Conversion of Associated Natural Gas to Liquid Hydrocarbons

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Abstract

Energy International is a leader in catalyst and process development as it relates to Fischer-Tropsch (F-T) technology. Through this activity, a concept evolved for a new technique for capturing the fuel value in the associated natural gas contained in crude oil. In the new concept, the dissolved natural gas would be processed via F-T technology to produce light hydrocarbons that would then, in one manifestation of this concept, be redissolved in the crude oil to produce a lighter crude than the original, containing all of the natural gas, but with the vapor pressure of the crude lowered to an acceptable level via the conversion process. This technique would be of particular interest in those instances where the alternative methods of collecting and utilizing the associated natural gas were expensive. A study of the application of this technology was undertaken by EI with support from the DOE.

The two conventional approaches currently used in U.S. territory for the handling of natural gas associated with crude petroleum production are reinjection and pipelining. Reinjection is sometimes desirable to enhance crude production but in some cases, it reduces or hampers production. It costs on the order of $0.25/MCF, and can range up to $0.50/MCF. This cost can be significant at high gas to oil ratios, and it does not make use of the gas resource.

For significant potential production of on-shore and "near-shore" gas, pipelining to market or to a use point is the other current approach. However, as distances from the shore increase, so do water depths, and distances to tie-in points to existing pipelines. Off-shore pipeline installation costs can range from $170,000/mile to over $1,000,000/mile. In addition, sea bottom conditions such as a potential for mud slides, can make building a pipeline too risky or too expensive. In the past few years, projects have been carried out in the U.S. Gulf of Mexico and significantly greater distances from shore and water depths. This trend is expected to continue, and gives incentives to consider alternatives to reinjection and pipelining.

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Conversion of natural gas to liquid product which can be transported to shore by tanker can be accomplished by Fisher-Tropsch (F-T) processing to produce hydrocarbons, by conversion to chemical products such as methanol or ammonia, or by cryogenic liquefaction (LNG). This study considers F-T processing and briefly compares it to methanol and LNG. An offshore F-T plant can best be accommodated by a FPSO (Floating Production, Storage, Off-loading vessel) based on a converted surplus tanker, such have been frequently used around the world recently.

The case considered is installation of a FPSO of a Fischer-Tropsch plant capable of handling 56,000,000 cf/d of wet associated gas derived from 22,400 bbl/d of crude, a GOR of 2,500. The FPSO would be a converted 200,000 DWT VLCC tanker costing $137 MM including $65 MM for synthetic line mooring and associated vessel facilities. The F-T plant would produce 25,000 bbl/day of premium quality synthetic crude, and would have a capital cost of $383 MM. The combination of an F-T plant with a FPSO is referred to as a FFTP (Floating Fischer-Tropsch Production system).

A major oil and gas company which is a Developer of deepwater gas/oil projects and a deep water Gulf of Mexico tract lease-holder has participated in this study on a anonymous basis. The Developer postulated development of a major oil/gas prospect at 6,000 ft water depth and a distance of 350 miles from the nearest available pipeline tie-in to the existing offshore to onshore pipeline transportation system. In this scenario, the Developer compared investment cost to produce the field via FFTP/shuttle tanker versus investment cost to produce the field via a new but conventional pipeline system. It was found that the FFTP/shuttle tanker system would enjoy a half-billion dollar investment advantage compared to production of the field via pipeline. Also, the field is produced by the FFTP approximately one year earlier than first oil is achieved via the pipeline system.

The Developer concludes his assessment as follows:

"In summary, if the Fisher-Tropsch process field-scale application will perform somewhat similarly to the representations made by EI, it appears that commercial interest in the F-T process/shuttle tanker development methodology is merited."

Consideration of other scenarios such as field development and delineation, or production of small fields shows that the FFTP may have merit in these also, partly due to being able to move the entire facility to a new location easily as compared to a pipeline which must be dedicated to a project location.

Compared to methanol, F-T products have a much larger market, and can be handled and processed by existing petroleum systems if desired. FFTP is probably more adaptable to the offshore than LNG, and will be practical at lower production rates.

Acknowledgments

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CONVERSION OF ASSOCIATED NATURAL GAS TO LIQUID HYDROCARBONS

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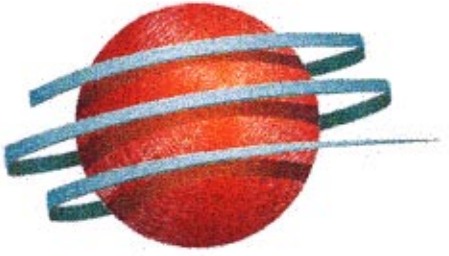


ENERGY INTERNATIONAL

A SUBSIDIARY OF WILLIAMS FIELD SERVICES

OBJECTIVE

Evaluate the economics of applying advanced Fischer-Tropsch technology to the economic utilization of remote associated natural gas.

SCENARIO

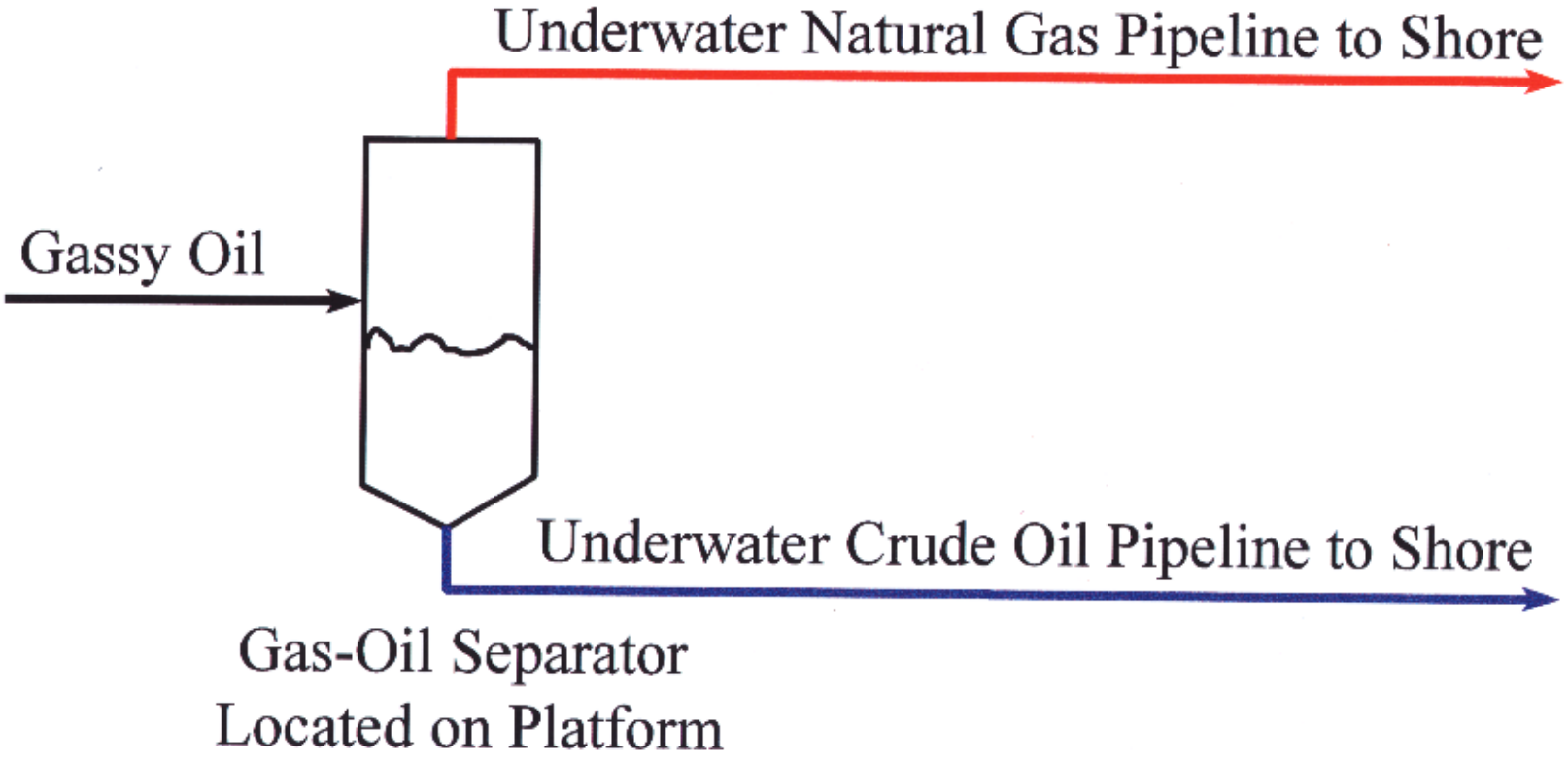
- Gulf of Mexico crude oil and associated natural gas is being discovered and produced in increasingly deeper waters and further from shore
- Current practice is to separate oil and gas on platforms
- Natural gas and crude oil are then transported separately to shore via underwater pipelines
- Capital cost of pipeline for delivering natural gas to market has increased substantially with water depth and distance from shore
- Associated natural gas must be either recovered and utilized or reinjected; flaring is not an option

SCENARIO (Continued)

Fischer-Tropsch technology:

- has been proven feasible for converting natural gas to petroleum-compatible hydrocarbon liquids
- has experienced dramatic improvements in catalyst technology
- has experienced dramatic reduction in reactor size and cost due to slurry bubble column reactor technology
- can benefit from continuing strides in natural gas reforming technology that have improved the economics of conversion to synthesis gas ($CO + H_2$)

UNDERWATER PIPELINES



PROCESS CHEMISTRY

The first step in natural gas processing:

STEAM REFORMING

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

Produces a mixture of carbon monoxide (CO) and hydrogen (H_2)

PROCESS CHEMISTRY

(Continued)

The second step:

FISCHER-TROPSCH PROCESS

$$(2n+1)H_2 + nCO \rightarrow H\text{-}(CH_2)_n\text{-}H + nH_2O$$

Produces n-paraffin hydrocarbons and water. Using a catalyst like ENERGY INTERNATIONAL's cobalt on alumina catalyst gives a very high proportion of straight chain saturated hydrocarbons which contain no sulfur, nitrogen, or metals.

PROCESS CHEMISTRY

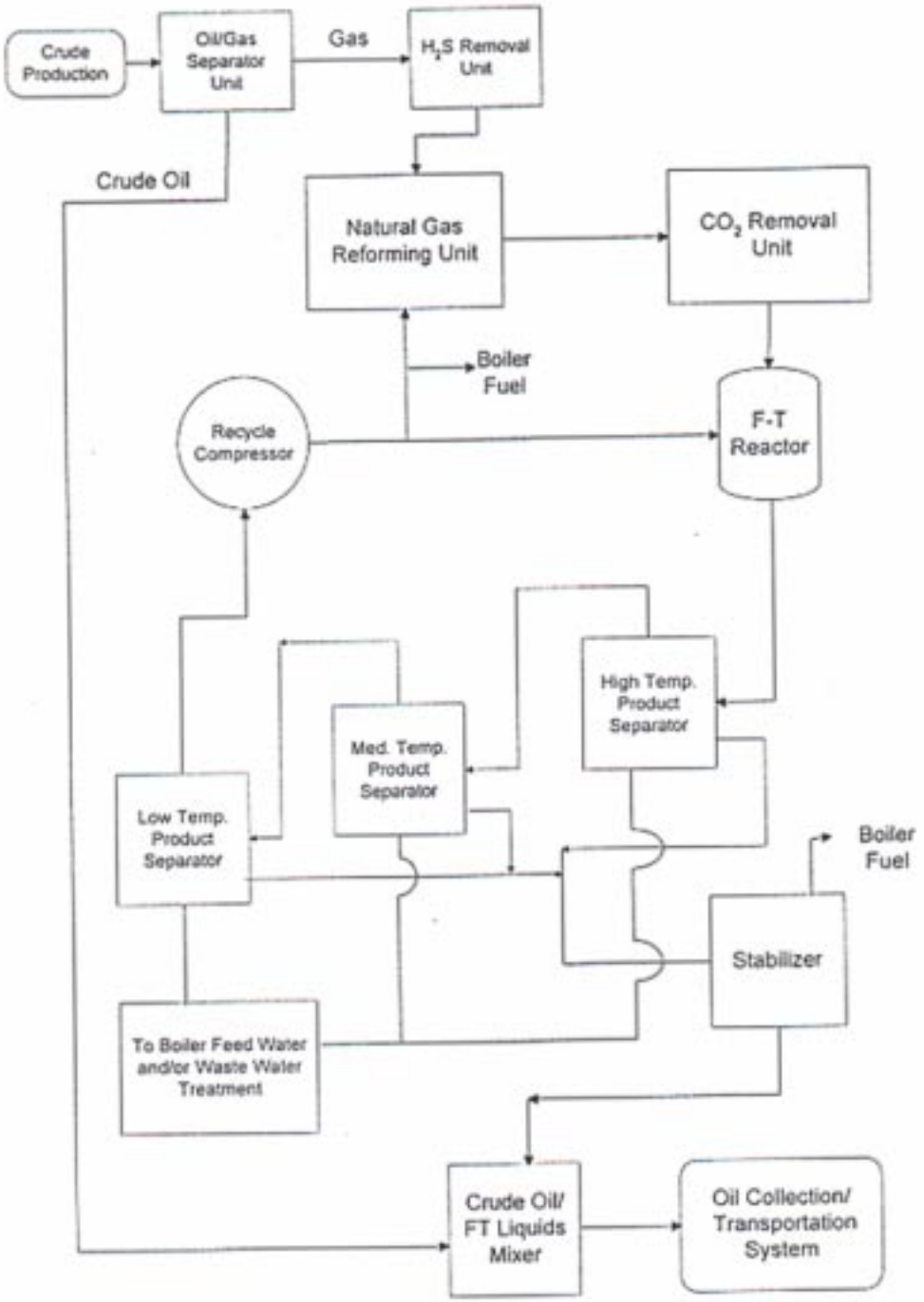
(Continued)

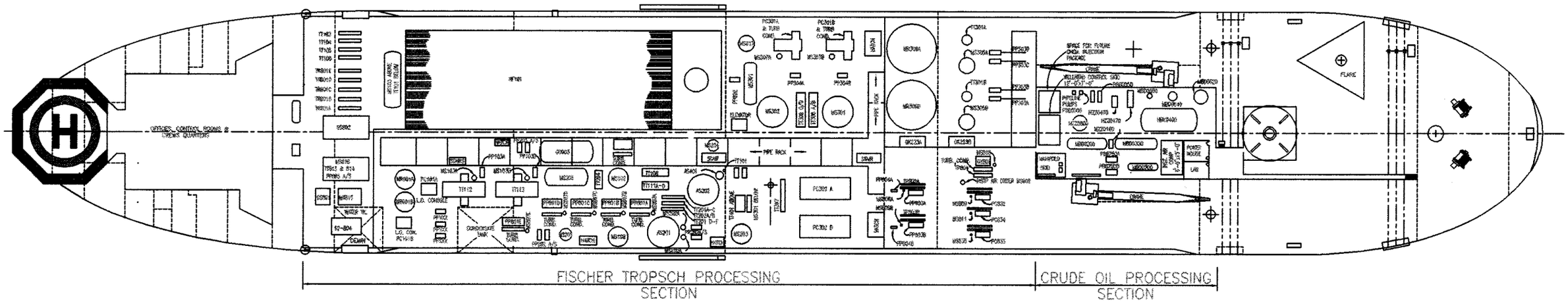
- The catalyst and the reaction conditions determine the upper limit for n, the number of carbon atoms in the hydrocarbon molecules produced.

- The "carbon number" of hydrocarbons produced by the Fischer-Tropsch reaction always has a wide range. "n" ranges from 1 to an upper limit of 50, 70, or even 100.

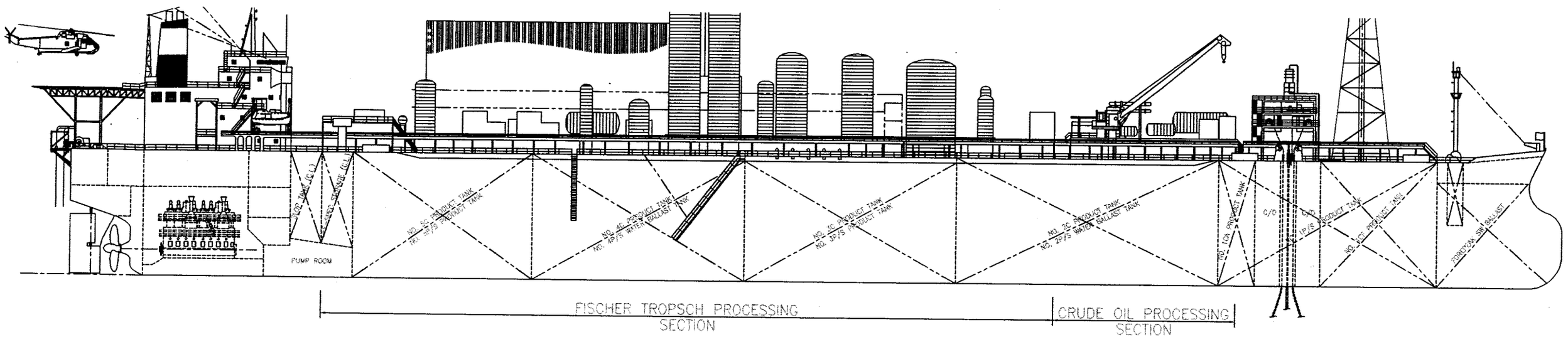
- Thus, the following products are produced:
  - LPG
  - NAPHTHA
  - DIESEL
  - HEAVY GAS OIL / WAX

OFFSHORE FISCHER-TROPSCH PLANT ASSOCIATED GAS TO HYDROCARBON LIQUIDS





E.I. FLOATING FISCHER TROPSCH PLANT



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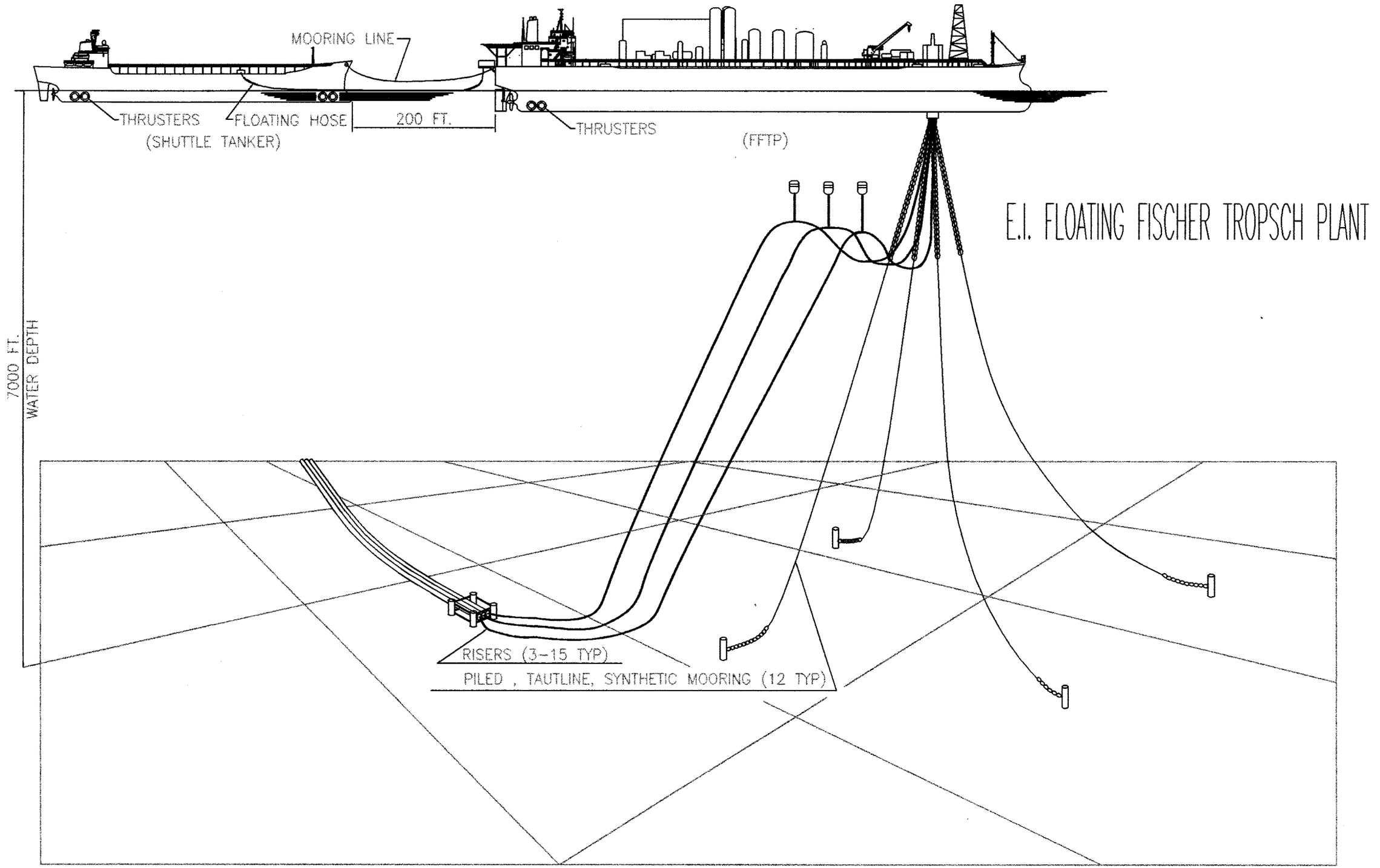
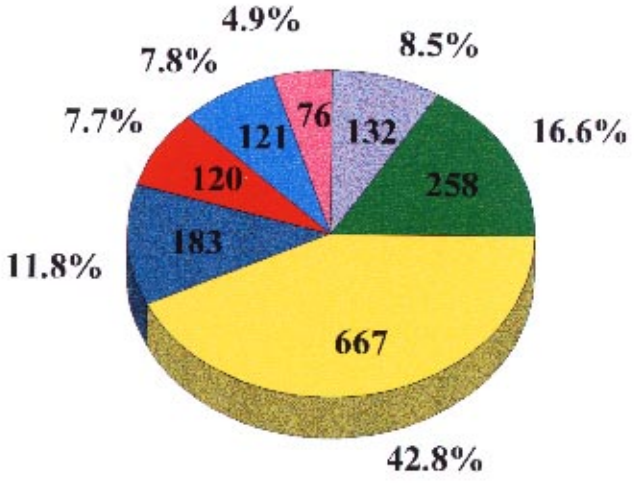

MOORING LINE
THRUSTERS
FLOATING HOSE
200 FT.
(SHUTTLE TANKER)
THRUSTERS
(FFTP)
E.I. FLOATING FISCHER TROPSCH PLANT
7000 FT.
WATER DEPTH
RISERS (3-15 TYP)
PILED , TAUTLINE, SYNTHETIC MOORING (12 TYP)

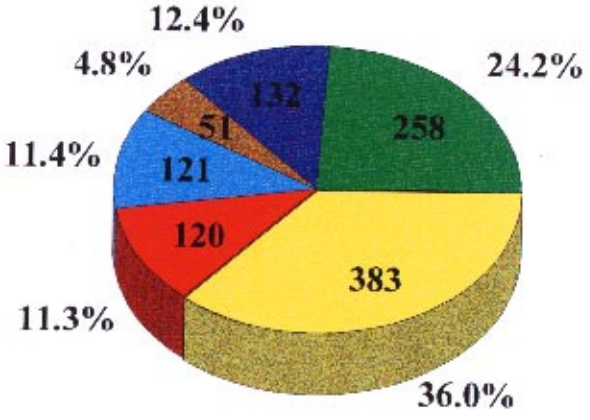
PIPELINE OPTION COSTS



TOTAL COST, $MILLION = 1557

- D&C 12 WELLS
- SUBSEA CLUSTERS(3)
- PROD/EXPORT RISER
- TANKER & MOORING
- TOPSIDES/PROCESS
- OIL EXPORT PIPELINE
- GAS EXPORT PIPELINE

FFTP OPTION COSTS



TOTAL COST, $MILLION = 1065

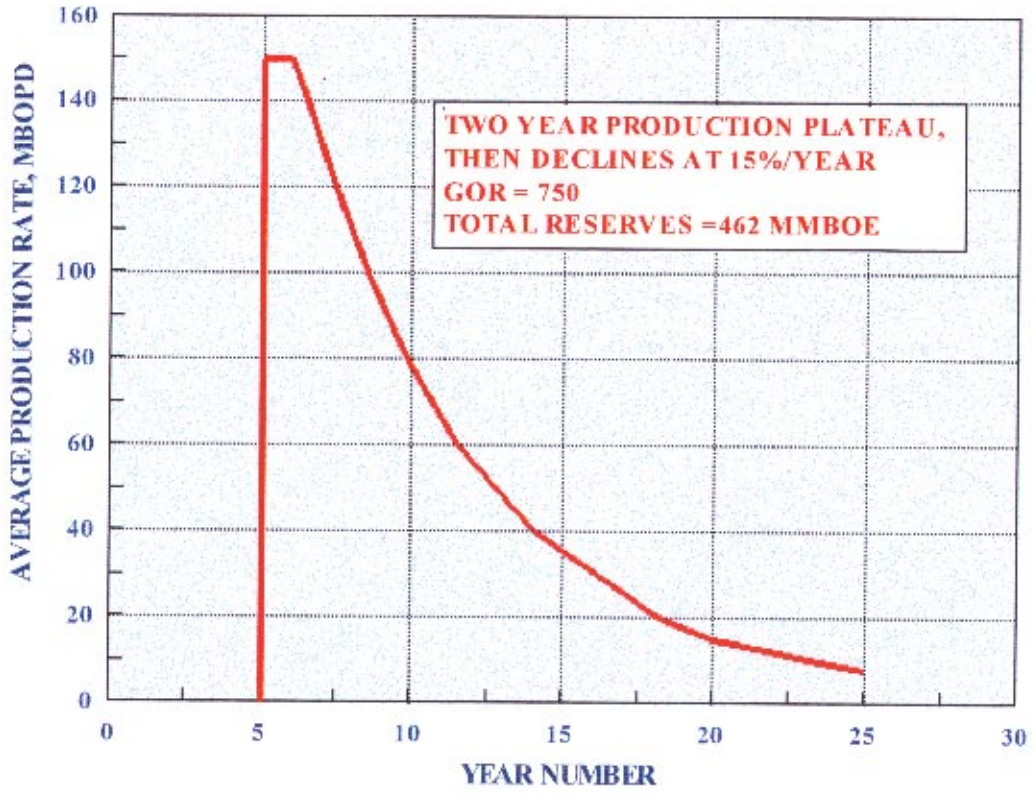
- D&C 12 WELLS
- SUBSEA CLUSTERS(3)
- PRODUCTION RISER
- TANKER & MOORING
- TOPSIDES/PROCESS
- F-T PROCESS

CONCEPTUAL CAPITAL COST ESTIMATE FOR A FLOATING F-T PLANT

Gas Consumption, MMSCFD	200
F-T Production, BPD	25,000
Vessel	VLCC (1030')

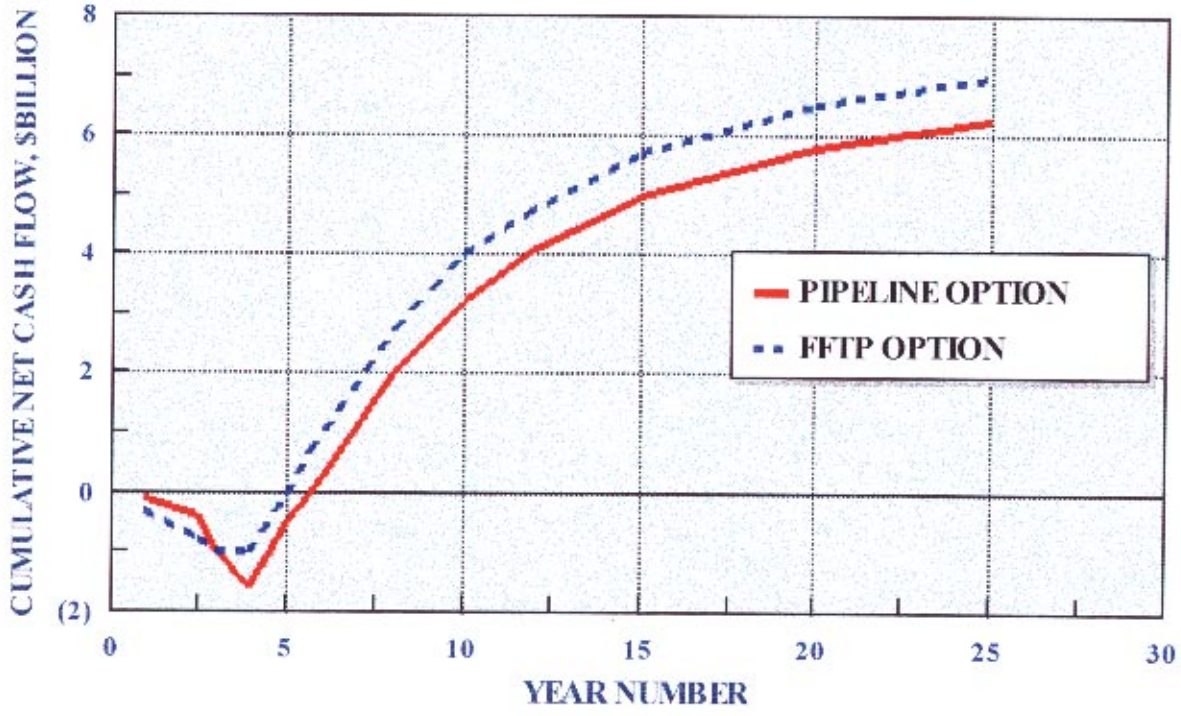
Cost Estimate, Millions of Dollars	
Vessel Acquisition & Amortization	15.60
Life Extension Measures	7.80
Engineering Systems & Structure for F-T Plant	24.00
Upgraded Ship Systems	10.50
Mooring & Internal Turret	65.00
Crude Process & Flare	16.20
Naval Architecture, Marine Engineering, Supervision	2.90
Subtotal	137
F-T Plant	383
Total FFTP/FPSO	**525**

HYPOTHETICAL FIELD DEVELOPMENT PROFILE USED FOR COMPARING PIPELINE AND FFTP OPTIONS



CUMULATIVE NET CASH FLOWS

UNDISCOUNTED, UNINFLATED, AND BEFORE TAXES



CONCLUSIONS

- In many water-based locations such as, but not limited to, the Gulf of Mexico converted tankers (VLCC's) offer an attractive "platform" for combining production operations with Fischer-Tropsch conversion of natural gas

- At pipeline distances of greater than 200 miles, or with difficult ocean bottom conditions, Fischer-Tropsch conversion of remote associated natural gas may provide superior economics to pipeline delivery of natural gas

CONCLUSIONS (Continued)

- Given the availability of a ship mounted production/Fischer-Tropsch facility, one could get an early start on producing a new discovery, i.e., otherwise marginal competitive economics could be made attractive from cash flow considerations
- FFTP is movable/usable for a series of short life projects
- Fischer-Tropsch options are to gas pipelines as coal derived synthetic fuels are to crude oil

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