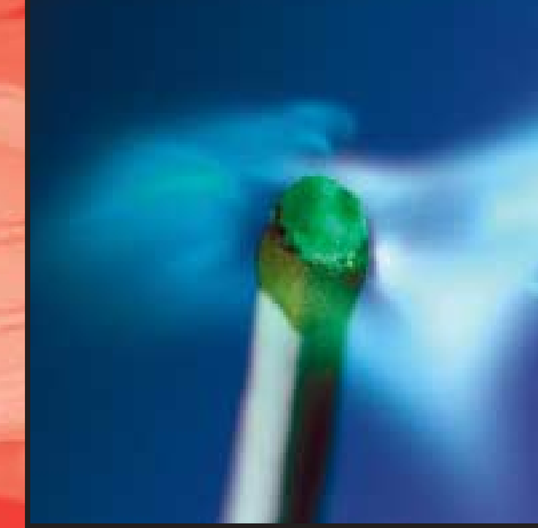

Towards Zero Flaring

An important issue in protecting the environment of the Gulf, which is no less fragile than elsewhere in the world, is the effect of hydrocarbon flaring from oil production operations. This causes many forms of pollution – noise, toxic gases, soot, acid rain and the production of carbon dioxide, the latter is one of the primary causes of global warming.

In this article, Alp Tengirsek and Nashat Mohamed explain the progress of a project in Abu Dhabi that has already eliminated oil flaring during testing and production, with the ultimate aim of eliminating all hydrocarbon flaring within a year.

The modern states of the Gulf region are fortunate in having inherited an untainted environmental legacy. The recent, bold development of their industrial base has taken into account the lessons learnt by other regions that have undergone industrial revolutions. Pristine expanses of land and sea are visible testimony to their success to date.

However, the environment of the Gulf is no less fragile than elsewhere in the world. In order to preserve their natural resources, environment ministers of the 21 Arab countries met in Abu Dhabi, February 2001, at the Gulf Cooperation Council's (GCC) 19th Summit to define an environmental strategy for the region. The result was the adoption of the Abu Dhabi Declaration, which lays down a strategy for the sustainable use of the region's environmental resources in the 21st century.

An important issue the Abu Dhabi Declaration addresses is hydrocarbon burning or flaring from oil production operations. This causes pollution – noise, toxic gases, soot, acid rain and carbon dioxide, the latter being one of the primary causes of global warming.

Rising sea levels and potential flooding due to global warming are particular concerns for the countries of the Middle East. The low-lying coastal areas of the United Arab Emirates, and areas such as the heavily populated Nile Delta in Egypt and the lower reaches of the Tigris and Euphrates river systems in Iraq are under threat from rising sea levels.

Recognizing and anticipating mounting international concerns over environmental issues, the Abu Dhabi Marine Operating Company (ADMA-OPCO) and the Zakum Development Company (ZADCO) have achieved dramatic reductions in hydrocarbon flaring from on- and offshore oil fields since 1997.

The companies formed a joint team and, with the help of Schlumberger, developed a multistage plan for reducing flaring emissions during well cleanup and well-testing operations. The ultimate aim is to achieve zero flaring within a short but realistic time frame. Zero flaring will also enable significant cost reduction for cleanup operations by allowing immediate flow of backflowed effluents through the test separator.

Countdown to zero

During conventional cleanup and well-testing operations (Figure 1.1), both oil and gas are burned away into the atmosphere. Water, collected by the test separator and then discharged into the sea, may contain acid used to stimulate production from carbonate reservoirs that could cause corrosion problems in the pipeline. The discharged water also contains unacceptable oil levels. Each of these – oil, contaminated water and gas – represents an environmental hazard during well testing and cleanup.

The first stage of the plan was to reduce oil burning by reinjecting oil recovered from water back into the production stream. This was introduced successfully to three ADMA/ZADCO offshore rigs in 1998. To recover the oil, cleanup fluids were used to reduce water acidity to pH 5.5–6, thus avoiding damage to service providers' equipment, subsea pipelines and onshore processing facilities. The separated oil was then returned to the production pipeline. This first stage of the zero-flaring initiative, however, did not address gas flaring, residual fluids and separated water that still contained spent acid and oil and continued to be discharged into the sea. In this stage of the initiative, measurement of flow rates continued to be made by separators and gauge tanks. This was an incomplete solution requiring conventional cleanup.

The second stage virtually eliminated oil burning (Figure 1.2). This was introduced to the same rigs between February and March 2000. Acid in the effluent discharged from the well during cleanup was immediately neutralized using sodium carbonate, which allowed oil to be injected safely into the production

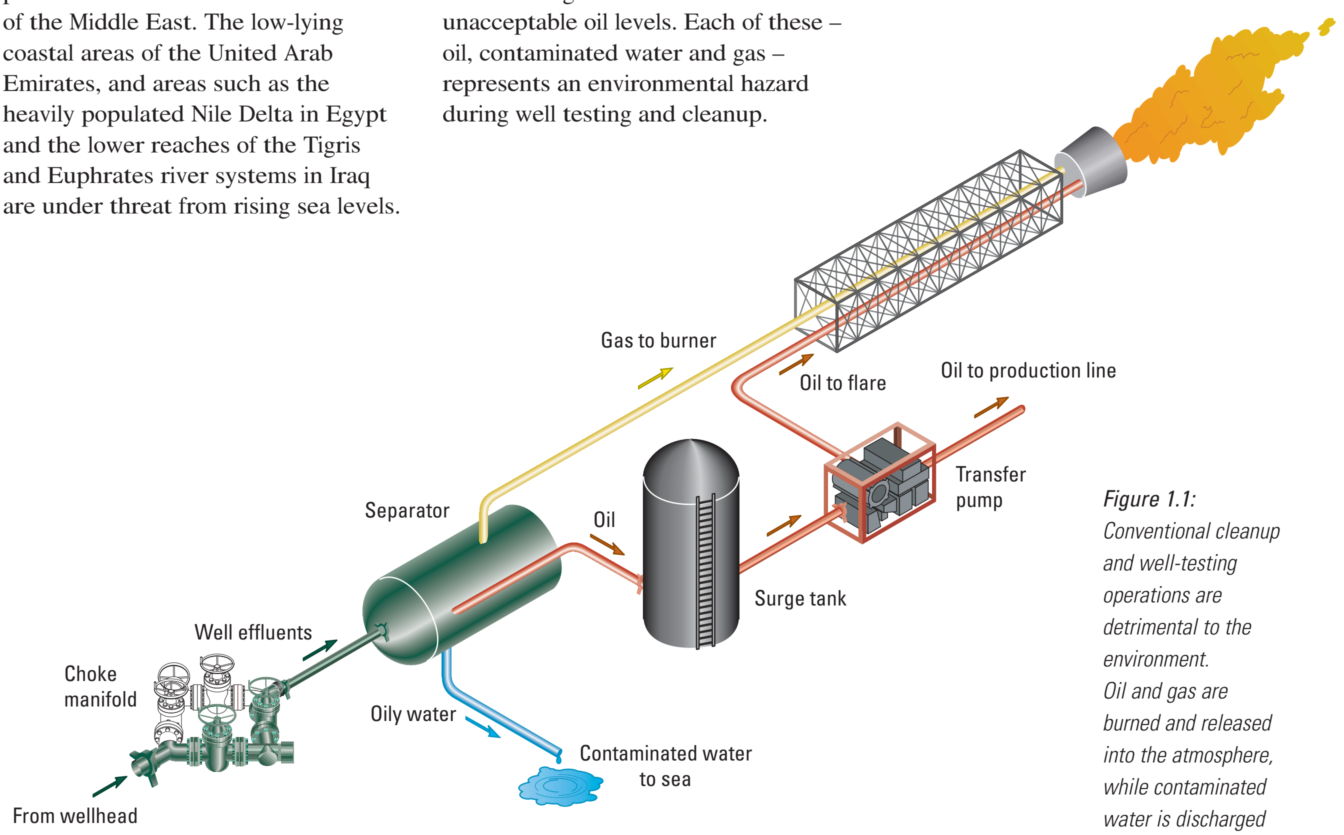

Figure 1.1: Conventional cleanup and well-testing operations are detrimental to the environment. Oil and gas are burned and released into the atmosphere, while contaminated water is discharged into the sea

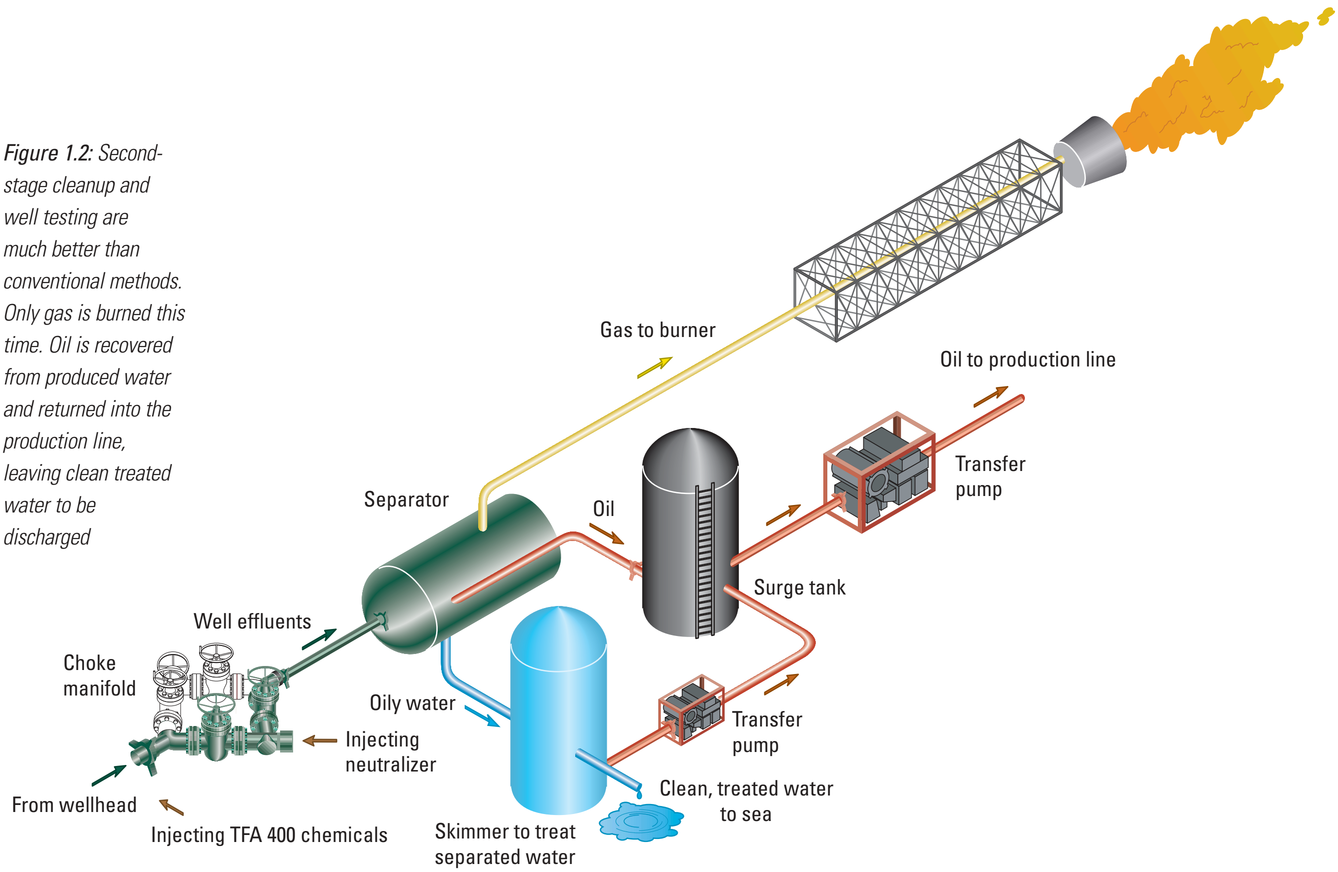

Figure 1.2: Second-stage cleanup and well testing are much better than conventional methods. Only gas is burned this time. Oil is recovered from produced water and returned into the production line, leaving clean treated water to be discharged

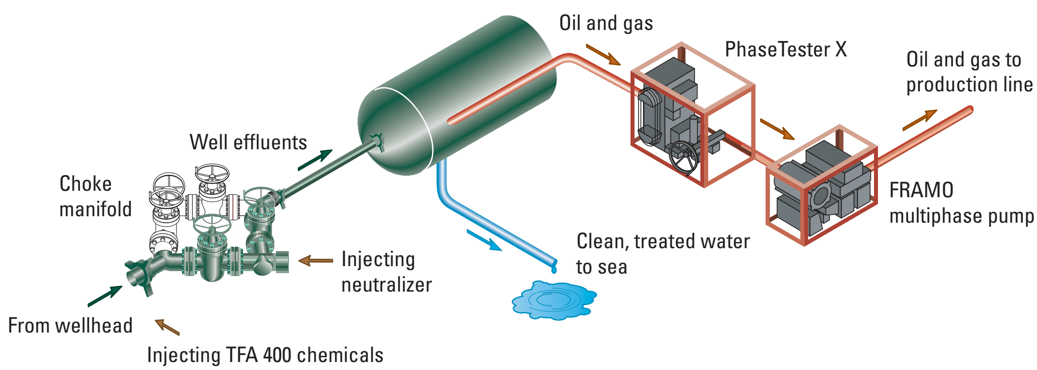

Figure 1.3: Future cleanup and well-testing operations will eradicate pollutants, with oil and gas being returned to the production line and clean water discharged safely into the sea

line as soon as the first barrel was produced. The oil-in-water content was reduced to less than 80 ppm by improving separation efficiency, using carefully selected chemicals to accelerate separation of the emulsion, and a skimmer. Using an emulsion breaker in this way improves the efficiency of the skimmer where emulsion is present. Gas would continue to be flared during this stage and water, no longer contaminated, was safely discharged into the sea.

The PhaseTester* portable multiphase periodic well testing equipment has been introduced into the system. It has enhanced operational flexibility and provided accurate phase flow rates. During the post cleanup operations, the PhaseTester led to the elimination of gas flaring. The minimal pressure drop across the meter and its high pressure rating make it possible to flow the well effluents naturally through the sea line without separating the well effluent phases. The deployment of this multiphase flow meter in the system has resulted in a reduction in the gas flaring of about 60% during duration of the job.

The final stage of the zero-flaring plan (Figure 1.3), expected in late 2002, is to fully eliminate gas flaring by returning gas, as well as oil, to the production line.

The use of gas compressors to overcome the pipeline pressure was studied, but was discounted for a number of reasons. These included the relatively large size of the equipment and its inflexibility in terms of flow characteristics, which would present difficulties during the cleanup phase. However, by measuring flow rates without the need for separation, the neutralized oil and gas mixture could be reinjected into the production line using multiphase pumps, which allow the flow of gas and oil together. This has been made possible by the recent introduction of Vx* multiphase well-testing technology, embodied in PhaseTester X.

Coping with the pressure

Eliminating flaring by returning well fluids to the production line is not a trivial task. The first challenge is to overcome the pressures needed to reinject oil from the low-pressure separator or surge tank into the production line. This pressure is greatest at the start of the cleanup operation, where the presence of completion fluid and pumped liquid contribute to a much greater hydrostatic pressure than that of a borehole filled purely with hydrocarbons. This is achieved using single-phase pumps, typically those used to pump oil to a burner or injection line, that have been modified specifically to cover the entire operating envelope of a wide range of flow regimes and sea line pressures. The pumps must also enable representative data to be acquired during production well testing. A relatively low separator pressure is required to respect choke performance and for critical flow conditions, where downstream pressure should be 50% less than upstream pressure.

Around 10 to 15 gallons per foot of 15% hydrochloric acid (HCl) are used for stimulation, with even higher volumes in deviated oil and gas wells. In horizontal wells, now commonplace in the carbonate formations of the Middle East, the long horizontal sections result in very large volumes of spent acid after stimulation. Even after the acid has been allowed to soak into the formation for four hours to allow proper contact with the formation, the spent acid at the surface during cleanup is pH 2–3, and it is clearly desirable to avoid discharging this into the sea. To overcome this, and to allow effluents to be passed immediately through the test separator, neutralizing agents (sodium hydroxide or sodium carbonate) must be injected downstream of the choke manifold to raise effluent pH to above 5.5, which is the acceptable limit for diverting the effluents through the surface equipment and the production line.

Emulsification of well fluids causes further problems when reinjecting oil into the production line. The intermixing of oil- and water-based fluids often forms high-viscosity emulsions. Water-in-oil emulsion, formed by invasion of drilling and completion filtrate or treatment fluids, has small droplets of water dispersed in a continuous phase oil. Oil-in-water emulsion and multistage water-in-oil-in-water emulsion, formed by agitation of the simple emulsion, may be present in produced well fluids.

Emulsions can be stabilized by surfactants and mutual solvents. Initially, four different chemicals were identified that, when added to the back-flow fluids, were effective in breaking down the emulsion at 5% concentration. However, this was unacceptable because the resulting water would be discharged into the sea. A multifunction demulsifying agent (such as TFA 400) that is a blend of surfactants was preferred. This is injected at the eruption manifold, which is connected to the flowline upstream of the choke manifold.

A series of laboratory tests – compatibility with the crude oil, well fluid and acid design – is used to determine the suitability of the treatment fluid formulation. An emulsion test and an anti-sludge test are also carried out.

Finally, the problem of discharging water with a high oil content must be addressed. Retention times when passing oil and water at 5000 B/D through a three-phase separator are

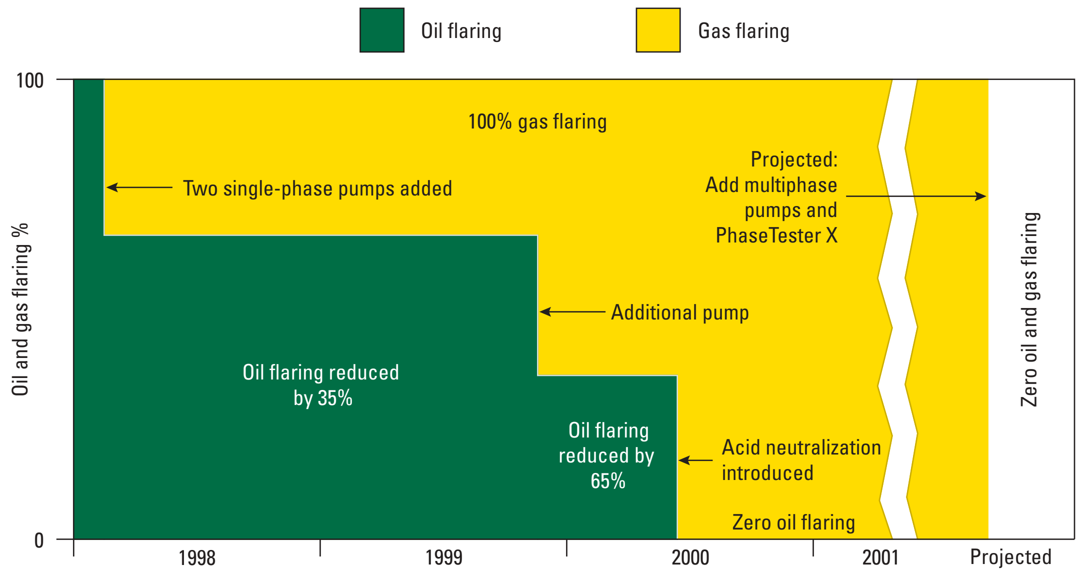

Figure 1.4: Remarkable advancements have been achieved in cleanup and well-testing operations in a short period of time

around 2 min. The gravity-precipitation velocity of water droplets into the bottom of the separator is not high enough to ensure complete separation in this time. As a result, the discharged water can contain more than 2000 ppm of oil, and some water is carried into the production facilities in the oil phase.

To improve water quality after separation, the retention, or settling, time is reduced using a skimmer unit, which decreases the oil-in-water concentration to 100–120 ppm before the water is discharged. This is possible because the skimmer has a higher volume than the separator and operates at a lower pressure. Oil-contaminated water from the bottom of the separator is routed into the skimmer with its two compartments. Fluid enters the water compartment, where it is treated with demulsifier. The increased separation time allows the oil droplets to separate out and float to the surface until they overflow into the other compartment, the oil–water interface being automatically controlled. The separated oil is then pumped into the production line.

Oil from the separator, mixed with demulsifier, is routed to an 80-bbl surge tank, where further residues of water that may have carried over are allowed to separate. The oil, having an acceptable pH value, is then pumped into the production line. Water is sampled frequently at various points in the separator inlet, the outlet and the bottom of the surge tank to check the effluent pH. Finally, gas from the separator, surge tank and skimmer is burned.

Action in Abu Dhabi

In Abu Dhabi, ADMA and ZADCO were burning oil during drilling-related cleanup and testing operations. It was decided to equip a number of rigs to carry out the first two stages of the flaring emission reduction project, following completion and acidization.

Two pumping systems, selected to serve the companies' full operating envelope for oil reinjection, were introduced during May 1998. The criteria under which reinjection of oil was allowed to proceed, in terms of basic solids and water (BSW) and pH levels, were specified by each company to avoid any compromise to production-line integrity. Under these conditions, oil flaring was reduced by 38% (almost 100,000 bbl) by the end of 1998. A third pumping system was added in December 1999. This increased the reduction of oil flaring to 65% (195,000 bbl).

The next step was to add neutralization units to allow immediate flow of well fluids through the separator. Sodium carbonate was used as a neutralizing agent for several reasons: as a constituent of drilling mud it is always available at the rig site, it produces soluble products in water and, it is cost effective. The pH of the backflowed effluents was raised to above 5.5 – the acceptable limit for diverting effluents through contractors' equipment and the sea line.

Adding surfactants to the well fluid to control emulsion, and installing skimmer units to reduce oil-in-water content by increasing retention time, completed the planned second stage of the project. In those installations where stage two has been implemented fully, liquid flaring has been eliminated.

Turning off the gas

The next, and final step towards zero flaring will be to eliminate gas flaring (Figure 1.4). The treated oil and gas mixture will flow directly through the multiphase PhaseTester X, which determines flow rates without the need for oil and gas separation.

Various methods for reinjecting gas and oil into the production line have been evaluated, including the use of gas compressors. However, these were considered unsuitable because of their relatively large size and their inflexibility in terms of flow characteristics. The most suitable method will be to replace the single-phase injection pumps with multiphase pumps, where gas and oil can flow together through the pump impeller without damaging it.

Clean and cost effective

The two-stage cleanup employed to date has resulted in spectacular reductions in the amount of oil flared during well tests and cleanups. By neutralizing spent acids before separation, and adding equipment to reduce oil in water, the objective of zero oil flaring is achieved while the quality of the discharged water meets environmental standards. Until recently, water discharged from the skimmer contained 100–120 ppm of oil and had a pH above 5.5, but a new environmental standard demands a reduction of oil in water to 15 ppm or less. This will be met with the introduction of the WDOU* Water De-Oiling Unit, which is a combination of a degasser, coalescers, a feed pump, a hydrocyclone and an oil tank, all contained on one skid. The WDOU should be in place in Abu Dhabi by the end of 2001. These improvements, realised through the use of existing equipment such as single-phase pumps, have become ADMA-OPCO standard procedures. The introduction of new equipment, such as multiphase pumps and multiphase testers, will bring about true zero flaring with the further elimination of gas flares. In addition to the obvious environmental benefits these techniques have brought, there is a very attractive additional bonus to satisfy even the most sceptical analysts. This environmental improvement comes with clear and significant cost savings.