



核能學會2016年學術研討會 後福島改善研討會
超越設計基準廠外事件之緩解策略(FLEX)

「實施FLEX要求」的審查及管制立場

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前言

- ❖ 針對福島一廠事故採行之加強安全措施，依我國核能電廠設計基準、地質環境及運轉狀況等特性，檢討現有機組因應類似福島電廠事故之能力以及異常天災發生後可能潛在之設備功能喪失危險要項
- ❖ 美國核管會依據NTTF報告建議事項4.2，在2012年3月12日發出命令(Order) **EA-12-049**，「Issuance of Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events」
- ❖ 原能會參照上述命令及2012年8月29日美國核管會發行該命令之幕僚暫行導則(ISG)，「命令業主對遵循10 CFR **50.54(hh)(2)**之保安有關設備增加對設計基準外部事件合理的防護，並須增加處置兩機組事件能力之設備」【JLD-ISG-2012-01, Revision 0】

美國因應福島事故之FLEX作為(1/3)

- ❖ 2011年7月12日提出近期專案小組(NTTF)報告
- ❖ 2011年9月9日提出須立即實施之項目(SECY-11-0124)
- ❖ 2012年1月13日業界與NRC會議，提出福島後改善措施之FLEX作法
 - 藉FLEX (Diverse and **flexible** coping strategy)策略之措施，防範爐心燃料受損
 - FLEX與SAMG (Severe Accident Management Guidelines)不同，SAMG係在爐心燃料受損之後開始適用
 - FLEX設計目的在擴展核電廠的安全餘裕，並確保使用事先備妥的後備設備及資源(例如，廠內之水源、柴油，及基於此目的所建立由廠外補充之資源)，幫助其能因應長期喪失電源之情況
 - FLEX方法論的概念，來自911恐怖攻擊之後美國核電廠新增的應急措施



美國因應福島事故之FLEX作為(2/3)



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美國因應福島事故之FLEX作為(3/3)

Status of Units Remaining to be in Compliance with EA-12-049

Units scheduled to be in compliance by the end of 2016

Unit	Expected Compliance Date
Beaver Valley, Unit 1	Fall 2016
Braidwood, Unit 1	Fall 2016
Browns Ferry, Unit 1	Fall 2016
Cooper	Fall 2016
Davis Besse	Fall 2016
Dresden, Unit 3	Fall 2016
Duane Arnold	Fall 2016
Farley, Unit 1	Fall 2016
FitzPatrick	Fall 2016
Ft. Calhoun	Fall 2016
Hatch, Unit 2	Fall 2016
Oconee, Unit 1	Fall 2016
Oyster Creek	Fall 2016
Peach Bottom, Unit 2	Fall 2016
Prairie Island, Unit 1	Fall 2016
Salem, Unit 1	Summer 2016
Summer	Fall 2016
Wolf Creek	Fall 2016
Hope Creek	Fall 2016

Units with all FLEX equipment and connections in place by the end of 2016. The final compliance depends on completing the hardened vent installation.

Unit	Final Compliance Date
Limerick, Unit 1	Spring 2018
Limerick, Unit 2	Spring 2017
Peach Bottom, Unit 3	Fall 2017
Susquehanna Unit 1	Spring 2018
Susquehanna Unit 1	Spring 2017
Browns Ferry Unit 2	Spring 2017
Browns Ferry Unit 3	Spring 2018
LaSalle Unit 1	Spring 2018
LaSalle Unit 2	Spring 2017
Monticello	Spring 2017
Quad Cities Unit 1	Spring 2017
Quad Cities Unit 2	Spring 2018
Columbia	Spring 2017

July 2016

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美國「實施FLEX要求」的經驗回饋(1/11)

❖ NEI 12-06 (FLEX)/NEI 06-12 (B.5.b)

假設條件	NEI 06-12 (B.5.b)	NEI 12-06 (FLEX)
超過設計基準事故(DBA)	火災、爆炸導致大規模破壞	嚴重的自然危害 (大地震、海嘯等)
ELAP及LUHS同時發生	未考慮	納入考慮
機組停機功能	考慮ATWS	正常動作
主控制室功能喪失	納入考慮 (監視功能、控制功能喪失)	未考慮
運轉員的影響	納入考慮 (另一機組人員未受影響)	未考慮
廠址進出的限制 (外部支援的可行性)	不受限制 (外部支援可行)	受限制 (在一定期間內外部支援不可行)
移動式設備的防護	未要求特定的防護	要求針對自然危害有合理的防護
與反應爐建築物的間隔距離	與反應爐廠房區域相距100碼	未考慮

- 依據NEI 12-06 (FLEX)建立之指引、程序書及設備等，應與NEI 06-12(即B.5.b策略)者有所區隔、不得混淆

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美國「實施FLEX要求」的經驗回饋(2/11)

❖ FLEX儲存設施



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美國「實施FLEX要求」的經驗回饋(3/11)

❖ FLEX儲存設施(續)

- FLEX Dome, Southern Nuclear Company (Hatch, Vogtle, Farley)

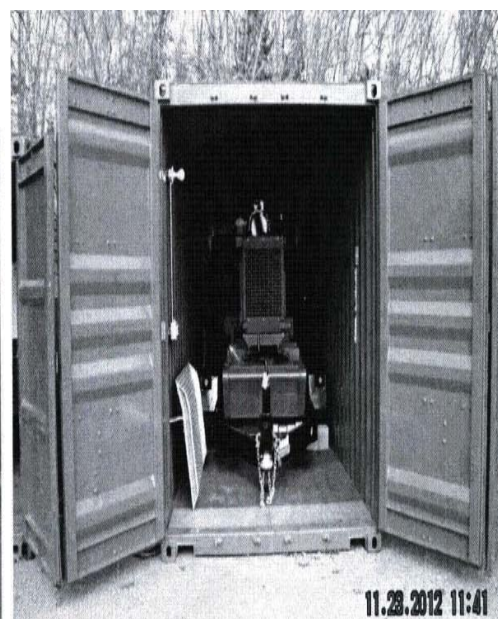


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美國「實施FLEX要求」的經驗回饋(4/11)

❖ FLEX儲存設施(續)

- Pilgrim Nuclear Power Plant



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美國「實施FLEX要求」的經驗回饋(5/11)

❖ FLEX儲存設施(續)

- North Anna、Milestone、及Surry等核電廠，已新增建可耐地震、抗洪水、極高溫、極低溫與飛射物防護之場所儲存FLEX設備等
- North Anna電廠為Dome結構體、Watts Bar 電廠為RC結構體、Diablo Canyon電廠採ASCE 7-10耐震結構等
- 核一、二廠「FLEX設備儲存場所」項目，採空地貯存規劃為暫行措施，後續應參照NEI 12-06相關規範(包括耐震、飛射物防護等)及國外電廠案例設計貯存建築結構

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美國「實施FLEX要求」的經驗回饋(6/11)

❖ FLEX 事件時序分析程式

- EPRI 3002001785, “Use of MAAP in support Post-Fukushima Applications”(June 2013)
- The NRC staff has not identified any concerns regarding the use of MAAP4 in performing **containment analyses** for **both BWRs and PWRs** in satisfying the intent of the NRC Order EA-12-049.
- However, for establishing a timeline which meets the intent of the order, the NRC staff has not received sufficient information to conclude that it is acceptable to use MAAP4 computer code in simulating the primary system during an ELAP event for a PWR.
- Therefore, those PWR licensees who choose to use MAAP4 for simulating the primary system need to provide the technical basis for its use.

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美國「實施FLEX要求」的經驗回饋(7/11)

❖ FLEX 事件時序分析程式(續)

- EPRI 3002002749, “ Technical Basis for Establishing Success Timelines in Extended Loss of AC Power Scenarios in **Boiling Water Reactors** Using MAAP4” (February 2014)
- CENTS – CE PWR (endorsement with limitations)
- NOTRUMP –Westinghouse PWR (endorsement with limitations)
- The NRC staff will evaluate a licensee’s application of the guidance in its development of the final safety evaluation documenting compliance with NRC Order EA-12-049. Individual licensees need to inform the NRC of their plans to abide by this generic resolution and their plans to address potential plant specific issues associated with implementing this resolution that are identified during the audit process.

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美國「實施FLEX要求」的經驗回饋(8/11)

❖ FLEX 事件時序分析程式(續)

- The NRC notes that the MAAP code contains simplified models and correlations and allows user-specified inputs that can affect the accuracy of its predictions for significant parameters such as core two-phase level and system pressure.
- Use of the MAAP4 code for the analysis of PWRs is of concern because the MAAP4 code has not been demonstrated to be capable of reliably predicting natural circulation and post-natural-circulation flows in PWRs.
- the MAAP4 code uses simplified models, correlations, and user-specified inputs in lieu of detailed mechanistic models.

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美國「實施FLEX要求」的經驗回饋(9/11)

❖ FLEX 事件時序分析程式(續)

- These questions are of particular concern in ELAP scenarios that must consider RCS leakage because the PWR version of the MAAP4 code lacks an explicit momentum balance and relies upon a coarsely nodalized representation of reactor coolant system loops.
- These simplifications could substantially affect predictions of when the flow in the RCS loops transitions from single-phase natural circulation to two-phase flow and boiler condenser cooling.
- Although the RELAP5/MOD2 code has been reviewed and approved for performing LOCA and non-LOCA transient analysis, the NRC staff had not previously examined the technical adequacy of this code for simulating an ELAP event.

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美國「實施FLEX要求」的經驗回饋(10/11)

❖ FLEX 事件時序分析程式(續)

- 核一、二廠--參考美國業界BWR電廠做法，提出遵循BWR通用文件EPRI以及執行個廠分析時之差異評估說明
- 核三廠--參照美國業界PWR電廠做法，提出可遵循通用文件之做法(例如，美國NRC在2015年6月15日同意 PWROG-14064-P, "Application of NOTRUMP Code Results for Westinghouse Designed PWRs in Extended Loss of AC Power Circumstances")，以及執行個廠分析時之差異評估說明

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美國「實施FLEX要求」的經驗回饋(11/11)

❖ NEI 12-06 (Rev. 2), December 2015

- **JLD-ISG-2012-01, Revision 1.** This ISG endorses, with exceptions, additions, and clarifications, the methodologies described in the industry guidance document.
- 針對目前OIP報告須再進一步精進部分加以補充進版，至少包括但不限於以下項目：
 - ◆ 本案分析採用的熱流分析程式，
 - ◆ 新增第3.2.3節，大修停機模式之策略內容，
 - ◆ FELX設備最低準備要求之修訂，
 - ◆ 新增程序管理之應用法規，如10 CFR 50.54(p)保安規定、10 CFR 50.54(q)緊急計畫以及消防計畫等之修訂變更，
 - ◆ 新增附錄E驗證導則(validation guidance)、附錄G新水災危害度議題以及附錄H新地震危害度議題等

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「實施FLEX要求」的審查及管制

- ❖ 相關重要議題的持續追蹤
- ❖ **10 CFR 50.155**, Mitigation of Beyond-Design-Basis Events (MBDBE)
- ❖ The conforming changes would delete 10 CFR 50.54(hh)(2), move the requirements to 10 CFR 50.155(b)(2), and re-number the remaining requirements under 10 CFR 50.54(hh)
- ❖ DG-1301, Flexible Mitigation Strategies for Beyond-Design-Basis Events, November 2015 (*Proposed New Regulatory Guide 1.226*)

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ANS Resources following Fukushima

- ❖ The Fifth Anniversary of the Fukushima Daiichi Nuclear Accident - Where We Are Today, March 11, 2016
 - “The nuclear energy industry in the United States has always maintained **the highest safety standards in the world,**” said ANS President Eugene S. Grecheck. “Five years later, our members are continuing to lead innovations based on lessons learned from Fukushima that **make nuclear energy production one of the safest processes** in the energy industry today.”

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結語

- ❖ 原能會因應日本福島事故要求檢討超過現行設計基準項目，包括廠區全黑因應能力、氣候變異下防洪能力以及抗海嘯、耐地震能力準則等重新評估及必要之強化
- ❖ 原能會將持續追蹤美國核管會有關FLEX策略的管制實務，確認核電廠採取強化提昇運轉安全之具體作法

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感謝聆聽 敬請指教



參考資料 (NEI 12-06, Rev.2)

3.2.1.13 FLEX Analyses, Methodologies and Generic Topics

As described above, in order to establish the FLEX capabilities, plant-specific analyses are required. Generally, best-estimate analyses are appropriate for this purpose. For some analyses, methodologies were established through the development of supplemental guidance. Additionally, generic topics were addressed similarly. The references to the supplemental guidance for these topics are as follows:

Topic	Subject	Guidance	NRC Endorsement	Notes Concerning Endorsement
Battery Duty Cycles	Extended battery life calculations for batteries	Nuclear Energy Institute (NEI) August 27, 2013 "Extended Battery Duty Cycles"	ML13241A188	Letter contains limitations
Boron Mixing	PWR Boron mixing	PWROG LTR-FSE-13-46, Rev. 0	ML13276A183	Letter contains limitations
BWR Anticipatory Venting	EOP override limits when only steam driven pump available	BWROG-13059 November 1, 2013	ML13358A206	None
CENTS Thermal-Hydraulic Code	Code handling of 2 phase flow and reflux cooling in PWRs	PWROG LTR-TDA-13-20-P, Rev. 0 November 20, 2013	ML13276A555	Letter contains limitations.
Maintenance Guide for FLEX	PM basis from EPRI Template	EPRI 3002000623	ML13276A224	None
MAAP analysis	Use of MAPP analysis for FLEX conditions	EPRI 3002001785	ML13275A318	Letter contains limitations
Shutdown/Refueling Modes	Provides required guidance for Shutdown/Refueling Modes	Nuclear Energy Institute (NEI) September 18, 2013, "Position Paper: Shutdown/Refueling Modes"	ML13267A382	The information for shutdown modes was incorporated into Section 3.2.3
NOTRUMP Thermal-Hydraulic Code	Code handling of 2 phase flow and reflux cooling in PWRs	PWROG-14064-P Revision 0 PWROG-14027-P Revision 3	ML15061A442	Letter contains limitations
SHIELD Reactor Coolant Pump	Seal leakage values	TR-FSE-14-1-P, Revision 1 and TR-	ML14132A128	Letter contains limitations

Seals		FSE-14-1-NP, Revision 1.		
FLOWERVE Reactor Coolant Pump Seals	Seal leakage values	PWROG LTR-OG-15-313, August 5, 2015	ML15310A094	Letter contains limitations
Original Westinghouse Reactor Coolant Pump Seals	Seal leakage values	PWROG-14008-P, Revision 2 PWROG-14015-P, Revision 2 PWROG-14027-P, Revision 3 PWROG-14074-P, Revision 0		
National SAFER Response Centers	Conformance of the NSRCs to the guidance in Section 12	NEI September 11, 2014, "National SAFER Response Center Operational Status" Letter	ML14265A107	None
Change Processes	Application of regulatory change processes to BDBEs	NEI August 19, 2014, "Change Process with respect to BDB applications"	ML14147A073	None
Maintenance Rule	Application of the Maintenance Rule to FLEX equipment	NEI June 24, 2015 letter Revision 4B to NUMARC 93-01.	ML15097A034	None
Hoses and cables	Quantity of spare lengths of hoses and cables	NEI May 1, 2015 letter, "Alternative Approach to NEI 12-06 Guidance for Hoses and Cables"	ML15125A442	Letter contains clarification.



參考資料 (10CFR50.155)

Proposed MBDBE Overview

- Proposed 50.155, Structured as:

50.155(a) *Applicability*

50.155(b) *Integrated response capability*

50.155(c) *Equipment*

50.155(d) *Training requirements*

50.155(e) *Drills and Exercises*

50.155(f) *Change Control*

50.155(g) *Implementation*

Proposed 50.155(b)

- 50.155(b)(1) – Mitigating Strategies for BDB Natural Phenomena (EA-12-049)
- 50.155(b)(2) – Extensive Damage Mitigation Guidelines (EDMGs – moved from 50.54(hh)(2))
- 50.155(b)(3) – Integrate with EOPs
- 50.155(b)(4) – Sufficient staffing
- 50.155(b)(5) – Command and control structure