Report 8

STATUS OF THE 100 B/D FLUID-BED METHANOL-TO-GASOLINE (MTG) PROJECT

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by

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Introduction

The status of the 100 B/D fluid-bed MTG project is briefly reviewed. This project is jointly undertaken by URBK, Uhde, and Mobil with financial assistance in part from US DOE and the German Government (Figure 1). The plant design was completed last year and construction has now been essentially completed. Precommissioning activities have already begun. The program schedule is summarized in Figure 2.

The major accomplishments over the last twelve months will be discussed in this review. First, the results of the Cold Flow Model (CFM) Studies conducted in support of the plant design will be summarized. The 100 B/D plant in Wesseling, Germany will then be described briefly.

Cold Flow Model Studies

An extensive hydrodynamic simulation of the reactor section of the fluid-bed MTG plant was conducted in a full-scale, non-reacting model, built at Mobil's Paulsboro Laboratory in New

Jersey. This Cold Flow Model (CFM) was operated for a period of 13 months between July, 1980 and November, 1981. The specific technical objectives of the CFM studies were:

- Design and verify catalyst circulation and recovery systems.
- Characterize reactor fluidization quality for the anticipated modes and conditions of operation.
- Collect engineering data to support and verify design calculations for the pilot plant.
- Design and evaluate the performance of reactor internals including baffles.
- Train personnel for plant operation and develop operational procedures including start-up and emergency shutdown.

A simplified flow diagram of the CFM is shown in Figure 3. The CFM uses compressed air at low pressure and ambient temperature to simulate all MTG pilot unit feeds and transfer line aeration. The major design features of this unit are:

o Fluidized bed reactor/riser - the dense bed reactor is 2' ID x 63' long, with a maximum catalyst bed height of 40'. The reactor is provided with Plexiglas sections to permit visual observation. It is also equipped with two main catalyst draw-off locations and an interchangeable perforated plate distributor. The dilute phase riser is 6" ID x 40' long and contains Pyrex glass sections for visual observation of the acceleration and steady-state mixing zones.

- The external catalyst cooler is 14" ID x 65' long, with a maximum catalyst bed height of 37'. It is equipped with a pipe grid gas distributor and mock heat exchanger tube bundles.
- The regenerator is 10" ID x 39' long, with a maximum catalyst bed height of 25'. It has a perforated plate distributor and no internal baffles.

Most of the experiments were carried out with an equilibrium FCC catalyst whose properties are given in Table 1. Some experiments, to quantify the effect of catalyst bulk density and particle size distribution, were carried out with lighter silica-alumina catalysts.

The experimental results from the CFM operation met all the program objectives. Vessel elevations were shown to be satisfactory for achieving the required catalyst circulation rates.

Stable and controllable catalyst circulation among the reactor, external catalyst cooler, and regenerator was demonstrated for the entire range of design conditions. Solids flow between the reactor and regenerator in the CFM was varied from 37 to 1,200 lb/hr. Reactor-cooler circulation was controlled between 5,000 and 60,000 lb/hr. Catalyst entrainment rates and cyclone recovery efficiencies were determined in the CFM reactor for superficial gas velocities between 1 and 4 ft/sec. The cyclone diplegs in the CFM drained smoothly during normal operation and required aeration to prevent catalyst bridging. The optimum aeration rates to each dipleg were determined. The diplegs were extended into the dense bed and mechanical sealing devices such as flapper valves were not used.

The reactor catalyst recovery system consists of a primary cyclone and filters. Filters were included in the 100 BPD Plant to minimize catalyst losses. The reactor distributor designs were optimized for good catalyst-gas distribution as well as moderate orifice gas velocities to limit catalyst attrition. The pressure drop through the distributor was designed to be 15-20% of the bed pressure drop for the internal cooling case and less than 10% for the external cooling case.

Reactor, cooler, and regenerator bed densities were determined as a function of gas velocity and solids circulation. Correlation of the reactor bed expansion using a modified Richardson-Zaki expression indicates that the 100 BPD reactor operates in a turbulent flow regime at gas velocities above 1 ft/sec (Figure 4). Reactor bed density was independent of solids circulation rate.

Evaluation of Reactor Internals

The decline in fluid bed reactor efficiency typically experienced with successive scale-up made it imperative to evaluate carefully various reactor internals for the 100 BPD MTG demonstration plant so that the target, almost complete, conversion level can be achieved. Several methods were used in the CFM to evaluate the effect of reactor internals on gas flow patterns and projected performance. The methods were:

- Gas tracer experiments.
- Capacitance probes.
- Bed expansion analysis.
- Visual observation.

These methods were applied to the fluid-bed CFM reactor without internals, and to four different baffle systems: one vertical design, and three horizontal designs. Figure 5 illustrates schematically vertical and horizontal baffles.

The gas tracer experimental set-up is illustrated in Figure 6. Sulfur hexafluoride (SF_6) tracer was injected into the reactor cone, and sampled from a probe above the fluid bed. The results were analyzed to detect gas bypassing and to quantify the degree of gas backmixing. The latter analysis, based on pulse response, was used to differentiate between the various baffles by comparing their conversion efficiency to that of an ideal plug flow reactor. This was done by applying an axial dispersion model and by comparing the axial Peclet numbers obtained for the various baffles.

A comparison of the pulse response of a bed without baffles and a bed with horizontal baffles is shown in Figure 7. By comparing the results of the gas tracer tests with the results of the other methods used, we found one set of horizontal baffles to be superior to the other designs tested. This design demonstrated good bubble size control, minimal radial variation in flow properties, a high axial Peclet number, and no over-restriction of solids backflow through the baffle sections.

100 BPD MTG Demonstration Plant

Construction of the 100 BPD MTG plant in Wesseling, Germany has now been completed and plant "shakedown" is now underway. A simplified flow diagram of the plant is shown in Figure 8. The reactor, catalyst cooler, and regenerator section is the same as the CFM. Commercial grade methanol is mixed with boiler feed water (to simulate crude methanol) and it is vaporized and superheated to 350°F. The reactor effluent is scrubbed of any catalyst fines and condensed. The aqueous product is separated from the hydrocarbons in the separator. The C_4^- fraction is removed from the gasoline product in a debutanizer. The operating conditions of major system components are shown in Table 2.

Referring back to Figure 2, the shakedown period will last about 3-4 months. The unit will be put on-stream late this year or early next year. A 21-month operating period is planned. It will include testing of external catalyst cooling and internal catalyst cooling. We plan to demonstrate steady state operation, with maximum gasoline yield and minimal catalyst requirements. The product testing will be carried out both in Germany and in the U.S. The program will culminate in a conceptual design of a commercial size fluid-bed MTG plant.

Table 1

Equilibrium Catalyst Properties
(Davison CCZ-11)

Particle Size Distribution

Microns	Fraction
0- 20	0.01
20- 40	0.15
40- 80	0.64
80-100	0.15
100-120.	0.05
	1.00

Density

Particle	1.22
Tightly Packed	0.87

Table 2

100 BPD MTG Plant
Operating Conditions

Methanol Feed Rate	80-200 BPD
Feed Composition	96% Methanol 4% Water
Reactor	
Top Pressure	25-30 psig
Temperature	750-800°F
WHSV	0.5-1.5
Gas Superficial Velocity	1-2 ft/s
Regenerator	
Top Pressure	30-35 psig
Temperature	850-900°F
Catalyst Circ. Rate	50-350 lb/hr
Gas Superficial Velocity	1-2 ft/s
Catalyst Cooler	
Temperature	600-700°F
Catalyst Circ. Rate	20,000-40,000 lb/hr
Gas Superficial Velocity	0.4-0.6 ft/s

FIGURE 1

100 B/D 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 DOE, URBK, Uhde, Mobil

Figure 2

100 B/D FLUID-BED MTG PROGRAM

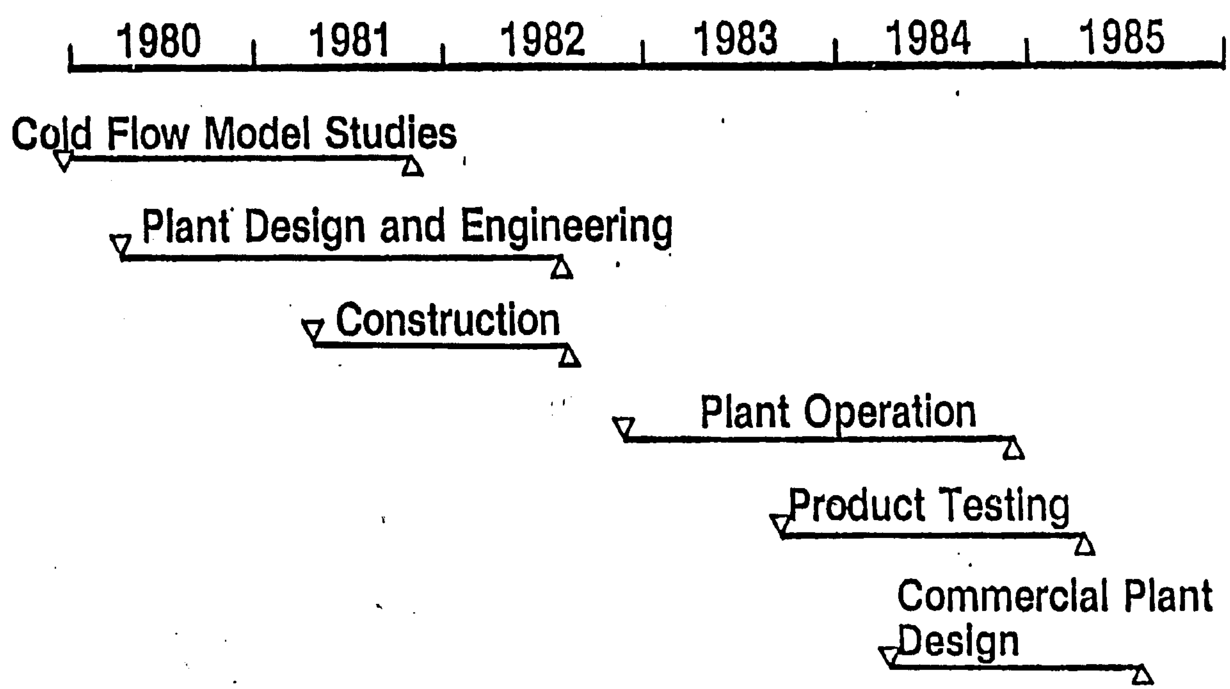
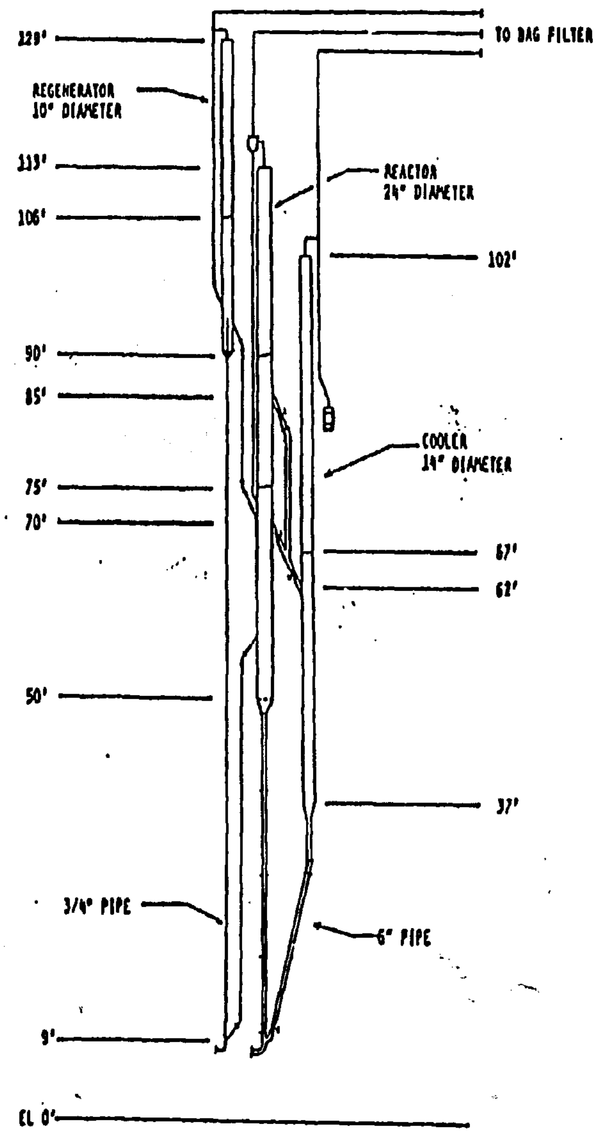


FIGURE 3

MTG COLD FLOW MODEL ELEVATION DIAGRAM



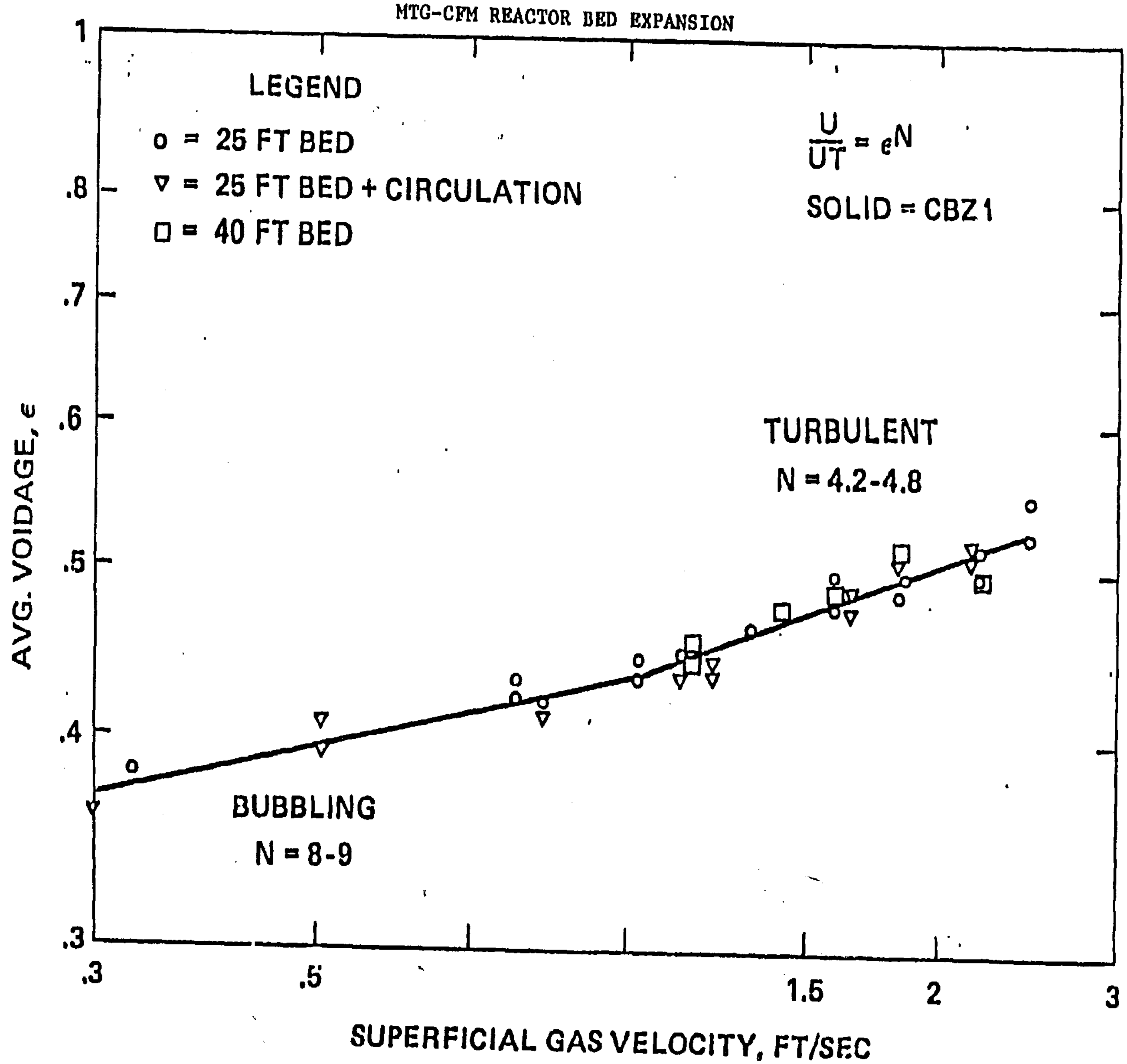
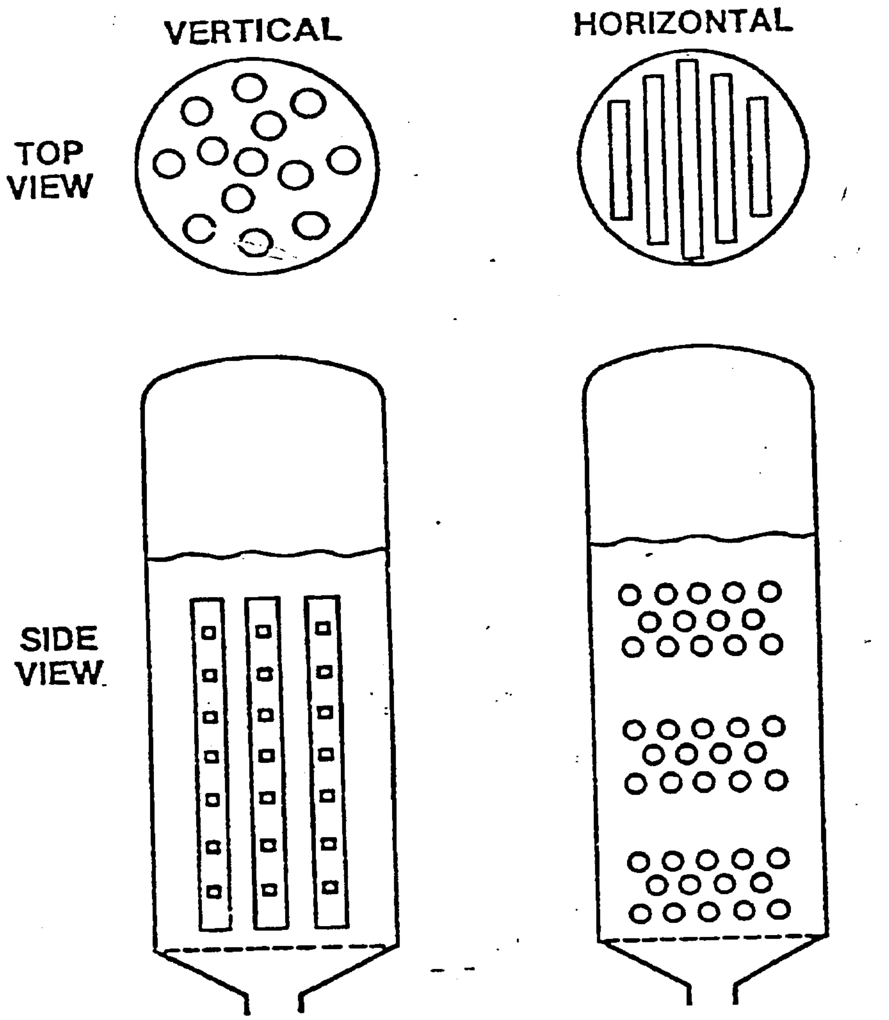

MTG-CFM REACTOR BED EXPANSION
LEGEND
o = 25 FT BED
▽ = 25 FT BED + CIRCULATION
□ = 40 FT BED
U/UT = εN
SOLID = CBZ1
TURBULENT
N = 4.2-4.8
BUBBLING
N = 8-9
AVG. VOIDAGE, ε
SUPERFICIAL GAS VELOCITY, FT/SEC
1
.8
.7
.6
.5
.4
.3
.3
.5
1.5
2
3

FIGURE 4

FIGURE 5

REACTOR INTERNAL BAFFLES



GAS TRACER TECHNIQUE

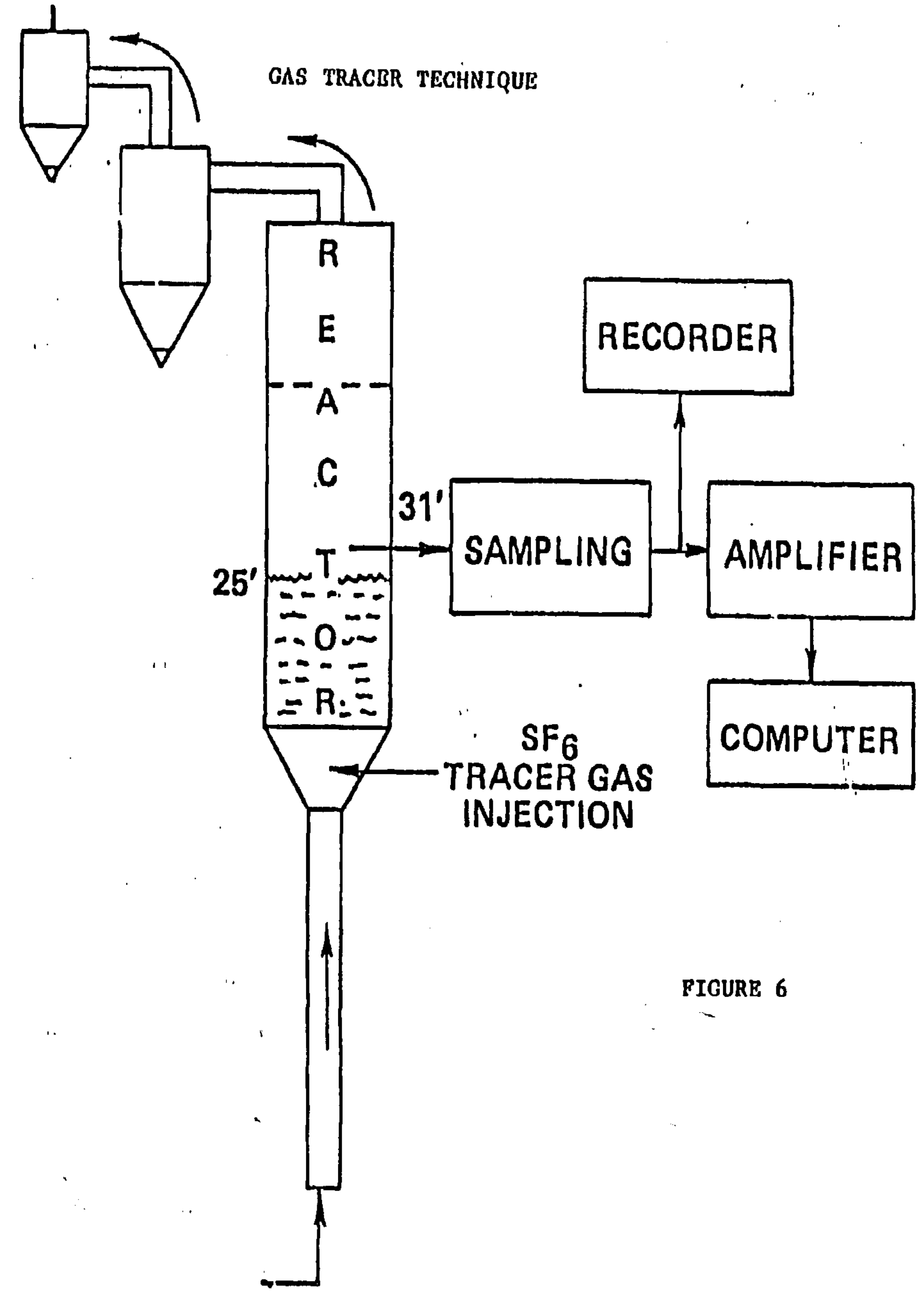
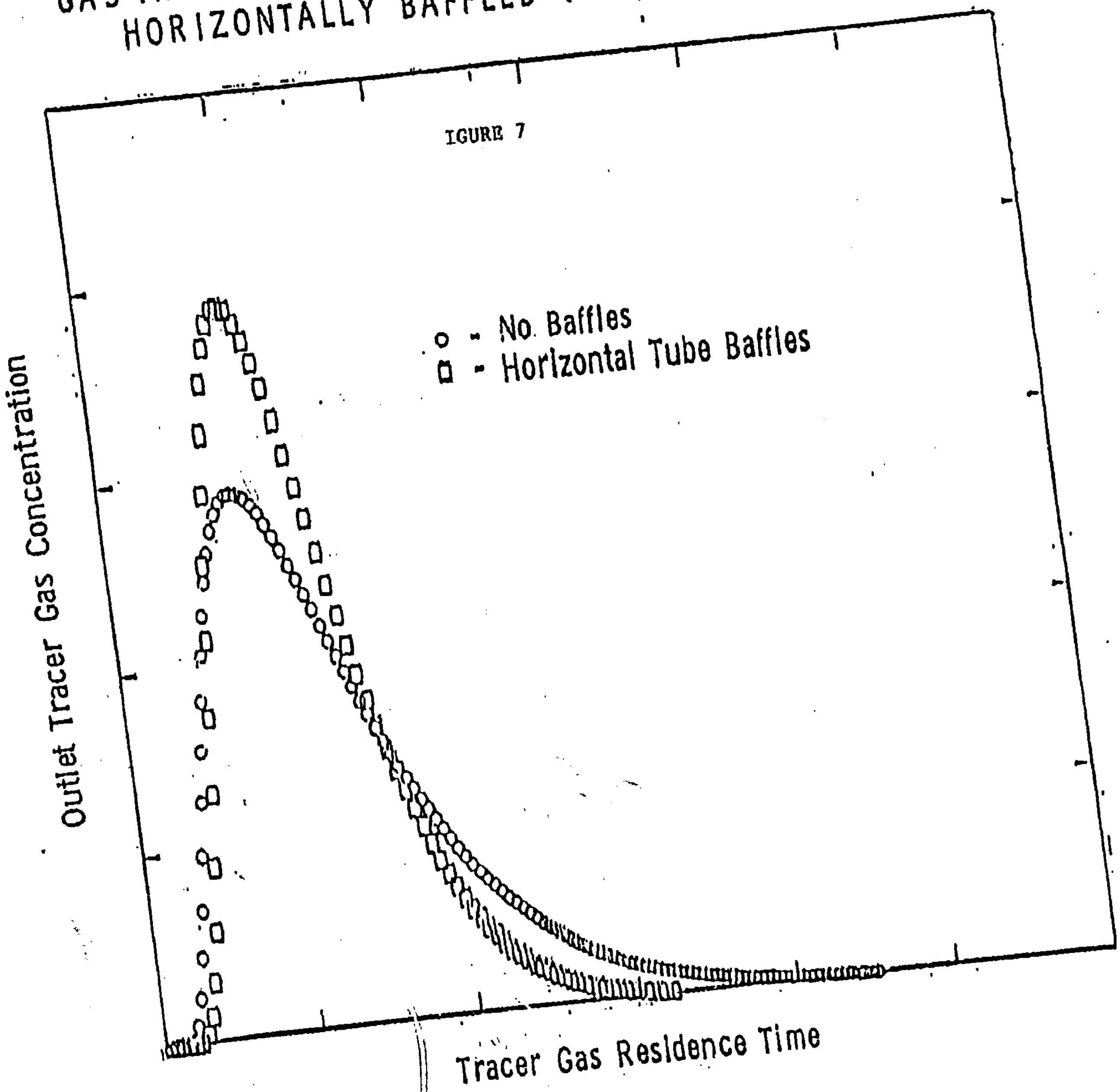
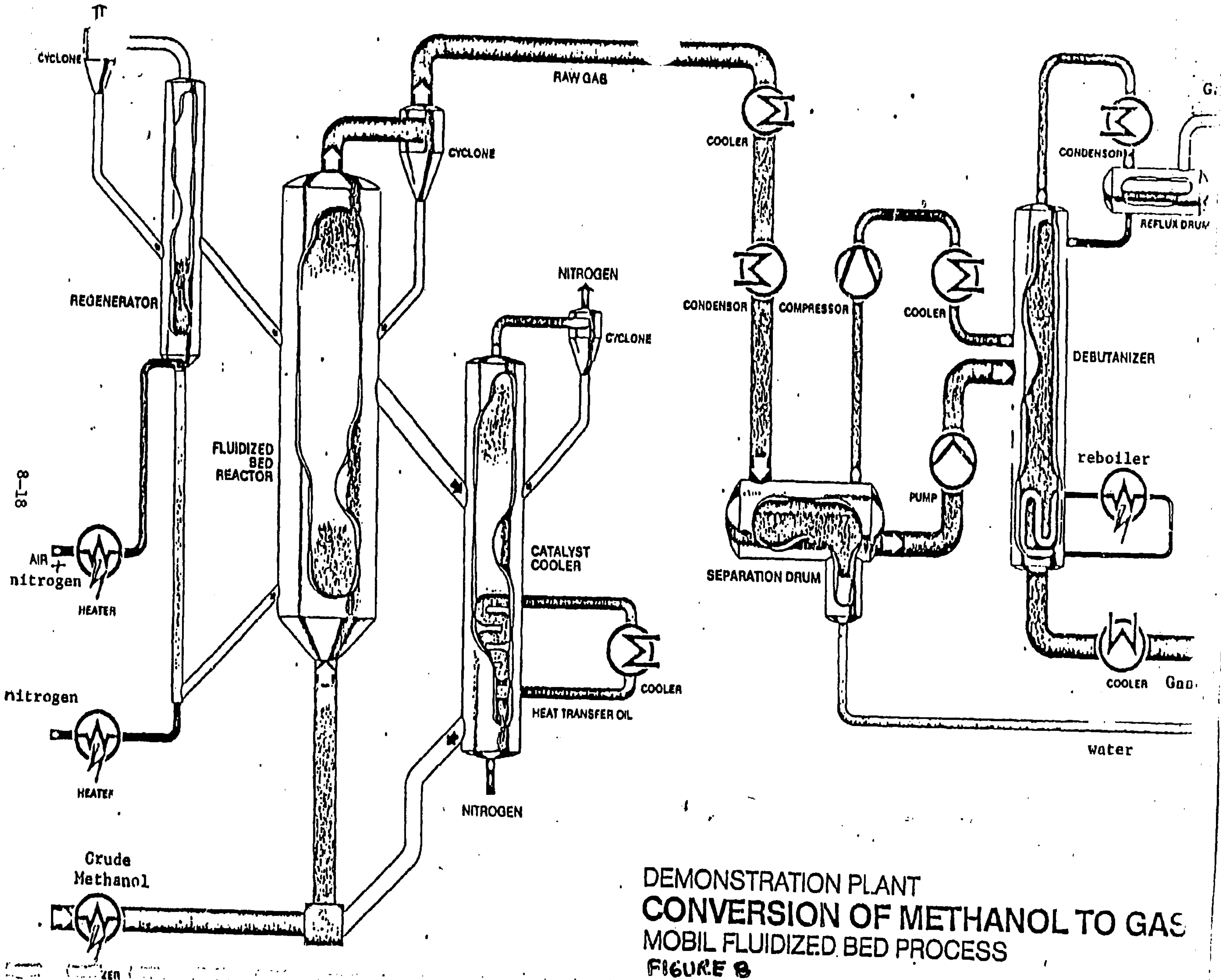


FIGURE 6

GAS TRACER RESIDENCE TIME DISTRIBUTIONS FOR HORIZONTALLY BAFFLED VS UNBAFFLED BED





DEMONSTRATION PLANT
CONVERSION OF METHANOL TO GAS
MOBIL FLUIDIZED BED PROCESS
FIGURE 8