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Program - Project - Job: **US – LHC DFBX**

Title: **DFBX Piping Thermal Contraction and Thrust Loads Analysis**

SUMMARY
This note reviews the thermal contraction of the pipes in the DFBX under various cool down scenarios and addresses the thrust loads resulting from various pressure conditions under test. Local supports sustain thrust loads and provide stability in areas where flex-hose or bellows break the pipe run. The thermal contractions were found to be acceptable for all test and operating conditions of the DFBX.

DISCUSSION
The piping assembly drawings for DFBXA, B, D and H, E, and F are 25I872, 25I871, 25I235, 25I873, and 25I874. DFBXC and G share the piping assembly drawing, 25I226. Boxes C and G at locations IP2 and IP8 have the most complex piping configuration. They were chosen for the initial pipe thrust analysis as they represent the most challenging routing and support conditions.

The warm locations of the pipes were determined from the cold position requirements at each of the magnet interfaces, taking into account the thermal movement of the cold masses for both the D1 and Q3 magnets. The interconnect location for each pipe was determined for the LQXC interface and the LBX interface for each DFBX. The QRL pipe end locations were not included since the jumper interconnections have flexible hoses at every pipe and the DFBX pipe end thermal contractions are well below the ± 10 mm of adjustment margin required by the interface specification.[1]

The thermal contraction for each of the pipes in the DFBX is calculated assuming linear thermal contraction and an average expansion coefficient of 0.3% for 304 Stainless Steel[2] for the temperature range from room temperature to 2K. These calculations predict thermal displacement based on a simple point-to-point length change for each pipe using the support location as a fixed point and assuming free thermal contraction at the ends.

For the thrust load analysis, the final configuration of each pipe was considered for stability and the need for thrust support. Wherever feasible in the revised pipe design, bellows were replaced by flexible hoses in appropriate locations along the pipe run to permit thermal contraction of the pipe and minimize thrust loads. Table I lists the pressure conditions for operation and testing for all of the piping. Bellows are used only on pipes Xb, the pumping line, and the bus ducts for the Q3 and D1 magnets, MQX1 and MBX1, respectively. The Xb thrust load is reacted by the vertical wall of the DFBX vacuum vessel via support brackets on the Xb line. (See Vacuum Vessel Note [1].) The thrust loads from the bus ducts are reacted by a support bracket mounted to the top of the helium vessel. (See Helium Vessel Note [2].)

[1] LHC-DFBX-ES-0240 rev. 1.1, J. P. Zbasnik, p. 13, LBNL, 2001.
[2] Cryogenic Engineering, R.B. Scott, p. 333, Met-Chem Research, 1963 edition reprinted 1988.

TABLE I. Pressure ratings of DFBX Components

Piping Subsystem	Nominal Pressure (bar)	Design Pressure (bar)	Test Pressure (bar)
Pumping Connections to Header B	0.016	4	5
Magnet Connections to Header C	3.6	20	25
Magnet Piping to Header D	1.3	20	25
Thermal Shield Piping to Headers E, F	19.5	22	27.5
lHe Chamber and HTS Lead Connections	1.3	3.5	4.4

RESULTS

Table A-I in the Appendix is a spreadsheet detailing the predicted thermal contractions for each pipe. The X and Z warm positions were derived from the cold positions at the interconnect. The Y-locations were determined by applying the thermal contractions to the warm Y-locations of the pipes. The contractions at the QRL interface were not considered as there is flexhose at all QRL pipe connections accommodating any transverse offset. For pipes with a significant vertical run from the QRL's the changes are generally taken up by flexhose in the intermediate section of the pipe. Warm and cold locations of the piping for all DFBX assemblies are tabulated in the D1, Q3 and QRL interface specifications. [3-5]

CONCLUSIONS

Although most of the cryo-pipes are supported together at the QRL heat shields, thermal contractions due to various cool down conditions are effectively uncoupled by the use of flexhose in each of the pipes. The bus duct assembly is the only exception to this design. Its thermal contraction relative to the helium tank is considered in the helium vessel analysis [2]. The predicted thermal contractions of the pipes under the most extreme test conditions were found to be acceptable. The thrust loads under test pressures are minimized and supported by thrust load brackets. The thermal contractions in the X-Z-plane for several of the pipes are predicted to be greater than the ± 2 mm limit. However, these pipes have a short section of flexible hose near the pipe end to facilitate interconnection and allow greater mismatch in the transverse plane.

REFERENCES

1. Vacuum Vessel Analysis, Engineering Note M8034, M. Bjork, C. A. Corradi, J. P. Zbasnik.
2. Helium Vessel Analysis, Engineering Note M8036, S. Virostek.
3. LHC Engineering Specification, "Interface Specification: Inner Triplet Feedboxes DFBX to LQX," LHC-DFBX-ES-0210.
4. LHC Engineering Specification, "Interface Specification: Inner Triplet Feedboxes DFBX to LBX", LHC-DFBX-ES-0230.00.
5. LHC Engineering Specification, "Interface Specification: Inner Triplet Feedboxes DFBX to QRL", LHC-DFBX-ES-0240.00

Appendix

Table A-I. Thermal Contraction of DFBX Pipes

Pipe	Sup't loc. Z (mm)	Sup't loc. Y (mm)	Sup't loc. X (mm)	warm Z (mm)	warm Y (mm)	warm X (mm)	Δ Y (mm)	Δ X (mm)	Δ Z pipe (mm)	Δ Z total w/suppt	α = 0.3%
CC3 25I217*	807.7	-2100.6	58.7	-197.4	-2800.0	167.3	2.1	-0.3	3.0	1.6	D1 end
CY2 25I215*	807.7	-2029.7	0.0	131.0	-2800.0	0.0	2.3	0.0	2.0	0.7	D1 end
E2 25I214*	807.7	-2033.6	0.0	-228.5	-2479.5	-166.6	1.3	0.5	3.1	1.7	D1 end
Ex 25I212	75.0	-1737.9	-389.6	-252.2	-2479.5	163.8	2.2	-1.7	1.0		D1 end
LD1 25I223	807.7	-426.6	0.0	-90.9	-2524.5	212.3	6.3	-0.6	2.7	2.0	D1 end
MBX1 25I213	-253.6	-1973.0	0.0	-134.2	-2481.0	0.0	1.5	0.0	-0.4	-1.9	D1 end
MBX2 25I219	306.1	-1414.9	-31.8	-82.5	-2790.0	98.0	4.1	-0.4	1.2		D1 end
V 25I206	0.0	-1264.2	0.0	0.0	-2532.5	0.0	3.8	0.0	0.0		D1 end
XB 25I211	443.2	-333.6	-230.5	-90.9	-2515.0	-212.3	6.5	0.1	1.6		D1 end
CC2 25I216*	807.7	-2033.6	-38.1	-299.0	160.0	-44.3	-6.6	0.0	3.3	2.0	Q3 end
KD2 25I520*	807.7	-2126.6	-159.4	-278.3	160.0	130.4	-6.9	-0.9	3.3	1.9	Q3 end
CC3 25I524*	807.7	-2100.6	0.0	-299.0	160.0	44.3	-6.8	-0.1	3.3	2.0	Q3 end
CY1 25I210	376.9	-269.0	0.0	360.0	160.0	0.0	-1.3	0.0	0.1		Q3 end
E1 25I209	807.7	-283.6	-58.6	75.0	160.0	389.6	-1.3	-1.3	2.2	1.5	Q3 end
Ex 25I212	75.0	-398.8	-389.6	75.0	160.0	-389.6	-1.7	0.0	0.0		Q3 end
LD2 25I208	807.7	-240.6	-63.9	277.5	160.0	240.0	-1.2	-0.9	1.6	0.9	Q3 end
MQX1 25I205	-269.4	-266.7	0.0	-150.0	160.0	0.0	-1.3	0.0	-0.4	-1.9	Q3 end
MQX2 25I301	280.7	-1132.1	31.6	0.0	160.0	150.0	-3.9	-0.4	0.8		Q3 end
V 25I206	0.0	-1264.2	0.0	0.0	51.6	0.0	-3.9	0.0	0.0		Q3 end
XB 25I220	376.9	-337.5	67.5	376.9	160.0	0.0	-1.5	0.2	0.0		Q3 end
XB 25I253	277.5	384.4	-125.7	-172.0	2515.0	-124.0	-6.4	0.0	1.3		D1 end
CY2 25I239*	807.7	2033.6	41.9	105.0	2800.0	150.0	-2.3	0.3	2.1	0.7	D1 end
LD1 25i245	807.7	426.6	-23.4	-89.5	2524.5	-211.1	-6.3	0.6	2.7	2.0	D1 end
V 25I252	0.0	1264.2	0.0	0.0	2532.5	0.0	-3.8	0.0	0.0		D1 end

Pipe	Sup't loc. Z (mm)	Sup't loc. Y (mm)	Sup't loc. X (mm)	warm Z (mm)	warm Y (mm)	warm X (mm)	Δ Y (mm)	Δ X (mm)	Δ Z pipe (mm)	Δ Z total w/suppt	α = 0.3%
CC3 25I238*	807.7	2100.6	-58.7	-197.4	2800.0	-167.3	-2.1	0.3	3.0	1.6	D1 end
E2 25I243*	807.7	2033.6	0.0	-225.4	2479.5	165.4	-1.3	-0.5	3.1	2.4	D1 end
MBX1 25I247	-680.3	1973.0	0.0	-134.2	2425.2	0.0	-1.4	0.0	-1.6	-3.2	D1 end
MBX2 25I249	306.1	1414.9	-31.8	-81.1	2790.0	97.3	-4.1	-0.4	1.2		D1 end
XB 25I253	807.7	333.6	-7.9	277.5	-160.0	-240.0	1.5	0.7	1.6	0.9	Q3 end

QRL spider offset for pipes supported there

nema	length	6	152.4	nema alpha	0.002	delta Z	0.3048	
hat sec'n	length	5.625	142.9	cu alpha	0.003	delta Z	0.428625	
total delta Z		0.733425	downward		Δ Z	-0.7		
nema*	length	18.5	469.9	nema alpha	0.002	delta Z	0.9398	
total delta Z		1.368425	downward		Δ Z	-1.4		

Helium tank offset for bus duct offsets

radius of tank	approx.	10	254	ss alpha	0.003	delta Z	1.524	(factor of 2 because tank is constrained
			downward		Δ Z	-1.5		at bottom surface

Ex offset	shield top width	33.9	861.06	cu alpha	0.003	delta X	1.3	toward center
	helium tank contraction length	57.2	1452.88	Δ Y		2.2	toward tank center	

Bus duct support Z-coordinate

length in Z	4.7	119.38
MBX z	-253.58	
MQX z	-269.38	

* lower side of top plate