KAJIAN ULANG DESAIN TERMOHIDROLIKA RSG-GAS
MENGUNAKAN PROGRAM COOLOD-N

Jaja Sukmana, A. Mariatma, Mashudi, Abd. Aziz RH

ABSTRAK

KAJIAN ULANG DESAIN TERMOHIDROLIKA TERAS RSG-GAS DENGAN
MENGUNAKAN PROGRAM COOLOD-N. Telah dilakukan kajian ulang terhadap data
desain termohidrolik teras RSG-GAS dengan menggunakan program Coolod-N. Kajian ulang
bertujuan untuk memverifikasi ulang program Coolod-N dalam perhitungan desain. Data
keluaran termohidrolik yang diperoleh diantaranya: fluxs massa rata-rata = 3763 kg/m²s,
temperatur permukaan plat =144 °C, temperatur maksimum meat bahan bakar 146 °C,
pembangkitan panas = 8205,4 W/cm², dan margin keselamatan = 3,67. Perbedaan hasil
perhitungan ini terhadap hasil program lain disebabkan adanya kesalahan data masukan, yaitu
hasil perhitungan mekanik dari dimensi teras dan bagian-bagiannya serta pemilihan formula-
formula terkait program itu sendiri. Dari kegiatan ini diharapkan dapat menambah kompetensi
sumber daya staf PRSG dalam menggunakan program komputer untuk menganalisis suatu
desain maupun perubahan terhadap desain awal.

ABSTRACT

RE-ASSESSMENT OF THE RSG-GAS CORE TERMOHIDROLIC DESIGN USING
COOLOD-N CODE. Re-assessment of thermohydric design for the RGS-GAS core has been
done using Coolod-N code. Re-assessment purposed to applied Coolod-N code on design
calculation. The thermohydric output data obtained include: flux mass average of 3763 kg/
m²s, surface plate temperature of 144 °C, maximum meat fuel temperature of 146 °C,
generation heat of 8205,4 W/cm², and safety margin of 3,67. The difference between this
calculation and other computer code because of difference of data input reflected on
mechanical data of core dimension and selection of certain formula to execute the program. It
is expected by exercising this a such measure is able to enhance the capability of the operator
in the light of analyzing of design modification or early design either using computer code.

PENDAHULUAN

Desain teras reaktor dan tindakan korektif
dari sistem pengendalian dan proteksi
reaktor, menjamin bahwa kerapatan puncak
panas lokal (peak local power) tidak akan
menyebabkan kerusakan elemen bakar
selama operasi normal atau operasi transien.
Kondisi tersebut juga tidak akan menyebab-
kan kerusakan pada pelat elemen bakar akibat
kecelakaan terparah yang dipostulasikan.

Tabel 1 menyajikan desain neutronik, termo-
hidrolik, dan mekanik RSG-GAS. Beberapa
dari data tersebut dapat ditinjau ulang
menggunakan program computer Coolod-N.
Coolod-N dipublikasikan oleh JAERI yang
disusun oleh Masanori Kaminaga (1987),
dipasang pada VAX8550 (1989) (pengem-
bangan dari Coolod oleh S.Watanabe, 1984),
 kemudian dimodifikasi ke dalam mesin AXP
oleh Kurnia Putranta (1996) dengan ditambahkan persamaan untuk menghitung para-
meter pelepasan gelembung (Eta) sesuai dengan persamaan yang digunakan oleh Interatom. Pada tahun 2004, program ini dikonversikan pada komputer PC. Saat ini program Coolod-N versi PC bisa dijalankan pada komputer yang menggunakan operating system Windows-2000/ NT/XP.

Tujuan kajian ulang dengan Coolod ini adalah melakukan verifikasi terhadap data termohidrolitka teras RSG-GAS dengan paket program komputer yang sebenarnya telah digunakan oleh staf PRSG yang saat ini telah dipindahkan ke Pusat Teknologi Reaktor dan Keselamatan Nuklir (PTRKN). Diharapkan dengan pengkajian ulang staf PRSG mampu memverifikasi secara mandiri terhadap keselamatan dalam pengendalian keselamatan operasi reaktor.

TEORI

Desain RSG-GAS

Reaktor Serba Guna G.A. Siwabessy (RSG-GAS) merupakan reaktor jenis MTR (Material Testing Reactor) pertama di dunia yang dioperasikan langsung dengan menggunakan elemen bakar pengkayaan Uranium rendah, LEU (Low Enriched Uranium). Pada saat rancang bangun RSG-GAS dilaksanakan, hanya tersedia elemen bakar LEU jenis oksida (U₃O₈-Al) yang dapat digunakan untuk memenuhi spesifikasi yang ditentukan. Oleh karena itu RSG-GAS menggunakan bahan bakar oksida dengan densitas Uranium dalam meat sebesar 2,96 g/cm³ dengan pengkayaan ²³⁵U sebesar 19,75%. Parameter desain neutronik dan termohidrolitka RSG-GAS telah disajikan mengacu pada SAR (safety analysis report) RSG-GAS Rev.7 dan LAK (laporan analisis keselamatan) RSG-GAS Rev.10. Program komputer yang digunakan untuk menghitung neutronik dan termohidrolitka pada SAR rev. 7 adalah COBRA-IIIC sedangkan di LAK rev.10 digunakan BATAN-FUEL dan BATAN-2DIFF. Parameter termohidrolitka RSG-GAS disajikan seperti tabel berikut ini.

<table>
<thead>
<tr>
<th>Parameter Desain Termohidrolitka</th>
<th>SAR Rev.7</th>
<th>LAK Rev.10</th>
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<tbody>
<tr>
<td>Aliran Pendingin</td>
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</tr>
<tr>
<td>Total laju alir sistem primer, kg/s</td>
<td>860</td>
<td>860</td>
</tr>
<tr>
<td>Nilai desain laju alir minimum, kg/s</td>
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<td>800</td>
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<tr>
<td>Laju alir efektif untuk pendinginan pelat elemen bakar, kg/s</td>
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<tr>
<td>Luas aliran efektif untuk perpindahan panas, m²</td>
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<td>Kecepatan rata-rata pendingin sepanjang pelat elemen bakar, m/s</td>
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<tr>
<td>Kecepatan massa rata-rata di dalam teras reaktor, kg/m²</td>
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<td>Perumaran tekanan di dalam teras reaktor, bar</td>
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<td>Suhu Pendingin</td>
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<td>Kenaikan suhu rata-rata di dalam teras reaktor, °C</td>
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<td>Suhu rata-rata di keluaran teras reaktor, °C</td>
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<td>Suhu maksimum di keluaran kanal panas, °C</td>
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<td>Perpindahan Panas</td>
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<td>Luas permukaan pelat elemen bakar, m²</td>
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<td>72,29</td>
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<tr>
<td>Flus panas rerata, W/m²</td>
<td>41,5 x 10⁶</td>
<td>41,5 x 10⁶</td>
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<tr>
<td>Flus panas maksimum untuk operasi normal, W/m²</td>
<td>221,7 x 10⁴</td>
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</table>
Tabel 1. lanjutan

<table>
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<th>Parameter Desain Termohidrolika</th>
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<tr>
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<td>146</td>
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<td>Suhu maks. di tengah bahan bakar pada daya nominal (awal siklus), °C</td>
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<td>154</td>
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<tr>
<td>Suhu maks. di tengah bahan bakar pada daya nominal (akhir siklus), °C</td>
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<td>187</td>
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<td>Suhu maksimum di tengah bahan bakar pada daya lebih (akhir siklus), °C</td>
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<td>Stabilitas Aliran</td>
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<td>2,31</td>
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<td>Marjin keselamatan min. untuk desain transien dan transien yang telah diantisipasi</td>
<td>1,48</td>
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Model Perhitungan dengan Coolod-N

Program perhitungan komputer (code) Coolod-N adalah suatu program komputer yang dipergunakan untuk perhitungan distribusi suhu dua dimensi, yaitu arah radial (y, arah ketebalan meat dan pelat) dan arah aksial (z, arah panjang atau tinggi pelat). Perhitungan dilakukan dengan cara mengasumsikan pembangkitan panas di dalam meat bahan bakar konstan ke arah radial (Q = q''y = konstan) atau hanya terjadi konduksi panas satu dimensi. Adapun distribusi suhu pelat bakar arah aksial dihitung dari suhu bulk pendingin lokal dan distribusi daya aksial (faktor aksial) seperti tertera pada Gambar 1. Sedangkan Gambar 2, menunjukkan model perhitungan distribusi suhu di dalam pelat bakar, yaitu dari arah luar (pendingin) ke dalam (pelat dan meat).

Jika kondisi pendinginan antara sisi kanan dan kiri pelat bahan bakar berbeda, maka code komputer Coolod-N akan menghitung suhu maksimum meat bahan bakar sampai suhu maksimum meat bahan bakar tersebut sama antara sisi kanan dan kiri dengan mengubah lokasi titik suhu maksimum. Tetapi jika kondisi pendinginan sisi kanan dan kiri dari pelat bahan bakar sama, maka suhu maksimum bahan bakar akan terletak di tengah meat bahan bakar.

Gambar 1. Contoh distribusi daya aksial (faktor aksial) yang digunakan di dalam code Coolod-N
Di dalam code Coolod-N, terdapat beberapa paket perhitungan perpindahan panas (heat transfer package) yang dapat dipergunakan untuk analisis termohidrolika reaktor riset. Adapun beberapa persamaan yang digunakan di dalam perhitungan untuk analisis reaktor RSG-GAS yang menggunakan pendinginan sirkulasi paksa (forced convection) dengan arah aliran dari atas ke bawah (downward flow) disajikan dalam lampiran.

METODOLOGI

a) Studi literatur desain RSG-GAS pada SAR rev.7, LAK rev.10,
b) Pelatihan menggunakan paket program Coolod-N under Windows,
c) Menyiapkan inputan data Coolod-N, yaitu parameter desain teras, elemen bakar, dan pendingin.
d) Menjalankan program Coolod-N. Alur pemrograman ditunjukkan seperti diagram alir berikut ini.
e) Menghitung distribusi suhu dan margin keselamatan menggunakan Coolod-N dan hasil-hasil lainnya.
f) Membuat kesimpulan.
HASIL

a. Inputan Coolod-N, sebagai berikut:

```
1.  PERHITUNGAN TERMOHIDROLIKAS RSG-GAS
2.  C <CARD B1> INFORM
3. C <CARD B2> JAMAX IMAX NMAX NPLLOT KEY(1) KEY(2) KEY(3)
4.  5 13 1 0 1 2 0
5. C <CARD C> QRR(MW) PFLOW TIN(DEG) DT(DEG) JAMX
6.  30.0 712.0 40.5 0.0 1
7. C <CARD E1> HI H2 H3 A B C D ITWC
8.  0.03 0.0 0.8 0.4 0.0 1
9. C <CARD E2> FRATE VIN VOUT PRESIN RAMF
10.  0.87 0.0 0.0 2.036 0.0
11. C <CARD F1> FUEL ELEMENT TITLE
12. ELEMEN BAKAR STANDAR
13. C <CARD F2> NPMX NFUEL MA UDENST POROTY IDPMX IDCMX EAREA FRATEN
14.  45.714 2.296 0.06 1 1 35.94 1.0
15. C <CARD F2> NUAL TUAL(1) TUAL(2) TUAL(3) TUAL(4)
16.  2 60.0 1.07 145 1.07
17. C <CARD F3> FR FCOLL FFILM FFLX FCGLAD FBOND FMEAT
18.  3.14 1.0 1.0 1.0 1.0 1.0
19. C <CARD F4> FZ DDZ ZET
20.  0.0001 5.0 0.0
21.  0.0001 5.0 0.0
22.  0.0001 5.0 0.0
23.  0.8500 5.0 0.0
24.  1.0201 5.0 0.0
25.  1.4722 5.0 0.0
26.  1.4722 5.0 0.0
27.  1.7001 5.0 0.0
28.  1.6421 5.0 0.0
29.  1.4722 5.0 0.0
30.  1.2021 5.0 0.0
31.  0.8500 5.0 0.0
32.  0.0001 5.0 0.0
33.  0.0001 5.0 0.0
34.  0.0001 5.0 0.0
35. C <CARD F5> FUEL PLATE TITLE
36. Elemen Bakar Terpanas
37. C <CARD F5> NPLATE FLOC IDPL KMX IPLOT IOUT
38.  21 1.0 1 1 0 1
39. C <CARD F5> ICHL(1) IHEAT(1) FRATEC(1) ICHL(2) IHEAT(2) FRATEC(2)
40.  1 2 1.0
41. C <CARD F6> XA XB XC YA HA HB HC
42.  0.027 0.027 0.065 6.275 1.25 60.0 1.25
43. C <CARD F7> XCHI YCHI MSFLW
44.  6.71 0.255 6
45. C <CARD F7> ZETA DH ZLAM HDE AR
46.  0.5 0.0 0.0 7.1141 50.7947
47.  0.0 4.95 56.9 7.1141 50.7947
48.  0.0 4.6 56.9 7.1141 50.7947
49.  0.329 0.0 0.0 4.78 17.945
50.  0.0 14.95 64.0 4.78 17.945
51.  0.0 0.0 0.0 4.78 17.945
52. C <CARD G1> KVELO JUMAX JLMAX IHTC KBFLG NCMAX NATIP
53.  1 2 4 3 0 0 0 0
54. C <CARD G4> (UMSH(NN,NNPJJ,XX),NNP=1,NPMAX),KK=1,KMAX)
```
Penjelasan mengenai kode dalam program disajikan dalam lampiran 2.

b. Menjalankan program (Running):

![Image of program running]

Data-data hasil eksekusi program:

0

*** PRIMARY COOLANT ***
REACTOR INLET TEMPERATURE = 40.50 C
REACTOR OUTLET TEMPERATURE = 50.58 C
PRIMARY TEMPERATURE DIFFERENCE = 10.08 C
PRIMARY COOLANT FLOW RATE = 712.00 KGS

0

*** REACTOR CORE ***
REACTOR THERMAL POWER = 30.00 MW
AREA OF TOTAL FUEL CHANNELS = 1642.96 CM2

NUMBER OF FUEL ELEMENTS = 45.7 ELEMENTS

AVERAGE HEAT GENERATION = 1537.07 (W/CMS)
AVERAGE MASS FLUX = 3770.266 (KGM2/SEC)

AVERAGE CHANNEL TEMPERATURE DISTRIBUTION

FLOW CHANNEL AREA = 35.94 CM2
NUMBER OF FUEL PLATES
Elmen= 21.0

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<tr>
<th>TEMPERATURE DISTRIBUTION</th>
</tr>
</thead>
<tbody>
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<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
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<td>4</td>
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</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>J</td>
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<td>---</td>
</tr>
<tr>
<td>1</td>
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<td>2</td>
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COOLOD-RSG THERMAL HYDRAULIC CALCULATION CASE = (JA-1 JA-1)
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CHANNEL DIMENSION = 6.710 * 0.255 (CM)
CHANNEL VELOCITY = 383.74 (CM/SEC)

TEMPERATURE DISTRIBUTION

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<thead>
<tr>
<th>J</th>
<th>COOLANT SURFACE (DEG.C)</th>
<th>CLadding INNER (DEG.C)</th>
<th>CLadding OUTER (DEG.C)</th>
<th>FUEL MEAT MAXIMUM (DEG.C)</th>
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</table>
** HOT CHANNEL FACTORS (EXCEPT FZ)**

\[
\begin{align*}
F(\text{COOLANT}) &= 3.140 \\
F(\text{FILM}) &= 3.140 \\
F(\text{CLAD}) &= 3.140 \\
F(\text{BOND}) &= 3.140 \\
F(\text{MEAT}) &= 3.140
\end{align*}
\]

- **HEAT TRANSFER CONDITION**

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<tr>
<th>J</th>
<th>FZ</th>
<th>HEAT COEFFICIENT</th>
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<tr>
<td></td>
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<td>(W/m²°C)</td>
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- **COOLD-REGS THERMAL HYDRAULIC CALCULATION CASE = (IA-1 JA-1)**

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**PRESSURE**

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>PRESSURE DIFFERENCE</th>
<th>COOLANT PRESSURE</th>
<th>HEAT FLUX (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INLET</td>
<td>2.03E+03</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>INLET (1)</td>
<td>1.961</td>
<td>0.01830</td>
<td>0.01830</td>
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<tr>
<td>INLET (1)</td>
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<td>0.01830</td>
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<tr>
<td>INLET (2)</td>
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<tr>
<td>INLET (2)</td>
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<td>0.01830</td>
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<tr>
<td>PLATE ENTRANCE</td>
<td>1.938</td>
<td>0.01069</td>
<td>0.02036</td>
</tr>
<tr>
<td>FUEL PLATE ZONE 1</td>
<td>1.938</td>
<td>0.00443</td>
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<tr>
<td>FUEL PLATE ZONE 2</td>
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<td>0.01171</td>
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<td>FUEL PLATE ZONE 3</td>
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<td>0.01766</td>
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<td>FUEL PLATE ZONE 4</td>
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<td>0.01758</td>
<td>0.05548</td>
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<td>FUEL PLATE ZONE 5</td>
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<td>0.01746</td>
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<td>FUEL PLATE ZONE 6</td>
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<td>FUEL PLATE ZONE 8</td>
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<td>FUEL PLATE ZONE 9</td>
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<td>FUEL PLATE ZONE 13</td>
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<td>PLATE EXIT</td>
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<td>STRATCH (3) INLET</td>
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<tr>
<td>STRATCH (4) INLET</td>
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<td>0.24733</td>
</tr>
<tr>
<td>STRATCH (4) OUT</td>
<td>1.824</td>
<td>0.00000</td>
<td>0.24733</td>
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<tr>
<td>STRATCH (5) INLET</td>
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<td>0.34019</td>
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<td>STRATCH (5) OUT</td>
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<tr>
<td>STRATCH (6) INLET</td>
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<td>0.35988</td>
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<tr>
<td>STRATCH (6) OUT</td>
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<td>0.00000</td>
<td>0.35988</td>
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<tr>
<td>OUTLET PLENUM</td>
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</tr>
</tbody>
</table>

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**DNBD=1 LABUNSCH WITH ZERO SUBCOOLING — DNBD=2 MIRSHAK, DURANT & TOWELL — DNBD=3**

**BERNATH CORRELATION**
PEMBAHASAN

Data masukan code telah disederhanakan yakni INFORM 1, IAMAX 1 sehingga QRR juga diisi dengan hanya daya nominal 30 MW. Pembagian segmen arah z (aksial) pada JMAX adalah 13, data ini dapat diubah lebih halus misal dengan 21, dst dan bagian CARD F4 juga harus mendapat data FZ yang sesuai. Data pada FZ dimasukkan berdasar hitungan sinusoidal. Data desain yang harus secara cermat dihitung juga terdapat pada bagian mekanis atau dimensi dari pelat EB dan teras yaitu data pada CARD F6 dan CARD F75. Data mekanis pelat EB RSG-GAS ditunjukkan pada Gambar 3.


Nilai eta dari running code sebenarnya dapat pula ditampilkan dengan mengubah masukan pada CARD G1, yaitu IHTC diganti dengan masukan 4. Sedangkan DNBR yang diperoleh dapat diambil dari tabel data keluaran code bagian terakhir, yaitu nilai terkecil pada kolom DNBR. DNBR diperoleh sebesar 2,71. Sedangkan distribusi suhu hasil code dapat digambarkan pada grafik berikut ini.

Gambar 3. Elemen Bakar RSG-GAS (21 plat)

Gambar 4. Distribusi suhu pada meat EB hasil Coolod-N

Tabel 2. Perbandingan parameter thermohidrolika hasil Coolod-N terhadap data SAR Rev.7

<table>
<thead>
<tr>
<th>HASIL COOLOD-N</th>
<th>SAR REV. 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor Inlet Temperature = 40.50 C</td>
<td>Nominal inlet temperature = 40.5 C</td>
</tr>
<tr>
<td>Reactor Outlet Temperature = 59.58 C</td>
<td>Average temp. at core outlet = 50.5</td>
</tr>
<tr>
<td>Primary Temperature Difference= 10.08 C</td>
<td>Average temp. rise across core = 10.0 K</td>
</tr>
</tbody>
</table>
Primary Coolant Flow Rate $\text{Eff} = 712.00 \text{ kg/s}$
  
  $\text{Eff flow rate fuel plate cooling} = 618 \text{ kg/s}$

Reactor Thermal Power = 30.00 MW

Area Of Total Fuel Channels = 1642.96 cm$^2$

Reactor core heat output = 30 MW

Eff flow area for heat transfer = 0.1643 m$^2$

Elemen bakar standar = 45.7 (ELEMNTS)

Average Heat Generation = 1537.07 (W/cm$^2$)

Average Mass Flux = 3762.646 (kg/m$^2$ sec)

Average power density = 1537 W/cm$^3$

Average mass velocity in core = 3761 kg/m$^2$ s

Channel velocity = 384.55 cm/sec

Temp distrl cladding surface = 144.27 C

Temp distrl fuel meat maks = 146.5 C

Heat trans cond, heat generation = 8205.369 W/cm$^3$

Heat flux in plate surface = 221.545 W/cm$^2$

Average coolant v along fuel plates = 3.7 m/s

Max plate surface temp = 145 C

Max central fuel temp at rated power = 175 C

Max power density = 8210 W/cm$^3$

Max heat flux for normal operation = 221.7e+4 W/m$^2$

$\text{Hasil perhitungan:}$

$n = \frac{(T_s(x) - T_c(x))/(\rho(x)/(\nu(x)))}{221.545}$

$n = 81.03$

$\delta = \frac{n}{n_c} = 81.03$

$\delta = 22.1$

$\delta = 3.67$

$\text{Min safety margin at rate power} = 3.38$

**KESIMPULAN**


**PUSTAKA**


(8) Model Penentuan batas keselamatan terhadap ketidak-stabilan aliran, digunakan persamaan:

\[ s = \frac{\eta}{\eta_c} \]

dimana, \( \eta = z(\log z) - T_C \) \( \log \left[ q'z(z) / (q''z(z)) \right] z'z(z) \)

\( T_S \): suhu saturasi, °C \( T_C \): suhu bulk pendingin, °C
\( V \): kecepatan pendingin, cm/det
\( q'' \): flus panas, W/cm
\( z \): jarak dari kanal masukan pendingin, cm
\( \eta_C \): parameter pelepasan gelembung kritis, yang besarnya ditetapkan 22,1 cm K/J.

\[ \frac{p_v - p}{p} = 0.7 \]
### Input data information for COOLOD-N2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TITL</strong></td>
<td>Title for the calculation</td>
</tr>
<tr>
<td><strong>INFORM</strong></td>
<td>Index for input data format (I)</td>
</tr>
<tr>
<td><strong>IAMAX</strong></td>
<td>Number of calculation cases (I) (1=&lt;IAMAX&lt;=10)</td>
</tr>
<tr>
<td><strong>IMAX</strong></td>
<td>Number of calculation points in fuel meat radial direction (I)</td>
</tr>
<tr>
<td><strong>JMAX</strong></td>
<td>Number of calculation points for fuel plate axial direction (I)</td>
</tr>
<tr>
<td><strong>NMAX</strong></td>
<td>Number of different fuel elements in the core (I) (1=&lt;NMAX&lt;=5)</td>
</tr>
<tr>
<td><strong>NPLOT</strong></td>
<td>Plot option of calculation results (I)</td>
</tr>
<tr>
<td><strong>IDMAX</strong></td>
<td>Number of division in cladding region &lt;CARD C&gt; Thermal-hydraulic parameter (Free format)</td>
</tr>
<tr>
<td><strong>QRR</strong></td>
<td>Reactor thermal power (MW) (R)</td>
</tr>
<tr>
<td><strong>PFLOW</strong></td>
<td>Primary coolant flow rate or average coolant velocity in the core (R)</td>
</tr>
<tr>
<td><strong>TIN</strong></td>
<td>IF KEY(1)=1 then the Primary coolant core inlet temperature (°C) (R)</td>
</tr>
<tr>
<td><strong>DT</strong></td>
<td>Increment of inlet temperature &quot;TIN&quot; (°C) (R)</td>
</tr>
<tr>
<td><strong>JAMX</strong></td>
<td>Number of calculation cases for &quot;DT&quot; (I) (Normally : =1)</td>
</tr>
<tr>
<td><strong>H1, H2, H3, A, B, C, D, ITWC</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ITWC</strong></td>
<td>Standard temperature for property (I)</td>
</tr>
<tr>
<td><strong>FRATE</strong></td>
<td>FRATE = (Effective flow rate for fuel plates cooling)</td>
</tr>
<tr>
<td><strong>VIN</strong></td>
<td>Coolant velocity in the inlet plenum (cm/s) (R)</td>
</tr>
<tr>
<td><strong>VOUT</strong></td>
<td>Coolant velocity in the outlet plenum (cm/s) (R)</td>
</tr>
<tr>
<td><strong>PRESSIN</strong></td>
<td>Core inlet pressure (kg/cm²abs) (R)</td>
</tr>
<tr>
<td><strong>RAMF</strong></td>
<td>Index for straight pipe friction loss for turbulent flow (R)</td>
</tr>
<tr>
<td><strong>NPMX</strong></td>
<td>Number of different fuel plates in this kind of fuel element (I)</td>
</tr>
<tr>
<td><strong>NFUEL</strong></td>
<td>Number of this kind of fuel elements in the core (R)</td>
</tr>
<tr>
<td><strong>MA</strong></td>
<td>Index for fuel meat material (I)</td>
</tr>
<tr>
<td><strong>UDENST</strong></td>
<td>Uranium density in meat (g/cm³) (R) (For U-Al and U-Alx dispersion type fuel)</td>
</tr>
<tr>
<td><strong>POROTY</strong></td>
<td>Porosity (-) (R) (For U-Alx dispersion type fuel)</td>
</tr>
<tr>
<td><strong>IDPMX</strong></td>
<td>Number of different configuration fuel plates in this kind of fuel element (I)</td>
</tr>
<tr>
<td><strong>IDCMX</strong></td>
<td>Number of different configuration flow channels in this kind of fuel element (I)</td>
</tr>
<tr>
<td><strong>EAREA</strong></td>
<td>Effective flow area for this kind of fuel element (cm²) (R)</td>
</tr>
<tr>
<td><strong>FRATEN</strong></td>
<td>Flow rate distribution factor for this kind of fuel element (-) (R)</td>
</tr>
<tr>
<td><strong>FRATEN</strong></td>
<td>Flow rate of this kind of fuel element/(Average flow rate of fuel element)</td>
</tr>
<tr>
<td><strong>NUAL</strong></td>
<td>Number of data sets (I)</td>
</tr>
<tr>
<td><strong>TUAL</strong></td>
<td>Temperature (°C) (R)</td>
</tr>
<tr>
<td><strong>UAL</strong></td>
<td>Thermal conductivity of the fuel meat (W/cm K)</td>
</tr>
</tbody>
</table>
FR: Radial peaking factor \( F_R \) (radial) \( \times F_E \) (uncertainty) (R)

FCCOL: Engineering peaking factor for bulk coolant temperature rise (R) \( F_B \)

FHFLX: Engineering peaking sub-factor for heat flux (R)

(\text{This sub-factor is used in the calculation of DNBR})

FFILM: Engineering peaking factor for film temperature rise (R) \( F_f \)

FCLAD: Engineering peaking factor for clad temperature rise (R)

FBOND: Engineering peaking factor for bond temperature rise (R)

FMEAT: Engineering peaking factor for fuel meat temperature rise (R)

FZ: Axial peaking factor (R)

DDZ: Distance from \( M_i \) to \( M_{i+1} \) or a segment length (R)

ZET: Resistance coefficient at \( M_i \) (R) (Normally: = 0.0)

NPLATE: Number of this kind of fuel plates in this kind of fuel element (R)

FLOCL: Local peaking factor (R)

IDPL: Identity number of fuel plate configuration (I) (See CARD F6)

KMX: Index for cooling condition of fuel plate (I)

ICHL: Identity number of channel configuration (I)

NHEAT: Coolant condition (R)

FRATEC: Flow rate distribution factor for this kind of channel (R)

XA: Half thickness of fuel meat for plate-type fuel (cm) (R)

XB: Distance between fuel meat center and clad inner surface for plate-type fuel (cm) (R)

XC: Distance between fuel meat center and clad outer surface for plate-type fuel (cm) (R) (Half thickness of fuel plate)

YA: Width of fuel meat for plate-type fuel (cm) (R)

HA: Distance between inlet of channel and top/bottom of fuel meat (pellet) (cm) (R)

HB: Length of fuel meat (fueled region) (cm) (R)

HC: Distance between outlet of channel and bottom/top of fuel meat (pellet) (cm) (R)

YCHI: Gap(thickness) of coolant channel (cm) (R)

XCHI: Width of coolant channel (cm) (R)

ZETA(1): Resistance coefficient of fuel element entrance (STRETCH(1)) (R)

DH(1): Distance between fuel element entrance and fuel plate entrance (cm) (R)