6 December 2017

LHCb UT CO2 cooling discussion

Istituto Nazionale
di Fisica Nucleare
Sezione di Milano

UT DETECTOR
CO2 COOLING SYSTEM

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For the Milano UT group
I.N.F.N. MILANO

Summary:

- **Open points for discussion**

- **Manifold working drawings**

PDF AND A STEP FILES UPLOADED ON THE INDICO PAGE

- **Orifices test and calculation for the STAVE INLET PRESSURE DROP STABILIZATION SYSTEM**

UT cooling distribution sytem production

The CO2 distribution system, as proposed for the UT detector is an assembly made of AISI-316L components:

- **from Swagelok catalogue (VCR fittings, 90° bend, flexible hosing, ferrule Swagelok fittings for the PT100 Rodax temperature transmitter)**
- **from commercial (when possible Swagelok) piping,**

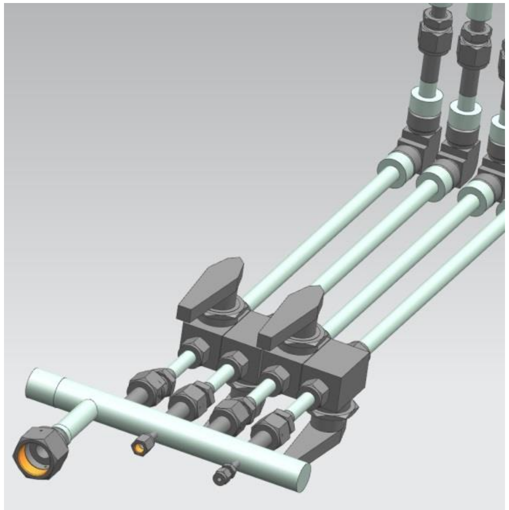
- **using micro-TIG weldig as a baseline for the junctions/ or laser welding (for thin thickness pipes)**

We met the company now in the SAES group https://www.saesgetters.com/saes-rial-vacuum-srl http://rodofil.com/rodofil_english/tecnologies.html,

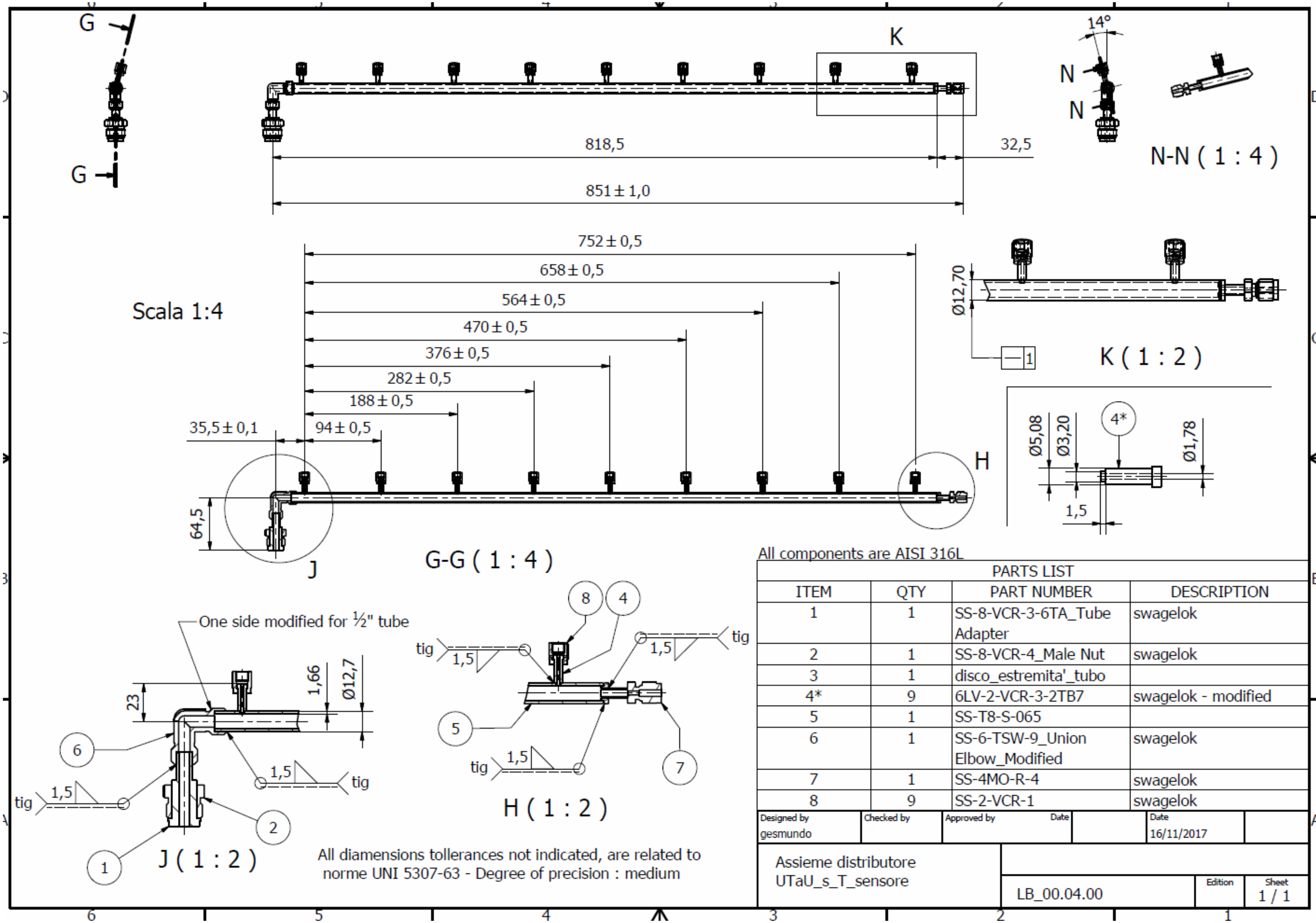
They realized for us laser the joints on ID 2mm/OD 2.5 mm SS pipe to Swagelok 1/8 fittings using laser technology: the coiled pipes are installed in the LHCb UT TRACI cooling test and survived a lot of thermal and pressure cycles.
Anyway the model presented, design by carlo Gesmundo, was mainly devoted to fit the assembly in the UT box, taking care of the integration issues, and the work is not yet completed. For sure we have to detail better the welding joints; a meeting with the company is foreseen the 28 november for this item, and asap we'll produce a prototype to test. We plan to pressurize to 190 bar and He leak check the assembly. If it would be qualified and if you approve, we could plan the full production of 8 top and 8 bottom manifold with the relevant distribution collectors, having one inlet and one outlet for each side of UT.

⇒ **there is a requirement from the UT collaboration, to flow partially the UT detector during installation and test. The simpler solution we proposed is to put ONLY in the inlet, ONLY on one side of the detector circuit, 4 ON/OFF valves on the 4 lines distributing the CO_2 to the 4 "half-panels", made of 8 or 9 parallel lines. This will allow to flow independently one (or maybe two) "half-panel" at a reduced power cooling during commissioning etc. Obviously this has to be approved and the alternative option is to remove these valves used in surface test, and nNOT have them in the final detector cooling system in the cavern. To be discussed.**

⇒ **A question: IS IT ADMITTED to use Swagelok ferrule compression system to mount the detector cooling circuit: the on/off valves should alternatively be welded (there are pro/cons!). * And what alternative solution if we don't use the valves?**

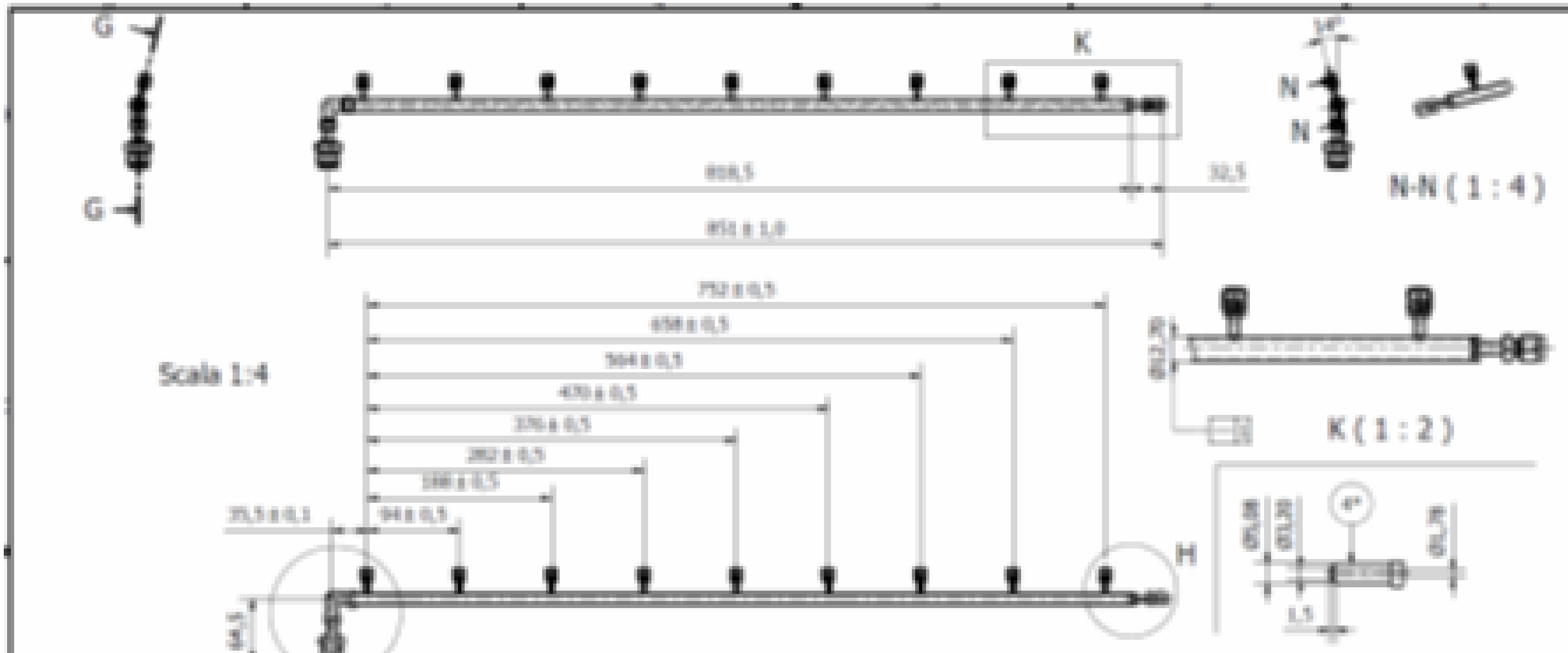


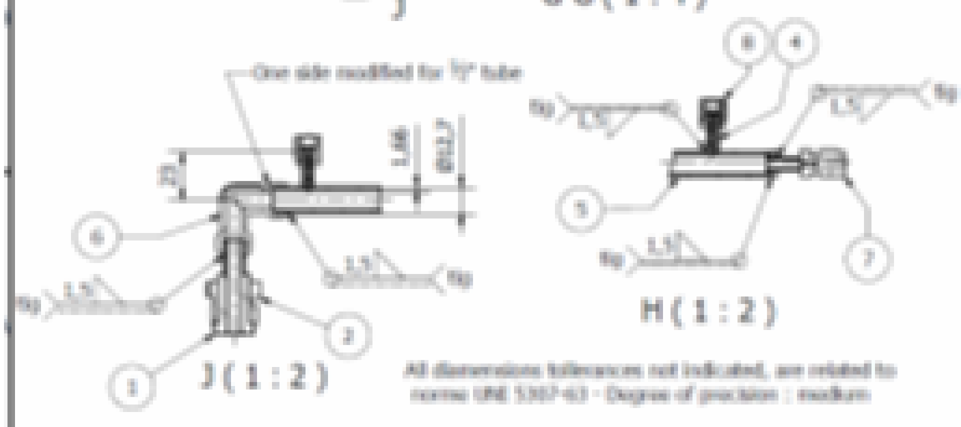
Working drawings, after themeeting with the company



PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	SS-8-VCR-3-6TA_Tube Adapter	swagelok
2	1	SS-8-VCR-4_Male Nut	swagelok
3	1	disco_estremita'_tubo	
4*	9	6LV-2-VCR-3-2TB7	swagelok - modified
5	1	SS-T8-S-065	
6	1	SS-6-TSW-9_Union Elbow_Modified	swagelok
7	1	SS-4MO-R-4	swagelok
8	9	SS-2-VCR-1	swagelok





All dimensions tollerances not indicated, are related to norme UNE 5307-63 - Degree of precision : medium

All components are AISI 316L

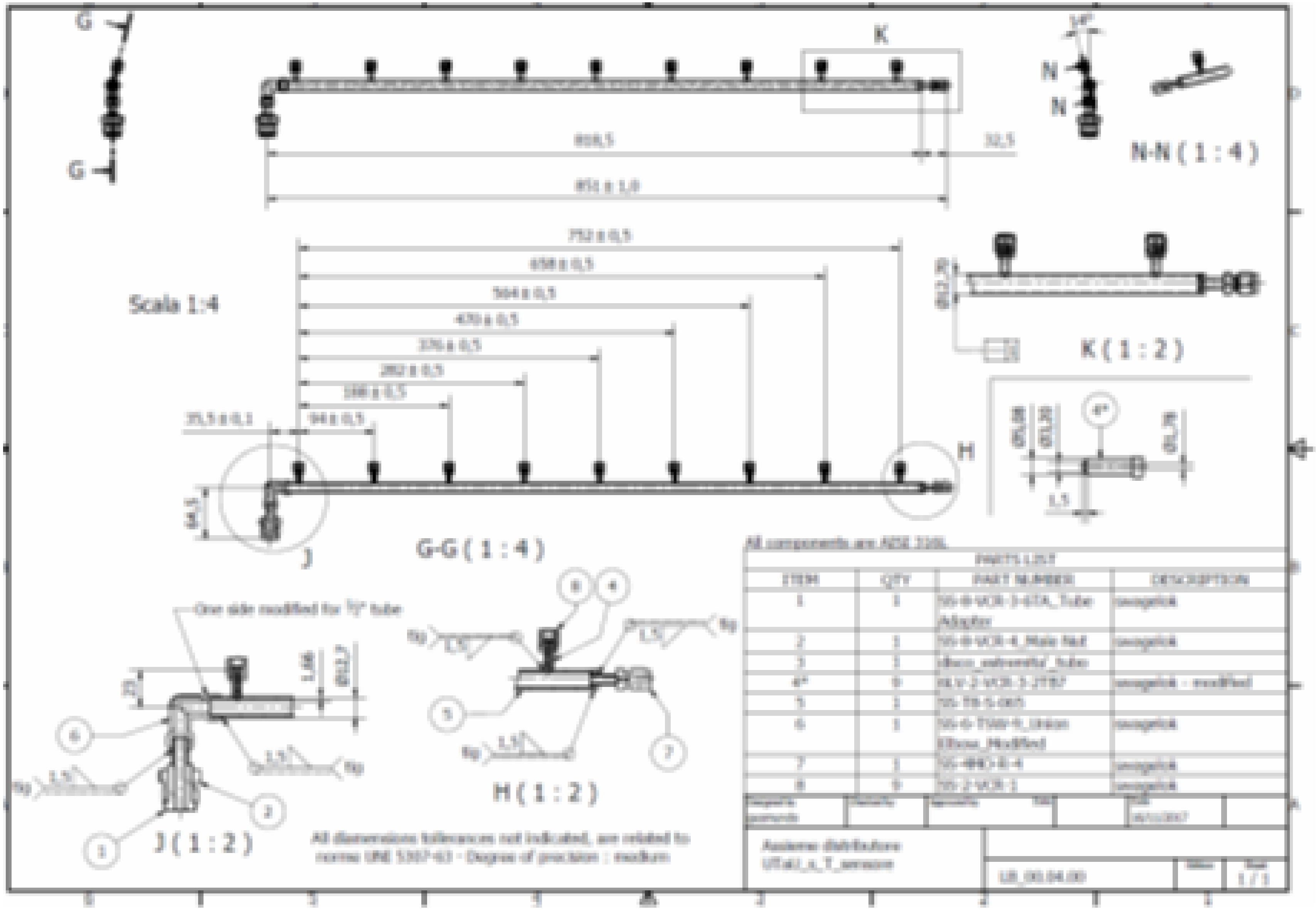
PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	SS-8-VCR-3-6TA_Tube Adapter	swagelok
2	1	SS-8-VCR-4_Male Nut	swagelok
3	1	tubo_universita'_tubo	
4*	9	6LV-2-VCR-3-2TB7	swagelok - modified
5	1	SS-T8-S-065	
6	1	SS-6-TSW-9_Union Elbow_Modified	swagelok
7	1	SS-4MO-8-4	swagelok
8	9	SS-2-VCR-1	swagelok

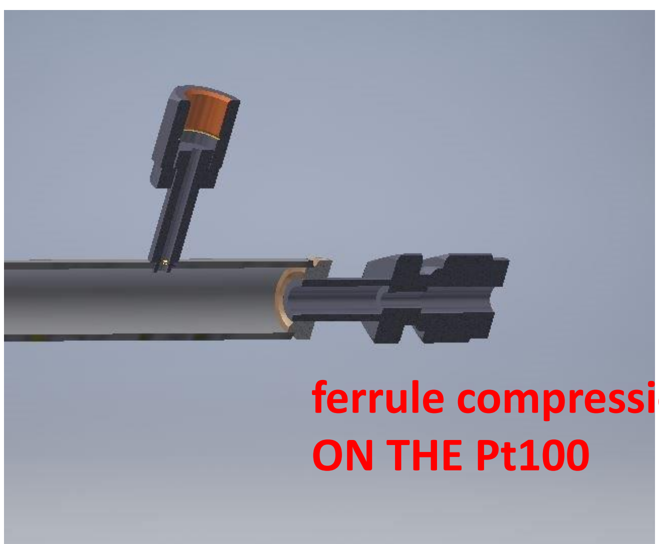
Assieme distributore UTati_x_T_sensore

LB_00.04.00

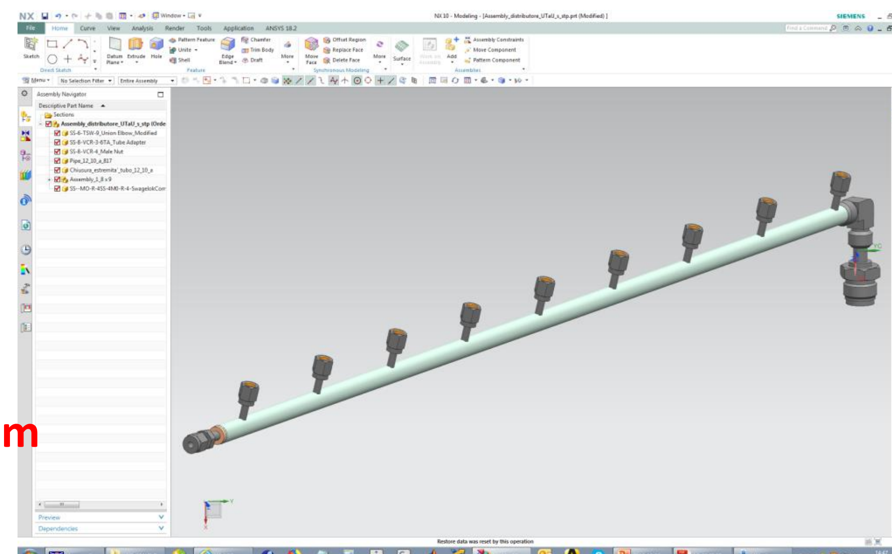
1 / 1


Scala 1:4
N-N (1 : 4)
K (1 : 2)
G-G (1 : 4)
H (1 : 2)
J (1 : 2)
32,5
851 ± 1,0
752 ± 0,5
658 ± 0,5
564 ± 0,5
470 ± 0,5
376 ± 0,5
282 ± 0,5
188 ± 0,5
94 ± 0,5

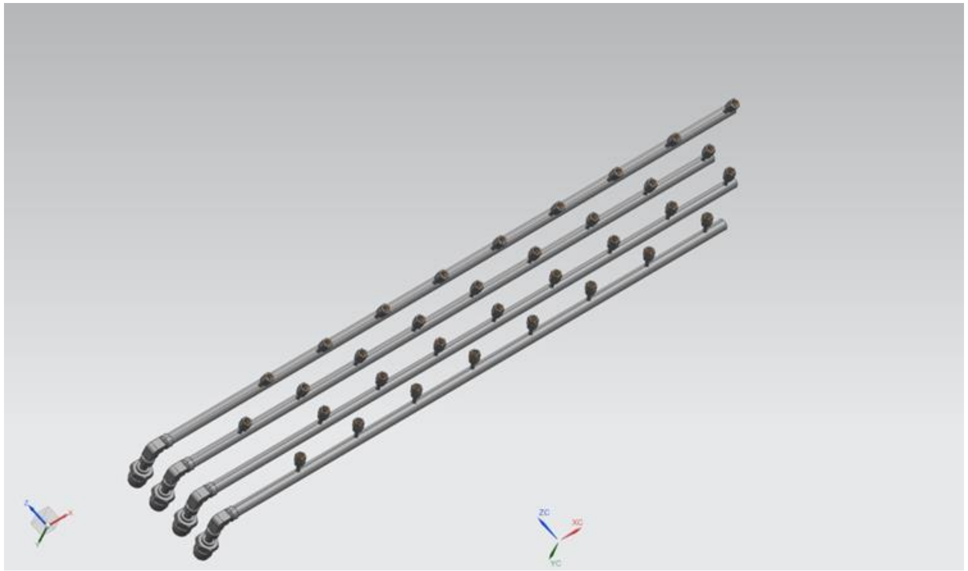
=> The sensors to be installed in the UT CO_2 cooling circuit need to be finalized, with CO_2 cooling plant advice: we proposed a simple T and P sensor location on the main CO_2 flow. As you suggest we could implement a measurement on any INLET manifold. 4 TOP manifold each detector side. See attached image showing an example: inserting a RODAX PT100 coaxially at the end of any manifold. The question are: * Michal: can we accommodate this in the detector room? Note that any PT100 has 4 wires that need to be routed out from the cold-box. * Are these signals usable from the control system ? Could we have any control if the measurements indicate not perfect values? The finaldesign of the CO_2 distribution system will implement the required number of T or P transmitters: there is no technical problem, other than allocation of space into the detector, in welding the sensors fitting in the assembly.



ferrule compression system
ON THE Pt100



WE NEED UPDATED MODEL OF THE UT BOX



ORIFICES FOR INLET PRESSURE DROP

- **CO_2 COOLING TEST WITH FLOW RESTRICTORS**
  - **SWAGELOK CALIBRATED ORIFICES**
  - **LASER LENOX CUSTOM ORIFICES**
- **CO_2 PROPERTIES**
- **SPREADSHEET FOR ORIFICE PRESSURE DROP CALCULATION**
- **VALIDATION MEASUREMENTS**

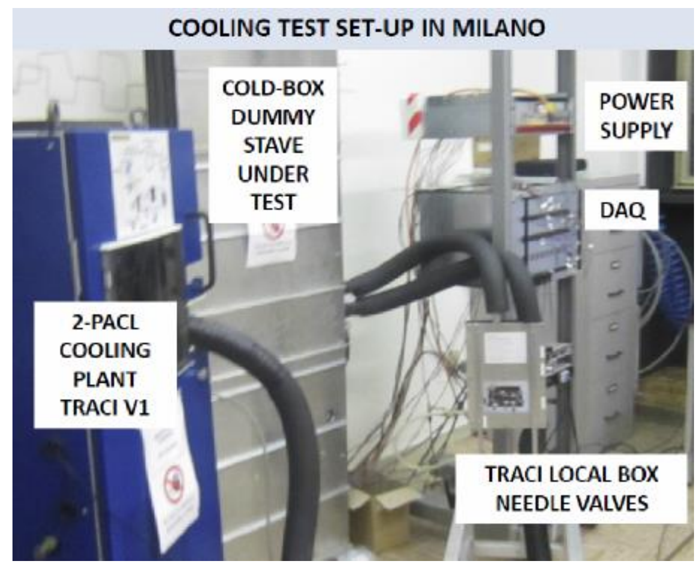
CO_2 COOLING TEST WITH FLOW RESTRICTORS

CO_2 COOLING TEST HAVE BEEN CARRIED OUT USING A CO_2 TRACI COOLING SYSTEM

CO_2 TRACI V.3 COOLING SYSTEM

TWO TYPES OF FLOW RESTRICTORS:

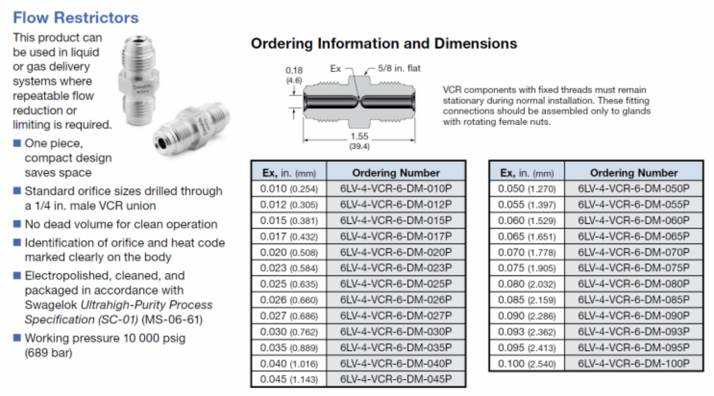
- SWAGELOK ¼ INCH FLOW RESTRICTORS
- LASER LENOX VCR ORIFICES



FORMER TRACI V.1 PLANT

FLOW RESTRICTORS CO_2 COOLING TEST

SWAGELOK ¼ INCH FLOW RESTRICTOR



Flow Restrictors

This product can be used in liquid or gas delivery systems where repeatable flow reduction or limiting is required.

- One piece, compact design saves space
- Standard orifice sizes drilled through a 1/4 in. male VCR union
- No dead volume for clean operation
- Identification of orifice and heat code marked clearly on the body
- Electropolished, cleaned, and packaged in accordance with Swagelok *Ultrahigh-Purity Process Specification (SC-01)* (MS-06-61)
- Working pressure 10 000 psig (689 bar)

Ordering Information and Dimensions

VCR components with fixed threads must remain stationary during normal installation. These fitting connections should be assembled only to glands with rotating female nuts.

Ex, in. (mm)	Ordering Number
0.010 (0.254)	6LV-4-VCR-6-DM-010P
0.012 (0.305)	6LV-4-VCR-6-DM-012P
0.015 (0.381)	6LV-4-VCR-6-DM-015P
0.017 (0.432)	6LV-4-VCR-6-DM-017P
0.020 (0.508)	6LV-4-VCR-6-DM-020P
0.023 (0.584)	6LV-4-VCR-6-DM-023P
0.025 (0.635)	6LV-4-VCR-6-DM-025P
0.026 (0.660)	6LV-4-VCR-6-DM-026P
0.027 (0.686)	6LV-4-VCR-6-DM-027P
0.030 (0.762)	6LV-4-VCR-6-DM-030P
0.035 (0.889)	6LV-4-VCR-6-DM-035P
0.040 (1.016)	6LV-4-VCR-6-DM-040P
0.045 (1.143)	6LV-4-VCR-6-DM-045P

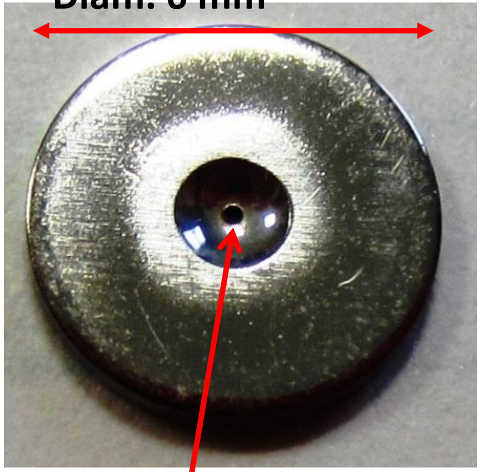
Ex, in. (mm)	Ordering Number
0.050 (1.270)	6LV-4-VCR-6-DM-050P
0.055 (1.397)	6LV-4-VCR-6-DM-055P
0.060 (1.529)	6LV-4-VCR-6-DM-060P
0.065 (1.651)	6LV-4-VCR-6-DM-065P
0.070 (1.778)	6LV-4-VCR-6-DM-070P
0.075 (1.905)	6LV-4-VCR-6-DM-075P
0.080 (2.032)	6LV-4-VCR-6-DM-080P
0.085 (2.159)	6LV-4-VCR-6-DM-085P
0.090 (2.286)	6LV-4-VCR-6-DM-090P
0.093 (2.362)	6LV-4-VCR-6-DM-093P
0.095 (2.413)	6LV-4-VCR-6-DM-095P
0.100 (2.540)	6LV-4-VCR-6-DM-100P

FROM CATALOGUE:
6LV-4-VCR-6-DM-010P, 6LV-4-VCR-6-DM-012P, 6LV-4-VCR-6-DM-015P, 6LV-4-VCR-6-DM-017P

LASER HOLE IN VCR GASKET

CUSTOM ORIFICES:
200, 225, 250, 275 µm
WE MEASURED THE OTHER GEOMETRICAL CHARACTERISTICS USABLE FOR THE PRESSURE DROP CALCULATION

1/8 INCH VCR GASKET
Diam. 6 mm



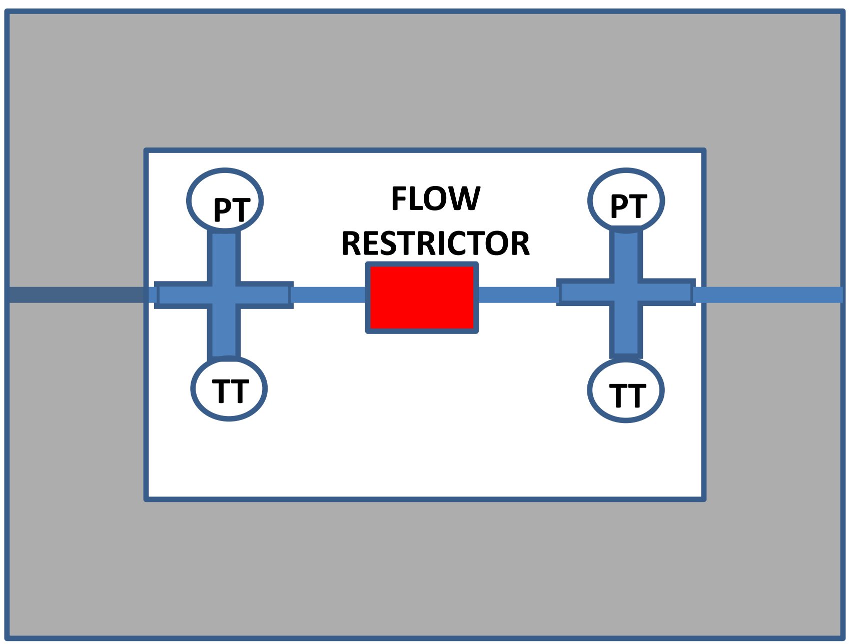
Hole: 0,250 mm (= 250 µm)

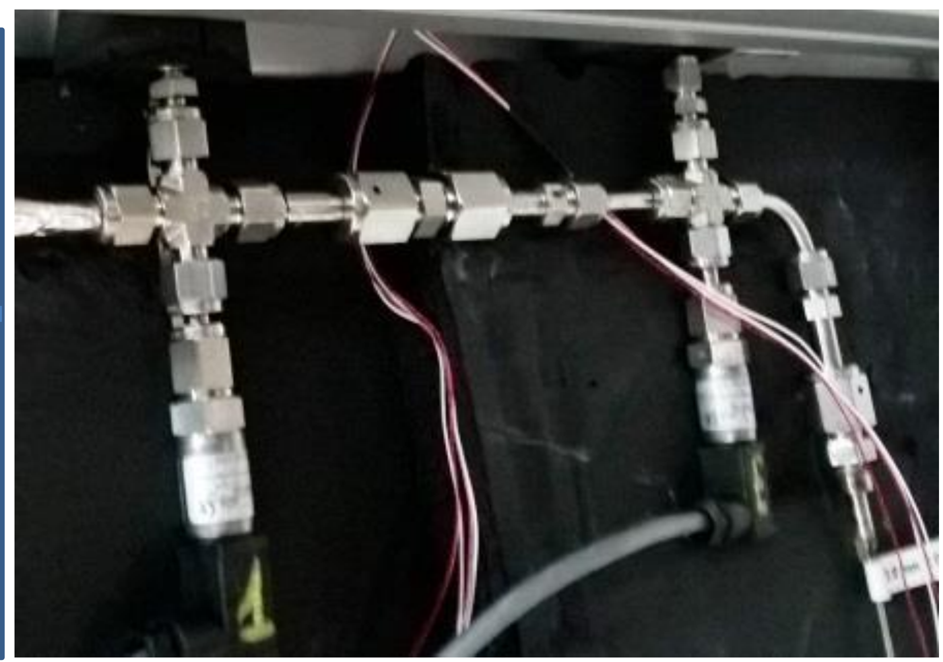
FLOW RESTRICTORS CO_2 COOLING TEST

PRESSURE TRANSMITTERS BEFORE/AFTER FLOW RESTRICTOR:
PIEZO-RESISTIVE 0-20 mA TRANSMITTERS - KELLER

TEMPERATURE TRANSMITTERS BEFORE/AFTER FLOW RESTRICTOR:
PT100-4 WIRES THERMO-RESISTIVE TRANSMITTERS - RODAX

MASS FLOW-RATE TRANSMITTER:
CORIOLIS MASS FOW-RATE TRANSMITTER IN THE TRACI UNIT

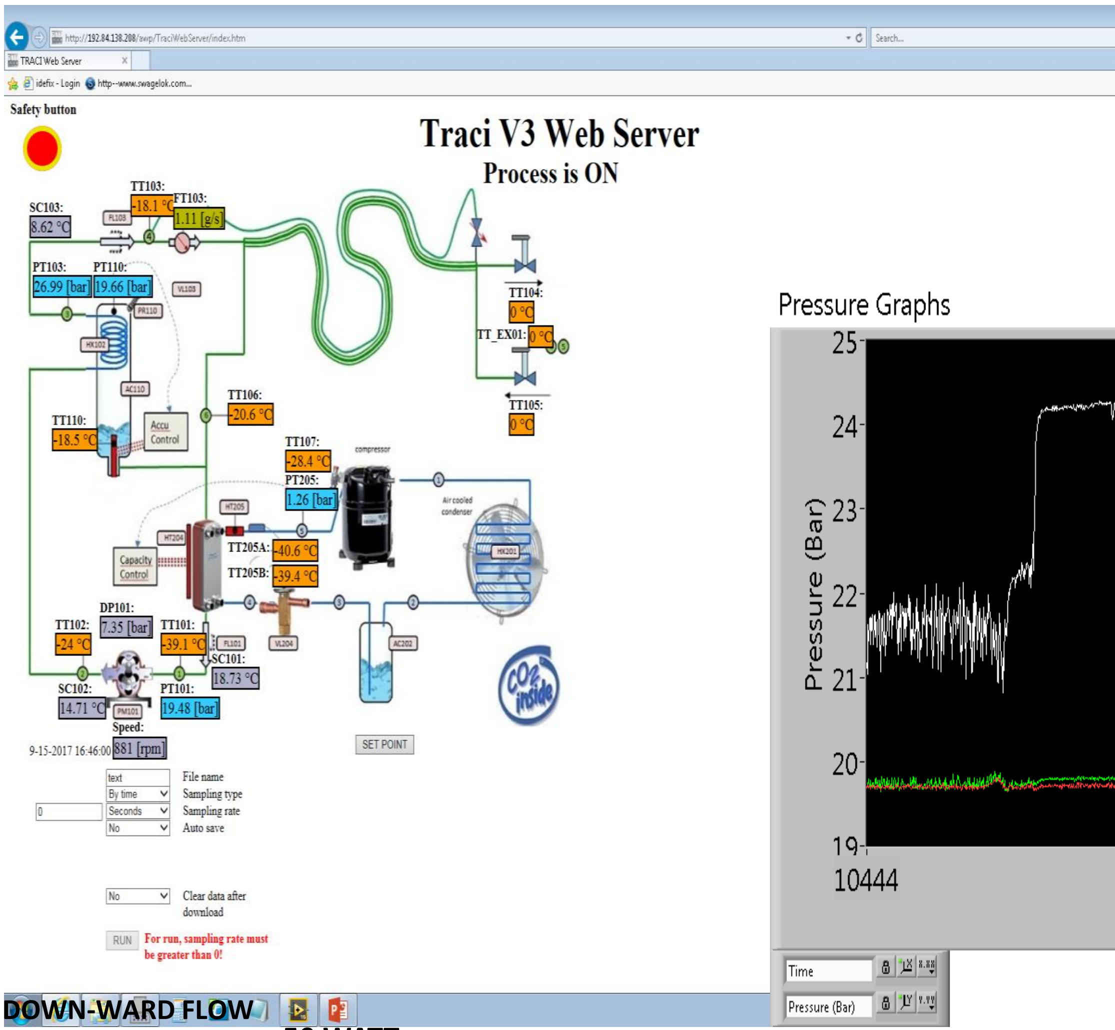


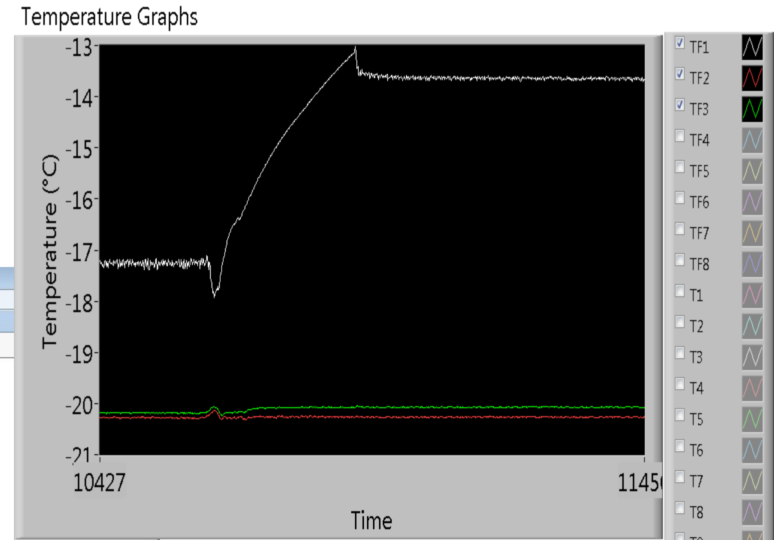


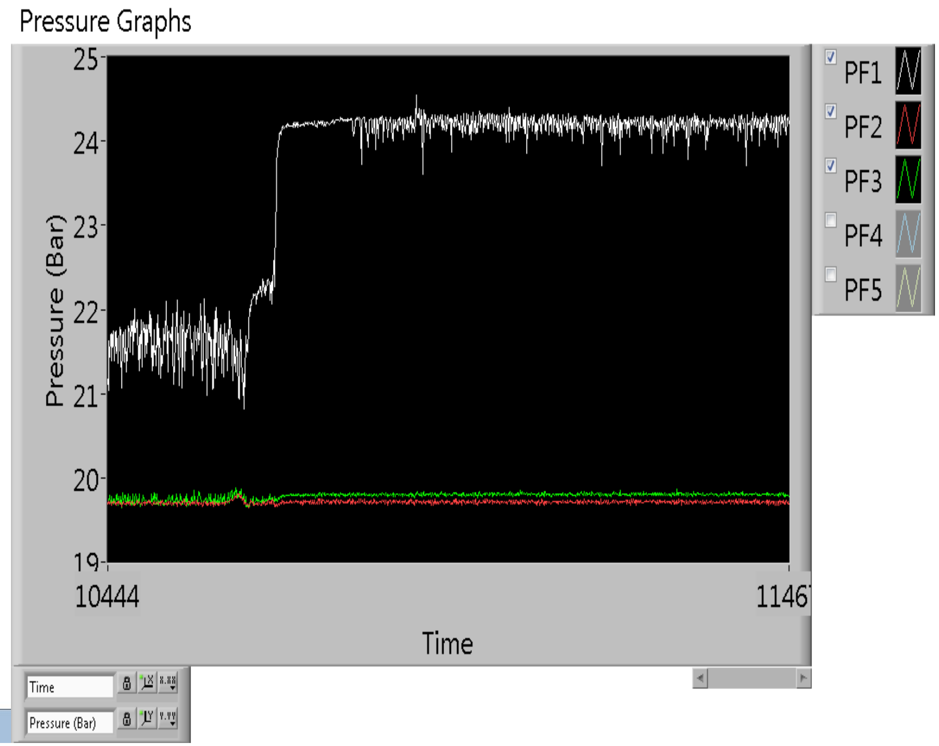
EXAMPLE OF A CO_2 COOLING TEST

250 MICRON LASER ORIFICE INSTALLED

MASS FLOW RATE
FROM 0,6 TO 1,2 g/s







DOWN-WARD FLOW
LATERAL STAVE

50 WATT

CO_2 PROPERTIES:

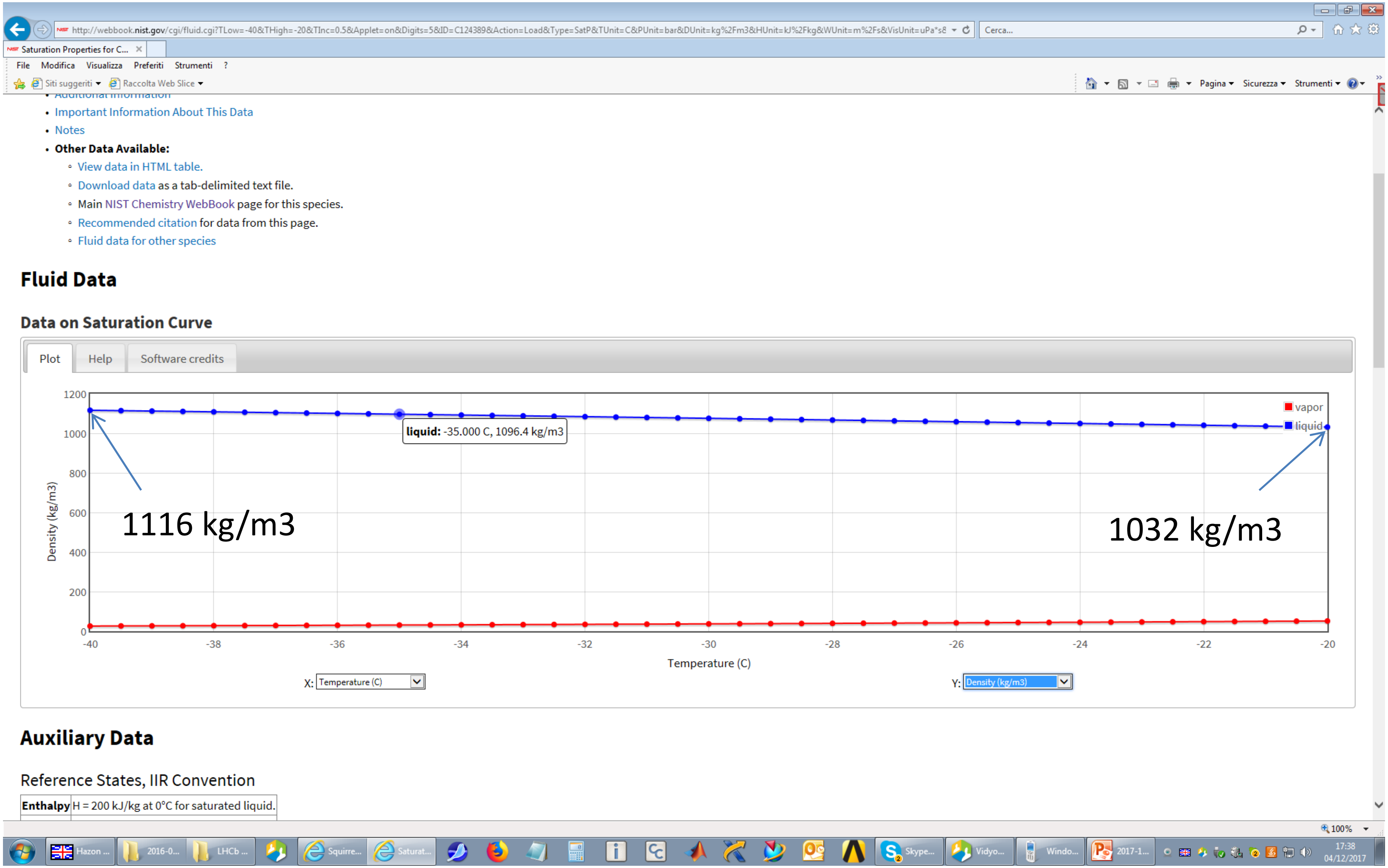
Saturation Properties for Carbon dioxide

In the range of interest:
-20 °C … -30 °C

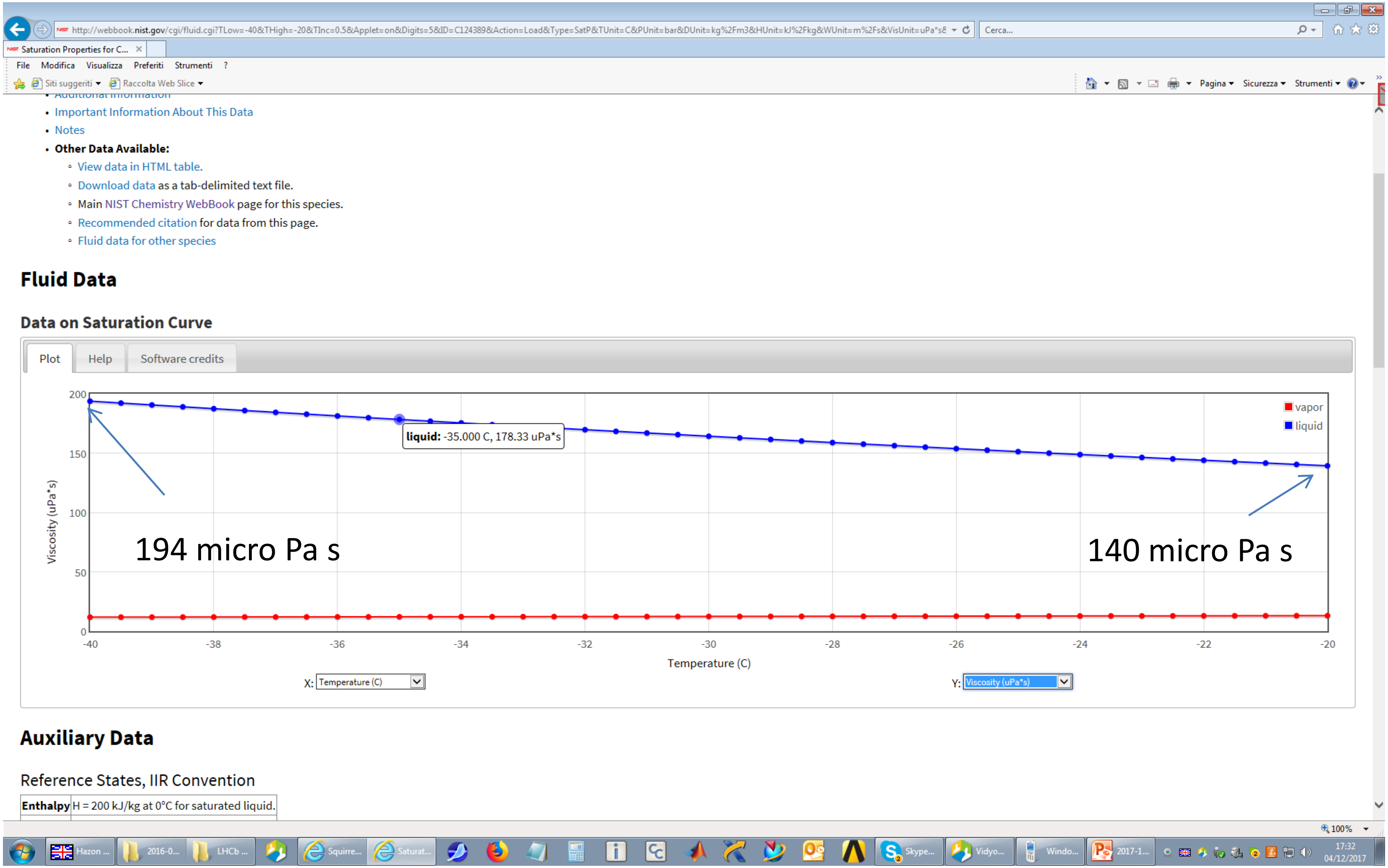
CO_2 physical properties <u>entering in the pressure drop calculation</u>:
*** Density**
*** Viscosity**

Next slides show some plots captured from the web site of National Institute of Standards and Technology (NIST)

CO_2 Density:


http://webbook.nist.gov/cgi/fluid.cgi?TLow=-40&THigh=-20&TInc=0.5&Applet=on&Digits=5&ID=C124389&Action=Load&Type=SatP&TUnit=C&PUnit=bar&DUnit=kg%2Fm3&HUnit=kJ%2Fkg&WUnit=m%2Fs&VisUnit=uPa*s
Saturation Properties for C...
File Modifica Visualizza Preferiti Strumenti ?
Siti suggeriti
Raccolta Web Slice
Pagina Sicurezza Strumenti
Important Information About This Data
Notes
Other Data Available:
View data in HTML table.
Download data as a tab-delimited text file.
Main NIST Chemistry WebBook page for this species.
Recommended citation for data from this page.
Fluid data for other species
Fluid Data
Data on Saturation Curve
Plot
Help
Software credits
vapor
liquid
liquid: -35.000 C, 1096.4 kg/m3
1116 kg/m3
1032 kg/m3
Density (kg/m3)
Temperature (C)
X: Temperature (C)
Y: Density (kg/m3)
Auxiliary Data
Reference States, IIR Convention
Enthalpy H = 200 kJ/kg at 0°C for saturated liquid.
100%
17:38
04/12/2017

CO_2 Viscosity:

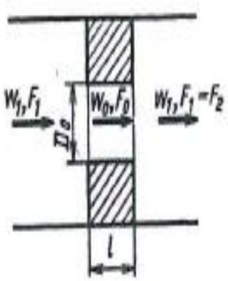


SPREADSHEET FOR ORIFICE PRESSURE DROP CALCULATION

FORMULAS FROM IDELCHIK HANDBOOK OF HYDRAULIC RESISTANCE
=> THICK-EDGED ORIFICE (OTHER MODELS DOESN'T WORK AS WELL)

222 *Handbook of Hydraulic Resistance, 3rd*

Thick-edged orifice ($l/D_h > 0.015$) in a straight tube (channel); $Re = w_0 D_h/\nu > 10^{3}$ [13,14]	Diagram 4-15



$$\zeta_1 = \frac{\Delta p}{\rho w_1^2/2} = \left[0.5\left(1 - \frac{F_0}{F_1}\right)^{0.75} + \tau\left(1 - \frac{F_0}{F_1}\right)^{1.375} + \left(1 - \frac{F_0}{F_1}\right)^2 + \lambda\frac{l}{D_h}\right]\left(\frac{F_1}{F_0}\right)^2,$$

where τ see the table below or graph a of Diagram 4-12 or

$$\tau = (2.4 - \bar{l}) \times 10^{-\varphi(\bar{l})};$$

$$D_h = \frac{4F_0}{\Pi_0}$$

$$\varphi(\bar{l}) = 0.25 + 0.535\bar{l}^{-8}/(0.05 + \bar{l}^{-8}),$$ see Chapter 2.

$$\bar{l} = l/D_h$$

$$\zeta_0 = 0.5\left(1 - \frac{F_0}{F_1}\right) + \left(1 - \frac{F_0}{F_2}\right)^2 + \tau\sqrt{1 - \frac{F_0}{F_1}}\left(1 - \frac{F_0}{F_2}\right);$$ for λ

Values of ζ_1 at $\lambda = 0.02$

At $\lambda = 0.02$ for the values of $\zeta_1 = f(l/D_h, F_0/F_1)$ see the graph

Section Four

SUDDEN VARIATION OF VELOCITY IN STREAM PASSAGE THROUGH AN ORIFICE
(Resistance coefficients of stretches with sudden expansion, orifice plates, apertures, etc.)

4-1. LIST OF SYMBOLS

- F_0 = area of the narrowest section of the stretch of the orifice, m^2;
- F_1 = area of the channel section before the narrow section of the stretch of the orifice, m^2;
- F_2 = area of the channel section behind the narrow section of the stretch of orifice, m^2;
- F_c = area of the contracted-jet section at the entrance to the orifice, m^2;
- $\varepsilon = \frac{F_c}{F_0}$ = coefficient of jet contraction;
- $\varepsilon_0^{Re} = \frac{F_c}{F_0}$ = coefficient depending on Re, of jet contraction in the section of a sharp-edged orifice at $\frac{F_0}{F_1} = 0$;
- $n = \frac{F_2}{F_0}$ = area ratio;
- Π_0 = section perimeter, m;
- D_0 = diameter of the narrowest section of the orifice, m;
- D_1, D_2 = diameters of the section before the orifice and the section behind it respectively, m;
- D_h = hydraulic diameter, 4X hydraulic radius, m;
- a_0, b_0 = sides of the rectangular section or semiaxes of the ellipse, m;
- l = length of the stretch, depth of the orifice, m;
- r = radius of curvature of the inlet-orifice edge, m;
- α = central angle of divergence of the diffuser or of convergent bell mouth, or of the opening of the aperture flaps in the wall;
- w_0 = mean stream velocity in the narrowest section of the orifice, m/sec;
- w_1, w_2 = mean stream velocities in the sections before and behind it, m/sec;
- ΔH = pressure loss or resistance of the stretch, kg/m^2;
- ζ = resistance coefficient of the stretch;
- M = momentum coefficient, or Mach number;
- N = kinetic-energy coefficient.

IMAGES FROM "HANDBOOK OF HYDRAULIC RESISTANCE" I.E. IDELCHIK

SPREADSHEET FOR THE ORIFICE PRESSURE DROP CALCULATION

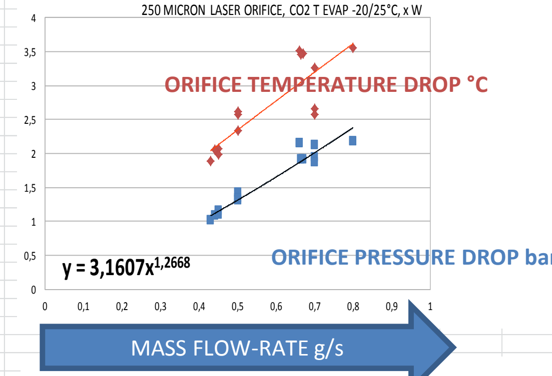
	01/12/2017		IN	OUT	
	CO_2 IN LIQUID PHASE				
		FORMULAS			
d,orifice diameter			250	micron	0,00025
D	diameter of the channel section before the narrow section of the stretch of the orifice				0,0044
F_0	Area of the narrowest section of the stretch of the orifice	A=(π*ϕ^2)/4	0,0490625	mm^2	4,90625E-08
F_1	Area of the channel section before the narrow section of the stretch of the orifice	A=(π*ϕ^2)/4	15,1976	mm^2	1,51976E-05
F_0/F_1					0,003
F_1/F_0					309,76
l	lenght of the stretch, depth of the orifice		0,2	mm	0,0002
r	hydraulic radius				0,0022
D_h	hydraulic diameter, 4* hydraulic radius				0,0088
l/Dh					0,0227
ρ	fluid density				1050
q_m	mass flow rate		1	g/s	0,001
w_1	mean stream velocity in the section before the narrowest section of the orifice				0,0627
l^-8					3,90625E+29
ϕ(l')					0,785
τ					0,394
μ	dinamic viscosity				0,000144
υ	kinematic viscosity				1,37143E-07
R_e	Reynolds number	Re=w_1*D/υ			2010,551
λ	friction coefficient of referred lenght of conduit (laminar flow)	λ=64/Re			0,032
ζ	resistance coefficient of stretch				180870,8373
Δp	pressure drop			Δp=(ζ*ρ*w1^2)/2	372906
					3,729

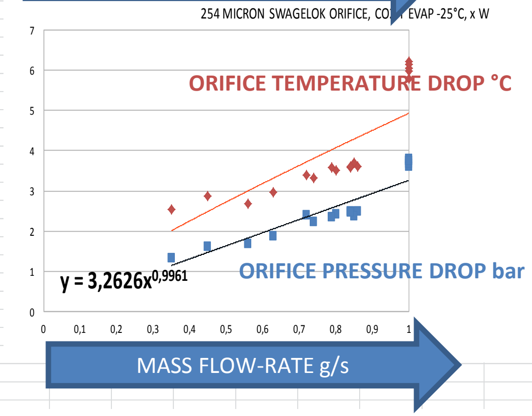
EXAMPLE OF PRESSURE DROP CALCULATION

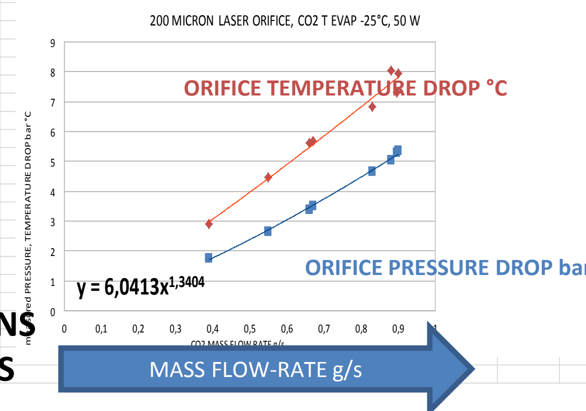
EXPERIMENTAL MEASUREMENT OF ORIFICES PRESSURE DROP

22/11/17
CO_2
LATERAL STAVE

DOWNWARD FLOW	FLOWRATE	POWER	ORIFICE DP	ORIFICE DT	T eva	Dawnward SNAKE-A DP	Dawnward SNAKE-A DT	NOTE				
	g/s	W	bar	°C	°C	bar	°C					
250 MICRON LASER	0,7		1,95	2,66	-17			2017-09-22-Tev-17-0W-0,7gs		0,7	1,95	2,66
250 MICRON LASER	0,7		1,87	2,58	-16,6					0,7	1,87	2,58
250 MICRON LASER	0,7	0	2,12	3,26	-20,2	0,069	0,056	2017-09-15-Tev-20-0W-0,7gs	0	0,7	2,12	3,26
250 MICRON LASER	0,8		2,18	3,56	-23,6	0,019	0,059	2017-10-10-localbox attaccata coldbox-laser250micron		0,8	2,18	3,56
250 MICRON LASER	0,5	38	1,31	2,58	-29,4	0,03	0,129	2017-10-10-Tev-30-38W-0,5gs	38	0,5	1,31	2,58
250 MICRON LASER	0,5	0	1,42	2,61	-29,5	0,006	0,088	2017-10-10-Tev-30-0W-0,5gs	0	0,5	1,42	2,61
250 MICRON LASER	0,5	38	1,34	2,34	-26,7	0,044	0,106	12/10/17	38	0,5	1,34	2,34
250 MICRON LASER	0,43	50	1,02	1,89	-26,3	0,054	0,108	12/10/17	50	0,43	1,02	1,89
250 MICRON LASER	0,66	64	2,15	3,51	-26,8	0,05	0,198	12/10/17	64	0,66	2,15	3,51
250 MICRON LASER	0,67	64	1,91	3,47	-26,8	0,087	0,199	12/10/17	64	0,67	1,91	3,47
250 MICRON LASER	0,665	64	1,91	3,46	-26,8	0,087	0,2	12/10/17	64	0,665	1,91	3,46
250 MICRON LASER	0,45	0	1,16	2,07	-28,2	0,008	0,072	13/10/17	0	0,45	1,16	2,07
250 MICRON LASER	0,44	50 A STAVE	1,09	2,05	-28,3	0,03	0,117	13/10/17	50 A STAVE	0,44	1,09	2,05
250 MICRON LASER	0,45	62 B STAVE	1,11	1,99	-28,1	0,034	0,131	13/10/17	62 B STAVE	0,45	1,11	1,99
	FLOWRATE	POWER	ORIFICE DP	ORIFICE DT								
	g/s	W	bar	°C								
254 MICRON Swagelok 0.01 inch	0,35		1,33	2,54	-28							
254 MICRON Swagelok 0.01 inch	0,45		1,61	2,88	-26					0,35	1,33	2,54
254 MICRON Swagelok 0.01 inch	1		3,8	6,21	-24					0,45	1,61	2,88
254 MICRON Swagelok 0.01 inch	1	62	3,61	5,79	-22,4	0,159	0,236			1	3,8	6,21
254 MICRON Swagelok 0.01 inch	1	50	3,74	5,97	-23,2	0,142	0,198			1	3,61	5,79
254 MICRON Swagelok 0.01 inch	1	trans	3,67	6,05	-23,6	0,123	0,184			1	3,74	5,97
254 MICRON Swagelok 0.01 inch	1	0	3,742	6,15	-23,7	0,089	0,112			1	3,67	6,05
										1	3,742	6,15
2017-03-14-Peva20bar-50W-LATERAL-STAVE-DOWNWARD												
254 MICRON Swagelok 0.01 inch	0,86	50	2,5	3,61	-18,7	0,093	0,227					
254 MICRON Swagelok 0.01 inch	0,85	50	2,37	3,69	-21,2	0,12	0,023			0,86	2,5	3,61
254 MICRON Swagelok 0.01 inch	0,84	50	2,49	3,58	-18,4	0,102	0,23			0,85	2,37	3,69
254 MICRON Swagelok 0.01 inch	0,84	50	2,47	3,61	-18,3	0,101	0,228			0,84	2,49	3,58
254 MICRON Swagelok 0.01 inch	0,8	50	2,41	3,51	-18,7	0,107	0,231			0,84	2,47	3,61
254 MICRON Swagelok 0.01 inch	0,79	50	2,36	3,58	-18,4	0,147	0,23			0,8	2,41	3,51
254 MICRON Swagelok 0.01 inch	0,74	50	2,23	3,33	-19,4	0,122	0,194			0,79	2,36	3,58
254 MICRON Swagelok 0.01 inch	0,72	50	2,4	3,39	-18,8	0,098	0,215			0,74	2,23	3,33
254 MICRON Swagelok 0.01 inch	0,63	50	1,88	2,96	-20,5	0,107	0,216			0,72	2,4	3,39
254 MICRON Swagelok 0.01 inch	0,56	50	1,68	2,67	-21,4	0,078	0,71			0,63	1,88	2,96
										0,56	1,68	2,67
	FLOWRATE	POWER	ORIFICE DP	ORIFICE DT	T eva	Dawnward SNAKE-A DP	Dawnward SNAKE-A DT	NOTE				
	g/s	W	bar	°C	°C	bar	°C					
200 MICRON LASER	0,67	0	3,35	5,13	-21,8	0,044	0,117	2017-10-24-Tev-22-0W-0.67gs				
200 MICRON LASER												
200 MICRON LASER	0,75 TRANS	0	3,79	6,34	-26	0,082	0,207	25/10/17				
200 MICRON LASER	0,71	0	3,84	6,39	-26,2	0,083	0,178	25/10/17				
200 MICRON LASER	0,67	0	3,35	5,3	-23,3	0,036	0,095	25/10/17				
200 MICRON LASER	0,6	0	3,05	4,8	-23,4	0,05	0,116	25/10/17				
200 MICRON LASER	0,48	0	2,4	3,75	-24	0,047	0,155	25/10/17				
200 MICRON LASER												
200 MICRON LASER												
200 MICRON LASER	0,3	0	1,35	2,12	-24,5	0,039	0,136	25/10/17				
200 MICRON LASER	0,18	0	0,79	1,24	-24,7	0,015	0,099	25/10/17				
200 MICRON LASER	0,9	50 A STAVE	5,36	7,95	-24	0,125	0,251	25/10/17				
200 MICRON LASER	0,895	50 A STAVE	5,3	7,3	-23,5	0,118	0,241	25/10/17				
200 MICRON LASER	0,88	50 A STAVE	5,05	8,03	-24,2	0,134	0,259	25/10/17				
200 MICRON LASER	0,83	50 A STAVE	4,67	6,82	-23,5	0,121	0,257	25/10/17				
200 MICRON LASER	0,67	50 A STAVE	3,52	5,69	-24,4	0,131	0,302	25/10/17				
200 MICRON LASER	0,55	50 A STAVE	2,65	4,48	-25,6	0,116	0,229	25/10/17				
200 MICRON LASER	0,66	50 A STAVE	3,39	5,62	-25,3	0,135	0,281	25/10/17				
200 MICRON LASER	0,39	50 A STAVE	1,75	2,92	-25,4	0,08	0,19	25/10/17				
200 MICRON LASER	0,375	50 A STAVE	[illegible]	[illegible]	-25,2	0,078	0,173	25/10/17				







PRESSURE AND TEMPERATURE DROP ACROSS ORIFICES IN DIFFERENT CONDITIONS

EACH FIGURE IS THE AVERAGE OF 20 EXPERIMENTAL POINTS: 1 MEASUREMENT/S FOR 20 SECONDS DATA-TAKING

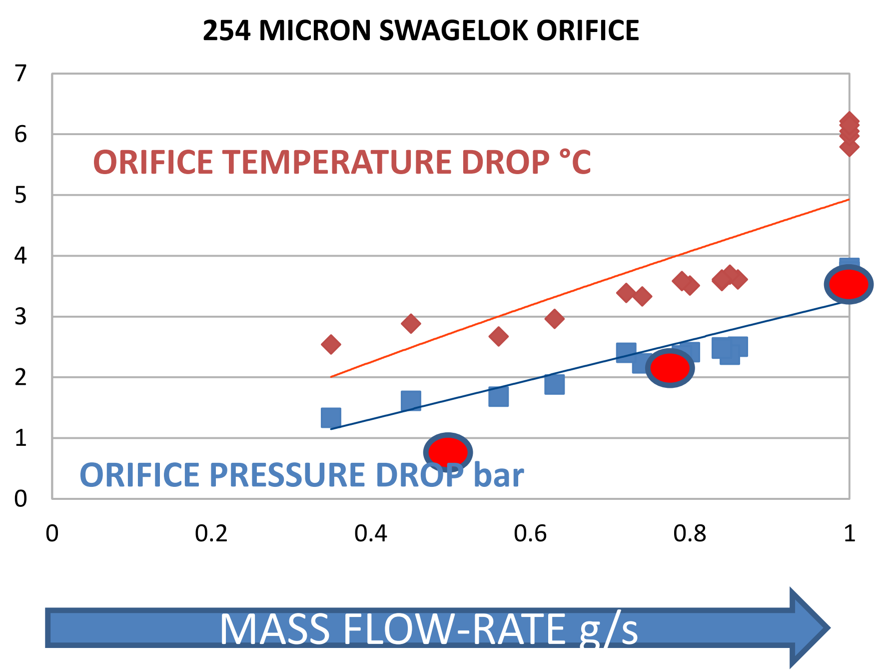
SPREADSHEET CROSS-CHECK WITH THE MEASUREMENTS

AGREEMENT WITH THE MEASUREMENTS:

DEVIATION AT 1 g/s

200 micron laser orifice	**=> calulated 9 bar, measured 6 bar => 33%**
254 swagelok orifice	**=> calulated 3,5 bar, measured 3,26 bar => 7%**
250 micron laser orifice	**=> calulated 3,7 bar, measured bar => 14 %**

WORK IN PROGRESS TO CALCULATE MORE PRECISELY THE % ERROR USING ALL THE DATA



CO_2 PHYSICAL CONDITIONS IN THE VALIDATION TEST

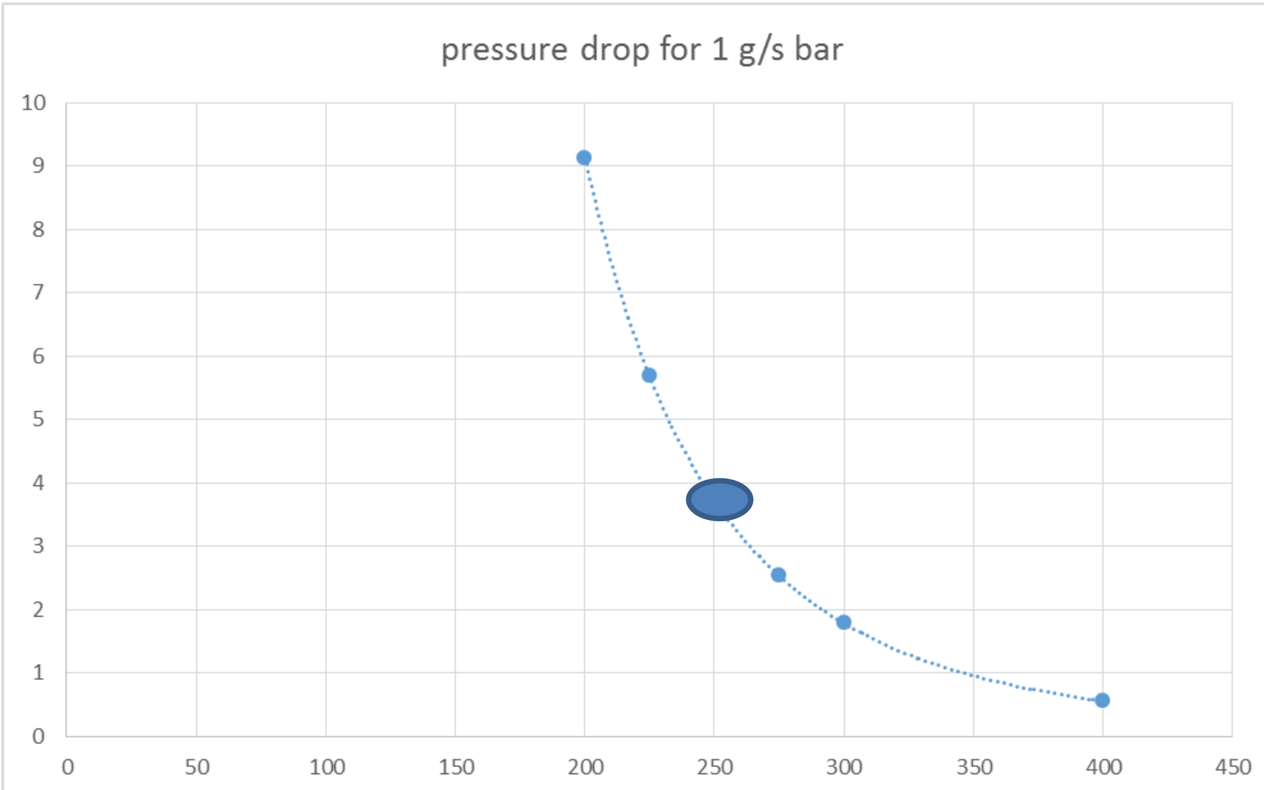
μ dinamic viscosity 0,000165 Pa*s

ρ fluid density 1050 Kg/m^3

254 MICRON SWAGELOK ORIFICE:
calculated
O.5 g/s => 0.88 bar
O.8 g/s => 2.24 bar
1 g/s => 3.5 bar

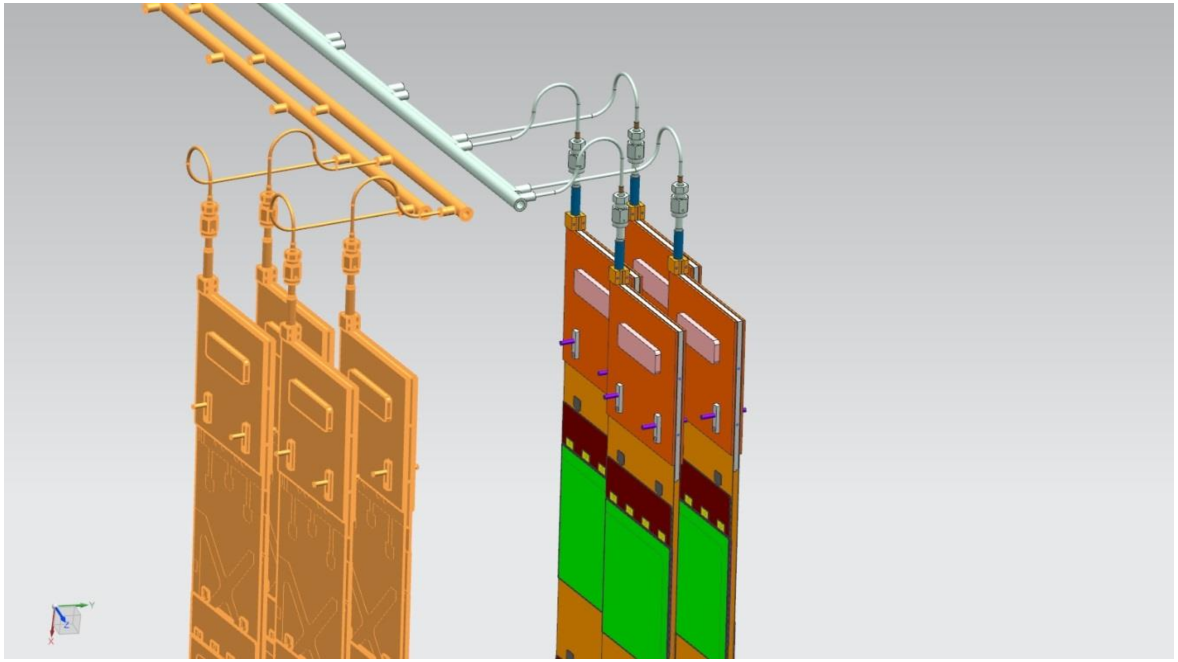
ESTIMATED PRESSURE DROP (+/- ERROR) VS ORIFICE DIAMETER FOR A GIVEN MASS-FLOW-RATE:

orifice diameter micron	pressure drop **for 1 g/s** bar
200	9,12
225	5,69
250	3,73
275	2,54
300	1,79
400	0,56



ORIFICE DIAMETER IN MICRON

BACK-UP SLIDES



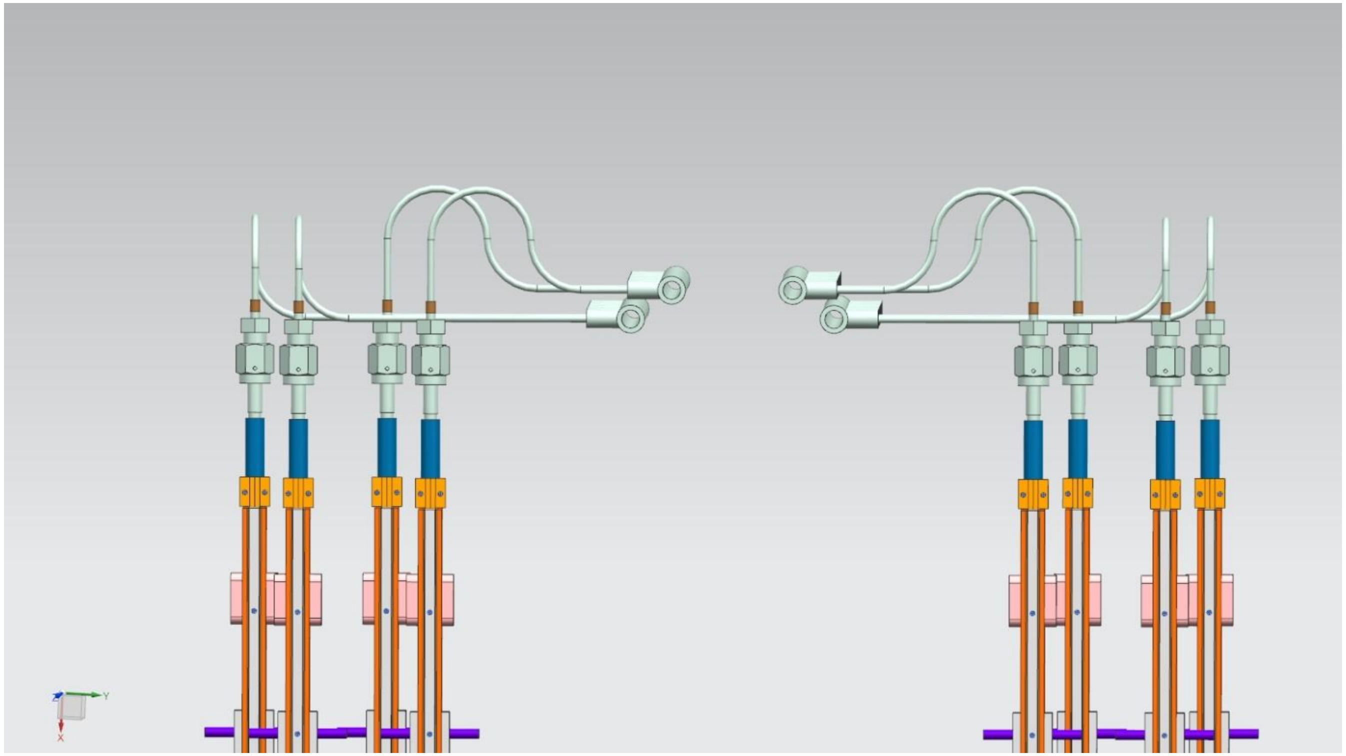
Another Top view of the "2015-10-21" model

The proposed connection cooling pipe is AISI 3016L, 2 mm ID, 2.5 mm OD

Prototypes order has been placed to

RODOFIL-REAL VACUUM company

The pipes will be welded with laser/microTIG to Swagelok fittings, then tested



Lateral view of the top region of the “2015-10-21” model

The four outlet manifolds are located in the “reserved region”, but there is freedom to move them inside this region to optimize the design

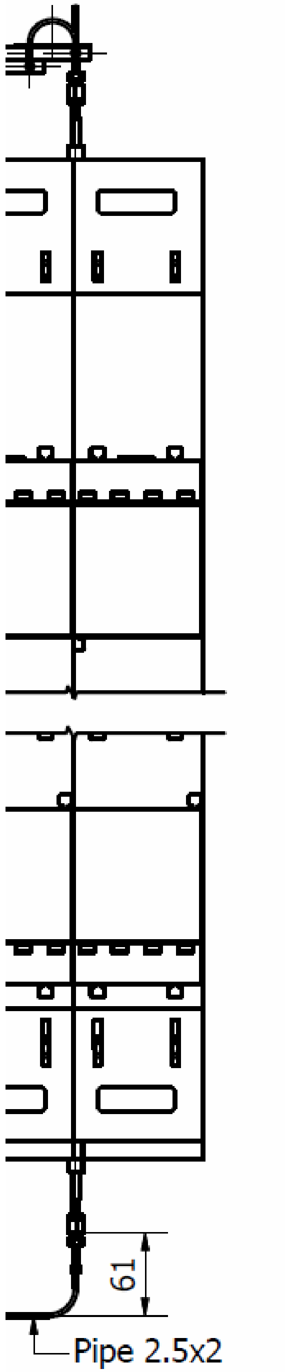
Manifolds need to be fixed to the frame

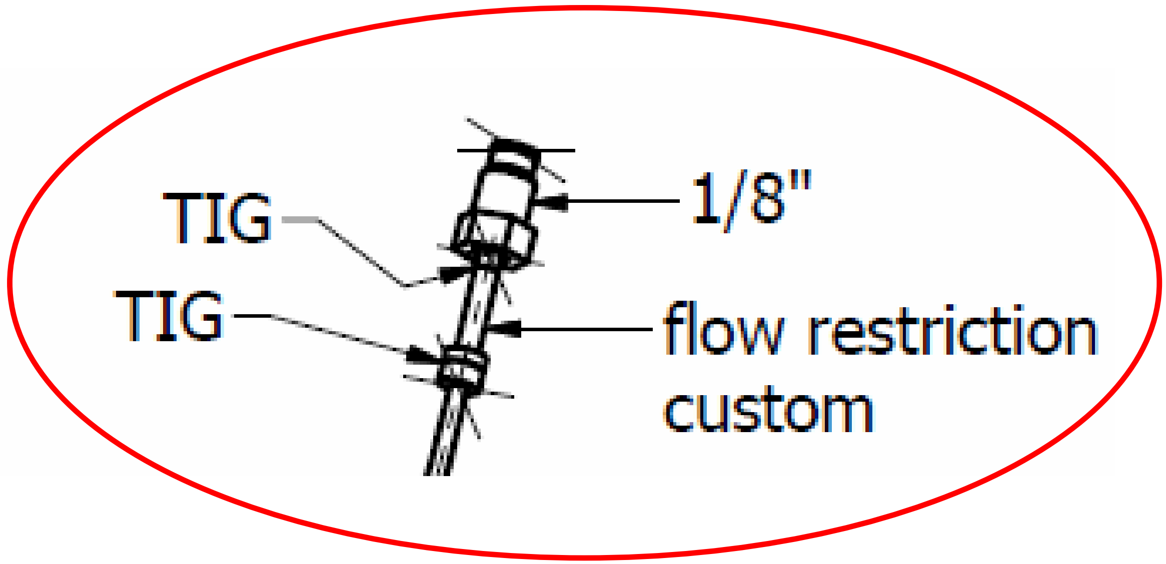
A medium length fixation point, plus sliders fixations on the extremities

To minimize the contraction effect on the staves

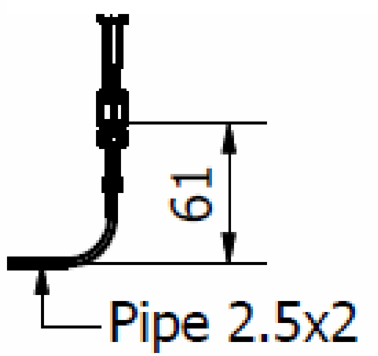
DETAIL OF THE STAVE COOLING INLET CONNECTION PIPE WITH INCORPORATED ORIFICE

one hypothesis under consideration

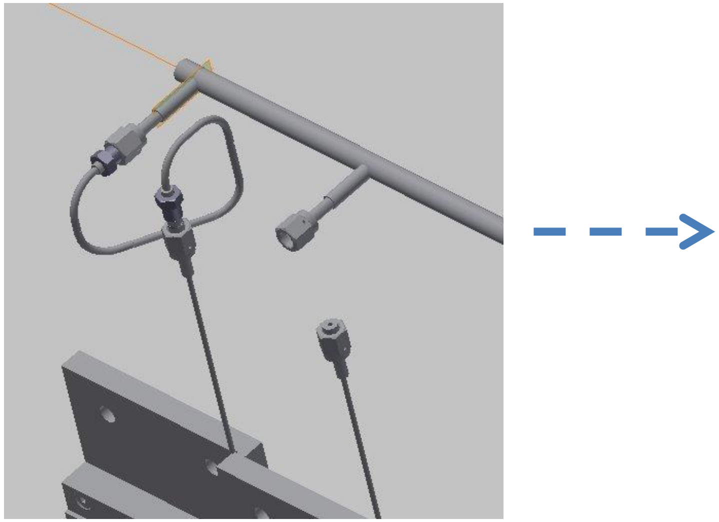




Micro-TIG joints details



COOLING CONNECTION DESIGN



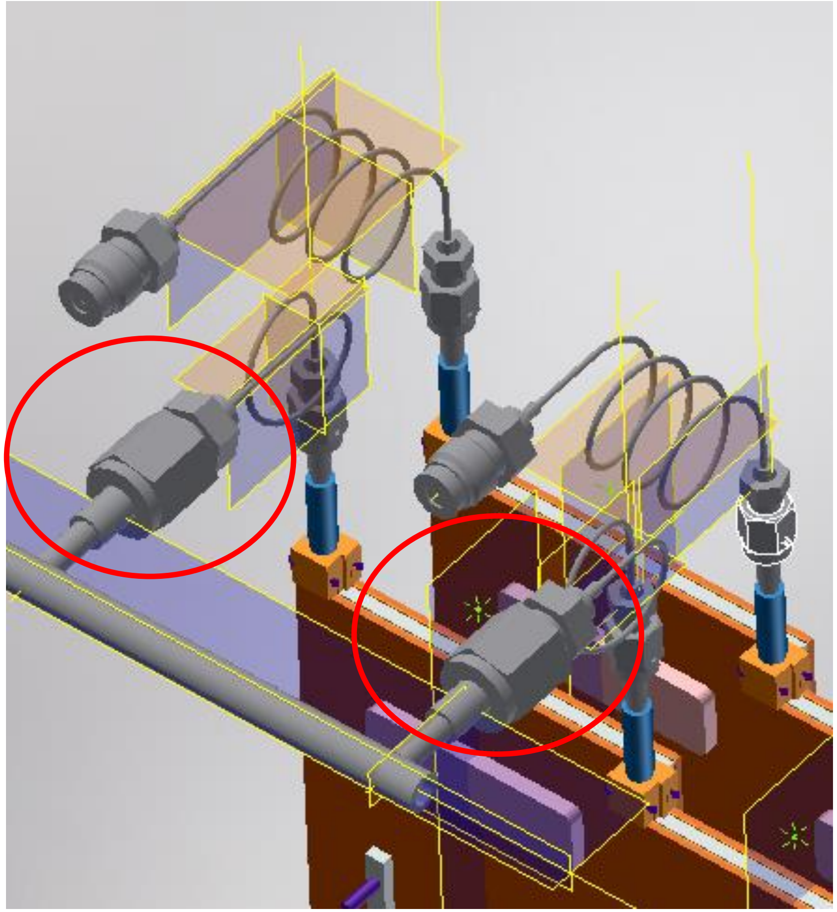
Study of the outlet

Possible routing of the outlet cooling pipe connection
With one or two coils
To be checked what the available space allows

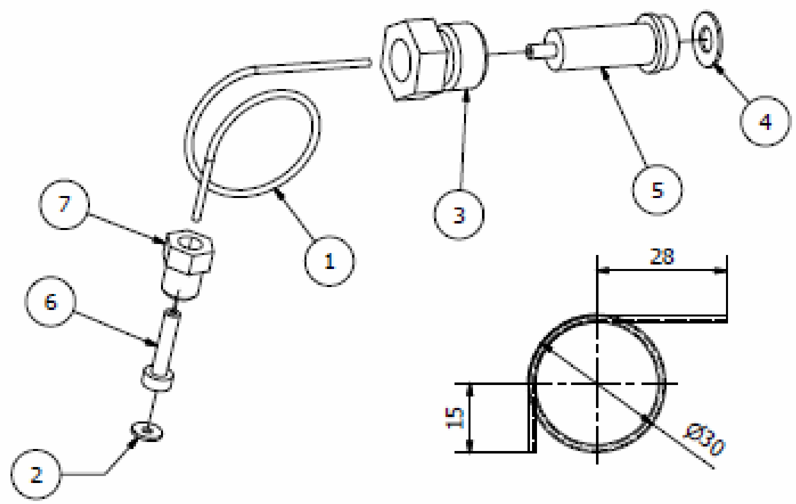
COOLING CONNECTION DESIGN

Study of the outlet

Using detachable ¼ “ VCR on manifold side



COOLING CONNECTION DESIGN



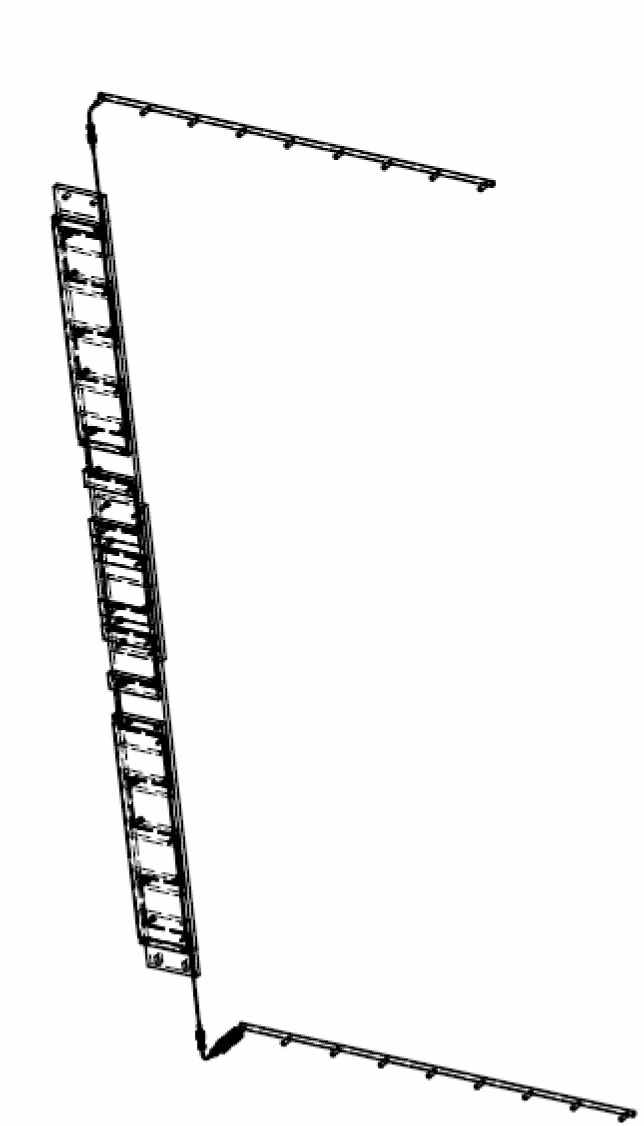
NOTE: item 1 - tubo AISI 304 - 2x2.5 mm
item 5/6 - componenti Swagelok modificati (foratura e sede tubo)

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Part1_outlet_lunga	
2	1	SS_2_VCR_2_21751	
3	1	SS-4-VCR-4	
4	1	SS-4-VCR-2	
5	1	SS-4-VCR-3_BL-modif_pipe_1.58	
6	1	SS-1-VCR-3	
7	1	SS-2-VCR-4	

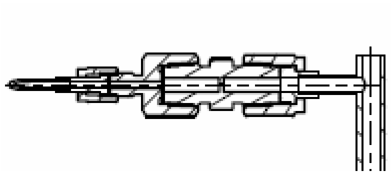
Designed by	Checked by	Approved by	Date	Date	
carlo				07/09/2015	

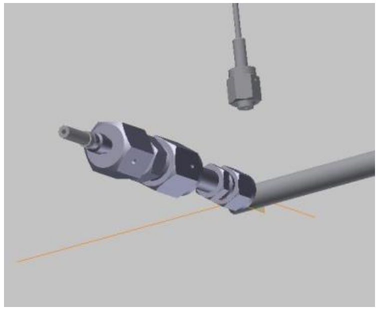
		Edition	Sheet
Assieme tubazione uscita linea 1/16"	Stave.00.01.10idw		1 / 1

COOLING CONNECTION DESIGN



1/16 inch S.S. annealed pipe





Calibrated orifice