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DEVELOPMENT OF OIL SHALE RETORTING PLANT IN JAPAN PART II : OPERATION OF THE PILOT PLANT

Abstract

On consignment from the Ministry of International Trade and Industry (MITI) and Japan National Oil Corporation (JNOC), Japan Oil Shale Engineering Co., Ltd. (JOSECO) commenced the operation of an oil shale pilot plant in May 1987.

Though JOSECO is still continuing the experimental operation as of the end of January 1988, all the data we have obtained to date have been satisfactory.

Introduction

After the integrated load trial runs and final adjustments of the pilot plants and the on-the-job training of the operators, the pilot plant started its formal operation in early May, 1987.

By the end of September preliminary tests were conducted. Through these preliminary tests, a number of factors have been checked and reviewed, including the performance and reliability of the equipment, procedures to ensure operational safety, and research on process conditions to maintain stable and efficient operations.

Based on the achievements of preliminary tests, JOSECO has been conducted the main tests using both Australian Condor and Chinese Maoming ores. To date all the data we have obtained have been satisfactory.

This paper introduces the outline of pilot plant operation.

Figure shows the operation schedule of the pilot plant after preliminary tests.

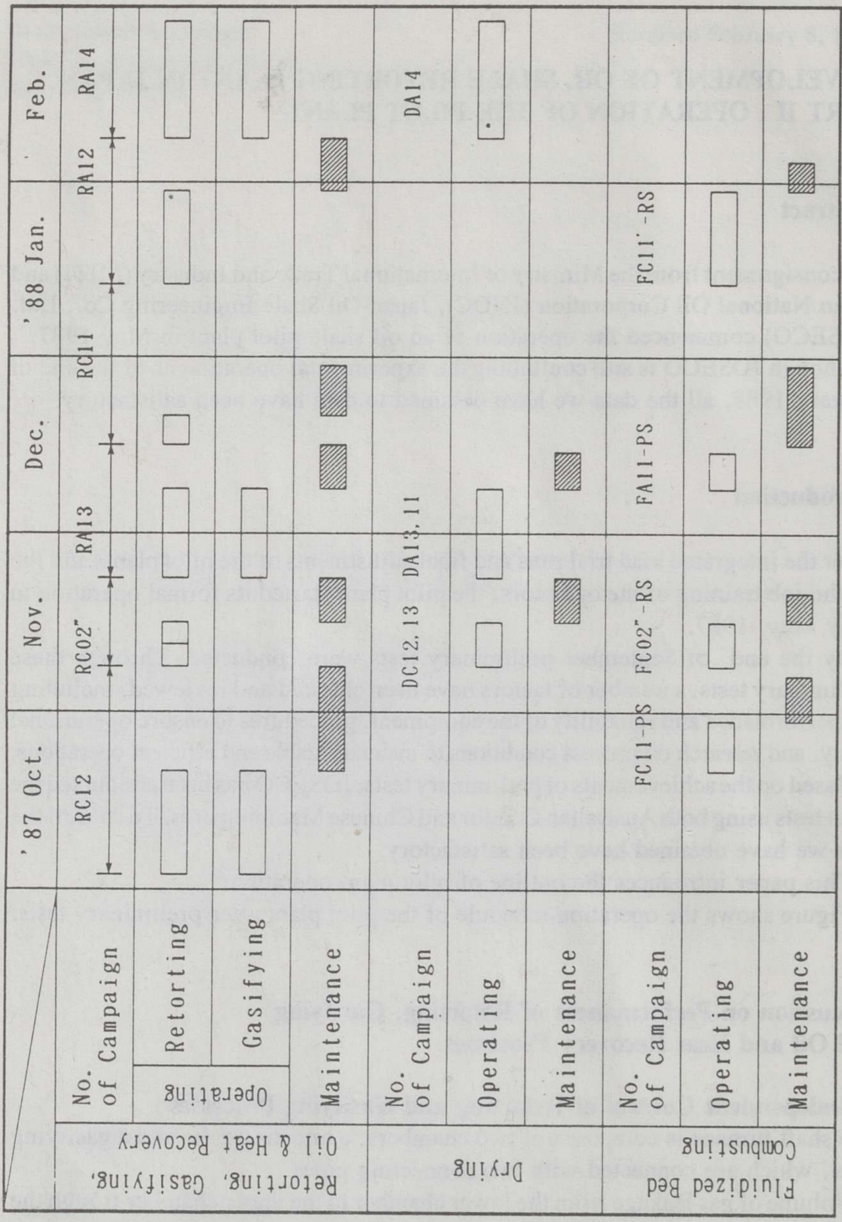
Discussion on Performances of Retorting, Gasifying and Oil and Heat Recovery Processes

1. Independent Control of Retorting and Gasifying Processes

The shaft furnace is composed of two chambers, a retorting zone and a gasifying zone, which are connected with two connecting pipes.

Volume of gas leakage from the lower chamber to the upper chamber trough the connecting pipe was maintained at about 2 % of recirculating gas volume by controlling the extraction volume of byproduct gas from the retort gas line. This gas leakage is detected and monitored as the pressure difference between top and bottom of the connecting pipes.

Success in suppressing the interference between the two processes to a negligible level was attributed to maintenance of a stable condition for each process.



Operation schedule

Table 1. **Typical examples of main retorting tests runs**

No.	Parameter	Unit	Oil Shale Ore	
1.	Feed Ore		Condor	Maoming (pre-dried)
	Moisture Contents	wt %	8.4	5.0
2.	Retorting Performances			
	Feed Rate	t/d	220	160
	Average Processing Rate	kg/m² • h	2,000	1,450
	Recirculating Gas			
	Volume	nm³/h	10,100	6,850
	Temperature	°C	590	590
	Top Gas Discharged from Retorting Zone			
	Temperature	°C	120	150
	Pressure Loss of Retorting Zone	mm Aq	1,700	800
3.	Oil Recovery Performances			
	Oil Yield	l/t	58	78
	Oil Recovery Rate	% of F/A	100	102
4.	By-Product Gas Recovery Performances			
	Volume	nm³/h	500	400
	Lower Calorific Value	kcal/nm³	2,730	2,960
5.	Gasifying Performances			
	Volume	nm³/h	8,710	6,400
	Temperature	°C	230	230
	Top Gas Discharged Gasifying Zone			
	Temperature	°C	640	600
	Composition H_2	dry %	3.0	3.8
	CO	dry %	3.6	4.5
	Pressure Loss in Gasifying Zone	mm Aq	1,100	900
	Gasification Rate	% of O.C.	76	74
6.	Heat Recovery Performances			
	Heat Recovery Rate			
	No1. Recuperator	x10³ kcal/h	2,300	1,650
	No2. Recuperator	x10³ kcal/h	900	700
	Flue Gas Volume	nm³/h	5,020	4,620
7.	Shale Properties		**FS RS SS**	**FS RS SS**
	T.C	wt %	10.5 5.3 1.4	13.8 7.4 2.1
	H_2	wt %	1.8 0.5 0.1	2.3 0.6 0.1
	S	wt %	— 0.7 0.3	— 1.2 0.5

(**FS**: Feed shale, **RS**: Retorted shale, **SS**: Spent shale)

It was confirmed that the control system using a basically constant controlled level of the gas supply condition to each zone was desirable for maintaining the stability of both retorting and gasifying processes as discussed below.

Table 1 shows data of typical main test runs.

2. Retorting Performance

Size range of charged ore was 6-70 mm and the weighted average diameter was around 27 mm. Actual particle diameter in the furnace was smaller than the above figure due to the thermal shock of the retorting process, which is a well-known characteristic of both Condor and Maoming ores.

In result, the permeability resistance coefficient within the furnace was about 3 times of that of the cold state in the case of both Condor and Maoming ores. This value was almost equal to the experimental result obtained through 3 t/d bench scale plant operation.

The maximum gas space velocity which maintained stable permeability in such a shale-filled condition within the furnace was 0.6-0.7 nm^3/sec.

The maximum ore processing amount restricted by the upper limit of supply hot gas volume was around 220 t/d (2000 $kg/m^2 \cdot h$) in both cases of Condor and pre-dried Maoming ores. As for Maoming ore, however, the above-mentioned figure was estimated based on the process data at the 160 t/d operation level (which was the maximum capacity due to the restriction by the capacity of pre-drying equipment: 15-17 % → 4-5 %).

Oil recovery rate achieved about 100 % at the later stage of experiments (220 t/d for Condor and 160 t/d for Maoming). This was attributable to two improvements in equipment, aimed at the improvement of the uniformity. One was the increase of effective cross sectional area at the position of hot gas injection beams by narrowing the width of the beams, and the other was a decrease in shale size segregation in the furnace through improvement of the charging device.

3. Oil Recovery Performance

Most of the dust carried-over in top gas (about 4 g/nm^3) was collected efficiently (about 97 %) by a recovered-oil spray type cyclone and no dust troubles in the retort gas line were experienced. Heavy oil containing the dust was sent to a centrifugal separator. Solid contents at its outlet were less than 0.1 % in recovered oil and more than 40 % in sludge.

Two-stage tower coolers of multi-stage thin packed layer type were selected as the gas cooler taking into consideration cooling efficiency and prevention of dust clogging. Heavy oil is caught by the oil sprayed primary cooler and light oil and retort water are caught by the oil/water sprayed secondary cooler and EP. The suitability of this design concept was confirmed through operation. Carried-over oil mist at each cooling stage was 10-20 g/nm^3. Most of the oil mist was recovered by EP of the final stage to reach less than 1 g/nm^3 at its outlet.

4. Gasification Performance

Some shales begin to experience the cohesion phenomenon at temperatures above 1050 °C, which is a well-known characteristic of both Condor and Maoming ores.

Our concepts were to establish the process conditions which prevent the formation of hard cluster and to select a reliable device which maintains stability and uniformity in material flow even in the case of partial cluster formation.

The desirable temperature pattern in gasifying zone was governed by the supply gas volume and O_2 + H_2O contents in supply gas. An appropriate amount of O_2 was supplied as an exothermic reaction agent and excess H_2O as a promotive agent for water gas reaction. 40-50 % of the heat generated in the gasifying zone was recovered as latent heat under the conditions which achieved the highest gasification rate. According to our experiences, this condition was the same as that for preventing the formation of hard cluster.

We presume that a small amount of weak cluster will normally be produced in our process. However, we believe that stable permeability has been maintained judging from the following:

- High gasification rate of 70-80 %
- Stable pressure loss in gasifying zone
- Small O_2 leakage into the gas discharged from gasifying zone

These are attributed to the straight furnace configuration which has no reduced-sectional area portions and to the screw conveyors which have forced-discharging ability.

5. Heat Recovery Performance

The temperature of top gas discharged from the gasifying zone was normally 600 °C and H_2 + CO contents in gas (dry base) were 8-10%.When the gas temperature after burning the combustibles in gas exceeded the design temperature at the inlet of recuperator (normally 850 °C), the gas temperature was controlled by using a part of recirculating gas.

About 70 % of the heat recovered from the gasifying process was transferred to the recirculating retort gas through two recuperators which were installed in series. Remaining heat was transferred to the air through another recuperator and released into the atmosphere as hot air at 250 °C.

Most of the carried-over dust (about 10 g/nm^3) in the top gas was collected at an efficiency of about 90 % by normal cyclones. Very fine dust, however, stuck to the tube inside walls of shell & tube type recuperators and heat exchange ability dropped below the design value in one or two days operation. To overcome this problem we installed a steel shot cleaning device. This device has been operating effectively since 1991.

Discussion on Fluidized-Bed Combustion Performances

Throughout the preliminary and main test runs, satisfactory results were obtained. Typical operation data are shown in Table 2.

Table 2. **Typical operation data**

N	RUN No.	FC-11(PS)		FC-02"(RS)		FA-11(PS)		FA-01(RS)	
1.	Feed Ore	Condor Powder Shale		Condor Retorted Shale		Maoming Powder Shale		Maoming Retorted Shale	
2.	Lenght of Run, h	62		63		54		65	
3.	Combustion Performances								
	Feed Rate, t/h	2.91		6.3		2.61		4.5	
	Particle Size, mm	3.5		2.4		2.9		2.6	
	Supply Air								
	Vol., nm^3/h	5,150		5,620		5,800		6,300	
	Temp., °C	169		392		97		276	
	Press. mmAq	450		615		400		570	
	Combustion Temp., °C	900-920		870-890		850-900		880-900	
	Combustion Efficiency, %	99-100		94- 95		99-100		92	
	Dust Carry-over Ratio, %	24		8		44		15	
4.	Shale Cooler Performances Temp., °C	138		206		85		172	
5.	Shale Properties	FS	SS	FS	SS	FS	SS	FS	SS
	OC, %	10.1	N.D	5.27	0.35	12.7	0.06	7.31	0.94
	H, %	1.7	N.D	0.56	N.D	2.2	N.D	0.71	0.07
	S, %	0.59	0.07	0.60	0.10	0.84	0.04	0.97	0.14
	Calorific Value, kcal/kg	1,170	—	520	—	1,440	—	700	—

The summary of results is as follows:

1. Combustion temperature of shale was around 900 °C.
2. Moderate shale particle size (D_p50) was 2 to 4 mm.
3. Combustion efficiency was better than 90 %.
4. In the case of combustion of powdered shale, especially of Maoming, collapse phenomena were observed.
5. Combustion dust through dust cyclones, was very fine and sticky.
6. Sensible heat of spent shale was recovered at around 80 to 90% in a fluidized bed shale cooler.
7. Engineering data on scaling up were obtained for designing a commercial plant.

Conclusion

1. JOSECO constructed an oil shale pilot plant and commenced its operation early May 1987.
2. By minor modification of equipment and improvement of operation techniques, the oil shale pilot plant is currently operating efficiently and providing promising results.
3. JOSECO is confident of success in early establishment of its own technology.

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