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MAOMING OIL SHALE CONCENTRIC CIRCLE JALOUSIE THIN LAYER RETORTING (CCJTLR) TEST

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On the basis of a cylindrical retort operated at Maoming a new design was developed for retorting oil shale using the concept of concentric circle jalousie thin layer retorting (CCJTLR). One of the Maoming production retorts was reconstructed and testing was made using both the whole recycle gas flow and the recycle gas mixed with gasification gas as heat carriers in the retorting process. The tests showed that the CCJTLR concept provided lower flow resistance and better gas flow distribution in the oil shale layer. Both versions led to increased shale oil yields from Maoming oil shale. The whole recycle heating flow gave better results compared to recycle-gasification flow.

1. Introduction

Maoming oil shale retorts of cylindrical type were built in 1969 and have gone into operation for about 30 years being a good contribution to development of shale oil industry in China. This retorting technology, however, was considered not adequate for the demand of situation. A new technology had to be developed to increase the yield of shale oil in the process. Experts in oil shale agreed that the Kiviter technology could be suitable to process Maoming oil shale. Thus a Maoming oil shale retort was reconstructed and the testing made on CCJTLR from December 1990 to December 1992. The design of the pyrolysis section of the retort was changed into concentric circle thin layer type in order to improve heat carrier gas flow distribution to obtain increased oil yields and higher throughput rates of the retort.

2. Flow Scheme for Testing and New Design of the Pyrolysis Section of the Retort

The flow scheme for retorting is shown in Fig. 1 and the design of the pyrolysis section of the newly reconstructed retort in Fig. 2.

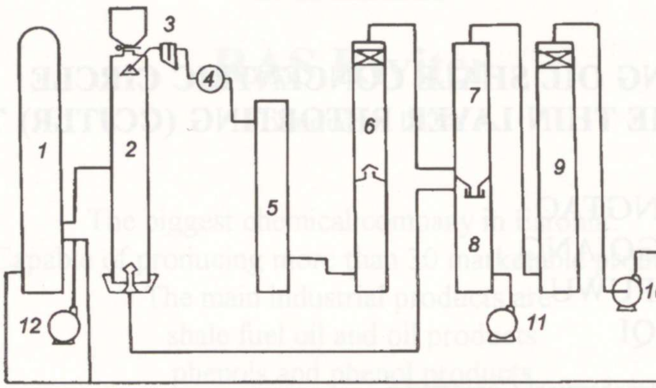

Fig. 1. The scheme for Maoming cylindrical retort: *1* - recuperative heater, *2* - retort, *3* - water seal, *4* - gathering pipe, *5* - scrubber, *6* - ammonium sulfate tower; *7* - precooler, *8* - saturator, *9* - final cooler, *10* -gas exhauster, *11* and *12* - air blast blower

Two heat carrier flow versions were used to testing: full recycle heating by providing the entire heat required for retorting by recycle gas entering from the middle of the retort without shale char gasification and combustion. The latter scheme enables to avoid shale oil losses caused by burning and to easily investigate the effect of the newly improved design of the pyrolysis section. The other version provides the use of heat carrier gas composed of recycle gas and gasification gas. In this version hot recycle gas entering the retort from the middle provides for part of the heat required for oil shale pyrolysis. The rest is provided by sensible heat of the gasification gas. The condensation and recovery system is the same as in the commercial retort (Fig. 1). The oil contained in the discharged retort water and oil sludge was not included in the oil yield calculation.

As may be seen in Fig. 2, the upper pyrolysis section of the retort was reconstructed into concentric circle jalousie thin layer design similar to the Kiviter technology. Recycle gas entrance in the middle of the retortwas still retained, but the flow of recycle gas decreased greatly. The bulk of the recycle gas was directed into the pyrolysis section via the newly designed upper entrance, then passed through spray nozzles arranged all over the furnace wall in upper pyrolysis section of the retort. A central gas collector made of alloy steel is arranged in the upper center of retort for outlet of pyrolysis gas.

Entering the retort from the top, oil shale moved downwards vertically in the pyrolysis section. Hot recycle gas sprayed from jet nozzles on the furnace wall, passed in a cross flow through the oil shale layer heating the latter and producing shale oil vapors which, mixed with the recycle gas, entered the central gas collector and moved upwards to outlet. The horizontal cross flow of heat carrier gas through a fairly thin oil shale layer (about 1.1-1.12 meters) resulted in lower resistance of the retort and more even distribution of gas over the shale layer which led to better heat distribution and a lower temperature gradient of the shale layer in comparison with vertical upward flow of the gas through a shale layer of 5-6 meters in commercial retorts of old design. As a result increased oil shale throughput rates of the retort and higher oil yields were achieved.

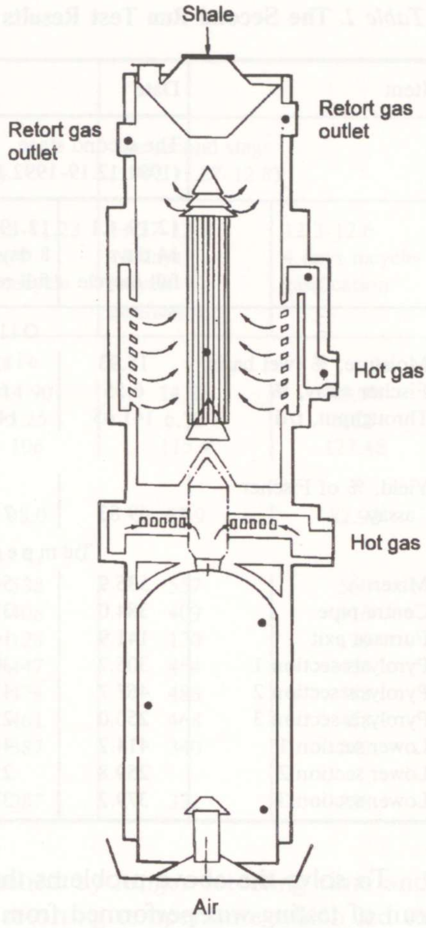

Fig. 2. Maoming oil shale retort of new design. • - temperature measuring points

3. Experimental

3.1. Process Tests

A single retort was reconstructed as shown in Fig. 2 in the first half year of 1991 and three testing runs were carried out. The first run was performed from May to August 1991. The testing showed that the design of the concentric jalusie was good, the distribution of temperature and pressure was normal. The key structures of the new design - the cross flow of gas through the descending thin oil shale layer, the arrangement of the gas and oil vapor collector in the center of the retort - showed good performance. However, there were some problems, such as: resistance of the recovery system was high, the quantity of the recycle gas was insufficient resulting in insufficient heating, and the spray nozzle bricks tended to break down.

Table 1. **The Second Run Test Results**

Item	Date				
	The second stage (1991.12.19-1992.1.1)			The third stage (1.18-1.30)	
	12.19-1.1 14 days full recycle	12.19-12.26 8 days full recycle	12.23-12.26 4 days full recycle	1.18-1.30 13 days full recycle	1.18-1.22 5 days full recycle
Oil shale					
Moisture, % (wet basis)	15.93	15.27	15.33	15.97	15.68
Fischer assay, %	6.55	6.82	6.64	6.69	6.85
Throughput, t/d	141.45	148.68	160.88	130.57	127.48
Oil					
Yield, % of Fischer assay	69.83	71.99	80.52	76.64	82.92
Temperature, °C					
Mixer	535.9	548.0	534.8	565.6	558.8
Centre pipe	384.0	376.1	368.5	378.3	381.0
Furnace exit	141.9	141.1	135.4	127.7	130.8
Pyrolysis section 1	305.7	306.8	309.3	319.3	309.4
Pyrolysis section 2	467.7	473.0	476.8	486.0	474.8
Pyrolysis section 3	250.0	253.8	251.0	400.9	383.0
Lower section 1	414.2	413.8	410.3	416.9	420.5
Lower section 2	259.8	259.5	258.6	262.6	259.2
Lower section 3	379.2	378.8	382.8	378.3	375.6

To solve the above problems the retort was improved, and the second run of testing was performed from November 1991 to January 1992. The test results are given in Table 1.

Most of the year 1992 was spent to improve the brick design for gas spray nozzles. Former inclined nozzles were changed into flat ones, and the third run was made in November - December 1992, the test results of which are shown in Table 2.

3.2. Results and Discussion

3.2.1. The two test runs showed that using full recycle heating flow in the retort of new design resulted in higher oil yields than in the retorts of old type. It was also evident that the new process flow scheme an the design of the reconstructed retort may be considered efficient and advanced.

(1) During the second test run using full recycle heating flow the shale oil yield was 70-80 % of Fischer assay at a retort throughput of 130-150 t/day. The third test run with full recycle heating flow showed oil yields of over 70 %, while at short-time testing continuously within four days the oil yield obtained was as high as 90 % at a decreased throughput

Table 2. **The Third Cycle Test Results**

Item	Date			
	The first stage (1992.11.13-11.23)		The second stage (1992.11.27-12.8)	
	11.13-11.23 11 days full recycle	11.18-11.23 5 days full recycle	11.27-12.8 12 days recycle-gasification	12.3-12.6 4 days recycle-gasification
Oil shale				
Moisture, % (wet basis)	15.20	14.90	14.83	15.68
Fischer assay, %	6.11	5.25	6.72	6.85
Throughput, t/d	109.45	106	115.4	127.48
Oil				
Yield, % of Fischer assay	72.5	98.0	67.9	82.92
Temperature, °C				
Mixer	537	538	557	560
Centre pipe	385	408	409	416
Furnace exit	123	128	130	129
Pyrolysis section 1	450	447	454	454
Pyrolysis section 2	475	474	483	483
Pyrolysis section 3	460	461	468	468
Lower section 1	397	387	340	340
Lower section 2				
Lower section 3	387	387	332	328

of only 105-110 t/day. It may be explained by longer retorting time and by a to some extent higher and stable retorting temperature which led to a more complete pyrolysis reaction.

(2) In comparison with the retorts of old type the shale oil yield increased 10-20 %. The test results may be considered trustworthy because the oil yield does not include the oil contained in sludge and waste water.

(3) The results of the third test run showed that full recycle heating flow leads to higher shale oil yields than the use of recycle-gasification mixed gas as the heating flow.

(4) Oil yield of the test retort was higher than that of the old production retort. The reason for this is as follows:

- by using full recycle heating flow, the heat carrier does not contain oxygen which enables to avoid losses of shale oil by burning
- by arranging the jalousie structure in the pyrolysis section, thin layer retorting was achieved leading to more even gas and heat distribution, and, consequently, to a more complete pyrolysis reaction.

3.2.2. The oil yield level which was achieved in the retort of new design is still lower than that expected by full recycle heating flow in ideal case. By full recycle heating flow the oil yield should be over 10 % of Fischer assay. So far, for a quite long time of operation the oil yield is 70-75 %. It is probably due to the fact that the heat supply is not enough and even:

(1) The temperature of hot recycle gas fluctuates greatly (in a range of 200 °C) from 450 to 650 °C, the average temperature being 550 °C. When the hot recycle gas temperature is lower than 500 °C, the pyrolysis reaction is not complete. When recycle gas temperature is above 600 °C, a part of oil will be cracked.

(2) The present gas distribution in the pyrolysis section is not even enough.

3.2.3. The key question on CCJTLR in respect of the structure of the new design is how to make gas spray bricks on furnace wall to possess very good mechanical strength, and to achieve good distribution of gas.

3.2.4. On retort throughput:
In the second test run (Table 1), at an average throughput of 160.8 t/day in a continuous run for four days (from 23 to 26 December), the oil yield was 80 % of Fischer assay. With throughput increase, the oil yield increased. The reason for this is that with throughput increase the retort top is not full and the total thickness of the shale layer is fairly thin. As a result, gas resistance is low, gas quantity is large, heat is abundant, gas distribution is even. All this contributes to achieving a higher oil yield.

So, throughput of the retort of new type can be increased only if heat is abundant and even.

4. Conclusions

4.1. The CCJTLR concept of retorting Maoming oil shale is advanced and reasonable, and is characterized by low gas resistance, good distribution of the heating flow and increased shale oil yields.

4.2. The use of full recycle heating flow is suitable for retorting Maoming oil shale, avoids losses of shale oil caused by burning and leads to increased oil yields.

4.3. By processing Maoming oil shale in the CCJTL retort with full recycle heating flow the oil yield is 10-20 % higher than in the old type production retort.

4.4. In the above retort oil yield is increased only if the heating is abundant.

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