STATUS OF THE 100 BPD FLUID BED METHANOL-TO-GASOLINE PROJECT

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Abstract

Evaluation of the fluid-bed Methanol-to-Gasoline (MTG) process is progressing smoothly in the 100 BPD pilot plant in West Germany. The project is being conducted jointly by Mobil Research and Development Corporation, Uhde GmbH, and Union Rheinische Braunkohlen Kraftstoff AG (URBK). The project is supported financially by the U.S. DOE and the German Government. Following a brief shakedown period, the plant was started up in December, 1982 at the URBK facility near Cologne. The plant has accumulated over 4,000 hours on stream at feed rates of up to 200 BPD methanol. The first operational phase of the project was completed as scheduled in September, 1983. Plant performance met or exceeded all design goals. Finished gasoline yields of 90 wt % of total hydrocarbons were achieved at base case conditions with complete methanol conversion. Gasoline octane was 95-96 Research clear. Preliminary tests indicate that product stability is excellent. Process sensitivity studies indicate the potential for increased yields and improved operation at the expense of product octane. Modifications are currently underway in preparation for the second phase of operation, to begin in January, 1984.

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Introduction

The status of the 100 BPD Fluid Bed MTG Project is reviewed briefly. The project is being conducted jointly by Union Rheinische Braunkohlen Kraftstoff AG (URBK), Uhde GmbH, and Mobil with financial assistance from the U.S. Department of Energy and the German Ministry for Research and Technology (Figure 1). The program schedule for the project is summarized in Figure 2. Cold Flow Model Studies had been conducted earlier to confirm the mechanical design basis for the plant. Plant construction and precommissioning activities were completed last year. The unit was started up in December, 1982 and proceeded smoothly through the first operational phase (external cooling of catalyst) which was completed as scheduled in September, 1983. Modifications are currently underway in preparation for the second phase of operation, which will evaluate the viability of internal removal of reaction heat. The 21-month operating program will be completed by late 1984. Product quality testing will be conducted both in the U.S. and Germany. The program will culminate in the conceptual design of a commercial fluid-bed MTG plant.

The major accomplishments over the previous 12 months will be discussed in this review. A brief overview of the precommissioning period will be presented and the results of plant operation will then be described.

100 BPD MTG Demonstration Plant

Plant Description

A simplified flow diagram of the plant is shown in Figure 3. Commercial grade methanol is mixed with boiler feed water to simulate crude methanol and is vaporized and superheated to 350°F prior to introduction to the reactor. Entrained catalyst is removed from the raw gas product, which is then cooled and separated into an aqueous phase, a C_4^- light gas, and a stabilized gasoline product. Heat released during the reaction is removed by circulation of hot catalyst to an external vessel, where it is cooled by a heat transfer oil system before being returned to the reactor. A small slip stream of catalyst is circulated continuously to the regenerator in order to maintain the desired level of coke on the catalyst.

Precommissioning

Highlights of the precommissioning phase are shown in Figure 4. Construction of the 100 BPD MTG demonstration plant, which is located at the URBK facility in Wesseling, Germany, was completed by mid-September, 1982. Installation and testing of on-line analytical systems and all equipment and control loop checks were finalized during the following month. Approximately six weeks of unit pretests using FCC catalyst were conducted in order to confirm operation of catalyst recovery systems and to calibrate unit instrumentation. The pretest period also served to train plant personnel in unit operations and safety procedures. Examples of data obtained during the pretest program are illustrated in Figures 5 and 6. These results parallel those obtained in the Cold Flow Model, thereby confirming the utility of large scale flow models in guiding the design of fluid bed systems.

Plant Operation

The demonstration plant was started up successfully on December 15, 1982 and completed its first phase of operation on September 30, 1983. In the interim, the unit accumulated over 4,000 hours on-stream. Excluding scheduled turnarounds, the service factor was about 85%, which is exceptionally high for a pilot plant facility. Unit performance was smooth and controllable for a wide range of process conditions. The exothermic heat of reaction could be removed efficiently in the external catalyst cooler. As shown in Figure 7, the temperature profile in the reactor dense bed is essentially isothermal. Methanol feed rates of 135-200 BPD were achieved during this period. Quantitative conversion of methanol was maintained at all times. Detailed results obtained during the shakedown, optimization, and steady state operating phases are described below.

Following start-up, the operation proceeded smoothly through a two-month shakedown phase. The objective of the run was to identify and correct all remaining mechanical and control difficulties so that continuous unit operation could be established. The plant was shut down periodically to rectify minor technical problems.

Initially, instabilities occurred in the catalyst circulation between the reactor and cooler. This problem, which was due to difficulties in filling the upper reactor-cooler transfer line with catalyst, was intensified by sensitivity of the catalyst valve control. Modification of the circulation control mode and reduction of valve trim improved circulation control only marginally. Installation of restriction orifices ahead of each control valve resulted in stable catalyst circulation between the reactor and external cooler (Figure 8). Performance of the reactor filter had also limited methanol throughput at the beginning of the program. The filter internals were modified and the blow-back system was optimized to permit operation at the desired feed rates. It should be emphasized that such mechanical problems are specific to this particular unit. Established methods for catalyst flow control and recovery are employed routinely in commercial fluid bed operations to achieve acceptable unit performance.

Preliminary evaluations were then conducted until the end of March, 1983. This period was highlighted by a 40-day continuous run at design conditions. Catalyst equilibration was continued while product recovery procedures were improved to provide material balance closures which were consistently above 97%. Both batch and continuous catalyst regenerations were demonstrated successfully.

After a turnaround in April for equipment inspection and scheduled maintenance, an experimental program was conducted to evaluate the effects of changes in key process parameters on unit performance. The objectives of the process sensitivity studies are shown in Figure 9. Data obtained under the first two objectives served to optimize process conditions in the large scale plant. The third objective will facilitate direct comparison of 100 BPD reactor efficiency with those of smaller units. The process sensitivity program involved evaluating plant performance within the parameter ranges indicated in Table 1. In most instances, the range of process variables represent practical unit limitations. Stable plant performance was achieved for all combinations of parameters investigated.

Product yields and properties at base case conditions are shown in Table 2. Product quality is excellent and exceeds all requirements for unleaded regular gasoline. The effects of pressure and temperature on gasoline yield are shown in Figures 10 and 11, respectively. A 2% yield improvement is realized at the higher pressure with about a half number decrease in finished gasoline octane. Durene yield also increases by about 2 wt %. An equivalent yield advantage occurs upon lowering reactor temperature, but with a more significant penalty in product quality. Variation of space velocity was shown to have minimal impact on product selectivities within the range investigated. Judicious choice of conditions for commercial oprations could provide for higher specific methanol feed rates and decreases in alkylation plant and compression requirements.

A successful demonstration of steady state plant operation was completed in mid-September, 1983. The results of the run (Figure 12) clearly show that scale-up of the externally cooled MTG process to a 100 BPD reactor system has been achieved. Analysis of plant data is continuing in order to quantify catalyst make-up requirements.

The unit is currently shut down for mechanical modifications required to operate in an internally cooled mode. The turnaround is scheduled to be completed by January, 1984.

Table 1

100 BPD MTG PLANT OPERATING CONDITIONS

Methanol Feed Rate	80-200 BPD
Feed Composition	96% Methanol 4% Water

Reactor

Top Pressure	25-60 psig
Temperature	700-800°F
WHSV	0.5-1.5
Gas Superficial Velocity	1-2 ft/s

Regenerator

Top Pressure	30-65 psig
Temperature	850-900°F
Catalyst Circulation Rate	50-450 lb/hr
Gas Superficial Velocity	1-2 ft/s

Catalyst Cooler

Temperature	600-700°F
Catalyst Circulation Rate	10,000-25,000 lb/hr
Gas Superficial Velocity	0.4-0.6 ft/s

Table 2

GASOLINE YIELDS AT BASE CASE CONDITIONS

	Base Case
Pressure, psig	25
Temperature, °F	765
Product Yields, wt %	
Raw C_5^+ Gasoline	64
Alkylate	24
C_5^+ with Alkylate	88
9 RVP Gasoline	90
Octane of Raw C_5^+ Liquid	
RON	96.0
MON	84.5

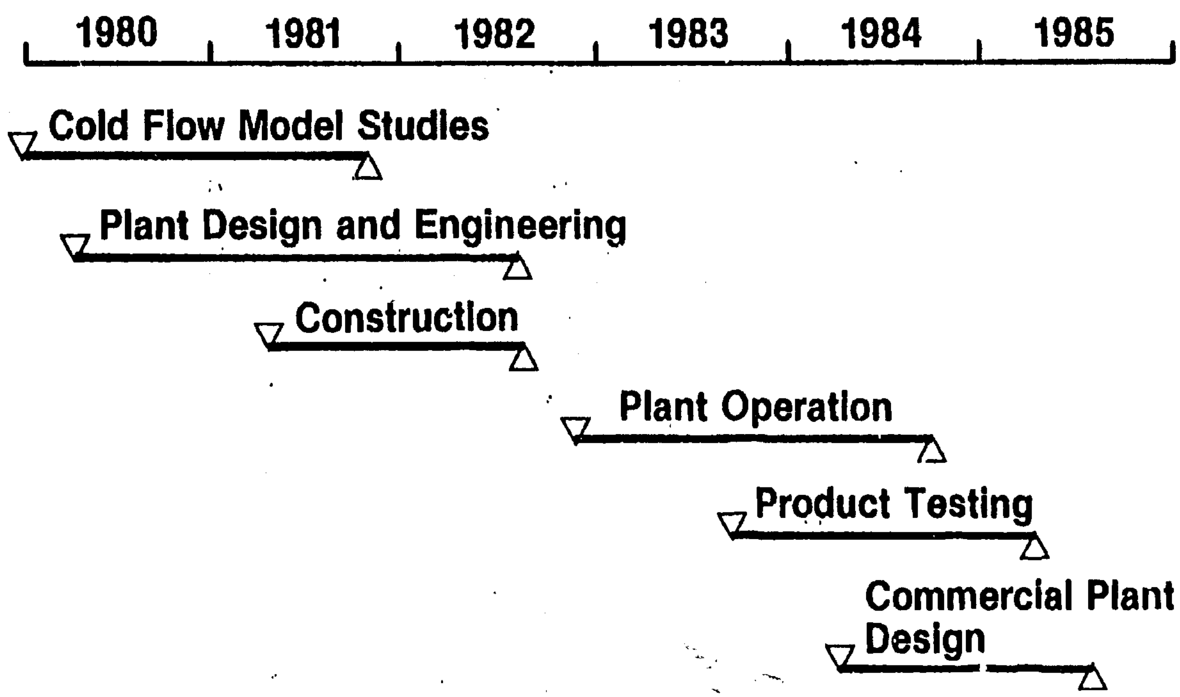
Figure 1

100 BPD FLUID-BED MTG PROJECT

- Demonstrate commercial feasibility of fluid-bed MTG
- Build a 2′ ID x 40′ high reactor in Germany and operate for 2 years
- Five year (1980-1985), 63 million DM program
- US DOE, German BMFT, URBK, Uhde, Mobil

Figure 2

100 B/D FLUID-BED MTG PROGRAM



Figure

100 B/D FLUID-BED MTG

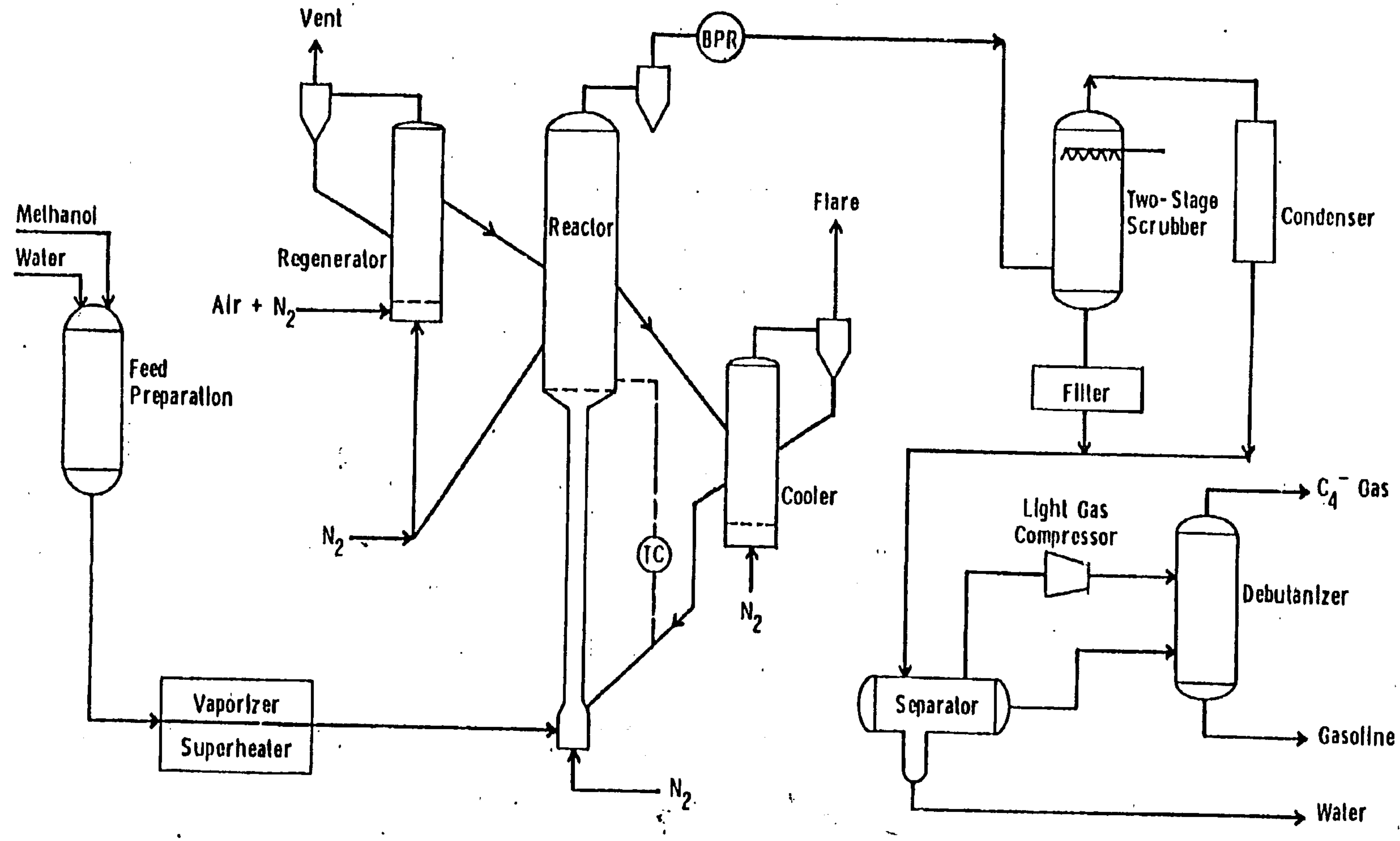


Figure 4

100 BPD FLUID-BED MTG PLANT PRECOMMISSIONING HIGHLIGHTS

- Mechanical completion on September 10, 1982
- Equipment and instrument loop checks completed October 15, 1982
- Pretests concluded November 29, 1982

Figure 5

REACTOR ENTRAINMENT VS SUPERFICIAL GAS VELOCITY

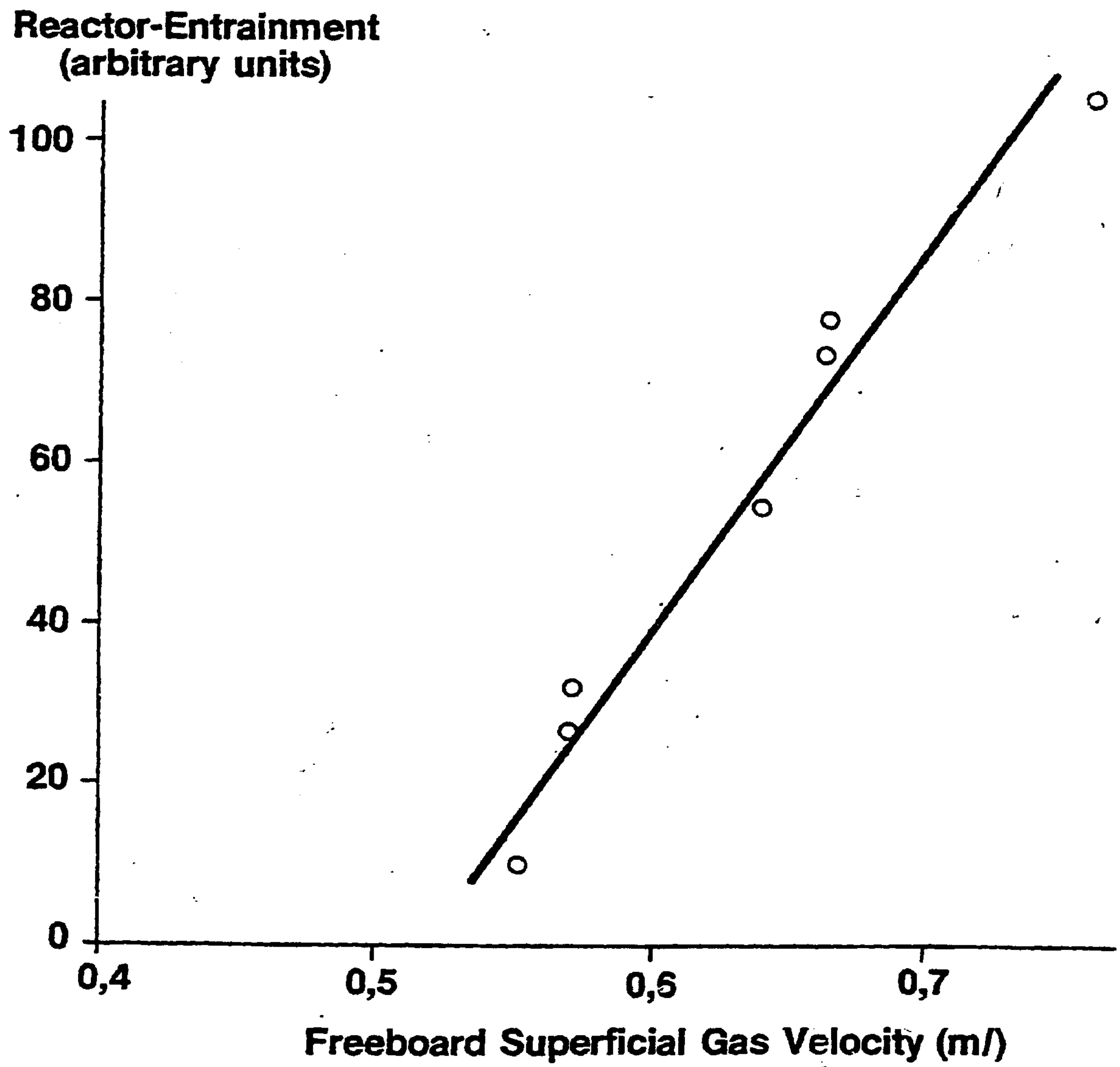


Figure 6

SOLIDS CIRCULATION RATE — REACTOR-CATALYST COOLER

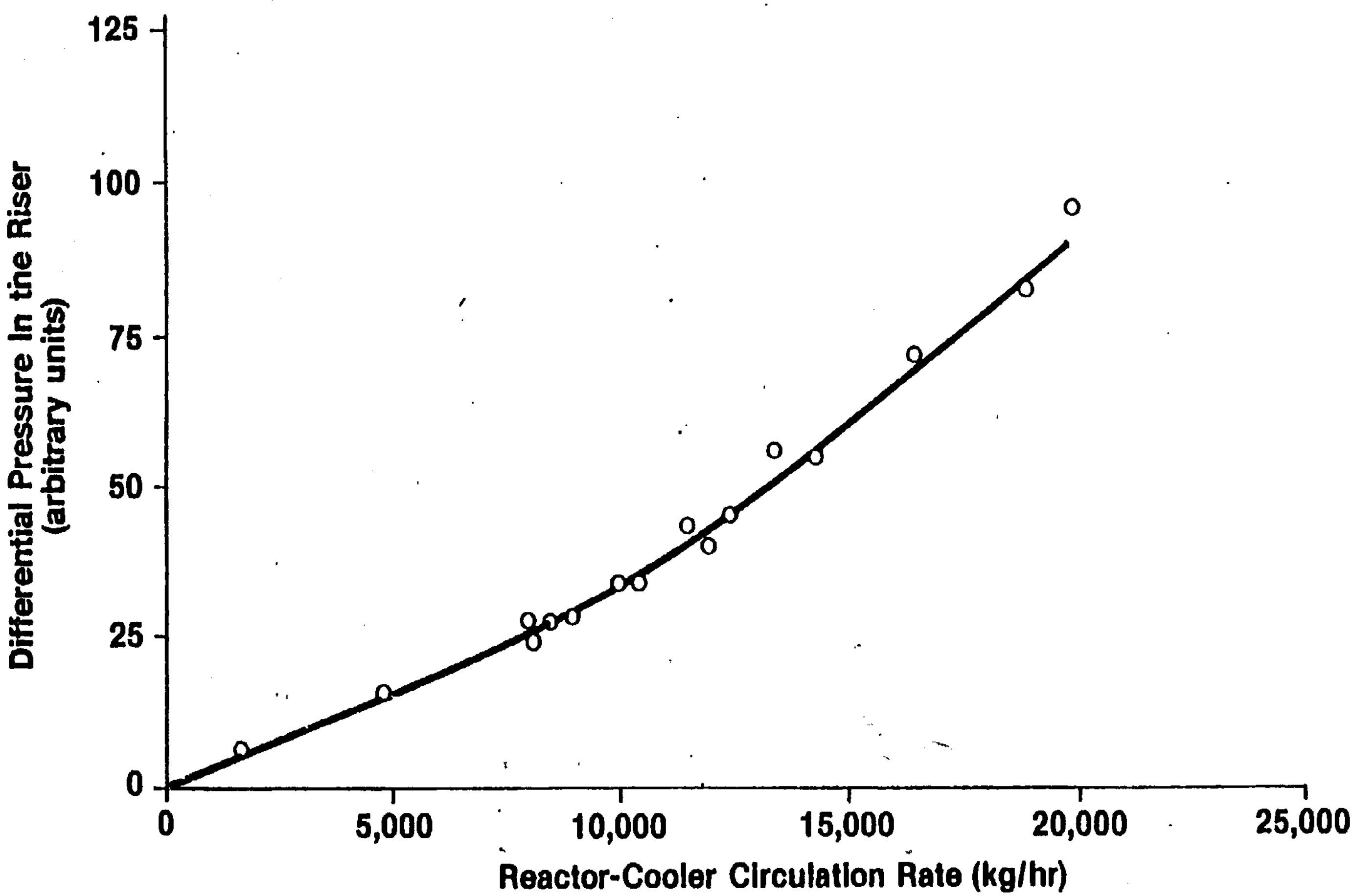


Figure 7

REACTOR TEMPERATURE PROFILE

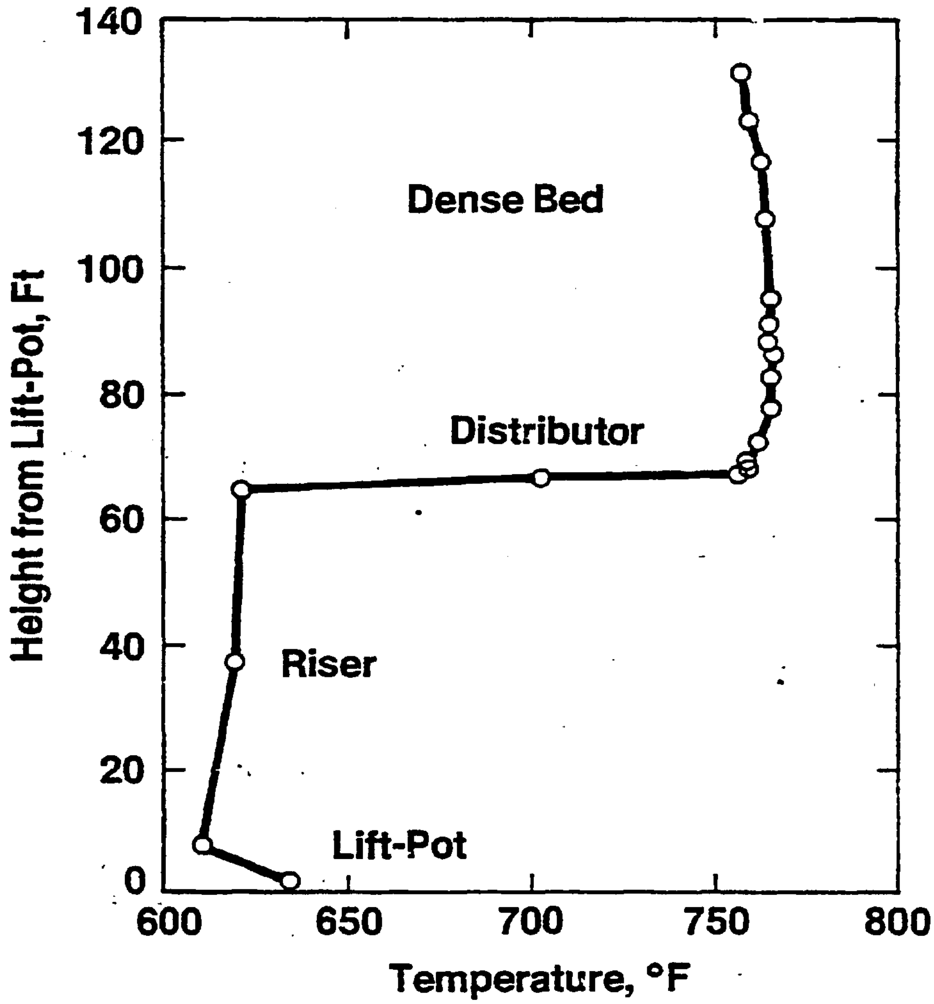


Figure 8

REACTOR-COOLER CATALYST CIRCULATION

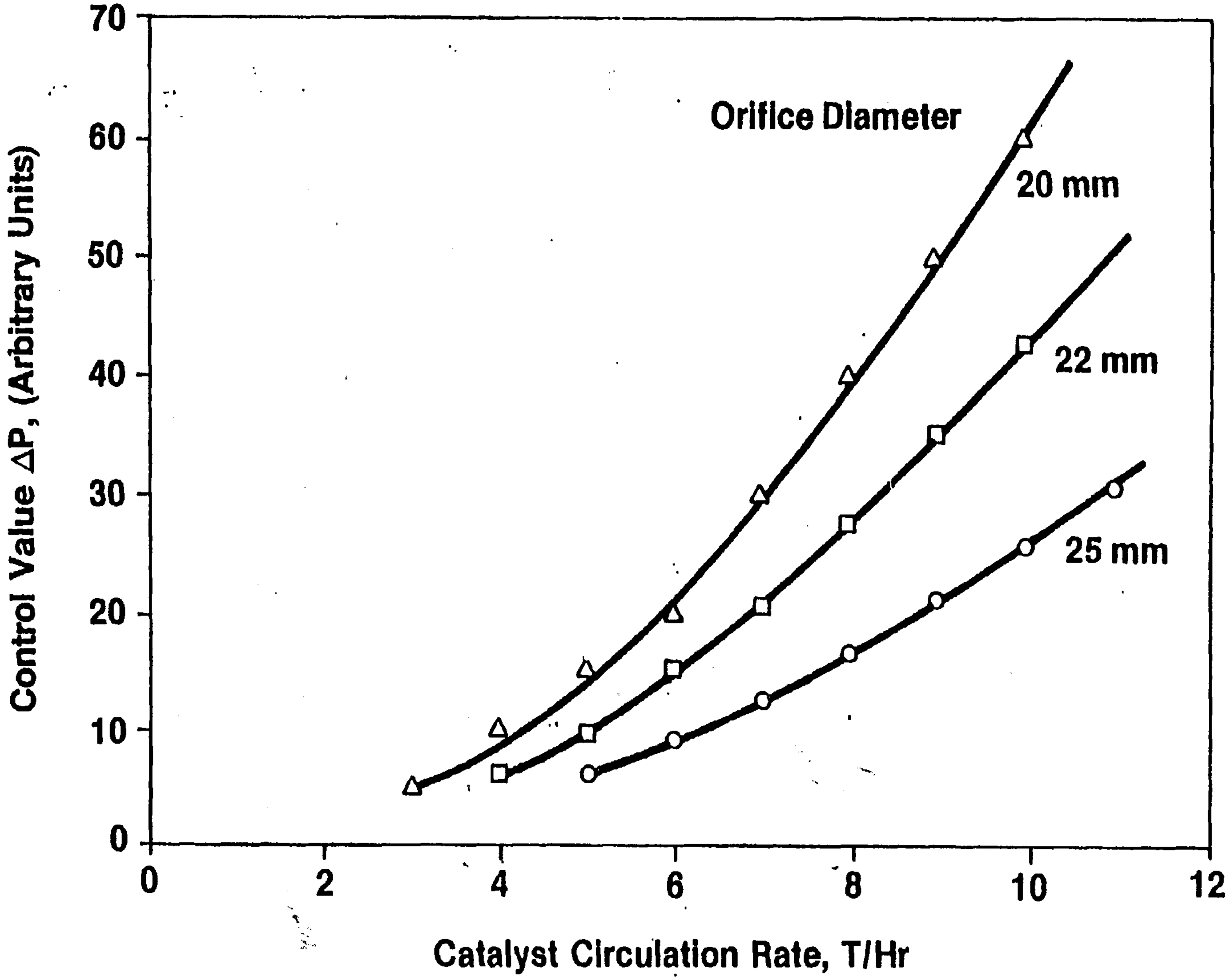


Figure 9

OBJECTIVES OF PROCESS SENSITIVITY STUDY

- Confirm gasoline yield and product quality at base case conditions of 1 WHSV, 765°F, 25 psig
- Quantify effects of selected process variables on hydrocarbon selectivities around optimum process conditions
- Determine unit sensitivity to changes in key process parameters in the region of methanol breakthrough

Figure 10

EFFECT OF PRESSURE ON GASOLINE YIELD

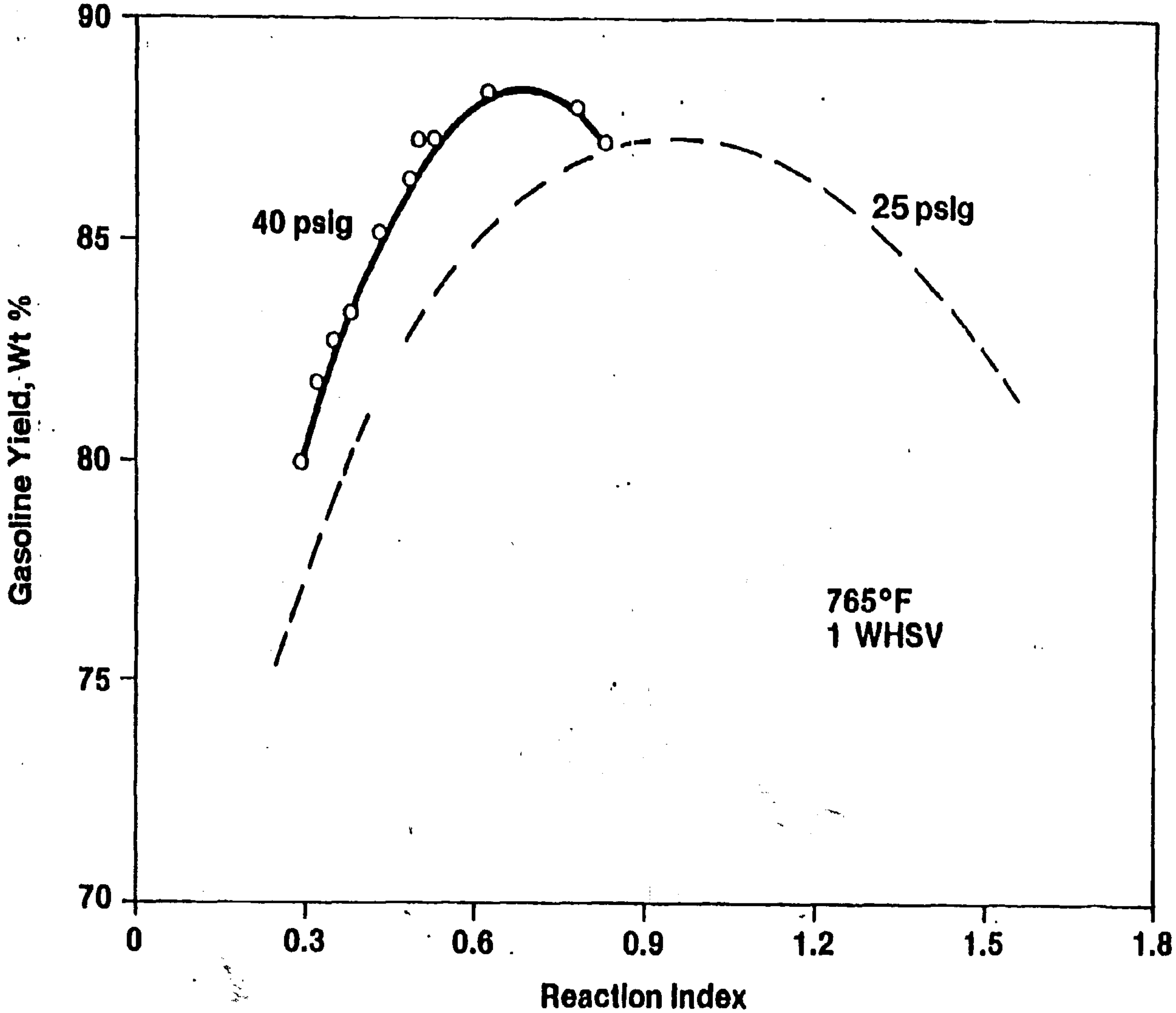


Figure 11

EFFECT OF TEMPERATURE ON GASOLINE YIELD

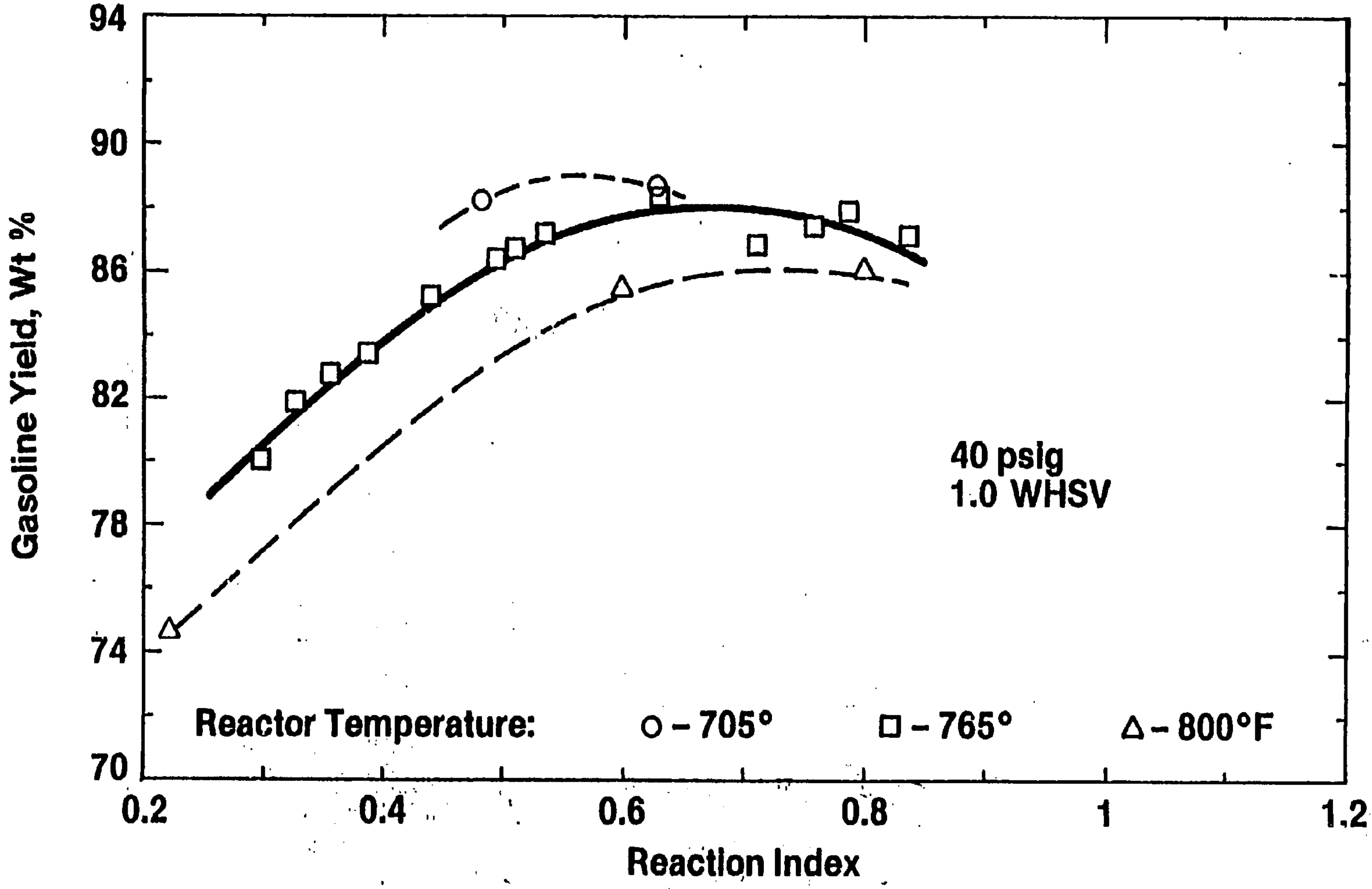


Figure 12

SUMMARY OF 100 BPD PILOT PLANT ACCOMPLISHMENTS TO DATE

- Demonstrated successfully external heat removal concept
- Confirmed product selectivities and gasoline quality at complete methanol conversion
- Optimized process conditions in the 100 BPD pilot plant
- Confirmed catalyst regenerability
- Produced 200 BBL stabilized gasoline for product evaluation
- Obtained data base required for conceptual commercial plant design of externally cooled system