AECL
TECHNOLOGIES INC.

January 28, 2005

Our File: 108US-01321-021-001
108US-ACNU05-0004L
Your File: Project No. 722

U.S. Nuclear Regulatory Commission,
Document Control Desk,
Washington, D.C. 20555

Attention: Ms. B. Sosa
Project Manager, ACR

References:

1. Letter J. Kim to G. Archinoff, "Requests for Additional Information – Thermalhydraulic Data for ACR-700 Application", September 23, 2004.
2. Letter G. Archinoff to B. Sosa, "Response to RAIs on Thermal Hydraulic Data: ACR-700 Data", 108US-ACNU04-0024L, October 04, 2004.
3. Letter G. Archinoff to B. Sosa, "Response to RAIs on Thermal Hydraulic Data: CANDU 6 Data", 108US-ACNU05-0003L, January 26, 2005.

Re: **Response to RAIs on Thermal Hydraulic Data: CANDU 6 Data (Non-Proprietary)**

In response to NRC's request for additional information on thermal hydraulic data (Reference 1) and in support of the NRC's pre-application review of the ACR-700, attachment 1 provides the requested thermal hydraulic data on CANDU 6. Please note that the ACR-700 data have been provided under cover letter dated October 04, 2004 (Reference 2).

The proprietary version of our response to these RAIs has been submitted on January 26, 2005 (Reference 3).

If you have any questions on this letter and/or the enclosed material please contact me at (301) 332-9152.

Yours sincerely,

Glenn Archinoff
Manager ACR Licensing

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/Attachments:
1. Response to NRC's RAIs on Thermal Hydraulic Data – CANDU 6 Data (Non-Proprietary)

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Attachment 1
(Letter G. Archinoff to B. Sosa, "Response to RAIs on Thermal Hydraulic Data: CANDU 6 Data (Non-Proprietary)", January 28, 2005)

Response to NRC's RAIs on Thermal Hydraulic Data – CANDU 6 Data (Non-Proprietary)

For the CANDU 6 design, AECL's response to NRC's RAIs on Thermal Hydraulic data are provided in the table below. Please also note the following regarding the data provided:

- All pressures are given in MPa(g);
- The steady state pressure, temperature and mass flow rate data are nominal values;
- The lowest elevation channel data provided are for channel W11, which is one of the lowest elevation channels;
- The average channel data provided are for channel L20. This channel is considered to be representative of an average channel since it is a mid-elevation channel and its power is very close to the average power per channel for the whole core.
- The hottest channel data provided are for channel O6, which is in the high-power region of the core.

INLET HEADERS

Parameter	CANDU 6
length (m)	
diameter (m)	
metal wall thickness (m)	
Material	Carbon steel
metal mass (kg)	
metal density (kg/m^3)	7859
metal specific heat (kJ/kg·K)	0.49
surface roughness (mm)	
# feeders	95
feeder diameter at header (m)	
off take angles (1, 2, 3, 4, 5, 6) (degrees)	
# ECI injection ports	

injection port diameter (m)	
axial location of first injection port (m)	
axial location of second injection port (m)	
axial location of interconnect line (m)	
ECI flow range (kg/s)	0 - 1000
Interconnect flow range (kg/s)	N/A
break orifice size (m^2)[1]	
break location	No restriction
mass flow rate (steady state) (kg/s)	
average pressure (steady state) (MPa(g))	
average temperature (steady state) (°C)	

1 Lower limit based on break area = 2 x largest feeder (3% of 2 x inlet header cross-sectional area); upper limit based on break area = 2 x inlet header cross-sectional area.

OUTLET HEADERS

Parameter	CANDU 6
length (m)	
diameter (m)	
metal wall thickness (m)	
material	Carbon steel
metal mass (kg)	
metal density (kg/m^3)	7859
metal specific heat (kJ/kg·K)	0.49
surface roughness (mm)	
# feeders	95
feeder diameter at header (m)	
off take angles (1, 2, 3, 4, 5, 6) (degrees)	
# ECI injection ports	
injection port diameter (m)	
axial location of first injection port (m)	
axial location of second injection port (m)	
axial location of interconnect line (m)	
ECI flow range (kg/s)	0 – 1000
interconnect ECI flow range (kg/s)	N/A
break orifice size (m^2)^2	
break location	No restriction
mass flow rate (steady state) (kg/s)	
average pressure (steady state) (MPa(g))	
average temperature (steady state) (°C)	

2 Lower limit based on break area = 2 x largest feeder (3% of 2 x outlet header cross-sectional area); upper limit based on break area = 2 x outlet header cross-sectional area.

INLET FEEDER (Leading to the lowest elevation fuel channel, channel W11)

Parameter	CANDU 6
length of pipe-header to inlet end fitting (m)	
Diameter (ID) of pipe-header to inlet end fitting (m), D	
Metal wall thickness-header to inlet end fitting (m)	
Material	Carbon steel
metal mass (kg)	
metal density (kg/m^3)	7859
metal specific heat (kJ/kg·K)	0.49
surface roughness (mm)	
elevation drop-header to channel (m)	
K value for total form loss[3]	
reference parameter for K value	D =
temperature at header (steady state) (°C)	
temperature at end-fitting (steady state) (°C)	
pressure at header (steady state) (MPa(g))	
pressure at end-fitting (steady state) (MPa(g))	
mass flow rate (steady state) (kg/s)	

3 K value includes loss coefficient of pressure break down orifice.

OUTLET FEEDER (Leading to the lowest elevation fuel channel, channel W11)

Parameter	CANDU 6
length of pipe-end fitting to header (m)	
Diameter (ID) of pipe-end fitting to header (m), D	
metal wall thickness-end fitting to header (m)	
material	Carbon steel
metal mass (kg)	
metal density (kg/m^3)	7859
metal specific heat (kJ/kg·K)	0.49
surface roughness (mm)	
elevation rise-end fitting to header (m)	
K value for total form loss	
reference parameter for K value	D =
temperature at header (steady state) (°C)	
temperature at end-fitting (steady state) (°C)	
pressure at header (steady state) (MPa(g))	
pressure at end-fitting (steady state) (MPa(g))	
mass flow rate (steady state) (kg/s)	

INLET FEEDER (For the average fuel channel, which is considered here to be channel L20)

Parameter	CANDU 6
length of pipe-header to inlet end fitting (m)	
Diameter (ID) of pipe-header to inlet end fitting (m), D	
Metal wall thickness-header to inlet end fitting (m)	
Material	Carbon steel
metal mass (kg)	
metal density (kg/m^3)	7859
metal specific heat (kJ/kg·K)	0.49
surface roughness (mm)	
elevation drop-header to channel (m)	
K value for total form loss[4]	
reference parameter for K value	D =
temperature at header (steady state) (°C)	
temperature at end-fitting (steady state) (°C)	
pressure at header (steady state) (MPa(g))	
pressure at end-fitting (steady state) (MPa(g))	
mass flow rate (steady state) (kg/s)	

4 K value includes resistance coefficient of pressure breakdown orifice.

OUTLET FEEDER (For the average fuel channel, which is considered here to be channel L20)

Parameter	CANDU 6
length of pipe-expander to header (m)	
length of pipe-end fitting to expander (m)	
diameter (ID) of pipe-expander to header (m), D_1	
diameter (ID) of pipe-end fitting to expander (m), D_2	
metal wall thickness-expander to header (m)	
metal wall thickness-end fitting to expander (m)	
Material	Carbon steel
metal mass (kg)	
metal density (kg/m^3)	7859
metal specific heat ($kJ/kg \cdot K$)	0.49
surface roughness (mm)	
elevation rise-end fitting to header (m)	
K value for total form loss (based on D_1) K_1 is for D_1 portion K_2 is for D_2 portion	K = K_1 = K_2 =
reference parameter for K values	D_1, D_2
temperature at header (steady state) (°C)	
temperature at end-fitting (steady state) (°C)	
pressure at header (steady state) (MPa(g))	
pressure at end-fitting (steady state) (MPa(g))	
mass flow rate (steady state) (kg/s)	

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INLET FEEDER (For the hottest fuel channel, which is considered here to be channel O6)

Parameter	CANDU 6
length of pipe-header to reducer (m)	
length of pipe-reducer to inlet end fitting (m)	
diameter (ID) of pipe-header to reducer (m), D_1	
diameter (ID) of pipe-reducer to inlet end fitting (m), D_2	
metal wall thickness-header to reducer (m)	
metal wall thickness-reducer to inlet end fitting (m)	
material	Carbon steel
metal mass (kg)	
metal density (kg/m^3)	7859
metal specific heat ($kJ/kg \cdot K$)	0.492
surface roughness (mm)	
elevation drop-header to channel (m)	
K value for total form loss (based on D_1) K_1 is for D_1 portion K_2 is for D_2 portion	K = K_1 = K_2 =
reference parameter for K values	D_1, D_2
temperature at header (steady state) (°C)	
temperature at end-fitting (steady state) (°C)	
pressure at header (steady state)(MPa(g))	
pressure at end-fitting (steady state) (MPa(g))	
mass flow rate (steady state) (kg/s)	

OUTLET FEEDER (For the hottest fuel channel, which is considered here to be channel O6)

Parameter	CANDU 6
length of pipe-expander to header (m)	
length of pipe-end fitting to expander (m)	
diameter (ID) of pipe-expander to header (m), D_1	
diameter (ID) of pipe-end fitting to expander (m), D_2	
metal wall thickness-expander to header (m)	
metal wall thickness-end fitting to expander (m)	
material	Carbon steel
metal mass (kg)	
metal density (kg/m^3)	7859
metal specific heat ($kJ/kg \cdot K$)	0.492
surface roughness (mm)	
elevation rise-end fitting to header (m)	
K value for total form loss (based on D_1) K_1 is for D_1 portion K_2 is for D_2 portion	K = K_1 = K_2 =
reference parameter for K value	D_1, D_2
temperature at header (steady state) (°C)	
temperature at end-fitting (steady state) (°C)	
pressure at header (steady state) (MPa(g))	
pressure at end-fitting (steady state) (MPa(g))	
mass flow rate (steady state) (kg/s)	

INLET END FITTING

Parameter	CANDU 6
Material	Modified Type 403 stainless steel
metal mass (kg); includes end fitting body only	
Mass, closure plug (kg)	
Mass, liner tube (kg)	
Mass, shield plug (kg)	
metal density (kg/m^3)	7750
metal specific heat at 300°C (kJ/kg·K)	0.56
fluid volume (m^3)	
flow area at feeder connect (m^2)	
hydraulic diameter at feeder connect (m)	
flow area at channel connect (m^2)	
hydraulic diameter at channel connect (m)	
flow area in annulus (m^2)	
hydraulic diameter in annulus (m)	
flow area of the 63 small holes (m^2)	
hydraulic diameter of the holes (m)	
K value for total form loss	
reference parameter for K value	A =
temperature drop-hottest channel O6 (°C)	
temperature drop-average channel L20 (°C)	
temperature drop-lowest elevation channel W11 (°C)	
pressure drop-hottest channel O6 (MPa)	
pressure drop-average channel L20 (MPa)	
pressure drop-lowest elevation channel W11 (MPa)	
mass flow rate-hottest channel O6 (kg/s)	
mass flow rate-average channel L20 (kg/s)	
mass flow rate-lowest elevation channel W11 (kg/s)	

OUTLET END FITTING

Parameter	CANDU 6
Material	Modified Type 403 stainless steel
metal mass (kg); includes end fitting body only	
Mass, closure plug (kg)	
Mass, liner tube (kg)	
Mass, shield plug (kg)	
metal density (kg/m^3)	7750
metal specific heat at 300°C (kJ/kg·K)	0.56
fluid volume (m^3)	
flow area at feeder connect (m^2)	
hydraulic diameter at feeder connect (m)	
flow area at channel connect (m^2)	
hydraulic diameter at channel connect (m)	
flow area in annulus (m^2)	
hydraulic diameter in annulus (m)	
flow area of all the little holes (m^2)	
hydraulic diameter of the holes (m)	
K value for total form loss	
reference parameter for K value	A =
temperature drop-hottest channel O6 (°C)	
temperature drop-average channel L20 (°C)	
temperature drop-lowest elevation channel W11 (°C)	
pressure drop-hottest channel O6 (MPa)	
pressure drop-average channel L20 (MPa)	
pressure drop-lowest elevation channel W11 (MPa)	
mass flow rate-hottest channel O6 (kg/s)	
mass flow rate-average channel L20 (kg/s)	
mass flow rate-lowest elevation channel W11 (kg/s)	

FUEL PINS

Parameter	CANDU 6
Number of pins	37
cladding outer diameter (m)	
cladding thickness (m)	
cladding material	Zircaloy-4
cladding mass/bundle (kg)	
cladding density (kg/m^3)	6520
specific heat of cladding at 300°C (kJ/kg·K)	0.323
fuel outer diameter (m)	
fuel material	Sintered pellets of natural UO_2 and slightly depleted UO_2
fuel mass/bundle (kg)	
fuel density (kg/m^3)	10510
fuel specific heat at 300°C (kJ/kg·K)	0.276
hottest channel power (kW) (channel O6)	
hottest channel decay power (kW)[5]	
average channel power (kW) (channel L20)	
average channel decay power (kW)[5]	
bottom channel power (kW) (channel W11)	
bottom channel decay power (kW)[5]	
fuel bundle length (m)	0.495
length of pressure tube[6]	
inner diameter of pressure tube (m)	
Wall thickness of pressure tube (m)	
material type	Zr-2.5Nb
metal mass (kg)	
material density (kg/m^3)	6515
material specific heat at 300°C (kJ/kg·K)	0.323

5 With decay power fractions at 6 seconds (0.0484) and 1 day (0.00639).
6 Includes portion of pressure tube rolled into each end fitting.

CHANNEL HYDRAULICS

Parameter	CANDU 6
Fluid volume (m^3)	
Flow length (m)	
Flow area (m^2)	
hydraulic diameter (m)	
wetted perimeter (m)	
K value for total form loss	
reference parameter for K value	A =
average surface roughness of channel (mm)	
inlet pressure-hot channel O6 (MPa(g))	
outlet pressure-hot channel (MPa(g))	
inlet temperature-hot channel (°C)	
outlet temperature-hot channel (°C)	
mass flow rate-hot channel (kg/s)	
inlet pressure-average channel L20 (MPa(g))	
outlet pressure-average channel (MPa(g))	
inlet temperature-average channel (°C)	
outlet temperature-average channel (°C)	
mass flow rate-average channel (kg/s)	
inlet pressure-lowest elevation channel W11 (MPa(g))	
outlet pressure-lowest elevation channel (MPa(g))	
inlet temperature-lowest elevation channel (°C)	
outlet temperature-lowest elevation channel (°C)	
mass flow rate-lowest elevation channel (kg/s)	