Section for WorldSID manual. DRAFT, Bernard Been 24 March 2015

Section 5.4 2D IR-TRACC 'Absolute Length' Verification

Euro NCAP implemented the WorldSID dummy with 2D IR-TRACCs in their 2015 protocols. The injury parameter is based on the lateral compression of the ribs. This requires calculation of the rib position in a co-ordinate system fixed to the thoracic spine. The 2D IR-TRACC assemblies shall be calibrated according 'IR-TRACC Absolute Length Verification Procedure' and Service Bulletin issued 24 October 2014 Humanetics.

The Absolute Length Verification is applicable to various versions of the 2D IR-TRACC and has applications in the WorldSID midsize male and small female dummy, as well as Q10. The 2D IR-TRACCs can be implemented in the left side and right side of the WorldSID and in the Q10 dummy in both lateral as well as in frontal orientation.

This manual section provides information how to implement the calibration parameters in the data acquisition system and/or post processing software (Section 5.6) dependent on its orientation in the dummy.

There are two important benefits of Absolute Length Verification. Firstly, the output of the 2D IR-TRACC makes that the actual rib position is known at any time. This f.i. allows checking the rib position between tests and allows to check if the dummy has deformation with respect to previous tests. A deviation may indicate a problem with rib permanent set or incorrect calibration parameters. Secondly, when changing over the IR-TRACC position from Left side to Right side, one only has to correct the Reference angle parameter in DAS or post process; all other calibration parameters and post processing formulas will remain the same and are independent of the orientation of the IR-TRACC.

IMPORTANT NOTE: the Absolute Length Verification procedure shall be carried out after replacement of a ball joint or angle sensor, as these items affect Absolute Intercept and Reference Angle and Polarity.

Section 5.5 Theory of the procedure

When the 2D IR TRACC absolute length is not implemented the data of length and angle are represented in a polar co-ordinate system which is not accurately defined nor fixed. The Absolute Length Verification defines the coordinate system according SAE-J211 (Figure 7) at the spine and fixes individual sensor parameters to this coordinate system. The relevant parameters of individual sensors are determined at the assembly level in a reproducible and traceable verification procedure. The verification parameters are given in the purple fields of the verification sheet, see Figure 1. The length calibration factors are also given in inverse units: the Inverse CF (slope) in [V/mm] and the Absolute Intercept Voltage [V]. The relation between Intercept in mm and Volts is given in Figure 2.

2D IR-TRACC ASSEMBLY- ABSOLUTE LENGTH VERIFICATION SHEET Applies for Right Hand Side IR-TRACC Orientation							Calculate IRTRACC Radius using formula: R = (Vsensor ^ -0.4514) * 33.87+11.62		
IR-TRACC		Angle Sensor			Date	16-Oct-14	Absolute Length Calibration Factors		
Test No.	101614DS3170	Test Nr.	0162014DQ5978		TEST No.	101614DS3170	Linearization exponent		-0.4514
Model No.	IF-367-R2S7	Model / SN	3670-11s		Technician	B.Chadwick	Calibration Factor [mm/V]		33.8666
Serial No.	DS3170	Ang cal/polarity	-0.003169	V_{sen}/V_{exc}/deg	Temp / Hum	23.8	Absolute Intercept [mm]		11.62
Calibration Range [mm]	80	Excitation [V]	5.0060	90	REF Length [mm]	105	123.61	Inv CF [V/mm] 0.02953	Abs.Interc.[V] -0.3432
V_{REF} Length [V]	0.1058	V_{REF} Angle [V]	-0.0504	$\varphi 0ffset_{Sensor}$ [deg]	3.18	φ_{IRT} [deg]	R [mm]	x [mm]	y [mm]
V_{REF} Tubes In [V]	0.1055	V_{REF} far [V]	-0.0562	φ_{REF} RIGHT	-86.82	90.4	105.1	-0.7	105.1
V_{REF} Tubes Out [V]	0.1060	V_{REF} near [V]	-0.0446	Ang cal/polarity	-0.003169	89.6	104.9	0.7	104.9
IR-TRACC pos1 [V]	0.0918	Ang pos1 [V]	0.2541	φ_{REF} LEFT	93.18	70.8	111.2	36.6	105.0
IR-TRACC pos2 [V]	0.0777	Ang pos2 [V]	0.4009	φ_{REF} FRONT	3.18	61.5	118.9	56.7	104.6

Figure 1 2D-IR-TRACC assembly Absolute Length calibration sheet

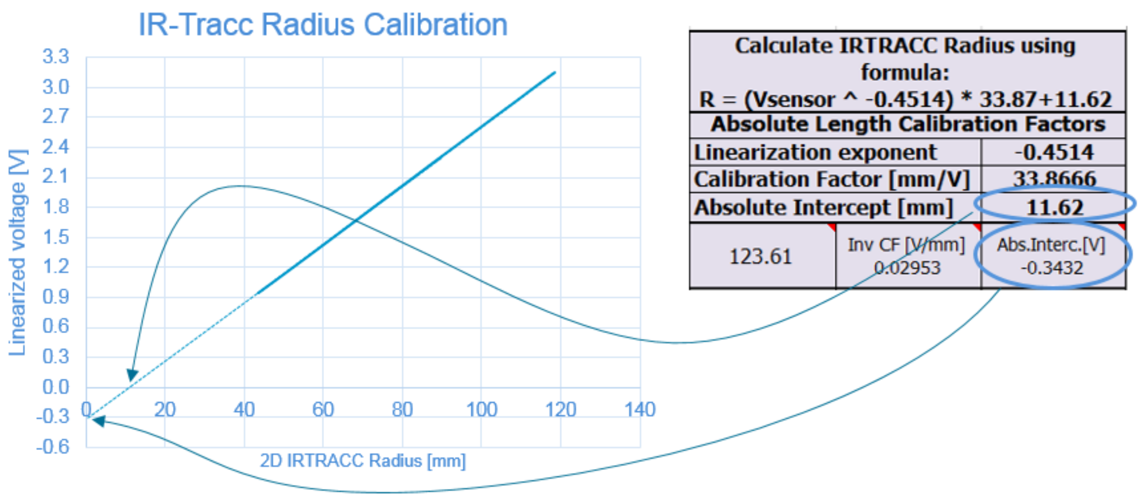

Figure 2 Relation between Absolute Intercept in mm and linearized voltage and values given in calibration sheet

When implemented the parameters *Linearization Exponent*, *Calibration Factor* and *Absolute Intercept* give the calibrated Radius of the IR-TRACC (pivot-to-pivot length). The angle sensor *Cal Factor*, *Polarity* and *Offset* determine the IR-TRACC angle in the co-ordinate system. The polar coordinates Radius and Angle can be converted to the Cartesian coordinates x and y by using the trigonometric functions sine and cosine. This is further defined in section 5.6.

The 2D IR-TRACCs are implemented in various orientations in the dummy: left side, right side, frontal (Q10) and upside down (WorldSID 5th Female, WorldSID 50th Male shoulder, all Q10 except lower lateral position). The current procedure was developed with the intention to keep trigonometric functions for post processing identical and independent of the orientation of the IR-TRACC in the dummy.

The chosen coordinate system follows SAE-J211. In this coordinate system the x and y co-ordinates are positive in right hand and frontal quadrant of the dummy, and the angle is 0 when aligned with the positive x-axis and increasing according the right hand rule (cork screw). The example shown in Figure 3 is the right side of the thorax, the angle sensor seen from the top, reflecting IR-TRACCs of the thorax and abdomen. When the IR-TRACC is aligned with the y-axis the IR-TRACC angle is +90°.

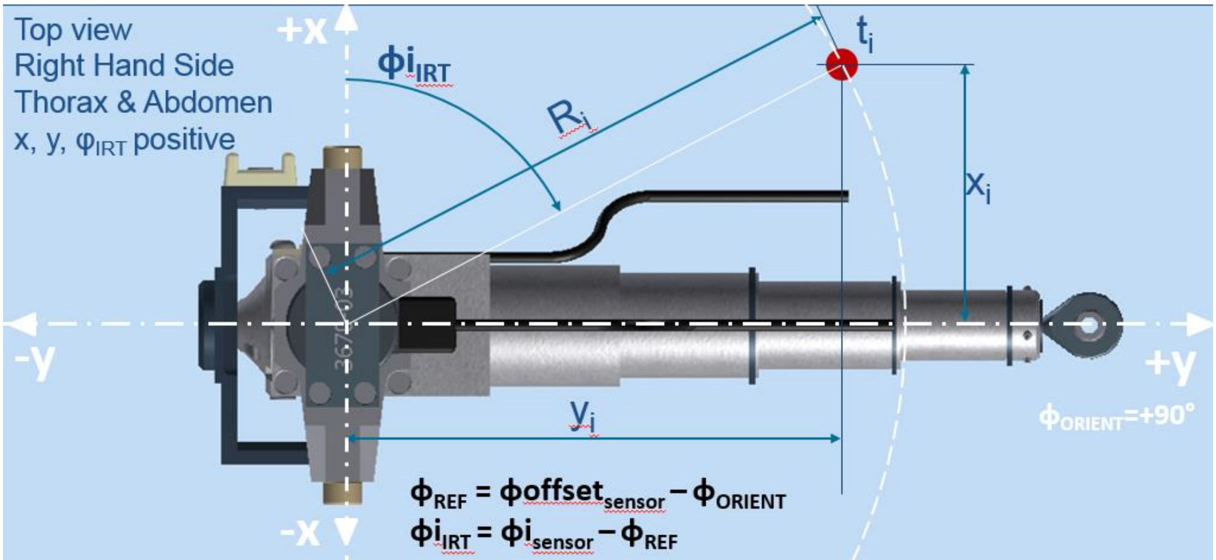

Figure 3 2D IR-TRACC assembly in co-ordinate system for right hand struck side, seen from top

The IR-TRACC orientation is reflected in two parameters: the polarity of the angle sensor defines the positive direction of the angle; the orientation angle ϕ_{ORIENT} defines the IR-TRACC orientation angle with respect to the spine box. The Absolute length Calibration procedure takes data in the standard orientation, ϕ_{ORIENT} = 90°, see Figure 3. In this position the polarity (+/- sign for positive angle) and the Offset angle of the sensor, $\phi offset_{sensor}$, are determined. The Reference angle ϕ_{REF} takes in account the Orientation angle and the Offset angle. The definitions are given in Figure 4.

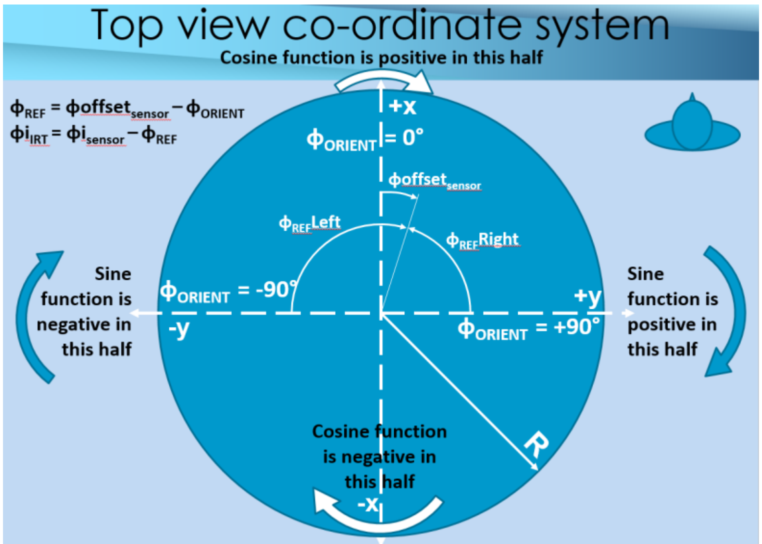

Figure 4 Orientation angle, Offset angle, Reference angle definitions

To reflect three possible dummy orientations, the calibration sheet gives three Reference angles, for left side, right side and frontal orientation: respectively ϕ_{REF}Left; ϕ_{REF}Right and ϕ_{REF}Frontal, see Figure 5. When the IR-TRACC is mounted in the right side thorax, apply the angle sensor polarity as given in the calibration sheet and use ϕ_{REF}Right in the post processing parameters. When the IR-TRACC orientation changes to Left side or Frontal orientation, the Reference angle ϕ_{REF} needs to be corrected to ϕ_{REF}Left and ϕ_{REF}Frontal respectively. These parameters are applicable to IR-TRACCs with angle sensors facing up. The polarity will remain the same.

Parameters WorldSID50 thorax /abdomen & Q10 lower lateral			
(Angle sensor sits on top of IR-TRACC)			
	Left	Frontal	Right
ϕ_{REF} [deg]	93.18	3.178	-86.82
ϕ_{REF} [Rad]	1.626	0.05546	-1.515
Angle Cal/Polarity			
[Vsen/Vexc/**deg**]	-0.003169		
[Vsen/Vexc/**Rad**]	-0.1815		

Figure 5 Angle Sensor calibration factor and polarity and Reference Angles for 3 assembly orientations Angle sensor up

When a 2D IR-TRACC is mounted upside down (WorldSID 5th % female, WorldSID 50M shoulder, Q10), the polarity of the angle sensor needs to flip sign (from + to -, or from – to +) to achieve positive output according the coordinate system. As the angle polarity is linked to the offset angle, this flips sign as well. Therefore, when the IR-TRACC is mounted upside down, the angle Cal Factor Polarity and Reference angle must be flipped in pairs. The correct pair of Angle Calibration Factor Polarity and Reference Angle is given on page two of the calibration sheet, see Figure 6 as example.

Parameters upside-down mounted 2D IR-TRACC			
(Angle sensor sits below IR-TRACC)			
WorldSID5F & WorldSID50 shoulder & Q10 (except lower lateral)			
	Left		Right
ϕ_{REF} [deg]	-86.82		93.18
ϕ_{REF} [Rad]	-1.515		1.626
Angle Cal/Polarity			
[Vsen/Vexc/**deg**]	-0.003169		0.003169
[Vsen/Vexc/**Rad**]	-0.1815		0.1815

Figure 6 Example of parameters for upside down mounted IR-TRACCs

Section 5.6 Data Post Processing

Figure 3 shows the thorax and abdomen 2D IR-TRACC on the right struck side in the local spine co-ordinate system. The formulas to calculate the position of the rib in x and y co-ordinates from the sensor Radius and Angle are given below. The parameters in the formulas are defined in Table 1 and Figure 3. The calculation formulas are applicable in all 4 quadrants of the co-ordinate system, provided that the correct Reference angle and polarity are implemented according the assembly orientation.

IMPORTANT NOTE: the IR-TRACC is a none-linear device and the offset at time 0 shall not be zero-ed by the data acquisition system, as this will invalidate the IR-TRACC measurement beyond recovery. Neither the angle channel shall be zero-ed, as the angle is fixed to the co-ordinate system. If offset zero-ing at t_0 is defaulted by the DAS, then the IR-TRACC and angle voltages at t_0 must be stored along with the data set.

Table 1 Calculation parameters, symbols and description

PARAMETER	DESCRIPTION
t_0 , t_i [s]	Time zero, Time i
V_{IRT} [V or LSB]	IR-TRACC output
EXP	Linearization exponent IR-TRACC output
Calibration Factor [mm/V]	Linearized voltage calibration factor IR-TRACC
Absolute Intercept [mm]	IR-TRACC offset length in pivot co-ordinate system

R, R_0, R_i [mm]	Sensor Radius at t_0, at t_i
x, x_0, x_i [mm]	x- co-ordinate, x at t_0, x at t_i
y, y_0, y_i [mm]	y- co-ordinate, y at t_0, y at t_i
Dx_i [mm]	Deflection in x direction at t_i
Dy_i [mm]	Deflection in y direction at t_i
ϕ_{ORIENT} [degrees]	Orientation angle of assembled IR-TRACC, see Figure 4
$\phi offset_{sensor}$ [degrees]	Sensor offset angle Absolute Length Calibration, see Figure 4
ϕ_{REF} [degrees]	Reference angle, see Figure 4
ϕ_{sensor}, $\phi 0_{sensor}$, ϕi_{sensor} [degrees]	Angle sensor output, at t_0, at t_i
ϕ_{IRT}, $\phi 0_{IRT}$, ϕi_{IRT} [degrees]	IR-TRACC angle along z-axis, at t_0 and at t_i

Calculation formulas

$R = (V_{IRT}\text{^}EXP) * (\text{Calibration Factor}) + \text{Absolute Intercept}$ [mm]

$\phi_{REF} = \phi offset_{sensor} - \phi_{ORIENT}$ [deg]

$\phi i_{IRT} = \phi i_{sensor} - \phi_{REF}$, $\phi 0_{IRT} = \phi 0_{sensor} - \phi_{REF}$ [deg]

$x = R * \cos(\phi_{IRT})$, $x_0 = R_0 * \cos(\phi 0_{IRT})$, $x_i = R_i * \cos(\phi i_{IRT})$ [mm]

$Dx = x_i - x_0$ [mm]

$y = R * \sin(\phi_{IRT})$, $y_0 = R_0 * \sin(\phi 0_{IRT})$, $y_i = R_i * \sin(\phi i_{IRT})$ [mm]

$Dy = y_i - y_0$ [mm]

Table 2 Example ISO codes for Thorax rib1 mounted on left struck side in SI units

PARAMETER	CHANNEL DESCRIPTION	ISO CODE (EXAMPLE LEFT THORAX1)
V_{IRT} [V]	Raw IR-TRACC output	??TRRILE01WSVO0P
V_{IRT} [LSB]	Raw IR-TRACC output	New code for LSB to be defined
EXP	CONSTANT Cal factor Linearization exponent	.Power func exponent (header)
Calibration Factor [m/V^{EXP}]	CONSTANT Cal factor Linearized voltage	.Power func sensitivity (header)
Absolute Intercept [m]	CONSTANT Cal factor offset length	.Power func eng offset (header)
Electrical offset [V]	CONSTANT	.Power func electr offset (header)
Electrical offset [LSB]	CONSTANT	.Power func electr offset (header)
R [m]	Absolute Length (IR-TRACC Radius)	??TRRILE01WSDC0P
ϕi_{sensor} [Rad]	Raw Angle sensor output	Not needed for export
Angle Cal/polarity [Rad/V]	polynomial coefficient (linear)	Inverse polynom coeff C (header)
ϕ_{REF} [Rad]	CONSTANT Reference angle	Inverse polynom coeff M (header)
		.Transfer function used (header)
ϕi_{IRT} [Rad]	Calculated [Filtered?] IR-TRACC z-angle w.r.t. dummy co-ordinate system	??TRRILE01WSANZ?
x [m]	Calculated [Filtered?] x- co-ordinate	??TRRILE01WSDCX?
y [m]	Calculated [Filtered?] y- co-ordinate	??TRRILE01WSDCY?
Dx_i [m]	Calculated [Filtered?] x Deflection	??TRRILE01WSDSX?
Dy_i [m]	Calculated [Filtered?] y Deflection	??TRRILE01WSDSY?

Section 5.5 Checking polarity

After implementation of the calibration parameters and channel post processing according the calibration sheet, it is important to check the polarities and output of sensors in the dummy with a live Data Acquisition System (DAS) and active post processing of data channels. The dummy co-ordinate system is show in Figure 7. Check the polarities in on-line measurement mode by manipulating the dummy. The correct polarities are given in Table 3. The typical value stated in the table is the expected output when the IR-TRACC is assembled in the dummy. The values are indicative and may vary, f.i. when the dummy is seated in a vehicle, ribs are rotated forward because of seat interaction, or mild permanent set has occurred on the ribs.

If (one or more of) the polarities are not matching, all calibration parameters should be checked and corrected. If no error can be found there may be a polarity switched somewhere in the measurement chain. It is recommended to perform (repeat) the Absolute Length verification procedure using the exact same measurement chain as used for dummy data acquisition.

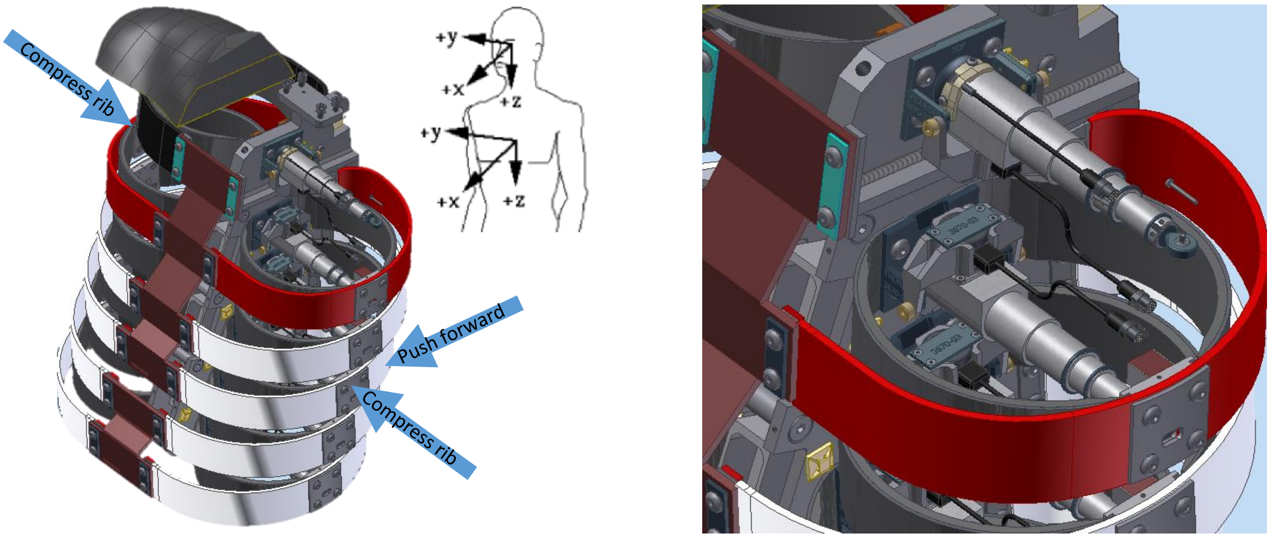

Figure 7 Co-ordinate system of the dummy, left struck side instrumented shown here

Table 3 Dummy manipulations and parameter responses (after post processing)

PARAMETER	POSITION	MANIPULATION	EXPECTED OUTPUT	TYPICAL STARTING VALUE
Angle ϕ_{IRT}	Left	Push rib forward	Angle increases (to zero)	~−90 degrees
	Right		Angle decreases (to zero)	~+90 degrees
x	Left		X increases	~0mm
	Right			
Radius R	Left	Compress rib	Radius decreases (to zero)	~+118mm
	Right			
y	Left		Y increases (to zero)	~–118mm
	Right		Y decreases (to zero)	~+118mm

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