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Discussion Regarding the Maximum Allowable Air-Cooled Heat Exchanger Nozzle Loads

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ABSTRACT: *The allowable nozzle loads as stated in table 4 of API 661[1] and ISO 13706 [2] are just the commonly accepted and agreed-upon values determined from the practicality and economics of the air cooler. In practice, however, it appears that it is difficult to keep the piping reactions below the allowable values. This is why engineering contractors and operating companies often increase the maximum allowable nozzle loads according to Table 4 by a load factor of 2 to even 3. The effects of the factor 2 to 3 on top of the maximum allowable nozzle loads according to table 4 have been investigated.*

KEYWORDS: *nozzle loads, air cooler, piping reactions, load factor.*

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I. INTRODUCTION

The standard approach is that each nozzle, in its corroded condition, shall be capable of withstanding the simultaneous application of the moments and forces specified in Figure 6 and Table 4 of API 661 / ISO 13706. Increased loads beyond those in Table 4 may only be applied if calculations are performed to demonstrate the integrity of the nozzle flange under the combined action of design pressure and externally applied loads. Moreover the calculation methods applied should appropriate for the geometry of the nozzle and the nozzle-to-header attachment In practice, however, it appears that the stresses due to external nozzle loads at the nozzle-header intersection are not decisive, which is why this investigation is focused on the nozzle flange connection rather than on the nozzle intersection.

II. SELECTION

Selection of the nozzle sizes and rating classes to be investigated are shown in Table 1.

Flange rating class [4]	Nozzle size NPS/DN	Nozzle neck thickness Schedule/mm [5]	Gasket type SPW/RTJ [6]
150	6/150	XS-80/10.97	SPW
300	6/150	XS-80/10.97	SPW
600	6/150	XS-80/10.97	SPW
900	6/150	120/14.27	SPW
1500	6/150	XXS/21.95	RTJ
2500	6/150	LWNF / 33.35	RTJ

Table 1

III. EXTENT OF FLANGE LOAD VERIFICATION

Loads are considered two times the moments and forces defined in Figure 6 and Table 4 of API / ISO 13706. Verification will be performed for a flanged nozzle DN (NPS) 150 (6) class 150 up to and including class 1500 welding neck flange made of A350 LF2 or A105 carbon steel with the exception of class 2500 for which a long welding neck flange (LWNF) is provided (Flange ID = 168.3 mm and Hub OD = 235 mm).

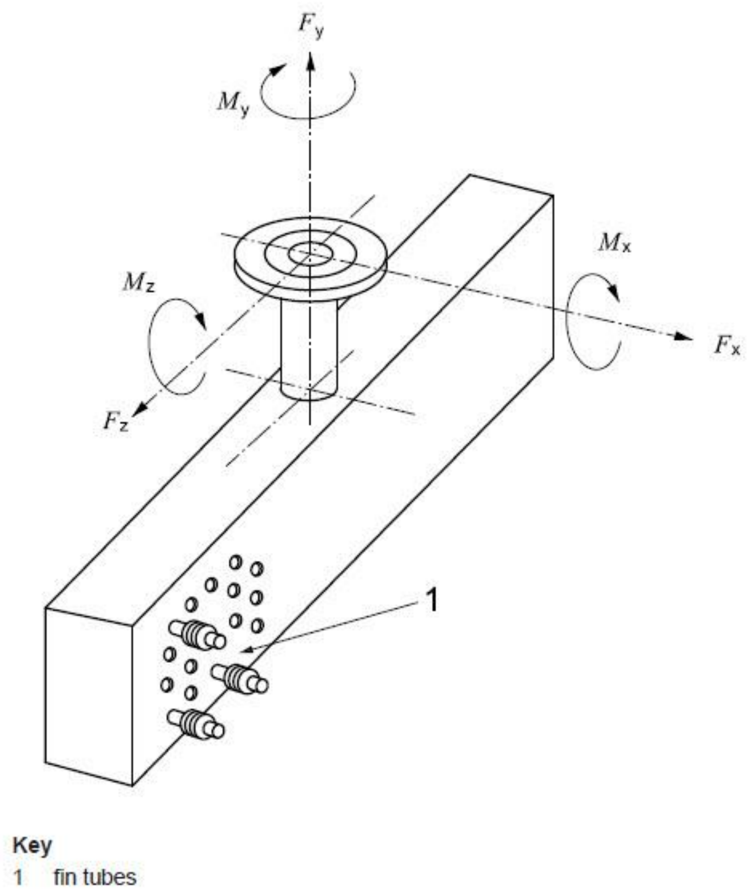


Figure 1 Nozzle configuration with loadings. (This figure is identical to Figure 6 of API 661 / ISO 13706)

Loadings according Table 4 of API 661 / ISO 13706

DN (NPS)	M_x (Nm)	M_y (Nm)	M_z (Nm)	F_x (N)	F_y (N)	F_z (N)
150 (6)	2140	3050	1630	4000	5030	5030

Table 2

Increased loadings by a factor 2

DN (NPS)	M_x (Nm)	M_y (Nm)	M_z (Nm)	F_x (N)	F_y (N)	F_z (N)
150 (6)	4280	6100	3260	8000	10060	10060

Table 3

Observation: Maximum allowable nozzle loads does not depend on rating class or material, but only on nozzle size.

IV. APPROACH

Equivalent bending moment

$M_e = 0.5 [M + (M^2 + T^2)^{½}]$
where: $M = (M_x^2 + M_z^2)^{½}$ and $T = M_y$

Equivalent pressure converted from imposed loads F_y and M_e (ignoring shear forces F_x and F_z)

$P_{eq} = [(4/\pi G^2) (F_y + 4 M_e / G. K_f)]$ [3]
where:
G = diameter at location of gasket load reaction as per ASME
K_f = optional auxiliary factor (Koves Factor) which is in fact a moment correction factor that smooth the effect of bending moments.

$K_f = 1 + [(\text{flange thickness})^2 + (\text{flange width} - \text{corrected bolt diameter})^2] / 2.6 (\text{flange thickness})^2$

Note that in case F_y is a compression force, F_y can be left out of consideration. However, for reasons of conservatism, the verification calculations assume that F_y is a tensile force that actually pulls the flanges apart instead of pressing each other. Moreover this is justifiable since the contribution of the moment is considerably greater than the force on the equivalent pressure.

Calculation equivalent bending moment for increased loading

$M = (4280^2 + 3260^2)^{1/2} = 5380$ Nm

$T = M_y = 6100$ Nm

$M_e = 0.5 [5380 + (5380^2 + 6100^2)^{1/2}] = 6757$ Nm

Compilation of flange data required for the determination of the "Koves" factor K_f

Flange rating class	Flange ID (mm)	Flange OD (mm)	Flange thickness (mm)	Bolt hole diameter (mm)	Corrected bolt hole diameter (mm) *	Koves factor K_f
150	146.36	280	25.4	22.3	19.036	2.745
300	146.36	320	35.0	22.3	19.036	2.827
600	146.36	355	47.7	28.6	24.414	2.464
900	139.76	380	55.6	31.8	27.356	2.455
1500	124.4	395	82.6	38.1	33.360	1.970
2500	168.3	485	108.0	54.0	44.912	1.832

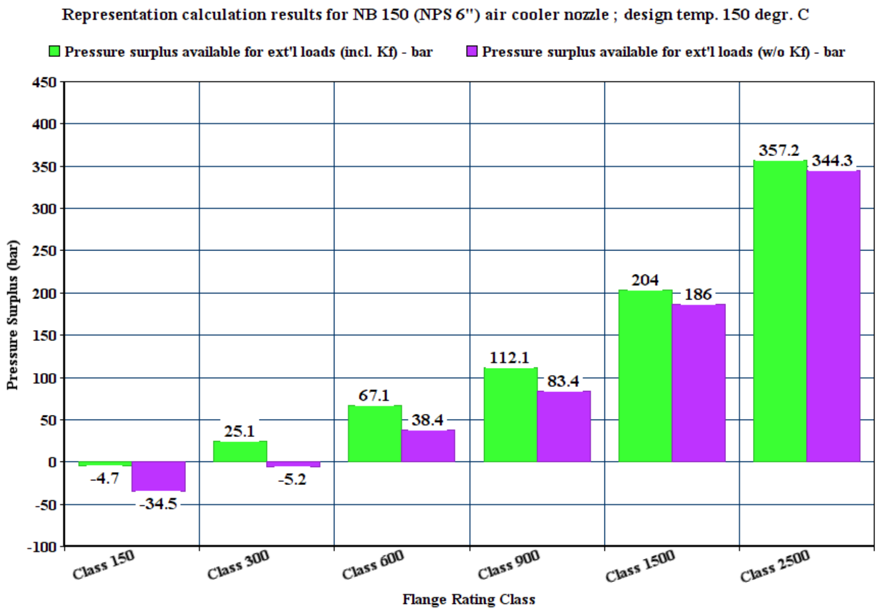
Table 4

* Corrected bolt hole diameter is : max [(1 – flange ID / 1000) bolt hole diameter ; 0.5 bolt hole diameter]

ASME B16.5 Class	G = Diameter at location of gasket load reaction (mm)	Auxiliary " Koves" factor	Equivalent pressure (MPa) / (bar)	Rated pressure @ 150 °C according ASME B16.5 (bar)	Ratio of rated pressure to the Equivalent pressure	Pressure surplus available for external loads (bar)
150	194.25	2.745	2.05 / 20.5	15.8	0.771	- 4.7 (!)
150	194.25	1.0	5.03 / 50.3	15.8	0.314	- 34.5 (!)
300	194.25	2.827	2.00 / 20.0	45.1	2.255	25.1
300	194.25	1.0	5.03 / 50.3	45.1	0.897	- 5.2 (!)
600	192.39	2.464	2.31 / 23.1	90.2	3.905	67.1
600	192.39	1.0	5.18 / 51.8	90.2	1.741	38.4
900	192.39	2.455	2.31 / 23.1	135.2	5.853	112.1
900	192.39	1.0	5.18 / 51.8	135.2	2.610	83.4
1500	211.15	1.970	2.14 / 21.4	225.4	10.533	204
1500	211.15	1.0	3.94 / 39.4	225.4	5.721	186
2500	228.60	1.832	1.82 / 18.2	375.6	20.637	357.2
2500	228.60	1.0	3.13 / 31.3	375.6	12.000	344.3

Table 5

(!) A negative value means that the nozzle flange connection cannot withstand a combination of simultaneous acting maximum allowable moments and forces with any internal design pressure. This demonstrates the criticality of specified maximum allowable nozzle loads for class 150 and class 300 connections.



V. CONCLUSION

A statement that each nozzle shall be capable of withstanding the simultaneous application of **two times** the moments and forces defined in Figure 6 and Table 4 must certainly not be applied for class 150 nozzle connections while this should be avoided for class 300 nozzle connections on air cooler headers unless rigorous analysis leads to different insights. Normally, a ratio of more than 2 ensures a sufficient margin for external loads. Although limited verifications are performed it seems that class 600, 900, 1500 and 2500 [up to DN 300 (NPS 12)] are capable to withstand the upgraded loads by a factor of two and could even a higher factor (e.g. 3) be considered.

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