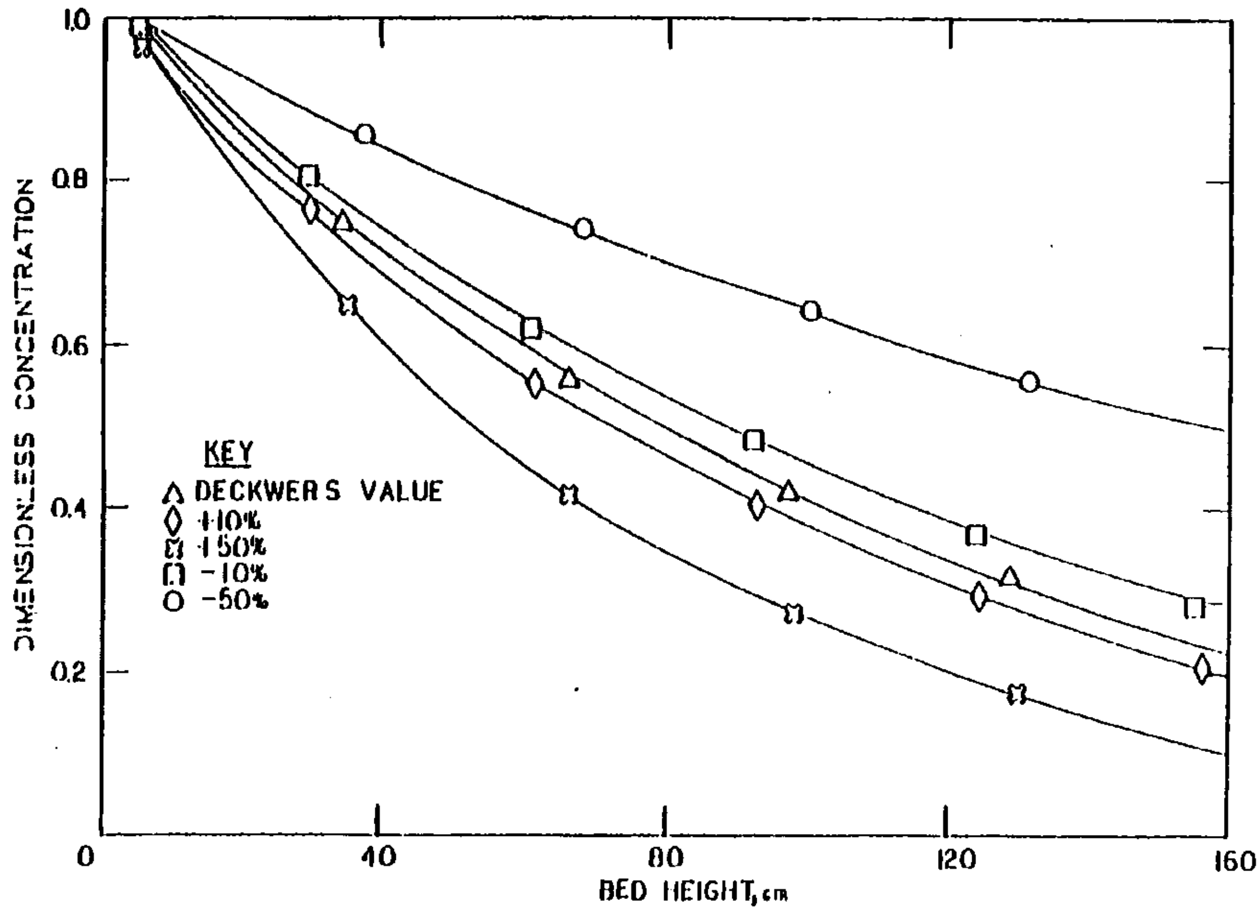

Figure 42. The effect of varying the reaction rate 10 and 50 percent above and below the rate predicted by Deckwer.

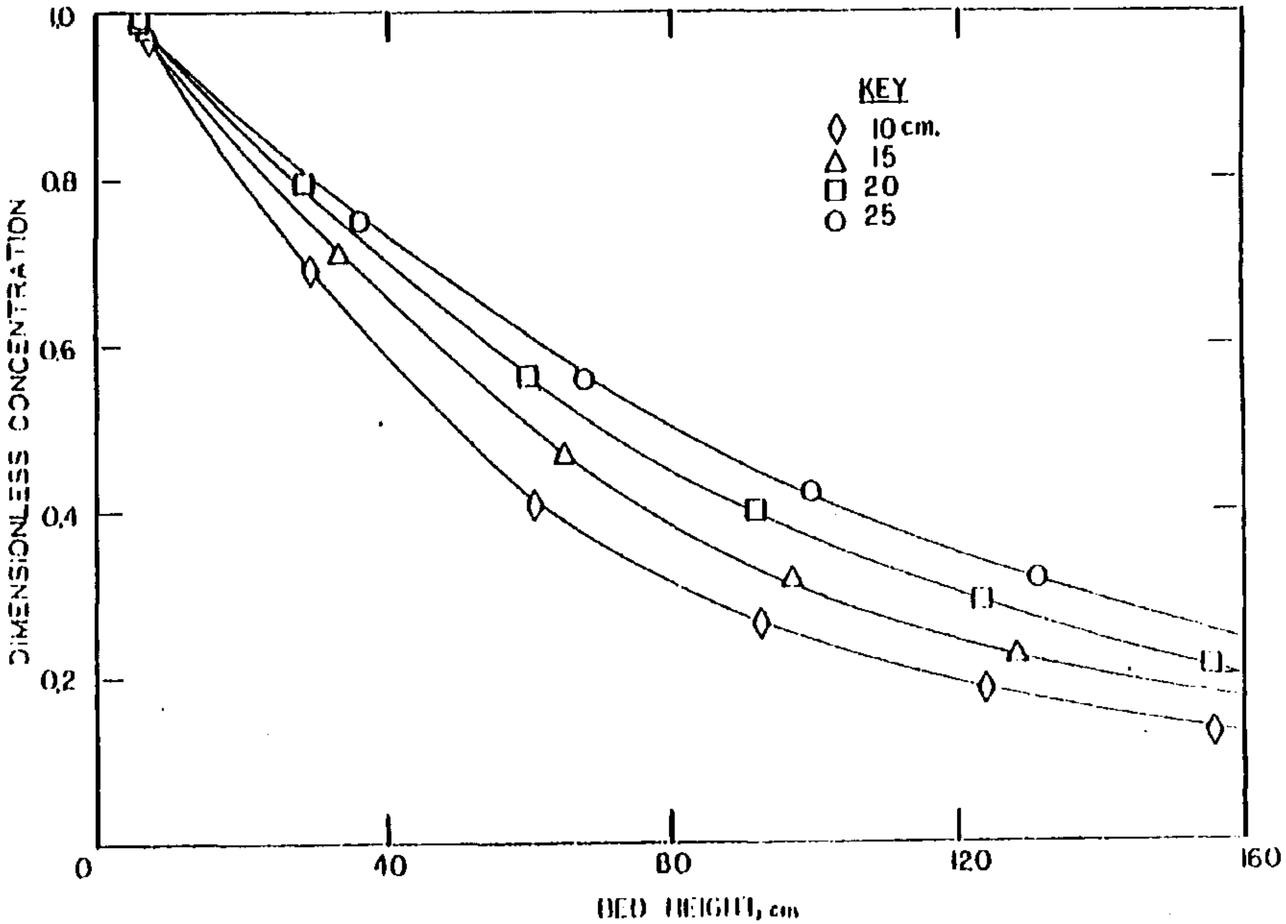

Figure 43 . The effect of reactor diameter on the hydrogen concentration profile.

Slurry Reactor. The values obtained for the parameters shown in Table 3 are listed in Table 7. The concentration profiles predicted by the slurry reactor model are shown in Figure 44. Also shown are the results of a similar model developed by Deckwer et al. (1982) for comparison. The models made use of many of the same assumptions and correlations but used different solution techniques. The concentration in the gas phase does not decrease significantly in the 160 cm reactor. Many Fischer-Tropsch test reactors are as tall as 7700 cm. Figure 45 shows the profile for one of these larger columns. Note that the conversion is much more complete. The height limitations that the simulator demonstrated with respect to fluidized beds do not apply to slurry reactors. Comparison with Figure 33 shows that the slurry reactor has a lower hydrogen conversion at any given height than the fluidized bed reactor. Thus the increased ease of operation obtained when a slurry reactor is used is achieved at the expense of column height.

The temperature profile in a slurry reactor is important. Slurry reactors are not as efficient as fluidized beds at dissipating heat. Thus the bed has the potential to produce hot spots. Figure 46 shows the temperature profile in the reactor. Note that the reaction is sufficient to offset the heat losses in most of the bed at

Table 7. Values calculated for the correlations for small scale phenomena occuring in a slurry bed.

Parameter	Value	Principle Independent Variable
He	1.96×10^{7} kPa cm^3/mol	T
ϵ_G	0.0352	u'_G
a	2.99 cm^{-1}	u'_G
k_l	0.0254 cm/s	$\bar{\rho}$, $\bar{\mu}$, T
h	42.17 J/cm^2s K	$\bar{\rho}$, $\bar{\mu}$, u'_g, c_p
D_g	218. cm^2/s	u'_g, d_R, ϵ_g
D_l	123. cm^2/s	u'_g, d_R
λ_{ax}	-3.22×10^{3} J/cm s K	D_l, $\bar{\rho}$, c_p

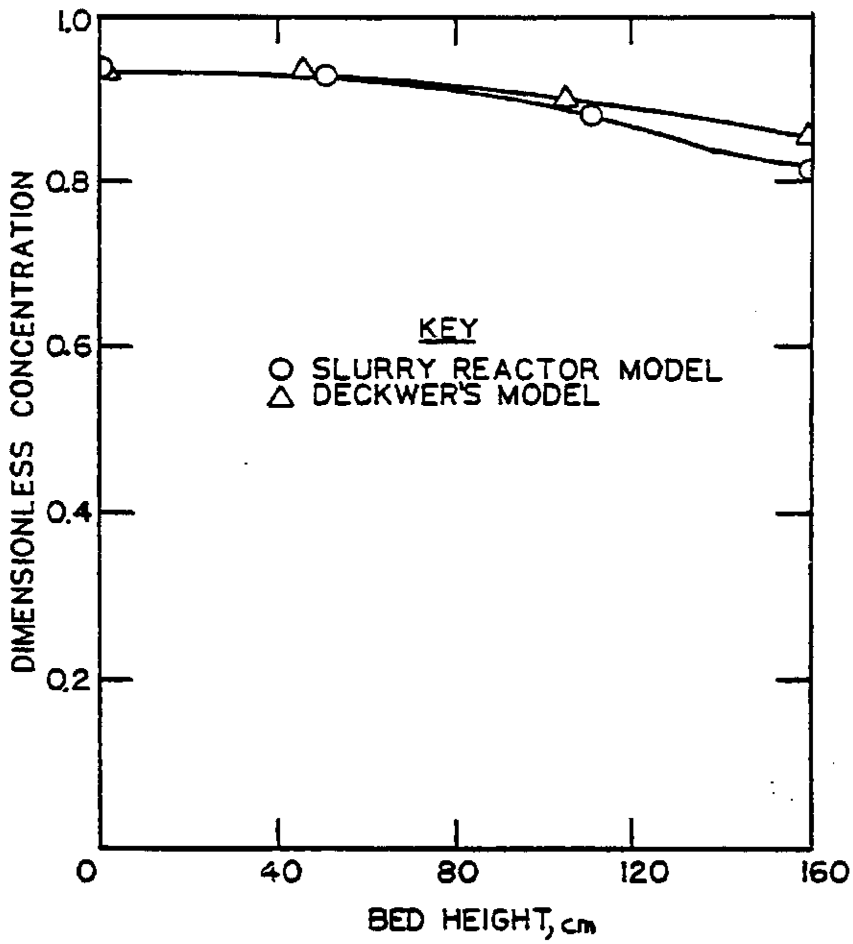

Figure 44. The concentration profiles in a slurry Fischer-Tropsch reactor using the model developed and Deckwer's model.

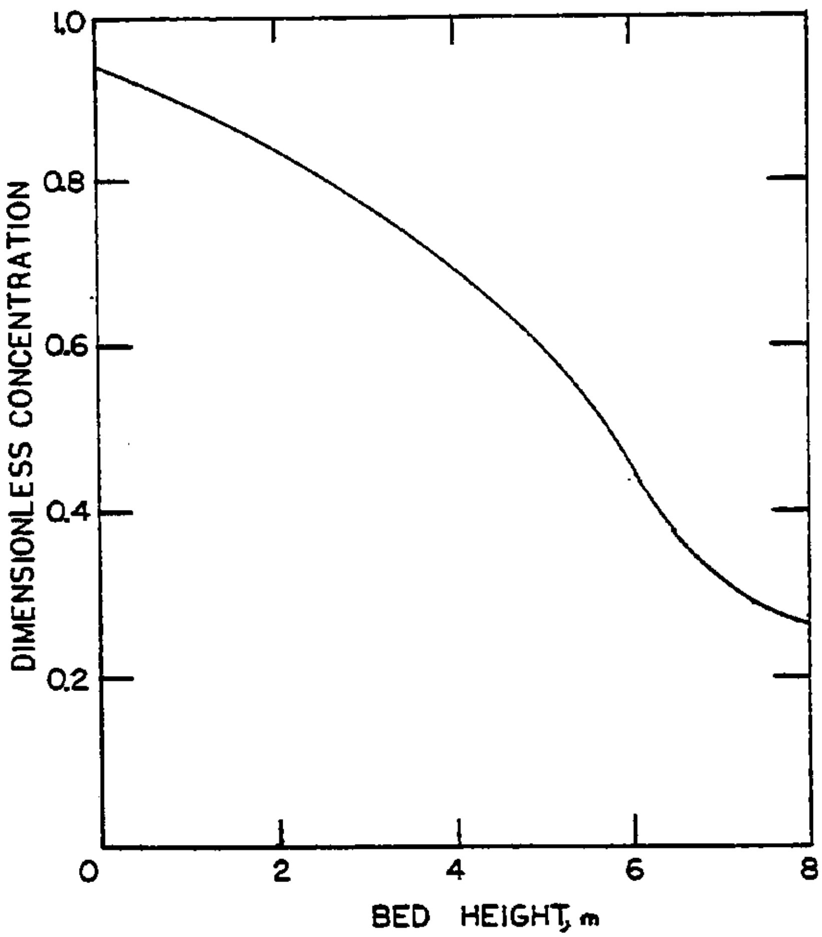

Figure 45. The concentration profile for a slurry reactor 8 meters tall.

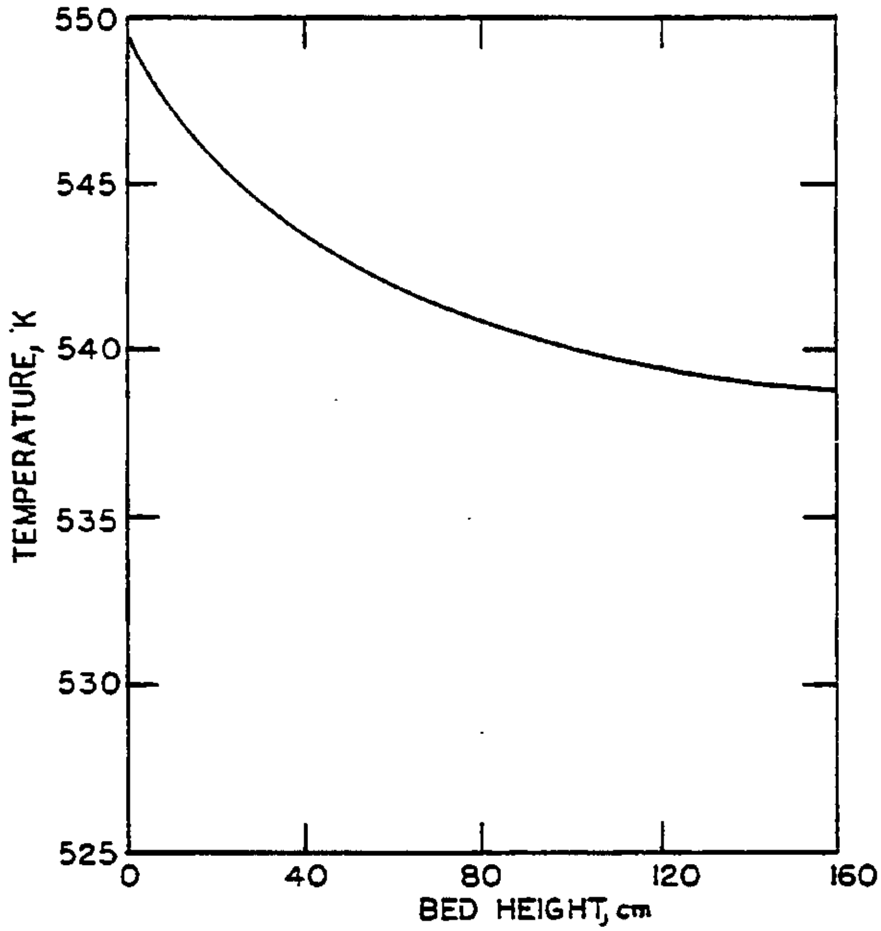

Figure 46. The temperature profile in a slurry Fischer-Tropsch reactor

the expected operating conditions. Temperature also has an effect on the concentration profiles as is shown in Figure 47. As in the fluidized bed, higher temperatures result in higher conversions. There is a double danger in the slurry reactor, however, when using higher temperatures. The catalyst is deactivated by heat so if the reaction tempera- ture is raised to the point where the reaction proceeds faster than the reactor can dissipate the heat of reaction the catalyst will be destroyed. The second danger is similar to the that in the fluidized bed. The higher temperatures produce less desirable products. Satterfield et al. (1985) found that 529 K was the optimal temperature for operation of a slurry reactor.

Scrubber

The scrubber model was effected by three of the four variables examined. The inlet gas temperature was the only variable found to not have a major effect on the behavior of the scrubber. This was primarily due the large dif- ference between the heat capacity of the gas and the liquid. Figure 48 shows the effect that the flow rate of the feed water has on the outlet gas temperature. Even at very small water flow rates the outlet gas temperature is brought down to that of the water. Studies of the outlet

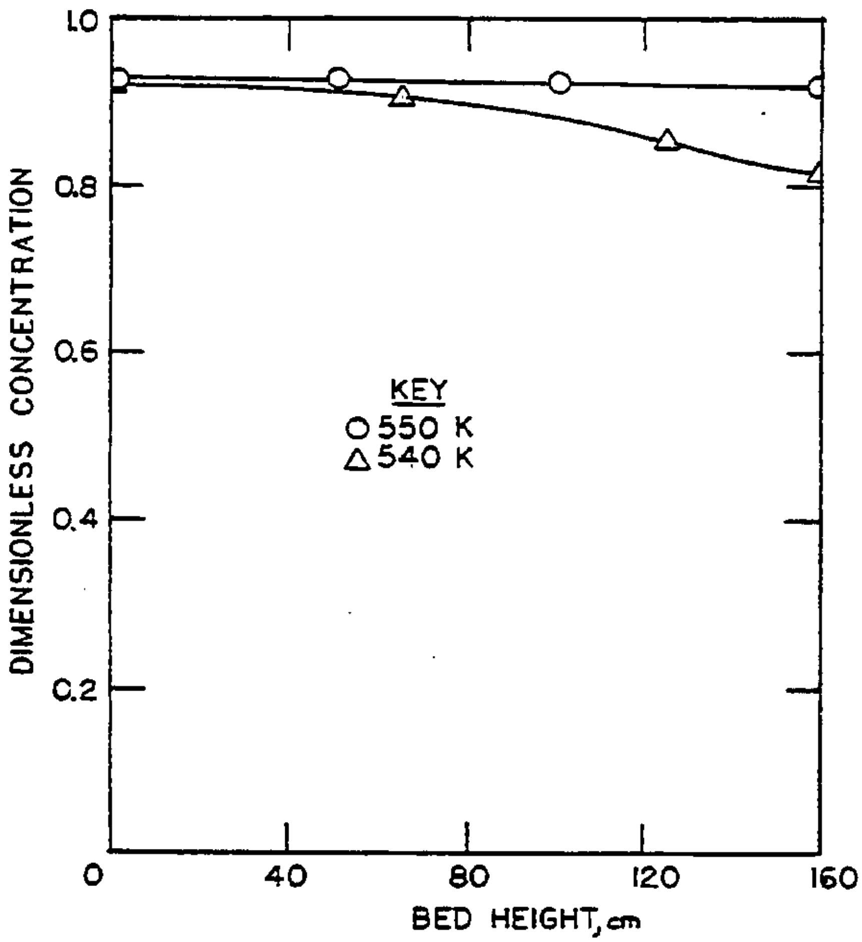

Figure 47. The effect of initial reactor temperature on the concentration profile for hydrogen in slurry Fischer-Tropsch reactor.

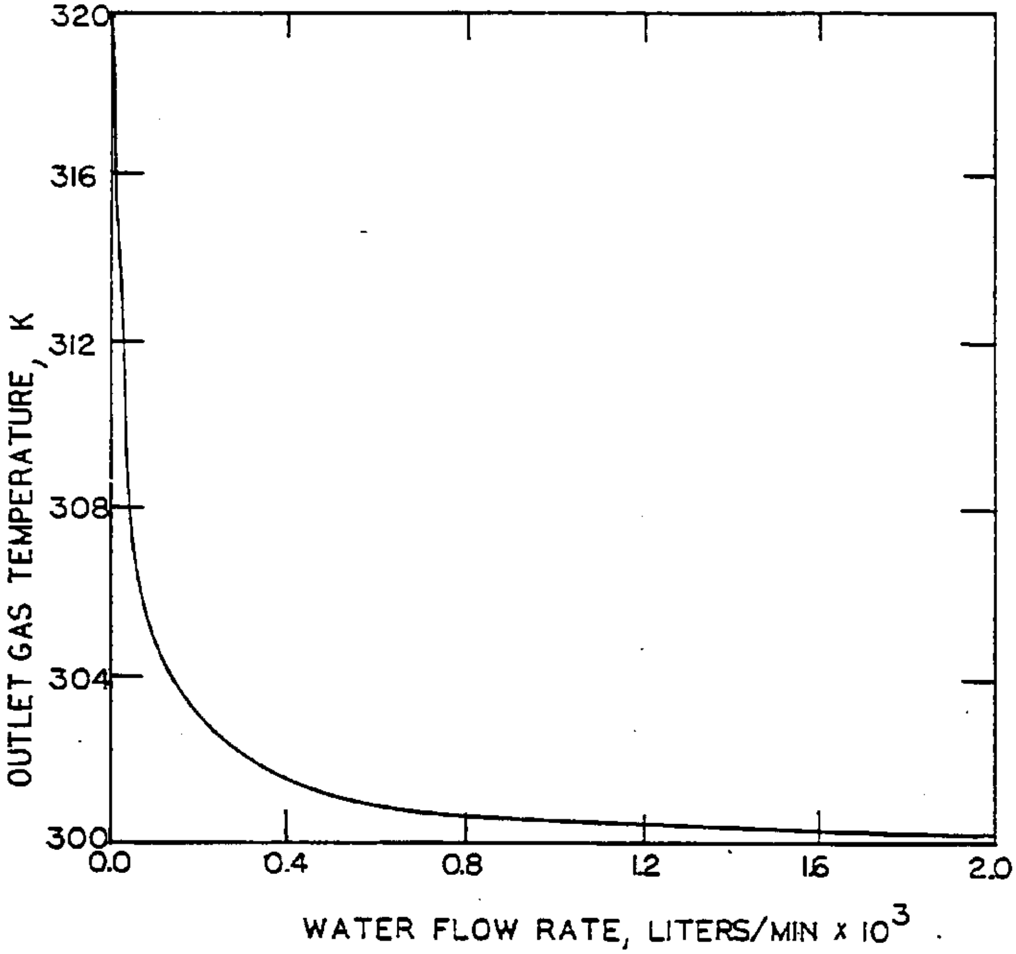

Figure 48 . The effect the flow rate of water has on the outlet gas temperature in the scrubber.

water temperature showed that for any reasonable gas flow rate and temperature the water temperature is fairly constant. Figure 49 shows the effect of gas flow rate on the outlet gas temperature. For achievable flow rates the temperature does not exceed the temperature of the water by more than 10°C.

Combustor

The combustor model showed that the four parameters tested all had a significant effect on the behavior of the combustor. The temperature of the reactor, the external temperature, the outer diameter, and the inner diameter were all important. Figure 50 shows the effect of the reactor temperature on the heat required to maintain the temperature of the reactor at a desired level. The model predicts that the heat requirement will increase linearly with the temperature. Figure 51 shows the effects increasing the external temperature has on the heat requirements. Since the heat loss through the outer wall is determined by this parameter the heat required fell with increasing external temperature. Figure 52 and Figure 53 show the effects of varying the outer and inner diameters of the combustor respectively. The larger the exterior diameter the greater the heat required to maintain the pyrolyzer.

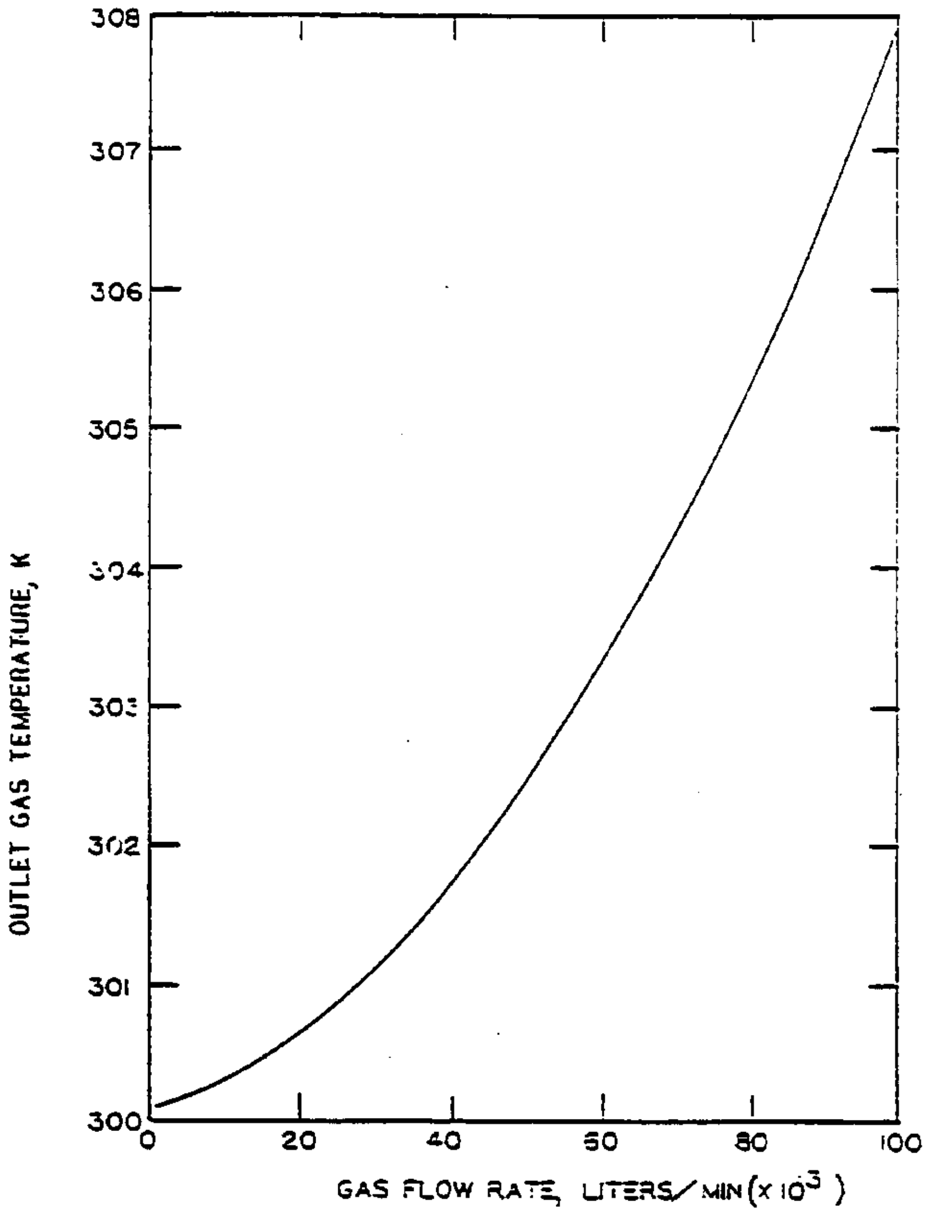

Figure 49. The effect of the gas flow rate on the scrubber outlet temperature.

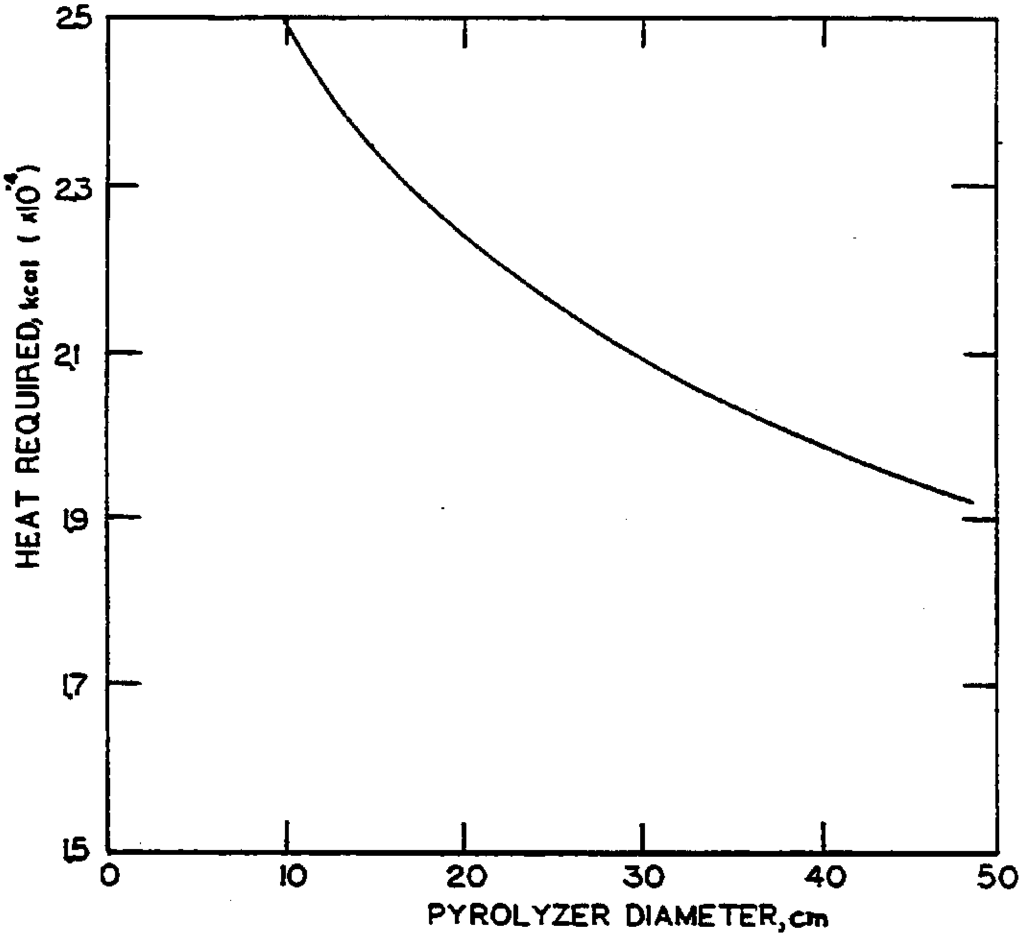

Figure 58. The effect the temperature of the pyrolyzer has on the heat requirements of the combustor.

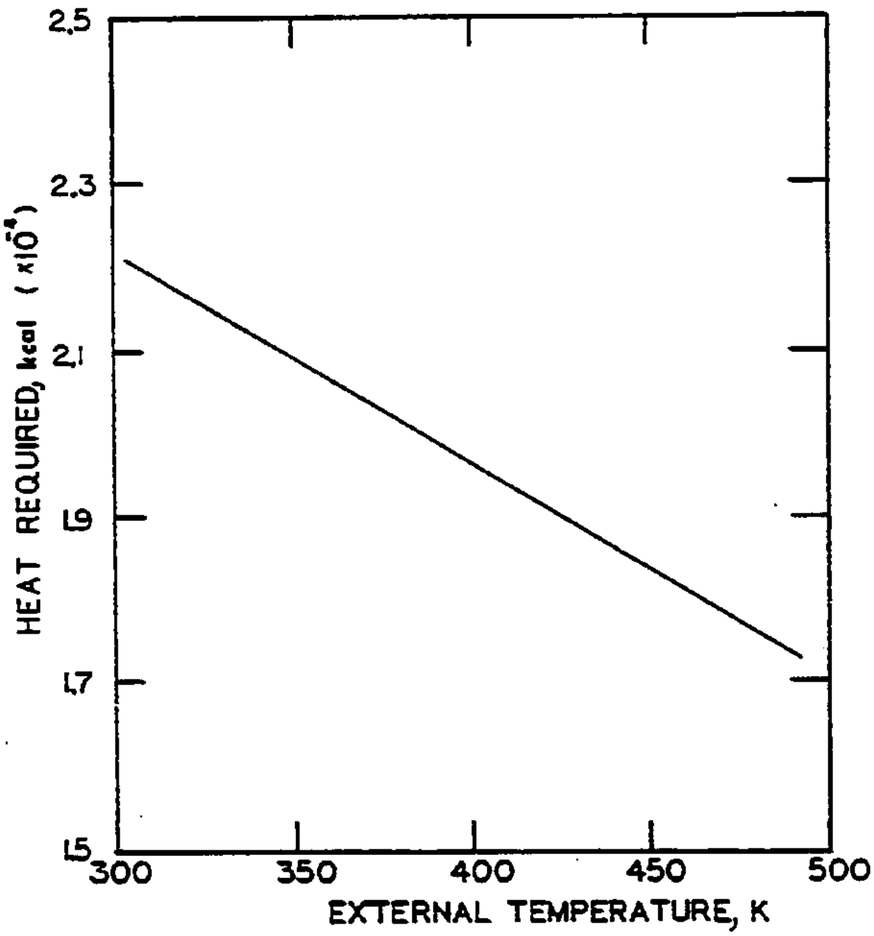

Figure 51. The effect the external temperature has on the heat requirements of the combustor.

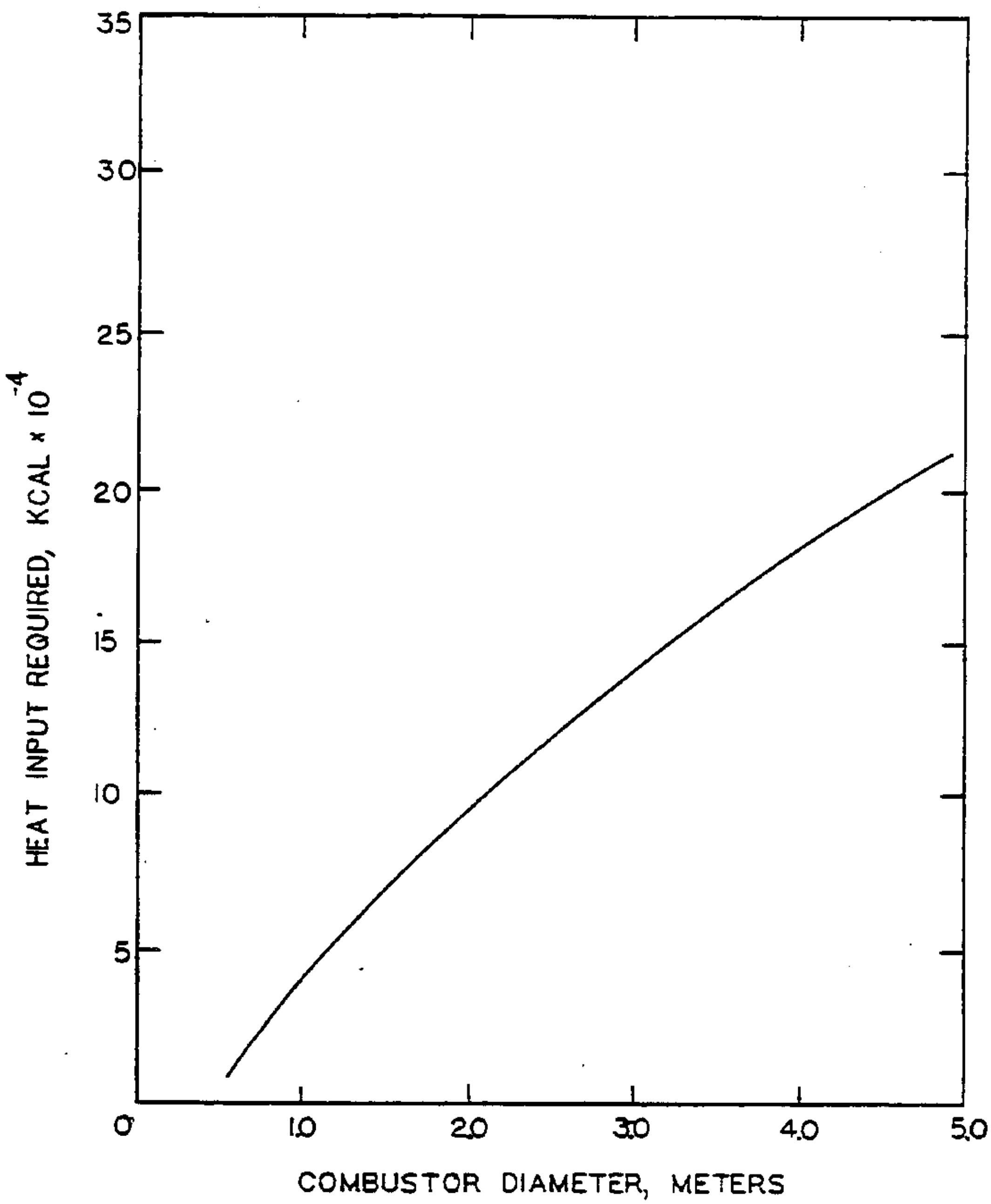

Figure 52. The effect of the combustor diameter on the heat required by the combustor.

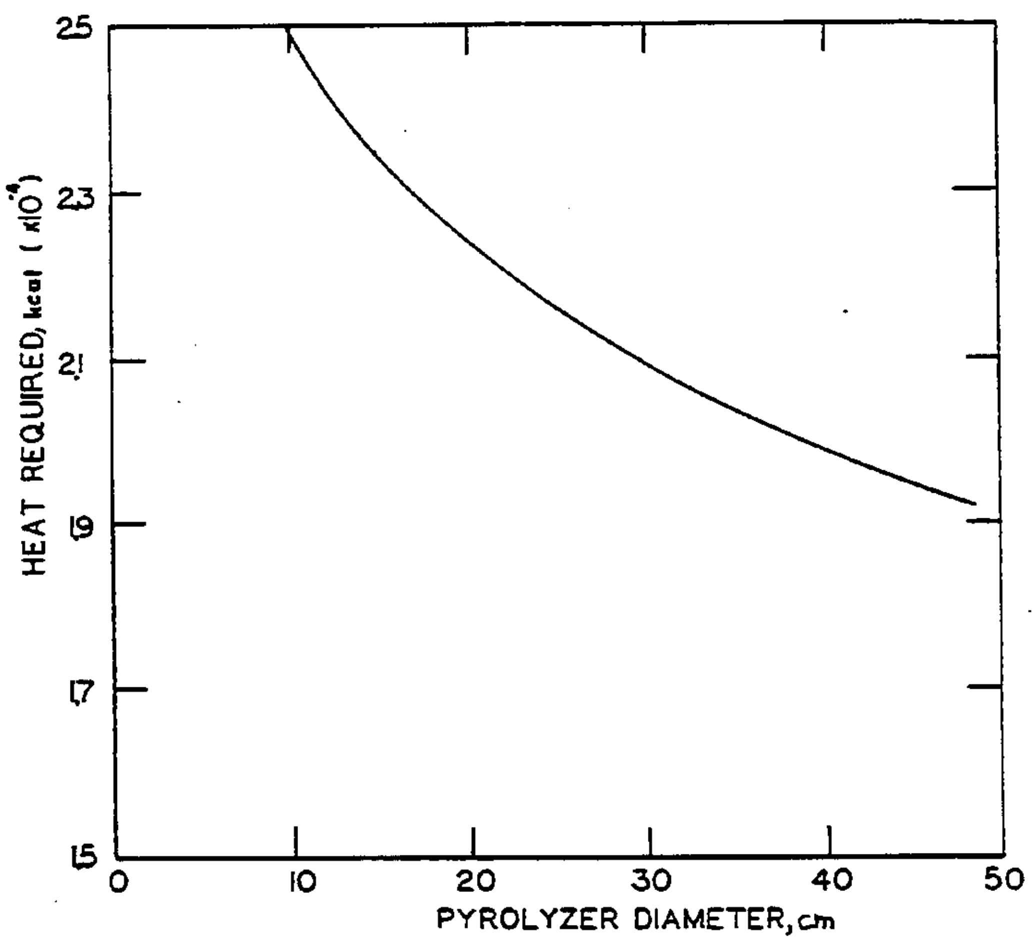

Figure 53. The effect of the pyrolyzer diameter on the heat required by the combustor.

Eventually however the effect decreases due to the increasing volume to surface area ratio of the reactor. The larger the inner diameter the lower the temperature of the combustor has to be to supply the needed heat.

CONCLUSIONS AND RECOMMENDATIONS

The computer models and the simulator indicate that the use of a staged reactor merits continued examination. It has the capacity to improve the usefulness of the indirect liquefaction technique to the point where it may become a commercially viable energy source.

The main conclusion that can be obtained from the computer models is that the staged reactor system is capable of achieving conversions at least as good as those obtained in the current system. Hydrogen conversions of 90 % are within the capabilities of the Fischer-Tropsch reactor. The pyrolyzer can produce an synthesis gas with the same concentration as the current pyrolyzer. The combustor model indicates that it will take considerably less energy to maintain the pyrolyzer at the desired temperature than in the current system. In the current system, the combustor must operate at from 50 to 100°C above the desired pyrolysis. The staged reactor on the other hand only requires a 2 to 3°C temperature differential.

The models also indicate that the use of a fluidized bed reactor for the Fischer-Tropsch synthesis would be preferable in a portable system because the fluidized bed reactor requires less height to reach a given conversion than the slurry reactor. However, if the reactor is going to be stationary the improved ease of operation and product characteristics that are acheived when using a slurry reactor becomes the determining factors. The reactor dimensions for a portable unit can be derived from the models. These key dimensions are shown in Appendix C.

The simulator studies indicate that though the staged reactor is difficult to operate it can be successfully controlled. The major operational difficulties encountered are due to the interaction between the various operating parameters. For example, the pressure drop through the Fischer-Tropsch reactor determines the flow rate throughout that reactor. It also determines the pressure of the pyrolyzer. The pressure of the combustor must match that of the pyrolyzer in order to prevent gas crossflow. The pressure in the combustor is controlled by the inlet pressure, the size of the exits, and the gas flow rate through the combustor. Thus the flow rate through the Fischer-Tropsch reactor can have a significant effect of the flow rate in the combustor.

The simulator also demonstrated that adequate solids transfer can be obtained by the use of transfer tubes that essentially catch the alumina and channel it to the other reactor. The transfer of the solid particles is not an essential feature of the reactor. If the solids are not to catalytic the system can be simplified by eliminating the transfer holes. This modified system would be considerably easier to operate than the proposed staged reactor.

The proposed reactor will be portable so a fluidized bed Fischer-Tropsch reactor was used. A diagram of the reactor and the associated control systems is shown in Figure 54. The pyrolysis and combustor stages can be fluidized with either air or steam. The air would be used during start up. The flow rate of both these components is controlled. Propane is supplied to both the pyrolyzer and the combustor. The pyrolyzer will burn propane during start up. After the reactor is running, only the combustor will be supplied with propane. In addition the combustor burners are supplied with oxygen in order to provide a hotter flame. The biomass is introduced through an insulated tube into the pyrolyzer. Steam is used to propel the biomass through the tube.

The gas exiting the combustor passes through a cyclone and then a control valve. The control valve is operated based on the pressure differential between the pyrolyzer and the combustor. The gas then passes through a scrubber and is vented.

The synthesis gas from the pyrolyzer also passes through a cyclone. It then moves to the scrubber stage.