Enhancing energy efficiency in the CDU

Revisiting your crude distillation unit may expose hidden potential for major energy savings

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Crude distillation is probably the oldest process in any refinery configuration. In the early days of refining, ‘black oil’ in simple batch stills was used to produce lighting oil (kerosene) as the main product, beside asphalts to meet the needs of the times. Following the development of the internal combustion engine, the need for improved fractionation led to the use of simple fractionation columns. Demand for increased throughputs and higher quality products resulted in the development of continuous fractionation units.

A simple crude distillation unit constructed in earlier times included a basic heat exchanger train in which generally hot atmospheric residue was used for preheating, as well as a furnace and a column which would not have any pumparound flows. The only aim was to meet product demands and produce higher quality products. Lowering the energy consumption of the unit would not be considered an important issue in a time of abundant and low-cost crude.

Over the course of time, energy saving has become one of the most essential topics in the oil industry because of environmental considerations and high production costs due to fluctuations in the price of products. Some studies such as the pinch method, developed at the end of the 1970s and extended to heat and power systems, were accepted among standard applications for refinery projects related to energy savings after the 1980s.

In refineries, crude distillation units (CDUs) are the largest energy consumers, utilising around 20% of a refinery’s total energy consumption, depending on configuration and type of crude processed.

Tüpraş Kirikkale Refinery is a medium-sized refinery with a capacity of 5 million t/y which began operating in 1986 with a Romanian designed CDU. It is a conversion refinery whose other units were developed to meet local product demands for Turkey. It may be considered a typical example of its type and was a perfect

Figure 1 Energy consumption in Kirikkale Refinery’s CDU as a percentage of total consumption by all process units

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Kirikkale refinery’s CDU

Kirikkale Refinery was designed to process 5 million t/y of 36 API Kirkuk crude. The unit design is a daily 18 000 m³ of crude oil. A simple flow scheme is shown in Figure 2.

Energy efficiency projects for the CDU

Change in diameter of air preheater tubes

As the regulations for emissions from industrial plants have tightened in the last 20 years, so the quality of the fuel oil burned in CDU furnaces has improved with reduced levels of sulphur and other impurities such as heavy metals. It was found that the two crude charge furnaces’ air preheater tubes were designed with a large diameter (3in) to avoid plugging by the ‘dirty’ fuel oil utilised in the 1980s. A project was developed to reduce the diameter to 2in and to increase the number of air preheater tubes in order to increase the heat transfer area in the air preheaters. In this way, furnace efficiency was increased by transferring more heat to the air fed to the burners. This modification resulted in an increase in heat surface area of 283 m² in both furnace A and furnace B. By changing the heat surface area, the stack gas temperature decreased by almost 40°C and fuel consumption in the furnaces decreased by 150-200 kg/h.

This decrease in fuel oil consumption corresponds to 1.7 Gcal/h of energy savings per furnace and a reduction in the need to use fuel oil as a burning agent. This project was approved as part of an energy efficiency programme begun in 2006 after the privatisation of Turkish Petroleum Refineries. As the cost of energy became a major item, Kirikkale Refinery researched a wide variety of opportunities for the CDU as well as other parts of the refinery to maintain the productivity of the plant. Many projects were evaluated according to their economic benefits and many of them were applied to the site between 2008-2014. Following completion of the new projects, a dramatic decrease in energy consumption in the CDU was achieved (see Figure 1). This article describes some of these energy saving projects.
in emissions of about 22 000 t/y.

Optimisation of naphtha and kerosene pumparounds
The CDU’s main column has two pumparounds – the kerosene pumparound and the naphtha pumparound – that are used to preheat crude oil before and after the desalter by removing heat from the column. The amounts and temperatures of the pumparound flows are crucial and should be optimised according to crude charge flow and type since they affect the inlet temperature of the desalter and furnaces and hence are a key parameter for fuel consumption in the heater. Design values of the kerosene and naphtha pumparound ratios were 1.09 and 0.885, respectively. An optimisation study for the pumparound flows against crude flow were carried out to increase heat transfer through the first and second preheat trains, to achieve energy savings in the furnaces. In particular, vapour-liquid equilibrium in the column and product specifications were taken into account.

After a simulation study, the naphtha and kerosene pumparound ratios were increased to 1.32 and 1.42; the crude flow and inlet temperature of the desalter and furnaces also increased by 6.2°C and 7.8°C, respectively. Energy savings were about 1.9 Gcal/h in the furnaces.

Additionally, an increase in pumparound levels resulted in a decrease in top reflux since extra heat removal reduced heat losses from the column top air coolers. As a result of reducing the amount of top reflux, a pump was shut down since only one pump was needed to transfer liquid as top reflux and splitter column feed.

Installation of variable speed drive
Crude oil from the desalter is sent to the furnaces via G-1102 A and B pumps (see Figure 2), one of them (A) with an electric drive while the other has a steam turbine. Now that the rate of crude charge changes frequently in response to economic conditions, a 6 kV variable speed drive was installed in the electric motor. Variable speed drives for that level of voltage are known to be expensive but a feasibility study showed that the return on investment was satisfactory. After installation of the variable speed drive, electricity consumption decreased by more than 50% (from 392 kWh to 180 kWh) for the same operating conditions.

Use of antifoulant
Crudes with a high asphaltene content cause more fouling in the second preheat train (after the desalter) because of its higher temperature compared to the first preheat train. Fouling in a preheat train directly affects the charge furnace inlet temperature and hence leads to greater fuel consumption. The loss of inlet temperature is measured as a decay rate of C/day and, by using an appropriate antifoulant in the second preheat train, it was found that the decay rate reduced to 0.0175 C/day from 0.08 C/day. The economic return on use of antifoulants is satisfactory and calculated at around $910 000/y. Using antifoulant also reduces cleaning time for the exchangers as a side benefit.

Tempered water system for cooling residues
In the original design of the CDU and VDU at Kirikkale refinery, cooling of atmospheric residue to storage was carried out by air coolers while vacuum residue run-down was cooled by a tempered water system. Cooling with air is not an efficient approach, especially for heavy products, since it depends on ambient temperatures which sometimes cause bottlenecks on hot summer days. A project was developed to combine the residue cooling systems of the CDU and VDU with tempered water cooling. Installing a combined tempered water circulation system removed the bottleneck in residue cooling and the recovered waste heat, about 3 Gcal/h, was transferred to crude oil before the first preheat train.

This also prevented shock condensation of chlorides and water in the naphtha pumparound in the first exchangers in the preheat train (E-1101 A-D in Figure 2) since crude from storage is at low temperatures (5-10°C) during winter. This sudden cooling of the naphtha pumparound was causing a corrosion mechanism involving HCl-water condensation, leading to heat exchanger tube leakage. This problem with the reliability of the heat exchangers was also prevented by increasing the inlet temperature of E-1101 A-D.

An old shell and tube heat exchanger taken from an unused reformer unit was rated...
by simulation and was retrofit
ted to be added to the first
preheat train so that crude oil
taken from tank is heated with
tempered water from the
resi-
due cooling tempered water
system. The approaches of ΔTs
in the current system were also
checked so as not to cause a
pinch problem due to over-heat-
ing of the crude charge. Only
the cost of piping and valves
applied to this project since the
water circulation pumps were
found to be adequate and
continued to be used with the
retrofitted old exchanger.

Using crude oil as a heat sink
and transferring waste heat to
the unit charge resulted in an
increase in the desalter and
furnace inlet temperatures and
hence fuel savings in the
furnaces. The inlet temperature
of the furnaces increased by
4-5°C and the economic return
of this project is $900 000/y.
Because less fuel is consumed,
emissions from the furnaces
also decreased as another bene-
fit of the project.

Additional pumparound flow
In the original flow scheme,
two pumparound flows (naph-
tha and kerosene) were used
for transferring heat from the
column to the crude flowing to
the furnace (see Figure 2). After
a process study, an opportunity
was discovered to install a new
pumparound flow which utilises heavy gas oil draw
from the column. It provided a
heat duty of about 14.8 Gcal/h
and was used for the reboiler
requirement of the splitter
column bottom. Because of this
additional free heat source, the
reboiler fired heater (F-1102 in
Figure 2) was removed after a
new shell and tube exchanger
was installed. Overall fuel
consumption reduced by 16.3
Gcal/h and a CO₂ equivalent
saving of 43 617 t/y was
realised.

Change in furnace air blowers
The refinery CDU’s charge
furnaces originally had six air
blowers which required 400 kW
each. Since they in excess of
requirement in the 1980s, only
one is utilised with a bypass
line for two furnaces. Sharing
air from one blower with a
bypass line caused an air distri-
bution imbalance between the
two furnaces, with a resulting
decrease in furnace efficiencies
and unreliable operation.
The refinery’s combustion
division developed a project
for furnace efficiencies in
which the capacity of the air
blowers was to be decreased
with the installation of new
blowers and a variable speed
drive fitted to the air blowers’
motors, adjusting fan speeds
according to oxygen demand
in the furnaces determined via
online oxygen analysers in the
stacks.
The saving in electricity is
calculated to be 3.2 million
kWh/y, with expected fuel
 savings of 11.3 million kWh/
year. Installation work is ongo-
ing and start-up of the project
is planned for the second quar-
ter of 2015.

Preheat train optimisation and
preflash drum
A heat integration study was
started in 2014 utilising pinch
analysis of the current flow
scheme of the CDU, with the
aim of finding out whether
there is an opportunity to
decrease hot-cold approaches
and add a preflash drum.
Using the SuperTarget tool
(from KBC), an optimisation
study of the preheat trains was
carried out. Among many
scenarios given by the model,
the Hv. diesel vs crude heat
exchanger (E-1104 AB in Figure
2) is to be relocated after the
desalter and a new heavy gas
oil pumparound heat
exchanger will be added to the
second preheat train. A
preflash drum will also be
placed before the charge heater
to separate crude vapours
which will be sent directly to
the kerosene zone of the atmos-
pheric distillation column.
Bottom liquid will be sent to
the furnace. After the preflash
drum, crude oil will also be
heated in another new heat
exchanger with atmospheric
residuum before entering the
furnace. By changing the flow
scheme and adding new equip-
ments, fuel consumption of the
fired heaters is calculated to
be reduced by nearly 16 Gcal/h
and the economic return of the
project will be $6.9 million/y.
Because of the high equipment
cost, a preflash column was not
selected, so two preflash drums
will be placed to guarantee no
entrainment by heavier prod-
-ucts inside the column.
Detailed engineering of the
project is continuing and
start-up will probably be in
2016.

Conclusion
The refining industry faces a
challenging situation when it
cannot control its biggest cost
item, crude prices, and many
refiners have to be at their
fittest to survive by cutting
operational costs by evaluating
hidden opportunities for
energy savings in an increas-
and improving fractionation, recovery, lower use of utilities heat integration, waste heat efficiency it contains vary from opportunities for energy effi-

ciency technologies and practices will meet the chal-

enge of both maintaining the high quality of products while reducing production costs.

Starting in 2008, Tüpraş Kirikkale Refinery developed an initiative for prioritising energy saving projects, not only for the CDU but also for other process units and utilities (see Figure 3). The CDU processes all of the crude oil charged to the refinery. It is a major energy user and the opportunities for energy efficiency it contains vary from heat integration, waste heat recovery, lower use of utilities and improving fractionation, though to other, smaller measures resulting in large gains. During such studies, it was seen that many possible energy saving opportunities generally require short payback times ranging between two years and as little as a few months.

Refiners monitoring such opportunities for savings will first need a benchmark of their CDU and other units to identify areas for improvements, and then an energy strategy and management programme to locate and apply the improvements according to their economic priorities. Even when such programmes are completed, there is a need to continue monitoring key performance indicators and discover further opportunities for savings.

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