Solutions for sustainability

Seven benefits of replacing a shell-and-tube with a gasketed plate heat exchanger, using only dimensional data

Shell-and-tube (S&T) heat exchangers have been around for ages and are widely used in many industries. Their popularity comes from its simple construction, manufacturability by anyone, made from any simple material, made to any size and to withstand any temperature or pressure.

Disadvantages can be listed as below:

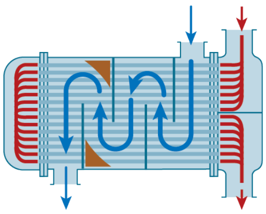
- Very low flow velocities causing fouling, likely dead zones for start of fouling.
- Not 100% counter current flow hence low efficiency.
- High hold up volume hence lagging temperature control.
- Costly to transport, heavy machinery is needed for installation.
- Large footprint, room to pull out the tube bundle.
- Difficult to maintain especially shell side.
- Heat losses from the shell side.

The shell side usually contains the clean fluid, as the tube side is comparatively easier to clean by manual rodding. Due these difficulties, S&T heat exchangers are seldom fully maintained, and fouling grows to such levels that it is faster and easier to replace them. Replacement with a gasketed plate heat exchanger (GPHE) can be as low as 1/3rd of the cost, depending on the material of construction.

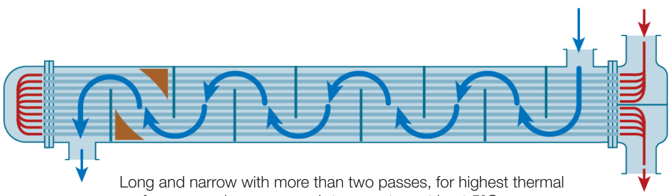
Typical construction of shell-and-tube heat exchangers

A short and fat S&T is typical for lowest thermal efficiency and performance. Approach temperatures for the two fluids cannot be better than 10°C and typically for oil cooling or steam applications with large diameter tubes and single pass.

Standard construction and flow regime



Low thermal performance short and fat.



Long and narrow with more than two passes, for highest thermal performance, closer approach temperature at best 5°C

Shell

Construction material is usually carbon steel with a tube sheet on either end and a header for the tube side inlet/outlet connections.

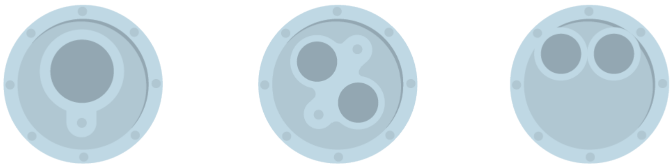
Tubes

Standard material can be copper, carbon steel, stainless steel. Tube diameter used in the construction of S&T is generally what is readily available in the market from tube manufacturers.

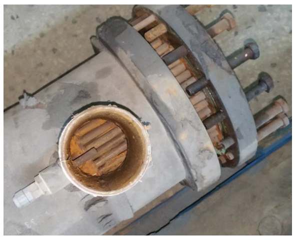
Copper or carbon steel in inches: ¼ ½ ¾ 3/8 etc.

Tube geometry is generally triangular pitch which is more efficient in layout of number of tubes. A square pitch is seldom used which aids cleaning on the shell side.

Tube side number of passes:



1-pass 2-pass 4-pass



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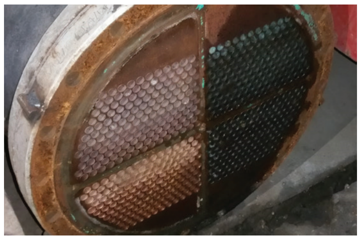

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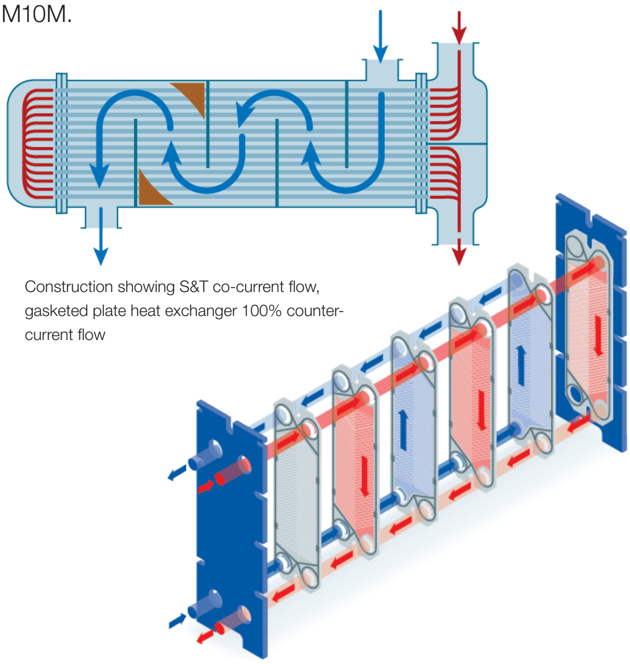
Gasketed plate heat exchanger types for replacement
Poor thermal performance from S&T heat exchangers is mainly due to flow regime of co-current flow. Best approach temperatures reachable with most S&T heat exchangers is 5°C or more. Hence, low thermal efficiency and low pressure drop type plates are best suited for replacement. These GPHEs are short, wide and have large channel gaps, e.g. M3, M6M, M10M.



Construction showing S&T co-current flow, gasketed plate heat exchanger 100% counter-current flow

Replacement with only dimensional information

Step 1 – Disconnecting the shell side fluid inlet which will show the material, diameter and pitch of tubes in the tube bundle.

Step 2 – Disconnecting the header will show the number of passes.

Shell diameter and tube diameter in a triangular pitch will give the number of tubes. Using the tube length, the approximate heat transfer area of the tubes can be calculated. Using the guide to the right for matching the heat transfer area for an Alfa Laval GPHE, an approximate number of plates will perform the duty 90% of the time, based on seasonal load and peak design conditions.

Example case:
- Application: water / water
- Shell: External diameter of 0.3 m and tube length of 3 m
- Tubes are copper material and 12.5 mm external diameter, pitch of 6 mm
- Construction: two passes

Using the surface area calculation tool shows approximate heat transfer area is 15.4 m² including 20% safety factor which can be used as the approximation accuracy.

Selecting an equivalent GPHE is as easy as approximating the heat transfer area required from a GPHE. Considering a higher turbulence, better efficiency as higher heat transfer coefficients achieved with GPHE, the area will be much less.

For typical applications, comparative heat transfer area can be chosen from the table below.

Water / Water	GPHE area m² = S&T area m² / 4
Oil / Water	GPHE area m² = S&T area m² / 2
Steam / Water	GPHE area m² = S&T area m²

Alfa Laval model	Connection diameter (mm)	Area per plate	Number of plates 20	40	60	80	100	120
M3	36	0.032	0.64	1.28	–	–	–	–
TL3	36	0.065	1.30	2.60	–	–	–	–
T5M	50	0.084	1.68	3.36	–	–	–	–
M6M	50	0.14	2.80	5.60	8.40	11.20	14.00	16.80
T8M	80	0.17	3.40	6.80	10.20	13.60	17.00	20.40
M10M	100	0.22	4.40	8.80	13.20	17.60	22.00	26.40
TL10P	100	0.48	9.60	19.20	28.80	38.40	48.00	57.60
M15M	150	0.62	12.4	24.8	37.60	49.60	62.00	74.4

As this case is a water/water application with a S&T of approximately 15.4 m².
An Alfa Laval GPHE with 15.4 / 4 = 3.9 m² will be enough.
A T5M with 40 plates is 3.36 m² but no room for expansion.
An M6M with 30 plates is just right with 4.2 m² heat transfer area (30 x 0.14 = 4.2 m²). This unit will have capacity for expansion should you need after installation.

Savings from heat losses to atmosphere
In comparison to a S&T a GPHE provides savings and contributes to sustainability in many ways. A major saving is reduced maintenance costs but there are also measurable savings from heat losses to atmosphere, from the large hold up volume which can pay back replacement with a GPHE in a few years.

In the below example if the shell side hold up volume is 1 m³ (1,000 kg) of water held at 60°C loosing 1°C in one hour, every hour.

Specific heat of water at 60°C is 1 kCal/kg.K or 4.172 kJ/kg.K

Hourly heat lost = 1,000 kCal/hr
= 4,172 kJ/hr
= 1.2 kW (3,600 seconds in 1 hour)

Duration savings for in kWhr?
Assuming equipment temperature is maintained 24 hours per day and 30 days per month.

Savings = 1.2 x 24 x 30 = 834 kWhr per month
Savings in monetary terms, assuming cost of 0.10 € / kWhr?
Savings = 834 x 0.10 = 83 € per month

With a 4 m³ hold up volume at 60°C, annual savings from heat losses will be 4,000 €.

▼ PRACTICAL TIPS

When sizing a S&T, usually a safety factor of at least 20% is applied to account for possible errors and expected fouling. GPHE plates can be added or taken away at any time after initial installation, to cater for mistakes or additional load that may be required at a later stage.