Título (Title):	**OPERATING TEMPERATURES OF MK D/E AND MK B COILS 101B REFORMER**
Author :	**OSCAR OLATTE – SOIL INGENIERÍA**

1. Summary

A review of the design conditions and current state of the materials of the MK-B (Hot feed gas), MK-D/E (Cold feed gas/IP Steam superheater) coils and connection piping between the two gas coils was carried out, to determine the maximum permissible operating temperatures. All the described parts are in the convection section of a MW Reformer.

Included are the graphs and diagrams that allow setting the maximum operating temperatures of metal for all the aforementioned components, considering the accumulated time in service.

2. Equipment or system information

Coil MK-B: Hot feed gas.

Material: ASTM A-312 TP 304H
Thickness: Sch 40 (6.02 mm)
Diameter: 114.3 mm
Design Pressure: 35.2 Kg/cm^2
Design Code: API RP 530

Coil MK D/E: Cold feed gas / IP Steam superheater

Material: SA-106 Gr B
Thickness: Sch 40 (7.11 mm)
Diameter: 168.3 mm
Design Pressure: 35.2 Kg/cm^2
Design Pressure: API RP 530

Piping de conexión entre MK-E y MK-B, NG-1006-14" (3P1) AH

Material: ASTM A-53 B Type E
Thickness: Sch STD (9.52 mm)
Diameter: 355.6 mm
Design Pressure: 35.2 Kg/cm^2
Design Pressure: ASME B31.3

Estimated consumed useful life, from 1989 to 2007: **157,680 hrs.**

3. Description of Events and History

During the revamping of the reformer executed during the year 1999, the following works were carried out on these coils:

Coils MK-D y E:

In the revamping carried out in 1999, reinforcement beams were installed under each of the existing supports, thus relieving a large part of the load that was transferred to the beams.
The tubes were not replaced.

Coil MK-B:

The brackets of this coil and the tubes of this coil were not replaced in 1999.
In the case of finned coils, the pipe sections that are supported on the intermediate supports were left without fins to allow free expansion of the tubes.

Connection piping between MK-E and MK-B, NG-1006-14" (3P1) AH.

This piping leg was not replaced.

None of the elements were damaged or failed during the coil failure that occurred prior to the 1999 revamping.

During the inspection work, prior to the start-up of the plant in September 2013, carried out in the area, all the coils were inspected, without finding of failures or damages. Likewise, all the coils were inspected during the work carried out in the T/A of 2006 concluding that their condition was appropriate for the service.

4. Study

Regarding the design codes, it can be said that both the MK-B and MK-D/E coils are designed to operate in the creep range. As for the NG-1006-14" connection piping section, it does not operate in the creep range and is governed by the static stresses determined by the ASME B31.3 code.

The fact that both coils are governed by API RP 530, establishes a theoretical design life of 100,000 hours and a degradation mechanism governed by operating pressure and temperature. It is clear that the coils have more than 100,000 hrs. in service at this time, hence the concern about the operation temperature.

The following assumptions were considered for the study:

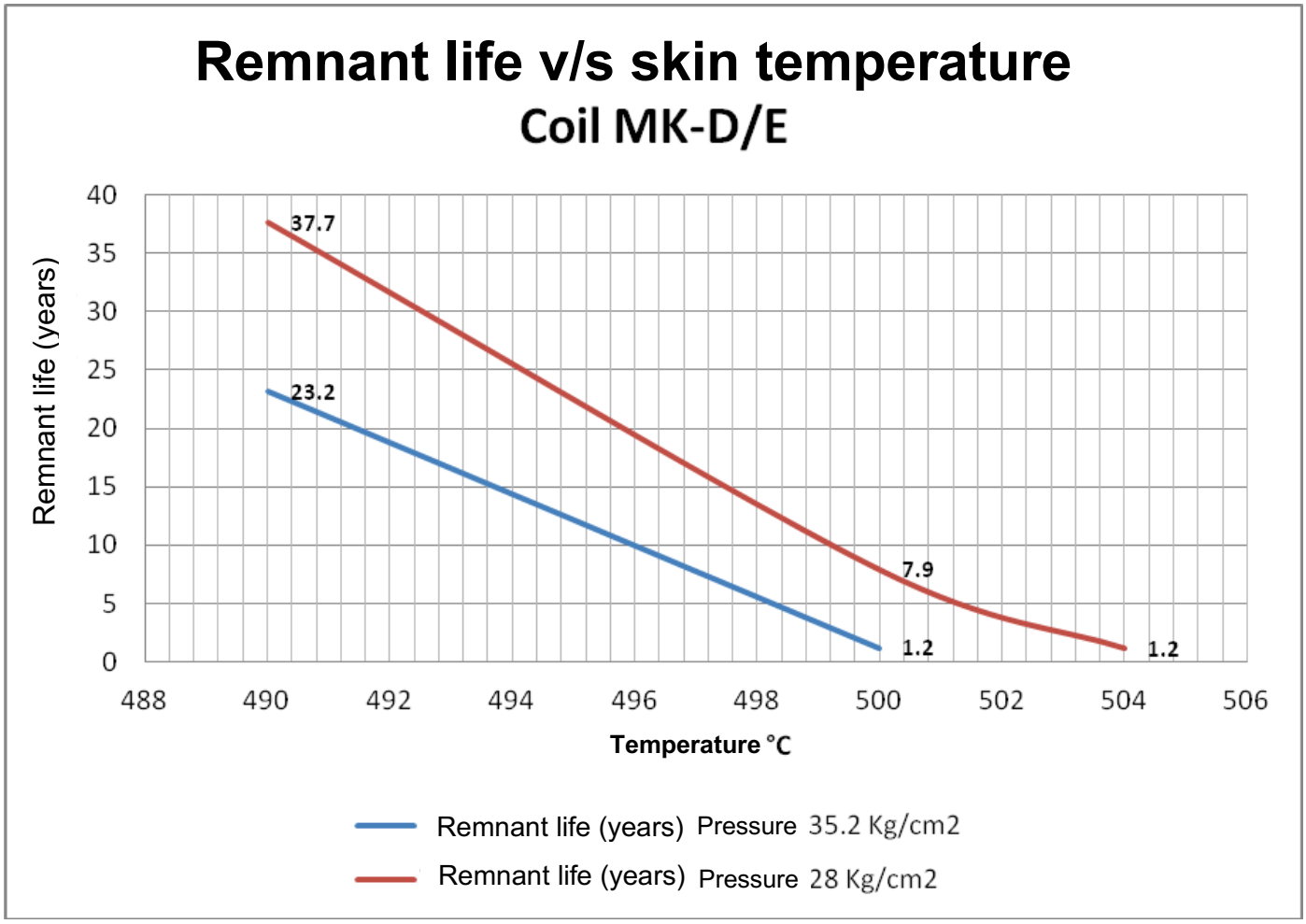
a) Damage accumulated by upsets or transients is not considered.
b) The maximum limit for determining the maximum operating temperature is governed by the design pressure.
c) The normal working pressure is 28.6 Kg/cm^2.

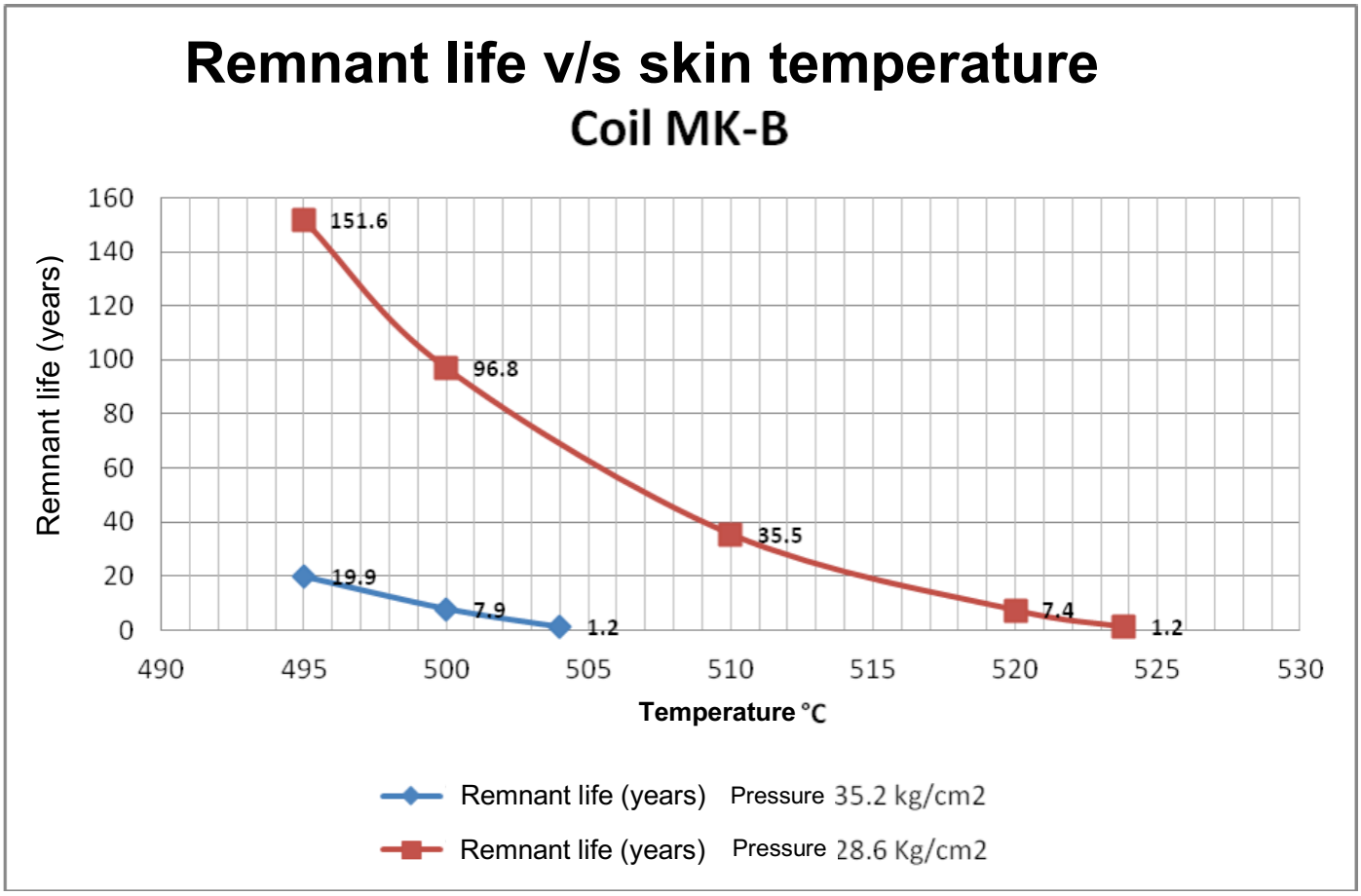
d) The calculations of remaining life consider a slack time for a change of these elements sufficient to study and carry out the project.
e) At a minimum, a time of 2.6 to 3 years of established remaining life is considered, according to the plans, as the period for the next T/A of maintenance.

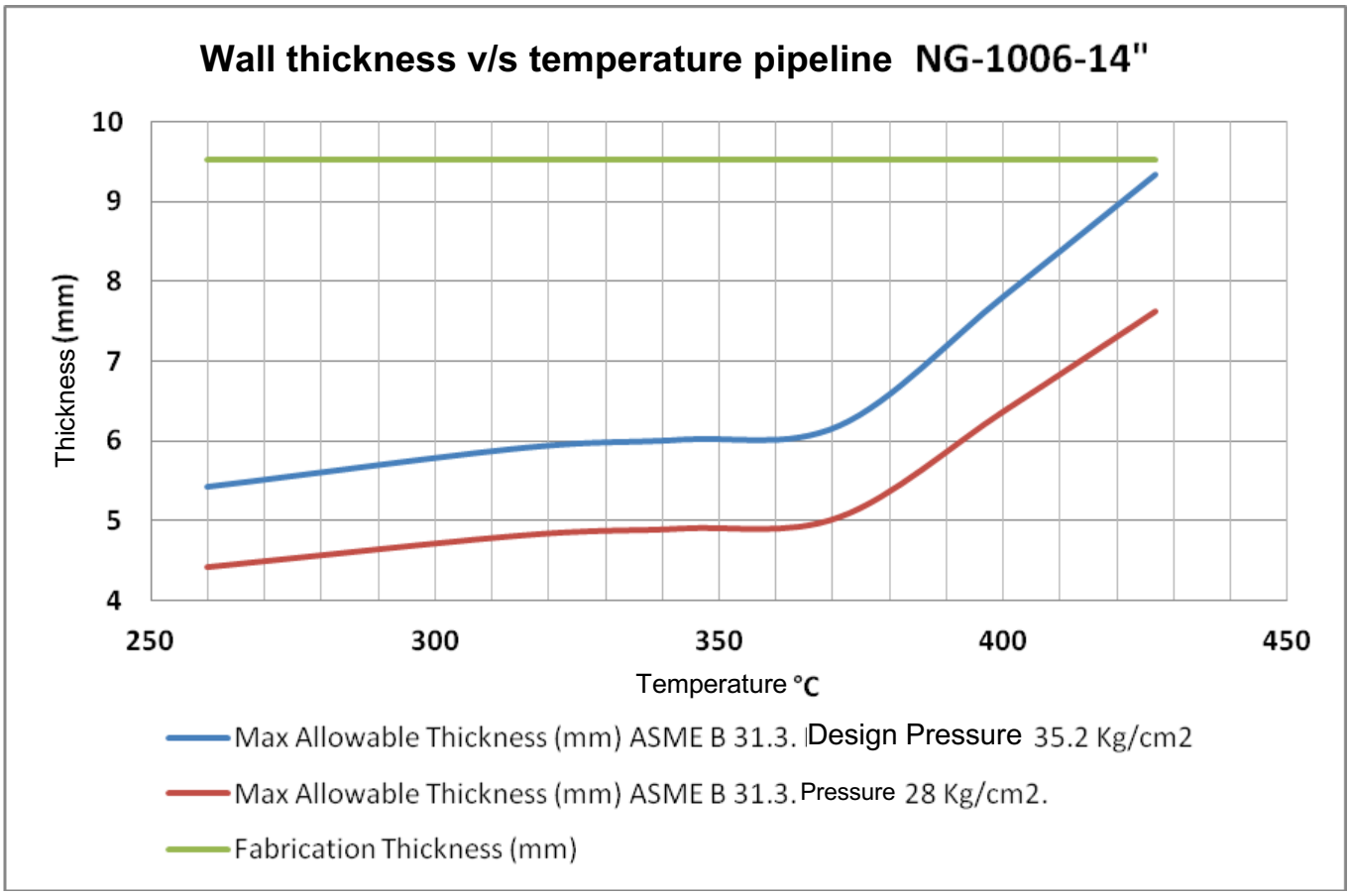
Results:

According to the design codes, maintenance history and future operating conditions the following are the results:

For the two pressures mentioned above, a range of temperatures in relation to the remaining life is generated, for the two coils:

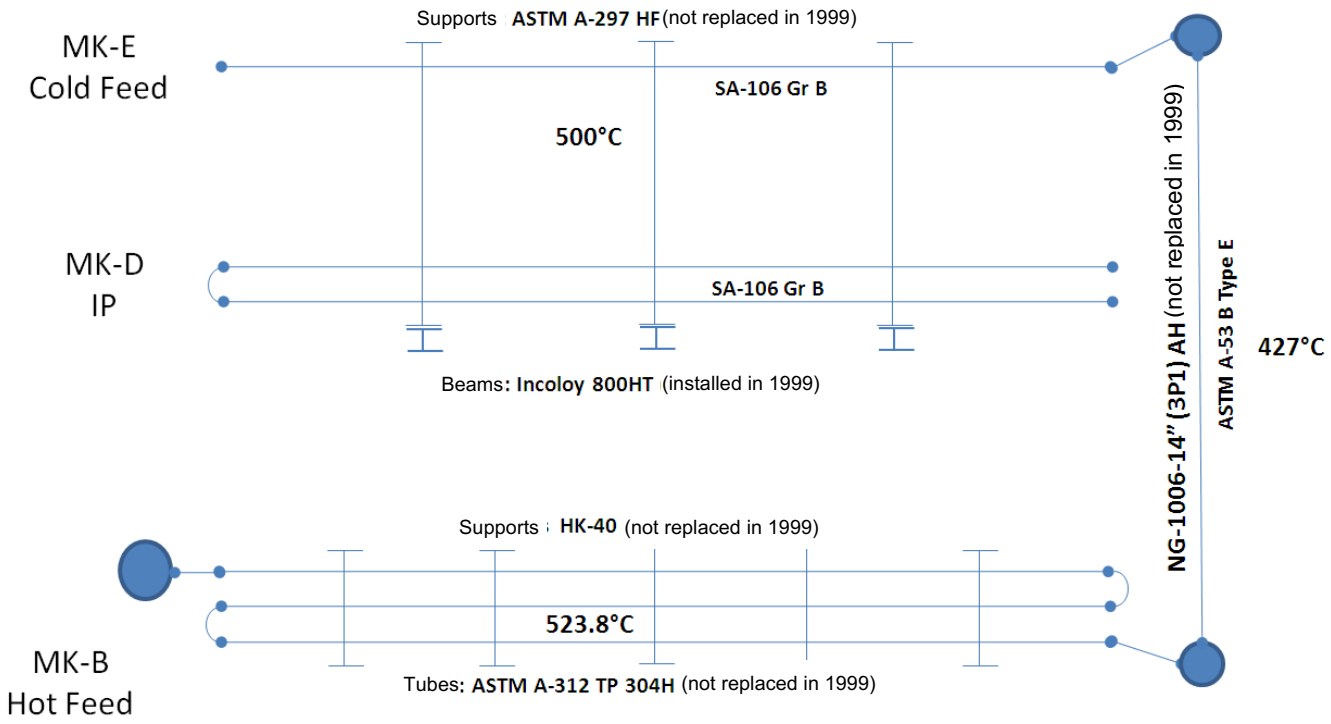



Remnant life v/s skin temperature
Coil MK-B
Remnant life (years)
160
140
120
100
80
60
40
20
0
490
495
500
505
510
515
520
525
530
151.6
96.8
35.5
7.4
1.2
19.9
7.9
1.2
Temperature °C
Remnant life (years) Pressure 35.2 kg/cm2
Remnant life (years) Pressure 28.6 Kg/cm2

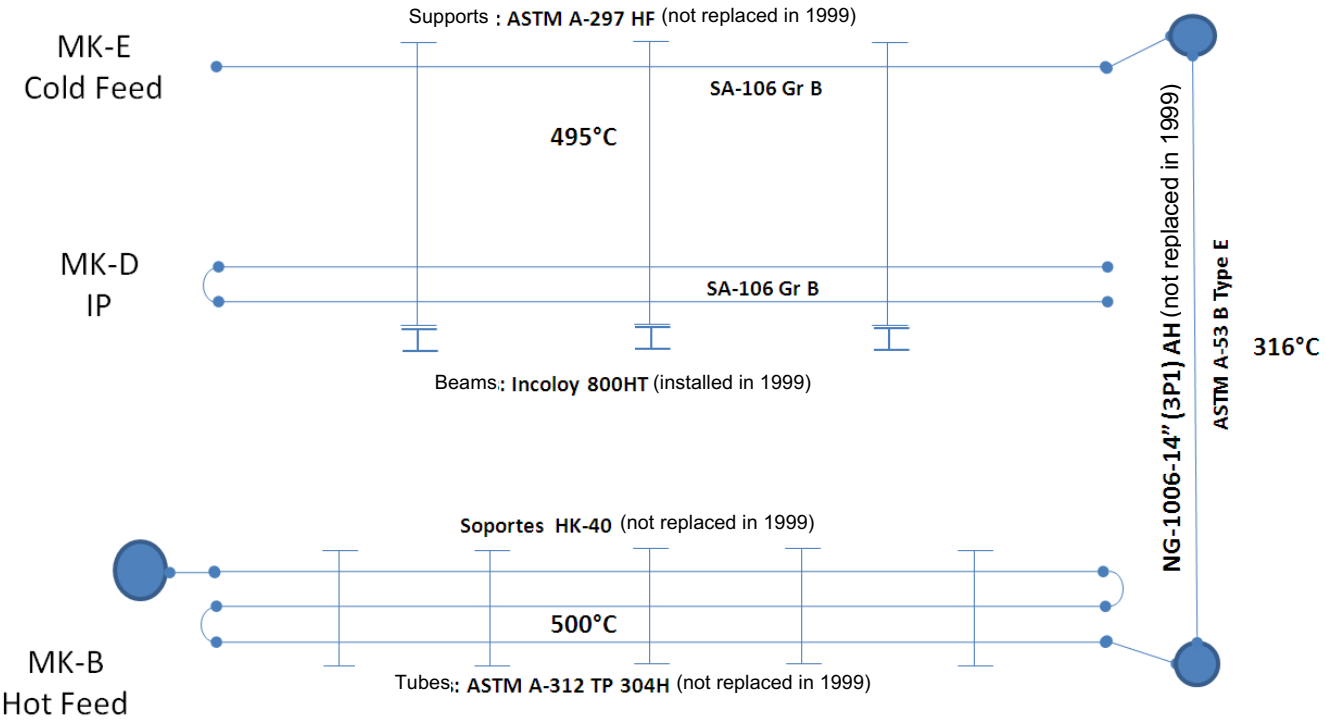


In summary, the following diagrams show the recommended temperatures for the coils for the two pressures considered:

Pressure 28.6 Kg/cm2



Design pressure 35.2 Kg/cm2 (upper limit)



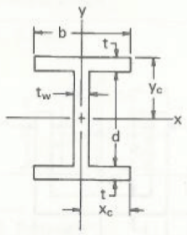
Supports:

MK-D/E coil beams:

For the calculation of the stress to be supported by each beam, it was considered that the intermediate support is relieved and only exerts a load on the beams, together with the tubes.

The following formulas were used for the calculation (ref: Roark's Formulas for Stress and Strain. Young – Budyans, McGraw Hill, Appendix A)

TABLE A.1 Properties of sections (*Continued*)

Form of section	Area and distances from centroid to extremities	Moments and products of inertia and radii of gyration about central axes
6. Wide-flange beam with equal flanges 	$A = 2bt + t_w d$ $y_c = \frac{d}{2} + t$ $x_c = \frac{b}{2}$	$I_x = \frac{b(d+2t)^3}{12} - \frac{(b-t_w)d^3}{12}$ $I_y = \frac{b^3 t}{6} + \frac{t_w^3 d}{12}$ $r_x = \left(\frac{I_x}{A}\right)^{1/2}$ $r_y = \left(\frac{I_y}{A}\right)^{1/2}$

Specs:

Coil MK-D/E:

Beams	Coil MK E/D		
Material	Incoloy 800 H		
Flange thickness	25	mm	t
Number	3		
Flange	200	mm	b
Web	166	mm	d
Half flange thickness	87.5	mm	xc
Half web thickness	108	mm	yc
Web thickness	25	mm	tw

Modulus of elasticity	
2003748	Kg/cm2

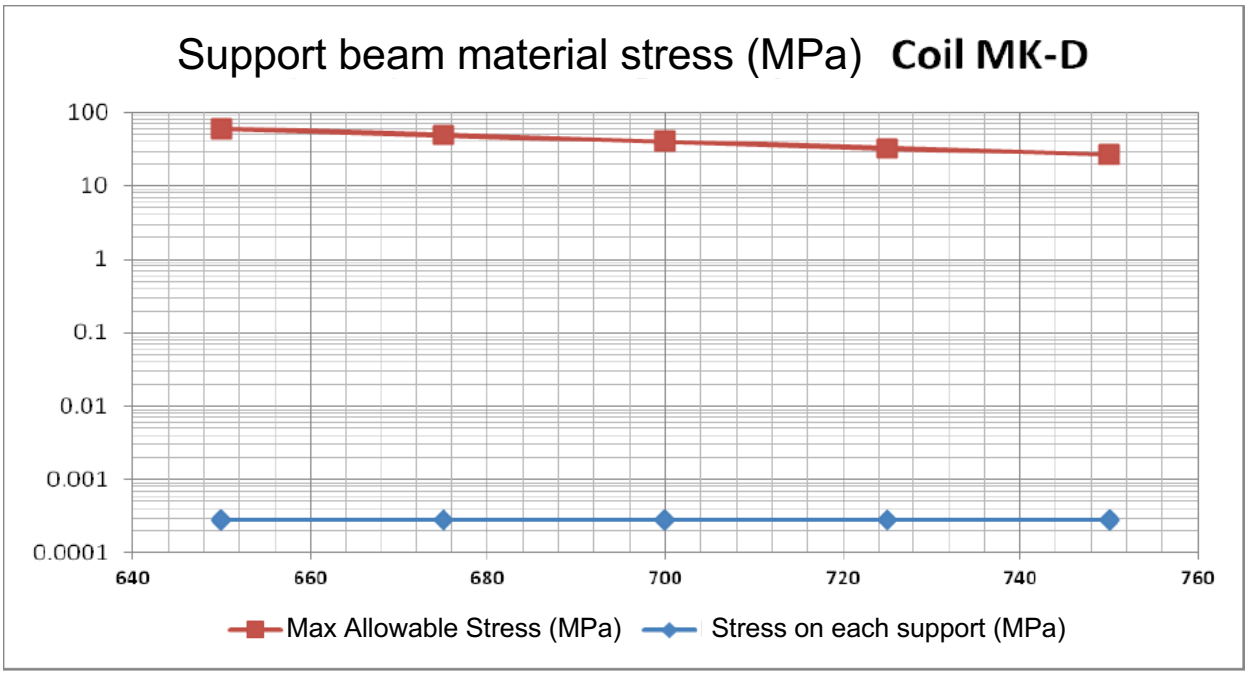
Support weight (1)	**565**	kg
All tubes weight	**23034.77**	Kg
Load on each beam	**8243.26**	Kg

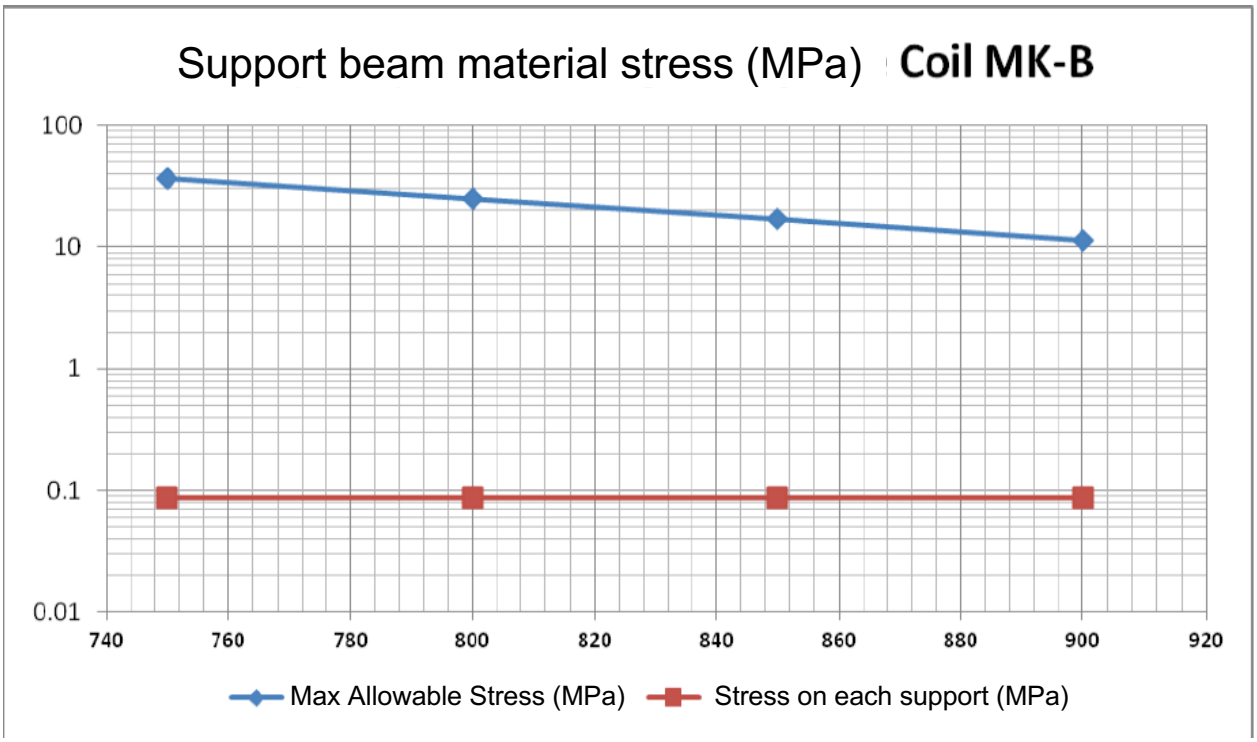
Coil MK-B:

Supports	Coil MK B		
Material	HK-40		
Flange thickness	19	mm	t
Number	5		
Flange	152.8	mm	b
Web	424.7	mm	d
Half flange thickness	62.4	mm	xc
Half web thickness	231.35	mm	yc
Web thickness	28	mm	tw

Modulus of elasticity	
1546753	Kg/cm2

Support weight (1)	**520**	kg
All tubes weight	**34552.15**	Kg
Load on each beam	**12037.38**	Kg





The results show that the supports are subjected to stresses below the maximum allowed for the respective materials:

Coil MK-B:

Inertia Moment (I) cm4	Bending Moment (M) Kg cm at the ends	Vertical distance from neutral axis to q (y) cm	Stress at point q (Kg/cm^2)	Stress at point q (MPa)
1207.42	681556.71	-0.00156	0.8805	0.0864

For this calculation it is assumed that the intermediate support is not supported at both ends to the wall anchor pieces of the convection section.

Coil MK-D/E:

Inertia Moment (I) cm4	Bending Moment (M) Kg cm at the ends	Vertical distance from neutral axis to q (y) cm	Stress at point q (Kg/cm^2)	Stress at point q (MPa)
3354.95	466733.17	-0.00002	0.0029	0.0003

5. Cost analysis/Impact of failure sceneries

Without delving too deeply into this topic, the impact of a failure of both coils imposes a high impact on both the costs associated with repair and those generated by production losses. It is on the basis of these considerations that the assumptions listed in the previous section are assumed.

The only case that can be handled in a prudent time and with a relatively minor impact on costs is the failure of the piping connection of the two natural gas coils.

6. Conclusions

1. Logically, the lower the pressure, the longer the remaining life and the higher the permitted operating temperature.

2. Coil MK D/E: Given the operating conditions of the coil and the material of the reinforcement beams (Incoloy 800HT) it is estimated that the maximum operating temperature, for the stress conditions to which they are subjected, allows them to operate at temperatures well above the effective operating temperatures and maintain their useful life.

3. Coil MK-B. The material of the intermediate brackets is outside the creep range for working temperatures, so failure of these brackets is not expected.

4. The maximum temperatures for normal operation (pressure of 28.6 Kg/cm^2 average) allow metal temperatures in the coils, according to the following table:

Coil	Max. Temperature
MK-B	523.8°C
MK-D/E	500°C
Connecting Piping	427°C

7. Recommendations

1. Process engineering must issue a technical standard establishing the new operating limits. It is suggested to hold a meeting with reliability to agree on the values to be transmitted to operations.

8. Attachments

There's none