ISOTHERMING®
HYDROPROCESSING TECHNOLOGY

Growing global demand for transportation fuel continues to drive refiners toward operations that maximize hydroprocessing capacity and capability either through unit debottlenecks or new unit construction. More stringent environmental regulations and the processing of cost-advantaged sour and heavy feed stocks make meeting this demand even more challenging.

IsoTherming® hydroprocessing technology is a commercially proven process that provides refiners a more economical means to produce today's transportation fuels.

The core of IsoTherming® technology, Figure 1, is the ability to provide the hydrogen necessary for the reactions using a liquid stream, rather than a recycle gas system. The reactor feed is saturated with hydrogen which ***eliminates the need for a recycle gas compressor***. To satisfy hydrogen requirements within the reactor, additional hydrogen can be added by means of an external liquid recycle stream or inter-bed hydrogen injection.

Operating the reactor liquid-full also acts as a heat sink for the exothermic reactions. Thus, the reactor operates closer to isothermal conditions, which reduces uncontrolled cracking reactions and lowers light ends make.

Application, design objectives and hydrogen requirements dictate optimal reactor design including required number of catalyst beds and recycle ratio. With similar operating temperatures and pressures to conventional technology, IsoTherming® technology has a number of very attractive benefits to a refiner.

Applications for IsoTherming®, whether grassroots or revamp, include:

- Kerosene Hydrotreating
- Transmix Hydrotreating
- Diesel Hydrotreating
- FCC Feed Hydrotreating
- Mild Hydrocracking
- Dewaxing
- Gas-To-Liquid (GTL) Upgrading
- Heavy Oil Upgrading

DuPont
Clean Technologies

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REDUCED OPERATING EXPENSES

By eliminating the hydrogen gas compressor and its ancillary recycle loop equipment, significant maintenance and operating cost savings can be realized. In addition, IsoTherming® recovers the heat of reaction by recycling a portion of the hot hydrotreated product back to the inlet of the reactor. This direct transfer of heat to the feed in turn reduces the fired heater duty. Overall, IsoTherming® technology has consistently demonstrated a 40-60% utility savings over trickle bed technology including:

- **FUEL GAS: 30 TO 60% USAGE REDUCTION**
  - Heat of reaction absorbed by liquid recycle
  - Liquid recycle used to heat the feed
  - Lower heater firing rates in normal operation
  - Lower greenhouse gas emissions
- **POWER: 30 TO 40% USAGE REDUCTION**
  - Reactor recycle pump vs. recycle gas compressor
- **ENERGY RECOVERY: 30 TO 50% INCREASE**
  - Optimized heat integration/heat recovery allowing for steam or power generation
  - Lower maintenance costs
  - Less equipment
  - Reactor recycle pump vs. recycle gas compressor

INCREASED CATALYST LIFE

With a liquid-full reactor, IsoTherming® technology ensures the catalyst is completely wetted thus drawing the heat of reaction away from the catalyst surface and minimizing local hot spots. In addition, even liquid flow throughout the catalyst bed results in a uniform radial temperature profile. These phenomena minimize light ends generation and catalyst deactivation due to reduced coke formation.

These claims are supported commercially by several operating units that have experienced catalyst life in excess of 4 years in VGO hydrotreating service.

CAPITAL COST ADVANTAGES

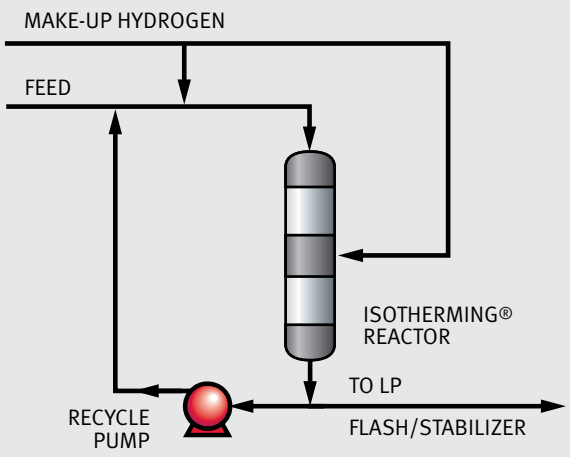
IsoTherming® technology has demonstrated significant capital cost advantages, particularly in the area of refinery hydroprocessing revamps and low hydrogen use applications (e.g. kerosene, transmix processing, dewaxing). While savings in excess of 30% have been seen, these are dependent upon the application under consideration, incremental capacity requirements and global economic factors.

Replacing the recycle gas compressor and ancillary equipment with a single recycle pump provides a clear advantage to IsoTherming® technology in the event of a revamp. There is no need to replace or supplement any existing recycle gas equipment. This is also a benefit when plot constraints are present for any project, whether it is a revamp or grassroots construction.

For those projects with low hydrogen consumption, the ability to supply the hydrogen through feed saturation rather than a gas recycle system inherently means fewer pieces of high pressure equipment resulting in lower capital costs.

As mentioned, IsoTherming® technology recovers the heat of reaction by recycling a portion of the hot hydrotreated product back to the inlet of the reactor. As such, the feed/effluent exchanger heat duty requirements are reduced, which contributes to the reduction in the number of pieces of high pressure equipment required when comparing to an equivalent trickle bed design.

FIGURE 1. ISOTHERMING® TECHNOLOGY



ROBUSTNESS, RELIABILITY AND SAFETY

An easier to operate process due to liquid full reactors enables reduced start-up and shutdown times. IsoTherming® technology has also proven to recover quickly from process upsets without loss of catalyst activity. In one instance, after a 4 hour refinery wide power failure, the IsoTherming® unit returned to stable operation producing on-spec product at similar inlet temperatures within 5 hours of power return. Typical recovery time of a trickle bed reactor from a similar event would be in excess of 24 hours and include catalyst deactivation.

Elimination of the recycle gas compressor and associated treating equipment also removes a large amount of high pressure equipment from the hydroprocessing unit. Not only does this result in a substantial plot space reduction, but also provides a significant reduction in overall unit hydrogen inventory. Since the hydrogen content in liquid full catalyst beds is limited by solubility, it eliminates any potential of reactor runaway. Therefore, IsoTherming® reactors are inherently safer than conventional trickle bed reactors.

CONFIGURATION FLEXIBILITY

For refiners contemplating a revamp of existing hydrotreating assets, IsoTherming® offers the option of utilizing an IsoTherming® reactor system as a pretreatment unit. If there is an existing hydrotreater, the IsoTherming® hydrotreating technology can be installed as a simple pretreat unit ahead of the existing hydrotreater, **Figure 2**.

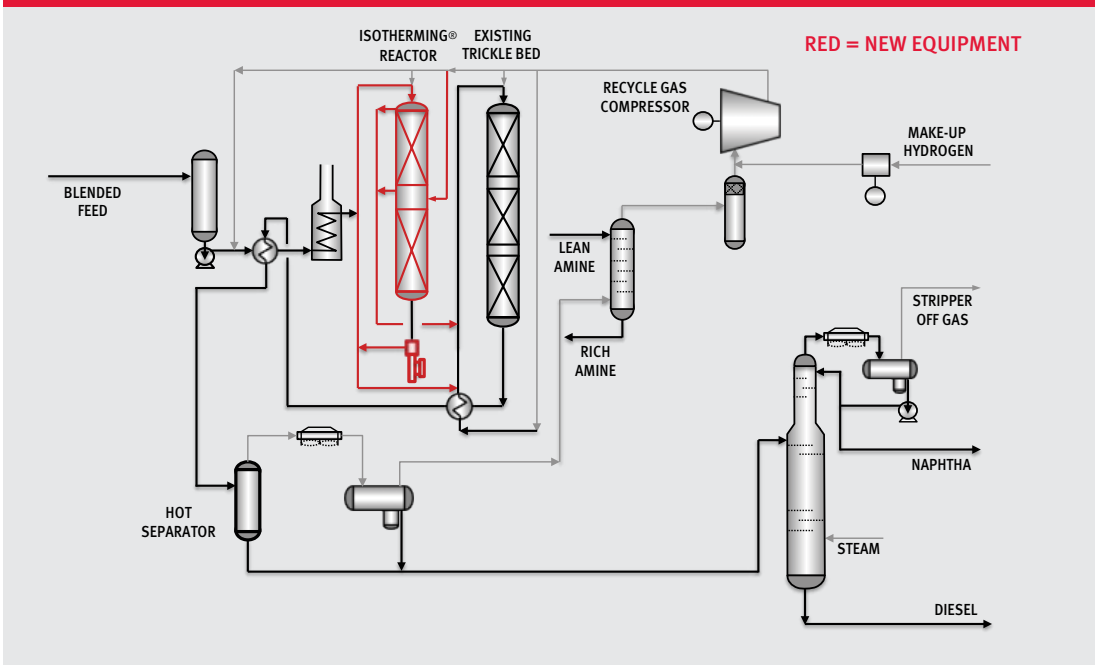
The pretreat configuration can be installed at a fraction of the cost of competing low sulfur technologies. The IsoTherming® pretreat reactors do most of the hydrodesulfurization, leaving less work for the existing conventional reactor, which now operates in a polishing mode. Any mass transfer limitation of the conventional trickle bed reactor is no longer a constraint because the IsoTherming® reactors have already transferred the bulk of the hydrogen to the oil. Because of this, catalyst deactivation due to coking in the conventional reactor is drastically reduced. For existing low pressure units, a higher pressure IsoTherming® loop can be installed maximizing the use of existing assets and minimizing overall costs.

REDUCED LIGHT ENDS MAKE

The lower temperature rise across the IsoTherming® reactor and liquid-full beds allow the refiner to achieve their desired product specification while minimizing undesired cracking reactions. This reduces the yield of light ends that have limited value within many refineries.

In addition, the reduced cracking reactions decrease hydrogen consumption for the same product specification. The degree of improvement, of course, will vary depending on a number of factors (feedstock, service, operating conditions and catalyst to name a few). For highly unsaturated feedstocks such as light cycle oil (LCO) or coker gas oil (CGO), the low temperature rise across the IsoTherming® reactor system provides a particular advantage not only due to decreased uncontrolled cracking, but allows for effective treatment of hard to remove nitrogen compounds without sulfur recombination.

FIGURE 2. ISOTHERMING® REVAMPED DHDS UNIT



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COMMERCIAL REFERENCES AND SUMMARY FOR ISOTHERMING® TECHNOLOGY LICENSING ACTIVITY TO DATE

OPERATIONAL UNITS						
			CAPACITY			
Licensee	Location	Year of Startup	BPSD	KTPA	M^3/HR	Application
CNOOC	China	2017	71,639	3,400	475	Grassroots ULSD Hydrotreater
CNOOC	China	2017	59,105	3,000	341	Grassroots VGO Hydrotreater
Allied	USA	2017	2,000	94	13	Grassroots ULSD Hydrotreater
Gladieux	USA	2017	5,000	233	33	Grassroots ULSD Hydrotreater
HPCL	India	2015	50,000	2,600	331	Revamp ULSD Hydrotreater
Sinochem	China	2014	78,501	3,900	520	Grassroots ULSD Hydrotreater
PetroChina	China	2013	12,487	625	83	Grassroots Diesel Hydrotreater
Zhejiang Meifu	China	2012	6,026	300	40	Grassroots Diesel Hydrotreater
Jinao Hubei	China	2012	20,000	1,000	132	Grassroots Diesel Hydrotreater
Proper Year	China	2011	8,000	400	53	Grassroots Mild Hydrocracker
Frontier	USA	2010	50,000	2,600	331	Revamp VGO Hydrotreater
Holly	USA	2009	15,000	750	99	Grassroots Mild Hydrocracker
Holly	USA	2009	15,000	750	99	Grassroots Mild Hydrocracker
Western	USA	2006	12,000	600	79	Grassroots ULSD Hydrotreater
Western	USA	2006	5,000	250	33	Grassroots Kerosene Hydrotreater
Western	USA	2003	3,800	190	25	Revamp ULSD Hydrotreater

AWARDED, IN DESIGN OR UNDER CONSTRUCTION						
			CAPACITY			
Licensee	Location	Year of Startup	BPSD	KTPA	M^3/HR	Application
TBA	Russia	2020	2,264	115	15	Grassroots Diesel Hydrotreater
TBA	Argentina	TBA	10,265	515	68	Grassroots ULSD Hydrotreater
TBA	China	TBA	45,890	2,275	304	Grassroots VGO Hydrotreater
TBA	China	TBA	6,026	300	40	Grassroots Mild Hydrocracker
TBA	China	TBA	6,026	300	40	Grassroots Mild Hydrocracker
TBA	Canada	TBA	1,500	82	10	Grassroots Distillate Hydrotreater
TBA	China	TBA	51,127	2,400	339	Grassroots ULSD Hydrotreater
TBA	USA	TBA	20,000	995	132	Grassroots ULSD Hydrotreater
TBA	China	TBA	6,026	300	40	Grassroots Diesel Hydrotreater
TBA	USA	TBA	46,000	2,300	305	Revamp ULSD Hydrotreater
TBA	USA	TBA	10,000	502	66	Grassroots ULSD Hydrotreater

WORLDWIDE SALES AND SUPPORT

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