S3374
APS In Flange Slits
FEA Report

Written by: A. R. Young

Approved by: S. Syme

FMB Oxford Ltd,
Units 1-4, Osney Mead
Industrial Estate, Oxford

OX2 0ES
UK

Contact: Steve Syme
Telephone: +44 (0)1865 320300
Fax: +44 (0)1865 320301
E-mail Steve.Syme@fmb-oxford.com

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EXECUTIVE SUMMARY

This report covers the FEA work carried out on the In Flange slits, which will be delivered by FMB Oxford Ltd to APS.

A Steady-State Thermal analysis was performed using ANSYS 17.0, where a Gaussian beam of 5W integrated power, FWHM(x)=0.8mm, FWHM(y)=0.54mm, was incident on a Tungsten Blade. The blade is cooled by a Copper braid connected to a Copper cooling pipe, through which is a flow of water.

The result of the Thermal Analysis was imported to a Static Structural Analysis, where the Maximum Principal Stress and Strain were calculated.

The analysis was done twice; for the beam fully incident on the blade and for 50% absorption.

Tables 1 and 2 summarise the results.

Table 1: 100% absorption

	Calculated	Failure Criteria
Tungsten Maximum Temperature	90.08°C	<2257°C
Cooling Wall Maximum Temperature	23.61°C	10°C below the boiling point at given pressure of the cooling water.
Cooling Maximum Heat Flux	0.01W/mm^2	<5W/mm^2
Tungsten Maximum Principal Stress	5.88MPa	<420MPa

Table 2: 50% absorption

	Calculated	Failure Criteria
Tungsten Maximum Temperature	65.19°C	<2257°C
Cooling Wall Maximum Temperature	22.8°C	10°C below the boiling point at given pressure of the cooling water.
Cooling Maximum Heat Flux	0.007W/mm^2	<5W/mm^2
Tungsten Maximum Principal Stress	1.5MPa	<420MPa

1. IN FLANGE SLITS ANALYSIS

1.1 GENERAL DESCRIPTION

The model used for the FEA included only the Tungsten slit blades, the Aluminium housing and the Copper cooling. This is shown in Figure 1.

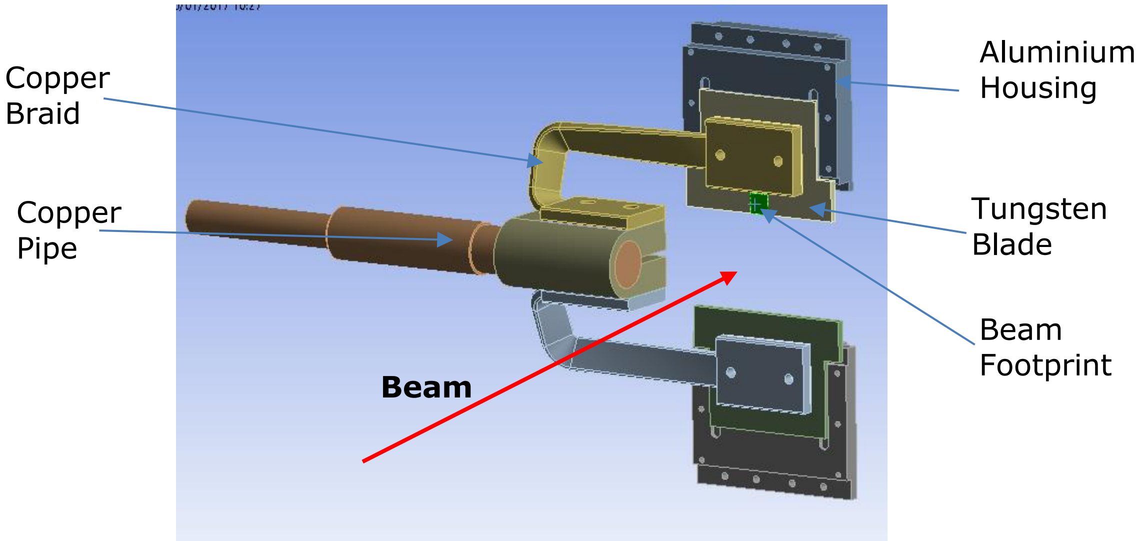

Figure 1. Components used for FEA

1.2 MESHING

The mesh refinement is shown in Figures 2 and 3.

Tungsten Blade: 0.5mm

Beam Footprint: 0.1mm

Copper Braid and Aluminium Housing: 2mm

Copper Pipe: 5mm

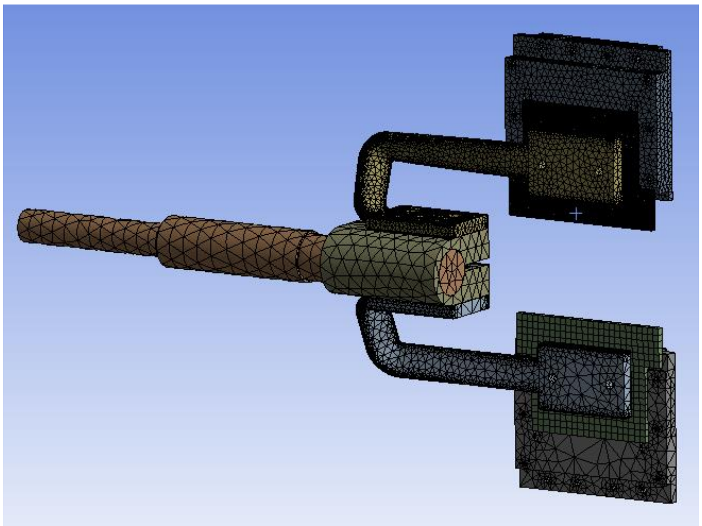

Figure 2. Refined mesh used for analysis

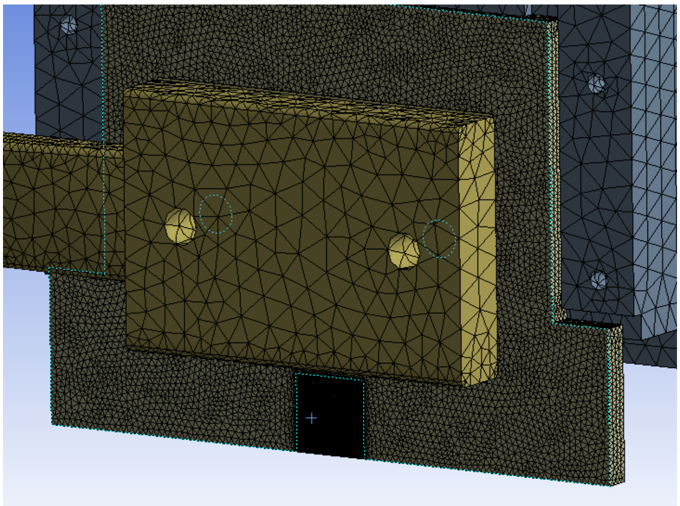

Figure 3. Close up of beam footprint

1.3 INITIAL CONDITIONS

The heat load was applied by use of a split surface on the face of the Tungsten Blade, and was of dimension 6mm x 6mm. The Gaussian profile, supplied by APS, was calculated in Microsoft Excel and was imported to ANSYS to be projected onto the split surface. The shape of the Gaussian is shown in Figure 4. The analyses assume full beam and 50% absorption by the blade, figure 5.

Gaussian Integrated Power = 5W

FWHM(x) = 0.8mm

FWHM(y) = 0.54mm

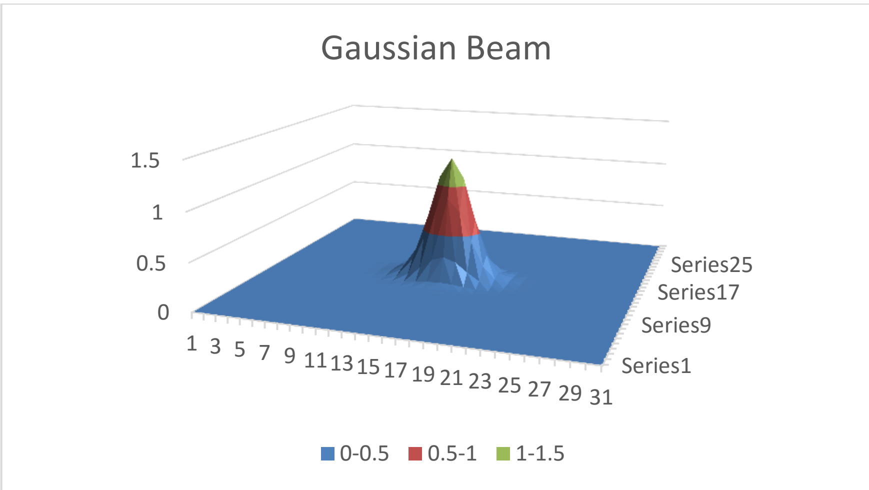

Figure 4. Gaussian Beam Profile

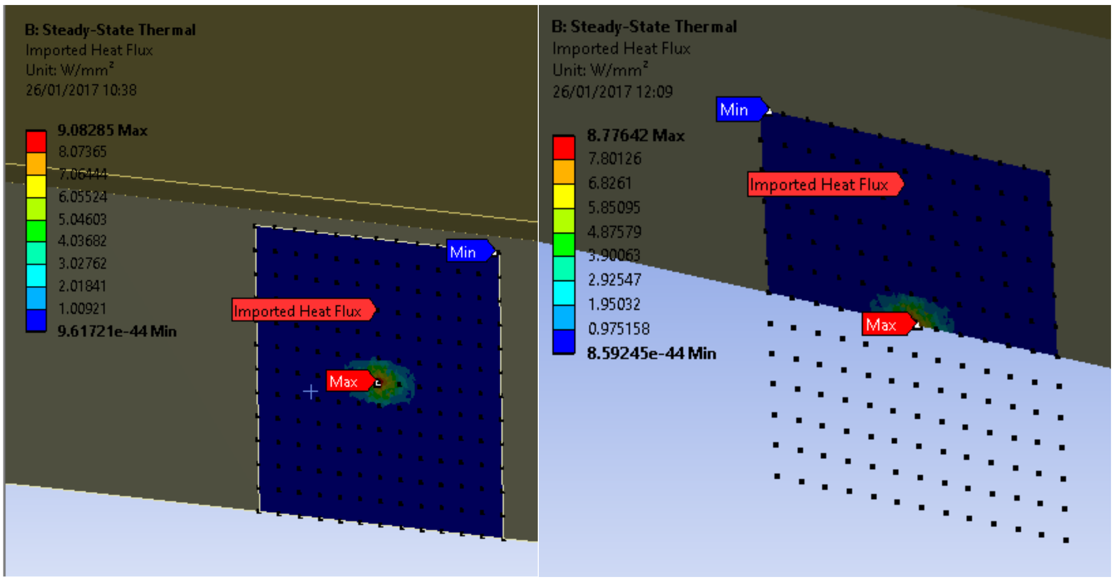

Figure 5. 2D Gaussian Heat Profile for 100% and 50% beam absorption

A cooling path through the model was simulated by creating a heat transfer coefficient at the following interfaces:

- Tungsten Blade to Copper Braid = No Separation, 5000W/m^{2}K
- Copper Braid to Copper Block (block is clamped to cooling pipe) = No Separation, 5000W/m^{2}K
- Copper Block to Copper Pipe = Bonded, 1000W/m^{2}K

Convection to the water from the Copper pipe was simulated by applying a convection coefficient of 3500W/m^{2}K to the inner face of the pipe, Figure 6. The temperature of the water is set to 22°C.

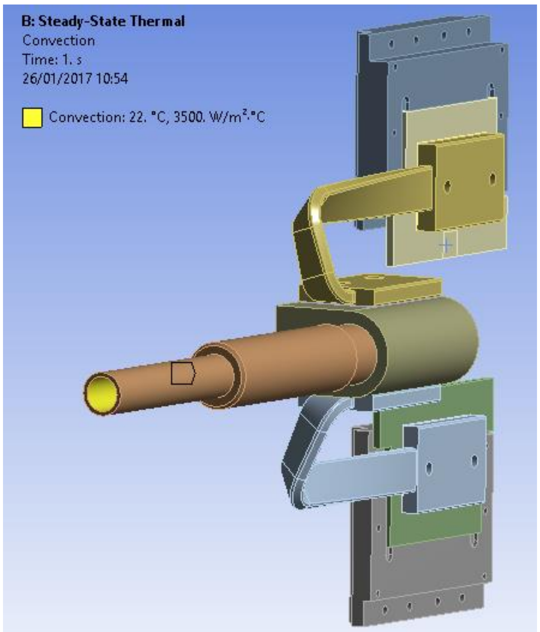

Figure 6. Cooling Face in Copper pipe

The ambient temperature was set to 22°C.

2. RESULTS

2.1 FULL BEAM ANALYSIS

The maximum temperature reached by the Tungsten Blade was calculated as 90.08°C, shown in Figure 7. The maximum lies in the centre of the beam footprint as expected.

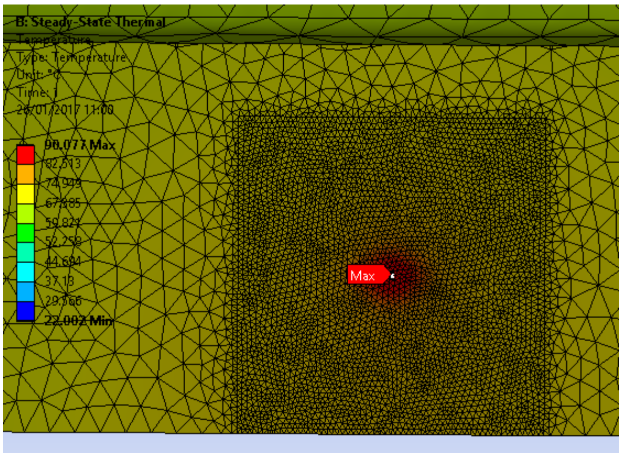

Figure 7. Maximum Temperature of the mask, 90.08°C

The maximum cooling wall temperature was calculated as 23.61°C, shown in Figure 8.

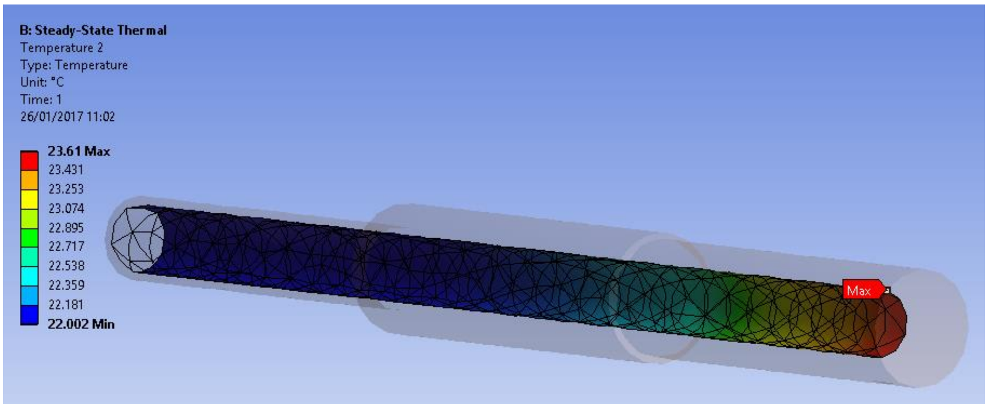

Figure 8. Maximum Cooling Wall Temperature, 23.61°C

The total heat flux across the cooling channel wall was calculated as 0.01W/mm^2, shown in Figure 9.

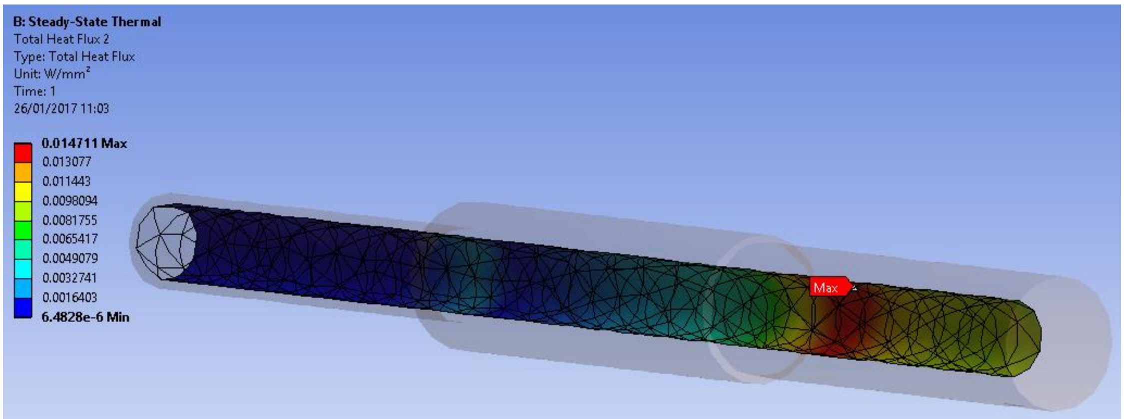

Figure 9. Total heat flux across cooling channel wall, 0.01W/mm^2

The Maximum Principal Stress of the Tungsten Blade was calculated as 5.88MPa. Figure 10.

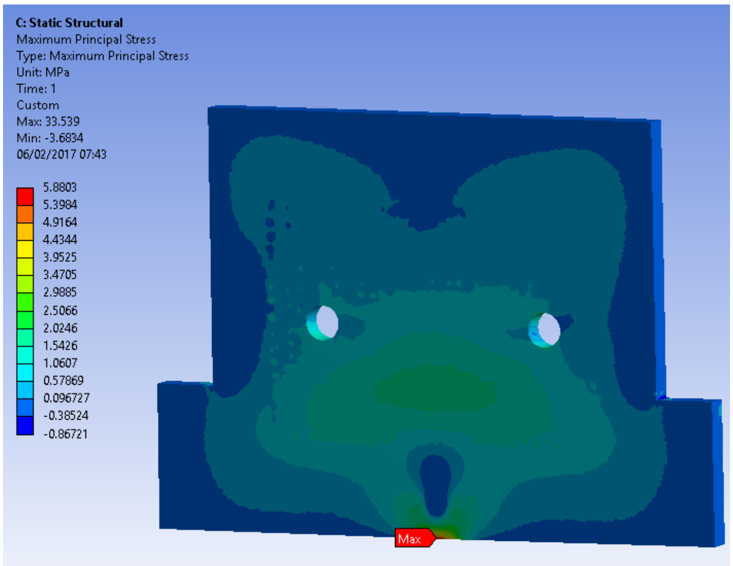

Figure 10. Maximum Principal Stress of the blade, 5.88MPa (upstream view)

2.2 50% BEAM ANALYSIS

The maximum temperature reached by the Tungsten Blade was calculated as 65.19°C, shown in Figure 11. The maximum lies in the centre of the beam footprint as expected.

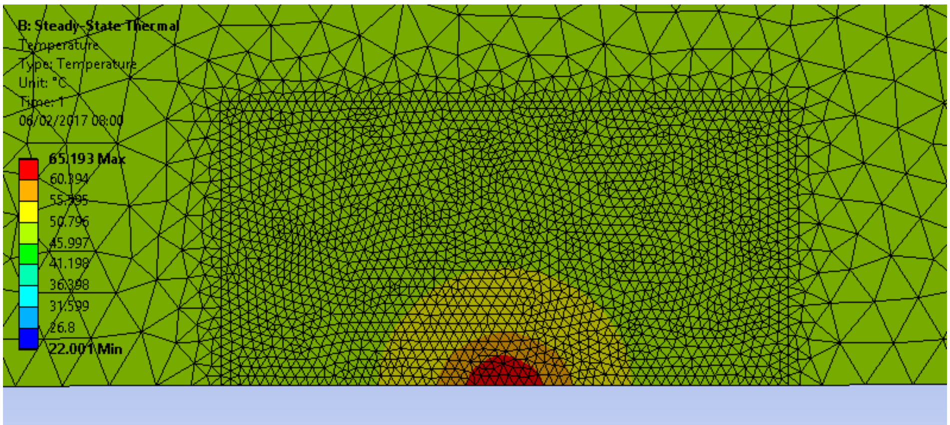

Figure 11. Maximum Temperature of the mask, 65.19°C

The maximum cooling wall temperature was calculated as 22.8°C, shown in Figure 12.

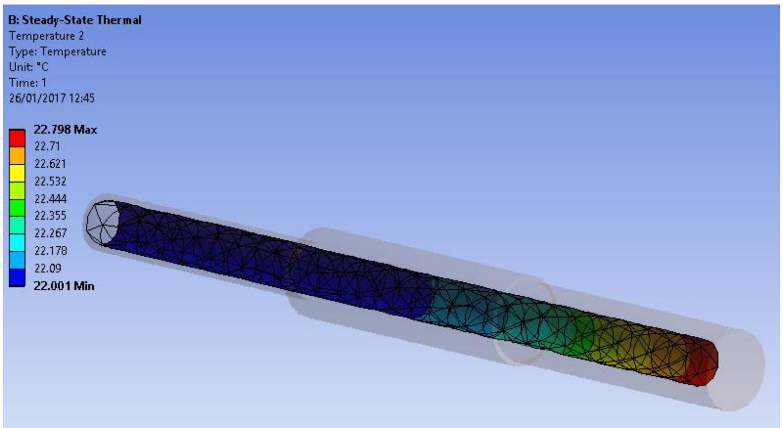

Figure 12. Maximum Cooling Wall Temperature, 22.8°C

The total heat flux across the cooling channel wall was calculated as 0.007W/mm^2, shown in Figure 15.

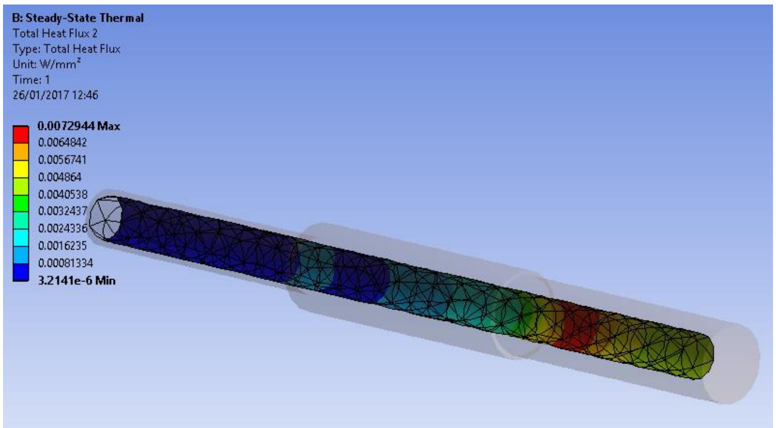

Figure 13. Total heat flux across cooling channel wall, 0.007W/mm^2

The Maximum Principal Stress of the Tungsten Blade was calculated as 1.5MPa. Figure 14.

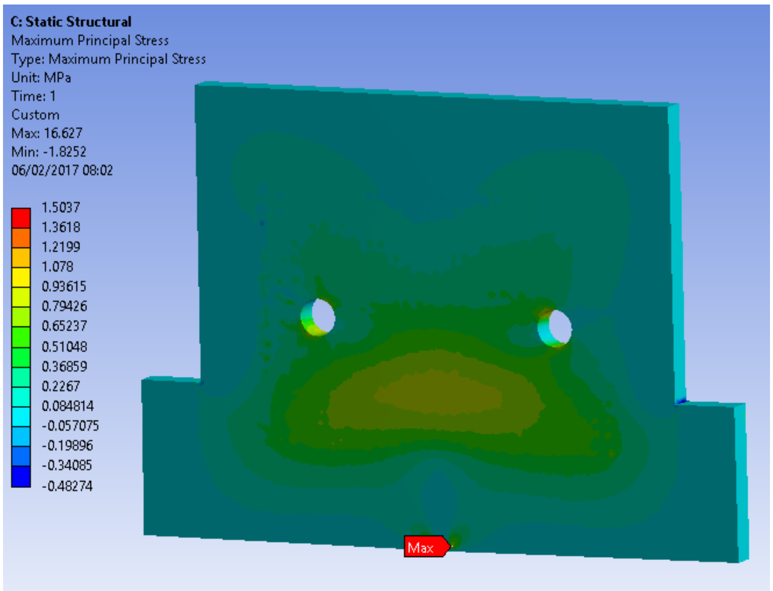

Figure 14. Maximum Principal Stress of the blade, 1.5MPa (upstream view)

3. SUMMARY

The results of the analysis on the In Flange Slits confirm that the design allows it to absorb the specified beam, while not being in breach of the failure criteria.

Tables 1 and 2 summarise the results.

Table 1: 100% absorption

	Calculated	**Failure Criteria**
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Table 2: 50% absorption

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