hiTRAN®
thermal systems

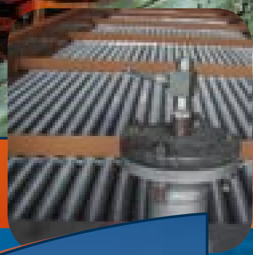
Enhancing performance of tubular heat exchangers and reactors

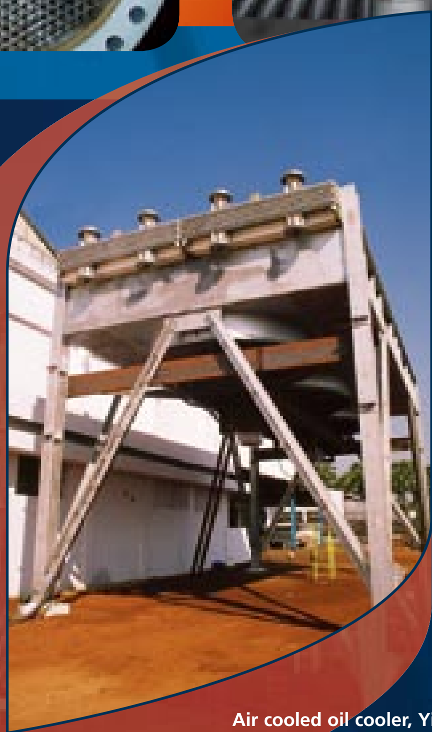
THIRTY YEARS 30 RESEARCH EXCELLENCE

CAL GAVIN
Process Intensification Engineering

hiTRAN® Systems

LNG condensate reboiler, duty increased, maldistribution corrected.
Courtesy: Woodside Offshore Petroleum, Australia





Air cooled oil cooler, Yibal.
Client: Petroleum Developments Oman
Courtesy: GEA, India

HEATERS • COOLERS • CONDENSERS • VAPOURISERS
REBOILERS • THERMO-SYPHON REBOILERS • REACTORS •
FALLING FILM EVAPORATORS • CLIMBING FILM EVAPORATORS
DE-VOLATILISERS • INTERCOOLERS • AFTERCOOLERS •

Market Sectors:

- Oil exploration and production
- Gas production, transmission and treatment
- Oil refining
- Petrochemical and downstream processing
- Organic and inorganic chemicals
- Plastics, polymers and resins
- Speciality and fine chemicals
- Fertilisers and agro-chemicals
- Food processing and pharmaceuticals
- Refrigeration and cryogenics
- Power generation and distribution

Over 30 years of experience

More than 16,000 exchangers enhanced worldwide

The applications for which Cal Gavin can provide successful technical solutions continue to expand even after 30 years. The process industry encompasses a very wide range of processes, systems and equipment, all purpose-designed to meet specific requirements. Each service and duty is different, each exchanger is individually designed and each proposal unique.

'DALIA', Angola, floating production. hiTRAN/Helical baffles. DKME/Samsung. Courtesy: Total Oil

hiTRAN Enhancement Systems provide unique solutions to substantially enhance the performance of all tubular construction heat exchangers, delivering an extensive range of technical and economic benefits including:

- increased production and longer run-times
- reduced processing and maintenance costs
- reduced energy costs
- improved product quality
- increased plant operability
- lighter, more compact designs
- lower cost of new plant

The core proprietary technology incorporates a system of Matrix Elements (hiTRAN System), that is installed on the tube-side of tubular exchangers and reactors. The resulting highly engineered systems are purpose-designed for each application. They are installed in new exchangers after fabrication and can easily be retro-fitted to debottleneck existing equipment. The systems are used to enhance both single and two-phase flow applications, high and low viscosity fluids, Newtonian and non-Newtonian fluids, together with a wide range of unique flow regimes.

With a variable geometry that can be selected to meet a broad set of requirements and conditions, most processes can benefit. Payback is usually rapid making the cost of ownership an affordable investment.

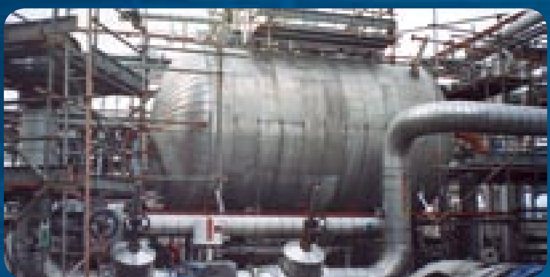
From strength to strength, research underpins all our engineering proposals.

Cal Gavin invests a considerable proportion of its revenue in researching and testing in the field of modified flow dynamics and heat transfer enhancement. The resulting data supports and extends hiTRAN.SP selection software, available for download from the Cal Gavin website www.calgavin.com. hiTRAN.SP is available as a plug-in which interfaces with HTRI and Aspentech, and also as a standalone programme for tubeside optimisation.

Cal Gavin strives hard to provide a professional and dedicated design support service. Our response and flexibility has proved to be valuable to our clients world-wide for over 30 years. Quality, Reliability and Service to be proud of; we have the experience and integrity to be relied upon.

M. J. Gough, Managing Director

• BOILERS
ECONOMISERS
• CHILLERS
OXIDISERS...



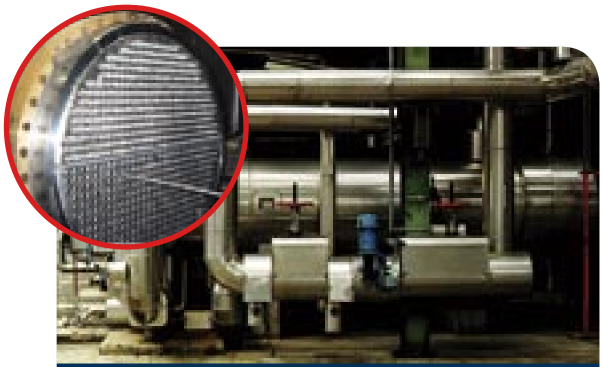
Ethylene vapouriser, Malaysia.
Courtesy: Optimal Chemicals

Compressor coolers, Algeria.
Courtesy: Nuovo Pignone

Oil cooler, power generation.
Courtesy: ALZ, Germany

Hydrocarbon processing – the technical justification for enhancement

Confidence in hiTRAN Systems for strategic refinery operations continues to grow, as good experience is established from long term operations. Retrofitting hiTRAN Elements increases plant productivity, product quality, effective utility utilisation and reduces energy with minimum or no change to the built network. For new plants, this technology provides significant capital cost reduction from reduced surface area, less exchangers, less plot space, lower weight and lower installation cost.



Vacuum residue/crude oil preheat exchanger
Heli-TRAN Exchanger (hiTRAN/Helical baffle)

- One shell only (half plain tube area)
- Previous unplanned shutdowns from fouling
- 9 year operation with hiTRAN enhancement
- Re-tubed 2005 – hiTRAN System re-installed

Fabrication: Mayr and Wilhelm
Location: Erdol Raffinerie, Lingen, Germany
Courtesy: Deutsche BP AG

Crude Oil Desalter Exchangers
8 Shells enhanced with hiTRAN System
(reduced from 20 shells without enhancement)
Installed cost reduced by over 50%
End User: Pemex, Mexico
Fabrication: EIGSA, Mexico
Installed: 2009
Design: Cal Gavin Ltd
Courtesy: EIGSA

hiTRAN Matrix Elements are widely used in refining processes to overcome poor heat transfer caused by laminar flow and boundary layer conditions. The Elements generate radial mixing of bulk fluid with stationary fluid near the wall, i.e. creating pseudo turbulence in the boundary layer, thereby increasing wall shear rate. Substantial enhancement in tubeside heat transfer rate, as high as 20 times plain tubes, is achieved depending on Reynolds number and element geometry selected.

hiTRAN Elements can be used very effectively to rectify maldistribution in headers by evening out pressure differential across the tube-sheet of all tubes. By reducing fluid residence time and increasing shear at the wall, (control of wall temperature) the Elements can significantly lower fouling caused by thermal degradation, particle deposition or crystallisation. Regulating wall temperate with tube-side enhancement, resolves pour point design limitations.

Creating highly turbulent annular flow at the wall limits the opportunity of particles to settle. The open structure of the Elements, usually more than 94% free volume allows particles of up to at least 0.5mm to pass through the exchanger.

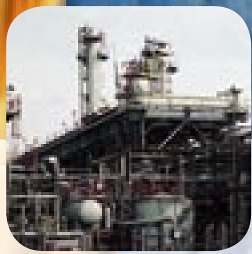
Benefits – new exchangers:

- Reduced size and number of shells/bundles
- Longer on-stream time – lower maintenance
- Performance maintained even under turn-down conditions
- Lower capital cost, lower operating cost

Benefits – retro-fit:

- Increased throughput at same terminal temperatures
- Selectable performance to meet process need
- Re-use of existing equipment – low capital expenditure, short pay-back time
- No increase in plot space
- Easily and quickly installed

HCGO/tempered water cooler. High wall temperature achieved to limit pour-point effects. 1 shell only needed. Courtesy: Imperial Oil, Canada



Heavy wax distillate cooling (atmospheric residue). Higher duty to meet column control need. Installed: 1992 Location: Grangemouth, Scotland. Courtesy: BP Oil, UK

Stabiliser reboiler on crude unit. Installed: 1996. Location: Grangemouth, Scotland Courtesy: BP Oil, UK

Gas oil run-down coolers. Location: Stanlow Refinery, UK Courtesy: Shell Oil, UK

High pour-point lube-stock coolers. Designed for minimum size and high wall temperature to overcome pour-point effects. Design & fabrication: Heat Exchangers International, Australia. Contractor: LG Industries Courtesy: Thai Petrochemicals

Examples of processes operating:

- Gas Oil Cooling
- Heavy Wax Distillate Cooling
- Tower Reboilers
- Light Hydrocarbon Vapourising
- Vacuum Residue Exchangers
- Atmospheric Residue Exchangers
- Raffinate Cooling
- Crude Oil Heating
- Fluxed Pitch Cooling
- Diesel Run-Down Cooling
- Crude Bottoms Exchangers
- Hydrotreater Feed Exchangers
- Stabiliser Light Ends Cooling
- Pitch Coolers
- Napthalenes (feed-effluent)
- Sulfolane®
- Benzene/Toluene
- Reduced Crude
- Fractionator Bottoms
- Tar Oil Heating
- Crude Oil Cooling
- Residues + Solvent
- Used Oil Refining
- Paraffinic Lube
- Residue Oil Heating
- Lube Oil Cooling
- Oil/Water Emulsion
- Heavy Lube Distillate
- Splitter Bottoms
- Benzene Reactor Preheating
- Tar Acid Flash Preheating
- Heavy Tar Oil Heating

Heating cracked-bottoms and coal tar mixture
Heating to 280˚C+:
28 years operation, negligible fouling.
Previous plain tubes fouled to shut-down every 2/3 months

Design: Cal Gavin Ltd
Courtesy: Cabot Carbon

Heating crude oil with hot jacket water from pumping stations
Crude oil pipeline

Location: Colombia
Courtesy: Occidental Oil

Hysomer feed/ effluent exchanger
Correction of vapour flow maldistribution

Installed: 1995
Location: Godorf Refinery, Germany
Courtesy: Deutsche Shell AG

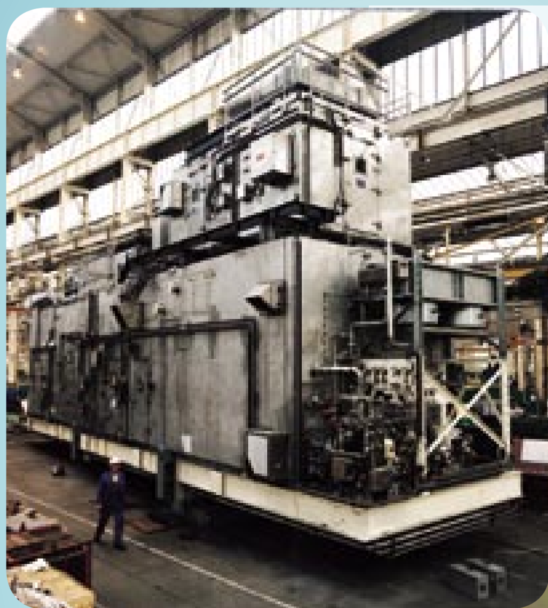
Oil & Gas Exploration, Production and Processing

Offshore platform module

Minimum weight and size
Location: Heera Field, India
Design & fabrication: BTT France
Client: ONGC
Courtesy: Hyundai, Korea

Lean amine solution chiller (MDEA).

Courtesy: Shell Western E&P Inc., USA.



Turbine oil cooler

Gas turbine power module. Compact design, minimum weight, plug head air-cooler.
Location: North Sea production platform
Design & Fabrication: Spiro-Gills, UK (GEA)
Client: Shell E & P
Courtesy : Dresser Rand

Lean/rich triethylene glycol interchanger.

Courtesy: Distrigaz, Belgium.

Feed effluent exchangers on hydrotreatment unit in catalytic reforming plant

hiTRAN System rectified maldistribution on tube-side, fired heater energy consumption reduced by 2.2MW, saving more than US$250,000 per year on fuel plus increasing plant throughput.

Client: Lukoil
Location: Volgograd Refinery, Russia
Contractor: JSC Neftezavodmontazh
Installation: 2009
Courtesy: Lukoil

Debottlenecking condensate stabiliser train (LNG)

Correcting film boiling and maldistribution.
Location: Karratha, Western Australia
Courtesy: Woodside Offshore Petroleum

hiTRAN Systems – space and weight reduction on offshore facilities

Offshore, weight is usually the most important issue for designers to accommodate. The cost of weight and space is high. Reducing the number and size of exchangers significantly with enhancement has proved to be a valuable option for many E and P companies. Combining enhancement on both tube-side and shell-side will minimise primary surface and limit shell diameter. These dual-enhanced options are now well proven with advanced baffle designs and/or low finned tubes.

Increasing cooling efficiency for absorption processes is a common need. Systems using Glycols, Amines, and proprietary absorption fluid such as Selexol®, Sulfinol® and Sulfolane® have all benefited from enhancement of new or retro-fitted plant. Even with only limited pressure loss available one pass or one row (air coolers) can be engineered to provide the necessary increased duty.

Optimising exchanger size to make use of available pressure allows considerable design flexibility for offshore package plant designers. Many of Cal Gavin's clients have now gained considerable experience and confidence incorporating hiTRAN enhancement systems in 2 and 3 phase flow processes.

Gas processing

- LPG/LNG Vapourising
- Selexol® Cooling
- Ethylene Gas Heating
- Inert Gas Condensers
- Sulfolane® Cooling
- CO_2 Intercoolers
- Purge Gas Heating
- Ethylene Glycol Exchangers
- CO Gas Cooling
- Ammonia Gas Cooling
- Sulfinol® Cooling

Enhancement of LNG forcing vapouriser on vessel
hiTRAN Matrix Elements designed to de-entrain droplet carry-over in steam heated high-flux exchanger to ensure design superheat level. Compact design exchanger developed following retro-fit application.

Installation: 1999
Equipment supplier: Hamworthy Gas Systems AS
Client: Abu Dhabi National Oil Company, UAE
Courtesy: Kvaerner Masa Yards, Finland

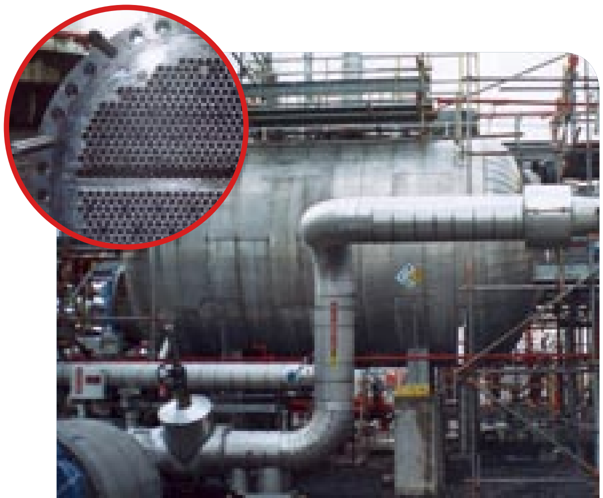
Inlet heaters – crude oil, gas & water mixture (tube-side)
Increased production and extension of platform life

Location: SIRI tie-in, new satellite platforms, Nini and Cecille

Design & fabrication: Bronswerk, Netherlands
Client: Dong, Denmark
Courtesy: Bronswerk

Delivering unique solutions for diverse applications

The practice of using enhancement in systems processing fluids such as Slurries, Polymers, Resins, Fatty Acids, Syrups, Emulsions and fluids at supercritical conditions is growing rapidly as engineers gain plant experience.



Ethylene vapouriser

Performance limitation. 'U' Tube bundle retrofitted.

Location:	Kerteh, Malaysia
Licensor:	Linde, Germany
Contractor:	Samsung, Korea
Courtesy:	Optimal Chemicals SDN BHD

Column Top Condenser

Reduced size / improved heat AND mass transfer

2 exchangers:	5 meters diameter – 7000 tubes, 7 meters diameter – 9000 tubes
End User:	Sinopec, China
Fabricator:	Doosan Mecatec
Designer:	DOW Chemicals + Cal Gavin Ltd
Location:	Zhenhei and Tianjin
Courtesy:	Doosan Mecatec

Such experience is also being gained now in the use of hiTRAN Elements for combined heat and mass transfer processes where reactions are taking place. Modifying flow characteristics in tubes to effect a highly-sheared and mixed flow close to the tube-wall provides the ideal environment for highly exothermic reaction processes. hiTRAN Elements can be used effectively to control temperature along the tube as the reaction proceeds, providing the micro mixing and high rate of heat transfer at the wall where it is needed.

Where expensive, corrosion resistant metals are specified, for example acid production, reducing weight can provide substantial economy. Shell diameter and consequently thickness, tube length, diameter, and number can all be reduced. Using low finned tube and hiTRAN enhancement will result in very compact exchangers.

Valuable technical and economic design options

hiTRAN Systems allows engineers to:

- Reduce steam pressure (wall temperature) for same duty
- Use thermal fluid for heating (shell-side) to replace steam for:
  - close temperature approach applications.
  - reducing energy costs
  - reduced fouling
  - elimination of pressure vessel operating costs
- Heat fluids evenly by mixing well under flow conditions with low ΔT, thereby improving product quality
- Cool fluids evenly maintaining wall and bulk temperature above crystallisation point
- Cool effectively in loop reaction processes containing catalytic particles
- De-entrain droplets (generated by boiling) ensuring full vapourisation of liquids
- Extend the life of thermal fluids by reducing wall temperature and fluid residence time

A selection of applications engineered:

Chemicals

- Polyisobutylene Tank Heating
- Cyclohexane Side Stream Cooling
- Sulphuric Acid Cooling
- Acid Flash Preheating
- Phenol Cooling
- Hydrocarbon Resin Cooling
- Methyl Ester Exchangers
- Water Cooled Alcohol Condensing
- Styrene/Ethyl Benzene Coolers
- Acrylics Reboilers
- Amine Vapour Superheating
- Hydroxylamine / Nitric Acid Exchangers
- Styrene/Cumene Preheating
- Napthalene Product Heating
- Polyvinylacetate Cooling
- Glycerine Vapourisers
- Paraxylene Vapourisers
- Monochlorobenzene Condensers
- Peroxide Exchangers
- Maleic Anhydride Aftercoolers
- Polyol Feed Heating
- Sulphonic Acid Cooling
- Butyl Rubber/Solvent Heating
- C4 Polymer Preheating
- Silicone Oil Heating
- Carbonic Acid Cooling
- Phenol/Acetone Coolers
- Chloromethane Vapourisers
- Trichloropropylphosphate Coolers
- Xylene Process Exchangers
- Acetylene Feed Preheating
- Cold Flare Blowdown Vapourisers
- Polycarbonate Heating
- H_2SO4 (concentrate)
- Aqueous Amine Oxide
- Butyraldehyde Heating
- H_2/H_2O Effluent
- PDMI Cooling
- Hexamethylene Diisocyanate
- Tar Acid Heating
- DADPM
- Dicarboxylic Acid
- MDEA
- Chlorosilane
- Methane
- HDI Residue
- Ethylene/EO+H_2O+HC
- TEG/Water/Benzene
- Di-Methyl Sebasilate
- Chlorinated Hydrocarbons
- PIB
- Organic Resin
- Amide + H_2SO4
- Dicarbonic Acid Melt
- Methylchloride/N2
- TCPP/TECP
- Acetaldehyde + Water
- Abietic Acid Esters
- TCS/VC Gas
- Exsol + Resin
- BPA + Phenol
- Ammonia
- Otho-xylene
- Monomero
- Isophytol
- Vitamin B
- Nitro-Benzene
- Ethylene
- Methacrylate
- Mercaptoethanol
- Triethanolamine
- PMDI
- TDI
- MDI
- AKD Polymer
- Oxygen
- CMD Isocyates
- Hexanol
- Propylene
- MMDI
- TA Slurry
- IDTA
- Deuterinium
- Xylenes (crystalliser)
- Acet/Diacet
- Propane
- Pedag Half-Ester
- IPDI
- Phosgene + Inerts
- Lanolin
- MIC
- MBT
- Methanol
- Slurry + Supercritical Oxygen
- Nitrogen
- Acrylic
- Ester resin
- Analon
- Triethanolamine
- CMD/MC polymers
- Ethanolamine
- Organic Peroxide
- Nitric Acid
- Polyethylene Wax + Air
- Polymethydiisocyanate
- Freon 22
- Styrene Vapour
- Olepoxide
- Waterglass + Sand
- Ethylene Propylene Oxide
- Sulphur

Food Processing

- Rape Seed Oil Heating
- Distillery Condensers
- Sugar Refining
- Fatty Acid Cooling
- Citric Acid Heating
- Syrup Heating
- Methylester/Vegetable oil
- Fatty Alcohol Cooling
- Vegetable Oil Heating

Power

- Turbine Oil Cooling
- Transformer Oil Cooling
- Lube Oil Cooling
- Waste Heat Boilers
- Compressor Intercoolers
- Boiler (fired heater) Tubes
- Steam Generators
- Feed Water Heating
- Luviskol Cooling
- Heat Transfer Oil Cooling/Heating

Methanol Synthesis tube-cooled converter. Higher duty retrofit. Location: Laverton, Victoria, Australia Courtesy: Coogee Energy Pty Ltd

Paraxylene Feed Vapouriser/Reactor Effluent Interchanger. Increased duty to overcome capacity and space limitation. Courtesy: Huntsman Chemicals (ICI UK)

Lube oil cooler. Solar Taurus gas compression turbine. Location: Kern River Fillmore Station, USA Courtesy: Air-X-Limited OK, USA

Ethylene let-down preheater. Retrofit to increase duty. Unit operating at critical temperature and pressure. Courtesy: European Vinyls Corporation

Transformer oil coolers. Courtesy: Spiro Gills, UK (GEA)

Boundary layer resistance – understanding the problem

Fluid flow dynamics through plain bore tubes do not provide ideal conditions for either heating or cooling. Frictional drag at the wall (laminar boundary layer) and viscous shear forces within the fluid create a velocity profile having maximum flow at the centre and zero flow at the wall. A thermally inefficient boundary layer results where minimal radial fluid movement occurs to or from the tube wall. Even when turbulent bulk flow is established, a significant boundary layer can still exist in both single and two-phase flow regimes.

Consequently, heat transfer is controlled significantly by the conductivity of the fluid boundary layer and its thickness, which results in low efficiency, large surface area heat exchangers. Thermal degradation, crystallisation and deposition fouling will also initiate and develop at a greater rate where stagnation occurs.

Solving the problem by removing the resistance

hiTRAN Matrix Elements induce shear and mixing effects which continuously remove stagnant fluid from the wall and replace it with fluid from the centre of the tube. Reducing frictional drag at the wall prevents a stable boundary layer from forming. These enhanced fluid dynamics create a flow regime that can be equated to annular flow. This is shown clearly by the coloured velocity vectors produced from Cal Gavin's Particle Imaging Velocimetry research *fig.1 (A) and (B)*. The results in *fig.1(A)* were taken starting 3mm down-stream from a hiTRAN Element.

fig.2 shows a single point velocity profile, also 3mm downstream after a hiTRAN Element, using Laser Doppler Anemometry techniques. Annular turbulent flow conditions are shown at Reynolds 500.

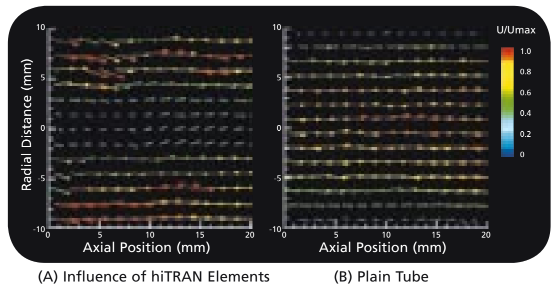


fig.1 **Particle Imaging Velocimetry Chart**
hiTRAN Elements create annular turbulent regime at low plain tube Re.No's.

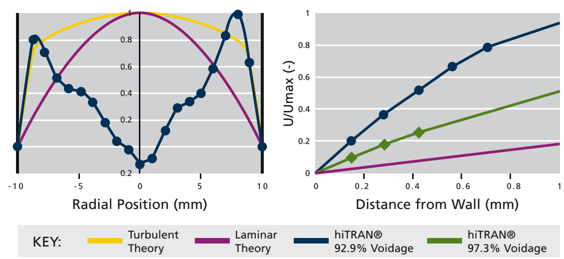


fig.2 **Laser Doppler Anemometry Flow Profiles**
hiTRAN Elements increase boundary layer velocity. e.g. 6x plain tube at 0.5mm from the wall, 10x at 0.2mm

By varying the geometry of hiTRAN Matrix Elements, the plain tube heat transfer rate can be multiplied by up to 25 times for liquid streams, and by up to 5 times for gas streams. In single-phase laminar flow systems, hiTRAN Matrix Elements provide consistent performance along the tube length, unlike plain bore tubes where heat transfer deteriorates as tube length increases (laminar boundary layer effect). Design uncertainty of plain tube heat transfer rates in the transition region is also removed, as tube-side heat transfer performance with hiTRAN Elements remains proportional to the flow rate over the whole Reynolds range.

As the tube-side heat transfer rate is increased by the elements, the temperature of the wall and tube-side fluid film will approach that of the bulk tube-side fluid. Lowering temperature differences between the wall and fluid film will reduce the rate of fouling when temperature-sensitive fluids are being heated or cooled. With increased film mixing particle deposition rates will also be reduced, keeping tubes cleaner and the heat exchanger in service longer.

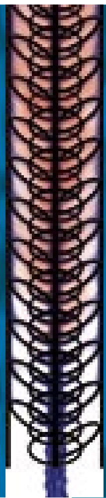
Two-phase flow enhancement

In two-phase flow, as with single-phase, creating radial movement in the boundary layer and in the bulk flow will enhance the rate of heat transfer. The heat transfer mechanisms are often complex though and may vary considerably along the tube length, from tube to tube and pass to pass. hiTRAN Matrix Elements contribute a range of beneficial effects, depending upon the particular application parameters. These effects may include both heat and mass transfer mechanisms, mixing, fluid distribution, drainage, de-entrainment, together with enhancing phase change at the interface.

Acknowledgement of support: LDV/PIV Measurements. Department of Chemical Engineering, University of Birmingham

Email us at hitran@calgavin.com
Technical Papers & Case Studies are available!

Condensers



Physically hiTRAN Elements effect a general draining of the fluid from the wall to the tube centre. Fluid attaches to the wires and is guides to form a rivulet down the core of the element. Mechanisms are similar for horizontal tube-side condensation with the core draining effect being more limited. In all cases vapour mass and heat transfer enhancement has a significant contribution and particularly in vapour phase cooling of multi-component mixtures.

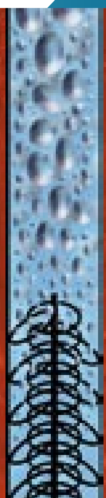
Benefits include

- Film mixing
- Film thinning
- Film draining
- Enhancing vapour phase cooling, particularly multi component mixtures
- Increasing inter-phase mass transfer rates

Typical applications

- Vent condensers
- Vacuum condensers
- Condensation of wide-boiling mixtures
- Reflux condensers

Boilers

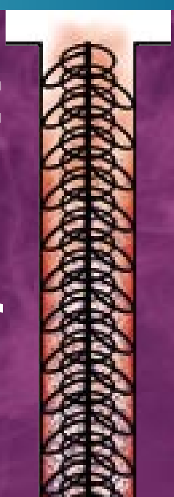


Enhancement of boiling generally follows single-phase convective augmentation added to which bubbles generated tend to be divided by the wire into smaller bubbles increasing their surface area and benefitting from their turbulent mixing behaviour. Reducing wall temperature prevents the onset of nucleate boiling. Exchanger area in sub-cooled region can be shortened, releasing more area for evaporation.

Benefits include

- Increasing convective boiling rate
- Shortening sub-cooled length
- Improving temperature distribution
- Use of low temperature driving forces

Vapourisers



Adding to the beneficial enhancement effects in boiling, hiTRAN Elements can be effectively used to de-entrain droplets formed towards the outlet of total vapourisers.

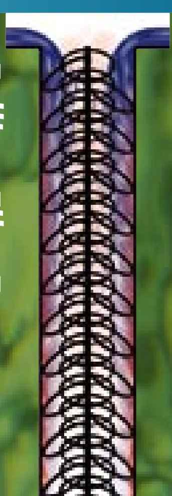
The occurrence of droplets usually occurs under high heat flux, high throughput conditions.

Benefits include

- Controlling film boiling
- Mitigating mist carry-over
- Enhancing fluid distribution
- Enhancing wall wetting
- Enhancing convection in sub-cooled region

Typical applications
LNG/LPG/Ethylene...

Falling Film Evaporators



Enhancement mechanisms at the wall are similar to condensation, boundary layer interruption and mixing, but with the elements reversed from that preferred in single-phase use.

In addition the loops effectively distribute fluid evenly over the whole tube surface compensating for any maldistribution that may occur at the inlet.

Benefits include

- Increased film heat transfer co-efficient
- Improved liquid distribution
- Concentration gradient minimised in boundary layer
- Shorter sub-cooled length
- Improved evaporation of viscous liquids
- Reduced wall temperature for equal duty
- Control of hold-up and residence time

Designing exchangers – higher thermal efficiency and lower fabrication cost

Minimum size, minimum weight, optimal thermal efficiency and lowest fabrication cost can be achieved with only 1 or 2 passes, combined with an optimised hiTRAN Enhancement System. The unique variable geometry construction of hiTRAN Elements permits the designer to optimise performance to meet the required duty using all the available pressure loss allowance.

hiTRAN Matrix Elements convert available pressure more efficiently into heat transfer. Note: Pressure loss increases to the square as passes are added with plain tube designs, but heat transfer remains linear with increased velocity. Therefore, adding passes fundamentally reduces thermal and power efficiency.

Technical benefits include:

Shell and tube

- reduced number of shells-in-series
- lower weight through smaller shell diameters
- reduced plot space through shorter tube lengths
- high efficiency single pass designs

Air-cooled

- reduced plot space requirement
- fewer tube rows
- fewer tube passes
- lower fan power and reduced fan noise

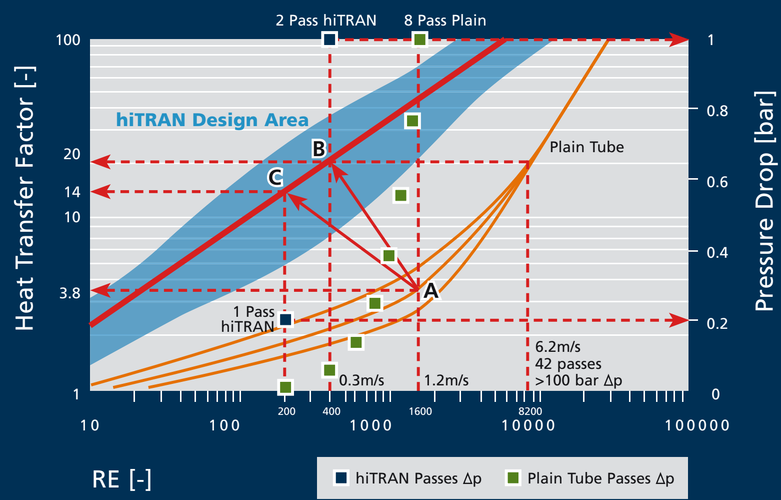
Retro-fitting exchangers for higher performance

hiTRAN Matrix Elements can be designed and manufactured to meet limited pressure loss availability, increasing duty within system restrictions. Where higher levels of performance are needed, exchanger passes can often be reduced to regain pressure loss for more efficient use incorporating enhancement.

Debottleneck/upgrade of exchangers – options for the design engineer

- fit hiTRAN System to:
  - the entire exchanger full length or, one or more passes
  - all or part length of each tube
  - vary enhancement within a pass to rectify maldistribution
- Vary enhancement along the tube length
- Reduce passes to regain pressure loss for more efficient use with enhancement
- Retain the shell or, for an air cooler the frame, and replace the bundle with a higher duty enhanced design
- Re-configuring exchangers from series to parallel
- Replace existing exchangers with new, higher duty, compact design

*Fig 3 (below): **A** & **B** shows heat transfer factor (htf) is increased over 5 times (3.8htf, 8 pass to 20htf, 2 pass) for the same 1 bar Δp. **C** (1 pass, 14htf) is 3.5 times higher than plain tube for only 0.2 bar Δp. Note: Trying to achieve 20htf with a plain tube design results in an exchanger requiring a fluid velocity of 6.2m/s, 42 passes and over 100 bar Δp, clearly not practical! Importantly, fouling is shown to be reduced with hiTRAN System operating at just 0.3m/s (20htf), equivalent to achieving wall-shear/fluid-mixing at 6.2m/s.*



		Design pressure loss	Heat transfer factor
A	8 pass plain tube	1 bar	3.8
B	2 pass hiTRAN Enhanced	1 bar	20
C	1 pass hiTRAN Enhanced	0.2	14

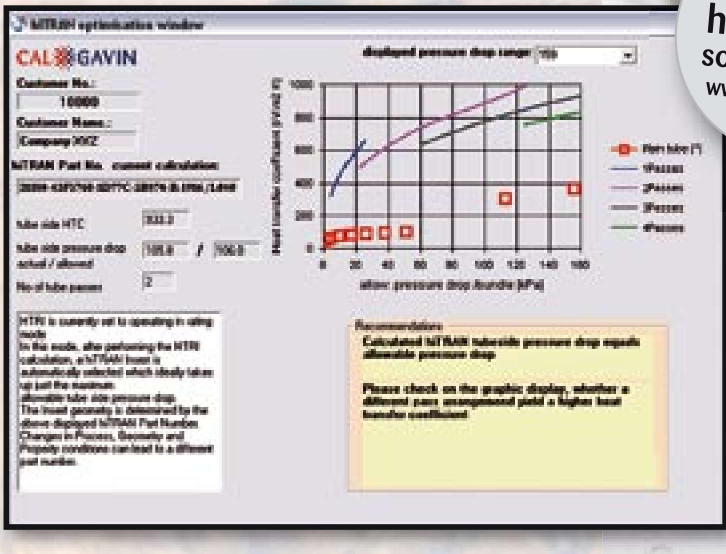
Fig.3 **hiTRAN Design Comparison**

hiTRAN.SP

SELECTION PROGRAMME

Download hiTRAN.SP software from www.calgavin.com

For HTRI Xchanger Suite® and Aspen Exchanger Design & Rating® Cal Gavin Ltd has developed hiTRAN.SP a software "plug-in" to simulate tubular heat exchangers equipped with hiTRAN Wire Matrix Elements. The use of this utility enables the equipment engineer to design a fully optimised heat exchanger using two of the most powerful software design packages currently on the market. The plug in is available to calculate shell and tube heat exchangers in Xist (HTRI) and Shell & Tube (Aspentech) and crossflow heat exchangers in Xace (HTRI) and AirCooled (Aspentech).

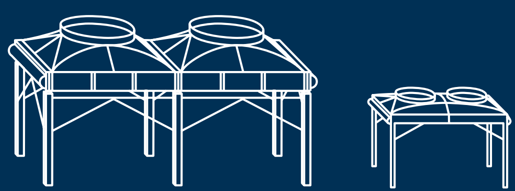


During the calculation process, hiTRAN.SP assigns a unique hiTRAN Wire Matrix Element Geometry to the design, which is determined by the bundle geometry, the process conditions and the property data. Each insert is designed to utilise the entire allowable pressure drop in order to maximise the heat transfer performance of the exchanger.

For users without access to HTRI or Aspentech Software hiTRAN.SP can also be used as a standalone enhancement selection programme for the tube side of heat exchangers.

The plug-in is free of charge and can be downloaded from the Cal Gavin web site (www.calgavin.com).

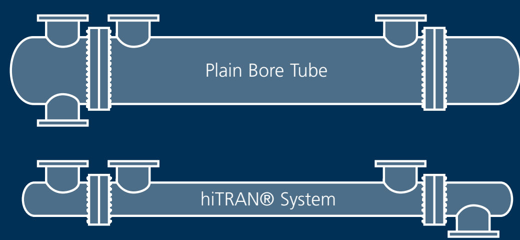
- On-line tutorial
- Quick response helpline
- Fast optimisation
- Full results print out
- Utilises all the allowable pressure loss
- Maximises the heat transfer potential
- Regular free upgrades to licensed users



Improved design for an air-cooled lube oil cooler, installed on a gas turbine driven compressor. Heat load: 373kW2

Design Comparison	Plain Bore Finned Tube	hiTRAN System
Number of rows x tubes/row	6 x 46	3 x 30
Tube length, mm	7925	3350
Number of tube passes	6	1
Heat transfer rate, W/m²K	3.29	20.95
Oil pressure drop, kPa	71	71
Finned surface, m²	3058	563
Total fan power, kW	11.8	5.0
Plot dimensions, m	2.74 x 8.54	2.05 x 3.96
Weight, kg	8500	2200

- Only 1/3 of the plot area needed
- Same duty at same pressure loss
- Less than ½ the fan power
- Allows lower noise level to be met
- Lowest cost cption



Improved design for a shell & tube heat exchanger, cooling heavy cycle gas oil in the fluid catalytic cracking unit of an oil refinery.

Design Comparison	Plain Bore Tube	hiTRAN System
Shell diameter	1524	689
Number of tubes	1828	371
Tube length, mm	6096	6096
Number of tube passes	8	1
Effective surface area, m²	874	179
Heat transfer rate, W/m²K	40	182
Tubeside pressure drop, kPa	70	70

- Only ¼ of the effective area needed
- Same duty at same pressure loss
- Lighter, simpler construction
- Further economy possible with low-fin tube
- Lowest cost cption

Investing in research, securing tomorrow's answers

Cal Gavin invests a considerable proportion of its revenue in research and testing in the field of modified flow dynamics, heat transfer enhancement and fouling mitigation. Our links with universities in the UK and overseas have developed into an extensive and valuable network for research, providing cutting-edge technology support to Cal Gavin for onward benefit of its clients. Cal Gavin welcomes links with research groups working in the field of thermal process enhancement and optimisation.

Single-phase testing

A new state-of-the-art single-phase test facility has been recently commissioned in Cal Gavin's thermal laboratory. This highly accurate test rig is now producing valuable data to enhance the scope and accuracy of performance predictions, subsequently incorporated in the hiTRAN.SP selection programme. The facility is used to optimise hiTRAN Element geometry and test new types of enhancement for special purposes.

Technical data

- Tube length 3 metres
- Tube diameters from 8mm to 34mm ID
- Viscosities from 0.1 mPas to several Pas
- Reynolds No's ranging from 1 to 200,000
- Capacity – 18kw
- Vacuum insulated jacket for minimum heat loss
- Heat balance accuracy – 95+%
- Traversing thermocouple across flow to check accuracy of bulk temperature measurement
- Temperature difference measurement accuracy to 0.05˚ CNVN
- Fully integrated control and data acquisition

Acknowledgment for support: University of Birmingham

Two-phase flow research

Condensation

Pure component condensation, based on refrigerant 113 in vertical tube, provided data giving 40-60% increased heat transfer, dependant on geometry.

Acknowledgment for support: Queen Mary's College, London

Reflux condensation research provided information on heat transfer and pressure loss together with the impact of flooding and affects caused by processing multi-component mixtures.

Results: For multicomponent mixtures (Methanol/Water) experiments and simulations show a substantial increase in interfacial mixing, resulting in much improved heat and mass transfer.

In addition it is shown that the use of hiTRAN Elements can be beneficial with respect to the onset of flooding.

Acknowledgment for support: Umist, Manchester

Boiling – Vapourisation

Thermosiphon Reboiling

Research focused on performance benefits provided by:

- smaller temperature differences between heating side and product side
- operating with higher viscosity substances
- operating with lower absolute pressure
- reducing sub-cooled length in operation with viscous fluids and under vacuum

Results show that operational stability is much improved over a wide range of operating conditions. hiTRAN Elements were found to control fluctuations in circulation rate, usually found with plain tube arrangements. Improved heat transfer was observed even at lower circulation rates and within acceptable operating pressure-loss. Research continues to identify underlying mechanisms in different flow sections.

Acknowledgement for support: University of Braunschweig, Germany

Falling film evaporation

Falling film evaporators are typically characterised by a short product residence time. When viscous liquids (higher Prandl number) are being processed, tube-side heat transfer is heavily controlled by the resistance of the laminar-wavy fluid film. hiTRAN Matrix Elements modify hydro-dynamics to provide well distributed liquid over the whole tube circumference, combating maldistribution. Experiments show that fluid entering the tube in the centre (extreme maldistribution) is evenly distributed after just a few diameters.

The elements also provide a support structure whereby film thickness is increased. The mechanism also provides for the removal of the stagnant layer

Single-phase test rig (Cal Gavin laboratory)

University of Bremen – Falling film studies

from the wall, effecting good back mixing between wall film and bulk film, resulting in a narrower residence time distribution under laminar and laminar-wavy conditions.

Results over the whole range of tests showed a substantial increase in heat transfer of up to 80%.

Acknowledgement for support: University of Bremen, Germany

Fouling mitigation studies

Hydrocarbon chemical reaction fouling

Crude oil tests

Reaction rates are heavily dependant on temperature, in general described with Arrhenius approach. Reaction rates are a function of the residence time that the process liquid is exposed to temperatures higher than the cracking temperature of the fluid. Experiments used light Arabian crude, Watson factor = 11.4. Parallel tubes, plain (control) and enhanced (hiTRAN Elements) were tested under similar conditions. Substantial and sustained fouling reduction was measured.

Acknowledgement for support: University of Bath, UK

Particulate fouling

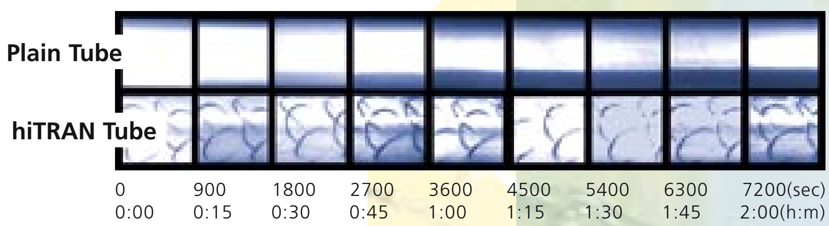
With increased wall shear and fluid mixing generated by the annular flow mechanism, hiTRAN Elements provide a high level of turbulence that mitigates particle deposition. In laboratory tests, a laser-based method of measurement and time-lapsed photography was used to quantify the rate of sedimentation and the thickness. Experiments using 50 micron particles (particle density 2500kg/m3) in water glycerol suspension was tested over a range of Reynolds Numbers. Vortices behind the wire loops cause turbulent mixing, resulting in the rate of partical removal being significantly higher than the rate of deposition. Even at low velocity particles remain suspended.

Acknowledgement for support: University of Edinburgh, Scotland

Two-phase flow pilot plant (ongoing research). Courtesy: UMIST, UK.

Thermosyphon reboiler studies. University of Braunschweig

Condensation visualisation studies (Cal Gavin laboratory)



Photographic evaluation of particles in flow

Higher shear rate at the wall causes homogenous distribution of particles. University of Edinburgh

hiTRAN® Manufacturing & Installation

Air-cooler for Shell Oil, Nigeria, fitted with hiTRAN Matrix Elements in less than 3 hours.

Courtesy of BP Oil, UK

'Key Link' system being fitted to citric acid heater. Courtesy: Miles Laboratories, USA.

hiTRAN installation. Courtesy: KCC

Securing hiTRAN Elements. Courtesy: Cabot Carbon, UK

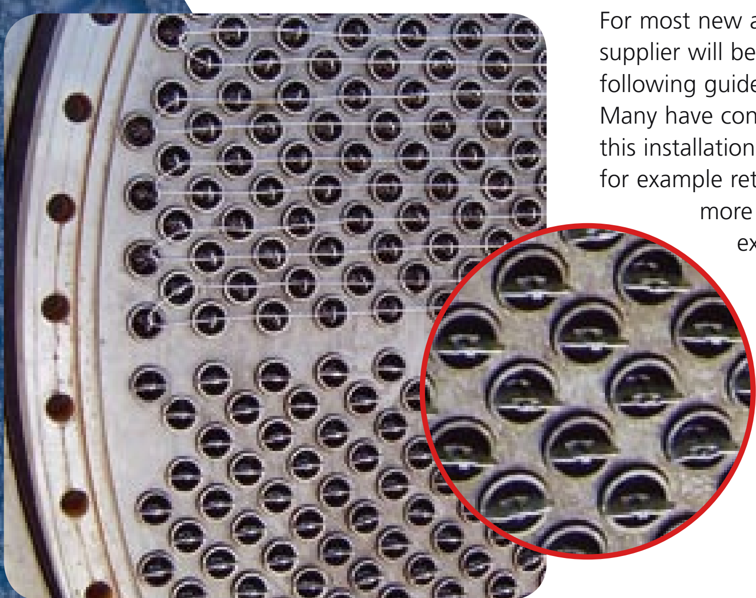
Ethylene glycol exchangers. Courtesy: Bronswerk Heat Transfer, Netherlands

Easily fitted, secure in service and easily removed... hiTRAN Systems installation

hiTRAN Matrix Elements are specially designed to be flexible along their length for ease of installation even where access is very restricted and the elements require a curved installation path. Elements are simply guided into place along the axis line of the tube. The elements are also flexible across their diameter and will adjust to normal tube bore tolerances.

In certain applications re-forming dies will be offered whereby the element diameter can be slightly compacted to reduce pull-in resistance. This flexibility feature of the elements allows them to be easily installed in old and sometimes pitted tubes. Exchanger tubes must, of course, be in a clean condition before the elements are installed. Contact with the tube-wall by the loops is clearly very important. Having a tighter fit though has not been found to add to the rate of heat transfer.

Being removable and not an integral mechanical part of the heat exchanger, hiTRAN Matrix Elements will satisfy all pressure vessel standards. The elements may be secured at the end of the tubes by using the hiTRAN 'Key Link' system or by joining the element centre cores together across the tube sheet.



hiTRAN Element fixing detail showing Key Wire and Core Anchor retaining systems

Other than for specific two-phase situations and outlet legs of 'U' tubes, the elements are installed in the same direction as the flow and should be removed also in the same direction. Instructions and diagrams are provided for each specific application to secure the elements in place, together with the necessary securing wires, joining fittings and pulling rods. Tooling for fitting and removal of the elements are selected to meet the requirements of the particular application.

For air-cooled heat exchangers with 'Plug Type' headers and other exchanger designs where access is restricted, hiTRAN 'Core Anchors' can be used. Elements are usually supplied in continuous lengths of up to 8 metres. For longer tubes, they may be joined and installed in series. hiTRAN Matrix Elements are manufactured to suit all tube diameters from 4mm to 150mm.

hiTRAN Matrix Elements can be manufactured from a wide range of materials, including most grades of stainless steel, low carbon steel, Hastelloy, titanium, tantalum, Monel, Inconel, copper based alloys, etc.

For most new applications, the original equipment supplier will be able to install the elements following guidelines provided by Cal Gavin. Many have considerable experience in completing this installation procedure. For specific applications, for example retro-fitting 'U' tube bundles and other more special installations, Cal Gavin's experienced site service engineers are available for training, installation or supervision requirements.

Talk to our engineers... we have the experience to help you

Cal Gavin, Thermal Process Engineers, provide a worldwide design and performance review service for heat transfer equipment. The scope can range from the overall operation of a plant to a specific piece of equipment. Identification of potential enhancement opportunities are developed and reviewed along with associated investment benefit.

Experience gained from engineering these systems for over 30 years has resulted in an extensive database of successful applications in a very wide range of processes.

In support of client's technical questions Cal Gavin's engineers are always pleased to have the opportunity to provide their extensive experience of thermal system design and exchanger operation. Our engineers will liaise closely with you to ensure the optimum design specifications are developed to meet your requirements.

Case Studies, Technical Papers & References available on request hitran@calgavin.com

Contact our engineers: hitran@calgavin.com

Established technology with over 30 years in the development

From the formation of Cal Gavin Ltd in 1980, our engineers have refined and developed hiTRAN technology to be the bench-mark enhancement system it is today. With the support from many university researchers in the UK and overseas, the company has been able to build up an impressive portfolio of research results that are providing a wide range of benefits to many companies world-wide.

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