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up in smoke

an end to wasteful flaring?

CLEANER FUELS | REACTOR DESIGN | PROJECT MANAGEMENT | PROCESS INTENSIFICATION

Keep it green

Steve Jackson pits process selection against environmental performance

PROCESS ENGINEERS will often need to justify process selection against environmental performance as part of design development. In the UK, this justification must be made against the principle of best available techniques (BAT) as set out in the Integrated Pollution Prevention and Control (IPPC) directive[1]. Outside the EU, other considerations will apply, but the approach to design selection should still include an evaluation of environmental impact.

Often, a BAT justification will require the consideration of a variety of direct and indirect environmental impacts and the trade-off between these may not always be straightforward. One area of considerable interest is the impact a process has in terms of global warming and the evaluation of design options against these criteria is an important part of the overall review process.

To illustrate the approach that can be taken to justify process selection against environmental performance, this article looks at the evaluation process required to justify BAT using two gas-processing examples: volatile organic compounds (VOC) recovery from tanker loading and energy recovery from pressure letdown.

environmental design requirements

The IPPC directive defines BAT as:

- **best** – the most effective technique for achieving a high level of protection of the environment as a whole;
- **available** – techniques developed on a scale that allows them to be used in the relevant industrial sector, under economically and technically viable conditions, taking into account the costs and advantages; and
- **techniques** – includes both the technology and the way the installation is designed, built, maintained, operated and decommissioned.

“plant designers must understand the assessment principles involved and ensure that they are applied throughout the course of a project”

Therefore, to demonstrate BAT, the process designer must have a good understanding of all environmental aspects associated with a process, their importance, where there are process options affecting environmental impact, and how the ‘best’ option can be determined.

A UK gas-process plant adjacent to an SSSI

the environmental review process

To support BAT justification for a final plant design, environmental aspects should be considered from the first stages of design work. To do this, plant designers must understand the assessment principles involved and ensure that they are applied throughout the course of a project and transmitted into the detailed design spec.

The environmental review process should include:

- understanding environmental aspects and identifying risks;
- quantifying environmental impacts and assessing risks; and
- comparing design options and justifying BAT.

When developing a BAT justification, a review of all technology options must be made. Often, a number of possible technologies can be ruled out with a high-level review if strong arguments can be presented. A more detailed review may be required for a final decision between the selected options.

Guidance on BAT is provided on the Environment Agency (EA) website[2] as part of its guidance on environmental permitting. The information is separated into sector-specific guidance and ‘horizontal’ guidance. Horizontal guidance covers general topics such as noise or energy efficiency and also contains general guidance on environmental risk assessment. In the sector-specific guidance there are generally three further sub-divisions per sector: UK-specific environmental permitting guidance, UK IPPC guidance and EU BAT reference documents (BREFs). Of these, the BREFs are the most comprehensive and the environmental permitting guidance the most streamlined, but essentially they all deal with the same topics.

A simple reference to the guidance will be enough to identify BAT for some parts of a design, but where the alternatives considered are complex, a more detailed justification is needed following the methodology set out in its guidance for risk assessments[3].

identifying environmental risks

An important first step towards a design that is in line with BAT requirements is to carry out an environmental impacts identification (ENVID) assessment. This will then form the basis for further evaluation work and help to highlight where detailed BAT justification work is required. An ENVID can also be used to identify environmental aspects that are considered ‘insignificant’ and where the proposed design can be considered in line with BAT without further detailed justification.

An important use of the ENVID process is also to identify aspects of the design that are ‘unknowns’. In this respect the review should highlight where further information is required to ensure that all environmental aspects are effectively managed through the design process.

Above: A rural setting for the construction of a new UK gas-storage facility

assessing environmental risks

As part of the design work for a new project, risk assessments should be carried out as part of the ENVID review closeout. This is generally done by comparison against environmental benchmarks such as environmental quality standards (EQSs) and/or environmental assessment levels (EALs). This can often be done using simple techniques to model the impact of a release of a particular pollutant. Where simple techniques show the impact is 'insignificant' compared against an EQS or EAL, no further work is generally necessary.

In the case of indirect impacts such as global-warming potential (GWP), absolute quantification is not straightforward. However, a relative comparison between the impacts associated with different options is an alternative approach that can be applied.

comparing options and identifying BAT

EA guidance on options appraisal for BAT justification is provided in Annex (k) of its risk-assessment guidance[iii]. Generally, the steps required in this assessment are:

- ranking options according to their environmental impact;
- selecting the option with least impact; or

example 1 – vapour-recovery unit (VRU) for crude tanker loading

The example assessment below is for a VRU collecting vapour from an existing crude tanker loading facility[4].

Available techniques for VOC vapour recovery include: condensation, adsorption, absorption and membranes. In this example, an initial high-level review was used to obtain a shortlist for further detailed assessment of the following specific processes:

- condensation against a liquid refrigerant;
- adsorption on a carbon bed with vacuum regeneration and crude-oil absorption; and
- absorption directly into crude oil with membrane separation on the tail gas.

identifying environmental aspects

The environmental aspects associated with these processes can be identified as: continuous emissions to air/deposition to land, accidental release, energy consumption (and thus GWP), VOC release leading to photochemical ozone-creation potential (POCP) and waste disposal.

quantifying environmental risks

Dispersion modelling was carried out to identify the impact of each process on local atmospheric concentrations of VOCs. When combined with local air-quality information and compared against the relevant benchmarks, this analysis indicated that the environmental impact of the condensation and carbon-bed processes could be considered insignificant and that the crude-oil absorption would require further detailed modelling to fully assess the impact.

Release of process fluids from the VRU was a possibility for all options if an accidental fire could cause relief valves to lift. In addition, it is possible that a compressor could malfunction, resulting in an accidental release from the crude-oil absorption and condensation processes. However, for all cases the environmental risks were assessed as low.

We quantified the associated POCP and GWP for each process using a conversion factor for electrical-power consumption. This showed that condensation would have the highest impact and adsorption the lowest.

The models showed that none of the options would have a forseeable significant environmental impact in terms of waste disposal.

BAT justification

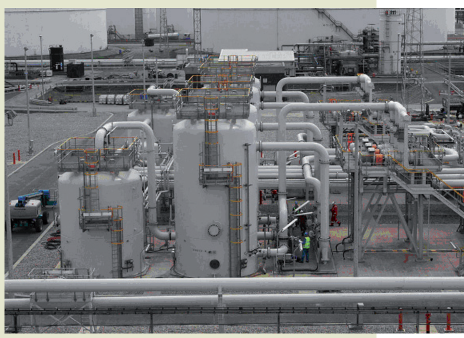
Based on benzene emissions, it was clear that the crude-oil absorption process would have a substantially higher impact on local air quality than the other two options.

The impact of the release of greenhouse gas was considered to be low for all options because the total GWP of the new facilities represents only a small fraction of the total site contribution. The impact of waste disposal was also low for all three options.

We did not judge the POCP score for all options to be a significant differentiating factor between the options because the VOC recovery from all schemes is relatively high.

Although both the carbon-bed and condensation schemes have a low impact overall, the carbon bed has less impact on local air quality, due to lower benzene levels and the fact that it consumes less power. This gives a lower score with respect to GWP. As both schemes have similar costs, we concluded that carbon-bed adsorption was the BAT option.

Below: The UK's VRU project



- making a justification based on costs versus benefits.

A BAT assessment summarises these steps and provides the justification for the final ranking of options.

Cost-benefit analysis is required if a justification is to be made for selecting an alternative to the option with lowest overall impact, such as if disproportionately high costs give a small marginal reduction in environmental impact. Guidance on the structure of this analysis is provided in the H1 guidance document but, in general, the final justification must be made based on a calculation of the total cost for each option compared against their relative impact.

summary

The two examples presented here give an outline of how BAT principles can be used to guide process-design selection.

It is important to remember that each of the process units considered also contain many equipment items that have design alternatives with varying environmental impact (eg, control-valve selection). As part of the environmental-review process for a complete plant design, all available technology and equipment options should be understood and BAT principles applied.

Regardless of the methodology applied in the environmental-review process, the important steps that need to be followed include: identifying and understanding the alternatives and their environmental aspects, quantifying the impacts, comparing technology options and concluding with a robust BAT justification, including cost-benefit analysis when required. **tce**

references

1 *Directive 2008/1/EC of the European Parliament and of the council of 15 January 2008 concerning integrated pollution prevention and control*

2 *http://www.environment-agency.gov.uk/business/topics/permitting/32320.aspx*

3 *Horizontal guidance Note H1 – environmental risk assessment for permits* (available on EA website)

4 *Control of tanker VOC emissions during loading, hydrocarbon engineering,* Dec 2000, Lee Scott

5 *Annex (h) of horizontal guidance note H1 - environmental risk assessment for permits* (available on EA website)

6 *Annex (k) of horizontal guidance note H1 - environmental risk assessment for permits* (available on EA website)

7 IEA technology road roadmap

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example 2 – energy recovery from pressure letdown

The second example is based on a gas-storage facility that both imports gas from the National Transmission System (NTS) and exports it, with the timing of cycles depending upon gas demand.

The pressure at which the gas is stored also depends upon the operating mode and, in some cases, a significant degree of pressure letdown is required to match export pressure with NTS pressure.

The base scheme for pressure letdown is to use a control valve. Gas expanding across a valve cools and, in this case, needs heating to avoid hydrate formation (freezing). The principal alternative to a control valve is to use an expander, which allows energy to be recovered from the gas and used to generate electrical power.

identifying environmental aspects

Apart from noise, which can usually be effectively mitigated by appropriate valve specification, the key environmental aspect associated with the pressure-letdown process is energy efficiency and thus GWP.

The expander option offers improved energy efficiency through the generation of electrical power, which avoids CO_2 emissions from power generation elsewhere. Against this, in the expander option there is a small increase in the release of CO_2 from the site heating medium system due to the lower gas temperature reached during pressure letdown.

Based on the sum of all CO_2 emissions from each scheme, it is possible to quantify the relative performance of the two options.

quantifying environmental risks

As operating conditions vary throughout the year, we identified a number of representative operation scenarios and used them as the basis for comparison. Against these scenarios we found that we would need a 10 MW expander to maximise power recovery, but this would often be under-utilised. Ultimately, the review included a half-sized machine because it was a better match to the annual demand profile.

As the base-case option does not have a specific CO_2 release associated, we quantified the impacts of the three options based on the CO_2 avoided relative to the control-valve base case.

This makes it possible to calculate the total CO_2 avoided based on the average CO_2 intensity of electricity generation[5] minus the CO_2 generated on site from additional gas heating. As the expander duty also varied with operating scenario, we derived a typical yearly figure from the identified operating scenarios.

BAT justification

Using EA guidance on cost-benefit analysis[6], it is possible to calculate an equivalent annual cost for each option based on estimated capital cost, operating costs, life expectancy and assumed discount rate.

In this example, the base-case option has little associated cost and, as such, a reasonable simplification is to calculate only the additional cost of the expander option and compare this with the CO_2 avoided relative to the base-case scheme.

The table shows example results based on a discount rate of 6% and a project life of 25 years. The operating revenues shown reflect the value of the electrical power generated by gas expansion.

Performance relative to control-valve option	*5 MW expander*	*10 MW expander*
capital cost (£000s)	7,000	13,000
operating costs/ revenues (£000s/y)	-70	-85
equivalent annual cost (£000s)	500	900
annual CO_2 release avoided (t)	1,100	1,300
cost £/t CO_2	450	690

The results show that there is no justification for using an expander in this case, based on the high cost of the CO_2 avoided. As a basis for comparison, the estimated abatement costs for carbon capture as applied to power generation is in the range 30-70 \$/t CO_2[7].

In addition to the simple comparison outlined above, the option to use an expander will result in other minor environmental impacts such as waste disposal from expander maintenance and possible fugitive emissions from seal systems.

Our conclusion therefore was that the BAT option in this case is pressure letdown using a valve.