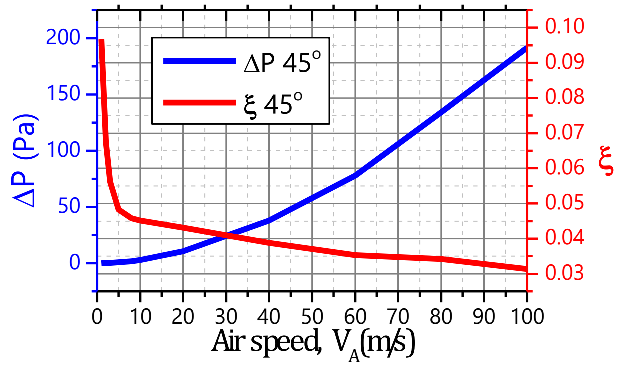
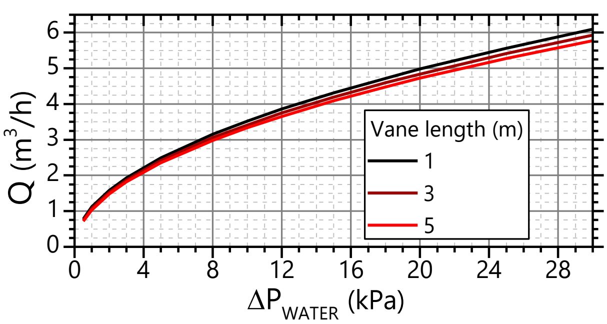
FEATURES

- 90˚ airflow turning angle.
- High-grade 6063-T6 anodized aluminum alloy.
- 6 internal channels for liquid cooling.
- Airflow temperature:
  - -100 ... +150˚C – dry air, no coolant, no icing conditions recommended;
  - +4 ... +95˚C – humid air, no icing conditions, water coolant.
- Airduct local resistance coefficient at V_{AIR}=40 m/s: ξ = 0.0388. *(Darcy-Weissbach coefficient in* $\Delta P = \xi \cdot \rho \cdot \frac{V^2}{2}$*)*
- Airflow speed range at the turning section inlet: V_{AIR} = 0 – 100 m/s.
- Max. coolant (water) pressure difference: ΔP_{WATER} = 500 kPa.
- Absolute burst pressure of the coolant channels: P_{BURST} = 0.6 MPa.



Airduct local resistance and pressure drops.



Summary water flow rate through all three vane channels vs. water pressure drop between the inlet and outlet ports. Standard piping configuration.

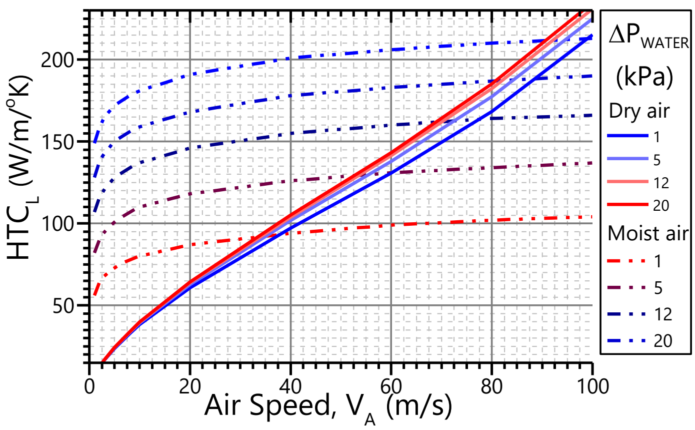
APPLICATIONS

- Recreational, scientific, industrial ventilation
- Single-loop and multi loop wind tunnels

GENERAL DESCRIPTION

Turning vanes designed for wind tunnel applications, suitable for both subsonic and transonic environments, focus on optimizing airflow management. These vanes are critical in research and indoor skydiving applications where precise airflow control is required. Made from 6063-T6 aluminum alloy with an anodized finish, they offer improved durability and heat dissipation capabilities. The aerodynamic design minimizes drag and turbulence, contributing to more accurate testing results.

The vanes come fully assembled with an integrated bearing structure (TTE-TSA) and, when necessary, coolant piping for easy installation. They feature a cooling system with six internal channels that can accommodate various cooling fluids, including water and glycol-based refrigerants. This design ensures efficient heat transfer while maintaining structural integrity, allowing for customization to different wind tunnel setups.



Heat Transfer Coefficient (per meter of the vane length) vs pressure difference between inlet and outlet ports. Standard piping scheme.

TTE GmbH
Stammheimer Str. 35 | 70435 Stuttgart
Registergericht | Registry Court: Amtsgericht Stuttgart
Handelsregisternummer | Commercial Register No.: HRB 766427
USt-ID | VAT No.: DE320246011
Tel: GER: +49 71 1925 3680
Tel. UK: +44 74 8881 8108
tunneltech.eu
info@tunneltech.eu

TABLE OF CONTENTS

SPECIFICATIONS

Airduct local resistance characteristics

The computation of local resistance coefficients is performed using the Darcy-Weisbach equation, as expressed in ***Equation 1.1.***

$$\Delta P = \xi \cdot \rho \cdot \frac{V^2}{2}, \quad (Eq.1.1)$$

Where:

ΔP - total pressure losses (pressure drop) in Pa;

ξ – local resistance (Darcy-Weissbach) coefficient;

ρ – fluid density (kg/m^3);

V – fluid velocity at the inlet cross-section (m/s).

Pressure drops and resistance coefficients are computed under the specified conditions:

- T = 20˚C
- Dry air
- Air density (ρ): 1.204 kg/m^3
- Air dynamic viscosity (μ): 1.716×10^{-5} N*s/m^2

Turning vanes speed vs. airduct local resistance parameters are given for two turning section angles of vane diagonal 45˚ and 60˚ (45U and 60E designations in the ordering code) and for the spacing of 153 mm, which is optimial by design. See ***Diagonal Angle Information*** section below.

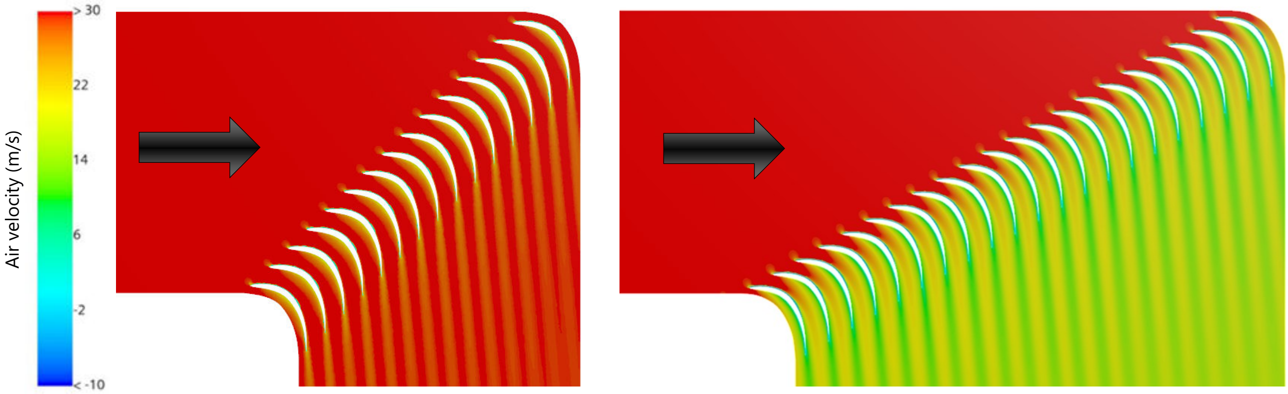


Fig. 1.1 *45˚ standard turning section (45U, uniform airflow), and 60˚ turning section (60E, expanding airflow)*

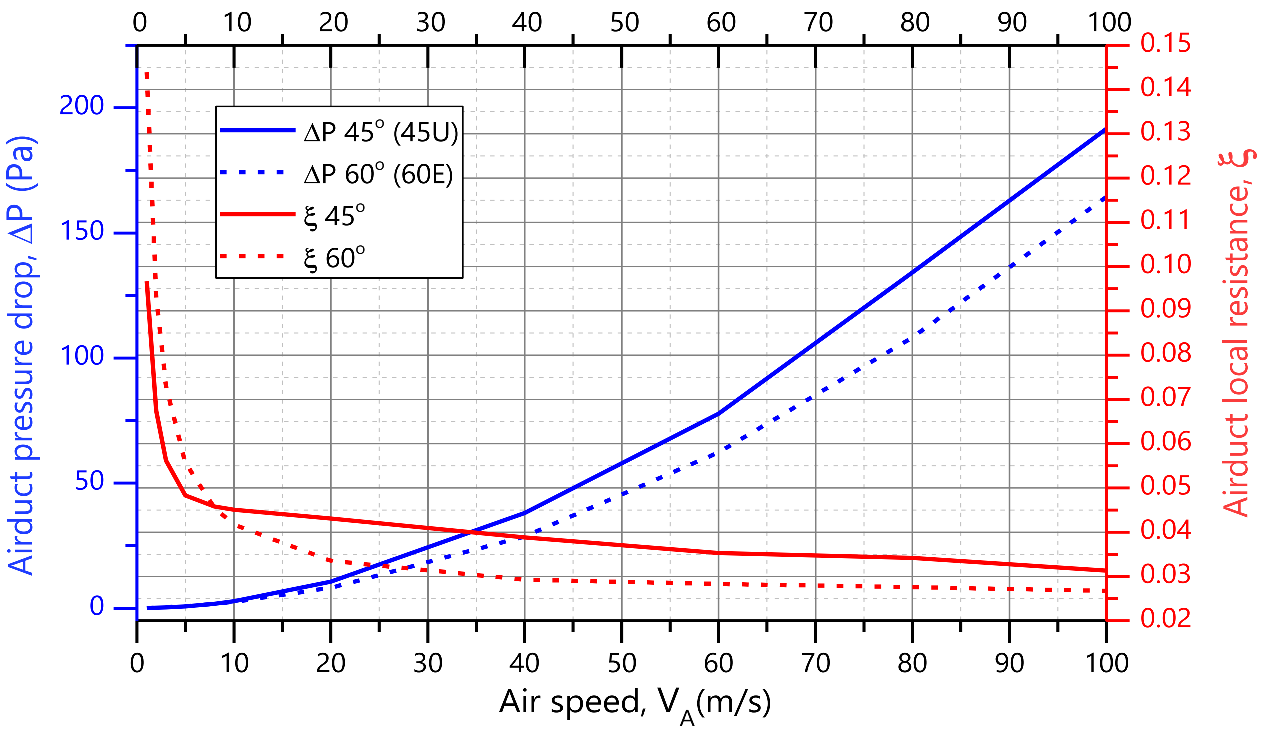
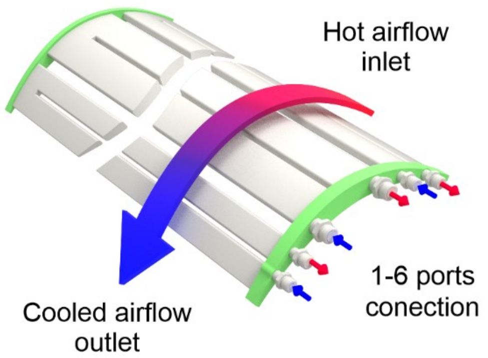


Fig. 1.2 *The graphical representation depicts the relationship between airduct local resistance and inlet airspeed for vane diagonal angles of 45˚ and 60˚ (expansion) with a standard spacing of s = 153 mm.*

Hydraulic characteristics

The correlation between the flow rate Q (m^3/h) and the water pressure drop ΔP_{WATER} at the inlet and outlet, from 1 to 6 ports is consolidated for all three channels of a single turning vane, presented as **Q=f (ΔP_{WATER})** below in ***Fig 1.4***. The data is also presented in tables in ***Appendix 3***.



Hydraulic parameters have been computed for the standard piping configuration outlined in ***Fig.A.1.8,*** see ***Active cooling systems*** for details (***Appendix 1***).

Fig. 1.3 *Cooling channels of the turning vane.*

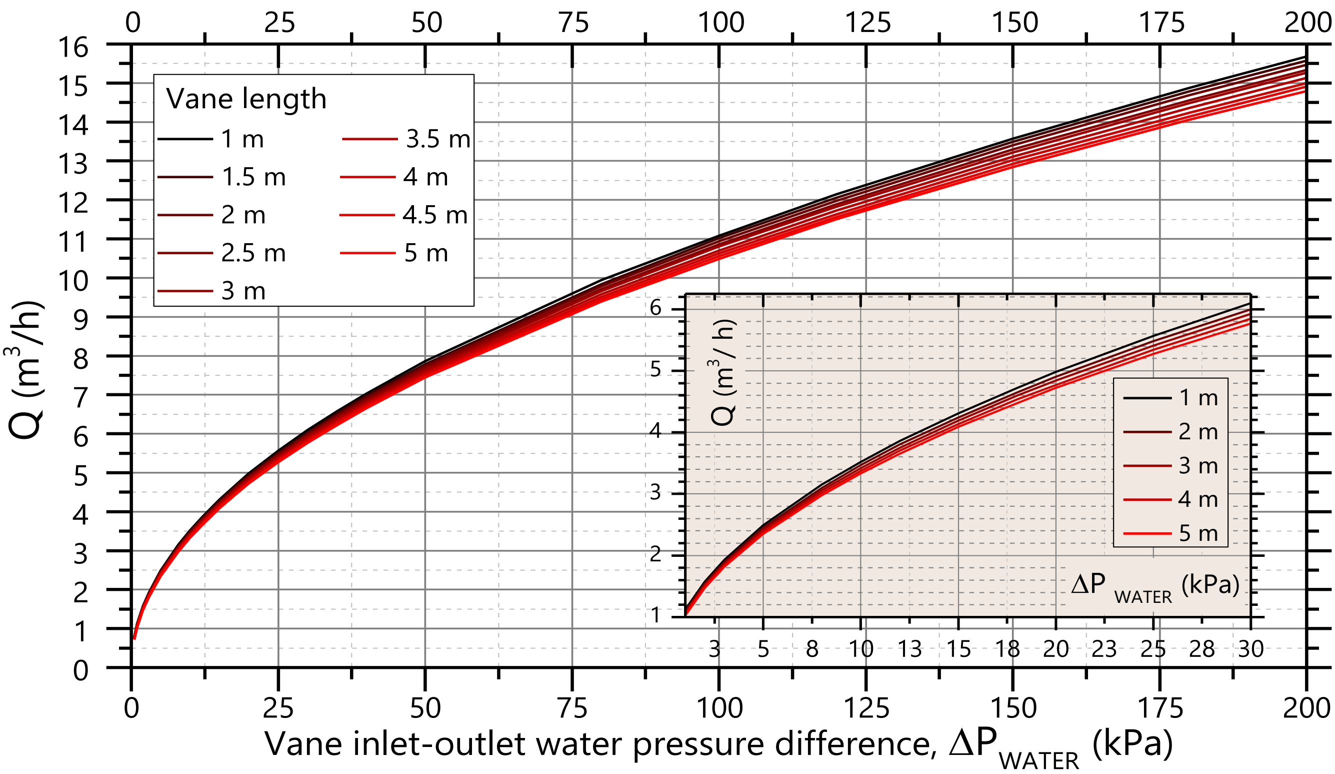


Fig 1.4 *Summary water flow rate through all three vane channels vs. water pressure drop between the inlet and outlet ports for different turning vane lengths. Standard piping configuration. (*)*

*(*) Standard piping scheme –see **Fig.A.1.8**. Standard deviation: ΔQ = ±10%. The dependence between Q, P, and L is specifically provided for the vane channels, port connectors, and the 500mm flexible hose start/end pipe spacer to ensure accurate flow profile considerations. For long flexible hoses or custom connectors, additional research is required to determine exact pressure drops. ΔP values for these components should be extracted from the customer's manifold system, as illustrated in this graph.*

Your hydraulic network should be designed to generate the desired pressure difference ΔP_{WATER}, as per ***Fig 1.4***, (or ***Table A.3.1***) corresponding to the required coolant flow rate Q. Calculate the required flow rate Q based on the comprehensive cooling power calculations for the entire turning section (refer to **Heat transfer characteristics** paragraph and HTC_L data ***Table A.4.1***) under various aerodynamic flow modes specific to your equipment.

Heat transfer characteristics

HTC_L (Heat Transfer Coefficient per Linear meter) is calculated as the heat flux (in Watts) per one meter of turning vane length, per one Kelvin of logarithmic mean temperature difference (ΔT_{LMTD}) between the external air and the turning vane coolant.

On subsonic wind tunnels operating in the common experimental range of flow parameters (see highlighted values in ***Table A.4.1***, ***Appendix 4***), ΔT_{LMTD} can be substituted with the difference between the inlet air temperature and the average coolant temperature for approximate calculations ($\Delta T_{LMTD} \approx T_{AIR\_in} - T_{WATER\_avg}$). The dimension W/m/K, while not strictly accurate in a physical sense, is adopted for convenience in engineering calculations. With knowledge of the HTC_L coefficient, the required temperature difference, and the amount of power to be dissipated, one can easily determine the necessary total length of the turning vanes in the turning sections.

HTC_L is determined through the following calculation:

$$HTC_L = \frac{W}{L \cdot \Delta T_{LMTD}}, \qquad (Eq.1.2)$$

Where: HTC_L (Watt / meter of TV length / Kelvin) – the heat transfer coefficient per 1 meter of turning vane length *(for standard piping scheme and 45˚ diagonal)*;
W (Watts) - total heat flux from hot air to the coolant;
L (meters) – length of the vane;
ΔT_{LMTD} (˚K) – logarithmic mean temperature difference. *Use $T_{AIR\_in} - T_{WATER\_avg}$ for experimental conditions, mentioned above. For a strict LMTD definition use link: Wiki/LMDT*

The heat transfer coefficient is given per linear meter since the turning vane surface and shape remain consistent across all standard TTE products.	⚠

The heat flux from hot air to the coolant through the vane was evaluated (*see **Fig.1.5-A, B** and **Table A.4.1***) for the standard piping configuration (***Fig.A.1.8***), for both dry air and moist air (including condensation and surface tension effect), considering the specified air and water conditions, outlined in the **Table 1** below:

Table 1. Calculation cases for the linear heat transfer coefficient **HTC_L**

Conditions	**Dry air** • 1 std. atm. • T_{AIR} = 26 … 36 ˚C • RH = 0%	**Moist air** • 1 std. atm. • T_{AIR} = 30 ˚C • RH = 90%
Method	• CFD-calculated, real gas mixture	• Experiment / Extrapolation
Cooling water temperature at the turning vane inlet	• T_{WATER_IN} = 8 ˚C	• T_{WATER_IN} = 8 … 12 ˚C
Airflow speed range at the turning section inlet	• 0 – 100 m/s (calculated)	• 0 – 36 m/s (experimental) • 0 – 100 m/s (extrapolated)
Air dynamic viscosity (μ)	• 1.84 .. 1.86 × 10^{-5} N*s/m^2	• 1.84 × 10^{-5} N*s/m^2
Air density (ρ)	• 1.16 – 1.18 kg/m^3	• 1.15 kg/m^3
Vane spacing	• Standard 153 mm	• Standard 153 mm
Results	• Fig.1.5 – A • Table A.4.1 - A	• Fig.1.5 – B • Table A.4.1 - B

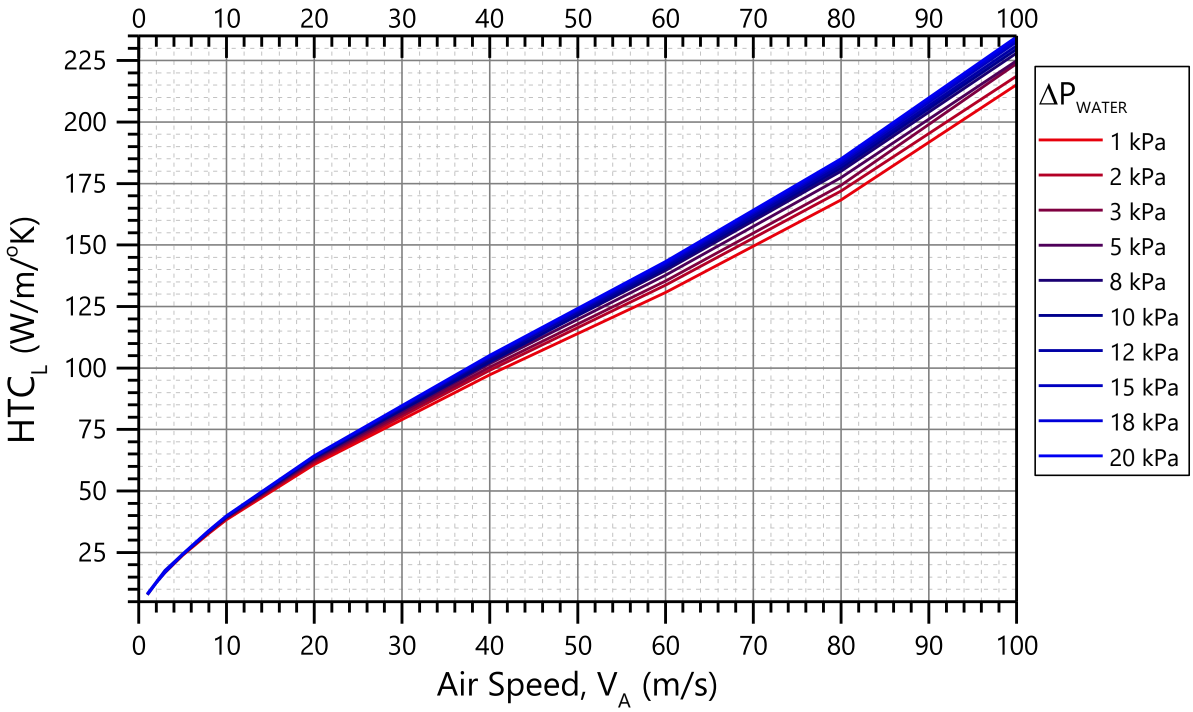


Fig. 1.5 - A *HTC_L for different ΔP_{WATER} and airflow speeds (**) for **dry air conditions** (see Table 1).*

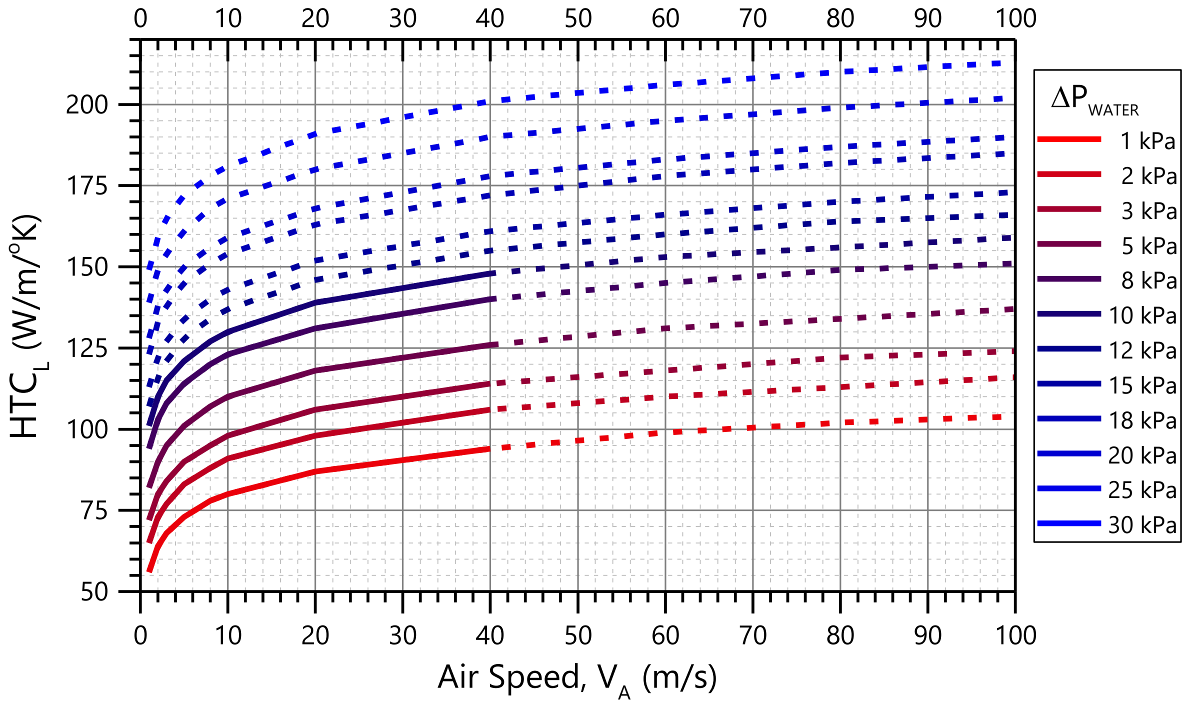


Fig. 1.5 - B *HTC_L for different ΔP_{WATER} and airflow speeds (**)*
*for **moist air conditions**, 90% RH at 30 ˚C (see Table 1).*

(**) Interpolating measured values within the specified experimental range mentioned earlier creates solid lines in the graph, while dashed lines represent extrapolated values. For system conditions falling within the aforementioned experimental range, the maximum relative error for HTC_L should be regarded as ±15% within the highlighted range.

Heat transfer calculations for alternative coolants, including propylene glycol, ethylene glycol, ASHRAE R-numbers, etc., can be conducted upon request.	⚠

A complete data tables of heat transfer coefficients is presented in the ***Appendix 4.***

ORDERING GUIDE

General principles and composition

The Turning Section Assembly, as depicted in **Fig. 2.1**, provides a comprehensive overview and typical composition of the TTE-TSA. This example showcases a specific ordering option: a 1-component configuration designed for vertical orientation with downward airflow rotation from the side. It also encompasses essential elements, such as turning vanes with A-side cooling port flanges, A-side manifold connection, B-side blind flange of the turning vane, inclusion of manifold casing, bottom manifold piping connection option, as well as the presence of a bearing frame and supporting structures (legs). The ordering code for the presented example should be *TTE-TSA-VS1B1-45U-1-A1B-W....-H....-XST*.

Basing on the presented example you can configure any other TTE-TSA design. Importantly, various elements can be replicated or repositioned/duplicated within the assembly as required, as well as implemented in 2-component section types.

The following primary components are mandatory included in the TTE-TSA product:

- bearing frame, needed for structural stability and the frame supports (legs);
- side diagonal supports (TTE-TSSDS) and turning vanes (TTE-TV) mounted to these supports;

The manifold assembly (TTE-TSMFA) and manifold assembly casing are optional.

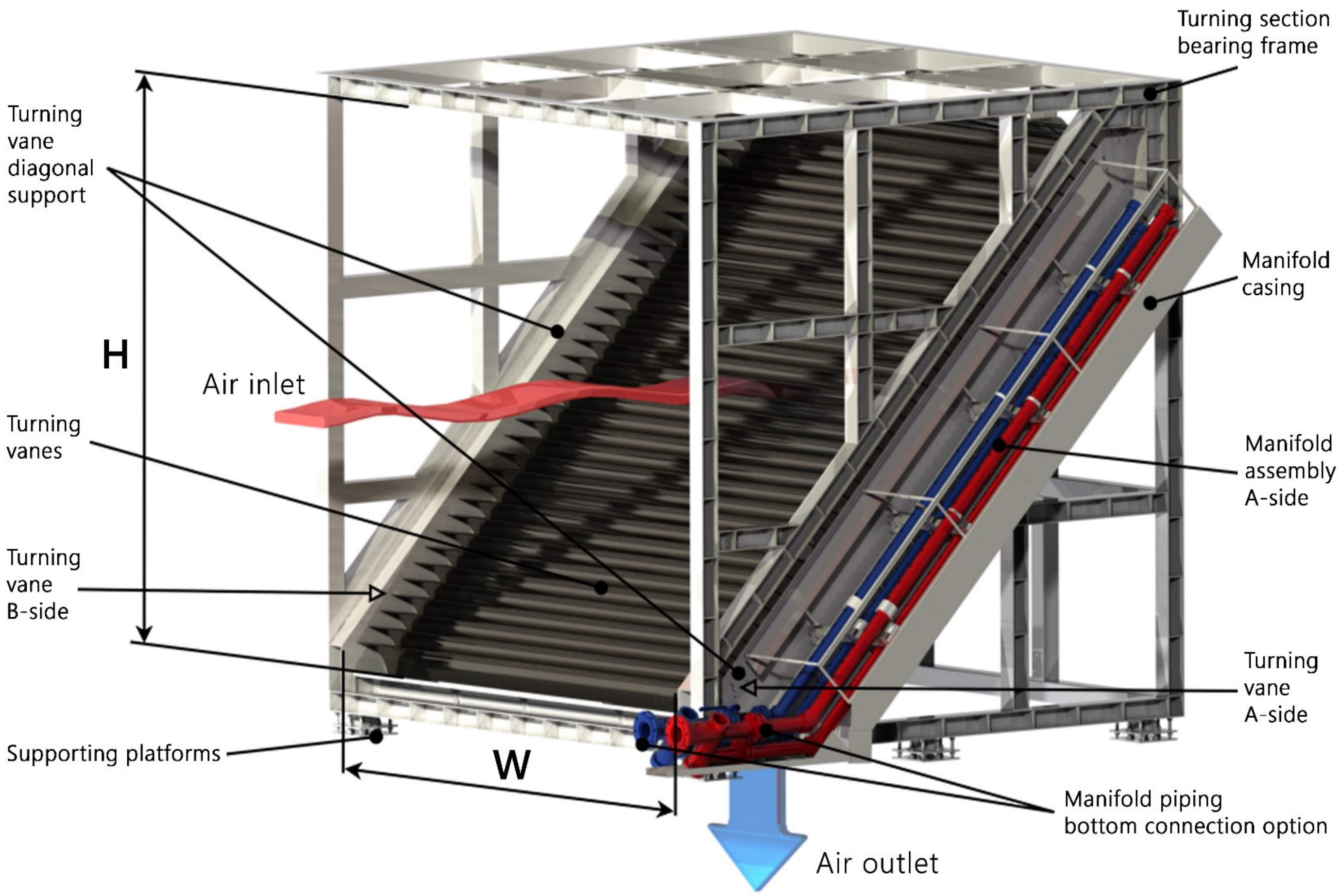


Fig. 2.1 Turning section assembly (TTE-TSA) detail description.

Ordering code information

Please select the ordering code as follows:

TTE-TSA	_ _ _ _ _	_ _ _	_	_ _ _	W _ _ _ _	H _ _ _ _	X _ _

Extended options (X _ _)

ST – standard options, doors included (if recommended)
NV – no vane door, maintenance door if possible.
NM – no maintenance door, vane door if possible
NN – no maintenance and no vane doors
CU –customization needed

Inlet cross-section height (H _ _ _ _)

in mm, measured **across** turning vanes

Inlet cross-section width (W _ _ _ _)

in mm, measured **along** turning vanes.

Manifold location and casing (_ _ _)

1st letter	A – Manifold is located at A side B – Manifold is located at B side C – Manifold is located at both sides
2nd letter	0 – no casing (RECOMMENDED) 1 – with casing
3rd letter	T – top piping connection B – bottom piping connection
All	NNN – No cooling (no manifold)

Single or split turning section (_)

1 – single component section
2 – double component section

Diagonal angle (_ _ _)

45U - Section angle 45˚, uniform flow
60E - Section angle 60˚, airflow expansion
60C - Section angle 60˚, contracting airflow

Orientation of the airflow and supporting platforms (_ _ _ _ _)

Vertical airflow rotation		Horizontal airflow rotation	
Single-loop turn:	Double-loop turn:	Single-loop turn:	Single-loop turn:
VT1S1	VB1S2	HCC	HCC
VB1S1	VS2B1	HCW	HCW
VS1T1	VT1S2		
VS1B1	VS2T1		
	VS1TB		
	VTBS1		

Orientation of the air flow and supporting platforms

TTE-TSA	_ _ _ _ _	_ _ _	_	_ _ _	W _ _ _ _	H _ _ _ _	X _ _

The orientation of the turning section is defined in relation to the ground and the direction of airflow rotation provided by the section. Each orientation option is associated with a specific part of the order code.

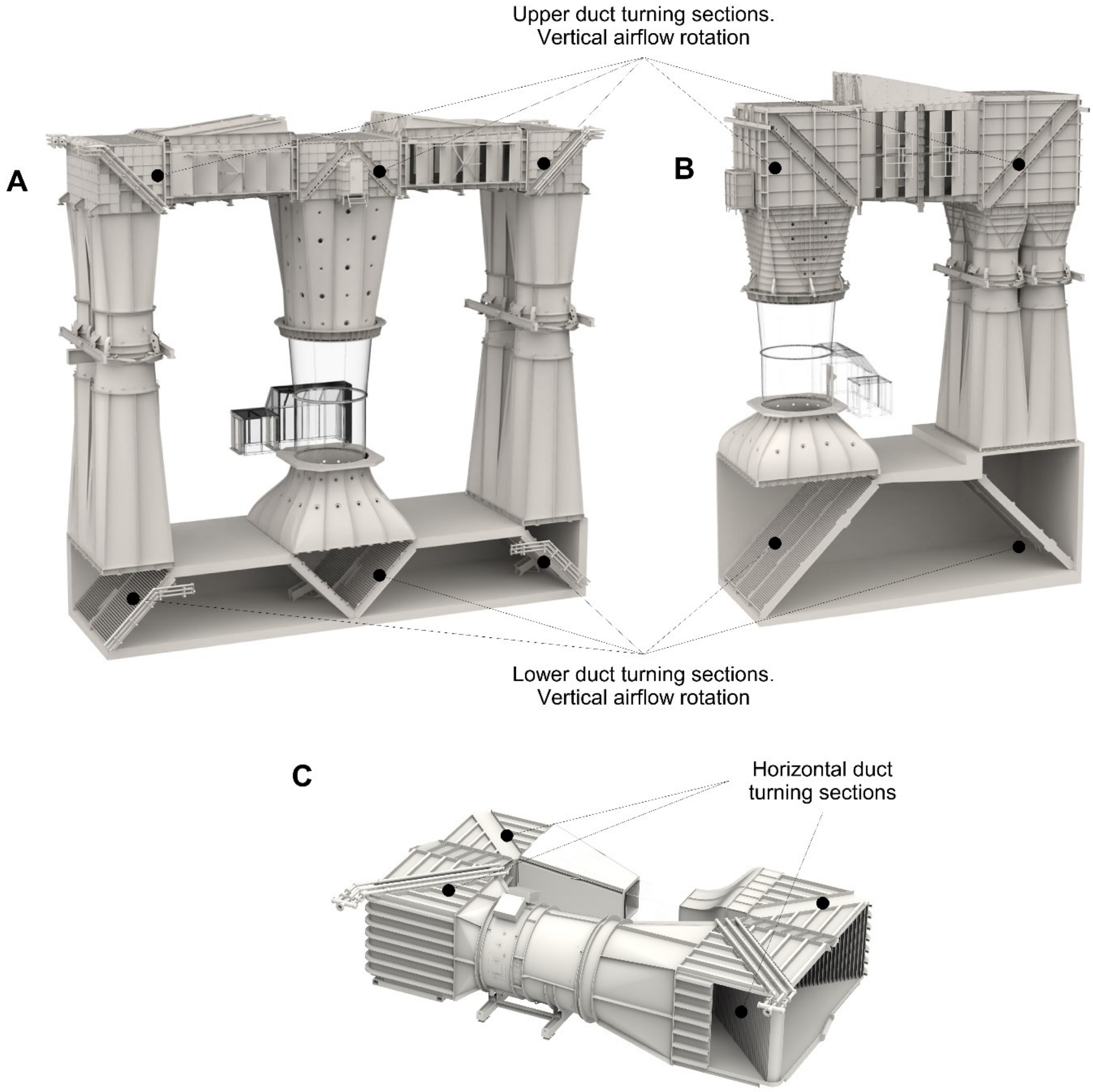


Fig. 2.2 *Closed loop wind tunnel examples:* ***A, B*** *– vertical, for indoor skydiving, TT45DL and TT52SL models.* ***C*** *– horizontal experimental wind tunnel, custom TT model.*

Table 2.1 Orientation ordering code sub-section principles.

Letter position	1	2 and 3	4 and 5	
Meaning	Air flow rotation plane	**For vertical:** Air flow inlet direction & № of duct inlet sections **For horizontal:** Air rotation & № of inlets	**For vertical:** Air flow outlet direction & № of duct outlet sections **For horizontal:** № of outlets of T-duct.	
Code letters:	V – vertical	T1 – 1 top inlet B1 – 1 bottom inlet TB – top + bottom inlet S1 – 1 side inlet S2 – 2 side inlets	T1 – 1 top outlet B1 – 1 bottom outlet TB – top + bottom outlet S1 – 1 side outlet S2 – 2 side outlets	
	H - horizontal	CW – clockwise turn CC – counterclockwise turn T1 – 1-side inlet T2 – side inlet	For T options only: 1 – one outlet *(only T21 option)* 2 – two outlets *(only T12 option)*	**Code examples**
Recommended location of the TSA in the wind tunnel	**SL and DL** (one inlet, one outlet)			
	Vertical			
Bottom corner, SL/ DL (*)	V	T1	S1	**VT1S1** (***)
Above flight chamber, SL	V	B1	S1	**VB1S1** (***)
Under flight chamber, SL	V	S1	T1	**VS1T1** (***)
Top corner, SL/DL (*)	V	S1	B1	**VS1B1** (***)
	Horizontal			
Corner, SL/DL	H	CC		**HCC**
Corner, SL/DL	H	CW		**HCW**
	DL only (two inlets or outlets)			
	Vertical			
Above flight chamber, DL (**)	V	B1	S2	**VB1S2** (***)
Custom (**)	V	T1	S2	**VT1S2**
Custom (**)	V	S1	TB	**VS1TB**
Custom (**)	V	S2	B1	**VS2B1**
Under flight chamber, DL (**)	V	S2	T1	**VS2T1** (***)
Custom (**)	V	TB	S1	**VTBS1**
	Horizontal			
After test section (**), DL	H	T1	2	**HT12**
Before test section (**), DL	H	T2	1	**HT21**

Marks in the table:

- **SL** – single loop; **DL** – double loop;
- **V** – vertical rotation, **H** – horizontal rotation; **T** – top direction; **B** – bottom direction; **S** – side direction; **CW** – clockwise rotation; **CC** – counterclockwise rotation;
- **1** & **2** – Number of duct inlets/outlets; **T12** & **T21** – T-shaped duct, where 1^{st} № – inlet, 2^{nd} № – outlet.

Recommendations:

- **(*)** – return duct option; **(**)** – central section; **(***)** – recommended for indoor skydiving.

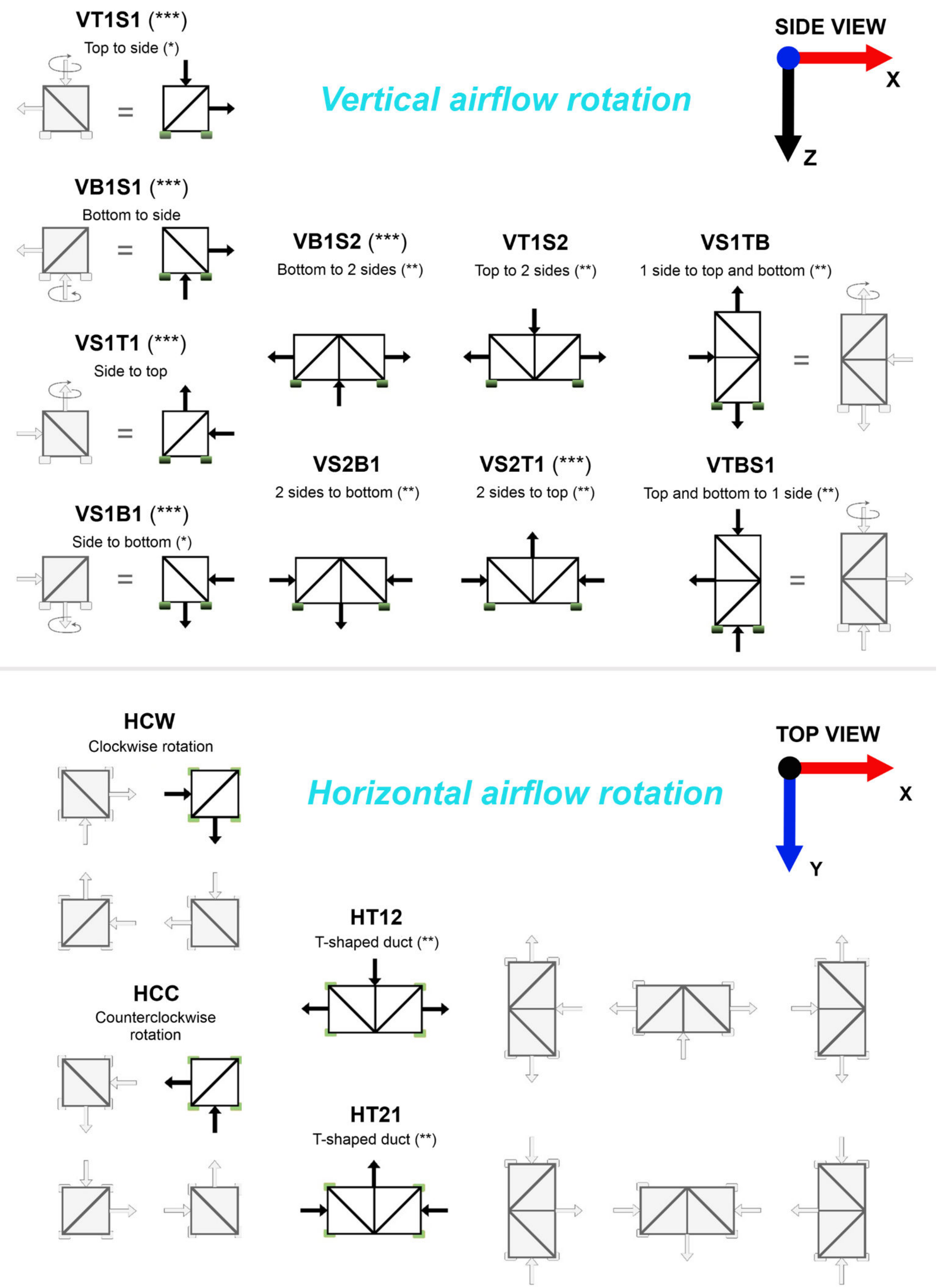


Fig. 2.3 Turning section orientation options relative to the ground and the airflow. Vertical and horizontal air rotation. Inlet and outlet airflow is shown by arrows. Identical options are indicated in grey, where the arrow marks the axis of the symmetry. Recommendations: (*) – return duct option; (**) – central section; (***) – recommended for indoor skydiving.

Diagonal angle information

TTE-TSA	_ _ _ _ _	_ _ _	_	_ _ _	W _ _ _ _	H _ _ _ _	X _ _

The airflow turning angle and diagonal angle are not the same. The airflow turning angle is always 90˚ for standard TTE-TSA products. For different airflow turning angles, please select the XCU code (custom option at the end of ordering code).

The basic angels are:

a) **45U -** for a uniform section of constant flow area (inlet cross-section = outlet cross-section) with **45˚** diagonal angle (See ***Fig. 1.1***, airduct local resistance vs. speed parameters - ***Fig. 1.2***).

b) **60E -** for a section that expands evenly by 2 times with a diagonal angle of **60˚**. The cross-section of the airflow expands after passing through the turning section (See ***Fig. 1.1***, airduct local resistance vs. speed parameters - ***Fig. 1.2***).

c) **60C** - for a section that is uniformly compressed 2 times when passing a turn. Section 60C and sections with other turning vane diagonal angles, should be discussed separately as a custom option. Airduct local resistance data for these sections can be provided upon request.

Single or split turning section configurations

TTE-TSA	_ _ _ _ _	_ _ _	_	_ _ _	W _ _ _ _	H _ _ _ _	X _ _

The central diagonal support (TTE-TSCDS) can be integrated into the 2-component (double) sections, as depicted below. If the section width exceeds a certain threshold (e.g., W > 4000 mm) and the aerodynamic force acting on the turning vanes intensifies, it is advisable to construct the section using two or more components. This method allows for reducing vane deformations and easing the load on the flange fastenings. Custom projects may request additional section components, but it is generally recommended not to exceed two if the airflow speed in the section is less than 40 m/s.

Fig. 2.4 *2-component (double) TTE-TSA, air flow rotation downwards from the side. No cooling system manifolds are mounted.*

Manifold location and casing information

TTE-TSA	_ _ _ _ _	_ _ _	_	_ _ _	W _ _ _ _	H _ _ _ _	X _ _

This parameter encompasses the positioning of the manifold or indicates its absence, includes the consideration of the manifold casing (if required), and specifies the locations for piping connections. The complete cooling construction for the turning section is detailed in ***Appendix 1: Core Technology.***

Understanding this parameter requires additional knowledge of sides A and B as defined in the technical illustration provided in ***Fig. 2.5.*** Orientation relative to airflow for both the turning vane and the turning section assembly is determined according to this illustration. When viewed from above the vane, with its leading edge aligned with the incoming airflow, side A corresponds to the left, while side B aligns with the right.

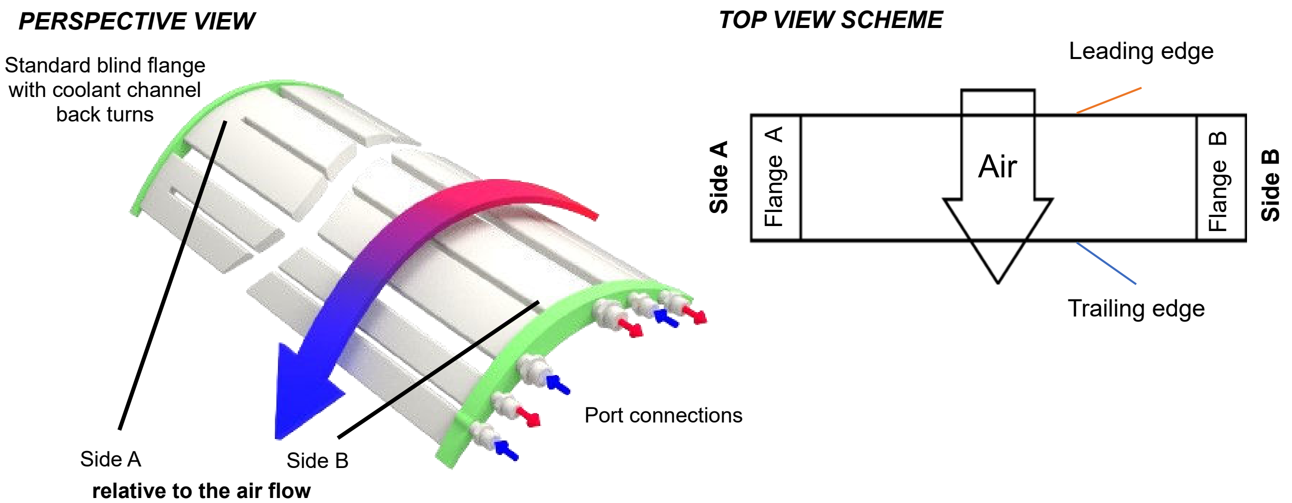


Fig. 2.5 *Air flow diagram relative to flange orientation, illustrating general principles of notation. A side for bling flange and B side for port flange are chosen as an example.*

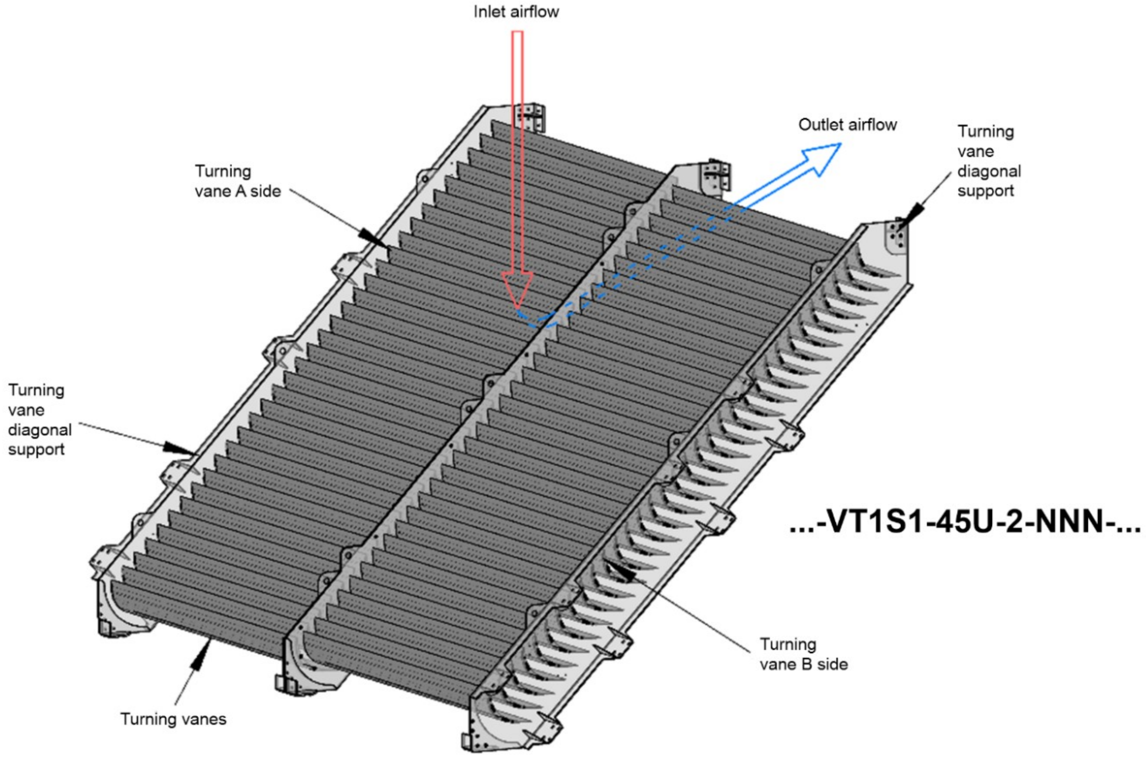
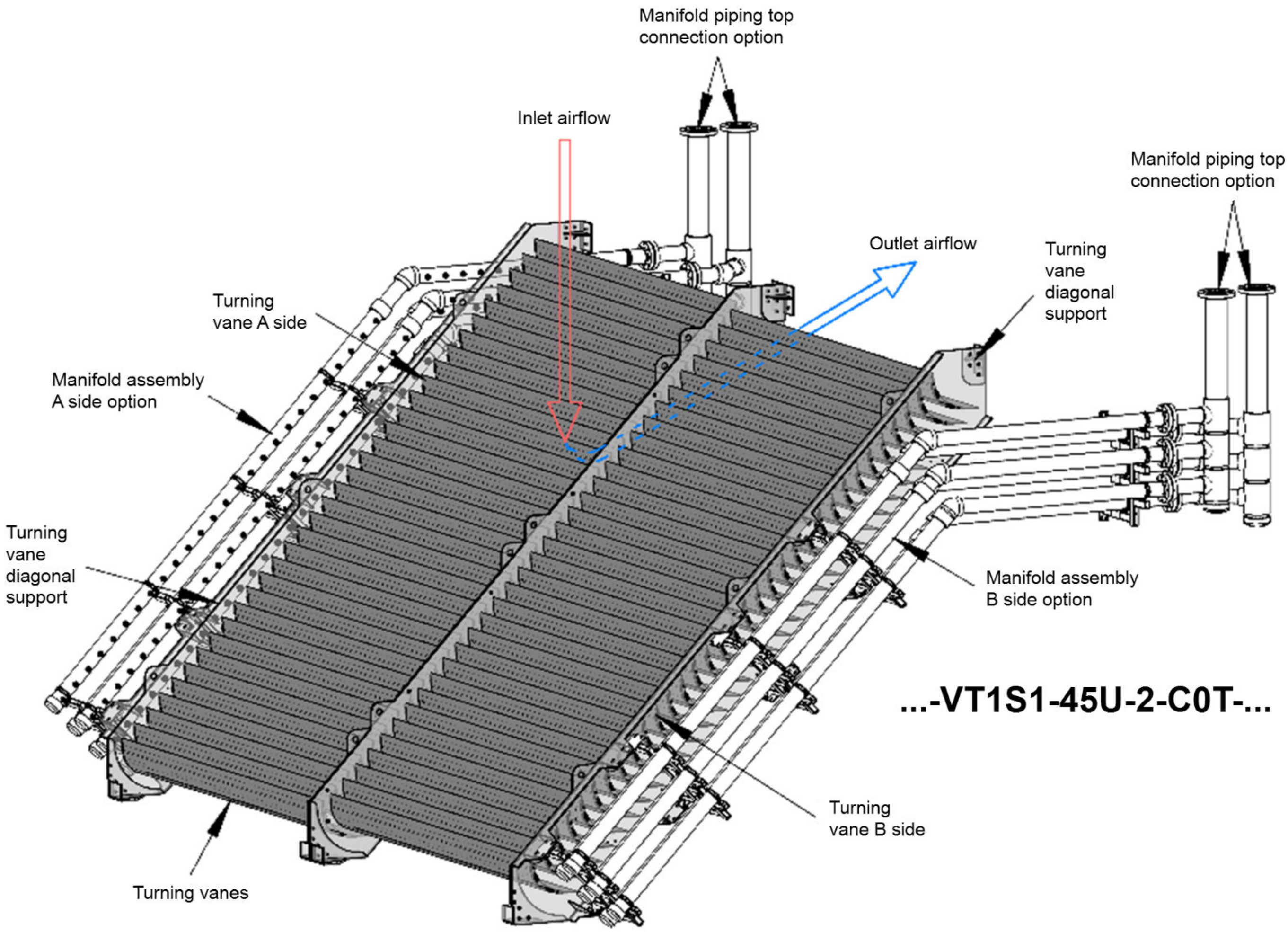


Fig. 2.6 *Split Turning Section Diagonal Assembly (TTE-TSDA) 2 - component example – without manifolds.*



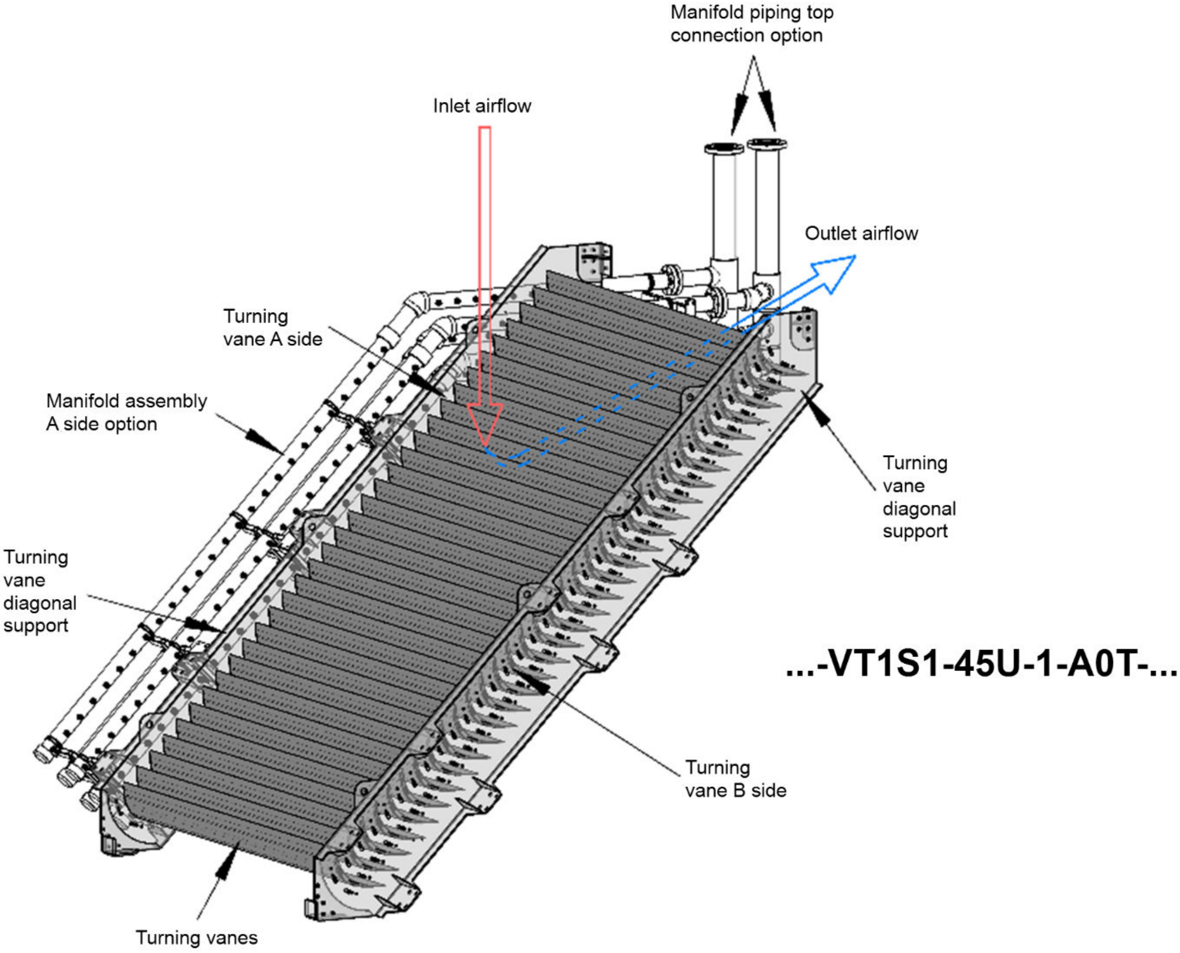
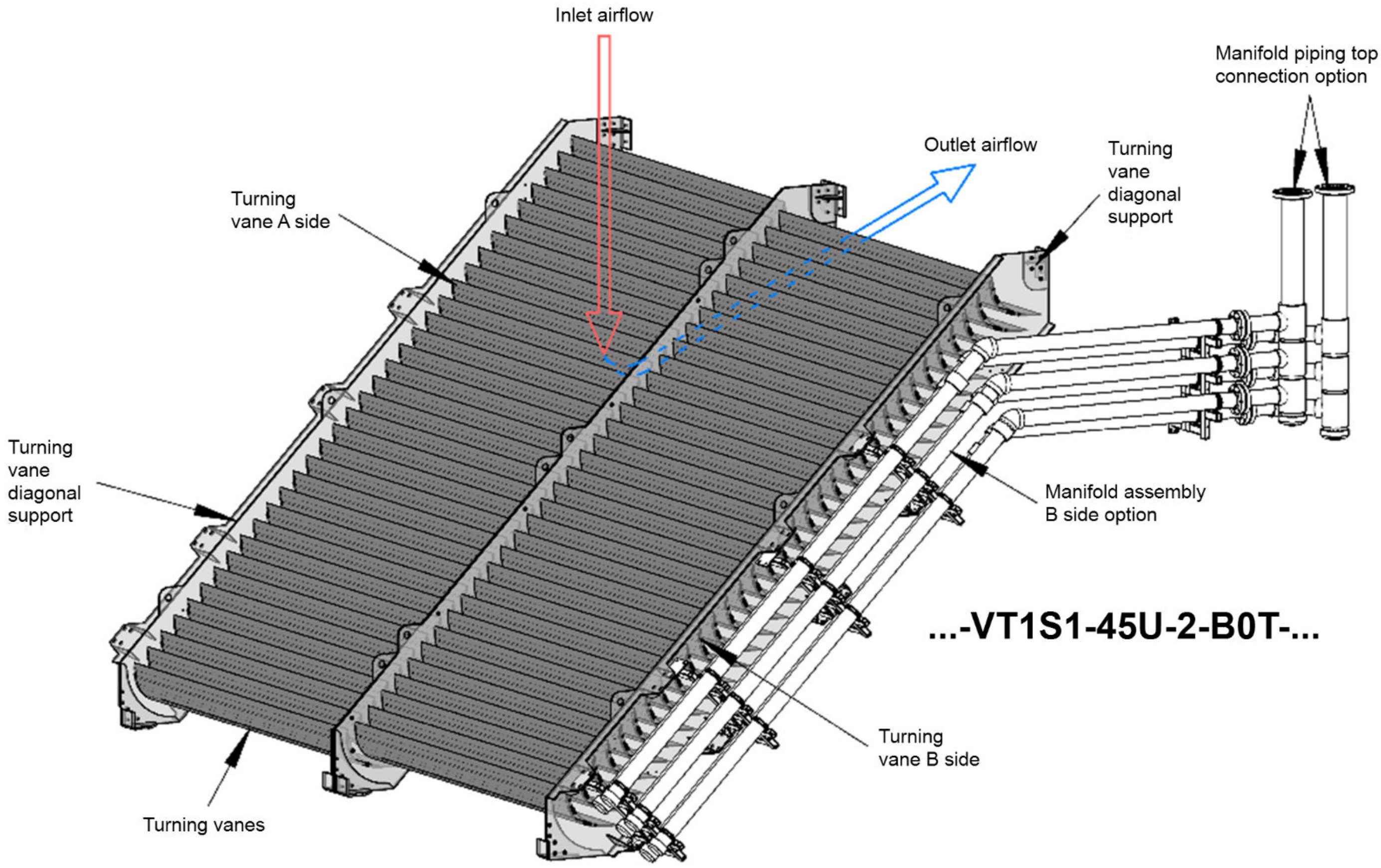
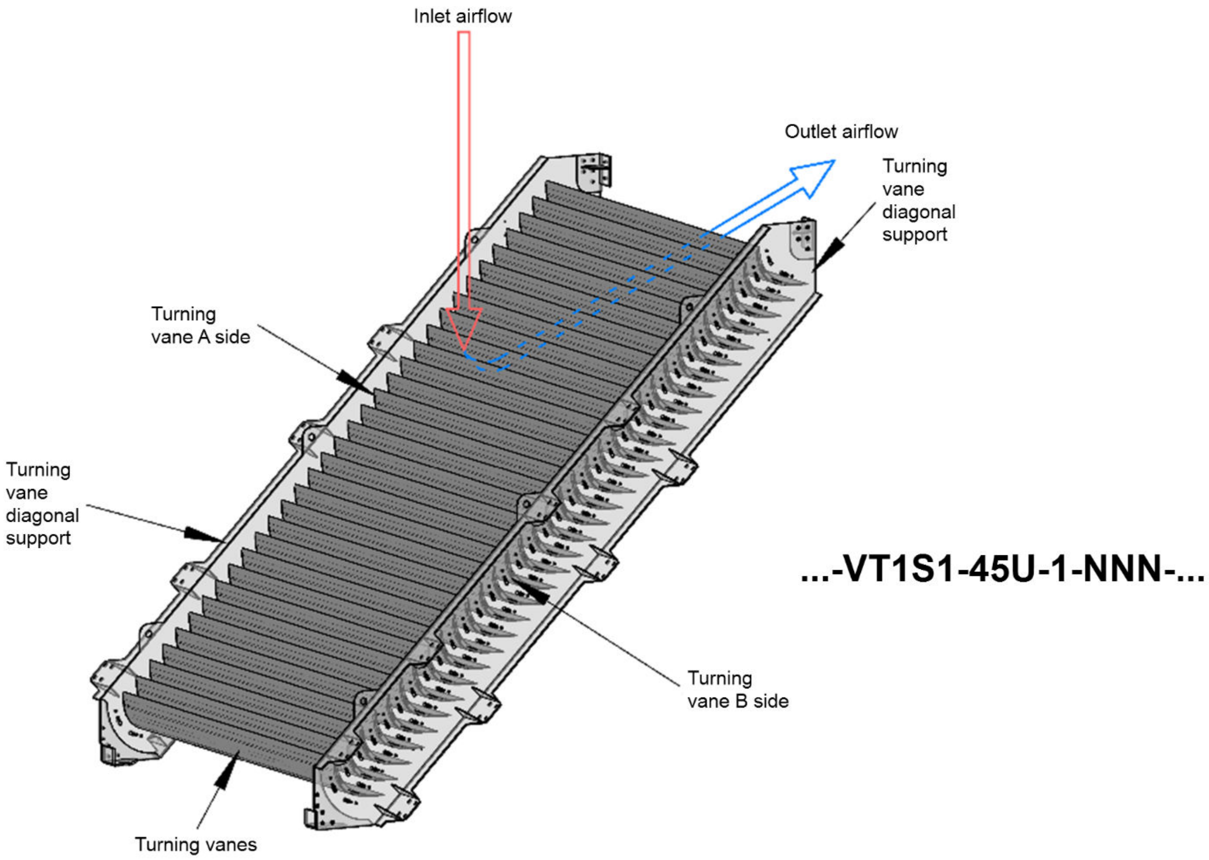


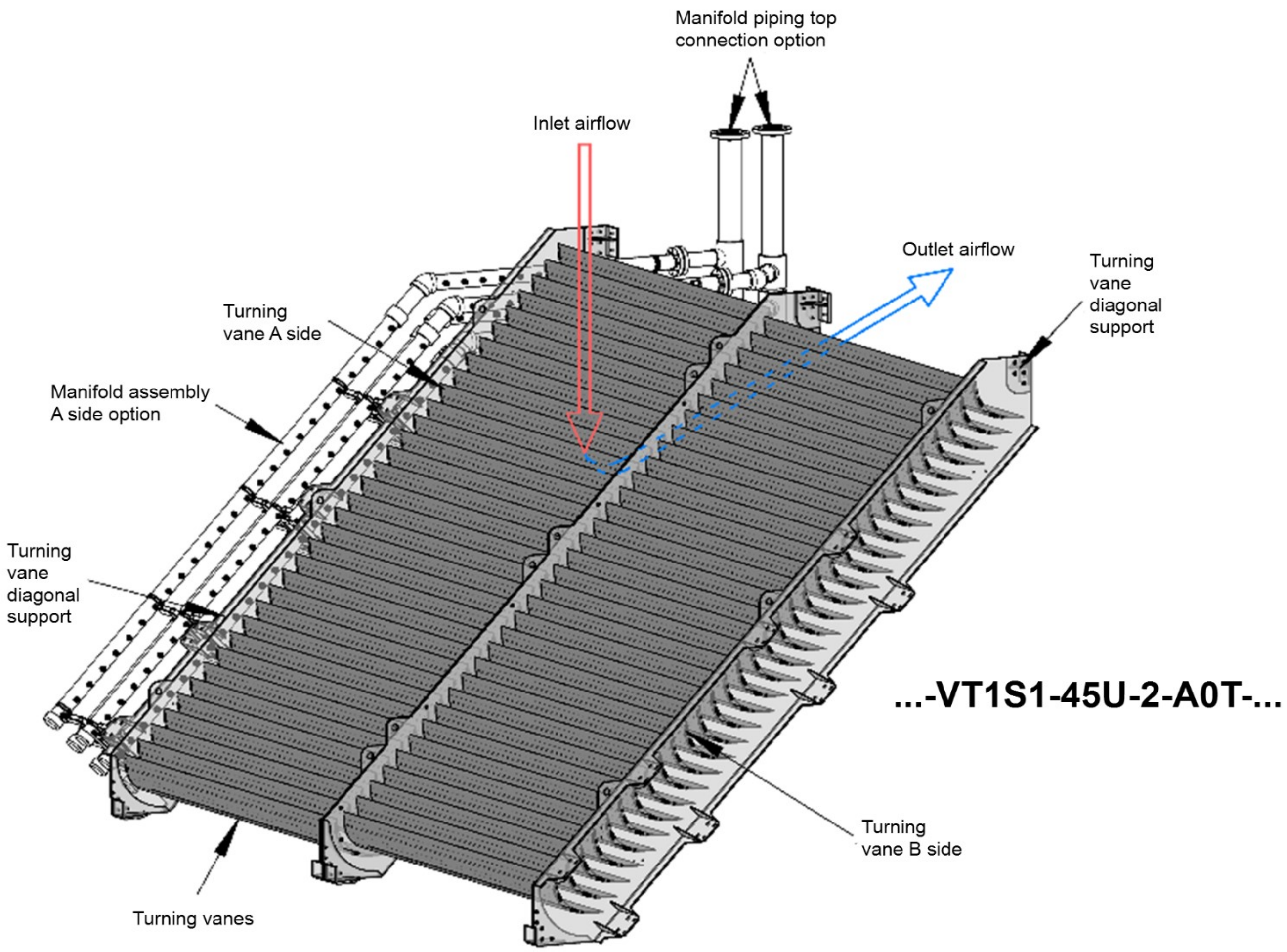
Fig. 2.7 *Turning section diagonal assembly (TTE-TSDA): 2-component example – manifolds on both sides. 1 - component example – manifold on A-side. A bottom piping connection is also possible.*





*

Fig. 2.8 *Turning section diagonal assembly (TTE-TSDA): 2-component example – manifold on B-side. 1 - component example – without manifolds. A bottom piping connection is also possible.*



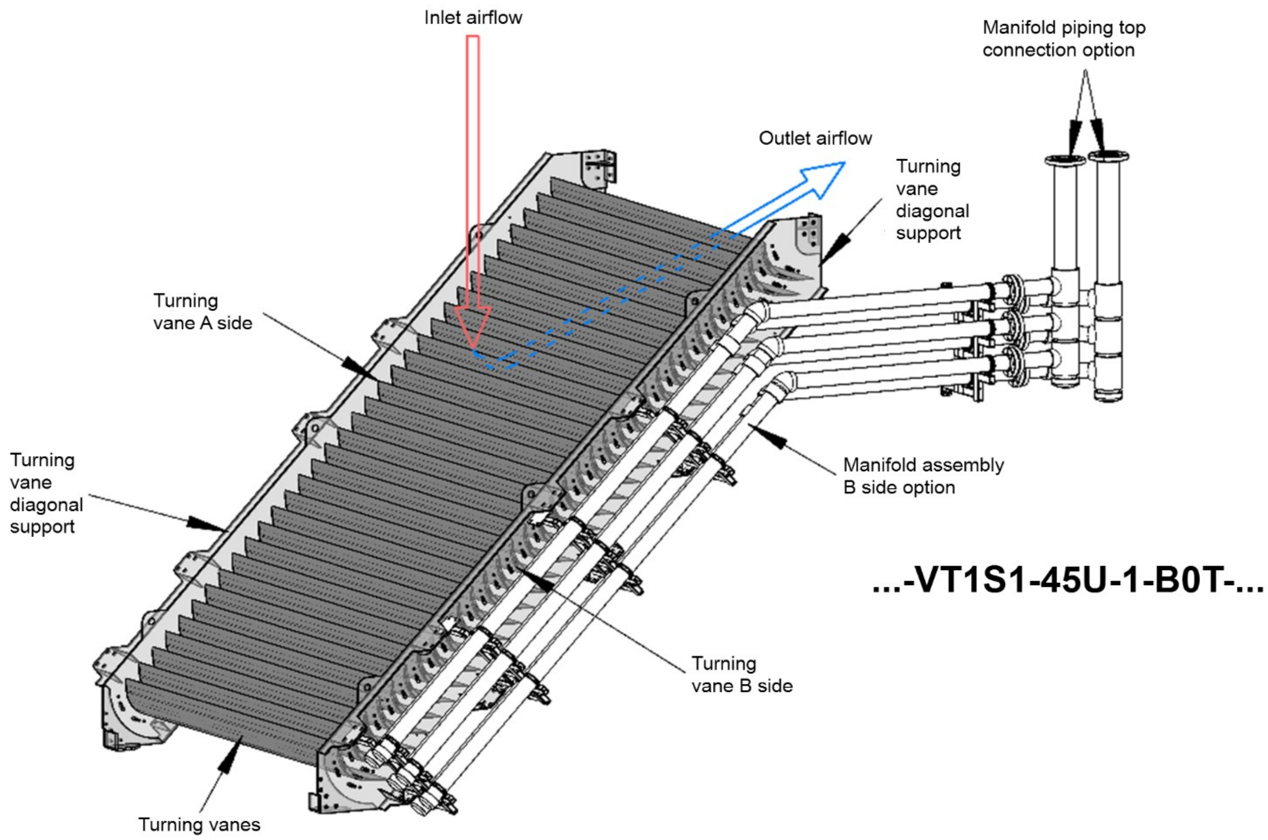


Fig. 2.9 *Turning section diagonal assembly (TTE-TSDA): 2-component example – manifold on A-side. 1 - component example – manifold on B-side. All examples have manifold top piping connection option. A bottom piping connection is also possible.*

Fig. 2.10 *Cooled turning vane manifolds and flexible hoses. Tunnel Tech PF45DL wind tunnel example. No casing. Top piping connection option.*

Inlet cross-section dimensions information

TTE-TSA	_____	___	_	___	W____	H____	X__

Dimensions H (height) and W (width) can be set by the customer on demand. For H and W of the 2-component sections, use the total length and width of the duct, including both components.

Example: *....2-A1B-W6000-H3000-.... this implies that the cross-section of the duct connected to the TTE-TSA assembly measures 3x6 meters, and the TTE-TSA assembly comprises two components, each measuring 3x3 meters. However, these components together form a combined 3x6 meters inlet.*

Extended options (custom projects)

TTE-TSA	_____	___	_	___	W____	H____	X__

In addition to the standard options (**XST**, XNV, XNM, XNN), we also offer custom projects. For custom orders, please use **XCU** in the code end position. Discussions should precede the ordering process, and additional agreements must be made for all custom parameters.

Orientations for custom air ducts with standard air turning options (90˚ horizontal / vertical turning) can be selected using the same principles as described in ***Orientation of the air flow and supporting platforms.***

Additional examples of custom options:

- Technical and maintenance doors (see example in ***Fig. 2.12***);
- Circle air duct cross-section (***Fig. 2.11***);
- ISO container integrated turning sections;
- Air turning with flow axis rotation;
- Non 90˚ airflow turning angle.

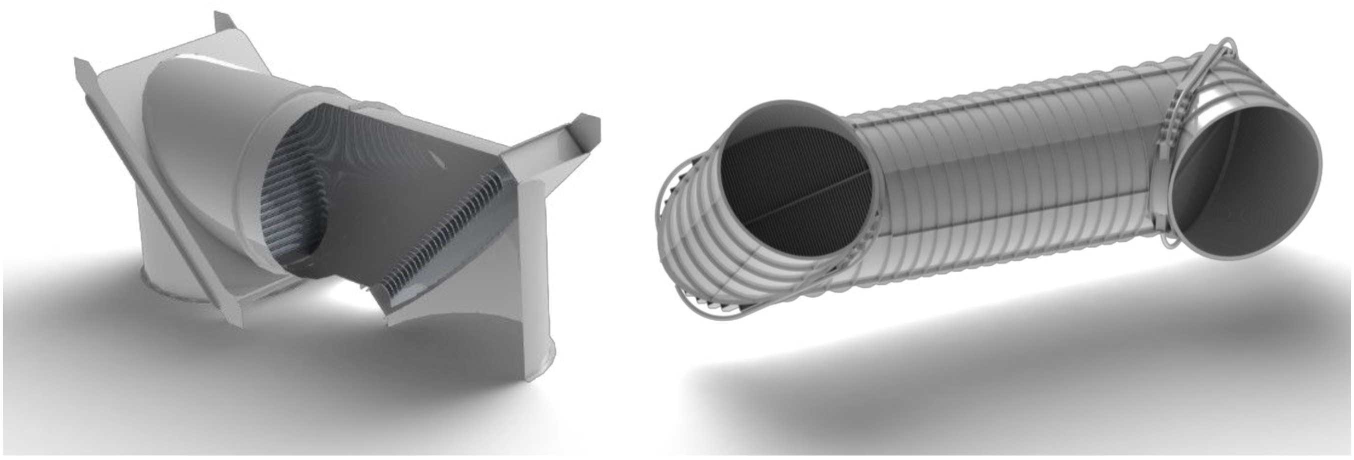


Fig. 2.11 *Custom turning section assembly examples.*
Left - Circle-shaped fiberglass duct. Right – non-planar turning.

Fig. 2.12 *Turning section doors: top - vane door,. bottom – maintenance door.*

APPENDIX 1. CORE TECHNOLOGY

Turning vane information

A detailed illustration of the turning vane assembly is shown in ***Fig. A.1.1*** below. Additional views given further.

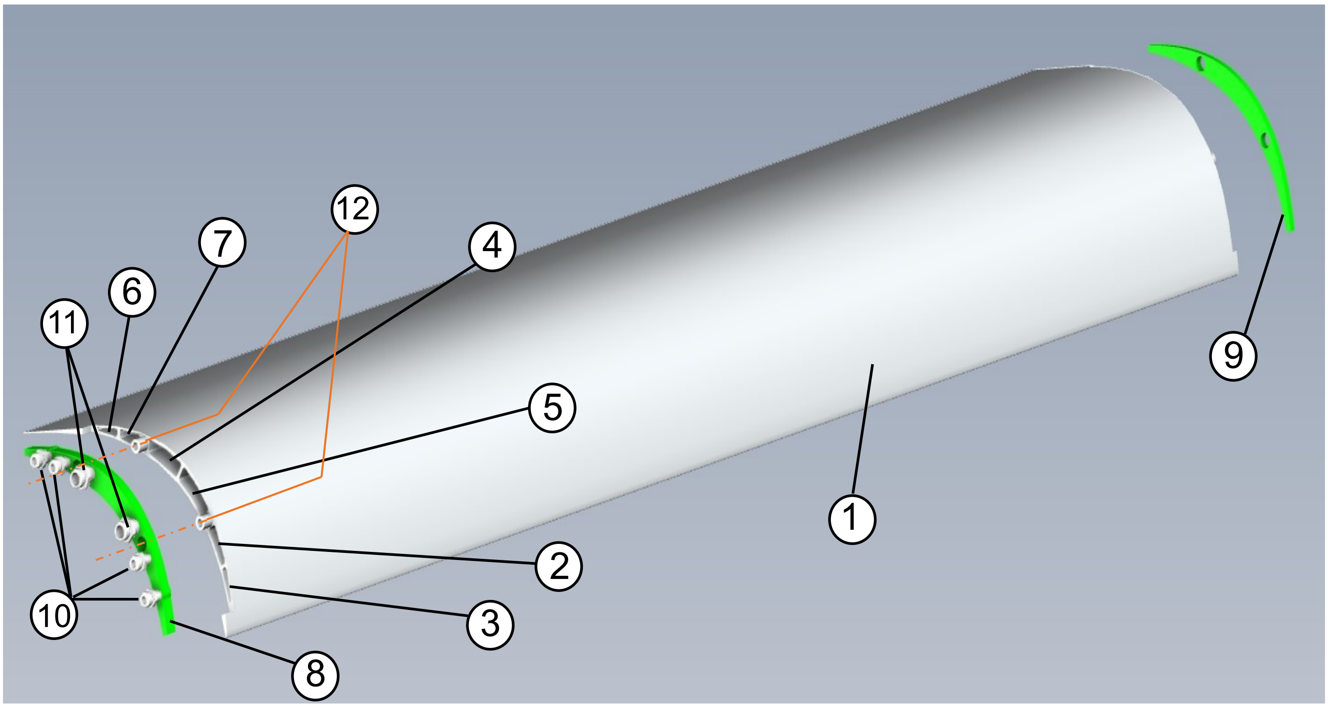


Fig. A.1.1 *TTE-TV Turning vane general view and components.*

TTE-TV turning vanes consist of the following components:

(1) Anodized aluminum body, 6063-T6 alloy.

(2) Leading edge cooling channel – inlet half-channel (Channel 3 inlet).

(3) Leading edge cooling channel - outlet half-channel (Channel 3 outlet).

(4) Central cooling channel - inlet half-channel (Channel 2 inlet).

(5) Central cooling channel - outlet half-channel (Channel 2 outlet).

(6) Trailing edge cooling channel - inlet half-channel (Channel 1 inlet).

(7) Trailing edge cooling channel - outlet half-channel (Channel 1 outlet).

(8) Flange with channel ports.

(9) Blind flange.

(10) Coolant inlet/outlet ports for channels 1 and 3.

(11) Coolant inlet/outlet ports for channel 2.

(12) Vane mounting holes, M12.

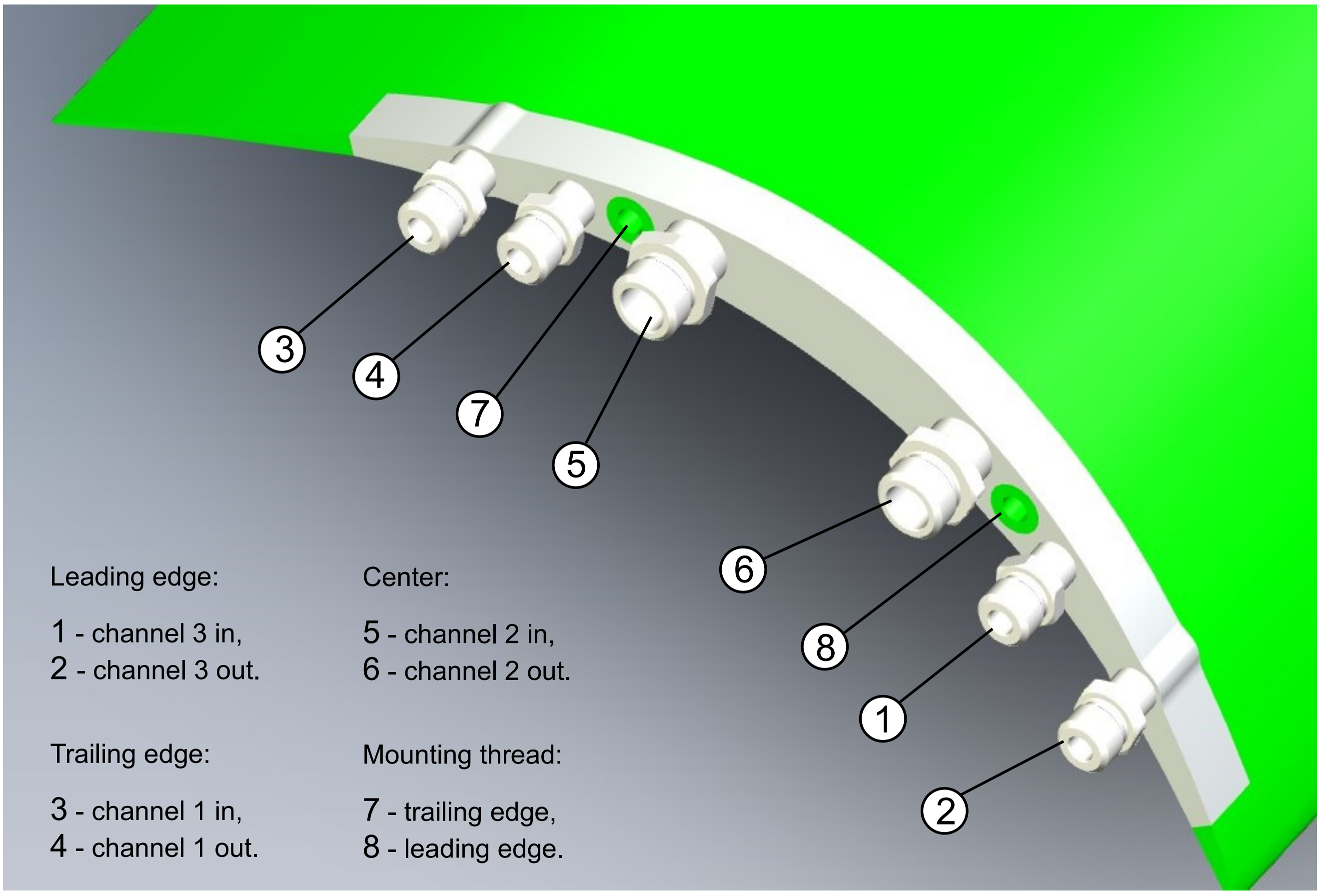


Fig. A.1.2 *Components of the turning vane include channel input and output ports, as well as mounting holes.*

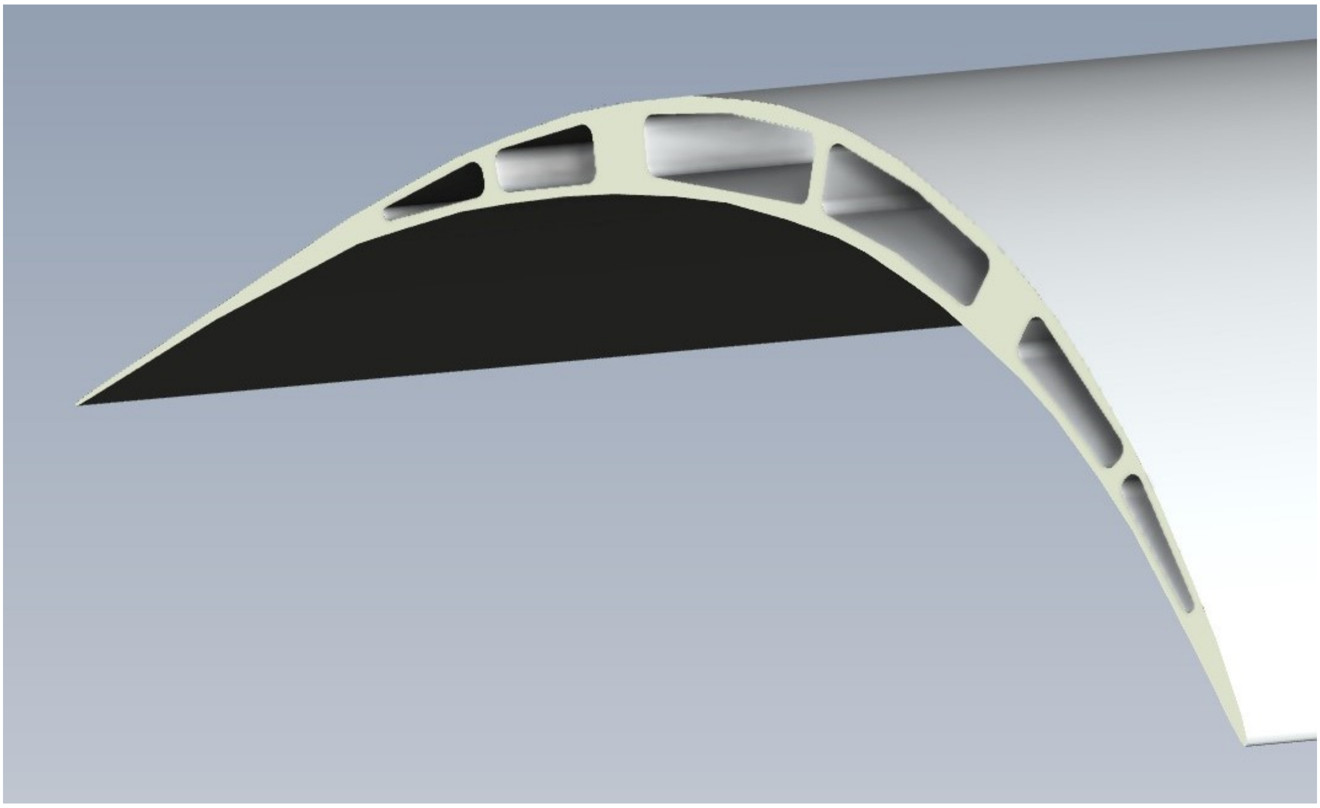


Fig. A.1.3 *Turning vane cooling channels. Cross-section.*

Fig. A.1.4 The illustration showcasing the method of attaching the vanes (TTE-TV) to the diagonal metal plates – the diagonal supports of the turning section (TTE-TSCDS and TTE-TSSDS).

Fig. A.1.5 Turning vanes (TTE-TV) installed in the turning vane diagonal assembly (TTE-TSDA). A-side diagonal support has not yet been mounted during the wind tunnel construction process.

Active cooling systems

This section presents air flow schemes, refrigerant flow, as well as hydraulic piping and connection diagrams.

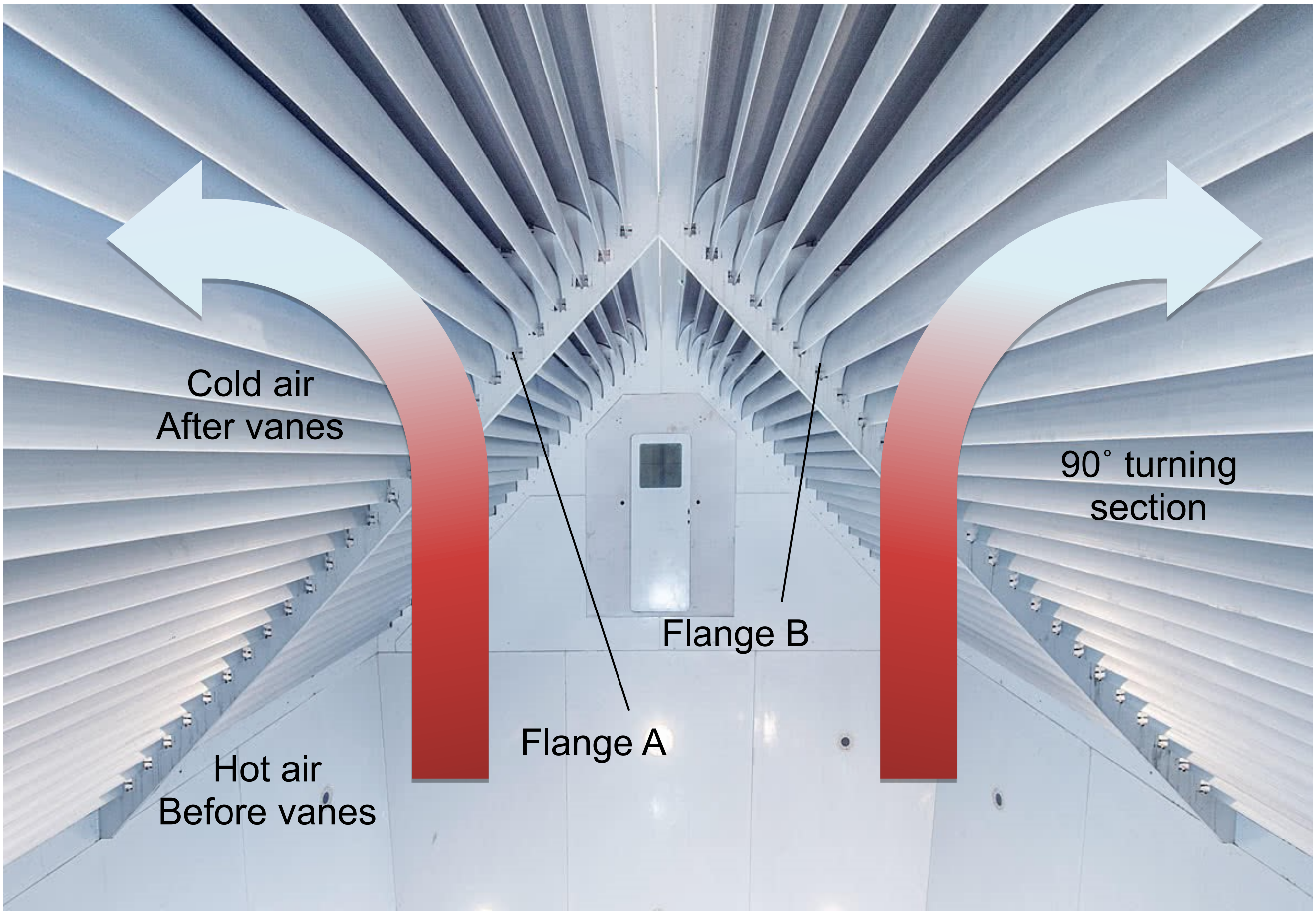


Fig. A.1.6 *Flow scheme - real example (Tunnel Tech, PF45DL).*

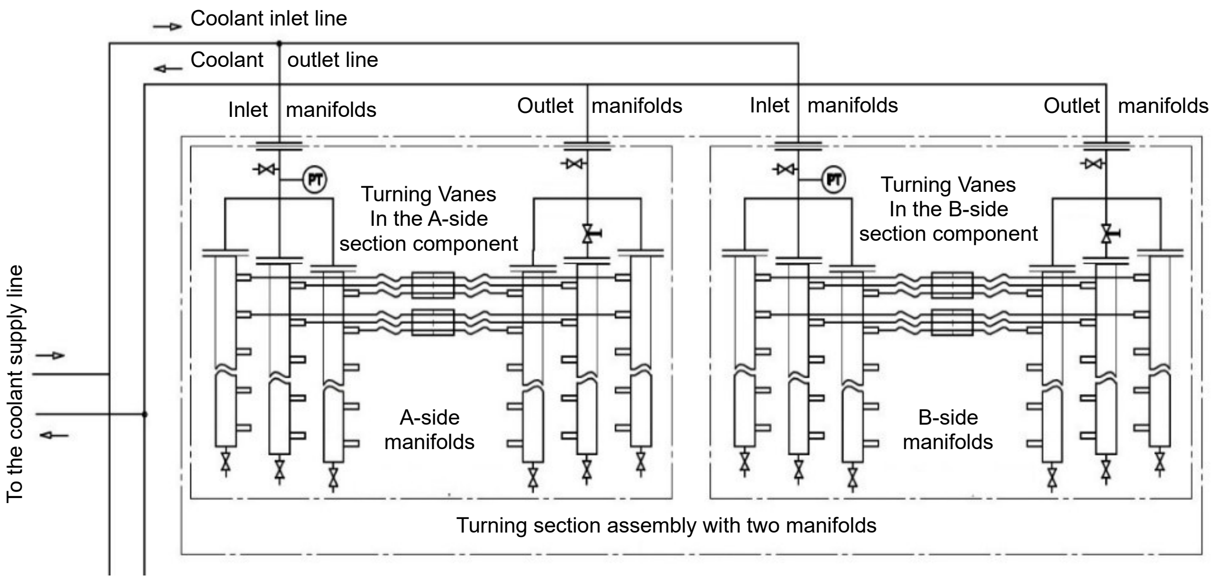


Fig. A.1.7 *The diagram illustrates the manifold piping for a cooled turning vane in a 2-component turning section. The example depicts only two vanes in each section component, and the schematic presentation showcases the piping from the manifold to the vane port flange.*

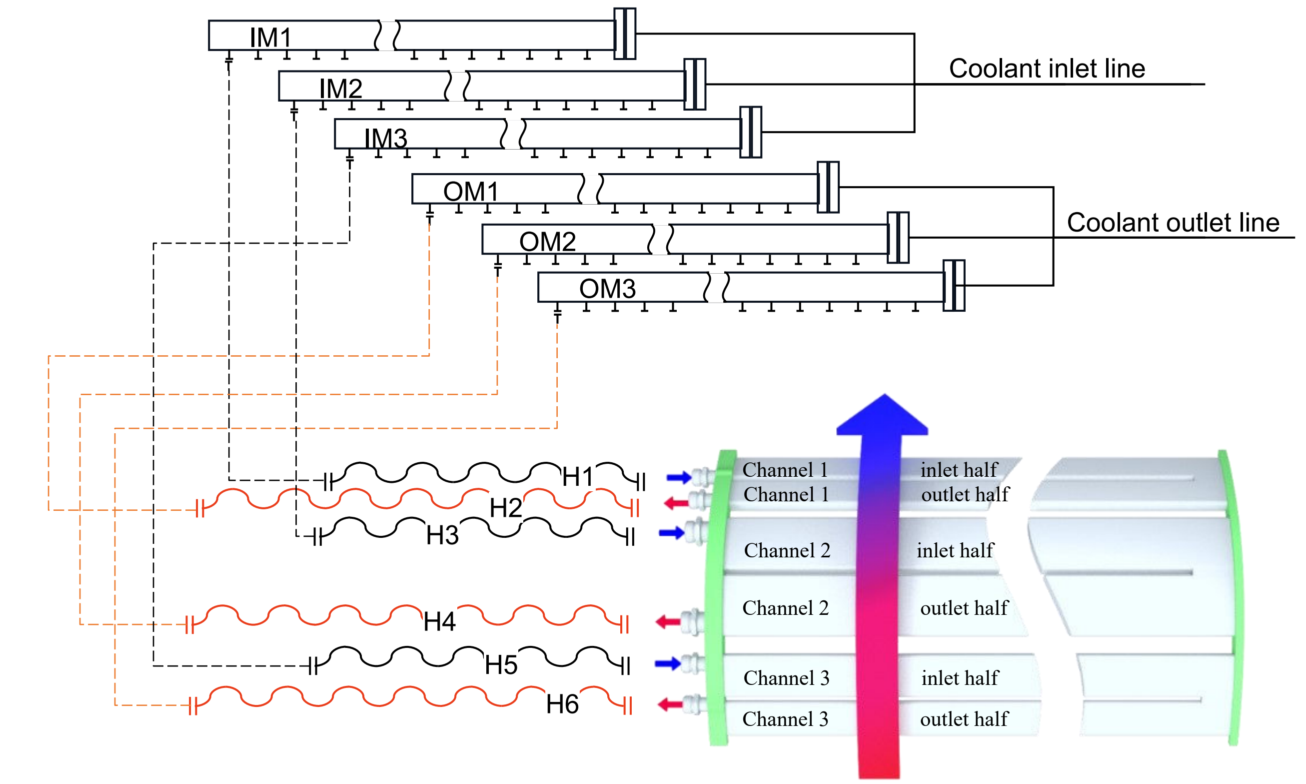


Fig. A.1.8 *Connections between the cooled turning vane and the manifold, along with internal coolant channels, are illustrated. The example features a standard port flange on the B side and a blind flange on the A side; **IM** denotes the connection to the inlet manifold, **OM** to the outlet manifold, and **H** signifies the connection flexible hoses.*

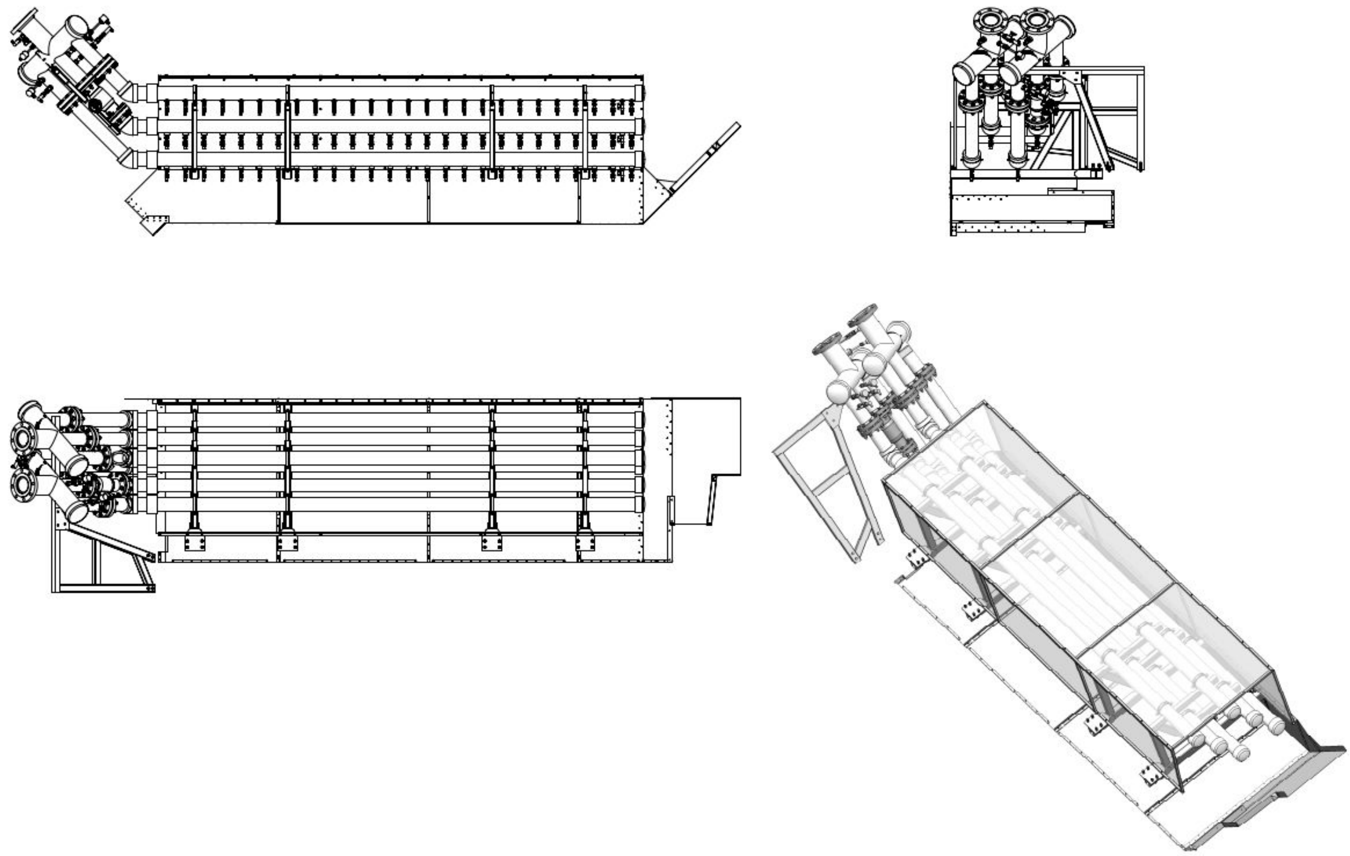


Fig. A.1.9 *Turning vane manifold assembly – example drawing.*

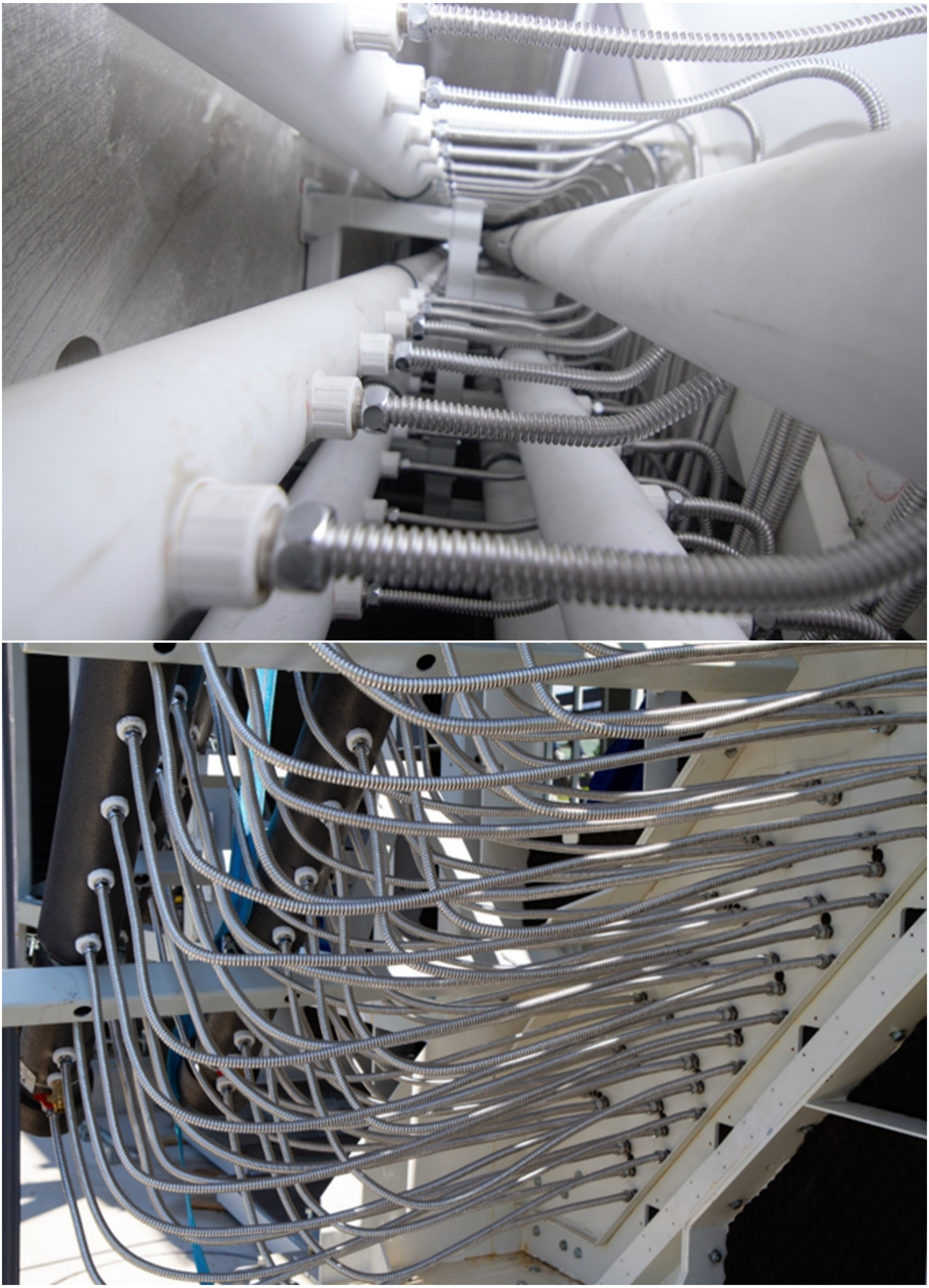


Fig. A.1.10 Custom manifolds.

APPENDIX 2. AIRDUCT LOCAL RESISTANCE DATA

Table A.2.1. 45˚ diagonal – Airduct local resistance vs. air speed at standard spacing.

dP = f(v), 45U code option		
Air speed (m/s)	dP (Pa)	ξ
1	0.06	0.0967
2	0.17	0.0674
3	0.31	0.0562
5	0.74	0.0483
8	1.80	0.0458
10	2.76	0.0451
20	10.57	0.0431
40	38.03	0.0388
60	77.77	0.0353
80	134.23	0.0342
100	191.56	0.0313

Table A.2.2. 60˚ diagonal (expansion) - Airduct local resistance vs. air speed at standard spacing.

dP = f(v), 60E code option		
Air speed (m/s)	dP (Pa)	ξ
1	0.09	0.1439
2	0.23	0.0933
3	0.40	0.0729
5	0.85	0.0557
8	1.79	0.0455
10	2.56	0.0417
20	8.20	0.0335
40	28.69	0.0293
60	62.32	0.0283
80	108.18	0.0276
100	164.38	0.0268

APPENDIX 3. HYDRAULIC DATA

Table A.3.1 Water flow rate Q vs pressure drop ΔP_{water} (kPa) between inlet and outlet vane ports.

Q (m³/h) v.s. ΔP_{WATER} (kPa)
Summary water flow rate through all three vane channels v.s. water pressure drop between the inlet and outlet ports for different the turning vane lengths. (*)
Standard piping scheme.

ΔP_WATER (kPa) Turning vane inlet-outlet pressure difference	**L (meter)** Turning vane length →	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**
	0.5	0.779	0.763	0.757	0.750	0.743	0.727	0.723	0.715	0.717
	1	1.123	1.113	1.095	1.087	1.080	1.062	1.056	1.047	1.030
	2	1.580	1.557	1.548	1.540	1.522	1.513	1.505	1.487	1.478
	3	1.932	1.916	1.896	1.886	1.866	1.856	1.847	1.827	1.817
	5	2.493	2.474	2.452	2.429	2.418	2.396	2.385	2.363	2.352
	8	3.154	3.119	3.095	3.081	3.057	3.043	3.019	2.995	2.982
	10	3.521	3.494	3.467	3.441	3.415	3.400	3.374	3.359	3.334
	12	3.858	3.819	3.802	3.774	3.747	3.720	3.704	3.677	3.652
	15	4.312	4.271	4.241	4.222	4.193	4.164	4.136	4.108	4.090
	18	4.719	4.686	4.644	4.625	4.596	4.563	4.533	4.503	4.474
	20	4.980	4.934	4.902	4.869	4.840	4.807	4.770	4.744	4.724
	25	5.563	5.514	5.479	5.446	5.411	5.376	5.341	5.307	5.274
	30	6.099	6.030	6.000	5.952	5.927	5.881	5.845	5.810	5.770
	35	6.581	6.526	6.475	6.433	6.398	6.349	6.302	6.269	6.227
	40	7.026	6.975	6.925	6.871	6.828	6.780	6.747	6.701	6.658
	50	7.866	7.783	7.736	7.683	7.631	7.579	7.527	7.483	7.447
	80	9.950	9.842	9.790	9.714	9.660	9.580	9.509	9.446	9.395
	100	11.084	11.017	10.941	10.861	10.807	10.701	10.624	10.556	10.489
	120	12.145	12.055	11.978	11.889	11.824	11.725	11.630	11.555	11.503
	150	13.573	13.488	13.402	13.295	13.215	13.106	13.025	12.921	12.843
	180	14.872	14.785	14.687	14.558	14.486	14.360	14.236	14.135	14.060
	200	15.681	15.576	15.471	15.338	15.264	15.130	14.999	14.907	14.795

(*) Standard deviation: ΔQ = ±10%. The dependence of Q on P and L is given only for the vane channels, port connectors and 500mm flexible hose start / end pipe spacer for correct flow profile considerations. Pressure drops for longer flexible hoses or other custom connectors are subject to additional research and should be extracted from the customer's manifold pressure difference to get the ΔP values, provided in the Table.

APPENDIX 4. HEAT TRANSFER COEFFICIENT DATA

Table A.4.1 – A. Heat transfer coefficient HTC_L vs air speed (m/s) and ΔPwater (kPa) (*) for **dry air conditions (0% RH at 30 ˚C)**. Cooling water temperature: 8 ˚C. See also Table 1 for details. The values are CFD-calculated.

HTC_L	ΔP_{WATER} (kPa)									
Air speed (m/s)	1	2	3	5	8	10	12	15	18	20
1	8.0	7.9	7.9	8.1	7.9	7.9	7.9	7.9	8.2	7.9
2	12.8	12.7	12.8	12.8	12.8	12.8	12.8	12.8	13.1	12.8
3	16.9	17.1	17.0	16.9	16.9	17.0	17.0	17.0	17.8	17.0
5	23.8	24.1	24.0	24.1	24.2	24.2	24.2	24.3	24.4	24.3
8	33	33	33	33	34	34	34	34	34	34
10	38	39	39	39	40	40	40	40	40	40
20	61	62	62	63	63	64	64	64	64	64
40	97	99	100	102	103	102	104	104	105	105
60	131	134	135	138	140	141	141	142	143	143
80	168	172	174	177	180	181	182	184	184	185
100	215	219	224	225	228	230	231	233	234	235

(*) A maximum absolute error of 9% can be applied to calculate the corresponding values in the temperature range of air flow from 18 to 36 ˚C and cooling water from 8 to 12 ˚C (in any combination).

Table A.4.1 – B. Heat transfer coefficient HTC_L vs air speed (m/s) and ΔPwater (kPa) (**) for **moist air conditions (90% RH at 30˚C)**. Experimental inlet cooling water temperature range: 8 … 10 ˚C. See also Table 1 for details.

HTC_L	ΔP_{WATER} (kPa)											
Air speed (m/s)	1	2	3	5	8	10	12	15	18	20	25	30
1	56	65	72	82	94	101	107	113	123	128	139	149
2	64	73	80	90	103	110	116	122	133	138	149	159
3	68	77	84	95	108	115	121	127	138	143	154	165
5	73	83	90	101	114	121	128	134	145	150	161	172
8	78	88	95	107	120	127	134	140	151	156	168	178
10	80	91	98	110	123	130	137	143	154	159	171	181
20	87	98	106	118	131	139	146	152	163	168	180	191
40	94	106	114	126	140	148	155	161	172	178	190	201
60	99	110	118	131	145	153	160	166	178	183	195	206
80	102	113	122	134	149	156	164	170	182	187	199	210
100	104	116	124	137	151	159	166	173	185	190	202	213

(**) Highlighted values in ***Table A.4.1 - B*** are derived through interpolation of directly measured values within the specified experimental range, as outlined in the Table 1. The moist air values left blank are extrapolated. For system conditions falling within the experimental range described above, the maximum relative HTC_L error should be acknowledged as ±15% of the highlighted range. Extrapolated data should be treated with caution, as it is impossible to assess the difference with the experiment, and should be checked for each specific use case.

APPENDIX 5. RELATED PRODUCT TYPES

Tunnel Tech products related to the turning vanes can be divided into the following types, according to ***Table A.5.1.*** Each type has its own product group code.

Table A.5.1. Turning section related product types.

Product	Product type	Part type / Material	Available for separate purchase	Datasheet / section
Turning section assembly	**TTE-TSA**	Assembly	Y	**TTE-TSA-datasheet** (This document) **ORDERING GUIDE**
Turning vanes	**TTE-TV**	Part / 6063-T6 aluminum alloy	YC	Use ordering code as described in **Appendix 6**
Turning section diagonal assembly	**TTE-TSDA**	Assembly	Y	Use ordering code as described in **Appendix 7**
Side diagonal support of the turning section	**TTE-TSSDS**	Part / Carbon steel	C	Custom order
Central diagonal turning vane support of the turning section	**TTE-TSCDS**	Part / Carbon steel	C	Custom order
Turning vane flange	**TTE-TVF**	Part / 6063-T6 aluminum alloy	N *	Available only as a part of a turning vane
Flexible hoses	**TTE-FXH**	Part / Stainless steel 304 – 321	C *	Custom order
Manifold assembly of the Turning section	**TTE-TSMFA**	Assembly	C *	Custom order
Turning section door	**TTE-TSDDD**	Assembly as an option	N *	Available only as an option for TTE-TSDA or TTE-TSA

Y – Order is possible by ordering code from the corresponding datasheet section.
YT –Terms of the contract need to be agreed upon. Ordering is possible, but MOQ requirements are applied.
N – Separate ordering is not possible.
C – Please contact us for custom order details. Ordering codes are not available.
(*) N and C options marked with * will be available for purchase as spare parts for Tunnel Tech clients on contracts.

APPENDIX 6. TURNING VANE ORDERING INFORMATION

Turning vanes (TTE-TV) can be ordered as a separate product.

Select flange location according to the information, described in TTE-TSA ORDERING GUIDE chapter, Manifold location and casing information paragraph.

Please use the following notation:

TTE-TV	0 9 0	_ _	L _ _ _ _ _

Turning vane length
in mm, measured **along** turning vane between flange mounting surfaces.

Flange location

1st and 2nd letters	**Standard options:** FA – Port flange at the A side, blind flange at the B-side FB – Port flange at the B side, blind flange at the A-side *NN – no flanges,* not cooled vane.
	Custom options: XX – Both flanges are blind, not cooled vane (it is recommended to use NN instead). PP – both flanges are port-flanges *(custom option, no hydraulic data available)*

Airflow turning angle

090 – standard (recommended)

Nonstandard options are possible on request and need to be agreed before order placement.
Please, change here only if clearly understand why you need other angles.
080 – 179 – custom angle
180 – for symmetrical airfoil shape heat exchanger.

The heat transfer, airduct local resistance and hydraulic parameters mentioned in this Datasheet, are given only for TTE-TV-090 standard product option. Parameters of nonstandard turning vanes are subject for research upon request. If you do not intend to evaluate all the parameters of your turning section equipment yourself, **please order standard TTE-TSA** products instead.	⚠

APPENDIX 7. TURNING SECTION DIAGONAL (TSDA, NO FRAME) ORDERING INFORMATION

The TTE-TSDA product does not have bearing frame. But diagonal support plate is not symmetrical, and manifold can be ordered as well. Due to the frame absence, there are no maintenance door option is available. Manifold assembly can be delivered separately, without the frame mountings for the TTE-TSDA product.

Orientation and other options for the TTE-TSDA should be selected according to the TTE-TSA ORDERING GUIDE.

Please select the ordering code as follows:

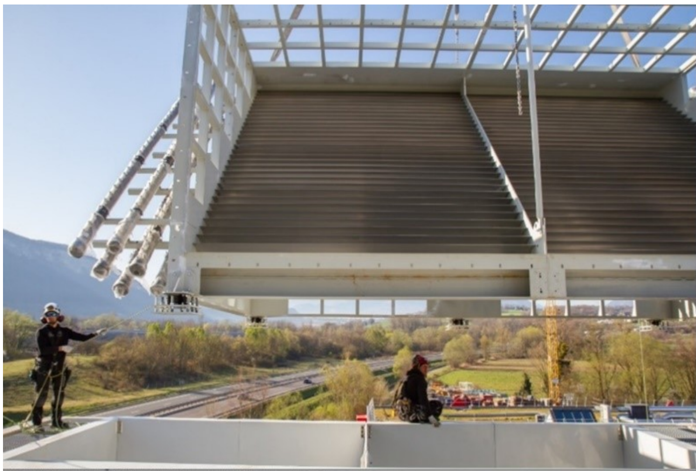
TTE-TSDA	______	___	_	___	W____	H_____	X__

Extended options (X__)
YV – vane door needed (all other options are standard)
NV – no vane door (all other options are standard)
CU –customization needed

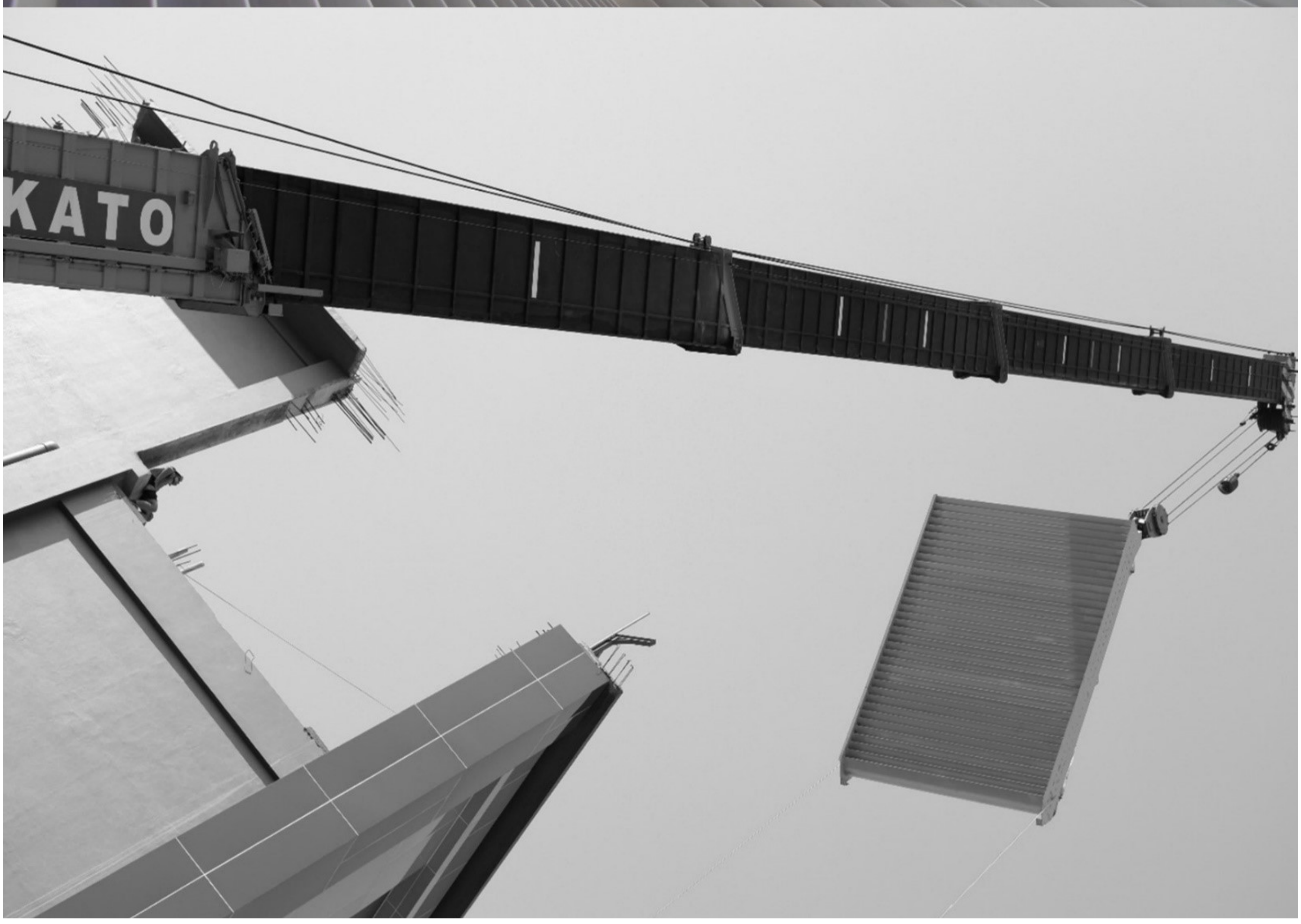
All options – as described for TTE-TSA

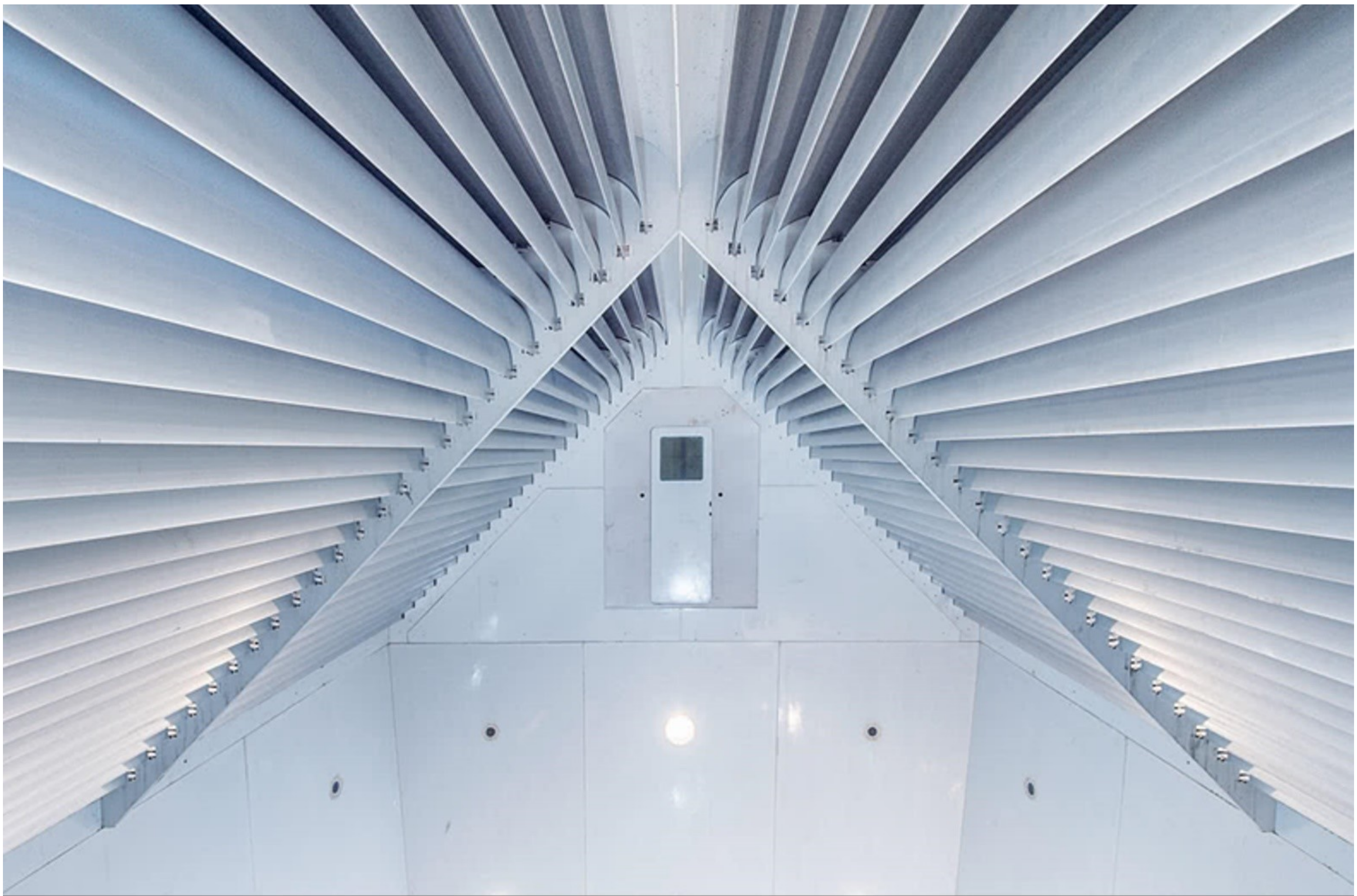
The heat transfer, airduct local resistance and hydraulic parameters are guaranteed only for TTE-TSA option, including standard solutions for Tunnel Tech frame, air duct shape and manifold piping. If you do not intend to evaluate all the parameters of your turning section equipment yourself, **please order standard TTE-TSA** products instead.	⚠

APPENDIX 8. TURNING SECTIONS IN THE PROCESS OF CONSTRUCTION






KATO



Tunnel Tech Turning Vane Section Assembly

TTE GmbH
Stammheimer Str. 35 | 70435 Stuttgart
Registergericht | Registry Court: Amtsgericht Stuttgart
Handelsregisternummer | Commercial Register No.: HRB 766427
USt-ID | VAT No.: DE320246011

Tel: GER: +49 71 1925 3680
Tel UK: +44 74 8881 8108
tunneltech.eu

info@tunneltech.eu