FIRST RESIDUE HYDROCRACKER STARTS-UP IN ASIA/PACIFIC

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ABSTRACT

TONEN Corporation of Japan started up their first residue hydrocracker, based on HRI's (now IFP North America, Inc.) H-Oil® Process in June 1997. This paper discusses the history of this project from technology selection to start-up. The field construction for this 25,000 BPSD unit was completed in a record time of less than 13 months. A smooth start-up was attributed to TONEN's excellent quality assurance programs and operating training. Recent operation and performance of the unit will be discussed. The H-Oil Unit is designed to upgrade and convert Middle Eastern vacuum residue to distillates while producing a good quality, low sulfur fuel oil product.

INTRODUCTION

TONEN Corporation of Japan is a major energy company that has built a reputation for pioneering new technologies in refining and other petroleum related fields. TONEN's major shareholders, Exxon and Mobil, provide the crude oil supplies for TONEN refinery operations. TONEN operates two refineries, one in the city of Kawasaki, part of the greater Tokyo metropolitan area, and in Wakayama in western Japan. The Kawasaki refinery has a crude distillation capacity of 255,000 bpd and produces a full range of products.

With the desire to handle heavier, sour crudes, TONEN constructed and started-up a 25,000 BPSD H-Oil Unit to hydrocrack vacuum residue from Middle Eastern crudes in June of 1997.

PROJECT HISTORY

Many refineries in Japan have added residue Hydrodesulfurization Units to respond to the new environmental regulations and to provide additional feedstock flexibility to their refinery. TONEN Corporation is the first refinery in Japan to add residue hydrocracking to maximize distillate yield while producing a stable, compatible residual fuel oil.

In 1990 TONEN evaluated two processing routes to meet its overall objectives, fixed-bed VRDS (Vacuum Residue Desulfurization) and ebullated-bed hydrocracking. Laboratory studies were conducted to provide a firm basis for developing preliminary engineering studies for these two processing routes. The results of laboratory, engineering and commercial plant data from existing facilities were provided to TONEN's major shareholders for review and confirmation of the design basis. After careful evaluation, TONEN selected IFP North America's (formerly HRI) H-Oil Process as the best route for achieving its technical and economic objectives.

The H-Oil Plant consists of a single train plant with two reactors in series. The weight of the ebullated-bed reactors was limited to approximately 1,000 metric tons because of various restrictions in the refinery and, in part, to the local airport which limited the height of the reactors. The H-Oil Unit was designed with the flexibility to operate at a

565ºC^{+} V% conversion in the range of 55 to 75% while making a stable, low sediment residual fuel oil.

UNIT CONSTRUCTION

The TONEN H-Oil project received approval in August 1994. Construction started by Chiyoda Corporation in March 1996. The 1,000 ton H-Oil Reactors were fabricated by JSW using the 3 Cr. 1-Mo metallurgy. The 40 meters high, 5 meters diameter reactors were raised using the VSL method. On June 28, 1996, the reactors were set in place. The plant includes a two- stage H-Oil Unit, amine plant, hydrogen purification plant, make-up hydrogen compressors, cooling water tower, sulfur plant and other auxiliary units. A photograph of the H-Oil Reactors is shown in Figure 1.

Figure 1 Tonen's H-Oil Reactor

The construction was completed virtually on schedule and less than 13 months for the Unit to be mechanically complete. Unlike many other construction projects, when this Unit was mechanically complete, no further work was required. TONEN used Quality Assurance and Quality Control Activities in order to ensure a minimum of re-work during pre-commissioning and start-up.

Mechanical completion officially occurred on May 15, 1997 and the commissioning efforts commenced. The commissioning efforts included a set of “Dummy Runs” that are operations at full Unit pressure, with light gas oil circulation and with no catalyst in the H-Oil Reactors. The main purpose of the “Dummy Runs” was to hydraulically test the

Unit out under normal operating conditions. The “Dummy Runs” are also used to test all of the automated emergency procedures that are designed to place the H-Oil Reactors into a safe position when emergency situation has taken place. Included in these procedures is full depressurization of the Unit to ensure that the depressurizing valves function correctly. These runs provided very good emergency situation training for the operators.
The “Dummy Runs” are an integral part of IFP NA’s pre-start-up procedure to ensure that everything possible has been thoroughly checked out as far as possible from a mechanical viewpoint as well as a process standpoint. These tests are very beneficial in detecting any defects in the system before operations with vacuum residue are commenced. For a Unit of such complexity as the H-Oil Unit, there were very few issues found which required rectification. A few lines were in need of steam tracing and there were a few others that required additional supports.

Conformance Check

Before mechanical completion, the Unit was thoroughly checked through by various parties including TONEN and their US affiliate, Exxon, and also IFP NA. The conformance check included a safety audit from a mechanical viewpoint of the complete high-pressure section of the Unit. TONEN applied all of their in-house techniques for Unit conformance checking to ensure that nothing was overlooked.

The Reactors were also inspected thoroughly. There were just a few items in the Reactors that required remedial work. These were quickly rectified. There were a number of other items found during the check including some instrumentation items that were corrected. The number of items found during the total check was quite low, which reflected the effectiveness of the Quality Assurance and Quality Control Activities. TONEN had implemented many checking programs for quality control from all aspects. One of them, a positive materials identification program, showed just how effective these quality assurance programs were when the end result was that of some 23,000 items inspected, zero defects were found.

Pre-Commissioning Efforts

TONEN and Chiyoda completed all of the pre-commissioning checks. This showed that the quality assurance programs implemented had also worked very well and there were extremely few issues to be handled. Unlike many other plants, there were no subsequent issues with line deposits and system fouling due to line trash. IFP NA had rarely seen a Unit especially of this size that was so clean prior to start-up and this contributed very significantly to the very easy start-up.

The unit was complete on the revised target date ready for government inspection and received clearance to commence start-up operations. Both TONEN and Chiyoda were prepared for the start-up. Daily meetings were scheduled to discuss all aspects of the activities. Maintenance, operations, project and technical departments as well as the licensor were all involved. Every aspect of the equipment performance had been examined beforehand and limitations were known. The operations staff was well trained both in the theory and the practice of the H-Oil Process through classroom training and simulator training. TONEN had decided earlier on during the project development to have a Training Simulator. This simulator for the H-Oil Process was developed by SACDA (now Honeywell Hi-Spec Solutions). The Training Simulator was used for operator training and was also used for pre-tuning and system response evaluations.

Training before Start-up & on-the-Job Training

What IFP NA had been very insistent upon was the absolute need to have as full a training program as possible, and to this end, IFP NA had offered TONEN a full training program. This included TIC (Training in Class), TAR (Training at Refinery) and TAJ (Training at Job). The TIC for the refinery process engineers was successfully carried out at IFP NA's offices in Princeton. The TAR for the refinery process engineers and the main operations personnel was successfully carried out at the Husky BPU H-Oil Unit in Lloydminster, Canada. An abbreviated TAJ was performed at the Kawasaki site and discussions on outstanding items and procedures were held. Technical, operations and projects were involved.

TONEN had taken maximum benefit from these training sessions. A Training and Operations Guideline manual had been used as the basis for the TONEN operational procedures. This manual covered all aspects of the H-Oil Process.

In addition to the above, the TONEN engineers had conducted in-house training programs based on the manual used for the original TIC. To have more practical training, each of the panel operators underwent four one week sessions on the Training Simulator to ensure that they were as familiar as possible before the actual start-up of the Unit. The Training Simulator is being used as an "on-the-job" training tool and it will be used for re-training as an on-going operation for all the operators and operations engineers. It will also be used for tuning parameter determination when changes are required.

START-UP

The initial start-up pace was slow due to the timing of the start-up (which was during the general refinery turnaround). The residue availability was also low and sporadic for a number of days due to the re-start of the remainder of the Refinery. The black oil rate was introduced at only 1,000 BPSD on June 21, 1997. It was increased slowly over 10 days to 16,000 BPSD on July 1, 1997. This was in part due to constraints put on the unit operation from outside (hydrogen and sulfur plant handling capacity until additional facilities were commissioned).

TONEN achieved a very aggressive target start-up date. TONEN's achievement of just over five weeks for the full commissioning to black oil in is a very good achievement. The planning which went into this start-up was extensive and TONEN achieved the goals due to the forward planning efforts made by their team. While the start-up went very smoothly, there were only two main problem areas that needed remediation to ensure that the continued good operation of the Unit was not jeopardized in any way. The TONEN start-up was effectively trouble-free. The issues were relatively minor. This reflects the emphasis put on quality control by TONEN and the fact that TONEN was fully prepared for the Unit start-up. There were relatively few problems encountered during the initial start-up that limited the overall operation. Constraints to increased H-Oil Unit throughput and residue conversion were brought about by the crude run planning, sulfur plant capacity limitations and hydrogen production capacity restrictions. Such constraints were

not abnormal or unusual and are to be expected on any Refinery especially when that refinery is undergoing a full turnaround.

INSPECTION OPERATION AND RESULTS

On July 24 1997, an "inspection run" was conducted on the H-Oil Unit less than five weeks after black oil introduction. Based on the results of this operation, the Plant was accepted by TONEN.

The highlights of the operation at that time were as follows:

- The unit capacity of 25,000 BPSD was achieved.
- A residue conversion level of over 65 V% of the $565^{o}C^{+}$ vacuum residue was achieved at the above capacity.
- The hydrogen consumption was within the allowances made.
- The desulfurization level of nearly 82 W% was achieved.
- The CCR removal of 62 W% was well above the required removal rate.
- The fluxed fuel oil had an IP-390 sediment of less than 0.1 W%. This is an extremely low value and well within the specification.

The unit performance was very close to that specified. With all fresh catalyst and little replacement during the first equivalent 30 days of operation (July 24th), the actual results are quite close to those expected.

DESIGN BASIS AND COMPARISON WITH INITIAL OPERATIONS

Design Basis

The TONEN Kawasaki H-Oil Plant was designed to convert and upgrade 25,000 BPSD of a Middle Eastern, deep cut vacuum residue using a two-stage in series H-Oil Reactor system. The reactors are ebullated-bed type and contain expanded beds of extrudate catalyst, which aid in the sulfur, nitrogen and CCR removal reactions. The conversion products are routed as follows:

- **naphtha** – to reformer,
- **middle distillate** – to product pool,
- **vacuum gas oil** - to FCC unit,
- **residue** - fluxed with FCC cycle oils to produce a stable heavy fuel oil product.

The H-Oil Unit was designed to operate in the range of 65 to 75 percent conversion of the 565ºC+ vacuum residue using VBR (Vacuum Bottoms recycle) to lower the level of reactor severity. The H-Oil Reactors utilize a second generation H-Oil catalyst that enables operation at relatively high conversion while producing high quality and stable conversion products. As with all H-Oil Plants, a portion of the catalyst bed is replaced daily and over a two to three month period, an equilibrium level of catalyst activity is attained. This will result in the production of constant product quality if operating conditions, feedrate and feedstock are consistent. The level of hydrodesulfurization, nitrogen and CCR removals are dependent on the residue conversion level and amount of daily catalyst replacement.

The unconverted vacuum residue from the H-Oil Vacuum Still is blended with aromatic FCC cycle oils to produce a stable heavy fuel oil product. In order to be marketable, this fuel oil must be stable and compatible. TONEN and IFP NA use the IP-375 and IP-390 sediment tests to assess stability. TONEN set very strict stability specifications of less than 0.10 W% IP-390 for the product fuel oil. These specifications have been achieved through the proper selection of operation conditions, catalyst type and usage rate, cutter stock quantity and type and blending technique.

Initial Equilibrium Operations

Black oil was introduced to the H-Oil Unit on June 21, 1997. As discussed above, within approximately five weeks, the plant was operating at design feed capacity and residue conversion level. Since the start-up and continuing through the first seven months of operation, the H-Oil Plant has operated with a feedstock generally heavier than the design feed and at throughputs ranging from 16,000 to 26,000 BPSD. The feedstock is a nominal $565ºC^+$ vacuum residue and typically contains 5 V% $565ºC^-$ vacuum gas oil by ASTM D-1160 distillation. No additional feed diluents are required. Typical feedstocks sulfur and CCR contents are 3.2–4.0 W% and 20-25 W%, respectively.

The level of residue conversion has typically varied from 60 to 71 V% with hydrodesulfurization in the range of 75 to 85 W%. CCR conversion is typically 55 to 62 W%. The amount of hydrogen consumption in the H-Oil Process is related to the conversion level and degree of hydrogenation. For the Kawasaki Plant, the quantity has ranged from 1,100 to 1,350 SCF/Bbl which is typical of a two-stage plant operating at moderate conversion level.

The first seven months of operation have been extremely successful with minimum operating problems. The feedstock, operating conditions and H-Oil Plant process performance and yields have been close to the expected values.

Comparison with Design Basis

A comparison of the key design basis items with actual results is shown in Table 1 below. The operating data is from typical operation after the H-Oil catalyst has attained an equilibrium level of activity. TONEN's processing objective is to route all the available vacuum residue to the H-Oil Unit and produce specification quality conversion products.

Table 1 - H-Oil Plant Design Basis and Actual Operation

	Design Basis	**Actual Operation** *November, 1997*
Feedstock	Middle Eastern Blend	Blend
Feedrate, BPSD	25,000	24,600
Feed Gravity, °API	8.6	7.8
Feed Sulfur, W%	3.6	4.0
Residue Conversion ($565°C^+$), V%	65 – 75	65
Hydrodesulfurization, W%	83	81.3
Hydrogen Consumption, SCF/Bbl	1,100 – 1,300	1,170
Fuel Oil Product IP-375/390 Sediment, W%	< 0.1	0.02

As shown in the table, even with a more difficult feedstock (10% higher sulfur), the H-Oil process performance is comparable to the original plant design basis. This design basis was developed using laboratory data on the feedstock and thus confirms the models and scale-up techniques utilized by IFP NA. The plant has operated at residue conversions as high a 75 V% while producing acceptable FCCU feed and a stable fuel oil product. The production of a stable fuel oil from deep cut vacuum residue feedstock at 65-75V% conversion is a significant accomplishment for TONEN's H-Oil Plant.

CONCLUSIONS

The TONEN H-Oil Unit start-up was nearly a flawless start-up with minimal issues. TONEN performed an excellent job overall. This was a result of:

1. Quality control measures during project development, construction and start-up
2. The well-trained operational staff
3. A high degree of technical support provided during all phases of the start-up

The initial seven months of operation at TONEN has been very successful with design levels of feedstock throughput and H-Oil Process performance demonstrated. The H-Oil Plant has produced high quality, stable, compatible fuel oil at relatively high levels of residue conversion and with a deep cut vacuum residue feedstock.

The H-Oil Plant at Kawasaki has quickly become a model ebullated-bed unit and a key element of the Kawasaki refinery with a high degree of reliability.