Reliable Operation of Gas Turbines on Crude Oil

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ABSTRACT

The paper deals with design criteria and operating experience of Authors’ Company Gas Turbine Power Plants operating on crude oils from different sources. In particular a group of power stations located in Middle East is described, where crude oils from different fields are used. While two of the above power stations use basically the same crude oil, the other ones are fed by different fuel sources. Accordingly, different fuel handling and treatment plants have been selected, different problems have been encountered and different operating experiences have been accumulated.

The positive operating results obtained confirm that reliable operation on crude oil requires each individual application be “tailor made” on the basis of the knowledge of the relevant fuels properties.

INTRODUCTION

Use of low grade fuel oils and in particular of crude oils in gas turbine power plants became, in the last years, a very frequent users demand, due to the problems related to fuel availability, quality and cost. Therefore a number of gas turbine power plants have been developed, with the capability to burn these fuels without sacrificing plant availability. Outstanding examples of this tendency are represented by the gas turbine power plants equipped with Fiat TG 20 gas turbines described hereafter, two located in Iraq and two in Saudi Arabia. While the latter ones are supplied by the same fuel sources, the former ones employ crudes from different fields.

The purpose of this paper is to give a brief description of the plants installation and of the operating experience gained handling the different types of crude oils.

POWER PLANTS OPERATING ON CRUDE OILS

A first power plant (I), owned by the State Organization of Electricity of Iraq, is located in a site in the center of Iraq, and it is equipped with four TG 20 units, for a total site output of about 112 MW at 50°C ambient temperature, when firing distillate oil.

A second power plant (II) also owned by SOE is installed in the North of Iraq, with five TG 20 units for a total site output of about 140 MW at the above mentioned site conditions.

The nine units installed in Iraq were commissioned in 81/82 and are now in operation for base power generation totalling, up to June 30 1986, about 200,000 running hours, 10 percent of them on crude oil and about 4.5 million MWh produced.

Detailed information is given in Table 1.

TABLE 1 - OPERATION DATA (UP TO JUNE 30, 1986)

<table>
<thead>
<tr>
<th>Power</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant 1</td>
<td>Plant II</td>
</tr>
<tr>
<td>(4 units)</td>
<td>(5 units)</td>
</tr>
<tr>
<td>Total running hours</td>
<td>80724</td>
</tr>
<tr>
<td>Gas fuel running hours</td>
<td>67536</td>
</tr>
<tr>
<td>Crude oil running hours</td>
<td>12465</td>
</tr>
<tr>
<td>Distillate running hours</td>
<td>723</td>
</tr>
<tr>
<td>Number of starts</td>
<td>1095</td>
</tr>
<tr>
<td>Total MWh produced</td>
<td>1921620</td>
</tr>
</tbody>
</table>
Fuels that can be burnt in Iraqi Power Plants are the following ones:
- natural gas
- distillate oil
- crude oil
- light naphtha

and consequently a complex fuel system has been provided, to allow handling of the various fuels, taking into account that:
- natural gas and crude oil are the basic fuels with preference to the gas, the high availability of which is the reason for the low hours percentage on crude oil
- distillate fuel is a start-up and shut-down fuel
- light naphtha is an emergency fuel.

A third power plant (III), owned by Saudi Electricity Corporation is located in a site in the North of Saudi Arabia, and it is equipped with 5 TG 20 units, for a total site net output of about 125 MW at 46°C ambient temperature (703 mmHg ambient pressure), when firing crude oil.

A fourth power plant (IV) also owned by Saudi Electricity Corporation is located in a site in the South of Saudi Arabia. It is also equipped with 5 TG 20 units for a total site output of about 118 MW at 50°C (646 mmHg ambient pressure) when firing crude oil.

The ten units installed in Saudi Arabia were commissioned in 83/84. As of June 30, 1986, they have been in operation for base power generation a total of about 60,000 running hours. Most of this time has been on crude oil since distillate is used only for starting and shutdown. The generated power is about 600,000 MWh.

Detailed information is given in Table 2.

| TABLE 2 - OPERATION DATA (UP TO JUNE 30, 1986) |
|-----------------|-----------------|-----------------|
|                 | Plant III (5 units) | Plant IV (5 units) | TOTAL |
| Total running h. | 31075            | 30434            | 61509 |
| Crude oil running h. | 30295          | 29559            | 59854 |
| Distillate running h. | 778             | 877              | 1655  |
| Number of starts | 782              | 402              | 1184  |
| Total MWh produced | 268580           | 306705           | 575285 |

The analyses of the crude oils used in the above power plants are listed in Table 3 (for power plant I two different types of crude oil are used).

<table>
<thead>
<tr>
<th>TABLE 3 - CRUDE OIL ANALYSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>POWER PLANT</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Density at 15°C</td>
</tr>
<tr>
<td>Kin.viscosity at 40°C</td>
</tr>
<tr>
<td>Pour point</td>
</tr>
<tr>
<td>Vap press. at 50°C</td>
</tr>
<tr>
<td>Carbon residue</td>
</tr>
<tr>
<td>Water</td>
</tr>
<tr>
<td>Ash</td>
</tr>
<tr>
<td>Sulphur</td>
</tr>
<tr>
<td>Sodium plus potassium</td>
</tr>
<tr>
<td>Vanadium</td>
</tr>
<tr>
<td>Lower heating V.</td>
</tr>
<tr>
<td>Higher heating V.</td>
</tr>
</tbody>
</table>
IRAQ POWER PLANTS

Crude oil handling system
Crude oil is stored in a 5000 cu.m untreated tank, that feeds an electrostatic type crude oil treatment plant, its outlet being delivered alternatively to two 1000 cu.m certification tanks. Certified fuel is transferred to a 5000 cu.m treated crude oil tank. All crude oil tanks are floating roof type, to prevent vapour formation, and are provided with floating suction to take advantage of the crude oil settling in the tank. Drains are provided in the tank bottoms to remove water and solid particles. The four (respectively five) gas turbine units are fed by individual fuel lines, each one provided with a centrifugal type fuel forwarding pump and a fuel injection pump, the latter one common to all liquid fuels. A three-way valve system has been provided upstream of the injection pump to permit feeding of either distillate, light naphtha or crude oil as well as to secure reliable fuel change-over.

Unit fuel system
The unit injection pump is a special single shaft multi-impeller centrifugal type pump, suitable to handle the three kinds of liquid fuel. The pump can guarantee almost constant pressure with the flow rates required by the different specific gravities and calorific values of the fuels. The final fuel filter is a simplex HP paper cartridge type, degree of filtration 20 microns.

Downstream from the HP filter, additive addition is carried out when the unit is fired with crude oil, to prevent the corrosive effect of vanadium contained in the fuel. Fuel is equally distributed to the fuel nozzles by means of a flow divider. According to its characteristics the crude oil is not heated from the treated tank to the gas turbine. In case of an emergency shut-down of the gas turbine, when it is running on crude oil or light naphtha, fuel piping is flushed and filled with distillate oil. A centralized turbine blade water washing system is provided to periodically wash the additive deposits on turbine blades that could reduce unit performance.

Fuel treatment plant
In both Iraqi power stations crude oil is treated by electrostatic type fuel treatment plants. At Power Plant I, a two stage 50 cu.m/h treatment plant has been installed, designed for a nominal sodium plus potassium content in the crude up to 15 ppm, while at Power Plant II, being the nominal sodium plus potassium content up to 5 ppm, a single-stage treatment plant was provided, with the same nominal flowrate.

Nominal performance for both treatment plants is a sodium plus potassium content in crude oil at plant outlet not exceeding 0.5 ppm.

The treatment plant consists of three packages: a pumping module, a treatment module and a control room module. A simplified schematic diagram of the treatment plant is shown in Figure 1.

FIG. 1 SIMPLIFIED SCHEMATIC DIAGRAM OF FUEL TREATMENT PLANT

A Treated crude oil outlet
B Untreated crude oil flowback
C Condensate return
D Steam supply
E Untreated crude oil supply
F Process water supply
G Effluent water return

1 Crude oil pump
2 Crude oil heater
3 Two-stage electrostatic separator
4 Diverter valve
5 Water pump
6 Water recycle pump
7 Demulsifier tank
8 Corrosion inhibitor tank
9 Chemicals dosing pumps
The pumping module houses a duplex filter and two A.C. centrifugal pumps (one in operation, one as stand-by). The treatment module houses the vessel and all its auxiliaries.

First the untreated crude oil is heated by means of steam to a temperature around 50°C, to reach the optimized viscosity for the electrostatic process. Subsequently, fresh water is added to the crude oil and is mixed with it in order to dilute the water phase, that contains all the contaminants: water percentage has been optimized at about 5% of the crude oil flow rate. In Power Plant I fuel treatment plant, fresh water is added to the second stage and then pumped from a recycle water pump to the first stage in order to get the maximum efficiency at the final stage with a counter current flow effect. Inside the pressurized vessel, the electric field created by a high voltage transformer (short-circuit proof type), increases of thousands of times the phenomenon of water droplet coalescence, thus achieving a separation of the two phases:

- in the bottom of the vessel, water that contains almost all the sodium plus potassium previously dispersed in the fuel;
- at the top of the vessel, a water free crude oil.

A demulsifier is injected before each stage. The optimized dosage resulted to be around 20 to 25 ppm.

Since water quality utilized in the fuel treatment plant proved to be acceptable, the adoption of water corrosion inhibitor has not been necessary, although the plant was provided with a facility for that purpose. The crude oil treatment plant has always produced crude oil with a very good effluent quality (sodium + potassium below 0.2 ppm); the rather low sodium content at plant inlet did not permit verification of the performance of the plant in the full range of design conditions.

**Fuel additive addition plant**

The fuel additive addition plant consists of a tank, a circulation pump and two dosing pumps (one as stand-by). The former pump has the purpose of keeping the additive always in motion during crude oil running, thus preventing additive settling problems. For a certain period, vanadium content rose above the specified levels (21 ppm for Power Plant I, 26 ppm for Power Plant II) with peaks up to 40 ppm. As a temporary solution, the two dosing pumps were put both in operation, in parallel, and a replacement of the above pumps with others of bigger size was foreseen. To ensure an alarm in case of lack of additive flow, positively preventing crude oil operation without additive addition, a special flow switch has been developed and installed in the additive line just before the injection pump.

**Fuel oil analysis**

An on-line sodium monitor (flame photometer) installed inside the electrostatic fuel treatment plant control room, has the purpose of alarm in case of treatment plant malfunction, with consequent sodium content at plant outlet exceeding the limit value. Due to some problems encountered during its operation, it has been mainly used as an emergency back-up of the spectrometer analyzer described here below.

The spectrometer is installed in the Chemical Laboratory to detect the content in the crude oil of a number of metals, such as sodium, potassium, vanadium, iron, lead, etc. It has mainly been used to control the sodium and potassium content upstream and downstream of the fuel treatment plant, and the vanadium content, in order to select the additive dosage. The analyses are performed on a daily frequency, with the purpose of a strict and constant control of the quality of the crude oil samples taken from the certification tanks.

The fuel can be sent to the treated tank after crude oil analysis and certification only, and subsequently is available for burning in the gas turbines. In spite of its complexity, the spectrometer proved to be a precise and reliable analyzer and the good results in corrosion inhibition can be partly ascribed to its performance.
Crude oil handling system

Plant III is provided with six 5000 cu.m crude oil tanks, among which three are used for untreated and three for treated crude oil. Plant IV is provided with four tanks of the same size, two for untreated and two for treated crude oil. The design of the above tanks is very similar to that of Iraq Power Plants (floating roof type with floating suction and bottom drains). Furthermore, the tank system is arranged in order to allow further crude oil settling by adopting a handling procedure that causes the crude oil to be unloaded to a first tank while another tank feeds the fuel treatment plant after having undergone a certain settling time. The same applies to treated tanks. In both power plants, downstream from the treated crude oil tanks, a manifold is provided at the crude forwarding pumps inlet. The seven crude oil forwarding pumps, installed in parallel for the five units (two as stand-by), are of vertical barrel centrifugal type. The adoption of barrel type pumps was necessary due to the very high vapour pressure of the crude oil at the maximum ambient temperature.

The crude oil manifold supplies, near the units, five individual lines, where three-way valves for change-over with distillate are installed. Two distillate oil forwarding pumps are provided, each one sized for the overall power plant flowrate.

Unit fuel system

The unit fuel system is provided with an horizontal heat exchanger, of bundle extractable type, in order to increase crude oil temperature by means of steam at the optimized value for its "troubleless" firing into the unit, as hereinafter described. The unit fuel injection pump is the special multimpeller centrifugal pump already adopted in Iraq Power Plants. Downstream from the injection pump and the valve assembly, a final fuel filter is provided, of the paper cartridge type, with a 20 micron filtration degree. Downstream from said HP filter, on-line additive addition is performed by means of a system with different characteristics in the two power plants, because of specific tender requirements, as later on described. Fuel is then distributed to the nozzles by a flow divider of the same type as for plants I and II. Effective performance of flow divider has been the main problem during plant start-up. Another difference between the two power plants concerns the facilities provided to withstand the condition of emergency shut-down on crude oil. Plant III is provided with an automatic system for flushing the lines with distillate, while this procedure is carried out manually on plant IV.

Crude oil treatment plants.

In both plants III and IV crude oil is treated by centrifugal type crude oil treatment plants, that consist of two sections, each one sized for the nominal 100% capacity. At Power Plant III, each section is composed of a two stage 60 cu.m/h treatment plant designed for a nominal sodium plus potassium content in the crude oil up to 25 ppm, while at plant IV each section includes only one stage for a nominal sodium plus potassium content not exceeding 15 ppm (for other crude oil characteristics see table 3).

Nominal performance for both treatment plants is a sodium plus potassium content at plant outlet not exceeding 1 ppm. The centrifugal system has been selected for these power plants according to its very good results with light Saudi Arabia crude oil.

A schematic of the treatment plant installed at plant III is shown in Figure 2. The plant mainly consists of a pumping module, installed inside the pumphouse, and of the treatment skids, installed inside the treatment building, that is also provided with two separate rooms (respectively control room and chemical laboratory). The pumping module consists of coarse duplex filter, cartridge type, and two A.C. centrifugal pumps, vertical barrel type, 60 cu.m/h nominal flowrate (each one devoted to its own section, with possibility of interchangeability). Each treatment module consists mainly of steam heaters to bring the crude oil temperature up to about 50°C, and of the two stages of treatment, each one provided with six centrifuges.

The plant is provided with all facilities necessary for water washing, by addition of water quantities up to 5% of crude oil nominal flowrate, including water pumps and tanks, mixers and additive addition system, to prevent water and crude oil emulsion. Nevertheless, the crude oil characteristics (as per table 3) with very low values of density and viscosity and actual sodium content lower than the specification, have allowed adopting a dry centrifuging of the crude oil, without water injection. Each centrifuge is provided with a system for automatic sludge discharge at fixed intervals (ranging from 2 to 4 hours according to crude oil characteristics). Water removed from crude oil is then treated by a water treatment plant before being sent to sewage.
The two crude oil treatment plants in Saudi Arabia have always produced crude oil with very good effluent quality (sodium plus potassium content lower than 0.2 ppm) but (as also occurred in power plants I and II) the low levels of contaminants at plant inlet did not permit operation of the treatment plant at its limits.

fuel additive addition plant

Power plant III is provided with an additive addition plant similar to that of Iraq power plants, with a small local additive tank near each unit, one recirculation pump and two dosing pumps (one as stand-by). Manual control of additive flowrate according to vanadium content is provided, while there is no additive flowrate variation according to crude oil flowrate. Power Plant IV is on the other hand equipped with only one centralized additive storage tank of big size (35 cu.m), an additive circulation loop that feeds the five unit lines and only the two dosing pumps installed near the gas turbine. This latter system has proved to be more convenient for the client from the point of view of additive unloading and storage, and no malfunction was experienced because of the longer additive lines. Furthermore, the additive flowrate control is performed manually according to vanadium content and automatically according to crude oil flowrate, thus allowing additive consumption savings and reduced deposit rates.

The vanadium content in the crude oil according to the specifications was respectively lower than 17 ppm for Plant III and 20 ppm for Plant IV. The actual figures for both plants range between 12 and 15 ppm, being very constant during the time. A more sophisticated device for additive flow detection, if compared with the one installed in Iraq Power Plants, was successfully tested and consequently adopted in Plants III and IV; it consists of a flow switch provided with a counterweight that initiates the alarm as soon as the additive ceases to flow in the line.

fuel oil analysis

Plant III is provided with two on line sodium monitors (flame photometer type) of the same type as for Iraq plants, one for each treatment section.

Some precautions were taken in the design of the supply lines to the instrument, that increased its reliability with respect to experience in Plants I and II, although it was still lower than the laboratory spectrometer. Plant IV is on the other hand provided with one flame photometer common to both treatment sections. Both plants were also provided with laboratory spectrometers, of simpler operation compared to those provided in Iraq, programmed for analysis of 6 metals (sodium, potassium, vanadium, lead, calcium and magnesium).
The sodium plus potassium content always being very low, the main concern of this laboratory instrument was to control the vanadium in the crude oil and the proper magnesium versus vanadium ratio downstream the additive addition point. Analyses are performed at each truck unloading and twice a day at treatment plant outlet and turbine inlet.

EXPERIENCE ON FUEL OIL SYSTEMS

Power Plant I is capable of burning crude oil of two different types; a third type of crude oil is available at Power Plant II; another type of crude oil is available at Power Plants III and IV. Here below the main problems related to the crude oil characteristics encountered in the four Power Plants are summarized.

Vapour pressure

During the summer season, with extremely high ambient temperatures (around 50°C), in the power plant insufficient pressure was experienced at suction of gas turbine injection pumps and of fuel treatment plant feeding pumps. This was due to a combination of several factors: vapour pressure of the crude oil, low level in the tanks, dirty filter conditions, and fuel flow rates greater than the nominal ones. All these factors resulted in a too low NPSH available at pump suction, with consequent vapour formation and cavitation of the involved pumps. The problem was solved by means of modifications to the system, such as enlarging of suction piping, change of filtration degree of filters at pump suction and insertion of calibrated orifices to ensure the nominal flow rates. At power plants III and IV automatic vents on outlet piping from crude oil tanks were installed with satisfactory results.

Gas content in the crude oil

This phenomenon has been experienced in Power Plant II due to the fact that the crude oil well is extremely close to the gas turbine plant. The gas content created at first some problems, whose cause was erroneously attributed to the crude oil vapour pressure: the problem has been tackled by a more careful plant operation, with frequent filter cleaning and more prolonged crude oil settling in the tanks.

Flow dividers clogging

On both Saudi Arabia Power Plants flow divider clogging has been experienced on all units after 600-700 operating hours. That was caused by a consistent quantity of deposits settling at the wheels sides and tips and at the corresponding surfaces of the wheels chambers too. When the deposit thickness became greater than the mechanical gap, the increased friction decelerated the flow divider, causing its shut-down and the turbine trip by flame failure. From the results of the analysis carried out on the deposits collected from the different flow dividers, it appeared that deposits were made of an inorganic compound (about 40%) crude oil insoluble and of an organic asphaltene content practically oil soluble at 70°-80°C. The inorganic portion was rich in Magnesium salts, mainly carbonates, with Fe and Si also present in lower quantity.

It should be noted that the magnesium present in the additive was an oil-soluble organometallic compound (Mg-Alkyl-Sulphinate). The magnesium salts found in the flow divider deposits were due to this organo-metallic compound hydrolysis. As a matter of fact, the free water contained in the crude oil can break the organo-metallic bond and give origin to an organic compound, still oil soluble, and an inorganic compound rich in magnesium. The crude oil acidity could increase the hydrolysis reaction and the presence of anions, like carbonates and silicates, in the free water could also facilitate the magnesium precipitation. A possible explanation of the phenomenon is related to the solubility of water in the fuel in spite of good performance of centrifuging and fuel handling. In the crude oil supplied to both power stations the water content (about 500 ppm) is present at 20°C as 10% dissolved water and 90% free water. Since the water solubility is function of the temperature, it was decided to increase the fuel oil temperature at additive injection point from the previous 50°C (required by the crude oil viscosity), to about 70-75°C, to drastically reduce free water content in the crude oil and also to modify the velocity of chemical reactions, and consequently to avoid the additive hydrolysis. In addition, this temperature is near the melting point of the solid deposit. This action, in conjunction with the operation on distillate oil at unit start-up and shut-down for few minutes more than initially scheduled, has solved the problem. The flow dividers are now inspected, as a precaution, for a possible cleaning on the occasions of the planned inspections of the hot parts.

Fuel system components

The design of the crude oil tanks, as above indicated, proved to be fully satisfactory. The settling effect, ensured by the adoption of both floating roof and floating suction, contributed to reduce the sodium content at fuel treatment plant inlet, to very low levels.
The fuel filters operation has been trouble free, except for a few problems encountered during the initial start-up because of the already mentioned causes (crude oil high Reid vapour pressure, gas presence in crude oil and other particles like sand and iron oxides coming from the piping). No filter plugging has been experienced due to waxes and asphaltene. Concerning the latter, it must be pointed out that the crude oil heating required by the treatment plant has a beneficial effect on all the crude oil line downstream the above plant so that the final high pressure filter (20 microns) has never been plugged. Fiat previous experience on other plants demonstrated this degree of filtration to be effective to protect the downstream items (flow dividers, fuel nozzles) and to be unnecessary to use smaller degree filters that are subject to quick clogging.

The operation of flow divider has been trouble-free in Iraq (where there has been no heating at all) and in Saudi Arabia after increasing fuel oil temperature to 75°C. Another interesting fact experienced is that neither high pressure filter failures nor fuel nozzle coking occurred, thanks to the good atomization and the removal of the sludges in the centrifugal plant. Furthermore the flushing procedure adopted increased start-up reliability.

Change over between distillate and crude oil
Distillate has been used only as start-up and shut-down fuel during crude oil operation. Optimization of the change-over between the two fuels took a certain time due to the contamination of distillate with crude oil, during the initial fuel change-over: this was solved in Plants I and II by means of a reset of the timers regulating the operation of the three ways valves on fuel inlet and on fuel recycle line to the tanks. In Plants III and IV a pneumatic shut-off valve was installed on the distillate line downstream of the change-over three-way valve as an additional safety.

BEHAVIOUR OF GAS TURBINE ON CRUDE OIL FIRING
Experience on turbine blades
The experience gained after more than four years of operation in Iraq and two years in Saudi Arabia for more than 75,000 cumulative operating hours firing crude oil shows that it can be burnt by Fiat gas turbines without any corrosion problem. This remarkable result was achieved thanks to:
- the appropriate design of the fuel treatment plants, their operating behaviour and careful maintenance
- the appropriate selection of the gas turbines hot part materials and of their protective coatings.

As regards this latter aspect, it is worth mentioning that the units installed in the four Power Plants employ nickel base U500 investment casting first stage rotating blades and cobalt base X45 first and second stage stationary vanes. Rotating blades and stationary vanes are protected by a Platinum – Aluminide Coating. In order to obtain metal temperatures lower than the gas temperatures, both first and second stage stationary vanes, and first stage rotating blades are cooled by air bled from the axial compressor delivery and cooled by an external air-to-air fin-fan cooler. Metallographic analyses have been performed on the hot parts of various gas turbines at different operating hours. These controls showed no sign of corrosion due to sulphidation of vanadium attack, but only deposits of soft and friable nature on the blades and vanes surface due to the vanadium inhibitor.

Turbine deposits and effect on performance
The vanadium content encountered in the four Power Plants (always exceeding 25 ppm in Plants I and II and 10 ppm in Plants III and IV) made it necessary to perform a careful additive addition, usually in the Mg/V ratio 3:1, based on the maximum fuel flowrate (on the actual fuel flowrate in the power plant IV). Consequently deposits build up has been experienced. Therefore, on the average base of 700-800 (up to 1000 in the power station IV) operating hours on crude oil a hot parts washing is performed, injecting through the atomizing air system 3000-4000 liters of cold water. The system has proved to be very effective, to clean the combustor baskets and the turbine vanes and blades. As a matter of fact the deposits are very easily water soluble. Comparative tests showed in fact that some turbine inner parts could be cleaned by simple immersion in water for a short time. In the Plant I it was found said washing not to be necessary because of the self spalling of additive deposits due to very frequent start-up and shut down of the units. The effectiveness of water washing allows maintaining the units performance also during base crude oil operation.

Reliability of the power plants
Thanks to the careful design and attention to all previously mentioned aspects it was achieved a very good availability/reliability on the power plants when burning crude oil, as shown on Table 4. (Due to low hour percentage on crude oil of Power Stations I and II, only the data applying to the Power Stations III and IV are reported).
We have therefore acquired from the design and operation on crude oil of the above Power Stations, beside other units, a widely positive experience that strengthens our firm opinion that it is necessary to tailor the fuel handling, treatment, additive addition and turbine systems according to the actual crude oil characteristics.

### Table 4

<table>
<thead>
<tr>
<th>Plant</th>
<th>Plant III</th>
<th>Plant IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL HOURS</strong></td>
<td>58650</td>
<td>69278</td>
</tr>
<tr>
<td><strong>RUNNING HOURS</strong></td>
<td>31073</td>
<td>30516</td>
</tr>
<tr>
<td><strong>AVAILABLE NOT RUNNING HOURS</strong></td>
<td>20579</td>
<td>30194</td>
</tr>
<tr>
<td><strong>SCHED. MAINTEN. UNAVAIL. H.</strong></td>
<td>6622</td>
<td>8128</td>
</tr>
<tr>
<td><strong>TOTAL AVAILAB.</strong></td>
<td>51652</td>
<td>60710</td>
</tr>
<tr>
<td><strong>FORCED UNAVAILAB. HOURS</strong></td>
<td>376</td>
<td>440</td>
</tr>
<tr>
<td><strong>TOTAL RELIAB.</strong></td>
<td>58274</td>
<td>68838</td>
</tr>
</tbody>
</table>

0.6% 0.6% 99.4% 99.4%