using naphtha feed. Note that credit has been taken for the lower maintenance costs required with the Fluor Solvent Process. The capital investment required for

**Table 3. Comparison of manufacturing costs for CO<sub>2</sub> removal from a gas generated using Fluor Solvent or Activated Potassium Carbonate Systems.**

	Using Fluor Solvent	Using Activated Potassium Carbonate
<b>Capital Requirements</b>		
Capital Investment, Including Royalty .....	\$1,440,000 .....	\$1,660,000
Initial Catalyst and Chemical Charge .....	10,000 .....	8,000
<b>Total Depreciable Capital</b> .....	<b>1,450,000</b> .....	<b>1,668,000</b>
<b>Operating Costs</b>		
<u>Utilities</u>		
Steam @ 50¢/thousand lbs. ....	— .....	26,600
Cooling Water @ 2¢/thousand gals. ....	5,200 .....	22,600
Electric Power @ 1¢/kwh .....	23,000 .....	41,600
<b>Sub-Total</b> .....	<b>28,200</b> .....	<b>90,800</b>
<u>Operating Labor</u>		
Foreman @ \$5.00/hr. ....	10,000 .....	10,000
Operators @ \$3.50/hr. ....	10,000 .....	14,000
Labor Burden @ 22% .....	4,400 .....	5,700
<b>Sub-Total</b> .....	<b>24,400</b> .....	<b>29,700</b>
Chemicals, Catalyst, Operating Supplies .....	4,000 .....	2,000
Maintenance (3.0/3.5% of Plant Invest.) .....	43,200 .....	58,200
Plant General (40% of Total Labor) .....	20,100 .....	25,800
<b>Sub-Total</b> .....	<b>67,300</b> .....	<b>86,000</b>
<b>Total Operating Costs</b> .....	<b>119,900</b> .....	<b>206,500</b>
<b>Fixed Charges</b>		
Interest @ 3.5% Avg. (7%) .....	50,700 .....	58,300
Taxes and Insurance (2.5% of Total Capital) .....	36,200 .....	41,600
Depreciation (10% of Total Capital) .....	145,000 .....	166,800
<b>Total Fixed Charges</b> .....	<b>231,900</b> .....	<b>266,700</b>
<b>Total Manufacturing Cost</b> .....	<b>351,800</b> .....	<b>473,200</b>
<b>Cost per Short Ton CO<sub>2</sub> Removed</b> .....	<b>4.45</b> .....	<b>6.00</b>

the Fluor process is slightly higher than that required for the alternate one, but the payout on the incremental investment is less than six months. For the case illustrated, the annual benefit accruing from using the Fluor Solvent Process is \$323,000.

Table 2 illustrates similar figures for the production of 1,000 ST/D ammonia and 700 MT/D urea using a natural gas feed. The capital investment includes costs for water treating, a cooling tower, and 30,000 tons of ammonia storage capacity. Here again, the reduced maintenance costs associated with the Fluor Solvent Process are credited. In this case, the payout on incremental investment is less than six months and the annual benefit from using the process is \$205,000.

Table 3 compares the economics of the two systems for removing acid gases from 14 million scfd synthesis gas, containing 32 volume per cent carbon dioxide (dry basis), generated in a partial oxidation unit. The advantage to the synthesis gas producer from using the Fluor Solvent Process is \$1.55 per ton of carbon dioxide removed.

The figures in these tables clearly indicate that the Fluor Solvent Carbon Dioxide Process has an economic advantage over the carbon dioxide processes presently used in synthesis gas plants. The magnitude

of this advantage varies with the end product of the plant—ammonia or urea, with the process scheme, and with the feed stock used to produce ammonia. In each case, it is sufficient to merit the attention of designers and operators of ammonia and urea plants. #



**T. P. Cook** earned his degree in chemical engineering from Washington University, St. Louis, Mo. He has worked for Phillips Petroleum and the Blaw Knox Construction Co. He is presently employed by Fluor as Chief Process Engineer responsible for chemical plants.



**R. N. Tennyson** obtained his B.S. in chemical engineering from the University of Minnesota. He has worked for B. F. Goodrich and Allied Chemical and Dye Corp., and is now employed by Fluor as Principal Process Engineer for chemical plant design.