Economic and environmental considerations increase when using flare gas recovery systems (FGRSs) to reclaim gases from flare header systems for other uses. An FGRS reduces flaring noise; thermal radiation; operating and maintenance costs; air pollution and emissions; and fuel gas and steam consumption while increasing process stability and flare tip life without any impact on the existing safety relief system. The article details installing an FGRS at the Khangiran gas refinery in Iran and how the system was involved in the reduction, recovery and reuse of flare gases. The system’s operation, design guidelines and process economics will also be covered.

**Introduction.** Flaring is used to consume waste gases—including hydrogen sulfide ($\text{H}_2\text{S}$) rich gases and gases burned during emergencies—in a safe and reliable manner through combustion in an open flame. It is used routinely to dispose of flammable gases that are either unusable or uneconomical to recover. Often, gas plant workers must do emergency flaring for safety purposes when equipment is depressurized for maintenance.

Worldwide, final product costs for refinery operations are becoming proportionally more dependent on processing fuel costs, particularly in the current market where reduced demand results in disrupting the optimum energy network through slack capacity. Recovering hydrocarbon gases discharged to the flare relief system is probably the most cost-beneficial plant retrofit available to the refinery. Flare gas use to provide fuel for process heaters and steam generation leaves more in fuel processing, thus increasing yields. Advantages are also obtained by reducing flare pollution while extending tip life.

In spite of the advantages, suitable projects for flare gas reduction and recovery have not yet been planned. Therefore, there is an essential need to emphasize installing FGRSs into the gas refinery to recover and reuse flare gases.

**Khangiran gas refinery.** Due to the large amount of flare gases produced in the Khangiran gas refinery (21,000 m³/hr), operational conditions were investigated, especially in the units that produced flare gases. Based on the existing data, it was found that the methyl diethanolamine (MDEA) flash drum, MDEA regenerator column and MDEA regenerator reflux drum, residue gas filter and inlet gas separator into the gas treating unit (GTU) were the most critical when looking at producing flare gases. Flare gas composition in the flare header during three tests is given in Table 1. Regarding the results of the data analysis—the mean value of the molecular weight of the flare gas is 18.16 and the flow discharge rate modulated between 2,500 m³/hr and the maximum of 10,000 m³/hr. The average temperature is 30°C and the average pressure is 6 psig.

Advised practical methods to reduce, recover and reuse flare gases for the Khangiran gas refinery are presented in Table 2.

<table>
<thead>
<tr>
<th>Test composition</th>
<th>No. 1 % mole</th>
<th>No. 2 % mole</th>
<th>No. 3 % mole</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{C}_1$</td>
<td>86.327</td>
<td>75.723</td>
<td>85.682</td>
</tr>
<tr>
<td>$\text{C}_2$</td>
<td>0.461</td>
<td>0.759</td>
<td>0.58</td>
</tr>
<tr>
<td>$\text{C}_3$</td>
<td>0.104</td>
<td>0.212</td>
<td>0.076</td>
</tr>
<tr>
<td>$\text{i-C}_4$</td>
<td>0.03</td>
<td>0.062</td>
<td>0.012</td>
</tr>
<tr>
<td>$\text{n-C}_4$</td>
<td>0.05</td>
<td>0.124</td>
<td>0.018</td>
</tr>
<tr>
<td>$\text{i-C}_5$</td>
<td>0.028</td>
<td>0.07</td>
<td>0.028</td>
</tr>
<tr>
<td>$\text{n-C}_5$</td>
<td>0.022</td>
<td>0.089</td>
<td>0.022</td>
</tr>
<tr>
<td>$\text{C}_6^+$</td>
<td>0.218</td>
<td>0.212</td>
<td>0.218</td>
</tr>
<tr>
<td>$\text{CO}_2$</td>
<td>8.2</td>
<td>14.575</td>
<td>8.713</td>
</tr>
<tr>
<td>$\text{H}_2\text{S}$</td>
<td>3.3</td>
<td>5.265</td>
<td>3.393</td>
</tr>
<tr>
<td>$\text{N}_2$</td>
<td>1.26</td>
<td>2.909</td>
<td>1.258</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

**TABLE 2. Advised practical methods to reduce, recover and reuse flare gases**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Advised practical methods</th>
</tr>
</thead>
</table>
| Reduce and/or reuse flare gases | • Improving structure of MDEA flash drum to reduce $\text{CO}_2$ and $\text{H}_2\text{S}$ to send gases to the fuel gas header  
• Improving equipment with predicted streams to send gases to the fuel gas header  
• Improving inlet gas separator internals |
| Recover and reuse flare gases | • Installing the flare gas recovery system for the MDEA flash drum  
• Installing the overall flare gas recovery system |
An important factor when installing
During the project
11
HC
LC
HC
To amine
Feed gas from flare

ENVIRONMENT/LOSS PREVENTION
varying gas loads and compositions. It consists mainly of com-
design, composed of three separate trains capable of handling
column in the drum. The recommended system has a modular
pressure control at the suction to the compressor will be main-
flare gases from various units in the refinery are available at this
single point. It is located upstream of the liquid seal drum, as
processors that take suction from the flare gas
compresses the gas and cools it for reuse in the refinery fuel gas system.
The compressor selection and design is crucial to the system capacity and
down capability. During the project design phase, the most appropriate type
and number of compressors were selected for the application. Liquid ring compressor
technology is commonly used due to its rugged construction and resistance to liq-
ụid slugs and dirty gas fouling. A number of factors that must be taken into account
when compressing flare gas are as follows: the gas amount is not constant, the gas
composition varies over a wide range, the gas contains components that condense
during compression, and the gas contains corrosive components. The recommended
system includes three liquid-ring (LR) compressors, three horizontal three-phase
separators, three water coolers, piping and instruments. The FGRS that used an LR
compressor at the Khangiran gas refinery is illustrated in Fig. 1.

The compressed gas is routed to the amine treatment system
for H\textsubscript{2}S removal. Some hydrocarbon vapor is condensed and
discharged into the separator together with motive liquid. The condensate is separated from the motive liquid in the three-
phase separator and routed to storage.

**Fuel gas consumption.** The expected effect of a devised
FGRS on flaring in the Khangiran gas refinery is shown in Fig. 2. The fuel gas at the Khangiran gas refinery is supplied by sweet
gas. Using flare gases as an alternative fuel gas resource can signi-
ificantly eliminate using sweet gas. The recommended FGRS
can reduce 21,000 m\textsuperscript{3}/hr of gas flaring and provide 4,810 m\textsuperscript{3}/hr
of sweet gas as an alternative fuel gas resource based on conditions
of the FGRS outlet stream. This is similar to conditions of a fuel
gas stream. Therefore, sweet gases that are used as fuel gas can be
injected again into the GTU outlet stream.

Another advantage of using an FGRS is that gas emissions
are reduced. The recovery and use as an alternative fuel source will not only offset fuel consumption but also reduce gas emis-
sions, a potent greenhouse gas. This waste put into fuel system
significantly or entirely reduces the facility’s emissions (such as NO\textsubscript{x}, SO\textsubscript{x}, H\textsubscript{2}S, CO, CO\textsubscript{2}
and other hazardous air pollutants/greenhouse gases) and the emissions are converted into a rev-
ue stream and profit center. By installing an FGRS at the Khangiran gas refinery, gas emissions were decreased by 90%.

**Thermal radiation.** An important factor when installing
an FGRS is the reduction of thermal radiation. Installing an
FGRS not only reduces gas flaring but also decreases the harm-
ful impacts of flaring. Thus, some safety considerations in pre-
liminary flare design can be neglected. When investigating the
thermal radiation from the flame at the Khangiran gas refinery, the radiation fluxes that vary with distance from the flame
were measured. Once the FGRS was installed, a simulation software
was used to predict thermal radiation from the flame. Fig. 3

In addition, the flame igniter system, flame safeguards and the
existing flare tip needed to be replaced. The existing flare control
system was not compatible with the distributed control system
(DCS) of the refinery and needed to be upgraded.

**FGRS design considerations.** The design considerations
include: flare relief operation and liquid seal drum, flare gas flow
and composition, and refinery fuel systems. The considerations
led to the unit design for normal capacity up to 21,000 m\textsuperscript{3}/hr at
25°C–30°C and 5 bar.

The proposed flare gas recovery system is a skid-mounted
package, located downstream of the knockout drum since all
flare gases from various units in the refinery are available at this
single point. It is located upstream of the liquid seal drum, as
pressure control at the suction to the compressor will be main-
tained precisely by keeping the increased height of the water
column in the drum. The recommended system has a modular
design, composed of three separate trains capable of handling
varying gas loads and compositions. It consists mainly of com-

**FIG. 1** Recommended FGRS.

**FIG. 2** Maximum monthly gas flaring before and after installing an FGRS at the Khangiran gas refinery.
shows the distribution of the radiation fluxes that were calculated using reduced flowrate of flare gas from the flame, before installing an FGRS. Each black line in Fig. 3 indicates a 10 m distance from the flare stack. In addition, the impact of wind direction and wind speed is obvious.

The results of thermal radiation reduction due to installing an FGRS are illustrated in Fig. 4. Comparing the results of our modeling before and after installing an FGRS shows that thermal radiation flux will be significantly reduced at the specific distance from the flame. The reduction of radiation fluxes increases the safe area around the flare stack.

**Noise level.** Just as portions of energy released in burning waste gas go to thermal radiation other portions of energy go to sound and light. In some cases, the sound level becomes objectionable and is considered noise. Flaring noise is generated by at least three mechanisms:

- From the gas jet as it exits the flare burner and mixes with surrounding air
- From a smoke suppressant injection or mixing
- From combustion.\(^{12}\)

The noise generated by the first two, especially the second, can be mitigated by the use of low noise injectors, mufflers and careful distribution of a suppressant.

The third important component when installing an FGRS is noise-level reduction. Flaring noise was investigated in a specific area, 100 m diameter from the stack. Comparisons between the results of modeling flare noise level at the Khangiran gas refinery before and after installing an FGRS are illustrated in Fig. 5. The results show that noise level will be significantly reduced at the specific distance from the flame. Also, reducing radiation fluxes creates an increase in the safe area around the flare stack.

**Economics.** The FGRS includes three separate trains capable of handling varying gas load and compositions. Thus, three LR compressors, three horizontal 3-phase separators, three water coolers, piping and instruments are needed. Finally, capital investment to install an FGRS is approximately $1.4 million.

This estimate includes maintenance, amortization and taxes corresponding to a payback period of approximately four months. These results have been obtained based on $0.15/m\(^3\) for fuel gas, $6/ton for steam and $0.05/KWH for electricity.

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**LITERATURE CITED**

1. www.khangiran.ir

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**Jet Mixer System**

Liquid jet mixers are used to mix and circulate liquids. With the jet mixers a three dimensional flow is achieved in the tank without producing a rotating motion.

Advantages: high efficiency, high operating safety, long life time, no turning parts so little wear and tear, simple construction, available in any material used in the equipment, resistant to fouling.

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Telefon: +49 7243 705-0, Telefax: +49 7243 705-330
E-Mail: info.gewi.de@geagroup.com, Internet: www.gea-wiegand.com

Select 167 at www.HydrocarbonProcessing.com/RS
The recommended system has a modular design, composed of three separate trains capable of handling varying gas loads and compositions.

![Noise level (dB) around the stack before (left) and after (right) installing an FGRS at the Khangiran gas refinery.](image)

**FIG. 5**

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**Ali Vatani** is a professor and head of the petroleum engineering department at the University of Tehran, Iran. He has written many research papers on various petroleum and natural gas engineering related topics and has conducted research on multiphase flow transmission and natural gas processing.

**Saeid Mokhatab** is an internationally recognized expert in the field of natural gas engineering with a particular emphasis on raw gas transmission and processing. He has been involved as a technical consultant in several international gas-engineering projects and has published over 180 academic and industry oriented papers and four books on related topics. As a result of his work, Mr. Mokhatab has received a number of professional awards and is listed in several international biographical listings.