

Safety Issues of the Subassembly Accident in the Liquid Metal Fast Reactor

150

(LMR) (Subassembly Accidents: S-A) LMR
가 .
S-A
가 . S-A , .
가 . S-A
LMR S-A 가 S-A
R&D KALIMER

Abstract

Subassembly Accidents (S-A) in the Liquid Metal Reactor (LMR) may cause extensive clad and fuel melting and are thus regarded as a potential whole core accident initiator. The possibility of S-A occurrence must be very low frequency by the design features, and reactor must have specific instrumentation to interrupt the S-A sequences by causing a reactor shutdown. The evaluation of the relevant initiators, the event sequences which follow them, and their detection are the essence of the safety issue. The credibility of this argument strongly depends on the experimental observation, and on analytical tools to interpret data and to extrapolate experimental results to the reactor case. The expectations are that melting should be precluded in the Design Basis Events and considered as a Beyond Design Basis Events. In general, a qualified cleaning procedure after construction, a quality controlled

fuel element production, and a sensitive detection system for monitoring reactor condition rules out S-A as safety risk. Since there is no research effort regarding the S-A of LMFBR in Korea, the foreign strategies for dealing with the S-A and the associated safety issues with experimental and theoretical R&D results are reviewed. The result will be reflected for the KALIMER design later.

1.

(LMR) (Design Bases Event, DBE)
 . LMR
 (Subassembly Accident: S-A)
 가 .
 S-A 가 LMR 가
 (foreign material)
 가 . 1966 Fermi
 blockage 가
 가 . LMR 가
 S-
 A LMR 가
 S-A
 , S-A
 S-A
 가 .
 가
 S-A R&D
 KALIMER (Park et al., 1997)
 가 .

2. S-A

LMR S-A
 가 가 .
 가 가 .
 (pin-to-pin failure propagation)
 가 ,
 가 .

(assembly-to-assembly failure propagation)

가

가

S-A

가

가

(i) S-A

가

가

blockage

가

blockage

(ii)

(sensor)

가

가

S-A

가

가

가

S-A

S-A

가

S-A

가

(iii) S-A

S-A

가

(adventurous pin failure)

1/yr

가

3. S-A

Blockage

3.1 S-A

S-A 가

가

가

1

5 가

blockage

가

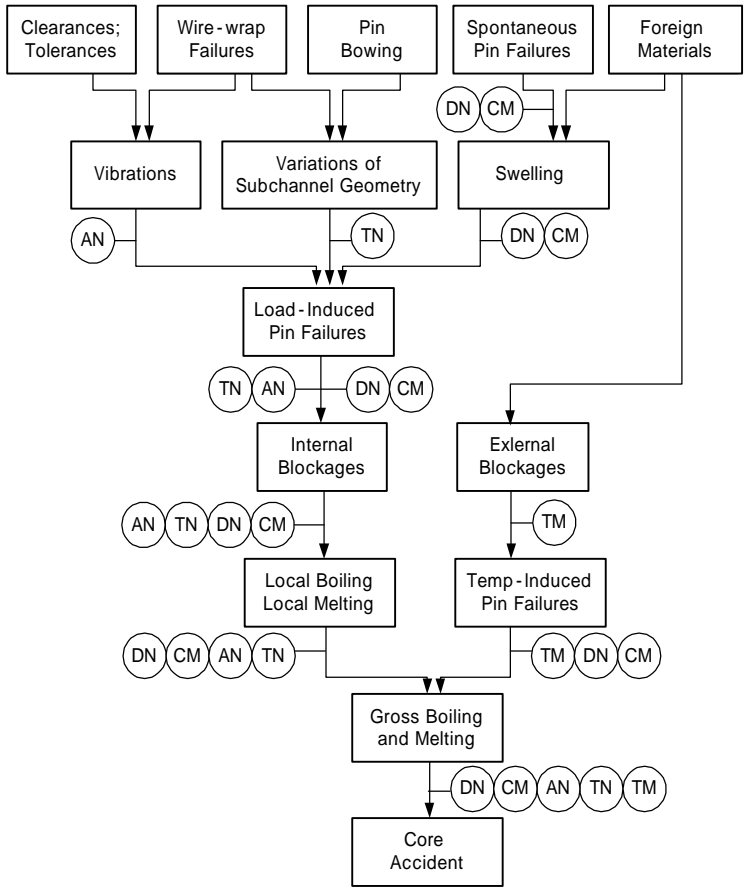
가

S-A

blockage

가

가



S-A
 가
 가
 가
 가
 blockage
 가
 S-A

1. S-A
 blockage

- (1) Pin Bowing :
 가 : pin bowing
 가 - (post irradiation)
 가 pin bowing
- (2) :
 가 :
 가 가 가
 가
- (3) : : (i)

wire-wrap,

(ii)

(iii)

3.2 Blockage

blockage 가

(i)

blockage

(ii)

(iii)

(iv) blockage

(v)

(vi)

blockage

grid-spacer

wire-wrap spacer

2

(Schultheiss, 1987)

blockage 가

(subchannel)

blockage 가

blockage

blockage

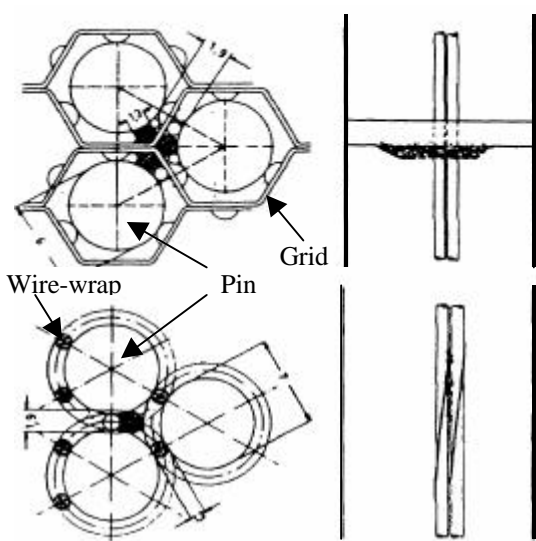
wire-wrap

3

wire-wrap

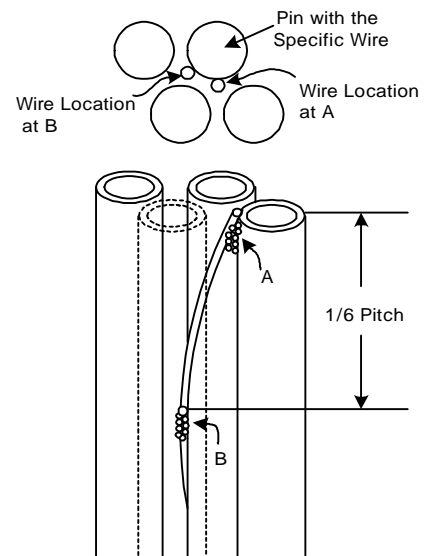
wire-wrap

grid-spacer



2.

blockage



3. Wire-wrap

grid 가 blockage 가
 blockage (pitch) wire-wrap (randomly) blockage 가 wire blockage
 Wire-wrap blockage 가 grid 가
 Blockage 가 blockage 가 Blockage 가
 가 가 blockage 가

ABACUS (Fiorini et al., 1982)

가 gag

(plenum),



Wire wrap
 Blockage
 Pin

blockage (filter)

(plane blockage)

blockage

1 mm

4. Wire-wrapped bundle blockage

S-A
 S-A 가 S-A 가
 S-A
 가 6
 blockage S-A KALIMER (Extremely
 Unlikely Event; XE) (Bounding Event; BE) BE
 DBE
 DBE
 BE : (1)
 (2) (3) (4) 가
 XE S-A 가
 가 10⁻⁷/
 가 BE S-A DBE
 KALIMER
 가 6
 BE (Total Instantaneous Subassembly
 Inlet Blockage: TISIB) 가
 TISIB 가 가
 S-A
 Kwon (1999a) 가 KALIMER
 DB BDBE
 KALIMER (Kwon, 1999b)

5. S-A

R&D

Blockage

Blockage 가
 blockage 가
 (porosity),
 가
 blockage Blockage
 가 가
 blockage Blockage
 blockage 가

blockage

LMR , KALIMER 가 R&D 가 R&D

가

가 cliff edge 가

(threshold in risk) . 가 R&D 가

(1) S-A 가

(swelling) 가

PHENIX (), PFR (), KNK II ()

가

가

가 S-A

KfK (in-pile) grid spacer

blockage (Schultheiss, 1977) , Screen model grid blockage 가

blockage

, blockage

가

blockage

blockage

blockage

, DND

blockage 가

: (i) blockage

(ii) pin bowing

(2) Blockage

(foreign particles)

3000

(inert) blockage

가 wire-wrap

가

(active) blockage

(breeder assembly)

(Begin of Life)

가

DND 가

blockage

, blockage

blockage

DND

가

blockage

3

COMMIX-1AR/P (Garner, 1992), SABRE (Mcdougall and Lillington, 1984),

MATRA-LMR (, 1998)

blockage SABRE

BACCHUS (Basque et al., 1985)

가

(3) Blockage

blockage

. DBE

가

60%

가

90%

blockage

20~30K

(sensor)

. EFR (Schleisiek et al.,

1990)

5

XE

(4) Bounding Event S-A

S-A

TISIB

가

CEA

SCARABEE(Papin et al., 1990)

. SCARABEE

DND

: (1)

(energetic event) (2)

/ blockage 가

(3) DND 가 가

(4)

(thermal erosion) (5) (heat flux)

(6) (7)

(stepwise) (8)

TISIB DB BDB S-A 가 가

BDBE 가 가 가

(5)

S-A 가

가

가

가 DND DBE BDBE S-A

DND 가

가 DND

가

CEA 가 SUPER PHENIX DND

가 (target unavailability)

10⁻⁷ DND , , 가

(common mode failure) 가

S-A 가

(Acoustic Boiling Noise Detection; ABND) (Ultrasonic Temperature Measurement; UTM) UTM

가

가 UKAEA ± 7 °C

, 가 가

6. KALIMER S-A

S-A

, (1) ()
), (2) - (), (3) .
 S-A .

(1)

KALIMER blockage
 가 : (i) , (ii)
 (iii) 가 receptacle
 , (iv) (orifice stack plate) , (v)
 , (vi) Wire wrapped rod bundle . KALIMER

LMR

blockage

(2)

가 . PRISM
 1 가 3

가 .
 (3)

가 가 (Cover Gas Monitoring System;
 CGMS) 가 가 가 ,
 CGMS
 가 . CGMS 가 .
 (Delayed Neutron Monitoring System: DNMS)
 (precursors)

(4)

blockage 가 . blockage 가
가 가 .
blockage 가 가 .
90% .
Clinch River Breeder Reactor (CRBR) 가 S-A
가 가 . CRBR PSAR
가 가 NRC
PSAR (RBCB)
가 KALIMER
CRBR 가 .
KALIMER PRISM NRC 가
가 (NRC, 1994) . PRISM
가 S-A
(bounding) flow blockage TISIB . NRC 가 가
(slot)가
가 .
TISIB , , 가
TISIB .
TISIB 가 가

7.

KALIMER

blockage .
가 blockage 가
가 가 가 가
cover gas 가
blockage 가 .

가
 S-A KALIMER
 S-A
 가
 가
 S-A
 가

1. , , , , “KALIMER
 ,” ’99 (1999a).
2. , , , “ MATRA-LMR ,”
 KAERI/TR-1050/98 (1998).
3. B. Basque et al., “Thermohydraulic Analysis of LMFBR Subassemblies with the BACCHUS
 Program,” Int. Top. Metg. on Fast Reactor Safety, Knoxville Tennessee , pp.465-471 (1985).
4. G. L. Fiorini et al., “The ABACUS Program: Experimental Study of Phenomenology Involving
 Subassembly Blockage”, Proceedings of the LMFBR Safety Topical Meeting, Lyon, France (1982).
5. Y. M. Kwon, “Safety Related Design Bases Events for KALIMER,” KALIMER/SA120-SB-
 01/1999,Rev.0 (1999b)
6. J. D. Mcdougall and J. N. Lillington, “The SABRE Code for Fuel Rod Cluster Thermo Hydraulics,”
 Nucl. Eng. Des., Vol.82, 171 (1984).
7. U. S. NRC, Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module
 (PRISM) Liquid-Metal Reactor, NUREG-1368 (1994).
8. P. L. Garner, R. N. Blomquist, E. M. Gelbard, COMMIX-1AR/P Code Manual, ANL-92/93 (1992).
9. J. Papin et al., “The SCARABEE Total Blockage Test Series: Synthesis of the Interpretation,” Int.
 Fast Reactor Safety Meeting (1990).
10. C. K. Park, Y. C. Kim et al., KALIMER Design Concept Report, KAERI/TR-888/97 (1997)
11. K. Schlesiak et al., “EFR Strategy on Local Subassembly Faults (S-AF) and Associated R
 & D Activities,” International Fast Reactor Safety Meeting, Vol.IV, pp.165-174, (1990).
12. G. F. Schultheiss, “On Local Blockage Formation in Sodium Cooled Reactors,” Nucl. Eng.
 Des., Vol.100, 427 (1987).
13. G. F. Schultheiss, “Model for Formation and Growth of Local Blockages in Grid Spaced Fast Sodium
 Cooled Breeder Fuel Elements,” Nucl. Eng. Des., Vol.43, 329 (1977).