DESIGNING ENHANCED SHELL & TUBE HEAT EXCHANGERS

For further technical information visit our Resource Portal at portal.calgavin.com

CALGAVIN

RESEARCH - EVALUATION - INNOVATION - SOLUTION

INTRODUCTION TO CALGAVIN®

Based in the heart of the United Kingdom and with global technical representatives, CALGAVIN® has built up an unrivalled expertise over 40 years in application knowledge, thermal design and analysis of process plants.

Our technical design and support team have extensive understanding of thermodynamics, heat transfer and fluid flow phenomena, combined with engineering experience offering improvement solutions to hundreds of plants worldwide.

CALGAVIN understands the importance of continuous research to improve the quality and widen the range of the products we manufacture and the services we offer to our clients. This includes investment in developing highly specialised testing equipment to accurately quantify performance of new enhancement devices and understand complex fluid properties with a focus to extend application areas for improving performance enhancement.

Alongside our world class enhancement product range, including hiTRAN® Thermal Systems, we provide practical and objective consultancy advice on improving plant operation.

In addition to our own research, CALGAVIN works with a significant number of universities globally, researching new avenues for our flow modification products and services.

We provide software licenses for our CALGAVIN®.SP design and selection program and clients are continually informed of new developments and company updates.

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RESEARCH

Research is at the centre of CALGAVIN®'s business, with a range of test facilities within its internal Research & Development department. CALGAVIN also actively develops research programmes, in collaboration with UK and overseas universities, to support their cutting-edge process enhancement solutions. This valuable network of research and the generation of performance data provides the high level of confidence needed by its clients.

EVALUATION

Working closely with clients from the onset, CALGAVIN's engineers carefully assimilate original and current plant data with client needs, to provide practical and economic proposals. The company's Best Practice Policy is supported and achieved by the use of state-of-the-art software including HTRI Xchanger Suite®, Aspen Exchanger Design & Rating, Ansys CFD® and Fluent®, in conjunction with CALGAVIN.SP design and selection program.

INNOVATION

For over 40 years CALGAVIN has built up unrivalled expertise in the thermal design and analysis of process plants. New products and new services are developed to meet ongoing process challenges. Our engineering team has extensive knowledge of thermodynamics, heat transfer and fluid flow phenomena, combined with global experience providing improvement solutions to hundreds of plants worldwide. (References upon request).

SOLUTION

Process systems and operating parameters are complex and often quite different from plant to plant. Each requires a detailed and professional study to find the optimum solution. CALGAVIN's products and services are engineered to meet defined needs for improving heating, cooling, boiling, vaporising, condensing, fouling mitigation, fluid mixing and other fluid management requirements. We provide the solution and the responsibility that goes with it.

INTRODUCTION TO HITRAN®

Our warrantied hiTRAN® Thermal Systems provide unique solutions to substantially enhance the tube-side heat transfer in all tubular constructed heat exchangers; whether considered at preliminary design phase, or through a retrofit to an existing heat exchanger.

hiTRAN Thermal Systems are a unique type of tube insert, easily installed to offer the greatest enhancement benefit for laminar and transitional flow regimes where the heat transfer coefficient can be increased up to 16x (dependent upon Reynolds number and turbulator geometry) and they can be used in both single and two-phase flow regimes.

Our product selection type is software generated to meet a broad range of requirements and conditions; in short, a wide variety of processes can benefit.

Extensive technical and process benefits can be delivered across process plants in addition to cost and energy saving from the enhanced performance of heat exchangers. hiTRAN Thermal Systems have been successful in resolving a wide variety of heat exchanger problems including;

- Energy reduction
- Increased throughput
- Reducing maldistribution
- Predictable performance under downturn
- Mitigation of flow instabilities
- Suppression of film boiling and mist flow.

Our extensive Case Study examples are a powerful statement to the benefits of hiTRAN Thermal Systems installation.

SINGLE PHASE

A

Empty tube for single phase flow (gas or liquid)

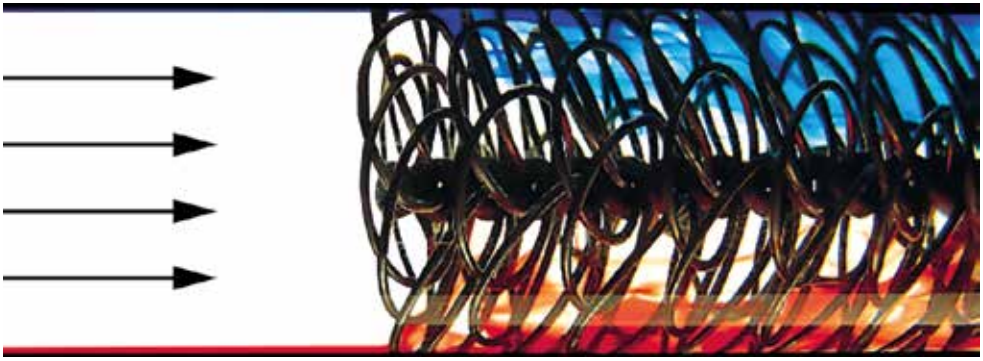
Heat transfer is limited, caused by laminar flow and boundary layer conditions where slow conductive heat transfer is the primary mechanism.

B

hiTRAN® enhanced tube

hiTRAN Thermal Systems work based on generating radial mixing of bulk fluid with stationary fluid near the tube wall. This mixing generates turbulence in the boundary layer, increasing wall shear rate. This high wall shear rate creates forced convective heat transfer, a higher rate of heat transfer compared to conduction seen in the empty tube.

Depending on Reynolds number and hiTRAN type, the heat transfer rate can be increased as high as 16 times the empty tube.



A **B**

hiTRAN can also enhance two phase services, including vertical and horizontal condensers, thermosyphon reboilers, vapourisers and falling film evaporators. The details of how hiTRAN works and it benefits such services are shown over the page

CASE STUDY

HEAVY CYCLE GAS OIL

hiTRAN® enhanced design gave 80% reduction in surface area

END USER

Imperial Oil

SERVICE

(FCC) HCGO cooler

EXCHANGER

BEM TEMA type, 1 Tube pass
371 tubes (25.4 x 2.1 x 6,094 mm)
Duty: Cooling HCGO from 138°C to 66°C using water with inlet temperature of 46°C

BENEFIT

- 55% diameter reduction after designing with hiTRAN (compared to empty tube design)
- Surface Area reduced by 80%
- 50% saving in total purchase and installation costs

Tubeside: HCGO

Flowrate: 11.76 kg/sec
dP Allowed: 70 kPa
Viscosity: 160cP
Prandtl Number: 3800

Tubeside Temperatures

Inlet: 138˚C
Outlet: 66 ˚C

Shellside: Water
Flowrate: 40.8 kg/sec

Shellside Temperatures

Inlet: 46˚C
Outlet: 56˚C

PROCESS COMPARISON

Process Details	Empty Tube	hiTRAN® Design
Reynolds number (in/out)	306/14	190/8
Overall service co-efficient (W/m2K)	40	182
Tube side heat transfer co-efficient (W/m2K)	51	295
Calculated tube side pressure drop (kPa)	70	70

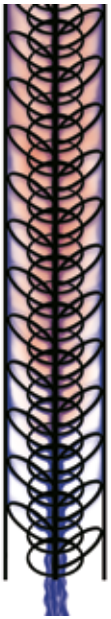
DESIGN COMPARISON

Performance Details	Empty Tube	hiTRAN® Design
Shell diameter (mm)	1524	689
Number of tubes	1828	371
Effective surface area (m^2)	889	180
Number of tube passes	8	1
Tube length (m)	6.1	6.1
Estimated Purchase/Installation Cost	$1,072,000	$552,000

HITRAN® DESIGN = 50% COST SAVINGS FOR PURCHASE AND INSTALLATION

HOW HITRAN® WORKS (TWO PHASE)

CONDENSING



hiTRAN is particularly effective for enhancing the condensation of multi-component mixtures, or vapours containing inert components. Improvements can also be seen in pure component condensation where there are low velocities and poor vapour-phase heat transfer.

The enhancement of both vertical and horizontal tube-side condensers is possible , with hiTRAN improving the radial mass transfer.

Benefits include

- Enhancement of the convective heat transfer coefficients in the bulk vapour and liquid film. .
- Increased turbulence in the vapour, which more thoroughly mixes components and prevent build-up of inerts.
- Wire matrix diverts the liquid flow towards the centre of the tube in vertical arrangements. This helps thin and drain the condensate film..
- Mitigation of phase stratification in horizontal arrangements

Typical applications

- Condensation of mixtures
- Column top condensers
- Reflux condensers
- Vacuum condensers

BOILING

Enhancement of boiling generally follows augmentation of single-phase and convective boiling heat transfer. In addition, bubbles are broken up thereby increasing their surface area and turbulent mixing behaviour.

Largest benefits seen are for process fluids high in viscosity, operating at small temperature differences, and in vacuum systems with large subcooled lengths. In thermosyphons, partial installation in the sub-cooled zone can improve performance without affecting the pressure balance.

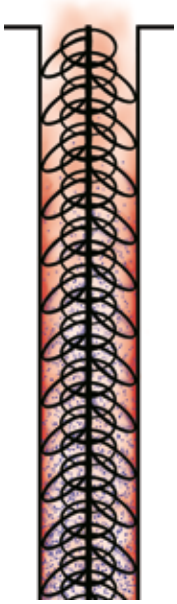
Benefits include

- Shorter sub-cooled length through enhanced single-phase heat transfer resulting in more tube length for boiling
- Reduction of flow instabilities by installation of hiTRAN through an increase of pressure drop.

Typical applications

- Thermosyphon reboiler
- Forced-flow reboiler

VAPORISING



Adding to the beneficial enhancement effects in boiling, hiTRAN Thermal Systems can be effectively used in total vaporising applications.

Typical limitations of vapourisers, such as film boiling and mist flow, can be mitigated. hiTRAN installation can be targeted in these zones. This improves performance and reduces uncertainty in the thermal design.

Benefits include

- Mitigation of film boiling by reducing superheat at the tube wall
- Dispersal of mist flow by improved vapour phase heat transfer, collision of the droplets with the wire matrix, and flash evaporation of droplets due to increased pressure drop.
- Enhancement of single-phase heat transfer where sub-cooled heating and superheating is required.

Typical applications

- LNG and LPG
- Ethylene
- Cryogenic vaporisers
- LOX, LIN and LAR

FALLING FILM

Falling film evaporators operate with very low temperature differences, which may limit effectiveness. Improving the heat transfer with hiTRAN can offset the disadvantage. Enhancement is more effective in high viscosity fluids or at low mass flow rates, where the flow regime within the liquid film can be laminar.

The direction of the hiTRAN elements is reversed from that preferred in single-phase use. This helps distribute fluid evenly over the whole tube surface.

Benefits include

- Increased convective heat transfer in the liquid film.
- Improved liquid distribution
- Concentration gradient minimised in boundary layer
- Improved evaporation of viscous liquids
- Reduced wall temperature can reduce product degradation.
- Control of hold-up and residence time

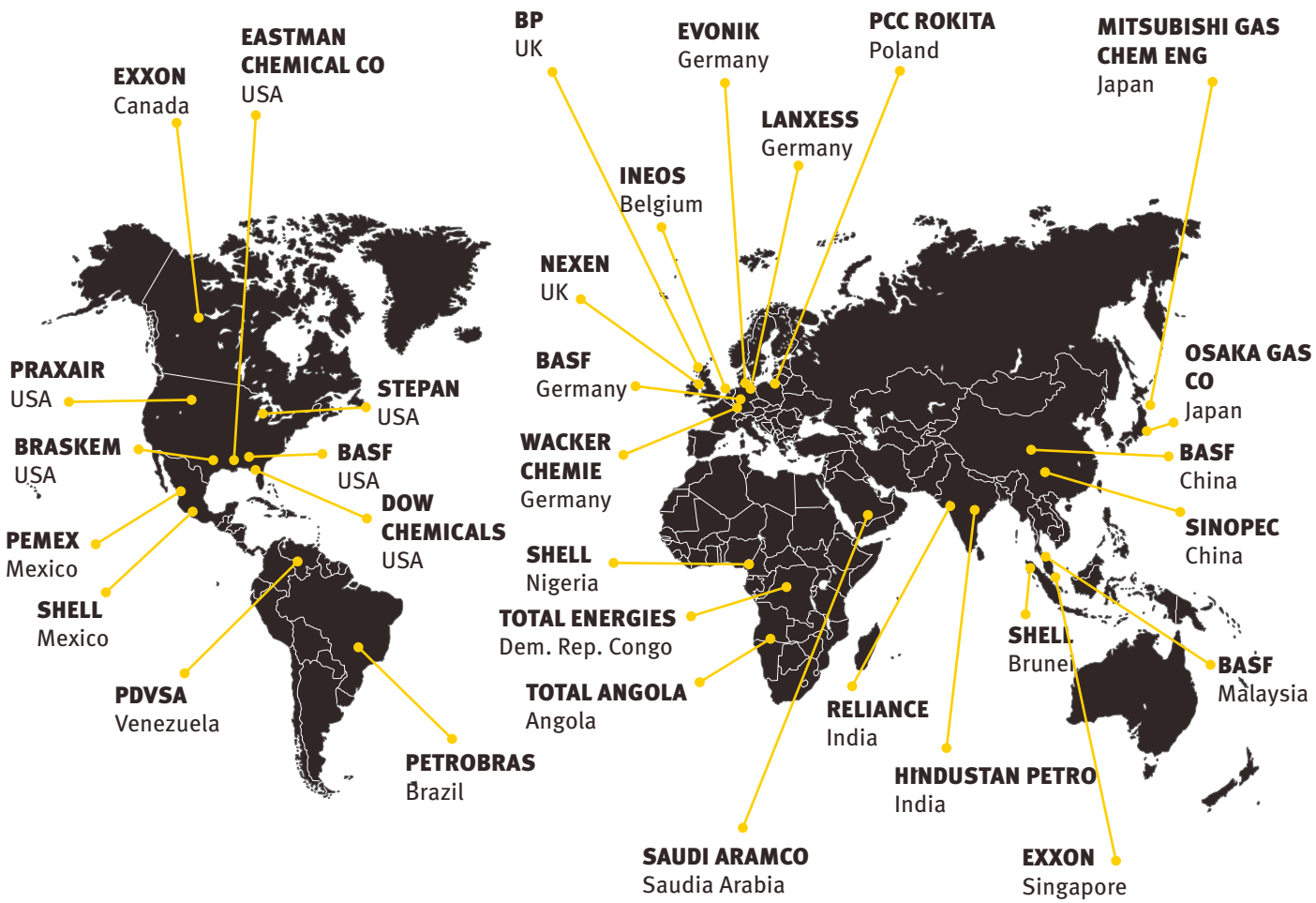
Typical applications

- Fine and speciality chemicals
- Temperature sensitive products
- Concentrating aqueous fluids

HOW HITRAN® WORKS (TWO PHASE)

ENHANCING THE WORLD'S EXCHANGERS...

CUSTOMER REFERENCES



...SINCE 1980

Note: This is a small selection from our complete list of shell & tube references

TWO PHASE CASE STUDY

hiTRAN® applied to compensate for loss of temperature difference after changing from nitrogen-based to oil-based cooling.

APPLICATION

The heat exchanger cools and partially condenses an acid mixture using nitrogen gas. Our customer intended to change to using a heat transfer oil instead, however this resulted in a significant reduction in temperature difference.

This would have rendered the heat exchanger unable to achieve the required cooling duty.

EXCHANGER TYPE

Shell and Tube, TEMA BEM (Vertical)

BENEFIT

Due to the acid mixture, the heat exchanger was constructed from high-cost corrosion-resistant alloys. Therefore, it was preferable to improve the duty of the original equipment using hiTRAN, rather than to replace with a new unit.

RESULTS

Our proposed solution was to use hiTRAN improve the heat transfer rate to compensate for the reduced temperature difference. The tube-side heat transfer coefficient was increased by 400%, giving a 140% increase in overall heat transfer coefficient.

This allowed the heat exchanger to achieve the cooling duty requirements using the heat transfer oil instead of nitrogen. By optimising the geometry of the hiTRAN elements, the maximum allowable pressure drop on the tubeside could still be maintained.

Tubeside Fluid:
Acid Mixture
Flowrate: 1350 kg/hr
dP Allowed: 14 kPa

Tubeside Temperatures
Inlet: -7˚C
Outlet: -63 ˚C
(partially condensing)

Shellside Fluid:
Heat Transfer Oil
(previously Nitogen)
Flowrate: 8 kg/sec

Shellside Temperatures
Inlet: -70.6 ˚C
Outlet: -65.7 ˚C

CASE STUDY

CASE STUDY

DISTILLATION COLUMN TOP CONDENSER

The goal of the design analysis was to reduce the vapour carryover of the hydrocarbon by using tube inserts.

APPLICATION

The heat exchanger is the top condenser of a distillation column and generates steam on the shell side.

SERVICE

The purpose of the heat exchanger is to condense a hydrocarbon mixture on the tubeside. On the shell side water evaporates at a pressure of ~2 bar with a heat transfer rate of >4000 W/m²K

EXCHANGER

BXM TEMA type Heat Exchanger (500 tubes, 25.4 mm tube OD x 5000mm tube length)

BENEFIT

Reduced vapour carryover of the hydrocarbon (~1100 kg/hr vapour carryover flared). tube design)

RESULTS

It was recommended to install hiTRAN thermal systems in a part of the tube length. The installation was carried out by CALGAVIN supervisors in one day.

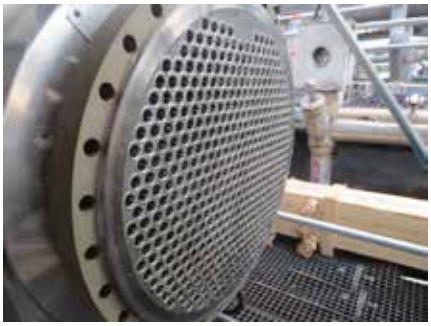
After the equipment start-up, the measured plant data indicated a reduction of 40C condensate outlet temperature.

This corresponds to a reduction of vapour mass fraction from 4.6% to 2.6%, with the reduction of vapour carryover of about 535 kg/hr at design conditions.

ECONOMICS

If no action was taken then 535 kg/hr vapour would be flared, or you would spend $135,000 for a new replacement heat exchanger. Alternatively an additional after-condenser of 3m long ($95,000) would have to be purchased.

The hiTRAN cost was 20% of the above costs, including installation, with a rate of return (ROI) achieved within a few weeks.



Flowrate: 25,500 kg/hr
dP Allowed: 1.2kPa
Heat Transfer: ~1200 W/m²K

Shellside Temperatures

Inlet: 128˚C

Tubeside Fluid:

Condensing vapour: Hydrocarbon ~98%, CS2 (carbon disulfide, volatile) and traces of water

Tubeside Temperatures

Inlet: 151˚C
Outlet: 141˚C

ETHANE VAPORISER

The goal was to vaporise the ethane in order to return to gaseous state after transportation.

APPLICATION

Ethane Vaporiser CXU Tema Type

SERVICE

The purpose of the heat exchanger is to vaporise the ethane in order for it to return to gaseous state after transportation as liquid under pressure and be processed later in the stream.

POOR PERFORMANCE

This vaporiser displayed film boiling at the tube wall and mist flow behaviour, even where the bulk fluid is well below the normal boiling point.

Liquid carryover due to mist flow was a likely visible effect of a part flooded outlet piping due to momentum effects from directional and velocity changes.

RESULTS

To ensure full vaporisation, eliminate mist flow and liquid carryover, hiTRAN inserts were installed through the vaporisation zone into the start of the superheating zone.

To minimise the impact on pressure drop, a low pressure drop insert geometry was fitted only in the full straight length of the inlet section.
The outlet temperature achieved with the hiTRAN inserts retrofit was ~650C with minimum efforts from all parties and ROI within a few days.

Tubeside fluid: Ethane (boiling liquid)
Flowrate: 8 kg/sec
dP allowed: 200 kPa

Shellside Temperatures:
Inlet: -1040C
Outlet: -90C
(operating empty tube)

Shellside fluid: Methanol
Flowrate: 6 kg/sec
dP allowed: 200 kPa
Temperature: ~800C

CASE STUDY

DESIGN & SIMULATION SOFTWARE

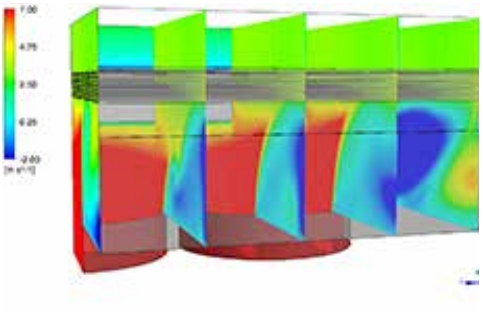
CALGAVIN® .SP
DESIGN & MODELLING OF HITRAN® THERMAL SYSTEMS

hiTRAN® Thermal Systems convert available pressure drop more efficiently into heat transfer, in laminar and transitional flow and this can be modelled using our free proprietary software CALGAVIN.SP design and selection program.

For HTRI Xchanger Suite® and Aspen Exchanger Design & Rating, two of the most powerful software packages on the market, CALGAVIN has developed the CALGAVIN.SP software plug-in to simulate shell & tube heat exchangers equipped with hiTRAN. The research taken from our single-phase test rig (heat balance accuracy +-5%) has contributed to the basis of our thermal and hydraulic program calculations, warrantable for clean recirculating fluids.

For users without access to HTRI or AspenTech software, hiTRAN.SP can be used as a standalone selection program for input into clients own calculations.

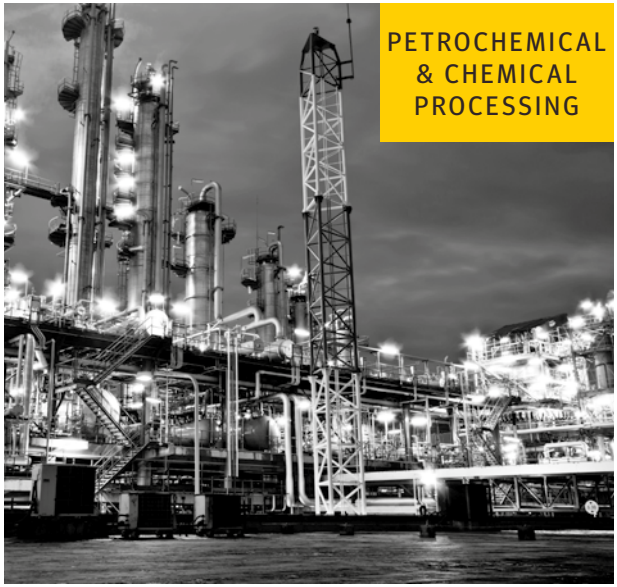
CALGAVIN® SP aspentech Xchanger Suite®



Computational Fluid Dynamics (CFD)

Complex geometries and flow conditions are assessed using CFD, computationally solving Navier-Stokes equations for fluid volumes divided into up to millions of mesh elements. CALGAVIN employs the use of Ansys CFX and FLUENT to solve challenging heat transfer scenarios encountered by plants around the world, giving detailed and accurate solutions.

Since 1980 we have been active in the process industries in plants around the world, helping to review, design and install our warrantied hiTRAN® Thermal Systems in heat exchangers. We serve the below industries and many more...

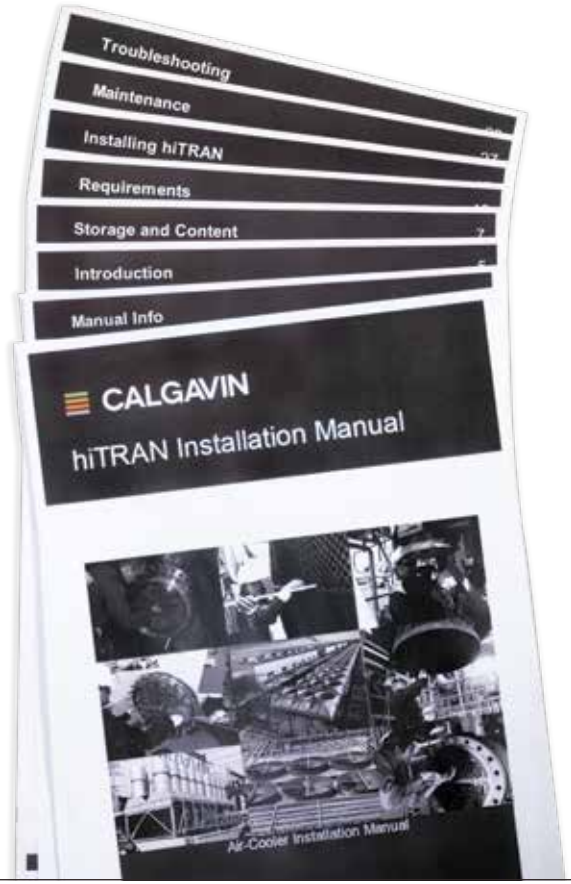


INDUSTRIES SERVED INCLUDE

INSTALLATION MANUAL

INSTALLATION OF
HITRAN® THERMAL SYSTEMS

To maximise the efficiency of hiTRAN® Thermal Systems, it is important that they are installed correctly. In summary, the installation of hiTRAN for straight tubes is simple and can be completed in three steps, sizing, fitting and retaining. Installation tools for sizing and fitting are provided in the supply, along with details on the retention of hiTRAN within the tubes.



CALGAVIN® provide a thorough step by step pictorial installation manual, custom made to your project. The manual covers the project summary, introduction, storage, content requirements, installing hiTRAN, maintenance, troubleshooting and contact information.

Our engineers have the know-how and the expertise to advise on any type of installation method, based on the application viability. Our video library is continuously being expanded to meet new hiTRAN Thermal Systems installations for a wider variety of heat exchangers.

Please contact our head office if you have any queries regarding how to perform an installation or if you have any maintenance questions about our hiTRAN Thermal Systems.

EXCHANGER SUPERVISION SERVICES

Users of our technology are offered our optional installation supervision service, where a member of our team will attend your workshop or process plant. This visit will include demonstrations of how to correctly install hiTRAN® Thermal Systems into shell & tube heat exchangers, including information on how to use the specialist tools such as our re-sizing dies for efficient installation.

Supervision will achieve an agreed target, leaving the customer with the peace of mind of a complete and successful installation, and fully trained personnel for future projects.

INSTALLATION SUPERVISION SERVICES

SHELL & TUBE HEAT EXCHANGERS

FREQUENTLY ASKED QUESTIONS

Q) CAN I REUSE HITRAN® THERMAL SYSTEMS?

Provided the correct removal procedure is followed and the elements are handled and stored carefully; they can be reinstalled into the same exchanger. Where a bundle or tubes are replaced, differences in tube tolerances may cause a poor fit. For such tubes replacement, re-supply of hiTRAN is recommended.

Q) CAN HITRAN® BE DESIGNED TO MEET MY PROCESS REQUIREMENTS AND APPLICATION SPECIFICATIONS?

hiTRAN has a large degree of flexibility in design geometry, which provides variable heat transfer and pressure drop characteristics. This flexibility is incorporated into our CALGAVIN®.SP plug-in, which enables the user to assess designs based on defined allowable tubeside pressure drop. The CALGAVIN.SP algorithm will revert to the lowest pressure drop or highest enhancement geometry, respectively, for the given conditions, where the allowable pressure drop is either too low or higher than required. This provides the designer with the necessary software tool to find the optimum solution.

Q) WHAT MATERIALS CAN HITRAN® THERMAL SYSTEMS BE MANUFACTURED FROM?

hiTRAN Thermal Systems can be manufactured from most material that can be sourced in wire form. hiTRAN is most often manufactured from the same material as the heat exchanger tubes to prevent any possibility of galvanic corrosion. The most common material selections tend to be stainless steels, however, special alloys and exotic materials such as Hastelloy®, tantalum and even silver have been supplied.

Q) CAN HITRAN® THERMAL SYSTEMS BE FITTED AS A PARTIAL INSTALLATION IN A PORTION OF THE TUBE?

CALGAVIN® engineers will look at all options to provide the most effective solution to your problem, including installation in only one or some tube passes or part of the tube length. Likewise, suitable installation and retention systems are available for these options.

Q) CAN HITRAN® BE RETROFITTED TO EXISTING SHELL & TUBE EXCHANGERS?

Thermally and hydro-dynamically the suitability of a shell and tube exchanger for improvement with hiTRAN is no different than an air cooler. However, retrofitting with hiTRAN may require modification of the pass arrangement, if the tube side allowable pressure drop is exceeded with hiTRAN. Unlike air coolers, the change in pass arrangement is simpler as it only needs removal of pass partition plates from the headers whilst keeping the same tube bundle and shell.

Q) ARE HITRAN® THERMAL SYSTEMS SUPPLIED AS A STOCK ITEM OR IS IT CUSTOM DESIGNED FOR EACH ORDER?

hiTRAN Thermal Systems are custom designed and manufactured based on process analysis, using the CALGAVIN.SP plug-in, considering thermal performance and pressure drop implications. CALGAVIN can support clients in optimising designs allowing hiTRAN to solve a greater range of problems.

SHELL & TUBE HEAT EXCHANGERS
FREQUENTLY ASKED QUESTIONS

Q) CAN HITRAN® THERMAL SYSTEMS BE FITTED IN A U-TUBE BUNDLE?

Installation in U-tubes results in reversing the fitting direction in one leg and requiring a lesser interference fit. Modified performance is taken into account in the calculations where U-tube is specified. Alternate installation and retention options are required and instructions are provided in our Installation Manual and on-site assistance can be provided.

Q) IN WHAT APPLICATIONS ARE HITRAN® THERMAL SYSTEMS NOT APPROPRIATE?

Benefits from enhancing performance with hiTRAN are greatest when the tube-side coefficient is substantially controlling (very low). This benefit reduces as the tube-side coefficient approaches equality with the outside coefficient at which point little overall enhancement is achieved. By example, applications where enhancement will not provide a benefit include :- where the outside coefficient is very low or where, on the tube-side, there is a high coefficient like steam or other condensing fluid.

Q) WHAT IS THE ADVANTAGE OF USING HITRAN® THERMAL SYSTEMS VERSUS TWISTED TAPE TYPE TURBULATORS?

The enhancement mechanisms are different between these turbulator types and this leads to markedly better performance by hiTRAN in the laminar and transitional flow regimes. hiTRAN can still offer higher heat transfer rates in turbulent flow, but lower pressure drop offered by twisted tapes means it can be a good option at high Reynolds numbers.

Q) WHAT CONSIDERATIONS NEED TO BE TAKEN WHEN APPLYING HITRAN® TO FOULING PROCESS FLUIDS?

Fouling is a complex issue with many different types and mechanisms. The enhancement effect hiTRAN has on flow inside tubes can be beneficial for some types of fouling, thereby providing a mitigation process. In practice, detailed information about the mechanisms is rarely available, such that a fouling reduction benefit cannot be easily calculated or guaranteed. Therefore, heavily fouling services need to assume that periodic cleaning will be required. As with empty tubes, it is important to monitor the exchanger performance to avoid excessive foulant build-up. While chemical cleaning options can be carried out with hiTRAN in-situ, mechanical cleaning methods require removal of hiTRAN before cleaning. Following the installation and removal procedures, including safe storage of the hiTRAN while cleaning, allows for reuse of the hiTRAN. Some spares would be advisable.

Q) WHAT ARE THE MINIMUM AND MAXIMUM TUBE DIAMETERS HITRAN® CAN BE MANUFACTURED FOR?

The smallest tube diameter hiTRAN can be designed for is 6mm and the range extends up to 150mm.

Q) ARE HITRAN® THERMAL SYSTEMS WARRANTIED?

CALGAVIN® warrants both thermal and hydraulic calculations provided directly or via the CALGAVIN.SP plug-in, based on customer data and design conditions, for clean recirculating fluids. In cases where uncertainties exist and for fouling applications, additional advice regarding expected performance may be provided.

CALGAVIN

RESEARCH - EVALUATION - INNOVATION - SOLUTION

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