LS OPTICS AB

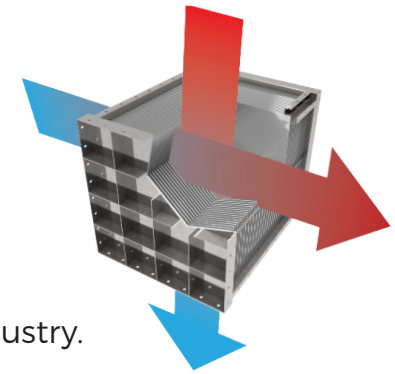
THE PENTAGON

A plate heat-exchanger for re-use of energy and increased production capacity

ABOUT HEAT RECOVERY

Heat recovery is taking advantage of used energy one more time.
This occurs when a gas or a liquid transfers its heat to another medium.

Recycling this energy is so important, Sweden's Parliament has decided that energy and material, particulary finite resoruces, need to be recycled.



The Pentagon plate heat-exchanger is an important element with regards to saving energy in industrial and commercial establishments such as hospitals, office buildings and hotels. It is used in air conditioning units, conduit systems and in the process industry.

Investing in a plate heat-exchanger saves money in several ways.

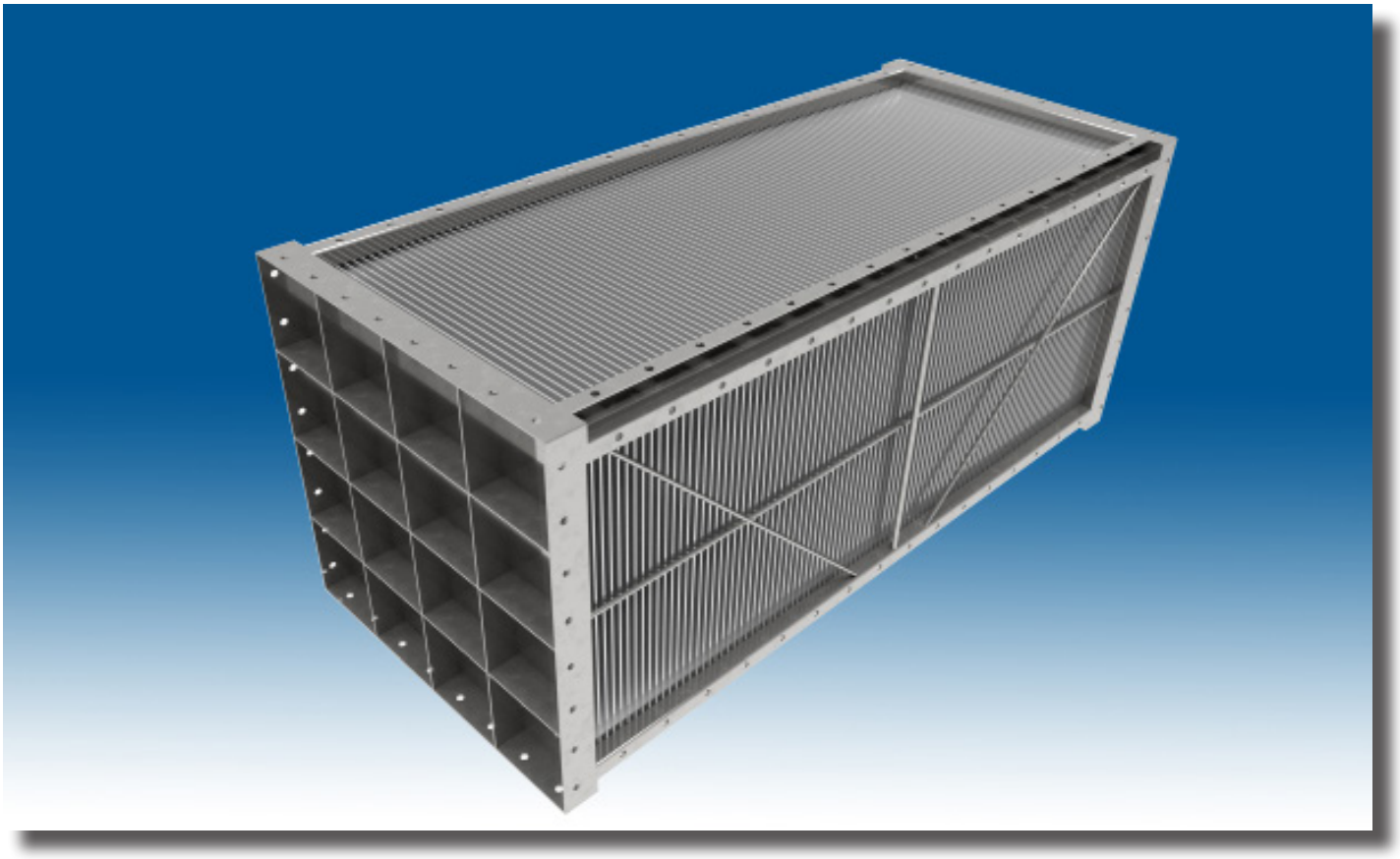
LS OPTICS

The Pentagon is a Swedish invention, born from the technology used in manufacturing wood drying systems for the sawmill industry. As a result of this, the founder Lars Svenningsson found the same principles could be used for heat recovery. The first Pentagon was delivered in early 2000.

OUR VISION

WITH CLOSE CO-OPERATION WITH OUR CUSTOMERS, SHARED EXPERTISE AND INTEGRATED DEVELOPMENT TO STRIVE TOWARDS THE END GOAL OF ACHIEVING 100% HEAT RECOVERY.

"We are driven by our conviction that the Pentagon is an integral part of the renewable future. With our passive unit, without need of electricity, we challenge efficiency"
- Lars Svenningsson



WHAT IS
THE PENTAGON?

We introduce the Pentagon, a cross-flow gas/gas plate heat-exchanger using a special lamellae developed according to the principles of entanglement and interweaving. This creates “highways” allowing electromagnetic waveleangths to pass through the lamellae.

The lamellae in the plate heat-exchanger transfer heat with large amounts of wavelengths, which transform to a lesser degree during passage through the lamellae. This technology allows the micro-crystalline structure of the lamellae to form a pentagon shaped pattern. The lamellae are specially alloyed which allows us to change it’s optical constants.

Heat recovery ≥98%

No moving parts
No electricity
Four identical sides

The Pentagon has been independently tested by AF and Södra Skogsägarna.

Weight:	**425 kg**
Dimensions (L x W x H):	**2,5 x 1 x 1 m**
Surface area:	**840 m2**
Temperature range	**-40 to +250 ^{0}C**
Capacity:	**1,0 n m^{3}/s - 10 n m^{3}/s.**

Not. Documented perfomance in this broschure is based on those test results.

Not. Higher capacity is possible after further investigation.

WHY CHOOSE THE PENTAGON?

Our plate heat-exchanger is designed for the recovery of thermal energy from any type of gas. Our new innovative lammelae will revolutionize the heating industry. It enhances the overall energy efficiency of heating processes while substantially reducing the operating costs of the entire system.

Part 1
Recovery
Measured by AF, the recovery rate is ≥93% and most importantly, **linear across the hole flow spectrum.**

Part 2
Capacity
With the possibility of combining multiple units, the Pentagon can handle calculated and required capacity.

Part 3
Quality
All Pentagons are tested in a water bath to ensure that the unit is properly sealed up to the calculated pressure drop.

Maintenance
The Pentagon has easily accessible inspection hatches for inspection during operation, and for cleaning the lamellae.

Material
In order to withstand low pH values, as well as other corrosive environments and substances, the entire plate heat-exchanger is built using acid proof stainless steel and fulfills the requirements set by the Swedish food charter.

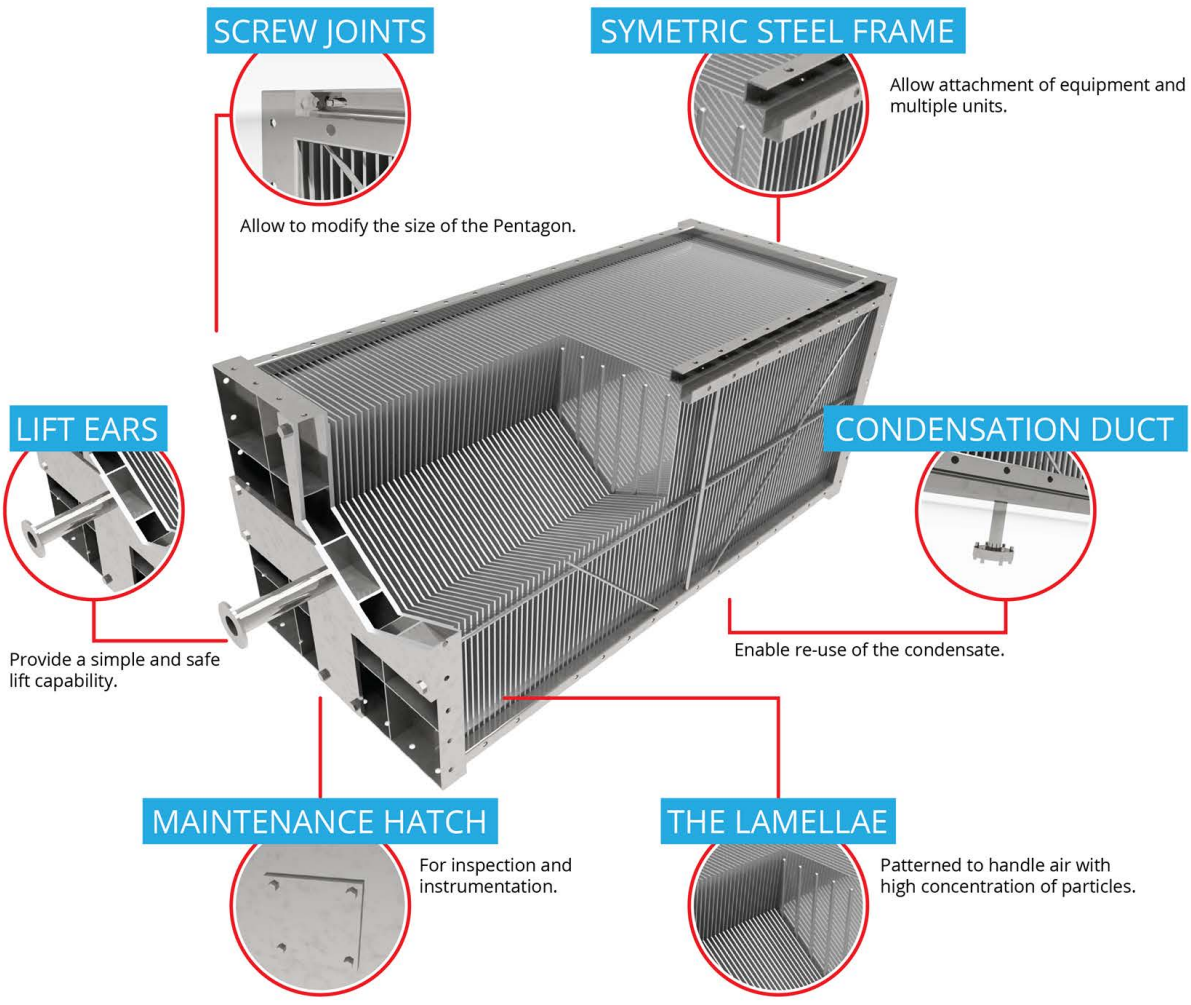
Life Expectancy
With regular use of the Pentagon, we guarantee a 40 year lifespan.

> The recovery rate is as high at the lowest flow to the highest flow

THE PENTAGON

FEATURES

The Pentagon has many special features that, when combined, give a high quality and effective plate heat-exchanger.



An Important Message

The AF report proves that after installation of the Pentagon, the energy consumtion is reduced by 40-50% based on the total process energy.

PENTAGON STATISTICS

LS-Optics has separate side-projects where we measure processes and make suggestions regarding heat recovery. Our analyses are built on logged trend curves from, among others, Knared and Derome.

It happens often that these side-projects transform into analysis of quality insurance of the product as well as capability.

Our work on these projects has given LS-Optics the necessary industrial expertise along with specializing in material technology.

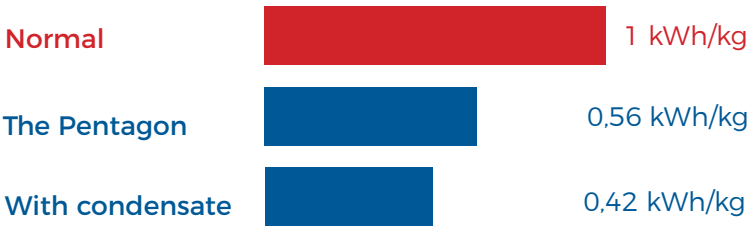
STATEMENT

The statistics presented below are of great importance because they show the capabilities the Pentagon has to reduce your energy consumtion.

Energy recovery comes in two stages where it is very beneficial to also use the recycled energy a second time by taking advantage of the heat in the condensate, wich often holds a temperature between 60°C to 80°C.

The Pentagon provides a very high energy re-use at both low and high flows since the lamellae do not depend on convection.

EQUIVALENT ENERGY CONSUMPTION



The Pentagon used in the process industry reduces the specific energy from 1 kWh/kg moisture down to 0,56 kWh/kg moisture.
If it is possible to use the condensate we are able to reach 0,42 kWh/kg moisture.

LS-Optics uses trend curves as a tool to analyze, calculate and size the Pentagon to meet the specific conditions in each case. We use these logs both before and after installation of the Pentagon to ensure we meet our target goals.

THE ASPECTS OF CHOOSING
THE PENTAGON

The Pentagon is beneficial from economic, environmental and health aspects.

With a well-proven technology, a long lifespan and highly effecient system, we strive to challenge all aspects of being a part of the sustainable future.

01

ECONOMICS

Normally the Pentagon has a payoff time of less then one year.

02

ENVIRONMENTAL

The plate heat-exchanger affects environmental impact by reducing the amount of carbon dioxide, greenhouse gases as well as acidic nitrogen pollutants .
100 kW of re-use in the heat exchanger reduces CO_2 emissions by the equivalent of the yearly average use of five automobiles.

03

HEALTH

Acidic nitrogen pollutants acidify soil and ground water. Nitrogenous gases are poisonous and can cause allergic reactions even in small amounts.

The plate heat-exchanger also dampens the noise level in and around it's environment to such a level that a separate sound dampener is not required.

OUR COMPANY
PROJECTS PORTFOLIO

Our portfolio spans the globe and we have experience in working together with different companies in an array of industries, setups, geographies and stages.

Presented is two different clients from Sweden.

"It is our determined understanding that we find the best solution together with our partners"

REFERENCES

Derome

– Från skog till färdigt hus!

DEROME

The Derome Group is one of Sweden's largest family-owned lumber industries dating back to 1946.

DEROME

A total of seven plate heat-exchangers since 2010. Note that the outlet tube, inlet tube and the gabels har insulated.

KNÄREDSSÅGEN AB

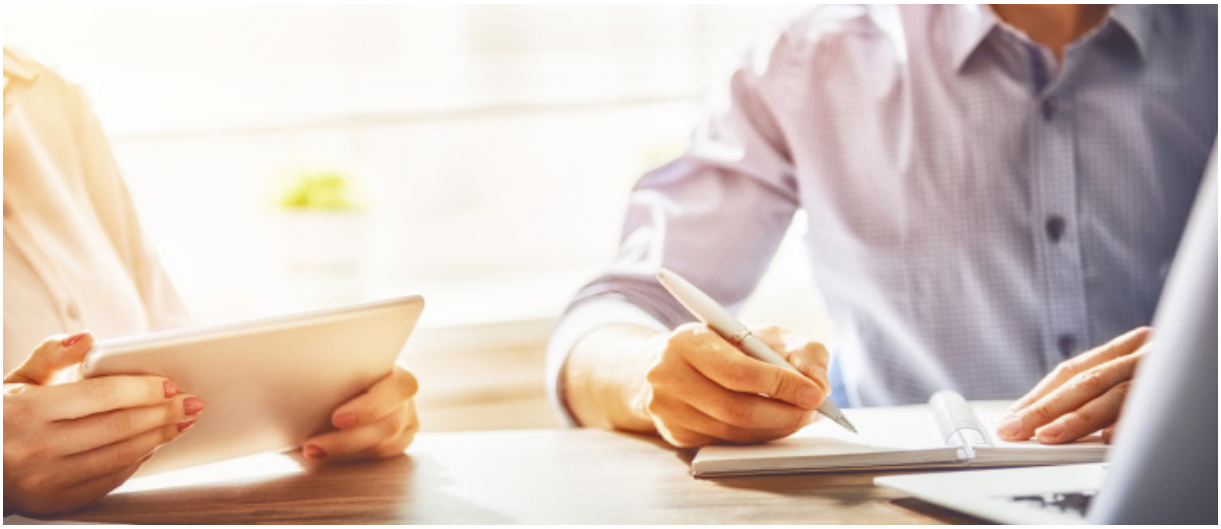
Knäredssågen AB is a family-owned sawmill, located near Halmstad dating back to the 1940´s.

KNÄREDSSÅGEN AB

Has one Pentagon in operation on a sawdust-dryer. Note the trend curves on page 8. These trend curves is being used to controll the process.

“THERE ARE SO MANY DIFFERENT WAYS TO CREATE ENERGY”

LS-OPTICS PARTICIPATE IN THE DEVELOPMENT OF LIGNIN - A NEW KIND OF BIO ENERGY SOURCE FROM THE TIMBER INDUSTRY.



SOLUTIONS

From our experience of installing the Pentagon in many different environments in a wide variety of processes, LS Optics has steadily expanded our services to meet the changing needs and specific demands found in each case. We provide a variety of solutions depending on the client and their own expercience and knowledge.

WE CALCULATE

When we receive a specification, we conduct the calculations necessary to optimize the Pentagon.

WE FIND THE RIGHT SOLUTION

The calculations often indicate the look of the solution, and the client's experience can have great impact.

WE INSTALL

We have great experience in installing the Pentagon in many different environments, and have the expertise needed for your installation.

WE EVELUATE AND REPORT

In connection with commissioning, we measure up the design data to verify heat recovery, energy recovery and provide a thorough report.

APPENDIX

This section presents a calculation model for estimating the heat and energy recovery of the Pentagon and a technical description.

TABLE OF CONTENTS

DESIGN DATA

Outlet Side

Area outlet air channel:	A_O	m^2
Outlet air volume flow:	v_O	m^3/s
Outlet air mass flow:	m_O	kg
Outlet air temperature:	t_O	°C
Outlet air relative humidity:	Rh_O	%
Area exhaust air channel	A_E	m^2
Exhaust air volume flow	v_E	m^3/s
Exhaust air mass flow	m_E	kg/s
Water density at t_E	ρH_2O_{tE}	kg/m^3
Condensate volume flow	v_C	m^3/s
Condensate mass flow	m_C	kg/s
Specific condensate enthalpy	r_C	kJ/kg
Exhaust air temperature:	t_E	°C
Exhaust air relative humidity:	Rh_E	%
Pressure drop O/E	Δp_{OE}	Pa

Fresh Side

Area fresh air channel:	A_F	m^2
Fresh air volume flow:	v_F	m^3/s
Fresh air mass flow:	m_F	kg
Fresh air temperature:	t_F	°C
Fresh air relative humidity:	Rh_F	%
Inlet air temperature:	t_I	°C
Inlet air relative humidity:	Rh_I	%
Pressure drop F/I	Δp	Pa

t_F = 7°C in Scandinavia
= daily average atmospheric temperature over the whole year

$1nm^3$ = One normal cubic meter is the amount of gas, which at nominal, one bar and and 0°C, has a volume of $1m^3$.

C_p = Air specific heat = 1.005 kJ/kg °K

ρ_F = Density fresh air 7°C = 1.244 kg/m^3

γ = H_2O volume expansion 0.00048 m^3/m^3 °C

$\rho H_2O_{t_E}$ = $\frac{10^3}{1+0.00048x(t_e-20)}$ kg/m^3

r_C = Specific condensate enthalpy kJ/kg at t_E

R = Individual gas constant Nm/kg °K

M = Molecule weight = the amount of kilogram as the atomic number

M = kilogram/kmol

M * R = Universal gas constant

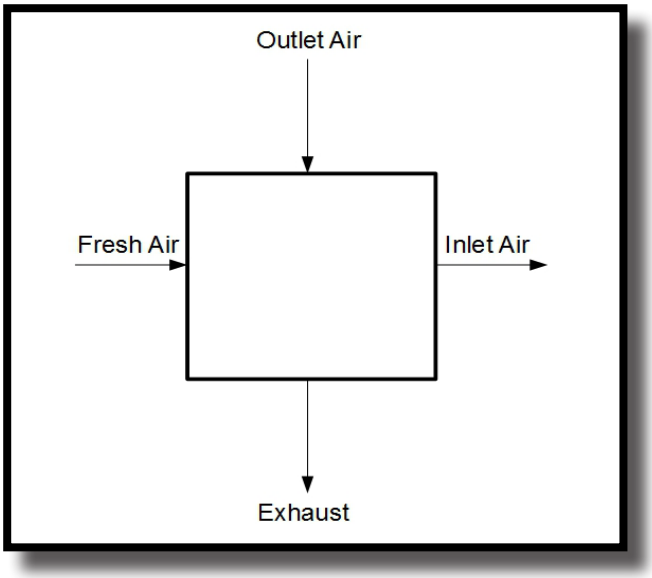
M * R = 8314 [Nm/°K]

$C_p - C_v$ = R

$\varkappa$ = C_p / C_v = 1.66, 1.40, 1.30

$\varkappa$ IS DETERMINED BY WHETHER THE GAS MOLECULE HAS ONE, TWO OR THREE ATOMS.

HEAT RECOVERY



$$\eta = \frac{\text{Inlet air - Fresh air}}{\text{Outlet air - Fresh air}} = \frac{t_I - t_F}{t_O - t_F} \geq 0{,}98$$

$t_I = 0{,}98\ (t_O - t_F) + t_F$

$t_I = 0{,}98\ t_O + 0{,}1\ t_F$

ABSORBED EFFECT

$P = 0.98 * m_F * C_P\ (t_O - t_F)$

$m_F = V_F * \rho_F$

$P = 1.219 * V_F\ (t_O - 7)\ [KW]$

OUTPUT

$P = m_C * \Gamma_C\ [KW]$

$m_C = V_C * \rho_{H_2O_{tc}}$

FLUE GAS

The calculation method for heat recovery is the same as the method for exhaust gases.

Using an exhaust analysis, we conclude the individual gas constant R[Nm/kg °C]

C_p and C_v can be calculated or estimated using R as above.

If the customer wants to condensate the flue gas below 100°C, there is a risk acids will be present, such as sulfuric acid H_2SO_4. In this case LS-Optics will participate to find the right solution.

MATERIAL

To be able to withstand low pH values as well as other corrosive environments and substances, the entire heat-exchanger is built using acid proof stainless steel.

TEMPERATURE LIMITS

The Pentagon has an operational range of -40°C to 250°C.

CONDENSATE

It is common that condensation accumulates when the outgoing air is cooled.

The condensation is handled on the exhaust side.

It is worth noting that the condensation can freeze during winter time, when this is a risk, the condensation ducts should be insulated.

The risk for freezing is present when $m_F > m_O$.

The condensation ducts should be a minimum of two inches in diameter.

The amount of reusable energy can be measured by the amount of condensation and it's temperature.

The temperature of the condensation is only 1 – 3°C lower than the outlet temperature.
Condensation is recycled energy which contains, even in small amounts, a high level of energy. This can be used a second time for heating purposes locally, or remotely in larger amounts.

PRESSURE DROP

The pressure drop over the plate heat-exchanger is to be restricted to the equivalent of air 10 nm3/s. In case of larger flows, multiple units can be attached to handle the capacity.

TESTING

The Pentagon has been independently tested by AF. Documented performance is based on those test results.

HYGIENIZATION

The Pentagon fulfills the requirements set by the Swedish food charter.

MAINTENANCE

The plate heat-exchanger has openings in the cones to allow inspection and cleaning of the lamellae. Measurement instruments can be placed here.

Planned maintenance intervals are recommended.

In particularly contaminated environments, a filter is required on the outlet side.

CONES

When connected to a plumbing system, it is advantageous to construct cones or boxes between the pipes and the plate heat exchanger, where the fluid mixes prior to passage through the Pentagon. The box depth should be half the plate heat-exchanger's.

DELIVERY TEST

Prior to delivery, all plate heat-exchangers are tested in a water bath to ensure the unit is properly sealed up to and including the calculated pressure drop. There is a quick drop in efficiency even when there's a tiny leakage.

The plate heat-exchanger is built using stainless steel and has no moving parts and requires no electricity. This along with identical bolt bindings on all four sides gives a weight of 425 kg, which eases both projection and assembly.

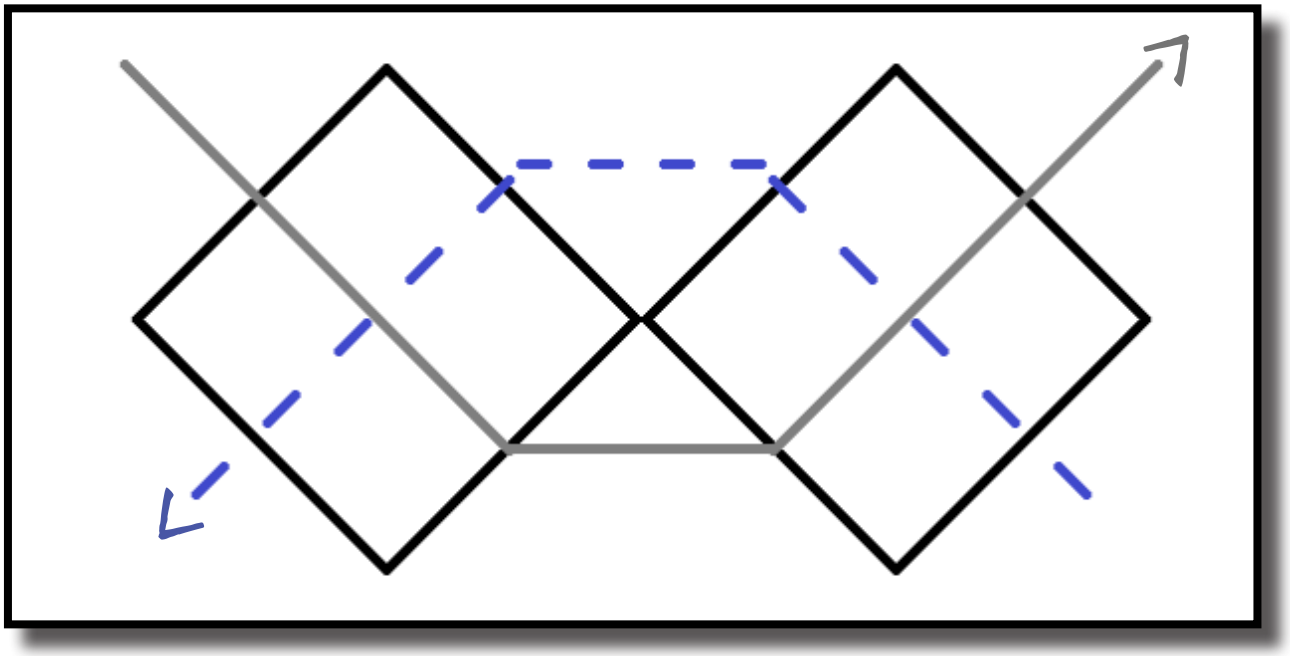
The four identical sides allow for multiple units to be easily attached on the width and height.

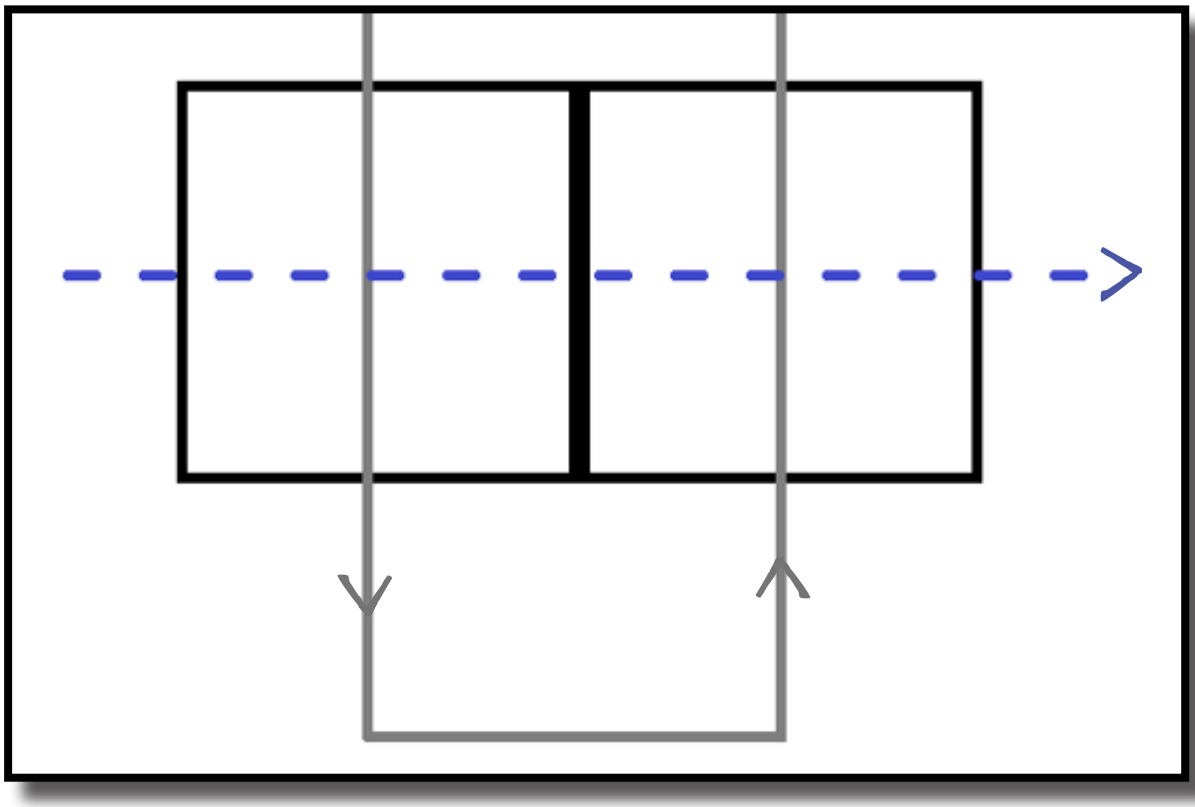
Lift ears on the gables provide a simple and safe lift capability.
It is recommended during the first year to measure the two pressure drops over the Pentagon, between the outlet-exhaust and fresh air-inlet, once every three months.

TRANSPORTATION

Our plate heat-exchanger must always be handled horisontly and may only be lifted by the gables' lift ears. Prior to transportation, all four lamellae sides must be carefully covered with plywood. The cones are normally transported separately.
The plate heat-exchanger is delivered screwed to a specially constructed wooden frame.

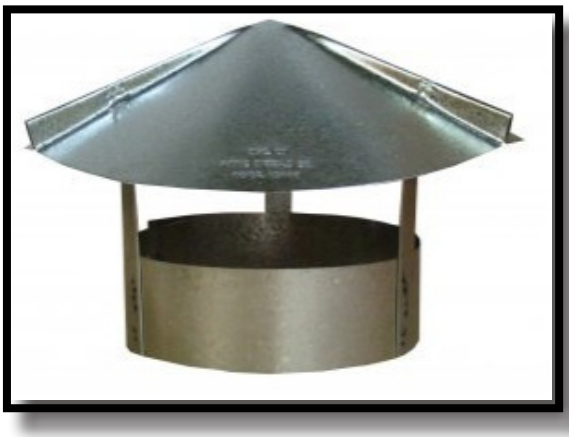
OTHER CONFIGURATIONS





Examples of different configurations on how to arrange multiple Pentagons in cases with need of high capacities. When using larger and vertically standing configurations, the lamellae are supported with seperate load planes.

ASSEMBLY AT THE INSTALLATION SITE



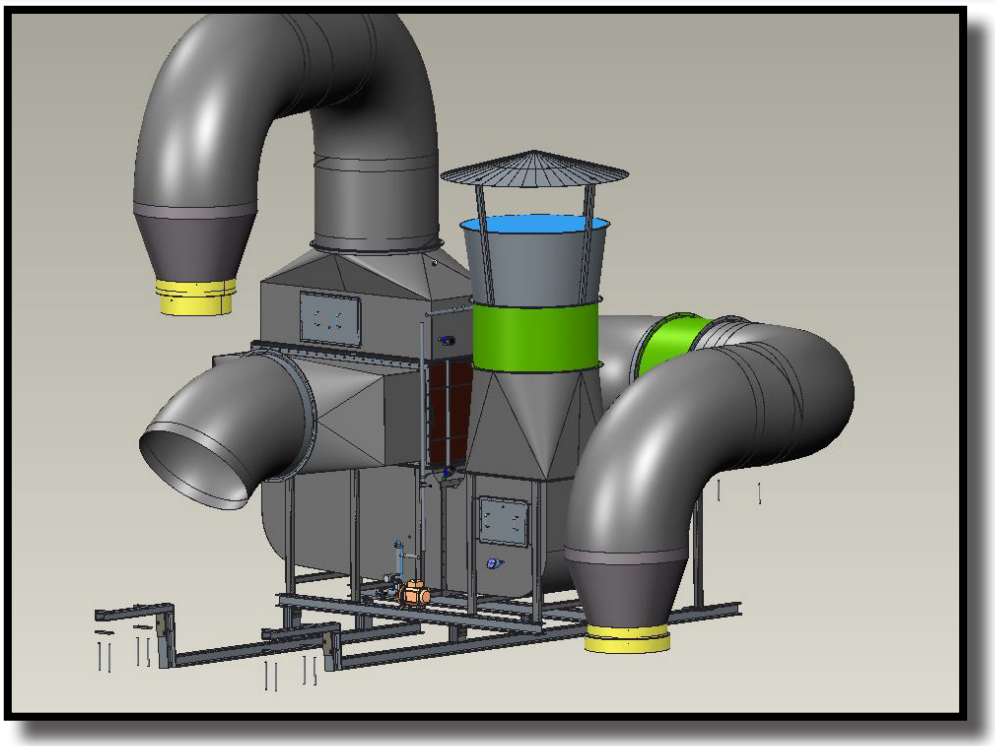
The lammelae shall if possible
remain vertical, if rotation is required,
it must not exceed a maximum inclination
of 45°.

When the cones are assembled, the flanges
shall be sealed with glue cement.

If there is a risk of rain into the fresh air
and exhaust air channels, the intakes must be covered by a rain cap.

Use glue cement instead of rivets when joining the pipes together.

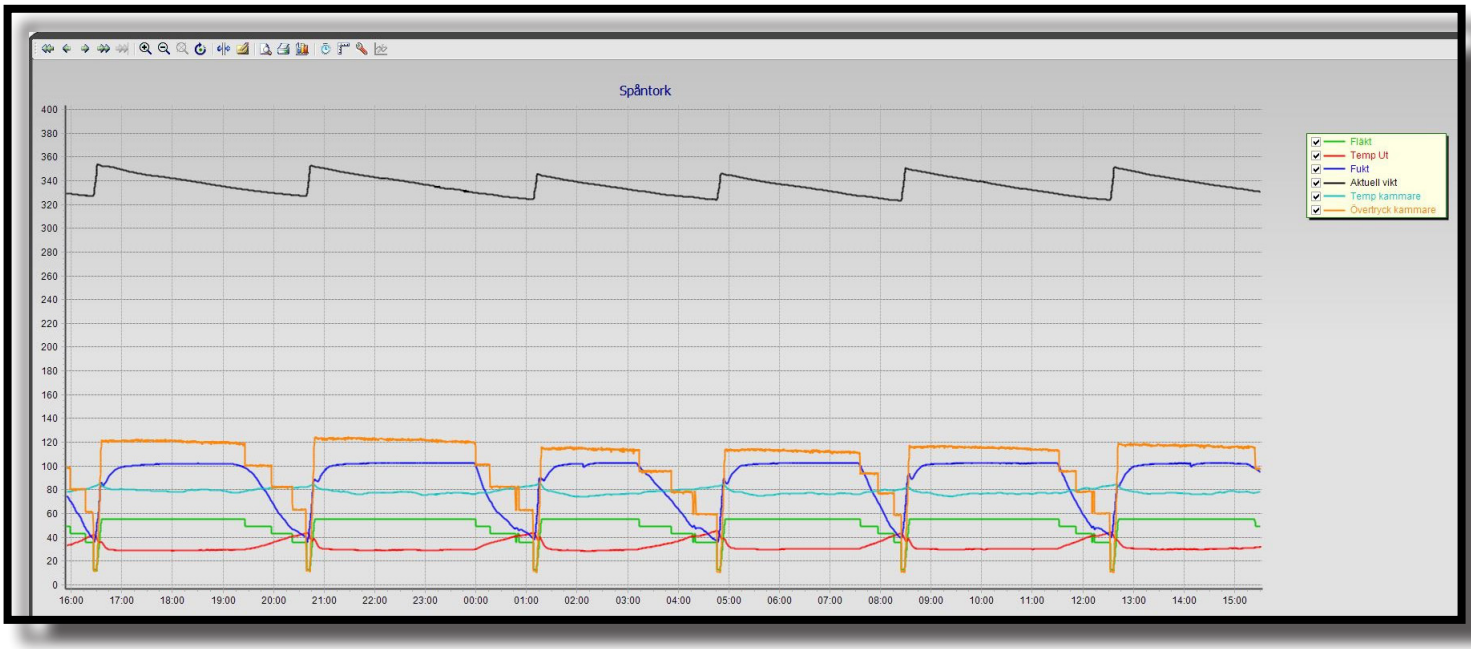
Ensure the air channels have a large enough diameter so the pressure drop per meter channel does not exceed 3Pa/m.



Here is an example of when a rain cap is needed for the exposed channels.

Because of the large amount of nutrients in this installation, which in turn leads to a high amount of bacteria residing within the system,
the plate heat-exchanger is cleaned using a combination of condensation and a pH 7.0 neutral chemical.

THE PENTAGON TREND IN A SAWDUST DRYER
Trend curves from the plate heat-exchanger and sawdust dryer at the Knared Sawmill. Six drying cycles per 24 hours.
Δp dryer 1200 Pa over the sawdust layer in the dryer, Rh = 100%, dryer temperature 80°C, fan speed = 50Hz, temperature inlet heat exchanger = 30°C



COMMISSIONING

Ensure that the plate heat-exchanger is assembled correctly, and all pipe connections are properly sealed.

Ensure eventual fans are correctly mounted and that they rotate in the right direction. If using axial fans, the motor must be mounted so that it comes before the fan wheel in the direction of airflow.

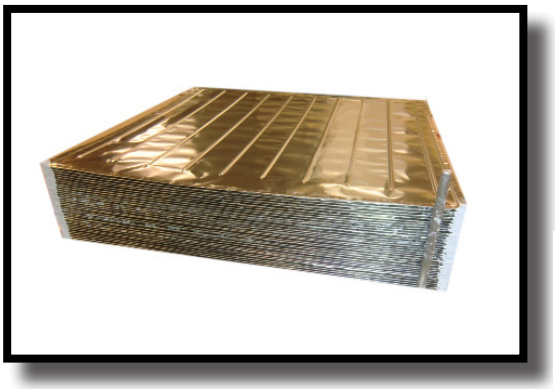
That the warm ducts; outlet and inlet as well as the plate heat-exchanger's gables are insulated.

Measure the two pressure drops over the Pentagon, between the outlet and exhaust as well as between the fresh and inlet air.

Measure the equivalent flow (m3/s), temperature and relative humidity as well as verifying the promised heat recovery.

If any of these values are found to be deficient, a thorough inspection will be conducted to correct the deficiency prior to commissioning.

FROM START TO FINNISH



840 lamella
creates the Pentagon

With reinforced framework
the Pentagon is ready to be
delivered.

Installed Pentagon with insulation on
outlet tubes, inlet tubes and
the plate heat exchanger.

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