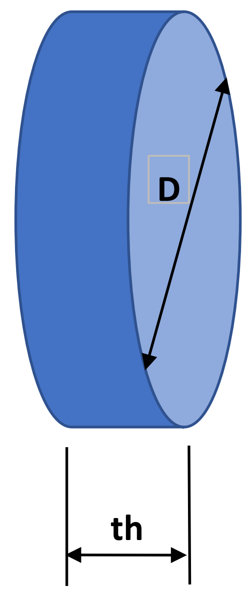
Aluminum density	2713	kg/m3
Fuel meat density	3612	m/s
Fuel plate avg density	2986	kg/m3
Aluminum thermal conductivity	235	W/m-K
Al2O3 thermal conductivity	12	W/m-K
U3O8 thermal conductivity	10	W/m-K
Average fuel plate thermal cond.	190	W/m-K
Fuel plate gap	2.95	mm
Fuel plate width	68.00	mm
Channel area	0.000200	m2
Number of gaps	18	
Total open area	0.003606	m2
D2O flow rate	6400	gal/min
	0.40	m3/sec
Number of fuel elements	24	
Flow through each element	0.016838	m3/sec
Flow through each gap	0.00094	m3/sec
velocity thru gap	4.669	m/s
Equivalent diameter	0.00565	m

Per Bob Williams:
The density of the fuel meat is 3.
The average density of fuel plate

https://www.azom.com/propert
https://sites.wustl.edu/weisense



.612 g/cc; it is about 80% Al by volume. The density of Al-6061 is 2.713 g/cc.
material is 2.986 g/cc.

Typical Al2O3 thickness 1-10 nm - 1e-09 to 10e-09 m
ee/items/thermal-conductivity-of-uo2-and-u3o8-jnm/#:~:text=The%20thermal%20conductivity%20of%20unir

radiated,with%20temperature%20like%201%2FT.

Disk of Fuel Meat

Fluid	**D2O**	
D2O bulk temp.	311	K
disc th.	2.95	mm
Channel equiv. dia.	0.0056	mm
Pressure	1	bara
Aluminum specific heat capacity	0.903	J/g-K
Aluminum density	2713	kg/m3
Fuel meat density	3612	kg/m3
Al2O3 thermal conductivity	12	W/m-K
Watt density	1368000	W/m2
Fuel Density	3612	kg/m3
Heat Source	5.40E+09	W/m3
Fuel meat conductivity	188	W/m-K

	Surface				
D	**A(cyl)**	**A(disc)**	**A(disc)**	**A(cyl)**	**Vol(cyl)**
mm	**mm2**	**mm2**	**m2**	**m2**	**mm3**
0.5	4.63	0.20	1.96E-07	0.0000046	0.58
1	9.27	0.79	7.85E-07	0.0000093	2.32
1.5	13.90	1.77	1.77E-06	0.0000139	5.21
2	18.54	3.14	3.14E-06	0.0000185	9.27
2.5	23.17	4.91	4.91E-06	0.0000232	14.48
3	27.80	7.07	7.07E-06	0.0000278	20.85
3.5	32.44	9.62	9.62E-06	0.0000324	28.38
4	37.07	12.57	1.26E-05	0.0000371	37.07
4.5	41.70	15.90	1.59E-05	0.0000417	46.92
5	46.34	19.63	1.96E-05	0.0000463	57.92

The average heat transfer coefficient for cross-flow correlation presented by Churchill and Bernstein:

$$Nu_{Cyl} = \frac{hD}{k} = 0.3 + \frac{0.62\,\mathrm{Re}^{1/2}\,\mathrm{Pr}^{1/3}}{\left[1+(0.4\,\mathrm{Pr})^{2/3}\right]^{1/4}}$$

where fluid properties are evaluated at the film tem

Mass(cyl) g	Temperature K	Density kg/m3	Viscosity kg/m-s	Cp J/kg-K	Therm.Cond. W/m-K	V m/s	Re	Pr
0.00209	311.0	1100.78	0.000820	4233.8	0.6083	4.669	3135	5.70
0.00837	311.0	1100.78	0.000820	4233.8	0.6083	4.669	6270	5.70
0.01883	311.0	1100.78	0.000820	4233.8	0.6083	4.669	9405	5.70
0.03347	311.0	1100.78	0.000820	4233.8	0.6083	4.669	12541	5.70
0.05230	311.0	1100.78	0.000820	4233.8	0.6083	4.669	15676	5.70
0.07532	311.0	1100.78	0.000820	4233.8	0.6083	4.669	18811	5.70
0.10252	311.0	1100.78	0.000820	4233.8	0.6083	4.669	21946	5.70
0.13390	311.0	1100.78	0.000820	4233.8	0.6083	4.669	25081	5.70
0.16947	311.0	1100.78	0.000820	4233.8	0.6083	4.669	28216	5.70
0.20922	311.0	1100.78	0.000820	4233.8	0.6083	4.669	31351	5.70

over a cylinder can be found from the

$$\overline{4}\left[1+\left(\frac{\mathrm{Re}}{282{,}000}\right)^{5/8}\right]^{4/5}$$

perature $T_f = (T_s + T_\infty) / 2$.

Nu (cyl)	h W/m2-K	Q W	fuel disk Delta T K	film Delta T K	fuel disk T-max K	fuel surface T K
50.85	61863.7	3.13	0.45	10.91	322.36	321.91
73.54	44734.5	12.51	1.80	30.18	342.97	341.18
91.75	37208.3	28.15	4.04	54.42	369.46	365.42
107.67	32747.9	50.05	7.18	82.45	400.63	**393.45**
122.13	29718.4	78.20	11.22	113.57	435.79	**424.57**
135.58	27491.4	112.60	16.16	147.32	474.48	458.32
148.25	25766.9	153.26	21.99	183.37	516.37	494.37
160.32	24381.5	200.18	28.72	221.48	561.20	532.48
171.90	23237.5	253.36	36.35	261.43	608.78	572.43
183.06	22272.5	312.78	44.88	303.06	658.94	614.06

Two Phase!?

Nu correlation
not valid!

Bead of Fuel Mea

Fluid	**D2O**	
D2O bulk temp.	311	K
disc th.	2.95	mm
Channel equiv. dia.	0.0056	mm
Pressure	1	bara
Aluminum specific heat capacity	0.903	J/g-K
Aluminum density	2713	kg/m3
Fuel meat density	3612	kg/m3
Al2O3 thermal conductivity	12	W/m-K
Watt density	1368000	W/m2
Fuel density	3612	kg/m3
Heat Source	5.40E+09	W/m3
Viscosity (bulk)	8.20E-04	kg/m-s
Viscosity (surface)	3.29E-04	kg/m-s
Thermal conductivity	1.88E+02	W/m-K

	Surface			
D	**A**	**Area**	**Vol**	**Vol**
mm	**mm2**	**m2**	**mm3**	**m3**
0.5	0.785398	7.85398E-07	0.065448	6.54482E-11
1	3.141593	3.14159E-06	0.523586	5.23586E-10
1.5	7.068583	7.06858E-06	1.767102	1.7671E-09
2	12.56637	1.25664E-05	4.188685	4.18869E-09
2.5	19.63495	1.9635E-05	8.181026	8.18103E-09
3	28.27433	2.82743E-05	14.13681	1.41368E-08
3.5	38.48451	3.84845E-05	22.44874	2.24487E-08
4	50.26548	5.02655E-05	33.50948	3.35095E-08
4.5	63.61725	6.36173E-05	47.71175	4.77117E-08
5	78.53982	7.85398E-05	65.44821	6.54482E-08

For flow over a sphere, Whitaker recom

$$Nu_{Sph} = hD / k = 2 + [0.4$$

which is valid for *3.5 < Re < 80,000* and
at the free-stream temperature T_∞,
temperature.

t

Mass g	Temperature K	Density kg/m3	Viscosity kg/m-s	Cp J/kg-K	Therm.Cond. W/m-K	V m/s	Re
0.000236399	311	1100.78	0.000820	4233.8	0.6083	4.669	3135
0.001891191	311	1100.78	0.000820	4233.8	0.6083	4.669	6270
0.006382771	311	1100.78	0.000820	4233.8	0.6083	4.669	9405
0.015129532	311	1100.78	0.000820	4233.8	0.6083	4.669	12541
0.029549867	311	1100.78	0.000820	4233.8	0.6083	4.669	15676
0.05106217	311	1100.78	0.000820	4233.8	0.6083	4.669	18811
0.081084835	311	1100.78	0.000820	4233.8	0.6083	4.669	21946
0.121036256	311	1100.78	0.000820	4233.8	0.6083	4.669	25081
0.172334825	311	1100.78	0.000820	4233.8	0.6083	4.669	28216
0.236398937	311	1100.78	0.000820	4233.8	0.6083	4.669	31351

ımended the following:

$$4\,\mathrm{Re}^{1/2} + 0.06\,\mathrm{Re}^{2/3}\big]\mathrm{Pr}^{0.4}(\mu_\infty / \mu_s)^{1/4}$$

l *0.7 < Pr < 380*. The fluid properties are evaluated
except for μ_s which is evaluated at surface

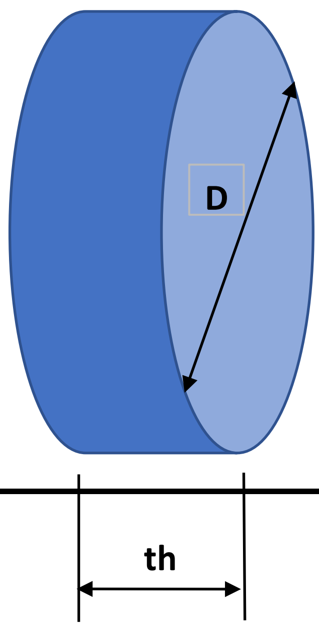
Pr	Nu (cyl)	h W/m2-K	Q W	fuel Delta T K	film Delta T K	fuel T-max K	fuel surface T K
5.70	90.84	110526.3	3.53E-01	0.30	4.07	315.37	315.07
5.70	133.26	81062.98	2.827363	1.20	11.10	323.30	322.10
5.70	167.16	67791.11	9.542349	2.69	19.91	333.61	330.91
5.70	196.53	59777.12	22.6189	4.79	30.11	345.90	341.11
5.70	222.95	54250.32	44.17754	7.48	41.47	359.95	352.47
5.70	247.24	50134.03	76.33879	10.77	53.85	375.63	364.85
5.70	269.89	46909.85	121.2232	14.66	67.15	392.81	**378.15**
5.70	291.24	44292.89	180.9512	19.15	81.28	411.42	**392.28**
5.70	311.51	42111.67	257.6434	24.24	96.17	431.41	**407.17**
5.70	330.87	40255.93	353.4203	29.92	111.78	452.70	422.78

Two phase?!
Nu correlation
not valid

Fluid	D2O	
D2O bulk temp.	311	K
disc th.	2.95	mm
Channel equiv.	0.0056	
Pressure	1	bara
Aluminum specific heat capacity	0.903	J/g-K
Aluminum density	2713	kg/m3
Fuel meat density	3612	kg/m3
Al2O3 thermal conductivity	12	W/m-K
Maximum heat flux	1.368E+06	W/m2
Equivalent Q/vol	9.275E+08	W/m3
Al conductivity	164	W/m-K

For laminar flow over a cylinder

Disc obstruction heat transfer



D mm	A(cyl) mm2	A(disc) mm2	A(disc) m2	A(cyl) m2
3	27.80	7.07	7.07E-06	0.0000278
5	44.30	19.63	1.96E-05	0.0000443
7	62.02	38.48	3.85E-05	0.0000620
9	79.73	63.62	6.36E-05	0.0000797
11	97.45	95.03	9.50E-05	0.0000975
13	115.17	132.73	1.33E-04	0.0001152
13.5	119.60	143.14	1.43E-04	0.0001196
14	124.03	153.94	1.54E-04	0.0001240
14.5	128.46	165.13	1.65E-04	0.0001285
15	132.89	176.71	1.77E-04	0.0001329
15.5	137.32	188.69	1.89E-04	0.0001373
16	141.75	201.06	2.01E-04	0.0001417
16.5	146.18	213.82	2.14E-04	0.0001462

https://www.sfu.ca/~mbahrami/ENSC%20388/Notes/Forced%20Convection.pdf

$$Nu_{Cyl} = \frac{hD}{k} = 0.3 + \frac{0.62\,\mathrm{Re}^{1/2}\,\mathrm{Pr}^{1/3}}{\left[1+(0.4\,\mathrm{Pr})^{2/3}\right]^{1/4}}\left[1+\left(\frac{\mathrm{Re}}{282{,}000}\right)^{5/8}\right]^{4/5}$$

Vol(cyl) m3	Mass(cyl) g	Temperature K	Density kg/m3	Viscosity kg/m-s	Cp J/kg-K	Therm.Cond. W/m-K
2.085E-08	0.05657	311.0	1100.78	0.000820	4233.8	0.6083
5.792E-08	0.15715	312.6	1100.20	0.000794	4232.2	0.6098
1.135E-07	0.30801	316.2	1098.76	0.000739	4228.3	0.6129
1.877E-07	0.50915	322.3	1096.10	0.000661	4221.1	0.6176
2.803E-07	0.76058	331.0	1091.74	0.000571	4209.8	0.6233
3.916E-07	1.06230	342.4	1085.15	0.000481	4194.6	0.6291
4.223E-07	1.14559	356.6	1075.76	0.000398	4176.9	0.6338
4.541E-07	1.23202	366.0	1068.85	0.000356	4167.0	0.6354
4.871E-07	1.32159	373.2	1063.29	0.000329	4161.0	0.6360
5.213E-07	1.41431	379.3	0.64	0.000013	1892.0	0.0253
5.566E-07	1.51017	385.1	0.63	0.000013	1883.2	0.0258
5.931E-07	1.60917	390.6	0.62	0.000013	1876.3	0.0262
6.308E-07	1.71131	396.2	0.62	0.000014	1870.9	0.0267

$$Pr = \frac{\text{molecular diffusivity of momentum}}{\text{molecular diffusivity of heat}} = \frac{\nu}{\alpha} = \frac{\mu C_p}{k}$$

$$Re = \frac{\text{inertia forces}}{\text{viscous forces}} = \frac{\rho V \delta}{\mu} = \frac{V\delta}{\nu}$$

h=Nu*k/D

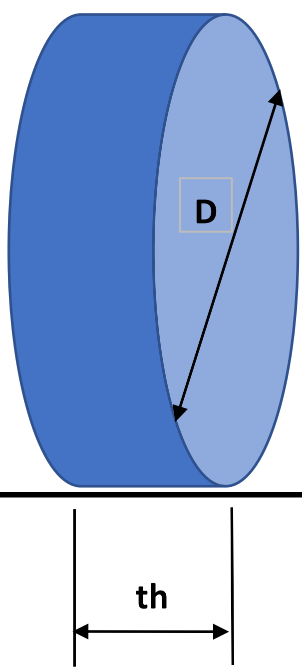
					from Qin	Al disk	film
V m/s	**Re**	**Pr**	**Nu (cyl)**	**h** W/m2-K	**Q** J/s	**Delta T** K	**Delta T** K
4.669	35415	5.70	197.03	39953.0	19.34	3.18	17.41
4.669	36557	5.51	199.27	24301.9	53.72	8.84	49.90
4.669	39196	5.10	204.28	17886.6	105.29	17.32	94.92
4.669	43712	4.52	212.42	14577.1	174.06	28.63	149.75
4.669	50402	3.86	223.60	12670.8	260.01	42.77	210.57
4.669	59519	3.21	237.54	11495.4	363.16	59.73	274.30
4.669	71252	2.62	253.84	11916.8	391.63	64.42	274.78
4.669	79227	2.33	264.13	11988.3	421.17	69.28	283.25
4.669	85327	2.15	271.66	11915.2	451.80	74.31	295.17
4.669	1322	0.96	20.86	35.2	483.49	79.53	103300.92
4.669	1279	0.95	20.48	34.1	516.26	84.92	110344.44
4.669	1239	0.95	20.13	33.0	550.11	90.48	117566.86
4.669	1201	0.95	19.79	32.0	585.02	96.23	124968.04

disk surface	disk					
T	**Tmax**		**T(Al)**	**Qout**	**Qnet**	**T'(Al)**
K	**K**		**K**	**J/s**	**J/s**	**K**
328.41	331.59		314.18	3.534	15.806	314.2
360.90	369.74		319.84	9.512	44.209	319.8
405.92	423.24		328.32	19.211	86.083	328.3
460.75	489.38		339.63	33.276	140.781	339.7
521.57	564.34		353.77	52.810	207.201	353.8
585.30	645.03		370.73	79.083	284.073	370.8
585.78	650.20		375.42	91.810	299.818	375.5
594.25	663.53		380.28	103.008	318.167	380.4
606.17	680.48		385.31	113.746	338.050	385.4
103611.92	103691.45		390.53	0.372	483.119	390.8
110655.44	110740.36		395.92	0.397	515.864	396.2
117877.86	117968.34		401.48	0.423	549.682	401.8
125279.04	125375.27		407.23	0.450	584.574	407.6

Fluid	**D2O**	
D2O bulk temp.	311	K
disc th.	2.82	mm
Channel equiv. dia.	0.0056	
Pressure	1	bara
Aluminum specific heat capacity	0.903	J/g-K
Aluminum density	2713	kg/m3
Fuel meat density	3612	kg/m3
Al2O3 thermal conductivity	12	W/m-K
Watt density	1368000	W/m2

Flat plate heat transfer	**Temperature (K)**	**Pressure (bar)**	**Phase**	**Density (kg/m3)**	**Viscosity (kg/m-s)**	**Cp (J/kg*K)**	**Therm. Cond. (W/m*K)**
	311	1	liquid	1100.78	0.000820	4233.8	0.6083

Disc obstruction heat transfer



D mm	**A(cyl) mm2**	**A(disc) mm2**	**A(disc) m2**	**A(cyl) m2**	**Vol(cyl) mm3**
3	26.58	7.07	7.07E-06	0.0000266	19.93
5	44.30	19.63	1.96E-05	0.0000443	55.37
7	62.02	38.48	3.85E-05	0.0000620	108.53
9	79.73	63.62	6.36E-05	0.0000797	179.40
11	97.45	95.03	9.50E-05	0.0000975	267.99
13	115.17	132.73	1.33E-04	0.0001152	374.31
13.5	119.60	143.14	1.43E-04	0.0001196	403.65
14	124.03	153.94	1.54E-04	0.0001240	434.11
14.5	128.46	165.13	1.65E-04	0.0001285	465.67
15	132.89	176.71	1.77E-04	0.0001329	498.34
15.5	137.32	188.69	1.89E-04	0.0001373	532.11
16	141.75	201.06	2.01E-04	0.0001417	566.99
16.5	146.18	213.82	2.14E-04	0.0001462	602.99

For laminar flow

$$Nu = \frac{hL}{k} = 0.664\,\mathrm{Re}_L^{1/2}\,\mathrm{Pr}^{1/3} \quad \mathrm{Pr} \geq 0.6 \quad ($$

$$Nu_{Cyl} = \frac{hD}{k} = 0.3 + \frac{0.62\,\mathrm{Re}^{1/2}\,\mathrm{Pr}^{1/3}}{\left[1+(0.4\,\mathrm{Pr})^{2/3}\right]^{1/4}}\left[1+\left(\right.\right.$$

https://www.sfu.ca/~mbahrami/ENSC%20388/Notes/Forced%20Convectior h=Nu*k/Dh

v [m/s]	Dh [m]	L(plate) [m]	A(plate) [m2]	Re	Pr	Nu(plate)	h(plate) [W/m2-K]
4.669	0.0056	0.5588	0.0686	35415	5.70	152.32	16406.1

Mass(cyl) g	Temperature K	Density kg/m3	Viscosity kg/m-s	Cp J/kg-K	Therm.Cond. W/m-K	V m/s	Re
0.05408	311.0	1100.78	0.000820	4233.8	0.6083	4.669	35415
0.15022	311.0	1100.78	0.000820	4233.8	0.6083	4.669	35415
0.29443	311.0	1100.78	0.000820	4233.8	0.6083	4.669	35415
0.48671	311.0	1100.78	0.000820	4233.8	0.6083	4.669	35415
0.72707	311.0	1100.78	0.000820	4233.8	0.6083	4.669	35415
1.01549	311.0	1100.78	0.000820	4233.8	0.6083	4.669	35415
1.09511	311.0	1100.78	0.000820	4233.8	0.6083	4.669	35415
1.17773	311.0	1100.78	0.000820	4233.8	0.6083	4.669	35415
1.26335	509.3	0.47	0.000018	1887.0	0.0375	4.669	690
1.35198	904.1	0.27	0.000035	2196.2	0.0889	4.669	203
1.44362	1297.6	: temperatu	#VALUE!	#VALUE!	#VALUE!	4.669	#VALUE!
1.53826	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	4.669	#VALUE!
1.63590	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	4.669	#VALUE!

(flat plate)

$$\mathrm{Pr} = \frac{\text{molecular diffusivity of m}}{\text{molecular diffusivity o}}$$

$$\frac{\mathrm{Re}}{282{,}000}\Big)^{5/8}\Big]^{4/5}$$

(cylinder)

$$\mathrm{Re} = \frac{\text{inertia forces}}{\text{viscous forces}} =$$

Watt density [W/m2]	W	delta T [K]
1368000	93783	**83**

h=Nu*k/D

Pr	Nu (cyl)	h W/m2-K	Qin J/s	Delta T K	T(Al) K	Qout J/s	Qnet J/s	T'(Al) K
5.70	197.03	39952.8	19.34	396.03	707.03	420.530	-401.191	311.0
5.70	197.03	23971.7	53.72	396.03	707.03	420.530	-366.809	311.0
5.70	197.03	17122.6	105.29	396.03	707.03	420.530	-315.237	311.0
5.70	197.03	13317.6	174.06	396.03	707.03	420.530	-246.474	311.0
5.70	197.03	10896.2	260.01	396.03	707.03	420.530	-160.520	311.0
5.70	197.03	9219.9	363.16	396.03	707.03	420.530	-57.375	311.0
5.70	197.03	8878.4	391.63	396.03	707.03	420.530	-28.903	311.0
5.70	197.03	8561.3	421.17	396.03	707.03	420.530	0.644	707.6
0.91	14.82	38.3	451.80	396.03	905.35	2.923	448.872	1298.8
0.86	7.96	47.1	**483.49**	396.03	1300.10	**6.197**	477.294	**1691.1**
#VALUE!	#VALUE!	#VALUE!	516.26	396.03	1693.59	#VALUE!	#VALUE!	#VALUE!
#VALUE!	#VALUE!	#VALUE!	550.11	396.03	#VALUE!	#VALUE!	#VALUE!	#VALUE!
#VALUE!	#VALUE!	#VALUE!	585.02	396.03	#VALUE!	#VALUE!	#VALUE!	#VALUE!

$$\frac{\text{omentum}}{\text{f heat}} = \frac{\nu}{\alpha} = \frac{\mu C_p}{k}$$

$$\frac{\rho V \delta}{\mu} = \frac{V \delta}{\nu}$$