Development of the HITEP_RCC-MRx program for the support of elevated temperature design evaluation and defect assessment according to RCC-MRx

2 April 2019

KAERI

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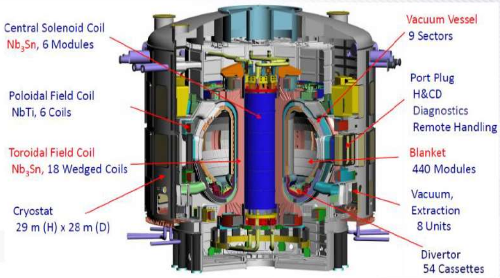
Outline

1. Introduction

❖ **Elevated Temperature Design (ETD) Codes**

- ➢ **ASME Section III Division 5 Subsection HB ('ASME-HB')**
- ➢ **RCC-MRx**
- ➢ JSME D&C Code for Fast Reactors, BDS (Japan)
- ➢ KEPIC MNH (SFR, Korea)



ITER

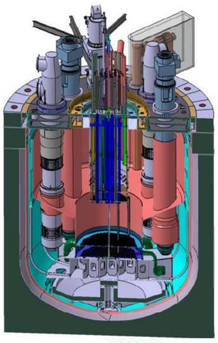
❖ **ETD Code for EU Gen. IV**

(ASTRID, MYRRHA, ALLEGRO)

- **RCC-MRx**

❖ **ETD Code for ITER**

- **RCC-MRx (Eurofer)**
- **ASME-HB**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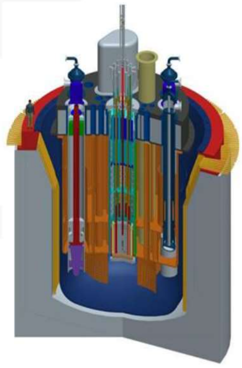
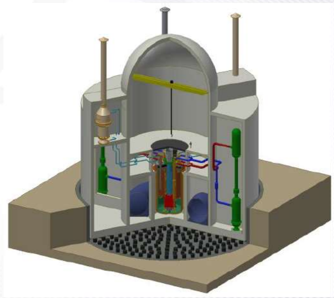
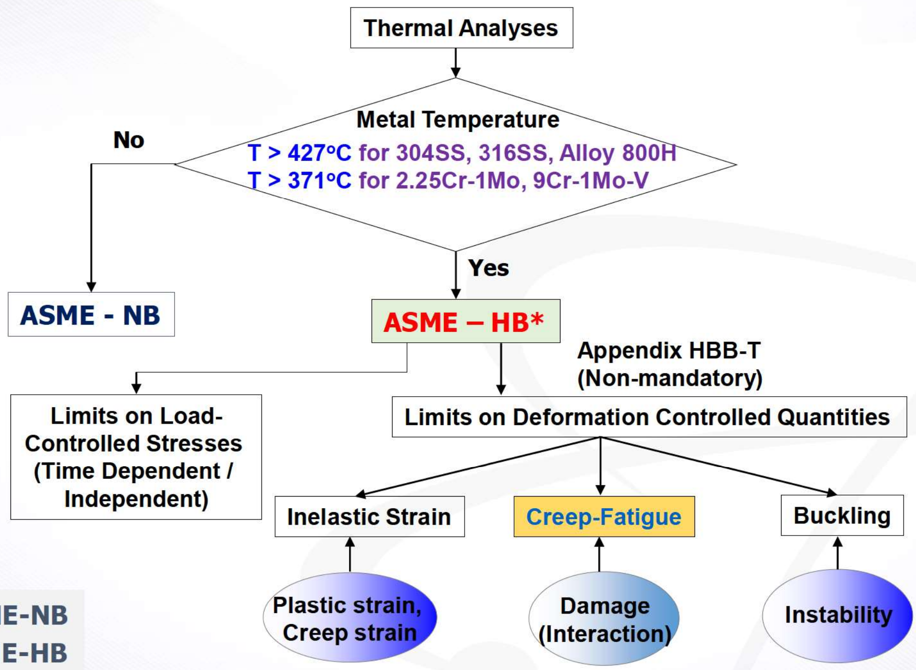

MYRRHA


ALLEGRO


PGSFR (Korea)

2. Elevated Temperature Design rules : ASME-HB



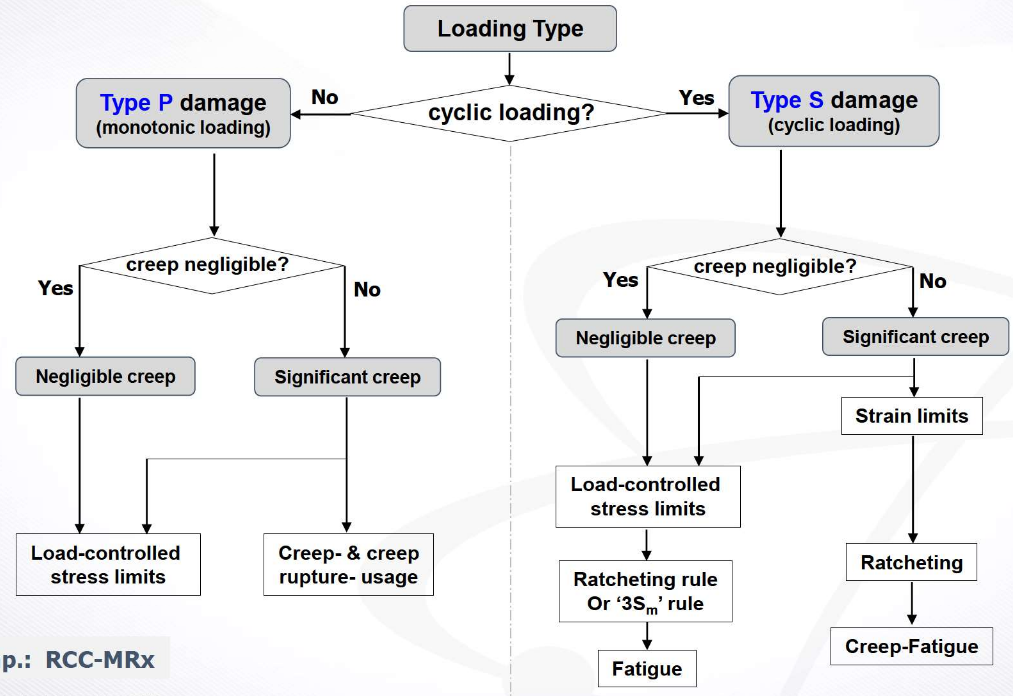
Materials

- 304SS
- 316SS
- 2.25Cr-1Mo
- Mod.9Cr-1Mo
- Alloy 800H
- Alloy 718(Bolt)

Low Temp.: ASME-NB
High Temp.: ASME-HB

*ASME-HB : ASME Section III Div.5 Subsection HB

2. Elevated Temperature Design rules : RCC-MRx



Materials
- 304
- 304L
- 316L
- 316L(N)
- 2.25Cr-1Mo
- Mod.9Cr-1Mo
- Alloy 800
- …

Low & High Temp.: RCC-MRx

2. Elevated Temperature Design rules : Comparison

❖ **ASME-HB**

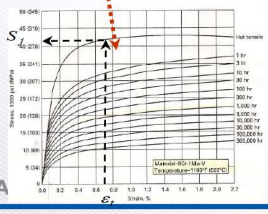
- strain based approach (strain results used)
- Equivalent strain range (peak strains should be excluded in elastic analysis approach)

$$\Delta\varepsilon_{equiv,i} = \frac{\sqrt{2}}{2(1+\nu^*)}\left[\left(\Delta\varepsilon_{x_i}-\Delta\varepsilon_{y_i}\right)^2+\left(\Delta\varepsilon_{y_i}-\Delta\varepsilon_{z_i}\right)^2+\left(\Delta\varepsilon_{z_i}-\Delta\varepsilon_{x_i}\right)^2 + \frac{3}{2}\left(\Delta\gamma^2{}_{xy_i}+\Delta\gamma^2{}_{yz_i}+\Delta\gamma^2{}_{zx_i}\right)\right]^{\frac{1}{2}}$$

$$\varepsilon_t = K_\nu \Delta\varepsilon_{\mathrm{mod}} + K\Delta\varepsilon_c$$

User dependent results because
- Hand calculations required
- Data are given in curve form

✓Isochronous curve based damage evaluation (both for creep & fatigue)



$$\sum_{j=1}^{p}\left(\frac{n}{N_d}\right)_j + \sum_{k=1}^{q}\left(\frac{\Delta t}{T_d}\right)_j \le D$$

❖ **RCC-MRx**

$\overline{\Delta(P+Q+F)}$

- strain from total S.I ($\overline{\Delta\sigma_{tot}}$) based approach (peak σ included : stress results used)

$$\overline{\Delta\varepsilon} = \overline{\Delta\varepsilon_{el+pl}} + \overline{\Delta\varepsilon_{cr}} \qquad \overline{\Delta\varepsilon_{el+pl}} = \overline{\Delta\varepsilon_1} + \overline{\Delta\varepsilon_2} + \overline{\Delta\varepsilon_3} + \overline{\Delta\varepsilon_4}$$

$$\overline{\Delta\varepsilon_1} = \frac{2}{3}(1+\nu)\frac{\overline{\Delta\sigma_{tot}}}{E}$$

$$\overline{\Delta\varepsilon_2} = \ldots$$

✓ Creep law is used for determining creep strain

$$\overline{\Delta\varepsilon_{cr}} \Leftarrow \varepsilon_{cr} = C_1 t^{C_2}\sigma^{n_1}$$

✓ Cyclic σ- ε curve

Better Reproducibility

Evaluation procedures more suitable for Programming

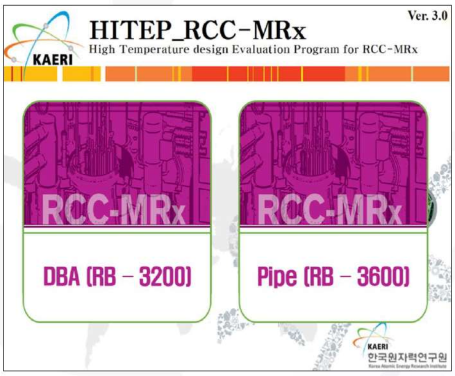
HITEP_RCC-MRx

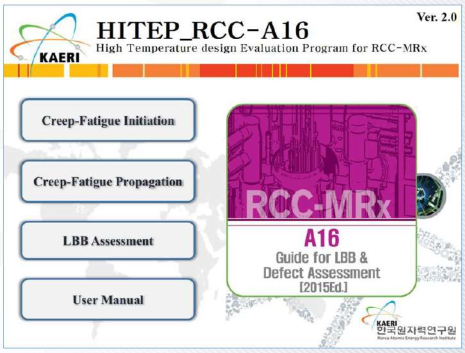
3. HITEP_RCC-MRx

- **'Design evaluation & defect assessment program' as per RCC-MRx (2018 Ed.).**
- **HITEP : HIgh Temperature design Evaluation Program of RCC-MRx.**
- **Language : PHP** (a server-side scripting language designed for web development)

  HITEP_RCC-MRx is operating at SMART phone as well (web-based program)

- **Three-module Program (3-piller)**
  - **DBA (Design-By-Analysis :RB-3200)**
  - **Pipe** (RB-3600)
  - **A16** (defect assessment)
- **Royalty License Agreement with CEA for DBA + Pipe module (9 Nov. 2017)**

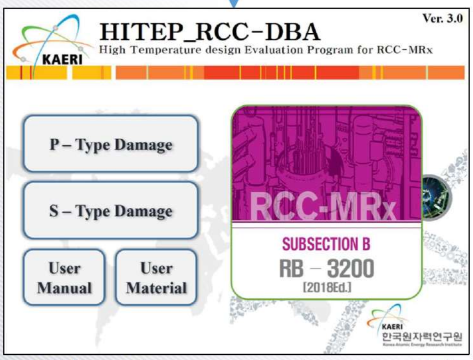




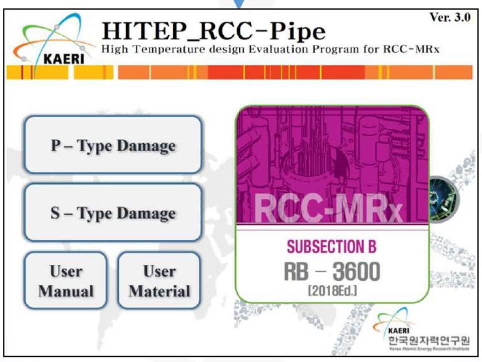
3. HITEP_RCC-MRx : Program Structure

HITEP_RCC-MRx Ver. 3.0

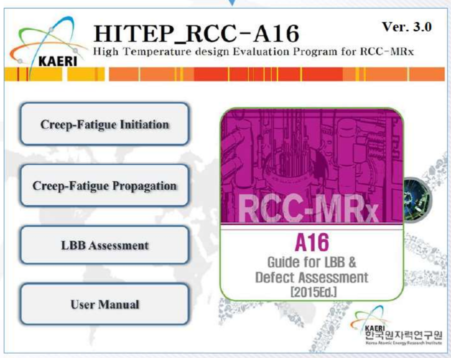
Design-By-Analysis (RB-3200)	Design-By-Rule for Piping (RB-3600)	Assessment for Defect (A16)
HITEP_RCC-DBA	HITEP_RCC-Pipe	HITEP_RCC-A16



DBA module (pressure boundary components)



Pipe module (pipe evaluations)



A16 (Defect & LBB assessment)

3.1 HITEP_RCC-DBA module

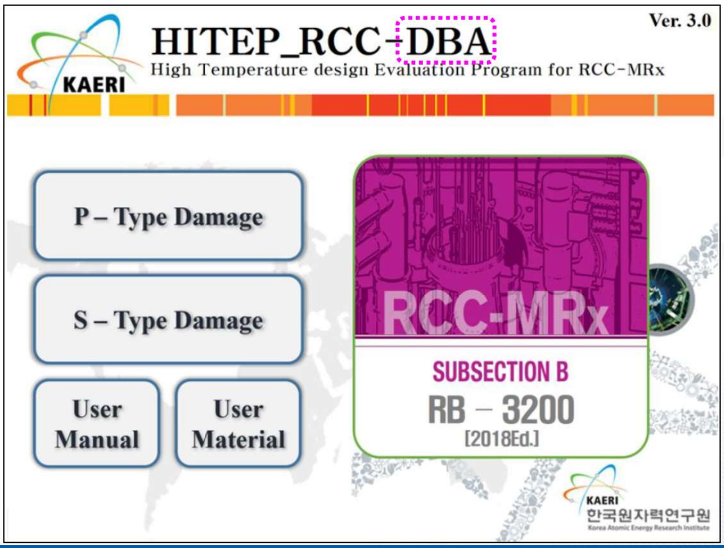
❖ **RCC-MRx RB-3200(DBA) design evaluation module**

- **Design-By-Analysis module for pressure boundary comp. (pressure vessel, Heat exchangers etc.)**
- **Main material properties (316L(N), 316L, 304, 304L, Gr.91, Eurofer) embedded.**
- **Creep-Fatigue Damage evaluation and Verification (third-party verifications)**

RCC-MRx RB-3200

P – Type Damage (RB-3250)
- Negligible Creep (RB-3251)
- Significant Creep (RB-3252)

S – Type Damage (RB-3260)
- Negligible Creep (RB-3261)
- Significant Creep (RB-3262)



3.1 HITEP_RCC-DBA module – Input & Output (1/3)

❖P-Type Damage

P - Type Damage

Material: 316L
Weld or Base: Base
Service Level: Level A / Level C / Level D
UNIT: MPa / Pa

[Primary Stress Component (Max)]

	σ_x	σ_y	σ_z	σ_{xy}	σ_{yz}	σ_{zx}
P_m	1.001	2.491	1.196	0.2092	2.171	-1.436
L_m	0	0	0	0	0	0
P_b	1.532	1.489	2.781	1.456	-4.317	-1.586
F	0.5823	0.386	1.776	0.8864	-0.9726	-0.6109

[Reset]

Max. temp (℃)	510	J-integral	350
Total Hold Time	15000	Cross-Section Coefficient(Φ)	0.88

[OK] | [Close]　[Save] [Reset All]

Input Window

P - Type Damage

P - Type Damage (Level A)

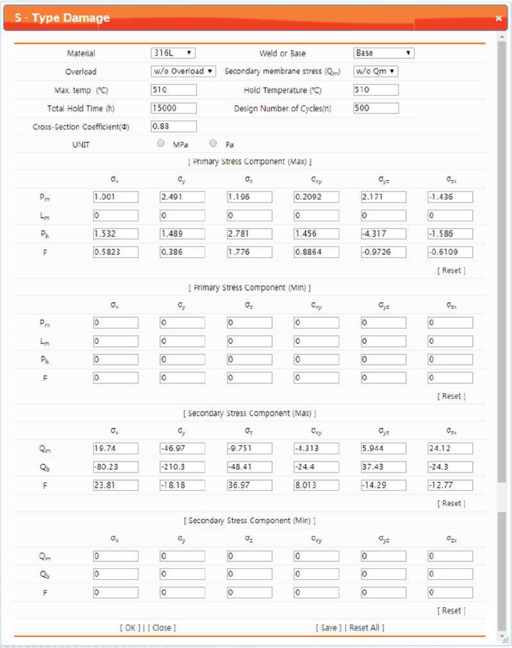
Material		316L		
Evaluation Items (Significant creep)		Calculated	Limit value	Remark
J-integral	$J_I < J_{IC}$	0 kJ/m^2	500 kJ/m^2	OK!! [+]
P_m	$P_m < S_m$	5.4674 Mpa	79.4 Mpa	OK!! [+]
P_L	$P_L < 1.5S_m$	5.4674 Mpa	119.1 Mpa	OK!! [+]
$P_L + P_b$	$P_L + P_b < 1.5S_m$	7.9891 Mpa	119.1 Mpa	OK!! [+]
$U_A(\Omega P_m)$	$U_A(\Omega P_m) \leq 1$	4.6860E-18	1	OK!! [+]
$U_A(P_m+\Phi P_b)$	$U_A(P_m+\Phi P_b) \leq 1$	1.9919E-16	1	OK!! [+]
$W_A(1.35P_m)$	$W_A(1.35P_m) \leq 1$	5.9928E-10	1	OK!! [+]
$W_A[1.35(P_m+\Phi P_b)])$	$W_A[1.35(P_m+\Phi P_b)] \leq 1$	3.5067E-9	1	OK!! [+]

[Back] | [Next]

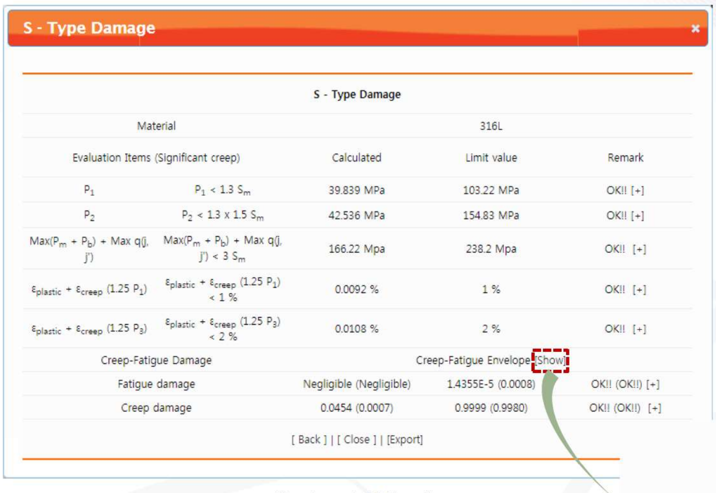
Output Window

3.1 DBA module – Input & Output (2/3)

❖S-Type Damage

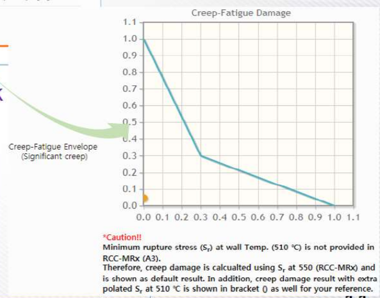


Input Window



Output Window

click



3.1 DBA module – Input & Output (3/3)

❖**Exporting total evaluation results in Excel form**

HITEP_RCC-DBA					
Material	316L				
Service Level	Level A				
Max. Wall Temp.	300				
Total hold Time	8507				
Hold Temperature	545				
Evaluation Items			**Caculated**	**Limit value**	**Remark**
P Type Damage	**Neglgible Creep**	$P_m < S_m$	31.118	102	OK!!
		$P_L < 1.5S_m$	31.118	153	OK!!
		$P_L + P_b < 1.5S_m$	43.891	153	OK!!
		J-integral	350	500	OK!!
	Significant Creep	$U(\Omega P_m)$	0.6607	1	OK!!
		$U(P_m+P_b)$	0.5519	1	OK!!
		$W(1.35P_m)$	4.7975E-16	1	OK!!
		$W[1.35(P_m+\Phi P_b)]$	6.0158E-14	1	OK!!
S Type Damage	**Nelgibile Creep**	$P_1 < 1.3\ S_m$	38.062	132.6	OK!!
		$P_2 < 1.3 \times 1.5\ S_m$	87.698	198.9	OK!!
		$Max(P_m + P_b) + Max\ q(j,j') < 3\ S_m$	396.72	306	Fail
		Fatigue Damage	0.0029	0.0099	OK!!
	Significant Creep	$\varepsilon_{plastic} + \varepsilon_{creep}\ (1.25\ P_1) < 1\ \%$	1.8903E-5	1	OK!!
		$\varepsilon_{plastic} + \varepsilon_{creep}\ (1.25\ P_3) < 2\ \%$	0.0315	2	OK!!
		Fatigue Damage	0.0029	0.0099	OK!!
		Creep Damage	0.2933	0.9768	OK!!

3.2 HITEP_RCC-Pipe module

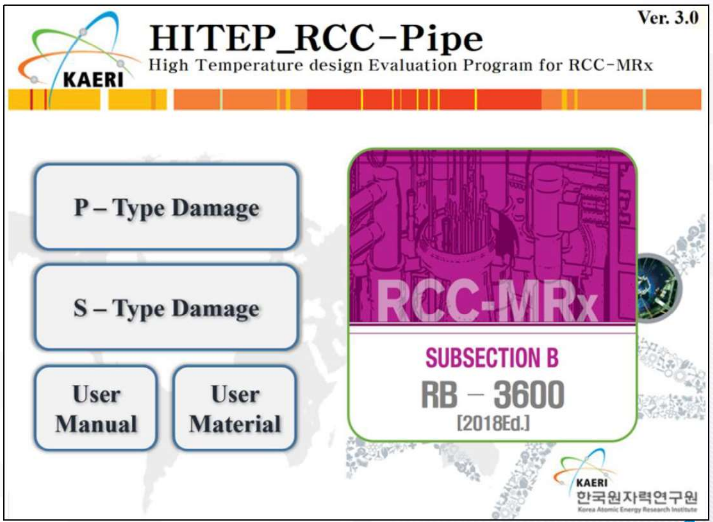
❖ **RCC-MRx RB-3600(DBR) program**

– Evaluations on P-Type & S-Type damage

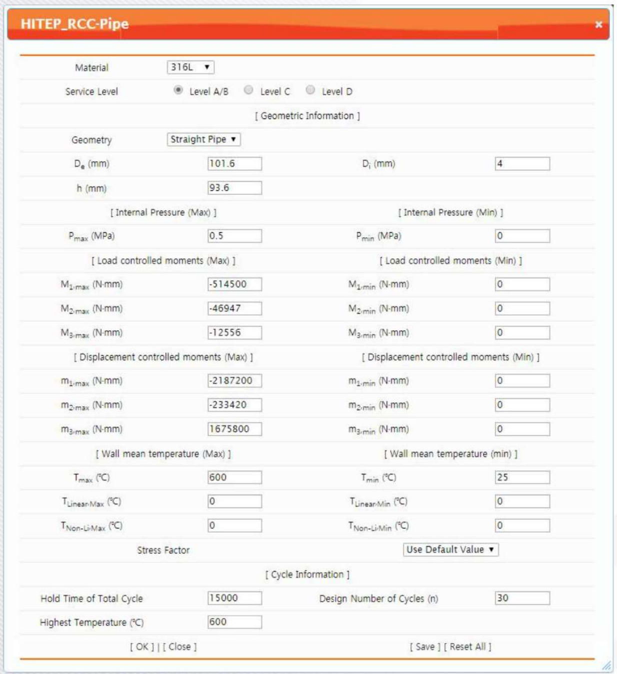
– Web-based DBR (Design-By-Rule) evaluation module.

RCC-MRx RB-3600

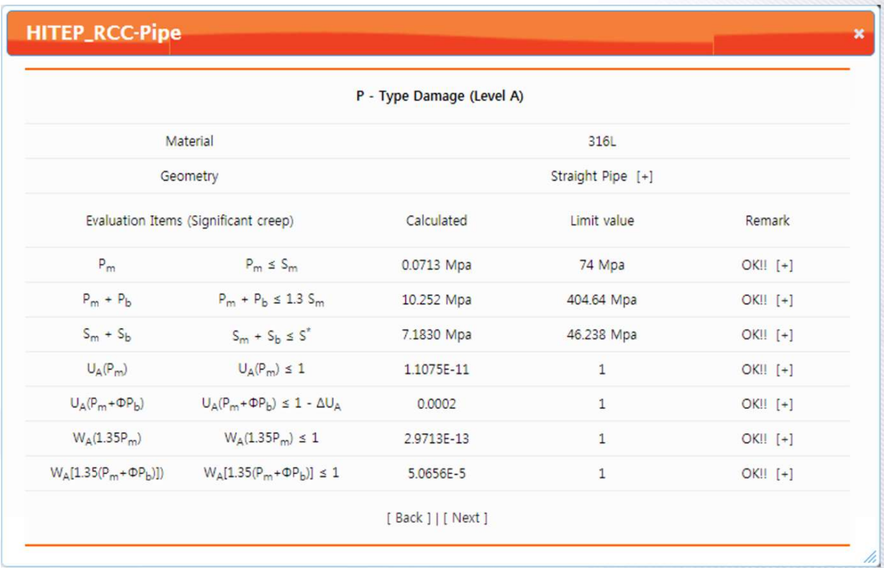
- **P – Type Damage (RB-3650)**
  - Negligible Creep (RB-3651)
  - Significant Creep (RB-3652)
- **S – Type Damage (RB-3660)**
  - Negligible Creep (RB-3661)
  - Significant Creep (RB-3662)



3.2 HITEP_RCC-DBA module – Input & Output (1/3)



Input Window



Output Window

3.2 Pipe module – Input & Output (2/3)

❖RCC-MRx RB-3600 (DBR*) based C-F damage evaluati

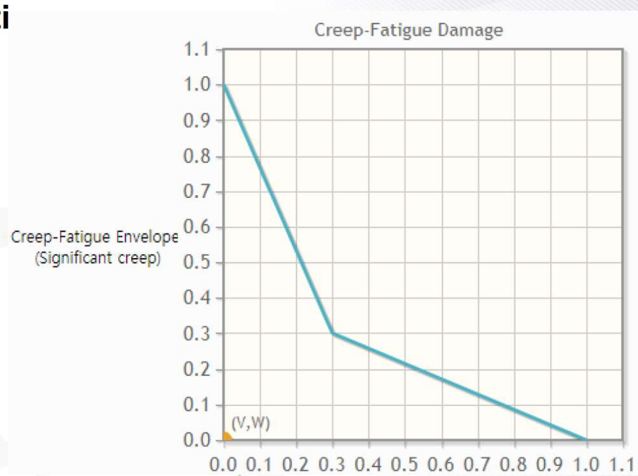
HITEP_RCC-Pipe

S - Type Damage (Level A)

Material		316LN		
Geometry		Straight Pipe [+]		
Evaluation Items (Significant creep)		Calculated	Limit value	Remark
P_1	$P_1 < 1.3\ S_m$	24.301 MPa	126.88 MPa	OK!! [+]
P_2	$P_2 < 1.69\ S_m$	45.036 MPa	164.94 MPa	OK!! [+]
Max(P_m + P_b) + Max q(j, j')	Max(P_m + P_b) + Max q(j, j') < 3 S_m	117.15 Mpa	292.8 Mpa	OK!! [+]
$\varepsilon_{plastic} + \varepsilon_{creep}$ (1.25 P_1)	$\varepsilon_{plastic} + \varepsilon_{creep}$ (1.25 P_1) < 1 %	0.0002 %	1 %	OK!! [+]
$\varepsilon_{plastic} + \varepsilon_{creep}$ (1.25 P_3)	$\varepsilon_{plastic} + \varepsilon_{creep}$ (1.25 P_3) < 2 %	0.0017 %	2 %	OK!! [+]
Creep-Fatigue Damage		Creep-Fatigue Envelope [Show]		
Fatigue damage		Negligible	4.8864E-9	OK!! [+]
Creep damage		0.0002	0.9999	OK!! [+]

[Back] | [Close] | [Export]

click



*DBR : Design-By-Rule

3.2 Pipe module – Input & Output (3/3)

❖ **Exporting total evaluation results in Excel form (for pipe design)**

HITEP_RCC-Pipe					
Geometry		Straight Pipe			
Material		316L			
Service Level		Level A			
Max. Wall Temp.		300			
Total hold Time		8507			
Hold Temperature		545			
Evaluation Items			**Caculated**	**Limit value**	**Remark**
P Type Damage	**Neglgible Creep**	$P_m < S_m$	31.118	153	OK!!
		$P_L < 1.5S_m$	43.891	153	OK!!
		$P_L + P_b < 1.5S_m$	0.6607	1	OK!!
	Significant Creep	$U(\Omega P_m)$	0.5519	1	OK!!
		$U(P_m+P_b)$	4.7975E-16	1	OK!!
		$W(1.35P_m)$	6.0158E-14	1	OK!!
		$W[1.35(P_m+\Phi P_b)]$	350	500	OK!!
S Type Damage	**Nelgibile Creep**	$P_1 < 1.3\ S_m$	38.062	132.6	OK!!
		$P_2 < 1.3 \times 1.5\ S_m$	87.698	198.9	OK!!
		$Max(P_m + P_b) + Max\ q(j,j') < 3\ S_m$	396.72	306	Fail
		Fatigue Damage	0.0029	1	OK!!
	Significant Creep	$\varepsilon_{plastic} + \varepsilon_{creep}\ (1.25\ P_1) < 1\ \%$	1.8903E-5	1	OK!!
		$\varepsilon_{plastic} + \varepsilon_{creep}\ (1.25\ P_3) < 2\ \%$	0.0315	2	OK!!
		Fatigue Damage	0.0029	0.0099	OK!!
		Creep Damage	0.2933	0.9768	OK!!

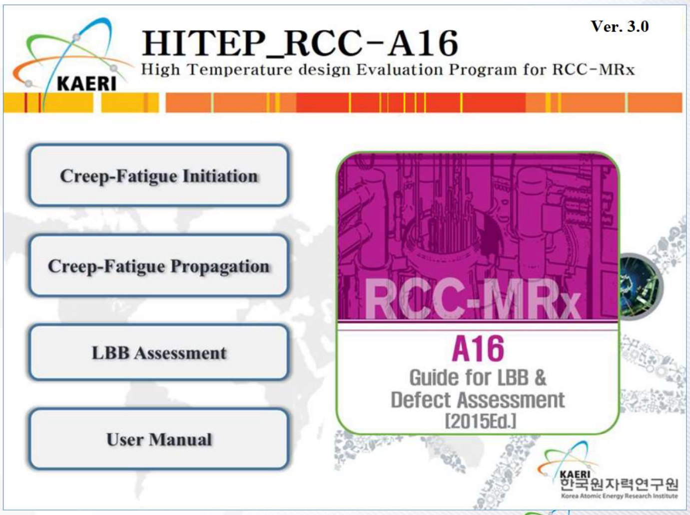
3.3 HITEP_RCC-A16 module

❖HITEP-RCC-A16

- 'Creep-Fatigue crack initiation', 'C-F crack propagation' and 'LBB' Evaluation Block.
- For verifications, direct calculations with Excel and MJSAM used.
- MJSAM example partly used for verification.

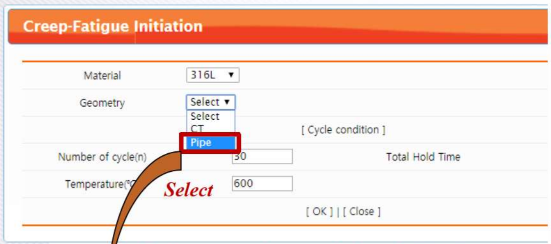
RCC-MRx Appendix A16

- **Creep-Fatigue Initiation**
  A16.3321.2, A16.3322.2
- **Creep-Fatigue Propagation**
  A16.3321.3, A16.3322.3
- **Leak Before Break**
  A16.3400



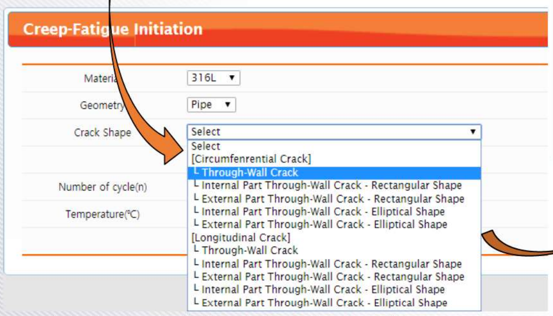
3.3 A16 module – **Creep-Fatigue Initiation** (1/2)

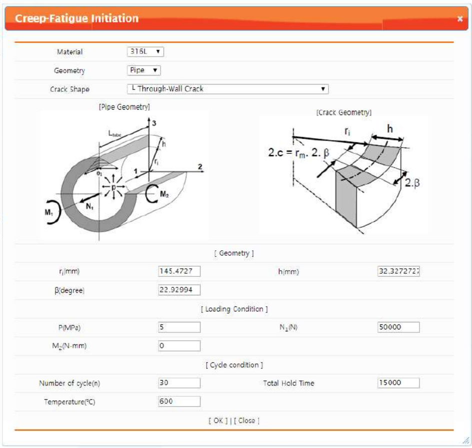
❖ Input window of C-F Crack Initiation evaluation



Select

Initial screen of creep-fatigue initiation





❖ Output window

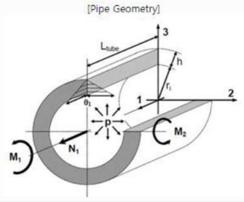
3.3 A16 module – Creep-Fatigue Propagation

❖ **Input window**

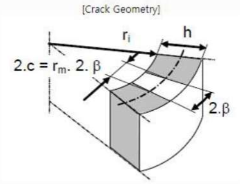
Creep-Fatigue Propagation ×

Material	316L ▾		
Geometry	Pipe ▾		
Crack Shape	└ Through-Wall Crack ▾		

[Pipe Geometry]



[Crack Geometry]



[Geometry]			
r_i(mm)	145.4727	h(mm)	32.3272727
β(degree)	22.92994		
[Loading Condition(Max)]		[Loading Condition(Min)]	
P_{max}(MPa)	5	P_{min}(MPa)	0.5
$N_{1,max}$(N)	5000000	$N_{1,min}$(N)	500000
$M_{2,max}$(N-mm)	0	$M_{2,min}$(N-mm)	0
[Cycle condition]			
Number of cycle(n)	30	Total Hold Time	15000
Temperature(℃)	600		

[OK] | [Close]

❖ **Output window**

Creep-Fatigue Propagation ×

Creep-Fatigue Propagation

Material	316L

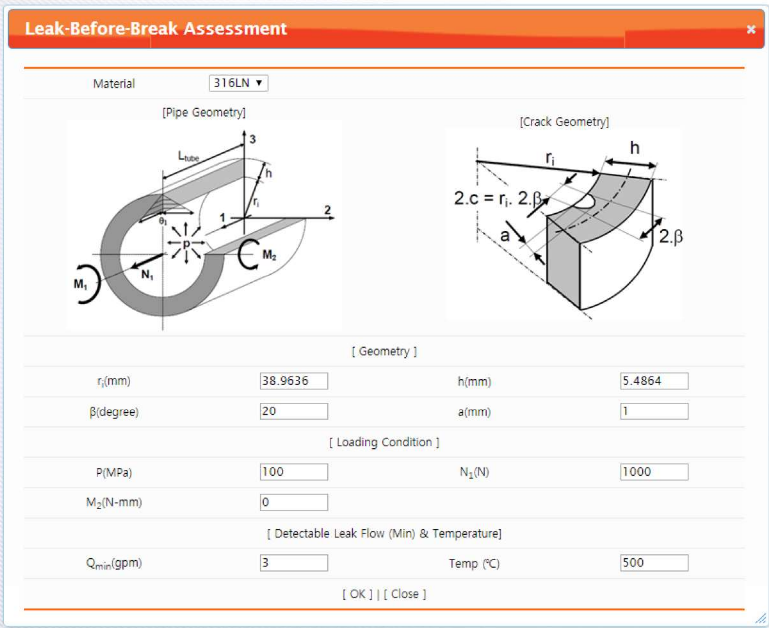
$$\boxed{a_{new} = C[(\Delta K_{eff})_i]^n + \int_{t_i}^{t_i+t_{mi}} A(C_i^*(t))^q\,dt}$$

Evaluation Items;	Calculated	Evaluation Items	Calculated
Final Crack Length(a_{final})	309.66	Final Crack Angle	132.19 [+]
Number of Cycles to wall penetration	22 [+]		

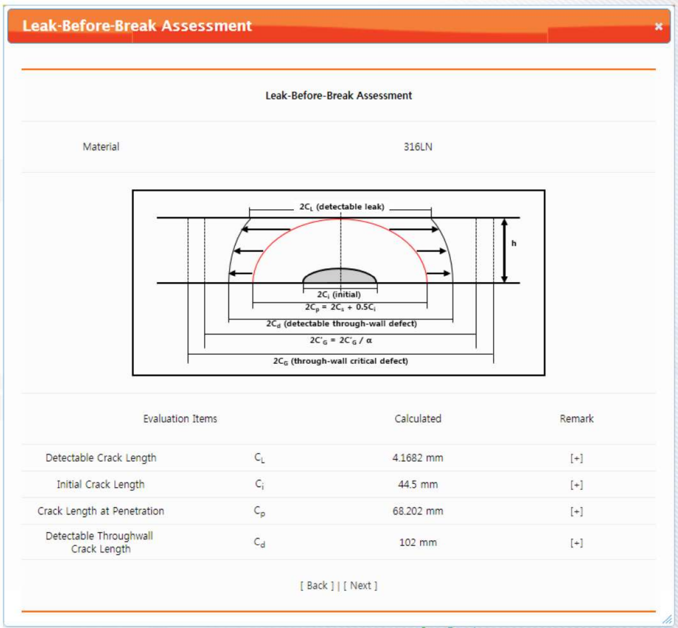
[Back] | [Next]

3.3 A16 module – Leak Before Break analysis (1/2)

❖ **Input window**

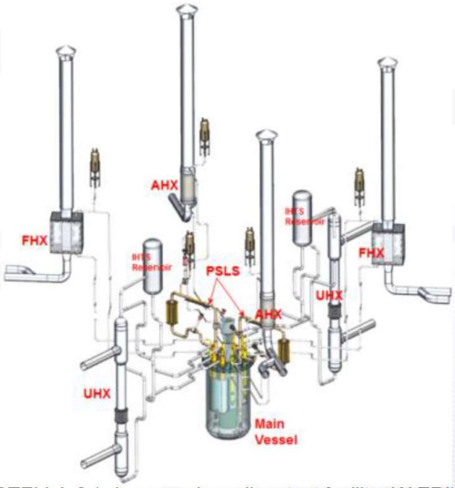


❖ **Output window**



4. Verification of HITEP_RCC-MRx

- **HITEP_RCC-DBA module**
- **HITEP_RCC-PIPE module**
- **HITEP_RCC-A16 module**



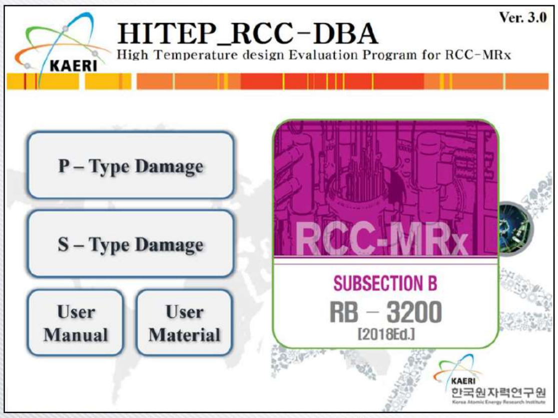
STELLA-2 (a large-scale sodium test facility, KAERI)

4.1 Verification of HITEP_RCC-DBA

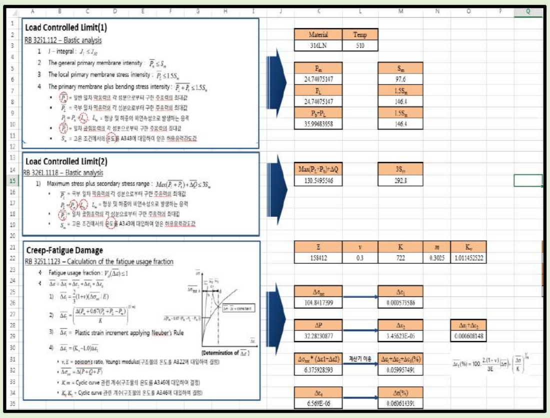
❖ **Method : Comparison of calculation results (HITEP vs. Direct Calculation with Excel)**

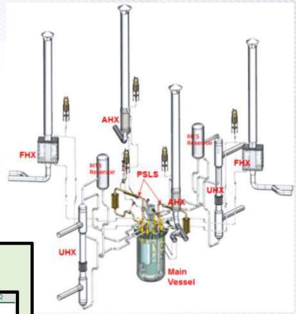
❖ **Material (present verification)**

- **316L : Main Vessel, Reservoir (Tank in ST-2*), AHX, FHX, UHX (HXs in ST-2), Exp. Tank (ST-1**)**
- **Gr.91 steel : DHX, IHX (STELLA-2)**
- **Eurofer : IHX (assumed material for IHX)**



Direct Calculation with Excel



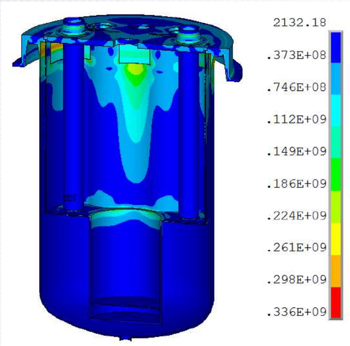


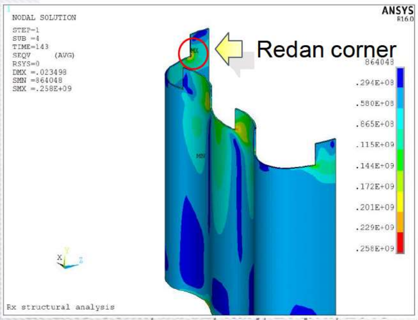
STELLA-2 Facility (KAERI)

*ST-2 : STELLA-2, **ST-1 : STELLA-1

4.1 Model Reactor Vessel of STELLA-2 (1/2)

❖ Material : 316L





➢ Comparison of the results

	HITEP	Excel
P_m	24.7	24.7
P_L	24.7	24.7
$P_L + P_B$	33.6	33.6
S_m	91.8	91.8
$1.5S_m$	137.7	137.7
$Max(P_L+P_b) + \Delta Q$	309.6	309.6
$3S_m$	245.16	245.16
$T_k(\sigma_k(0)/0.9)$	1855198	1856319
$T_k(\sigma_k(30)/0.9)$	2490919	2505228

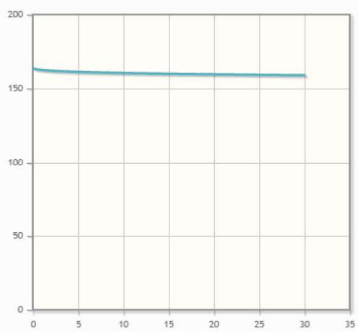
❖ Temp, Hold time, Cycle

Temperature	Hold Time	Number of Cycle
470℃	30 h	500

❖ Creep Damage detailed results

Creep damage	0.0065	0.9996	OK!! [+]
$W_k(\sigma_k)$ =	$t_k / T_k(\sigma_k)$		
$\Delta\varepsilon_{fl}$ =	$\overline{\Delta\varepsilon_{fl}} = \int_0^{T^*} \dot{\varepsilon}_{fl}(\sigma_k)\,dt$	$\sigma_k(0)$ =	$P_{max} + K_s\Delta S^*$
P_{max} =	33.6 MPa	K_s =	0.5765
ΔS^* =	$\Delta\sigma^* - \Delta P$ =	225.98 MPa	
$\Delta\sigma^*$ =	225.98 MPa	ΔP =	0 MPa

Stress Relaxation



$\sigma_k(0)$ =	163.89 MPa	$\sigma_k(30)$ =	158.86 MPa
$T_k(\sigma_k(0)/0.9)$ =	1855198 h	$T_k(\sigma_k(30)/0.9)$ =	2490919 h

4.1 Model Reactor Vessel of STELLA-2 (2/2)

❖ Creep – Fatigue Damage

Evaluation results of creep-fatigue damage

➢ **Comparison of the results (316L)**

	HITEP	Excel
Fatigue Damage	0.0001	0.0001
Creep Damage	0.0065	0.0064

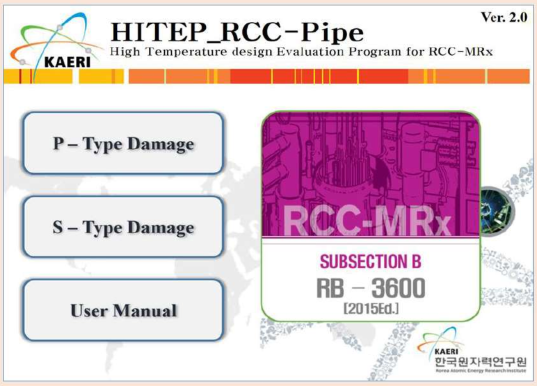
4.2 Verification of HITEP_RCC-PIPE

❖ **RCC-MRx RB-3600(DBR) based program**

➢ **Verification of HITEP_RCC-Pipe**

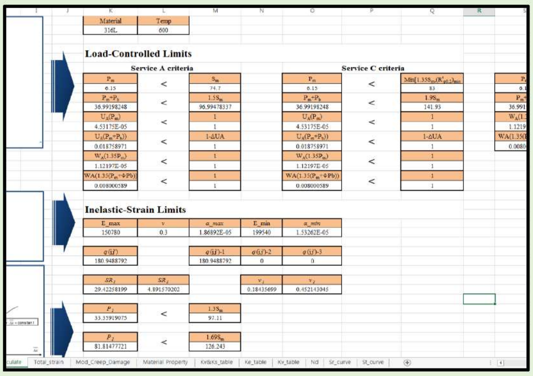
- Comparison of results (HITEP vs. direct calculation with Excel)

HITEP_RCC-PIPIE



comparison

Direct calculation with Excel

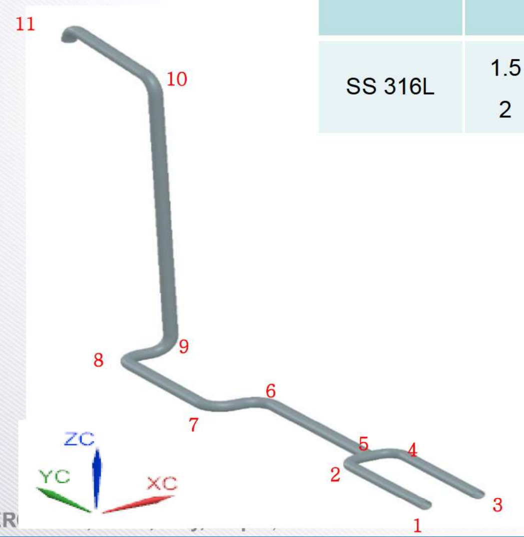


4.2 Hot Leg Piping (1/2)

❖ **Hot leg of IHTS* in STELLA-2 sodium test facility**

❖ **Material : 316L**

Material	R/D	Size, SCH	OD/WT (mm)	Rtemp. (℃)	Design Temp.(℃)	Design Pressure (Mpa)
SS 316L	1.5 2	3.5” SCH20S 4” SCH20S	101.6./4 114.3/4	25	600 (H/L)	0.5



Node conditions

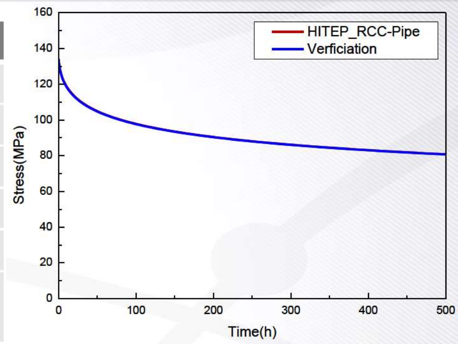
- Node 1, 5, 11 : Built in
- Node 6, 7, 8, 9, 10 : R/D=2
- Node 2, 4 : R/D=1.5=LR
- Node 1~5 : 3.5” SCH20S
- Node 3~11 : 4” SCH20S
- Node 3 : Tee & Reducer 3.5” to 4”

* IHTS : Intermediate Heat Transfer System

4.2 Hot Leg Piping (2/2)

Creep-Fatigue Damage evaluation result

	HITEP	Excel
$\Delta\varepsilon$	0.2354	0.2354
$N_j(\Delta\varepsilon)$	13972	13977
$\Delta\varepsilon_{el+pl}$	0.1339	0.1339
$\Delta\varepsilon_{fl}$	0.1014	0.1014
$\Delta\varepsilon_{1}$	0.1234	0.1234
$\Delta\varepsilon_{2}$	1.5295E-5	1.5295E-5



Stress relaxation analysis result

	HITEP	Excel
Fatigue Damage	0.0021	0.0021
Creep Damage	0.2505	0.2483

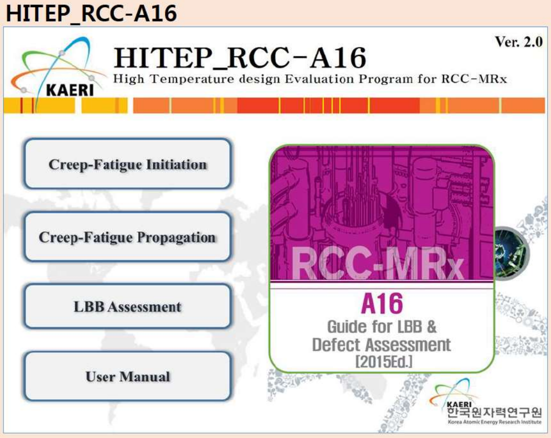
4.3 Verification of HITEP_RCC-A16

❖ RCC-MRx A16 based program

➢ Verification of HITEP_RCC-A16

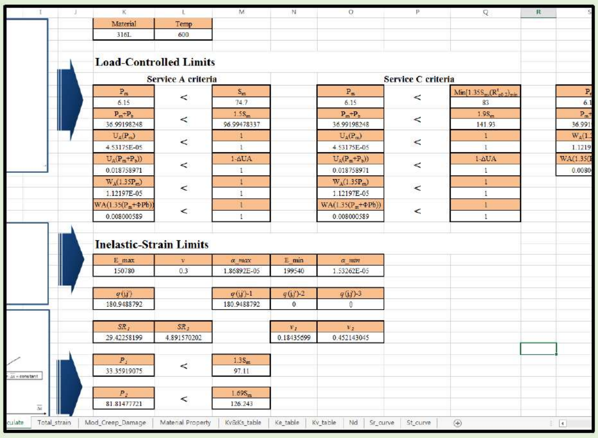
- Comparison of results (HITEP vs. direct calculation with Excel)

HITEP_RCC-A16



comparison

Direct calculation with excel

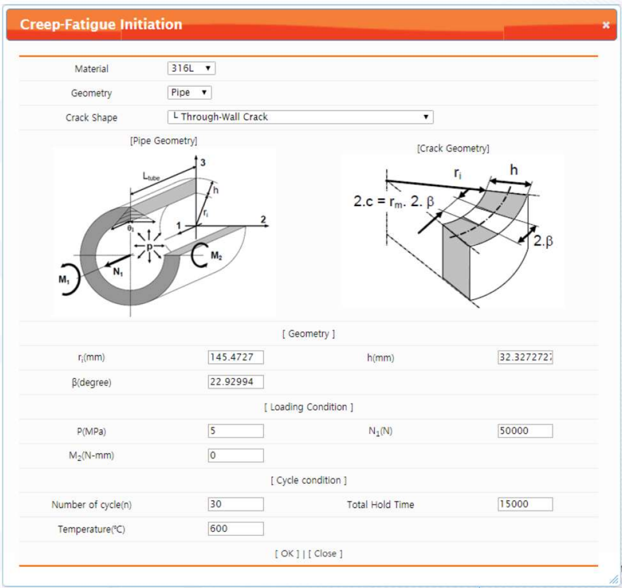


4.3 Creep-Fatigue Initiation (1/2)

❖ Assessment of Creep-Fatigue Crack Initiation with HITEP_RCC-A16

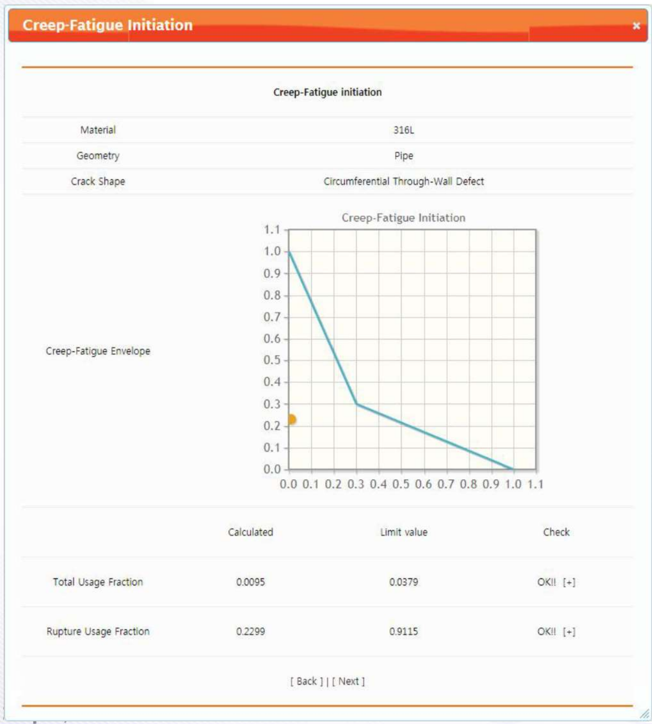
- **Verification Ex. : Pipe with through-wall crack**
- **Verifications : Calculations from A16 module & direct calculations**
- **Specifications**

	Specifications & Loading Conditions	
Pipe with semi-circular penetrated crack	Material	316 L
	r_i (mm)	145.4727
	h (mm)	32.3272
	β (mm)	22.93
Loading conditions	N_1 (N)	50,000
	M_2 (N-mm)	0
	P (MPa)	5
	Temperature (°C)	600
	Number of cycle	30
	Total hold time (h)	15,000



4.3 Creep-Fatigue Initiation (2/2)

❖ **Output window**



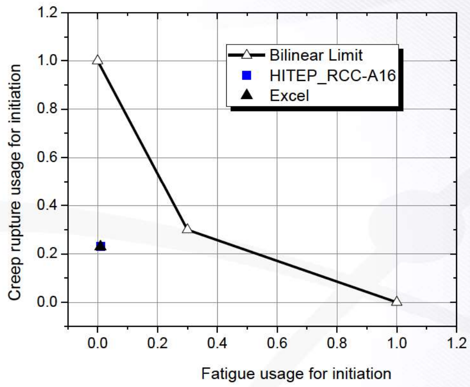
Creep-Fatigue Initiation

Creep-Fatigue initiation

Material	316L
Geometry	Pipe
Crack Shape	Circumferential Through-Wall Defect
Creep-Fatigue Envelope	

	Calculated	Limit value	Check
Total Usage Fraction	0.0095	0.0379	OK!! [+]
Rupture Usage Fraction	0.2299	0.9115	OK!! [+]

[Back] | [Next]



Assessment results on C-F crack initiation

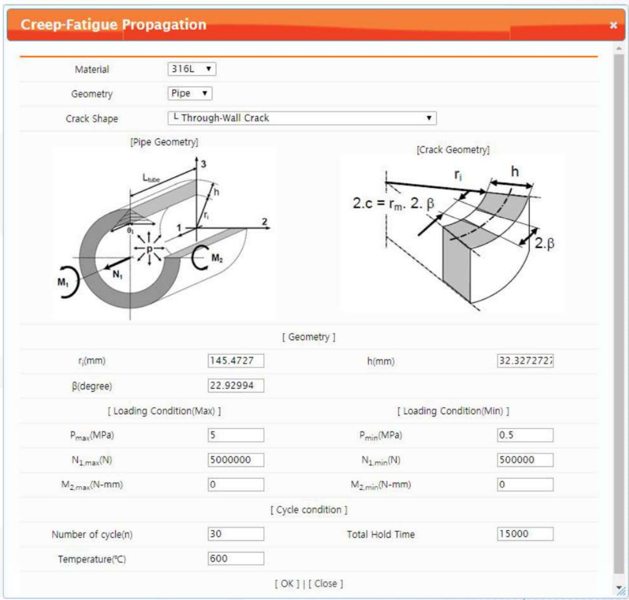
Evaluation Items	HITEP	Excel
Total Usage Fraction	0.0095	0.0095
Rupture Usage Fraction	0.2299	0.2299

4.3 Creep-Fatigue Propagation (1/2)

❖ Assessment of Creep-Fatigue Crack Propagation with HITEP_RCC-A16

- **Verification Ex. : pipe with through-wall crack**
- **Verifications : Calculations from A16 module & direct calculations**
- **Specifications**

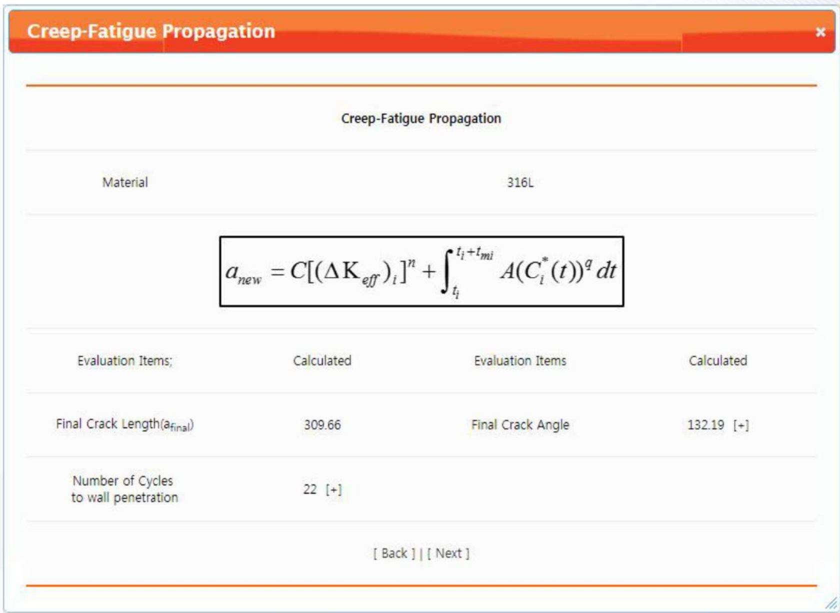
	Specifications & Loading Conditions	
Pipe with semi-circular penetrated crack	Material	316 L
	r_i (mm)	145.4727
	h (mm)	32.3272
	β (mm)	22.93
Loading conditions	N_1 (N)	5,000,000 / 500,000
	M_2 (N-mm)	0
	P (MPa)	5 / 0.5
	Temperature (ºC)	600
	Number of cycle	30
	Total hold time (h)	15,000



4.3 Creep-Fatigue Propagation (2/2)

❖ Assessment results on C-F crack propagation

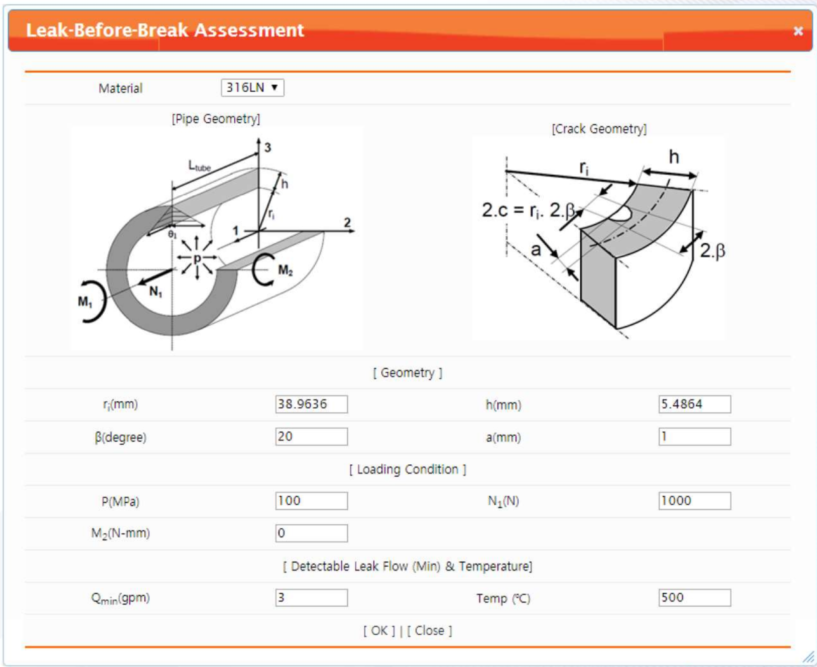
Evaluation Items	HITEP	Excel
Final Crack Length	309.66	309.66
Final Crack Angle	132.19	132.19
Number of Cycles to wall penetration	22	22



4.3 Leak Before Break analysis (1/2)

❖ Input data

Input data		HITEP_RCC-A16
Geometry	r_i (mm)	38.9636
	h (mm)	5.4864
	β (degree)	20
	a (mm)	1
Loading	P (MPa)	100
	N_1 (N)	1000
	M_2 (N-mm)	0
Q_{min} (gpm)		3
Temp (℃)		500



Leak-Before-Break Assessment ×

Material 316LN ▾

[Pipe Geometry] [Crack Geometry]

[Geometry]

r_i(mm)	38.9636	h(mm)	5.4864
β(degree)	20	a(mm)	1

[Loading Condition]

P(MPa)	100	N_1(N)	1000
M_2(N-mm)	0		

[Detectable Leak Flow (Min) & Temperature]

Q_{min}(gpm)	3	Temp (℃)	500

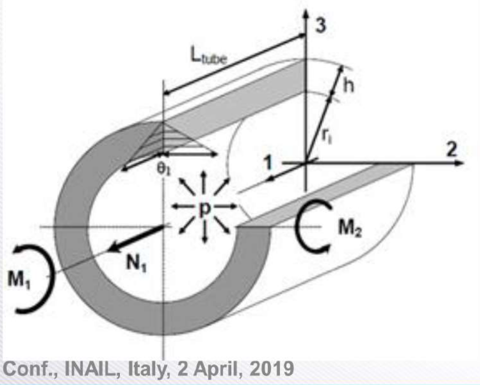
[OK] | [Close]

4.3 Leak Before Break analysis (2/2)

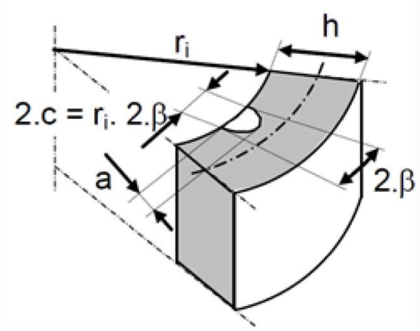
❖ Comparison of assessment results on crack lengths

Evaluation Items	HITEP_RCC-A16	Excel
Crack length at penetration	7.8270 mm	7.8270 mm
Detectable through-wall crack length	38.052 mm	38.052 mm

[Pipe Geometry]



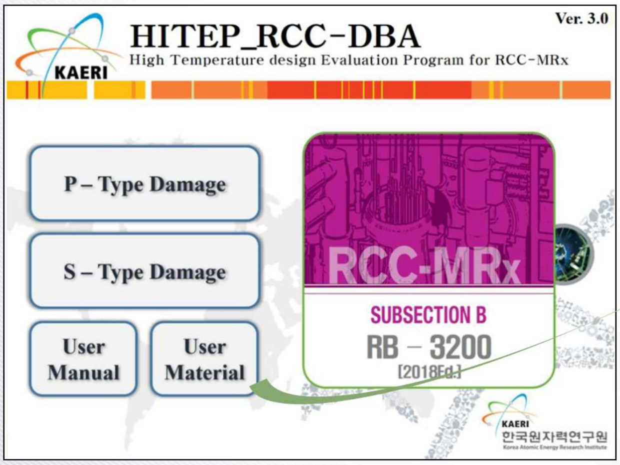
[Crack Geometry]

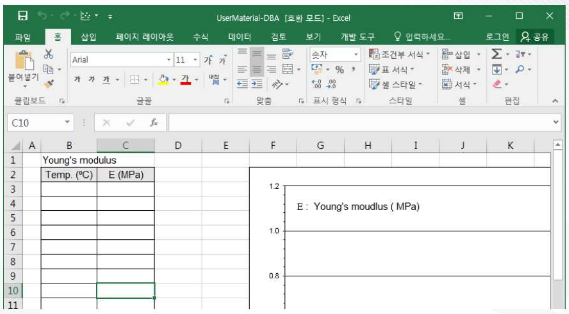


4.4 User Material (e.g. ARAA) option in HITEP (1/2)

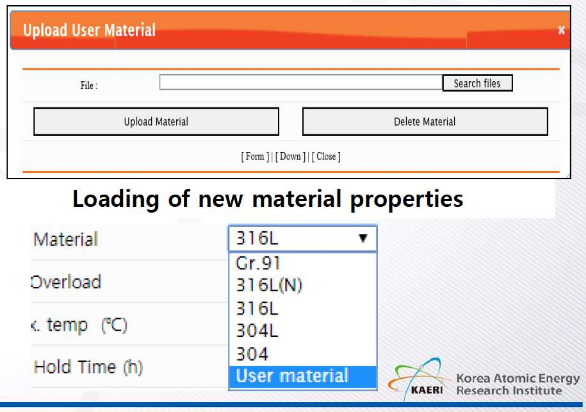
❖ **User materials**

- User can use a new material not registered in A3.
- Excel file should be uploaded as shown below.





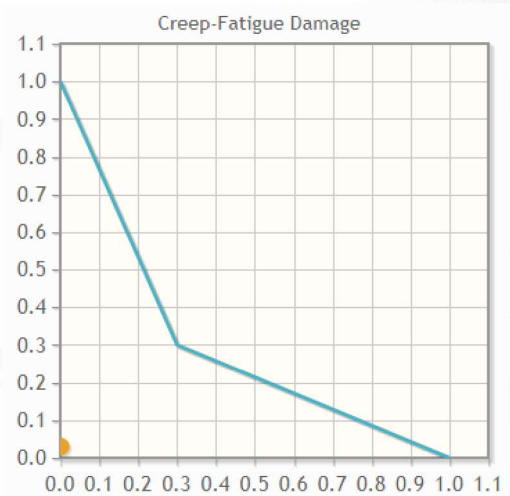
click



4.4 User Material (e.g. ARAA) option in HITEP (2/2)

❖ **Eurofer (IHX)** **(Evaluation results as per RCC-MRx 2018Ed.)**

Evaluation Items		HITEP	Excel
P-Type Damage	P_m (MPa)	9.9749	9.9749
	$P_m + P_b$ (MPa)	12.905	12.905
	$U_A(P_m)$	2.3356E-10	2.3356E-10
	$U_A(P_m + \Phi P_b)$	2.0458E-9	2.0458E-9
	$W_A(1.35P_m)$	3.3429E-11	3.3429E-11
	$W_A[1.35(P_m + \Phi P_b)]$	3.2145E-10	3.2145E-10
S-Type Damage	P_1 (MPa)	34.887	34.887
	P_2 (MPa)	39.683	39.683
	$(P_m + P_b) + q(j,j')$ (MPa)	134.92	134.92
	$\varepsilon_{plastic} + \varepsilon_{creep}$ $(1.25P_1)$	0.0006 %	0.0006 %
	$\varepsilon_{plastic} + \varepsilon_{creep}$ $(1.25P_3)$	0.0013 %	0.0013 %
Creep-Fatigue Damage	Fatigue Damage	0.0001	0.0001
	Creep Damage	0.0033	0.0033



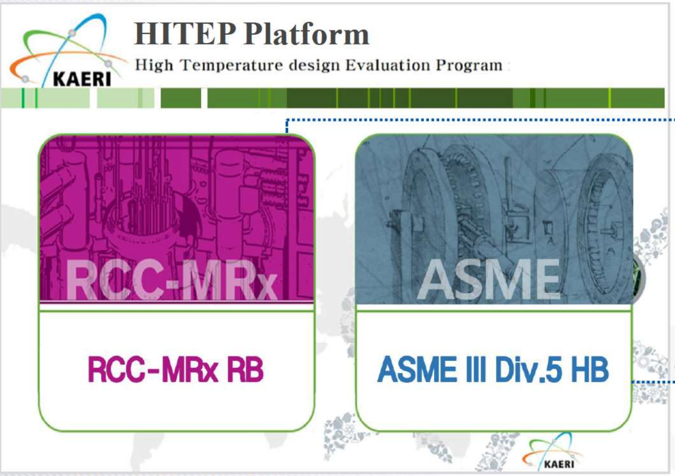
Creep-Fatigue damage evaluation result

▪ 'HITEP' Platform

*ETD : Elevated Temperature Design

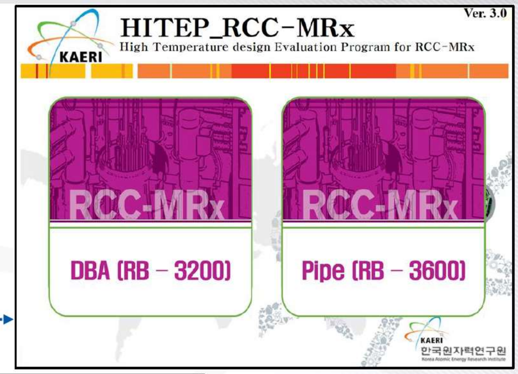
❖ **HITEP platform** for comprehensive ETD* evaluations.

- **RCC-MRx : HITEP_RCC-MRx**
- **ASME Section III Div.5 sub HB : HITEP_ASME-HB (Draft developed)**

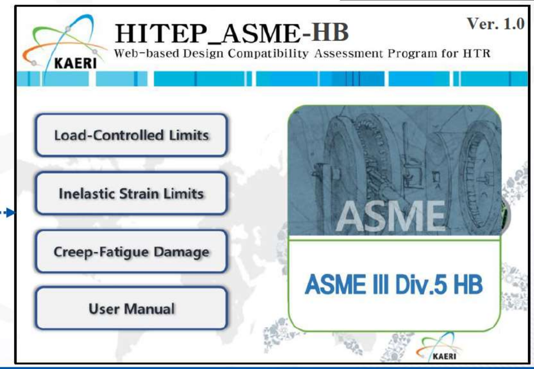


HITEP_RCC-MRx HITEP_ASME-HB

click



click



5. Summary

❖ **Web-based program of HITEP_RCC-MRx (Ver. 3.0) for design evaluation & defect assessment as per RCC-MRx has been developed. (2018Ed.)**

- **HITEP_RCC-DBA (Design-By-Analysis : Pressure boundary components)**
- **HITEP_RCC-Pipe (pipe design)**
- **HITEP_RCC-A16 (defect assessment)**

➢ **Eurofer Material Properties incorporated in Ver. 3.0**

➢ **'User Material' option added, new material (e.g. ARAA) can be used for design evaluations (sensitivity analysis before Codification of the new material).**

➢ **HITEP program can be used for reliable & efficient design evaluations and defect assessments as per RCC-MRx. (verifications were conducted.)**

THANK YOU

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