Assessment of the Modifications in the Fuel Oil System of Khartoum North Power Station to Suit the Waxy Sudanese Fuel Oil (Unloading Area, Storage Tanks & Delivery System)

A Thesis submitted in Partial Fulfillment for the Degree of Master of Science in Power System Engineering

By:
Omer Mohammed Abdelaziz Taha

Supervised By:
Dr. Mohammed Ahmed Abdelbagi Siraj

University of Khartoum
Faculty of Engineering & Architecture
Department of Electrical & Electronic Engineering

July 2005
الآية القرانية

قليلاً إلّا العلم من أوّتِمُ وَمَا رَبِّي أَمَرَ مِنَ الرَّوحِ ْقُلِ الرَّوحُ عِنۡدَكَ وَيَسِّئُلُونَكَ (٨٥) الآية الإسراء، السورة ٨٥
DEDICATION

I would like to present my research as a present to the souls of my mother and my brother Faisal Mohammed Abdelaziz, to my father to my wife, and to my second mother Awadia Alyass, and to my brothers and sisters, and finally to everyone who loves me.
ACKNOWLEDGEMENTS

After saying thanks for god, I would like to express about my gratitude and acknowledgement to my supervisor, Dr. Mohammed Ahmed abdelbagi suraj for his patient supervision, which guide and assist me in my research. I am deeply grateful to him for all his help.

I am particularly indebted to national electricity corporation and the family of Khartoum north power station for the preparation of the necessary data and information needed for this research.

Sincere thanks are due to the family of Alzaiem Alazhari University especially Dr. Altayeb Ibrehim Altayib the dean of the faculty of engineering for his follow up and his assistance.
I am also grateful to Dr. Abdelrahman Karar the co-ordinate of power generation course for his useful time he paid in supplying the graduates with all information they need.

Especial thanks are due to my friends Osman Ahmed and Alsadig Fikry and Howiada Hashim for all what they did to me during my study.
ABSTRACT

The work presented in this research consists of assessment and analysis for some of the operational problems that appear in Khartoum north power station after using the waxy Sudanese fuel oil instead of the imported fuel oil (bunker c) power station design fuel oil.

The main problem associated with the Sudanese fuel oil is its relative high wax content, which raises its pour point and consequently generates problems in unloading process, storage and delivery in side the plant.

So this research is divided into three parts, the first part deal with the unloading area problems, the second with the storage tanks problems and the last deals with delivery system problems. The adopted solutions were assessed and discussed. Moreover, further solutions were suggested to improve the situation. Negative side effects resulted from the application of some of these solutions were also discussed and assessed.
خلاصة

يحتوي هذا البحث على تقييم وتحليل لبعض المشاكل التشغيلية الناتجة عن استخدام زيت الوقود السودانى في محطة الخرطوم بحرى الحرارية لإنتاج القدرة الكهربائية، بديلًا عن زيت الوقود المستورد الذي صممت المحطة لتعمل به.

وقد تعرضنا في هذا البحث تحديداً للمشاكل الناتجة عن ارتفاع نسبة الشمع في زيت الوقود السوداني، الشيء الذي يجعله غير قابل للانسكاب إلا في درجات الحرارة المرتفعة، مما يولد مشاكل في عمليات التفريغ والتخزين والمناولة.

وقد قمنا بتسليط الاهتمام على ثلاثة أجزاء، بحيث استعرضنا في الجزء الأول المشاكل في منطقة تفريغ الزيوت، ثم المشاكل في منطقة خزانات الوقود، وأخيراً المشاكل الناتجة في منطقة مضخات المناولة. كما استعرضنا بعض الحلول التي تم تطبيقها محاولةً تشخيص أثر تطبيق هذه الحلول وتحديد المشاكل التي لم يتم حلها على الكفاءة الحرارية والأداء لمحطة الخرطوم بحرى الحرارية لإنتاج القدرة الكهربائية.
Chapter one

INTRODUCTION:

The national electricity corporation (NEC) generates electricity from hydro and thermal power sources. Generally the thermal power plant contributes with more than 65 %. This contribution may rise during the autumn up to 85 %. During the winter the share of the thermal power drops to about 30 % of the total power generated for the main grid. This is because of the fact that the summer power generation from hydro source is negatively affected by the Blue Nile flood.

Khartoum North steam power plant (KNPS) contributes with about 20 % to the total grid power in the Sudan. It was constructed mainly to balance the deficiency in the hydropower generation during the flood seasons, and shutdown periods. KNPS was constructed in two phases: phase 1; which consists of two units each generating 30 MW, and phase 2; which comprises also two units, but each generates 60 MW of electric power. Fig. (1-1) shows the schematic diagram for these two phases.

The fuel oil system of the KNPS was designed for heavy fuel oil of bunker "C" type according to the British standard. This fuel was supposed to be produced in Kosti refinery, which was planned
to process Sudanese crude oils. The preliminary characteristics of discovered Sudanese crude oil were proved to be different from those for which the refinery was designed. The fuel oil had been produced since the nineties has the advantage of low percentages of sulfur, vanadium, and sodium, yet its wax content is relatively high. For economical reasons the Sudanese fuel oil is to be used instead of bunker "C", which was originally been imported for KNPS.

The Sudanese crude oil is a paraffin based oil, therefore it contains relatively large amount of paraffin wax (10 – 20%). This relatively high wax content in the fuel oil raises its pour point. This in turn leads to handling problems during transportation, unloading, and storage of the fuel oil. Modifications have been made in the KNPS fuel oil system to cope with the new specifications of the Sudanese fuel oil. The transportation and handling means were also changed to overcome these problems, and to maintain the same original performance.

The objective of this study is to assess the modifications that have been made in the fuel oil handling system of KNPS to suit the waxy Sudanese fuel oil during unloading, storage, and supply to the boiler burners system.
Chapter Two

PROBLEM FORMULATION:

For economical and strategically reasons a decision was taken by the Sudanese government to use the Sudanese fuel oil instead of the bunker "C" (Power station design fuel). Since then KNPS faces a lot of problems due to the vast differences in the specifications of the two fuel oils. The characteristics features of the Sudanese fuel oil are high wax content, non-distinctive partial refined oil products, variation in type, and relatively considerable sediments content. These characteristics make its usage impossible without necessary changes in the modes of transportation to the plant and handling inside the plant. Fuel oil transport trucks and railway tankers are equipped with steam heating coils to heat up their contents prior to and during pumping the fuel oil into storage tanks through pipes at KNPS. Heating liquefies the wax and decreases its
viscosity, hence facilitates oil pumping and prevents solidification inside the pipes.

Due to its relatively high wax content, the fuel oil temperature should be raised up to 60 °C, during unloading from the road and railway tankers. The inadequate command of the heating process during unloading and the elementary design of heating coil and its connecting manifolds do not secure proper heat distribution inside the road or railway tankers nor supplying heat with necessary rates to unload those containers. It may take up to 8 hours in winter to unload 20 ton of fuel oil, showing a potentially deficient non-optimizes fuel oil heating process during unloading. Local excessive heating may increase the temperature of the fuel oil up to near its flash point, which again depicts a non-optimized heating process.

The rough and improper handling of the fuel oil during unloading of road and railway tankers results in a dirty oil contaminated delivery yard.

Fuel oil filters need to be cleaned and changed more frequently than before due to the relatively high contamination content in the Sudanese fuel oil; this increases the maintenance cost and makes filter complete blockage sometimes possible, especially when unloading some types of fuel oil having high sediment contents.

After being unloaded, the fuel oil is pumped later from storage tanks to the boilers house. This necessitates also heating up the fuel oil to facilitate its pumping. Again the adverse characteristics of the Sudanese fuel oil lead to intensive drops in
pump efficiencies and causes pump wear. Pumps should be frequently maintained, repaired or even discarded.

The irregular supply of fuel oil throughout the year, and the intensive handling problem of the fuel oil during the relatively cold winter necessitate making good stocks of fuel oil during summer, and hence large capacity storage tanks are required for continuous power generation in the station. Unfortunately, the storage tanks capacity could not be fully utilized due to the heavy sludge formed inside them. Smooth and easy further pumping to the inside boiler house also demands comprehensive command of the heating process inside the storage tanks. The variation in the specifications of the fuel oil supplied together with the relatively high wax content result in layers building of different fuel oil species inside the tanks, this also adds to the persistent pumping problems.

The above-mentioned problems affected and are still affecting the performance of the KNPS negatively; they lower its overall efficiency by using steam with relatively high rates during the unloading and handling the fuel oil inside the plant. An unnecessary additional intensive work in the station for unloading of the fuel oil has also been created. Moreover, a quick smooth self-restart of the power station is made difficult if not impossible.

Great efforts have been made to solve these problems, and many suggestions and modifications in the fuel oil system have been introduced without commanding fully the drawbacks and negative side effects resulted from the application of these solutions for the waxy Sudanese fuel oil usage.
Chapter Three

LITERATURE REVIEW:

As mentioned before, the major problem associated with the Sudanese fuel oil is its high wax content, which consequently affects in transportation, unloading points, flow in pipes, and combustion in boiler. It is clearly understood that two options required immediate attention; either adjusting the fuel oil specifications to suit operational standards, or modify the end user processes to be operable with the present fluctuating specifications.
The following modifications and suggestions have been adopted in the fuel oil system of KNPS as a result of the relevant studies carried out by ALSTOM combustion service limited, ASEA BROWN BOVERI (ABB), and NEC in collaboration with the University of Khartoum.

Modifications had been made to the fuel oil system in KNPS in its three main area, namely, unloading area, storage tanks farm area, and forwarding pumps and heating area. A schematic diagram for the three main problematic areas is shown in Fig. (3-1).

3.1 UNLOADING AREA:

Fuel oil unloading area is the area where the supplied fuel oil is unloaded. Fig. (3–2) shows the schematic diagram of the unloading area. This area consists of 38 unloading points as follows:

- 20 unloading points from railway lines.
- 6 unloading points from road tanker line phase 1.
- 12 unloading points from road tanker line phase2.

The manpower of the unloading area is composed of 18 labors, adopting shift system (3 persons per shift), under the responsibility of the Operation Shift Charged Engineers.

The labors of unloading area in charge of heating, delivering the fuel oil, cleaning the unloading area, checking the sumps, and checking the whole system from the unloading lines to the fuel oil tanks.
3.2 STORAGE TANK FARM AREA:

The fuel oil storage tanks farm is the area where the fuel oil is stored for the daily or future use, Fig. (3-3) shows the schematic diagram of the tank farm areas. The two areas are similar. Each one serves two boilers or one phase with the possibility of change over. the two storage tanks are contained with in a rectangular retaining wall with 125 m long by 68 m wide, measured from wall crown to crown in each case, the majority of this wall is earth with slope of approximately 30º , giving a wall height of about 4.1 m with 1 m wide wall way along the crown. Midway along the east wall the earth is replaced by reinforced concrete wall to enable pipe work to and from the storage tanks to the forwarding pumps.

Fuel oil storage tanks are vertical cylindrical cone roof tanks. The tanks are 42 m diameter and 15.3 m high giving a gross capacity of 21200 m³, and working volume of approximately 20800 m³. The tanks are fabricated from carbon steel plate. The tank shell consists of 8 courses of plates ranging in thickness from 22 mm at the bottom to 8 mm at the top. The roof is self supporting and consists of radial trusses supporting plates of thickness 7 mm. The tanks design conditions are 60 ºC and 7.5 n barg pressure / 2.5 n barg vacuum. [1].

Tanks heater has a length of 1500 meters of 40 mm N.Bsch 60 serpentine coil, split into 12 sections. The maximum pipe length in each section is restricted to 150 meter to avoid condensate blanking. These coils are sized to raise the temperature of the fuel oil
by 0.2 °C/hr, which would require a steam flow of approximately 3500 kg/hr. [1].

3.3 DELIVERY SYSTEM:

There are also two forwarding pump areas each one serves one phase. The main components of these areas are the forwarding pumps, filters, the seam and the electric heaters, regulators, and many valves. Fig. (3-4a) & Fig. (3-4b) shows the schematic diagram of the delivery system. The old centrifugal fuel oil pumps have been replaced by screw type pumps to pump efficiently the hot and low viscosity fuel oil. All filters are changed with self cleaned filters. [1].

From each generation unit, some part of the steam is taken for the auxiliaries, e.g. the turbine condenser vacuum ejectors and fuel oil heating processes. The part needed for the heating of the Sudanese fuel oil has been increased in the last three years, especially in the unloading area, and the storage tanks farm. Fig. (3-2) shows the schematic diagram for the unloading area with auxiliary steam supply. The steam used for the fuel oil heating in the unloading area and storage tanks has a flow rate of 6 kg/s, it's about 6% of the total steam generated in the plant. [1].

To increases the unloading rate of the fuel oil, all road tankers and railway tankers should be equipped with internal steam coils. Auxiliary steam at 6 bar pressure and 220 °C temperature is used for indirect heating processes. [1].
In order to overcome the non-homogeneity of the fuel oil in the storage tanks due to the differences in patches delivered to KNPS the following mixing mechanisms are suggested:

- Pumping the fuel oil from the bottom to the top of the tank Fig. (3-5).
- Pumping the fuel from two different levels inside the tank through heater to the top of the tank Fig. (3 - 6).
- Using mixer inside the tank to mix the fuel oil. [2]

To decrease the heat losses from the fuel oil pipe line to the atmosphere an electrical trace heating is used. A cleaning mechanism using diesel oil is also suggested to clean the pipe line from the sediments and frozen wax of fuel oil. The cleaning cycle consists mainly of diesel tank; a pump, and filters, Diesel oil is pumped from the tank through a pipe line while both fuel oil tank outlet valve and the fuel oil pump suction valve are closed. A filter separates fuel oil from the diesel oil and allows diesel oil to collect in the diesel tank to be used again for cleaning processes. After finishing a cleaning process both the diesel oil pump delivery valve and tank inlet valve are closed. [3].

The high of many asphaltic crude oils and the high pour points of many waxy crude oils present significant problems in their transportation over long distances by pipeline and tanker. While heating the oils and insulating the pipelines will help alleviate the problem, there is danger associated with an extended shutdown of flow and either congealing or solidification of the oil. Possible
solutions which have been studied in the laboratory are the emulsification or dispersion of the oil in the water or brine so that shear takes place in the continuous aqueous phase rather than the oil droplets or particles.[4].

All the above mentioned scenarios are attempts solve the problems rises from using of Sudanese fuel oil in KNPS. It is obviously clear that all the above solutions did not overcome all problems. Moreover, the application of some of these solutions generates new problems in KNPS. Therefore the assessment of all those previous solutions is important if not essential.
Chapter four

PLANT DESCRIPTION:

KNPS is designed to burn heavy fuel oil, imported either by rail tankers or road tankers both of which are steam heated in the unloading area to facilitate the flow of fuel oil and then unloaded by pumps into the storage tanks.

Fuel oil is drawn from the storage tanks, via steam outflow heaters, by forwarding pumps which deliver the oil to the steam raising boilers. An electric outflow heater is provided for start up when no steam is available.
The major components of the fuel handling system and their functions are summarized below.

4.1 FUEL OIL UNLOADING RAIL SIDING:

These are located along the western edge of the site. Two sidings equipped with piping manifolds, for fuel oil, heating steam, and condensate is provided. Connection on each manifold allow for maximum of 10 rail tankers per siding. There is space available for two further sidings, and run-around track. Those rail sidings are constructed in accordance with Sudan rail requirements. Each siding is approximately 143m long and consists of a reinforced concrete plate form sloping towards a channel between each pair of rails. The two channels connect to the rail siding sump.

Between the two sidings there are dual fuel oil, steam, and condensate pipes with connections for the rail tankers. The two fuel oil pipes have a diameter of 250 mm, with 10 branches for coupling to the rail tankers. These branches are arranged in 13.36 m apart to suit the length of the average rail tanker.

Twenty fuel oil, steam, and condensate hoses are provided for connections to the rail tankers on each siding. The steam and condensate hoses are of wire reinforced rubber, 4 m long, 25 mm nominal size. Each end is fitted with a carbon steal flange. The fuel oil hoses are of tensile reinforced oil-resistant rubber, and incorporate on anti-static wire. Each hose is 4 meters long, 100 mm
size; and fitted with a carbon steel flange for connection to the pipe work, and 4.5 inch thread coupling to suit the rail tanker outlet.

There are a number of sizes of fuel oil rail tanker in use with the net tonnage for heavy fuel oil ranges from 27 to 34 ton nominal.

4.2 FUEL OIL UNLOADING PUMP:

Fuel oil from the unloading area is pumped to the fuel oil storage tanks via 4 pumps 25 m³/hr per each, as required. Each pump is mounted on a unit tray with associated inlet and outlet isolation valves and an inlet filter. Between the inlet isolation valve and the filter a bellow assembly is provided to allow movement due to thermal expansion in the inlet supply heater.

The pump suction filter is a "plenty" simplex type with a 20 mesh basket. The pumps type are screw type complete with 12.5 KW motor.

Two motor-driven screw pumps are provided to discharge oil from the tankers to the fuel oil storage tanks. Each pump may draw from either siding. The pumps are provided with duplex suction strainers. Each pump is rated for 133 m³/hr at 46.4 m differential head. The two pumps are located on a plinth adjacent to the sidings, which also supports the suction strainers and fuel oil flow meters. The plinth is protected by a sunshade.

Fuel unloading pumps are positive displacement, twin-screw type pumps, of cast iron construction, and driven by 55 KW motors.
Each pump is protected by a full pressure unloading valve, which is integral with the pump. The pressure setting is adjustable.

4.3 FUEL OIL PIPE WORK:

Fuel oil pipe lines 250 mm diameter, from the manifolds between the rails sidings pass through a culvert beneath the eastern siding to fuel oil unloading pumps via duplex suction strainers. Fuel oil pipe work and valves are of carbon steel. Fig. (4-1) shows the schematic diagram for the pipes connecting the unloading area with the storage tanks farm. Pipe work design conditions are 10 barg at 75 °C, with a 1.5 mm corrosion allowance.

Fuel oil pipe work is electrically trace heated and insulated to prevent the oil becoming cool, viscous, and therefore difficult to pump.

Fuel oil pipe work is sized for the fuel oil unloading pumps; each rated at 133 m³/hr. The corresponding velocity in the 200 mm discharge lines is 1to 2 m/s. The suction line is 250 mm to minimize pump suction pressure drop. It must be emphasized that satisfactory operation of fuel oil unloading pump depend on an adequate fuel oil temperature, and the usage of trace heating.

4.4 STEAM & CONDENSATE PIPE WORK:

Steam at a nominal 6 barg, saturated, is supplied to the unloading area via pipe with a diameter 150 mm. This line follows
the route of the fuel oil lines 200 mm diameter. The size of steam pipe work is based on a maximum flow of 3500 kg/hr of steam to the unloading area.

Steam condensate pipe work in the unloading area is limited to the twin headers of diameter 40 mm, which slope towards the outlet to the oily water collection system; and fuel oil unloading pump seal outlets.

Steam and condensate pipe work is of carbon steel. Pipe work design conditions are 20 barg at 215 ºC, with 1.5 mm corrosion allowance. Steam and condensate pipe work is insulated for heat conservation and personnel protection.

Steam traps are provided at intervals along the steam lines to dispose of condensate, which chiefly occurs during the startup warming of the pipe.

Electric trace heating of the fuel oil pipes, from the unloading points to the storage tanks farm, and from the storage tanks farm to the forwarding pumps, and from the forwarding pumps to the boiler oil burners, has been provided. The trace heating has been designed to maintain the fuel oil lines at the correct operating temperature, providing the ambient temperature does not fall below +5 ºC; the correct operating temperature varies between 40 ºC and 75 ºC depending upon the line.

4.5 FUEL OIL STORAGE TANKS:
Fuel oil storage tanks are vertical cylindrical cone roof tanks. Storage tanks are 42 m diameter and 15.3 meter high, giving a gross volume 21200 m³ and working volume of approximately 20800 m³.

The tanks are site fabricated from carbon steel plate, and have a corrosion allowance of 2 mm. The tank shell consists of 8 courses of plate ranging in thickness from 22 mm at the bottom to 8 mm at the top. The tank floor consists of a 500 mm wide by 13 mm thick margin plate. With remainder of the floor from 9 mm plate.

The roof is self supporting and consists of radial trusses supporting 7 mm thick plate.

Tank design conditions are 60 ºC and 7.5 m barg pressure/2.5 m barg vacuum (excluding static heat of oil). Access to the top of the tanks is by spiral stair case.

Tank heater is in the form of 1500 meter of 40 mm N.B.Sch 60 serpentine coil, split into 12 sections. The maximum pipe length in each suction is 150 m to avoid condensate blanking. The tank coils are sized to raise the temperature of 20 000 m3 of fuel oil by 0.2 ºC/hr, which would require a steam flow of approximately 3500 kg/hr.

Steam outflow heaters and electric heaters are fitted through nozzles in storage tank wall. The vent pipe of the storage tank is protected by a wire cage. The drain nozzle of the storage tank is located in a boot in the tank floor.

4.6 FUEL OIL FORWARDING PUMPS:
Two fuel oil forwarding pumps are provided to supply fuel oil from fuel oil storage tanks to the boilers. Each pump is rated for 25 m3/hr at 69.1 m differential head.

Each pump is capable of supplying both boilers. The required oil flow depends on the grade of the fuel (since the calorific value changes with grade). The rated capacity of forwarding pump is approximately 130% of the flow requirement for both boilers.

The pumps are mounted on a plinth adjacent to the east bund wall of storage tanks. The plinth also supports the suction strainers; fuel oil flow transmitters, fuel oil spillback valves, and auxiliary steam preserve letdown station. It is protected by a sunshade.

Fuel oil forwarding pumps are positive displacement, twin screw type pumps of similar construction of fuel unloading pumps. Nominal pumping temperature for 3500 sec Redwood oil viscosity is 45 ºC. Care should be taken to ensure that this oil temperature is maintained to avoid overload in fuel oil forwarding pump motors, and a proportionately higher temperature is required for heavier, i.e. more viscosive, grads of oil.

4.7 ELECTRICAL OUTFLOW HEATER:

Heater is arranged to permit recirculation of heavy fuel oil at 20 ton/hr. Cold oil will initially enter the heater at a maximum temperature of 20 ºC and flow rate of 4.7 ton/hr. The final outlet temperature will be minimised at a maximum of 55 ºC.
The heating elements are arranged in 3 banks, 2 at 25.2 KW and 1 at 37.8 KW. Each heater bank has an individual adjustable control thermostat phase one common adjustable over temperature thermostat.

The electric live heater will only be used on cold boiler starting when there is insufficient auxiliary steam available to operate the tank steam heater, and when the tank contents are below 45 °C.

The steam outflow heater is sized to rise the temperature of 40 ton/hr of heavy fuel oil from 45 °C to 55 °C with steam supplied at 9 bar.

4.8 INTERCEPTOR AND CLEAN DRAIN:

During the unloading there is a considerable amount of fuel oil drops on the ground as a result of bad fuel oil handling and non-homogeneity of heating. This fuel oil is collected into two trenches to the two interceptor sumps one for each phase. In which there are two pumps to pump the fuel oil to the storage tanks, before this fuel oil is collected in the interceptor to separate the fuel oil from water depending on the difference in density between fuel oil and water, fuel oil is pumped again to the storage tanks and water is drained to the clean drain and then to the river. Fig. (4-2) shows schematic diagram for the fuel oil and water cycle from unloading area to the storage tank and river.
Chapter Five

PROBLEMS IN USING WAXY FUEL OIL IN KNPS:

As a result of using the Sudanese fuel oil in KNPS problems rises in fuel oil unloading and storing and delivery in the plant, these problems can be summarized as follow:

5.1 UNLOADING AREA PROBLEMS:

1- Heating process: In which the temperature should be raised to (60 – 70) °C which require unloading time of (6 -4) hour too long unloading time.

2- Railway tankers are not equipped with steam trap to condensate the steam to be used again in the plant, to decrease the steam consumption.

3- Road tankers are not equipped with internal heating coil which led to the direct heating process which causes increase in steam consumption, water formation in the storage tanks, waste of the fuel oil by overflow, contamination of the unloading area with the fuel
oil, decreases the safety environment for the labor, increases the consumption of the hoses and flanges and the cost of maintenance.

4- Filters blockage due to frozen wax and sediments which causes many frequencies of cleaning and consumption of cleaning material, and high consumption of spare part.

5- Interceptor problems: These sumps are open to atmosphere which causes dust and sediment in the fuel oil.

6- Pumps problems: problems in pumps can be summarized in:

   - Low viscosity of fuel oil due to high temperature lowered the volumetric efficiency of the pump which increases the unloading time.

   - High temperature of the fuel oil causes pump wear due to the low viscosity and high temperature of fuel oil.

   - Interceptor pumps consist of rubber layer inside it which expanded due to heating which finally lead to the decrease in pump overall efficiency.

      - Heavy wear in the pump due to the sediment content in the fuel oil, resulting in low flow rate and low boiler output.

      - Occasional pump cavitations due to high temperature of fuel oil.

7- The pipeline problems:

   - All pipes are trace heated with electric coil rise the temperature to 45 °C but the required is 60 °C, which require high consumption of electrical power.

   - Water In the fuel oil causes pipe wear and decreases its life time, water formation is from the direct heating of the fuel oil.
- Turbulent flow of the fuel oil in the pipe, due to the boiling fuel oil.
- Fuel oil hoses and pipe line blockage due to the wax frozen.

8- Heating coils in some road tankers are not well designed some of them cover small space in the tanker and the other have a height from the bottom of the tanker. This increases the unpumpable mass of the fuel oil.

9- Rail tankers unloading pipes have T shape under the rail tanker which is far from the heating coil therefore it’s always blocked with the waxy fuel oil. Also its safety valve hand wheel at the top of the rail tanker connected to the safety valve at the bottom of the rail tanker with a rod, so fail to open more frequent. Fig. (5-1) shows cross section for a rail tanker.

5.2 STORAGE TANKS PROBLEMS:

1- Due to differences in specification of the fuel oil from one batch to another different density layers are build in the storage tank for fuel oil and water layer from the direct heating.

2- Heating in storage tank not enough to heat up all the fuel oil in the tank. Only the forwarding pumps is pumping form the heated side of the tank which change the surface profile of the tank, and led to wrong dipping measurement of fuel oil stock.
3- Water in the tank cause tank wall wear. Water formation in the tank is due to direct heating in the road tankers, water contamination on site from sump recovery, tank heater leaks and the atmosphere.

4- Precipitation of sediments and sand inside the tank increase the unpumpable height of the storage tank to more than 1.5 m height, so the storage tank capacity can not be fully utilize.

5- Water layer formation in the storage tank causes pressure drop in the fuel oil pressure which causes boiler trip with fuel oil pressure low, which cause immediately unit trip.

6- Proximity of pour point to flash point makes close monitoring of fuel oil storage and system temperature necessary to avoid hazardous conditions at storage tanks.

7- Mixing of fuel oils from different fields can cause precipitation of sludge inside the storage tanks.

5.3 DELIVERY SYSTEM PROBLEMS:

1- All the three high pressure oil pumps on phase 1 (both units 1&2) were said to be in poor condition.

2- Maximum outlet pressure was 24 bar instead of the design 38 barg.

3- All the three pumps on each unit were running where only two should have been necessary.

4- The load on the units was alleged to be restricted because of the pumps failure to deliver the required pressure.
5- The first pump revealed wear on the idler screws consistent with an abrasive present in the fuel oil.

6- There is bruising on the main pumps screw possibly caused by cavitations.

7- The reading of the fuel oil forwarding pumps suction pressure gauge not true, because of duplex filter lying between this gauge and the pump.

8- The duplex filters have 100 mesh baskets fitted and across each filter unit a differential pressure gauge is connected, the gauges on both filter units do not work, so there is no telling when the filter requires cleaning.

9- Several of the filter baskets were damaged.

10- For its high wax content, the fuel oil need to be stored at 55 ºC, which was sufficient to keep it flowing. This was more by luck than judgment as the tanks has no mat heaters working and the outflow heater temperature controls have long since failed.

11- On phase 2 units there is only one set of pumps. These are located in the forwarding area and draw oil from the storage tanks, discharge through stand alone heaters and then straight to the boiler front. The original twin screw pumps have suffered a similar fate to the phases 1 system. One pump has been replaced by a centrifugal pump.
12- The pressure gauge associated with the fuel oil system need calibration immediately; there would not be half the problems with the fuel oil system if the instrumentation was working correctly.
Chapter six

SOLUTIONS AND SUGGESTIONS:

The following solutions and suggestions are advised to solve the problems in using the waxy Sudanese fuel oil and to improve the situation, they can be summarized in the three problematic areas as following:

6.1 UNLOADING AREA:
1- Make it a rule to check the coming road tankers before they enter the power station and to refuse those, which arrive to the delivery point without steam coils.

2- Avoid heating the road tankers from the top to avoid overflows.

3- Provide road tankers with efficient steam heating coils. The suggested construction for the steam heating coil of 3 inches is shown in the Fig. (6-1) with steam trap.

4- Fix steam trap at the steam exhaust pipe for both road tankers and rail tankers.

5- Flour around rail way should be leveled and made with concrete and cement.

6- Trenches for west and east lines should be heated with steam pipes extended as the trench length.

7- A barrel must be placed under each unloading valve (rail tanker and road tanker) in order to keep the unloading area clean.

8- When venting the pump, the trenches should be drained to avoid accumulation of solidified fuel in the system leading to the pumps. Install trace heating in the trenches.

9- Install new self-clean rotary filters to reduce wear on the pumps and sludge formation in the storage tanks. The filters should be of larger capacity to reduce oil pressure loss to the forwarding pumps and burners. And should be hand operated. The rotary filter will facilitate the removing of sediment.
10- Interceptor sumps should be covered to prevent dust and sand contaminates the fuel oil.

11- Find a system to remove the fuel from the hoses after delivery, without putting it on the ground: the half-barrels could be a good idea.

12- Contract should be done not only to put sand on the spread fuel oil, but also to remove all of it from the area of unloading and to improve the cleaning of the area. Have strong requests face to the contractor regarding the expected results (of course if we suppose there is no more spread of fuel oil).

STORAGE TANK:  6.2

1- The In view of the varying type of fuel, it will be advisable to check the oil viscosity and pour point of the oil after every delivery, especially if it is thought that the oil has changed. Also the problem of the differences in patches of the fuel oil delivered to KNPS, this can only be solved by a new contract with refinery Companies to adjust all fuel oil specifications, according to the requirements of NEC.

2- The bottom steam heater should be used effectively, not only purely using the heater at the exit of the tank.

3- There is always water in the bottom of fuel oil tanks and this is normally drained off, perhaps once every two weeks
via the manual tank drain valve. Sediment is normally removed during tank cleaning every few years.

4- The existing steam heater coils should be fitted with steam temperature control valves and manual bypasses fed with low pressure, near saturated steam. The outlet from each heater section should be fitted with steam traps, again with manual bypasses, and lead to drain. This steam mat heater will maintain the whole tank fluid. It will not be necessary to lag the tank since on the waxy or heavier oils, which require this type of heating, a solid layer will form around the tank walls, thus reducing heat losses.

5- Steam control on this size of tank should be from a multipoint measuring system. However, in order to minimize costs, we would propose utilizing several self acting steam control valves with capillary sensors fitted around the tank to ensure that the heating was widespread.

6- The actual tank heater is sized for 3600 hg/hr steam flow. This is the mount necessary to raise the tank temperature from cold. A steam flow of approximately 1500kg/hr should be used to maintain the tank contents at a temperature of up to 55 °C.

7- At present we understand that the bulk of the tank is maintained at around 35 dg C. We would recommend increasing the tank temperature to approximately 50/55 deg C, depending upon the oil stored. This setting will avoid continual adjustment of the tank temperature and will drive off some of the light fractions present in the lighter oils. This will tend to reduce the gassing currently experienced on the unit when firing this type of oil.
1- Trace heating: Improve electric tracing around existing filters and pumps. The trace heating should be up rated to maintain 55 °C in the lines instead of the current 40 to 49 °C. Items such as the pumps, flow meters and filters should be wrapped with more turns of heating tape than at present or fitted with heating pads to increase the body temperature and prevent waxing or pump cavitations. The tracing should also be switched on at least a day before start up of the system following any cold shut down. Both tracing and installation should be extensive, thorough and manufactured to a recognized accredited standard when handling a high pour point oil, due to the wax content.

2- It has been shown that the fuel currently used at KNPS requires a new pumping system. In view of this, the opportunity has been taken to consider changing the oil system from the current 2 stage system to incorporate single stage pumps as used on the other boilers.

3- Alstom combustion services Limited recommend the following upgrades/modifications to the existing Fuel Oil system on phase 1 at KNPS to achieve a greater level of plant reliability on units 1 and 2. Our recommendations are given in a suggested order of application to give maximum effect on the performance of unit 1 and 2. They can offer two options for new pumps, option A – single stage pumping as phase 2 or Option B - 2 stage pumping as exists at
present. However, they recommend the single stage option as this creates the potential for commonality with units 3 and 4 which are recommend be addressed following successful completion of this scheme.

4- Install new self-clean filters to reduce wear on pumps. The heating of the tank should virtually eliminate the sediment coming through to the filters and allow a longer time between filter cleaning.

5- Install 3 new 100% duty (each for 2 boilers flow rate) variable displacements high pressure pumps of larger capacity, to cater for lower density oils, lower viscosity pumping and give a greater wear margin. In order to minimize temperature rise at the pumps oil is recirculated back to the tank when warming the system.

6- The pressure control of the oil at the pump will be less consistent since the oil pressure maintaining valves are some distance away. Padlocked manual isolating valves will be provided to ensure that oil is recirculated back to the tank.

7- In order to achieve full boiler load, with the lower density oil currently being fired, it will be necessary to install larger pumps.

8- The pump will be capable of variable speed operation to give flexibility of output and avoid over recirculation of the oil due to the
high wear allowance when the pump is new. This will be achieved with the use of inverter control.

9- The discharge pressure of the pumps will be controlled by two new, 100% duty, pressure maintaining valves, since the pump output have been increased to cope with the lower density of some of the oils handled and to give a greater wear margin. The pump pressure maintaining valves will return oil to the main tank to keep the oil circulating and avoid pipeline cold spots or causing overheating of the pumps themselves when no oil is being fired. The valves will be of self acting type as are the existing valves.

10- A new return line, fitted with a manual isolating valve, would have to be installed to return oil to the main storage tank, and thus back to the pump inlet when the system is being warmed.

11- By changing the oil burner atomizers the pump discharge pressure can be reduced to be more in the line with that of the other boilers. The pressure at the pump discharge would be reduced to approximately 26 barg. This pressure is still higher than on the other boilers due to the different amounts of over fire capacity required to cope with the one burner out of service condition.

12- Low pressure switches should be used for alarm and trip purposes at the pump inlet to stop the pump if wax or sludge did stop flow to the pump.
13- Fit a viscometer to allow oil storage and atomizing temperatures to be determined to avoid gassing, tank vapor loss and enable full pump capacity.

14- A new oil viscometer should be fitted in the common line to the two boilers to enable the storage, pumping and atomization temperatures to be determined. This would give a continuous measurement of oil viscosity.

15- Install heaters in the dirty oil drain separator tanks and install the separator tanks.
CONCLUSION AND RECOMMENDATIONS:

We have based our recommendations on the oil analyses so far received from KNPS. The designations bellow refer to particular analysis to the fuel oil in the tanks which conclude the following:

1- Fuel oil viscosities varying considerably.

2-Fuels oil from different crude source does not mix, they are compositionally incompatible. Scummy deposits result.

3- Fuels oil of different specific gravities stratifies in the storage tanks, thus giving a constantly variable fuel viscosity and density.

4- fuels oil contain approximately 3% water by their hydroscopic nature, the waxy fuel oil contain 5% water due to water contamination on site from sump recovery, storage tanks heater leak and the atmosphere.

5- Fuels contain solid contaminants, sand, Sediments, etc…

6- The fuel in the storage tanks have greatly varying pour point.

7- The fuel have greatly varying flash point.

The atomizing temperatures are similar for all fuel oil patches.
8- The fuel oil contains waxes which in some cases solidify in room temperature.

9- The fuel oil has little compatibility with the fuel for which KNPS was designed.

The effect of the above factor on the KNPS can be concluding in the following:

7.1 VISCOSITY:

The screw type pumps upon which the system relies were originally sized to accept fuels in a range between 1500 and 5500 Rw. The pump is sized according to this viscosity and type of media to be pumped. The pump type itself has increased internal leakage as pressure increases, thus the plant designer makes allowance for this and provides an additional factor regarding volumetric capability.

The current situation viscosities at the pump inlet are approximately 750-460 Rw, so it has higher leakage and thus the pumps are less efficient. This condition is made worse by wear caused by water and solid contaminants. The pumps are the singular cause of the overall problems which ultimately affect KNPS performance.

7.2 FUEL BLENDS:

Fuels from differing crude sources are incompatible. Currently scummy deposits caused by this cause blockage to filters and
generally pass into the system requiring more frequent filter changes and subsequently greater opportunity for dirt, water and air to enter the system.

7.3 SPECIFIC GRAVITY:

On its own specific gravity causes the fuel to form layers in the storage tank thus different fuels are used as the tank level drops. The highest fuel being at the top. Additionally the flow metering on the site depend upon the specific gravity of the fuel being reasonably constant. Currently no reliable flow metering exists because the system was built for fuel at 0.95 specific gravity as opposed to 0.87 specific gravity at present.

7.4 WATER:

Water in the fuel under normal circumstances would causes little operational problem. However, due to the conditions of the system as currently operated this water after being heated flashes off as steam in the burner header and thus drop the pressure. In addition water causes rapid wearing of the screw type pumps.

7.5 SOLID CONTAMINANTS:

Causes rapid wear in screw pumps, abrade burner components.
7.6 POUR POINT:

This is quite important with regard to the fuel currently supply to KNPS. Its Pour point range from 28ºC to 45 ºC. However, the waxes present in the fuel oil causes the fuel to solidify at above their theoretical pour point. Thus to pump from the storage tank heat has to be added that lowers its viscosity below pump specification.

7.7 FLASH POINT:

The flash point determines the fuels susceptibility to vaporize and is critical for the safe operation of the plant if vapors are not contained. Currently to attain the correct viscosity the temperature would need to be 108º C which is above the fuel flash point.

7.8 FUEL OIL REQUIREMENT:

Oils supplied must have the following characteristics:

1- Viscosity not less than 2200 Rw. Preferably nearer 3000 Rw.

2- Viscosity at 50 ºC TO be not less than 1500 Rw.

3- Pour point should ideally be 40 ºC or less.

4- Water and solid contaminants to international standards.

5- Chemical element must remain within international standards.

Otherwise we recommend using one product of fuel oil of defined reliability of supply and quality to avoid returning to storage
tanks full of fuels oil of different characteristics. The root of many future problems.

KNPS is unable to maintain or even achieve its full load because of the fuel supplied and the consequential difficulties of pumping and burning of the oil. The current standard of the oil will rapidly wear out the refurbished pumps and then less power will be able to be generated. This will repeat itself until the fuel oil meets the original design criteria for the system. In addition to this, these partially refined products are unstable in the burner system and causes gassing at the burners. Some of these gasses may actually lower the heat generated. This is wasteful both in terms of money and resources and can only be rectified along with associated pumping problems by a comprehensive and costly redesign and refit which will not benefit NEC if the fuel supplied then changes specification regularly.

The recommended storage temperatures for the various oils vary from 40°C to 58°C with recommended pumping temperatures varying between 50°C and 58°C and recommended atomizing temperatures varying from 71°C to 100°C. The recommended atomizing temperatures vary from 71 ºC to 100 ºC.

The use of very different oils, produced from different crude oil sources, means that reactions may occur to produce a putty or sludge type of material. This may be formed in the tank itself and may not settle out as it often has a density very like the oil itself, it is therefore important to avoid producing this material as it is very
problematical in a fuel system. Normally oils are taken from the same crude to avoid the production of such contaminants and this is our strong recommendation.

Fig. (1-1) Khartoum North Power Station Phase 1 & 2
Fig. (3-1) The three problematic areas
Fig. (3-3) Tank Farm Area.
Fig. (6.1) three level steam heating coils with steam trap
Fig. (3-2) Unloading area
Fig. (3.5)

Fig. (3.6)

Fig. (3-4 b) delivery system – phase 2
Fig. (4 -1) shows the pipes connecting unloading area with storage tank.
Fig. (4-2) fuel oil & water cycle from unloading area to river
Fig. (5-1) Across section for rail tanker

KNPS sumps
- Water + FO
- Water
- FO

Tank B
Tank A
Filter
Interceptor PH I

FO pumps PH I

FO pump not available (motor missing)
1/2 Water pumps available

Tank C
Tank D

FO pumps PH II

2/2 Water pump available
FO pumps available

Pumphouse sump PH I

Cooling tower blow down PH I

Pumphouse sump PH II

Cooling tower blow down PH II

River Side

Clean drain PH I

PH I boilers drains + HP area FO flooding

Burners and filters cleaning

Clean drain PH II

PH II boilers drains

Final treatment plant
Not available

Rail siding area

U/L interceptor

Little Tanks

Pipe not available blocked

ground