Saving fuel costs with WPHEs

WPHEs save fuel costs and serve as a cost-effective CO_2-trimming technology by reducing heater duty in reformers and HDS units. The resulting fuel cost savings add to emission trade benefits

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It is clear that major resource and processing industries will soon have to compete in an evermore greenhouse gas (GHG) constrained world. While the exact timing and detail of some GHG legislation is still uncertain, consultants generally advise that proactive companies can "self-insure" and prosper by adopting innovative and cost-effective CO_2-trimming technologies.

The processing industries have already been operating for some time under restrictive legislation on NO_X and SO_X emissions. To provide a degree of flexibility on compliance, a market has been set in place that trades emissions credits for these two acid rain-forming chemicals. Those who have found ways to reduce their emissions below quota can now profitably sell their excess "right to emit" to those who have not. This market is fairly active. For instance, in 2003 in the California and Texas markets there was consistent trading from month-to-month in both the allowance and emission reduction credits (ERC) markets. This trend should continue given the US Environmental Protection Agency's (EPA's) mandate to further reduce emissions in both Houston and Los Angeles. The two cities have been competing for the unfortunate privilege of having the worst air quality of any major metropolitan area in the US.

Heat recovery

Excellence in process heat recovery is an important aspect in an oil refiner's overall strategy for dealing with atmospheric emissions. In fact, replacing generated heat with recovered heat should be a priority, because it is one of the few compliance tools available with a positive return on investment (ROI).

In the reactor section of many hydrotreating and reformer projects, the Packinox welded plate heat exchanger (WPHE) technology has significantly lowered both the operating expense of
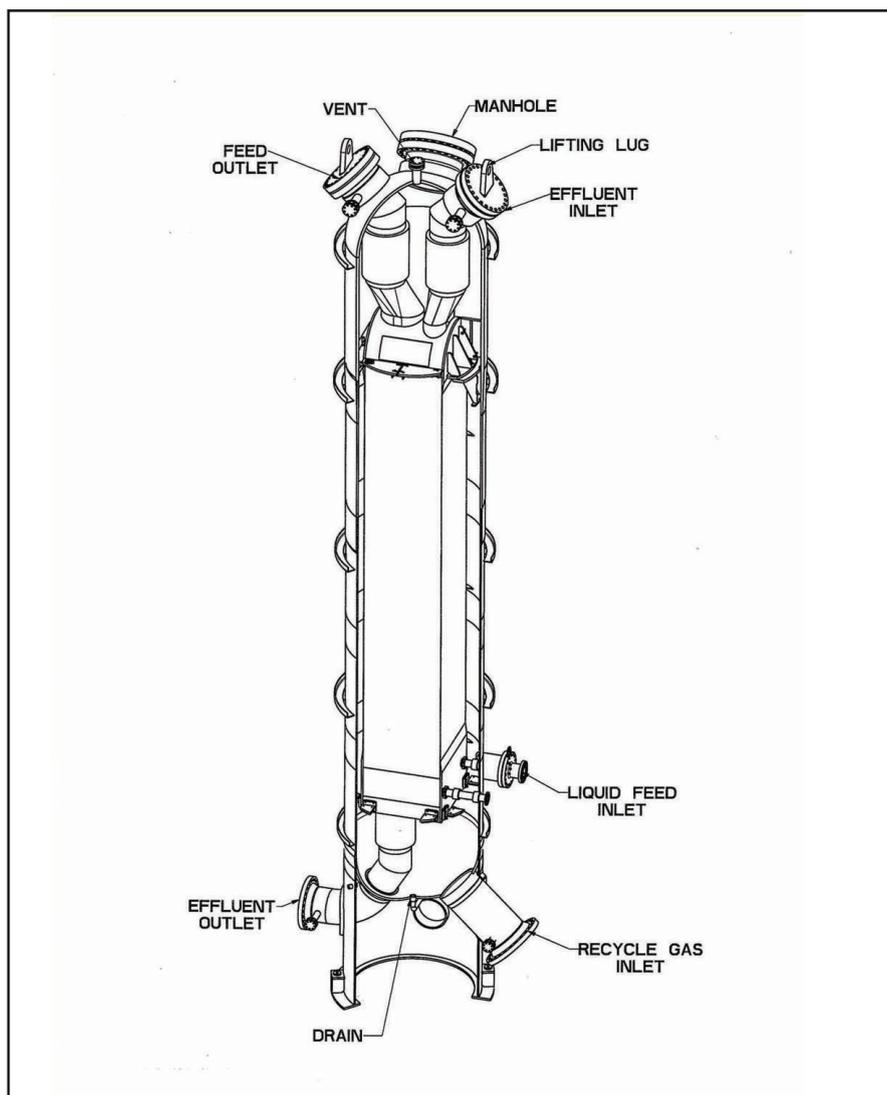

Figure 1 *Reformer reactor feed/effluent HE*

fuel and the total life-cycle cost of installed plants, relative to that possible with alternative exchanger types. Figures 1 and 2 illustrate WPHEs in reactor feed/effluent (F/E) service of low-pressure reformer and high-pressure HDS units.

WPHEs are built as a one-pass, true counterflow plate pack inside a pressure vessel. The use of long plates allows for tight thermal pinches between process streams and permits optimised heat recovery. The compactness of the design allows for large heat-transfer surface areas in relatively small exchangers. This keeps pressure drops low despite the high heat recovery. WPHEs have been built with areas over $15\,000m^2$ ($160\,000ft^2$) and duties up to about 150MW (500MM BTU/hr). A WPHE
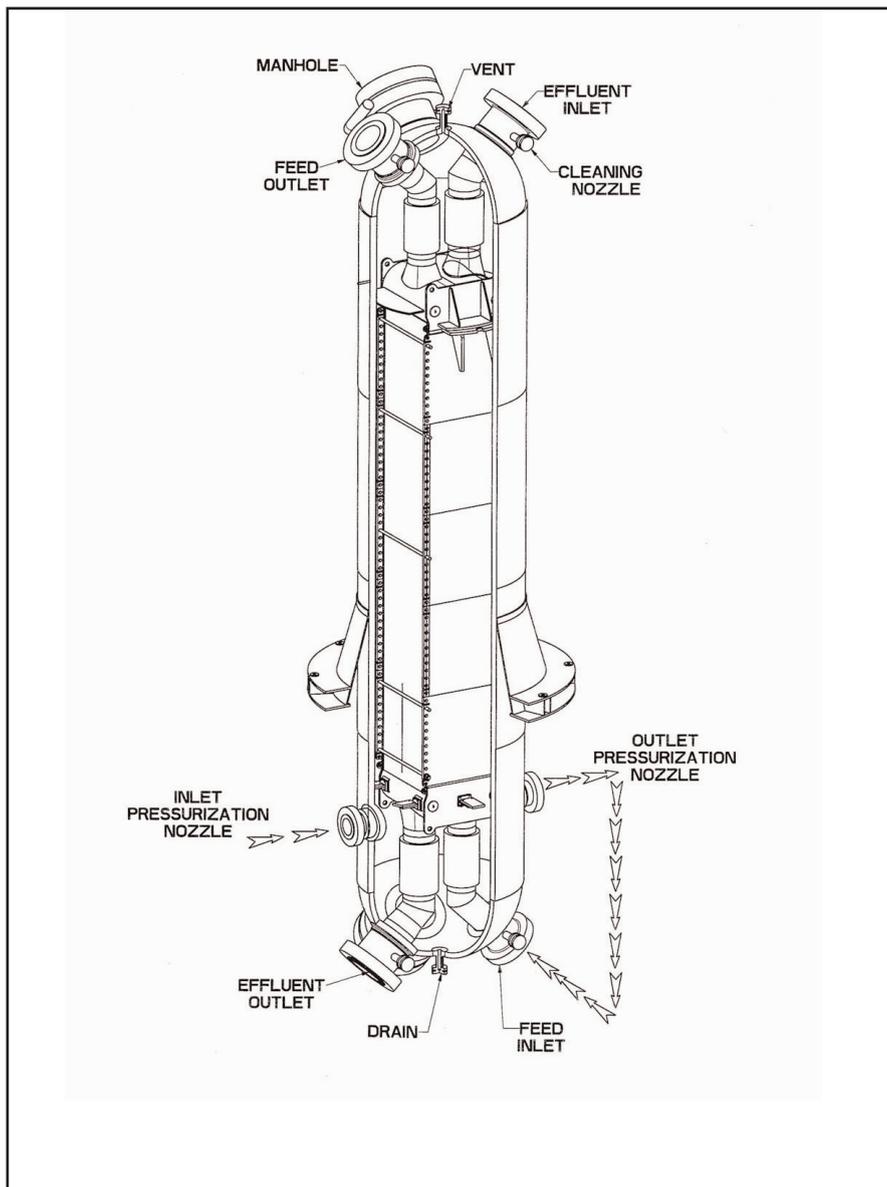
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Figure 2 HDS unit reactor feed/effluent HE

operates comfortably up to 550°C (1000°F). Maximum operating pressure is determined only by the design of the surrounding pressure vessel. WPHEs have so far been put in service at up to 120 bars (1750psi).

Typical payout times are less than two years, sometimes less than one. Traditional fuel savings still represent the greatest added value of a WPHE. However, in the new clean air era, the spin-off benefits from CO_2, NO_X and SO_X credits may add extra value, amounting to about 15–25% of the fuel cost savings of an energy-saving WPHE project.

Kyoto overview

In 1990, a group of eminent scientists and Noble Prize winners reported that: "the growing greenhouse effect has the potential to produce dramatic changes in climate."[1] The GHG emissions list includes CO_2, methane and some CFCs (chloro-fluoro carbons). Excluded are well-known acid rain or toxic air pollutants such as SO_x, NO_x and particulates. For most practical purposes in discussions of GHG legislation, trading and project planning, GHG simply means CO_2.

The Rio Convention of 1992, signed by the US and 155 other nations, called for a non-binding goal to stabilise GHG emissions at 1990 levels by 2000. It was later realised that most "Rio-signatories" could not or would not meet their 2000 GHG targets, so in 1995 a Conference of the Parties (COP-1) called for a new, stronger but more doable deal to be negotiated. This led to the Kyoto Protocol of 1997 (Kyoto). This treaty was signed by more than 160 nations. After ratification back home, a nation becomes a member state and is bound to meet its agreed GHG targets. For each first-world industrialised country, the broad goal is to cut GHG emissions to about 7% below its 1990 levels by 2012 (for example, 6%, 7% and 8% below for Japan, the US and EU, respectively). Aiming for efficient progress towards global GHG targets at the lowest overall cost, Kyoto allows industry to harness global market forces via three flexible mechanisms, in effect all variations of domestic or international emissions trading (ET).

Slowing but not stopping Kyoto's progress are some grey areas. These include debates on how to fairly allocate the allowed global total CO_2 emission between first- and third-world countries; how to monitor GHG emissions (at home and abroad); how to manage international ET; and how to set company penalties for non-compliance. Expected deterrents are fines, plant closures and even prison terms for senior company officers. In 2003, certain US congressional supporters of Kyoto sponsored a bi-partisan bill requiring the US to reduce its GHG emissions to 2000 levels by 2010, and then to 1990 levels by 2016. Meanwhile, several US companies are already cutting GHG. For example, by improving pollution controls and energy conservation, DuPont has slashed its emissions to 60% below 1990 levels.

Despite all such impediments, work has continued widely to resolve lingering disputes and to finish translating Kyoto's broad ideals into the fine details of workable legislation. By October 2004, 124 countries, including the EU, Russia, Japan, Canada, Switzerland and Norway, had ratified Kyoto to make it supported by countries that emit at least 55% of the world's GHG. At this level, it became international law on 16 February 2004 and will legally bind 55 signed-up industrialised nations to make significant GHG cuts by 2012. Many observers believe that Koyto's slow but steady progress toward universal acceptance is now unstoppable. They hope and trust that non-member large emitters like China and the US will eventually feel obligated to do their part in retarding global warming.

Kyoto: working details

A simplified summary of Kyoto's emerging workplan is now offered. The glue that holds it all together is the CO_2 emission allowance (EA), also called a CO_2 permit or credit. One EA confers the right to emit one metric ton of CO_2 (or CO_2 equivalent). In January 2008, at the start of the five-year commitment period (2008–2012), a signed-up member state or government (G) will be deemed to hold a stockpile of EAs based on the 1990 CO_2 levels it negotiated at Kyoto in 1997.

A nation's current accountable GHG

level will be taken as the total annual CO_2 emissions reported by all its large final emitters on a manageable list of included industries in three main sectors: oil and gas, electricity and mining/manufacturing. The huge transportation sector is notionally covered by regarding it as part of the oil industry, whose fuel sales are deemed to be fuel burned by the oil companies. Matching CO_2 emissions are then included in the oil industry's annual CO_2 tally. In this way, each developed country can adequately account for about 75% of its total CO_2 emissions.

From its EA stockpile, a G now allocates or freely grants an appropriate number of its EAs to each included company on its three-sector list. For the 2008–2012 commitment period, the initial EA numbers allocated in, say, December 2007 will be related to each company's 1990 CO_2 emissions. For oil and gas companies, this includes all the CO_2 emitted when their customers burned all refined fuel volumes sold by the oil companies in 1990. For the selected large industries, CO_2 emission performance is to be annually reviewed and improved. Such industries may buy or sell EAs by free market ET. Soon after the end of each commitment year (probably beginning around March–April 2009):

— Each company must complete and report to its G its CO_2 emission record for the previous year. It must then surrender to the G enough EAs to match the CO_2 it emitted last year. In Europe, the proposed shortfall fine is €40 per EA due but unreturned.[3] A similar fine may well apply in the US if/when Kyoto is ratified or the M&L bill passes. As it applies only to the CO_2 margin above permit, the EU fine for EA shortfalls should not be likened to the dreaded carbon tax idea that would apply to every ton of CO_2 emitted

— The G must delete or write off about 1% of its EAs each year. This ratchets down the member state's total CO_2 EA, keeping the G on track to meet its December 2012 Kyoto target. For each successive year, the G reallocates an ever-diminishing EA stockpile to the included companies on its three-sector list after any required updates.

The ET programme for CO_2 would be similar to existing programmes for SO_x and NO_x trading. Companies that trim their emissions below allowance level could sell their surplus EAs to firms that exceed their emission limits. Thus, excessive emitters can buy cheap, traded EAs to avoid costly shortfall fines, while more entrepreneurial industries have a bonus incentive (beyond lower fuel costs) to implement real energy-saving projects.

The Europeans are currently developing a central electronic EA registry system. This will hold all details of both national and company EA accounts and will record details of EA ownership changes due to emission trades. A balance will be sought between environmental transparency and commercial confidentiality.

Free market forces alone will determine the price of traded EAs. How closely the traded EA price will approach the shortfall fine (for example, $40) will depend on EA supply and demand. In turn, these two factors will depend over time on:
— The likelihood of Kyoto law applying in the location concerned
— How well most local companies are meeting their CO_2 quotas.

While CO_2 credits were traded in the US during October 2004 at about $1 per credit, some US emission traders have forecast market prices of around $20 before 2008 (ie, about half the €40 shortfall fine previously quoted). This suggests that many US oil industry analysts foresee a 50:50 prospect of US laws on CO_2 emission within three or four years, with a significant number of included companies still tardy in their energy conservation efforts and therefore obliged to bid for additional EAs. By contrast, companies proactive in energy conservation are foreseen to have an attractive market for their surplus EAs.

CO_2 trade: the 15% rule

As a general rule of thumb, CO_2 credits may add extra value, amounting to about 15% of the fuel cost savings of an energy efficiency project. To quantify the $ value of GHG reduction, handy guidelines have been developed as follows:
— For international readers and for brevity, heat duties are stated in megawatt (MW)
  Conversion factors: 1MW = 3.413MM Btu/hour = 20 640tcal/day
— To relate easily with annual GHG mass-flow accounting, both CO_2 and hydrocarbon fuel flows are stated in metric tonnes per annum (tpa) rather than in imperial volumes per hour.

For natural gas (NG) fuel, broad-brush estimates may be derived per MW reduction in charge heater radiant cell duty via data and equations as follows:

Flows of NG and CO_2 saved:

LHV, natural gas	= 11 500tcal/t	
On-stream factor	= 350 days pa	
NG/MW released	= 20 600/11500*350	
	= 627tpa/MW	
At radiant cell eff'y	= 65%	
NG fuel saved	= 627/0.65	
	= 965tpa/MW	(1)

Carbon/typical NG = 71 %wt
CO_2/NG burned = 44/12 * 71%
= 2.6 ton/ton
CO_2/radiant duty = 965 * 2.6
= 2500tpa/MW
(2)

Gas price G $/t related to crude $/bbl:
LHV of crude oil = 10 400tcal/t
LHV ratio NG/crude = 1.106
Crude oil sp Vol = 7.2bbl/ton
Crude price/barrel = B $/bbl
At same $/btu:
NG price/ton: G = B* 7.2 * 1.106
G = 8 * B $/ton
(3)

Annual $ benefits per MW:
NG cost saved = 965 * 8 * B
= B * 7700 $pa
(4)
CO_2 trade price = Ec $/ton
CO_2 trade value = Ec * 2500 $pa
(5)

Typical example values/MW:
Say crude oil B = 40 $/bbl. And:
CO_2 credits Ec = 20$/t. Then by Eq 4.5:
Fuel cost saved = 308 000 $pa/MW
(6)
CO_2 trade value = 50 000 $pa/MW
(7)

Thus, when Packinox cuts charge heater radiant cell duty by "Q" MW, typical fuel cost savings are about $Q * 300 000 pa. However, for Kyoto member states, CO_2 credits are a significant bonus, adding roughly another $Q * 50 000 pa of profit.

SO_x and NO_x trade: the 10% rule

As a rough rule of thumb, combined SO_x and NO_x credits (when applicable) can add value amounting to around 10% of fuel cost savings for an energy efficiency project, as derived in the following discussion. (Unlike the 15% for CO_2 credits, this 10% estimate may vary widely — for example, 0–20% — depending on the sulphur and nitrogen contents of the fuel burned.)

Molecules of SO_x & NO_x cause local acid rain rather than global greenhouse warming. Thus, for SO_x and NO_x, emission legislation generally focuses on some perimeter-defined bubble, not on the whole planet. However, as such differences do not impede the SO_x or NO_x ET, refiners that use Packinox equipment to cut fuel bills may also benefit from such trade. If emitting below allowed SO_x caps, the refiner can sell surplus SO_x permits. If emitting above caps, decreasing emission will save the refiner the purchase cost of SO_x permits. Either way
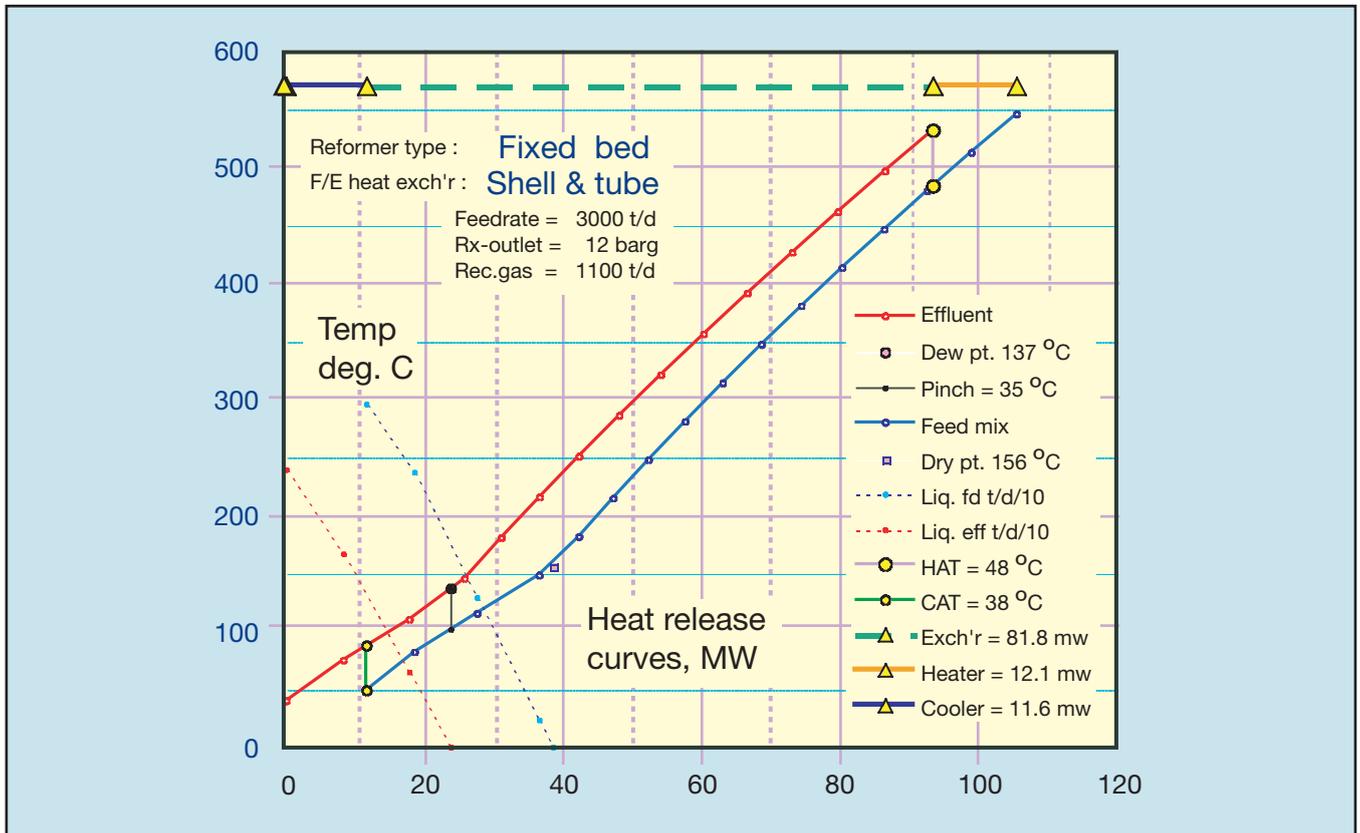
Figure 3 *F-bed reformer, S&T*

gives about the same ET benefits.

For quick scouting studies on SO_x and NO_x trade incentives to reduce charge heater duty, simple steps (at constant fuel price per heat unit) may be employed as follows:

All sulphur (atomic wt = 32) in fuel burns to SO_x, calculated as SO_3 (mol.wt = 80). Fuel gas is typically amine treated and sweet fuel oil (FO) is usually the main source of oil refinery SOx emission. For a fair scouting estimate (in the absence of any flue gas sulphur-removal system), factors per MW reduction in charge heater radiant cell duty may be derived as follows:

Flows of oil and SO_x saved:

LHV, fuel oil	= 10 000tcal/t	
FO/MW released	= 20 600/10 000 *350	
	= 720tpa/MW	
At radiant cell eff'y = 65%:		
Fuel oil saved	= 720/0.65	
	= 1100tpa/MW	**(8)**
Sulphur/fuel	= S %wt	
SO_x/S ratio	= 2.5t/t (= 80/32)	
SO_x reduction	= 1100 * S/100 * 2.5	
	= 27*S tpa/MW	**(9)**

Economic incentive:

SO_x ET price	= Es $/ton	
SO_x ET value	= 27*S*Es $pa	**(10)**

Typical example values/MW:

For SO_x ET, Es	= 1000$/t	
& FO sulphur, S	= 0.6 %wt*	

SO_x trade value	= 16 200 $pa/MW	**(11)**

Total NO_x has two main sources :
— Thermal NO_x: high temperature oxidation of molecular N_2 in pure air
— Fuel NO_x: direct oxidation of organic nitrogen (for example, NH_3) in fuel.

These are separately calculated, then added to give total NO_x make. Finally, this sum is corrected for any post-combustion NO_x control technology, such as selective catalytic reduction of acidic NO_x to benign N_2, to give actual NO_x emission to atmosphere.

Thermal NO_x is primarily a function of flame temperature (Tf). In turn, Tf is a complex function of fuel LHV, stoichiometric air/fuel ratio, excess air, air preheat, flue-gas recirculation, humidity, low-NO_x burners, burner intensity, heat-removal rate and gas-mix residence time. Often, in practice, some factors are trivial or absent and may be neglected.

ExxonMobil R&D reports a comprehensive calculation method for thermal NO_x.[4] This takes into account all the previously noted factors, but is outside the scope of this discussion. However, for quick ET scouting studies, Equation 9 gives a rough estimate for thermal NO_x emission in tpa per MW radiant cell duty. This simulates typical modern heaters on-line for some 350sd/yr with about 150°C air preheat.

Thermal NO_x = 3 +/-1.3tpa/MW		**(12)**

The user may choose to "gestimate" small variations on either side of the base number if they know of some factor that will increase or decrease typical Tf (for example, large hydrogen contents of fuel gas will raise Tf and thermal NO_x, and absence of air preheat will lower Tf and thermal NO_x).

The fuel NO_x calculation assumes that all N (at.wt = 14) burns to NO_2 (mol.wt = 46). Then, approximate factors per MW reduction in charge heater radiant cell duty may be derived as follows:

Fuel/radiant duty	= 1100tpa/MW	
Nitrogen/fuel	= N %wt.	
NO_x/N ratio	= 3.3t/t (= 46/14)	
NO_x reduction	= 1100 * N/100 * 3.3	
	= N * 36tpa/MW	**(13)**

Total NO_x economic incentive:

NO_x ET price	= En $/t	
NO_x ET value	= (3+36*N)* En $pa/MW	**(14)**

Typical example values/MW:

For fuel nitrogen N = 0.25 % and NO_x trade price, En = 1000$/t:

NO_x value by Eq 14	= 12 000 $pa/MW	**(15)**

Combined benefit of SO_x and NO_x credits

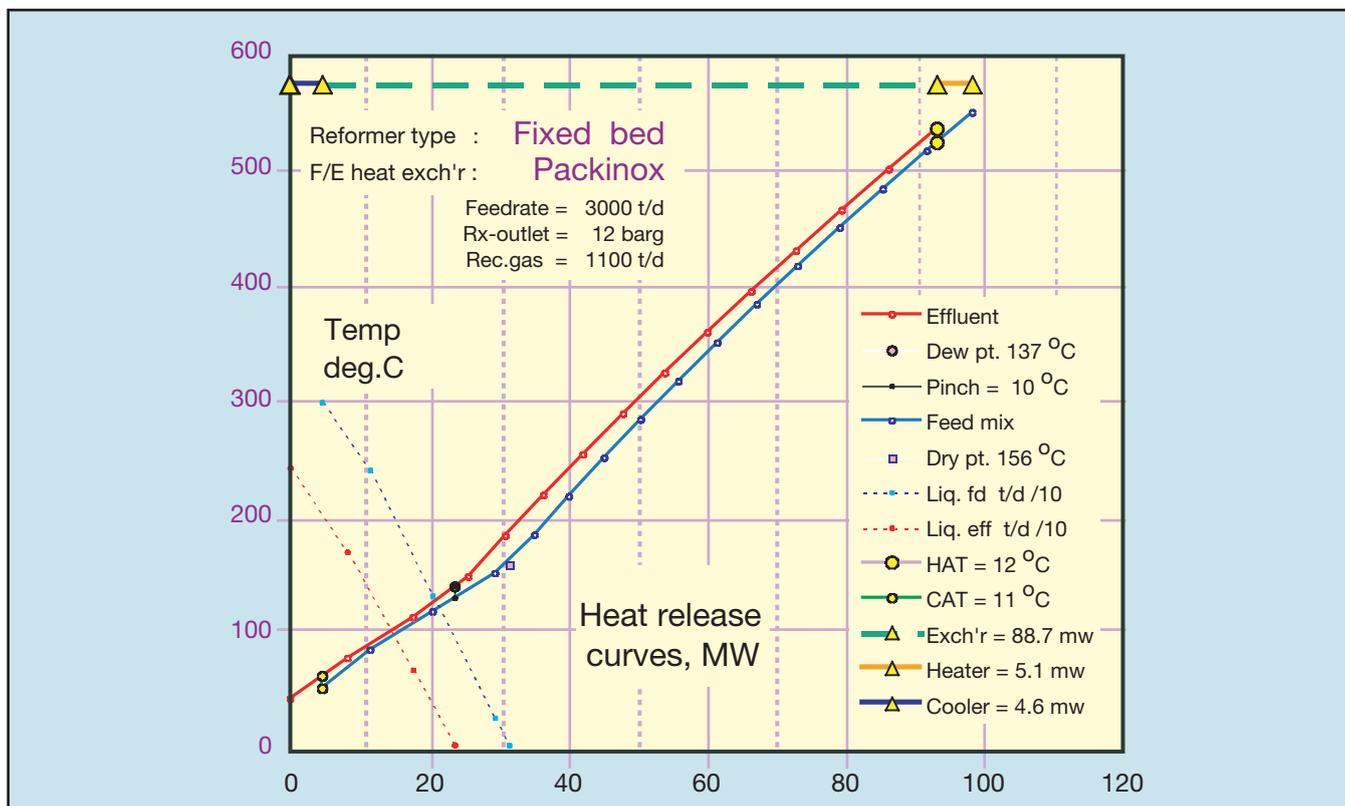Per MW reduction in radiant cell duty, the previously noted example values

Figure 4 *F-bed reformer, PHE*

would provide total SO_x and NO_x credits of almost 30 000 $pa/MW. As before, fuel cost savings would be some 300 000 $pa/MW. Thus, the notional ratio of potential SO_x and NO_x credits/fuel savings is about 10%.

How a WPHE saves fuel
In refinery oil conversion or hydrotreating units, WPHEs are widely employed as reactor F/E heat exchangers in the high-pressure (HP) reactor loop. In such loops, the fired heater's key role is to inject a slug of high-level heat into reactor charge, essentially via the radiant cell. However, radiant heat transfer is typically only around 60% of the total heat released by fuel combustion. The remaining 40% is waste heat, of which about half may be recovered at a relatively low temperature level (for example, in a waste heat boiler, WHB), while the rest is directly wasted as hot stack gas to the atmosphere.

In most refineries, abundant low-level heat sources (such as in hot flue gas, hot column top-vapours and uncooled product rundowns) greatly outweigh the scarce low-level heat sinks (such as heavy oil tanks and lines). When WHB steam from avoidable hot flue gas ultimately condenses against a low-level heat sink, the warming of that sink usually dooms the potential recovery of truly unavoidable waste heat from elsewhere. Thus, in the final analysis, marginal heat recovery in a plant WHB

may have little impact on total refinery fuel consumption. Consequently, within the accuracy of carbon credit arithmetic, the long-term fuel burn and CO_2 result of changes in radiant cell duty (or reactor charge heat duty) may be computed as if the fired heater had no WHB. Thus, we may take fired heater efficiency = radiant cell efficiency = 60%, or 65% for a more conservative analysis.

The following case studies show how charge heater duties are reduced by achieving much closer pinch temperatures (or delta-Ts) within the F/E plate exchanger than practically possible with tubular exchanger types. As shown in the example heat-release curves of Figures 3 to 6, this also means smaller HAT and CAT values (hot-end and cold-end approach temperatures) for the HE. Thus, the charge heater's inlet temperature is hotter, its heat duty is lower, so less fuel is burned and less CO_2, SO_x and NO_x are emitted. Pushing the concept to its logical extreme, one particular Packinox-based HDS-type unit with a high reactor exotherm now operates well with its charge heater totally bypassed and thus its stack emissions cut to zero. In all cases, the smaller CAT value means the required cooler duty is also lower, with further savings in capital cost and plot space.

Low-pinch technology
The vital small-pinch results from the combination of:

— **Carefully managed, uniform distribution of two-phase flow:** F/E inlet lines have patented liquid/vapour pre-mixing devices. The wide-slot entry to all flow canals plus static mixer type flow homogenisation within the plate pack ensures well-mixed turbulent flow at every point in the plate pack, with no troublesome dead zones

— **High overall heat-transfer co-efficient (OHTC):** Packinox OHTC is about twice that of S&T exchangers due to the above flow pattern plus corrugations on Packinox plates that are optimised to promote useful turbulence with minimal pressure drop

— **Very large heat-transfer surface areas:** compact plate pack construction facilitates more m^2 area per m^3 of shell volume.

In numerous cases, the overall effect of these three factors has allowed refiners to get a larger guaranteed heat duty (and a lower pressure drop) from a single HE than would ever have been possible from multiple S&T exchangers. The Packinox option also saves installation costs by simplifying piping and using less plot space.

Case 1
Fixed-bed reformer: F/E exchanger upgrade
In one early 1990s revamp for capacity increase, an Asian reformer's F/E HE system was upgraded by replacing its early model Texas Tower with a more efficient WPHE. This avoided an

expensive charge heater project plus a difficult and costly extension of the product cooler with limited available plot space. Total capital cost of the Packinox option was significantly less than the heater-plus-cooler-based alternative revamp.

Figures 3 and 4 show key reactor loop conditions plus F/E exchanger HRCs before and after the revamp. For about a year after the revamp, the unit was only required to run at its original 3000t/d capacity. Due to F/E pinch point improving from 35–10°C, charge heater duty decreased from 12.1–5.1MW, lowering radiant cell duty by 7MW. The corresponding drop in fuel gas consumption was about 6700tpa (see Equation 1).

At cost parity with 40 $/bbl crude, the fuel cost savings amount to $2.1 million pa (= 7MW * 308 000 $pa/MW, Equation 6). This paid out the WPHE in a short time and continues the refiner's annual opex benefit to this day.

The post-revamp fuel reduction per MW was actually greater than the previous discussion predicted. This is because, with the charge heater radiant cell now at below half its design capacity, flue gas outlet temperature from the radiant cell fell enough to raise effective heater efficiency from 60–70%. In the decade since this Case 1 revamp, F/E exchangers have been further improved so that now Texas Towers

claim pinch points of 22–25°C, while WPHEs compete today with pinch points of 7–10°C. Today, delta emission credits may be predicted by Equations 7, 11 and 15 as follows (Note: the following example calculation assumes that refinery fuel price equates to crude at $40/bbl, S/fuel = 0.6%, N/fuel = 0.2%, and applicable CO_2/SO_x/NO_x credits are 20/1000/1000$/t):

CO_2: 7MW * 50 000 $pa = $350 000 pa
SO_x: 7MW * 16 000 $pa = $112 000 pa
NO_x: 7MW * 12 000 $pa = $84 000 pa
Total emission credits = $546 000 pa

For input data other than assumed in this discussion, these estimates can be easily reworked using the simple equations provided.

Case 2

CCR reformer: F/E exchanger upgrade
To compare reformer types, this study examines a revamp similar to Case 1, but with a more modern CCR reformer whose F/E exchanger HRCs are shown in Figures 5 and 6. It is assumed that the CCR upgrade options will be either a modern Texas Tower with a 22°C pinch point or a Packinox HE with a 7°C pinch point.

At the same naphtha charge rate of 3000t/d, this unit runs at about half the ROP (6 not 12 barg) and a much lower mol-ratio, since recycle gas (RG) flow rate is much lower (250 not 1100t/d).

This much lower vapour-to-liquid

ratio, coupled with the requirement for lower pressure drop, has made it a lot more difficult to consistently achieve proper dual-phase feed distribution and uniform, vigorous liquid lift inside the heat-transfer bundle. In that respect, the static mixer effect generated by the geometry of plate heat exchangers has become a significant asset in the drive toward lower hydrogen-to-oil ratios.

The Packinox option now reduces heater duty by an additional 3.4MW (9.2–5.8), with fuel savings of about $1.05 million pa (= 308 000 * 3.4, by Equation 6). Ongoing million $pa savings such as these clearly make a WPHE (rather than a S&T) the better economic option for any CCR upgrade.

Using the same method as in Case 1, emission credits are predicted as follows:
CO_2: 3.4MW * 50 000 $pa = $170000 pa
SO_x: 3.4MW * 16 000 $pa = $54 000 pa
NO_x: 3.4MW * 12 000 $pa = $41 000 pa
Total emission credits = $265 000 pa

Case 3

Gas oil HDS redesign
In the mid-1990s, a large number of HDS studies were commissioned for interested refiners in Asia, Europe and the Americas. For the average study capacity of 35 000bpd, the five-year benefit was $10 million for selecting Packinox PHEs rather than S&T exchangers. This equates to just under
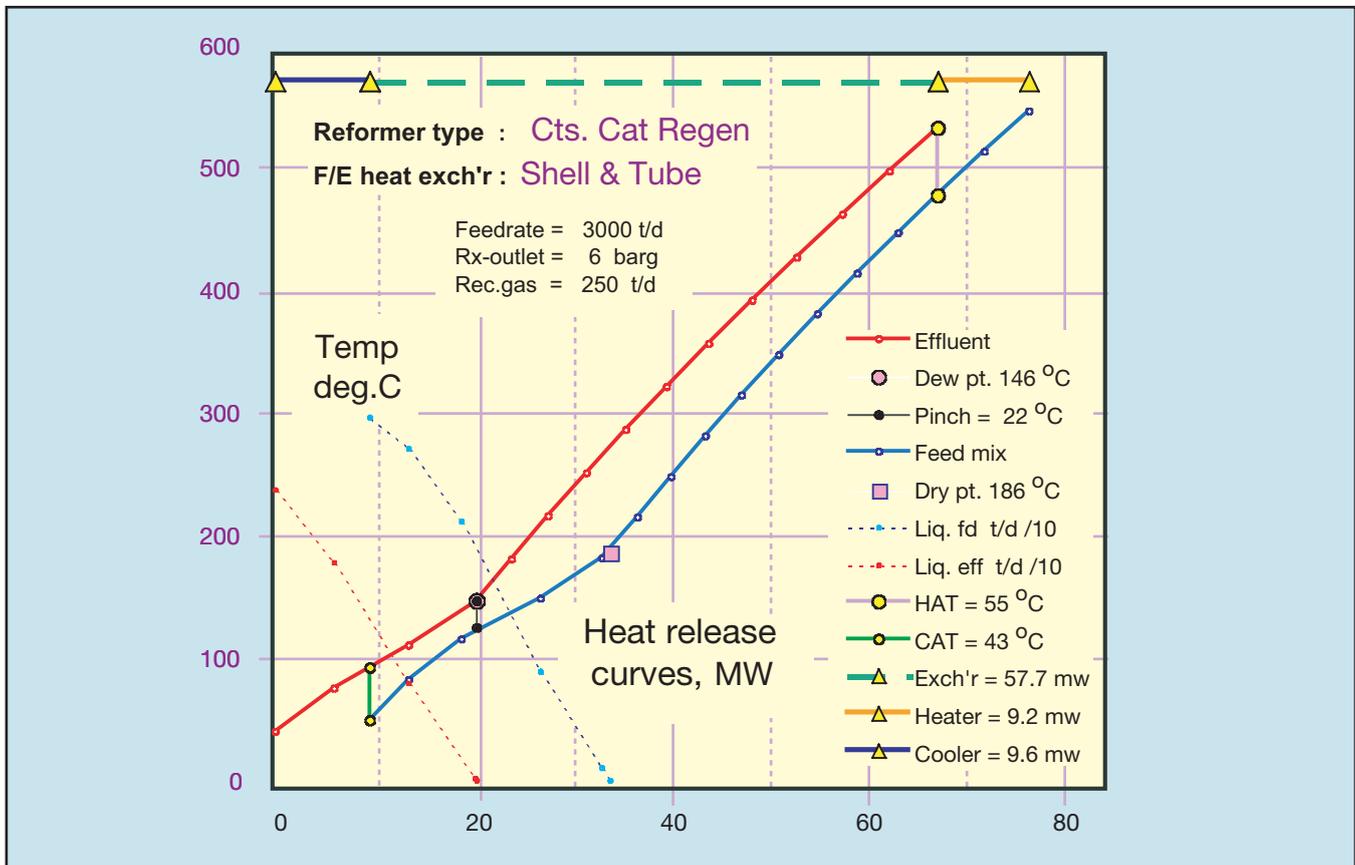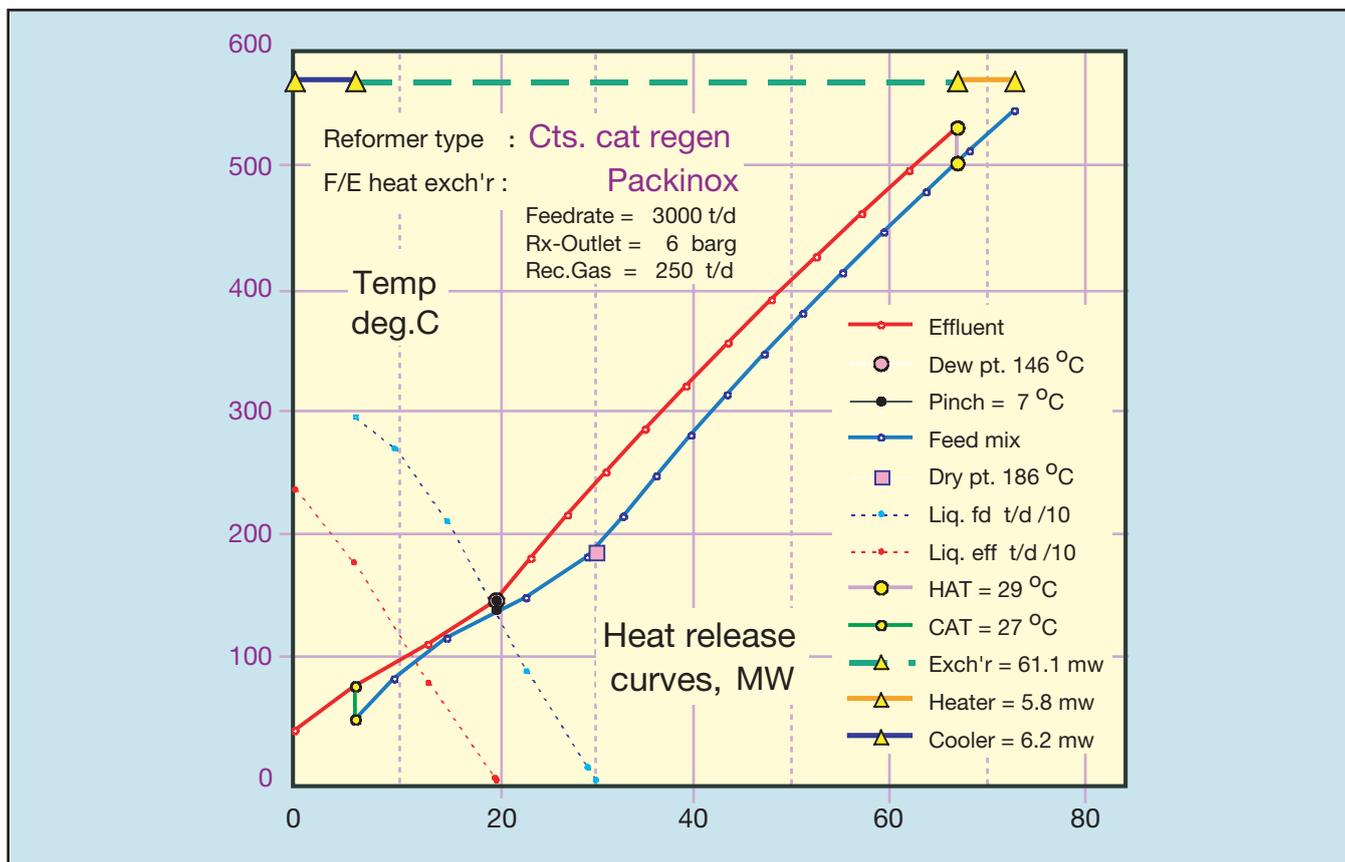

Figure 5 CCR reformer, S&T

Figure 6 *CCR Reformer, PHE*

$3 million per 10 000bpd for a mix of hot and cold HP separator designs.

In 1996, a major Taiwanese refiner (FPC) was planning two new 65 000bpd (= 8600t/d) cold separator HDS units. For all reactor and stripper F/E duties, FPC selected PHEs (rather than S&T exchangers). After a careful redesign by IFP, it was confirmed this would save $48 million in the refiner's five-year business plan. In effect, this 1996 design study compared IFP alternatives (see Figures 3 and 4, *PTQ Spring 2004*, p87, with the referenced Figure 4 heater-duty corrected to 5MW) as follows.

For each plant, a 20MW energy saving (direct fuel and electricity) was valued at $3.3 million pa, or $16 million for the first five years of operation. In addition, fewer and smaller equipment items would cut installed capital cost by $8 million. Thus, total five-year savings = (16 + 8) x 2 = $48 million for the two units. This equates to $3.7 million per 10 000bpd (ie, close to the previously mentioned study average).

Compared with the 23MW heater in the superseded S&T option of Figure 3 (*PTQ Spring 2004*), FPC's project now operates successfully as per the Figure 4 from *PTQ Spring 2004*, with charge heater duty reduced by 18MW to only 5MW (Des, 12MW). Recycle gas compressor power is reduced by 1.5MWe, equivalent to about 2MW radiant cell duty. In the foreseen Kyoto era, the net reduction of 20MW in radiant cell duty would be now credited with saving future fuel costs of about $6.2 million pa (= 20 * $308 000).

Where applicable, CO_2 emission permits would be worth about $1 million pa (= 20 * 50 000). Then, SO_x plus NO_x permits would add possibly another $0.6 million pa. (This emerges by combining Equations 11 and 15 to obtain 20MW x $30 000/MW). As estimated earlier, scouting-type total emission credits of $1.6 million pa are roughly 25% of the $6.2 million pa total fuel cost savings.

Of the $8 million capex saved per HDS unit at FPC, only $1 million was directly due to lower F/E exchanger purchase costs compared with S&T costs. The other $7 million was due to spin-off effects, such as smaller fired heaters, coolers and compressors, plus lower civil and piping installation costs. This project highlights a common issue found on many Packinox projects, where the price difference between PHE and S&T equipment is relatively trivial but hides much larger savings elsewhere.

The authors extend their appreciation to the editorial and technical contributions from Daniel Sloan, president, Emission Reduction Specialists in the USA.

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On March 18, 2005 ALFA LAVAL has acquired PACKINOX which will change its name to ALFA LAVAL PACKINOX.