Chapter V

DISCUSSION

The investigation on oil shale retorting employing fluidization techniques is quite satisfactory. The optimum conditions observed are, mean particle sizes from 0.500 to 0.576 mm., temperatures from 550 to 580 °C using nitrogen gas as the fluidizing medium. The maximum oil yield is 7.05% higher than the Fischer assay.

The first part of the investigation involves the determination of two important variables in retort design, the shape factor and the density of oil shale particles. Kozeny and Carman's correlation (3.2.3, Chapter III) was used to evaluate these values since it covers the mass and momentum balance of fixed bed systems and were found to be 0.604 and 2.47 gm/cm^3 respectively (4.1, Chapter IV). The report values of shape factor of sand to bituminous coal of 0.600-0.625 (24) are very agreeable with the observed value. The observed density is also very close to the bulk density of oil shale of 2.3 gm/cm^3 (4.1, Chapter IV).

Various assumptions and considerations were made in calculating the variables in designing the equipment. They are discussed as follows :

1. As Mae Sot oil shale is dense and tough, non-porous particles was assumed in the determination of particle density and the voidage of bed at minimum fluidization was calculated. The observed density of oil shale particles must be reproducible in order to obtain reliable values of minimum fluidizing voidage of bed.

2. The nitrogen gas was selected because it is readily available, inert, and simple to use and handle. The physical properties of nitrogen gas such as viscosity, density, thermal conductivity and specific heat can be obtained from any textbook.

3. According to the author (15), the error of Eq. 2.8 for prediction of minimum fluidizing velocity was considered to be within ± 50%, particularly if the particles are non-spherical. For mean particle size of 0.576 mm., theoretical value of minimum fluidizing velocity is 55.2 cm/sec but the actual or experimental value is 20.56 cm/sec, or the actual value is less than that of calculated value by about 62.75%. The difference is greater than the permissible error of the prediction by about 12.75%, because some of the assumptions made in the prediction of minimum fluidizing velocity became invalid for oil shale particles. However, the observed minimum fluidizing velocity of raw oil shale was accepted.

4. Heat requirement and specific heat of Mae Sot oil shale were assumed to be the same as that of Colorado and

Green River oil shale having similar properties at the same temperature level and modified Fischer assay respectively.

5. Mass transfer of kerogen decomposition was assumed to be similar to evaporation of water from solids. Hill (17) reported that at high temperatures (450° to 620 °C), oil evolving from the pores in which it is located is very rapid. Hence the phenomena of mass transfer of shale oil may be analogous to the drying process.

6. The calculated operating time was obtained to be about 18 minutes (Appendix A.3 and A.4). Reyburn (20) found the residence time in oil shale fluidized bed retorting of 15.44 minutes gave maximum oil yield for continuous process employing the same condition. Therefore, the designed operating time for batch process of 30 minutes was used to make sure that the removal of the products from the retort was complete.

7. The effect of elutriation due to erosion of particles could be neglected. Although the oil shale particles were heated and forced to move up by the hot nitrogen flow for the operating period of 30 minutes, the mean particle size changed only about 8 percent of the original weight. Therefore, it is shown that Mae Sot oil shale has sufficient strength to be applied in a fluidized-bed retort. This is supported by Rammler (7) who found that organic matter acts as a binder and the strength of spent shale depends on the

composition and structure of the mineral components such as Al_2O_3, Fe_2O_3, SiO_2, etc.

The considerations made in the equipment design and operation are presented in the following discussion :

1. Stainless steel No. 304 was selected in constructing the retort because of its corrosion and high temperature resistance. In designing, the size of the retort was chosen to be 2 inches ID. since it is smaller than D_{max} (Appendix A.1) and larger than the limit of the minimum size of 5 cm. ID. (15). The height of retort was obtained to be about 18 inches to prevent the particles from engaging (14). In addition a cyclone was attached to the exit line to prevent dust or small particles from entering the condensation equipment, thereby preventing shale oil from being contaminated.

2. The selection of a gas distributor in the retort was successful concerning the gas distribution, therefore homogeneous fluidization was obtained. Besides, the distributor would help to preheat the nitrogen gas input from the copper coil.

3. The nitrogen velocity at minimum fluidizing condition was applied because the actual value in the retort may be higher than this according to the volumes of liquid vapours and gases from oil shale decomposition. The actual velocity of fluidizing medium, approximately 1.234 times of the average minimum fluidizing velocity between raw shale and

spent shale particles (Appendix A.5), was applied to prevent the turbulent flow of oil vapour which may cause difficultly to condense.

In view of the effect of retorting temperature on oil yield, the result can be discussed as follows : From Fig. 4.6-A, the optimum temperatures of 550, 560, and 580 °C for three samples of different particle sizes 0.715, 0.576 and 0.249 mm. gave maximum oil yields. The optimum temperature of the smaller particles was lower than that of the larger ones because of the lower flow rate of nitrogen gas for fluidizing these particles. However,the effect of particle size on the optimum retorting temperature by fluidization method seems to be small, as shown in Fig. 4.6-B. This is supported by Reyburn (20) who found that both particle size of -1.68 + 0.25 mm. and of minus 3.17 mm. gave maximum oil yield at the same optimum temperature of 516 °C.

Considering the experiment on the retorting of oil shale of particle size 0.576 mm., the optimum oil yield at retorting temperature 560 °C (Fig. 4.6-A) was obtained to be about 107.05 wt % of Fischer assay. This result shows that at lower temperature the oil yield is low because the incomplete conversion of kerogen and incomplete evaporation of oil, and at higher temperatures cracking of shale oil is promoted, the result obtained is also low in oil yield. This is supported by Rammler (7) and Chomnanti (13) who stated that oil shale decomposition started at about 300 ° C. The evolution of shale oil was substantially complete at 500 °C and there were some evidence that some of the shale oil cracked when pyrolysis was carried out at 600 °C.

The maximum oil yield of 12.51 wt % was obtained at 560 °C which is greater than that of the Fischer assay by about 7.05%. The following results may be discussed as follows :

1. The difference between the retort oil yield and the Fischer assay oil yield may be accounted for by the nitrogen atmosphere in the fluidized-bed retort. The carrier gas would withdraw the oil vapour from the pores of shale more rapidly before cracking of shale oil could occur.

2. The advantages of fluidization method as mentioned in Chapter I, particularly more uniformity of temperature in the fluidized-bed retort compared with the Fischer assay. The retorting temperature was controlled directly in the bed of oil shale particles whereas in the Fischer assay the controlled temperature was at the wall of the retort. Although, in the Fischer retort, there are perforated disks providing uniform heat to the particles, it is not as efficient as the heat transfer in the fluidized-bed retort (2.9.1, Chapter II).

3. The experimental process is a batch process. Therefore, the decomposition of kerogen may occur completely, particularly for the long operating time of 30 minutes. The effect

of operating time is supported by Reyburn (20) who found that longer residence time would give higher oil yield; for example in the continuous process of fluidized-bed retort the raw shale that was retorted for a residence time 15.44 min., gave an oil yield of 106.32% F.A. whereas only 100.38% F.A. was obtained when retorting for 9.12 minutes at the same conditions.

The experimental result concerning the effect of particle size of oil shale on oil yield indicates the optimum particle size in the range of 0.500-0.576 mm. as shown in Fig.4.7.

The result of retorting oil shale of smaller particle size which gave lower oil yield is supported by Beck et al (8) as the effect of crushing process in which the brittle material which composes of little kerogen is more likely to be crushed to a greater extent. This experiment shows small difference of maximum oil yield between particle size of 0.576 mm. and 0.249 mm. (107.05 and 106.37% Fischer assay respectively.

For larger particles, the oil yield obtained became lower because of less heat and mass transfer per unit weight than that of oil shale of optimum size, and because of the longer distance for the retorting products to diffuse to the particle surface. Therefore larger particles resulted in lower yields. This is supported by Matzick (9) and Hill et al (7), respectively.