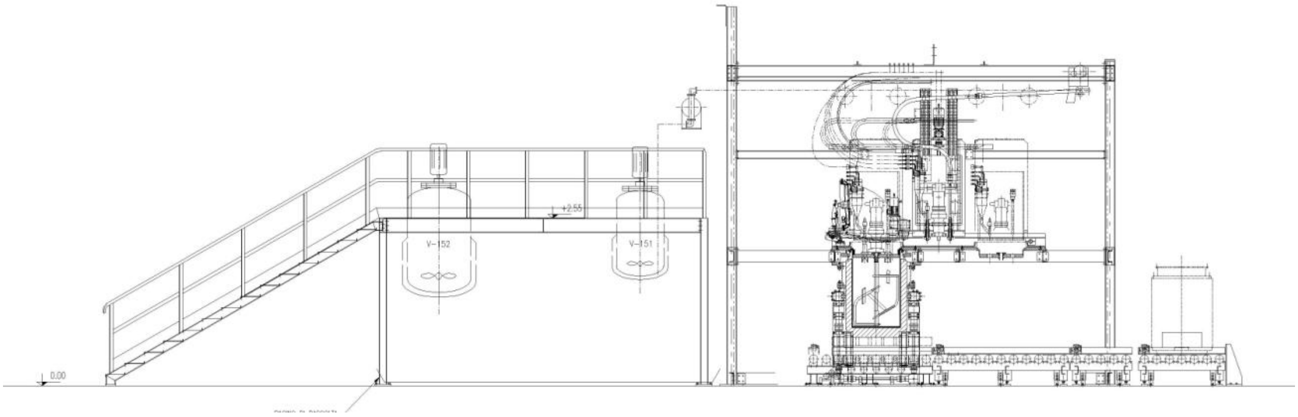
3.2 義大利 Sogin 公司發展α廢液水泥固化系統

義大利 Sogin 公司發展α（U, Th）廢液水泥固化系統，主要設備包括全遙控裝桶、攪拌、密封設備。主要進料動力使用汽動泵抽送以減少未來二次廢棄物。另外配置兩具主從式機械臂，以防遙控系統失靈。整體系統估計成本約 100 萬歐元，會員現場反應均認爲以此成本於市場上相當有競爭力。



圖五、義大利 Sogin 公司α廢液水泥固化系統設計圖

圖六、義大利 Sogin 公司α廢液水泥固化系統實體照片(一)

圖六、義大利 Sogin 公司 α 廢液水泥固化系統實體照片(二)

圖七、義大利 Sogin 公司水泥固化體測試

3.3 日本 Fugen 電廠除役計畫發展除役經費預估模式

日本 JAEA 於 JPDR.除役時及已開始建立相關除役經費預估模式。基本構想是將除役經費對應至人力工時，以數學模式描述各種除役工作項目，並經由預估單項工作所需人力工時，進而精算除役經費。估算各單項工作的人力工時，則用標的系統的重量為輸入參數。並將工作性質分為清理/準備類及拆除類兩種。

1) Calculation formulas of preparation/ clean-up process

$Y = a_{wi}$ (man-hour)

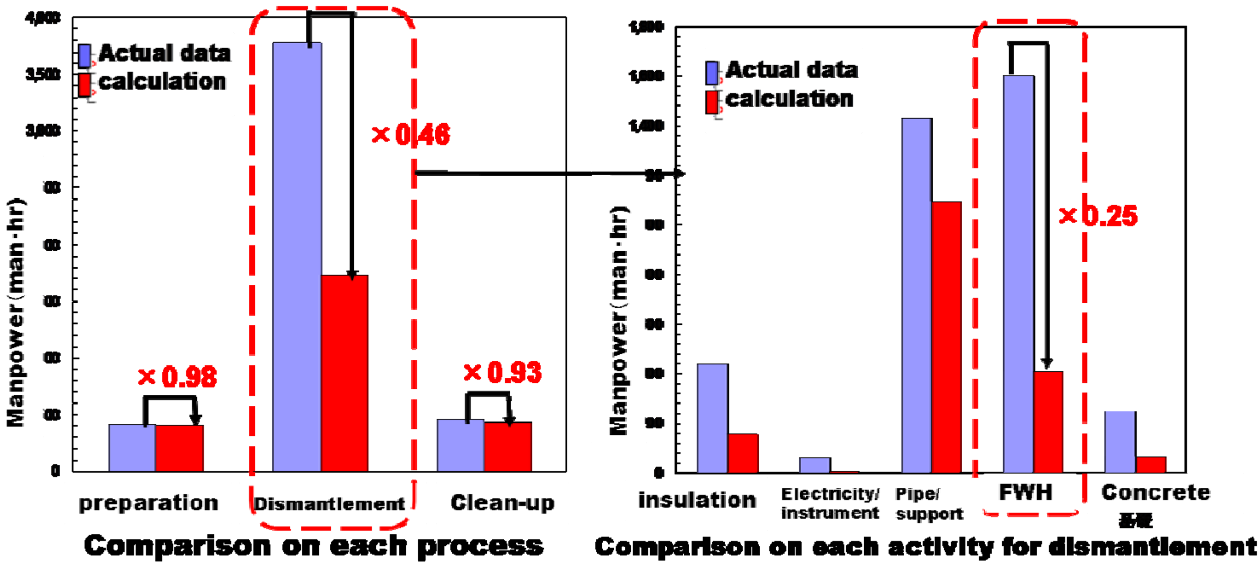
- a_{wi} : unit productivity factor (man-hour)
- w : work item (clean-up of floor, ...)
- i : work levels depending on area (i = L1, L2, L3)

2) Calculation formulas of dismantling process

$Y = a_e \times m$ (man-hour)

- a_e : unit productivity factor (man-hour/ton)
- e : kind of equipment (feedwater heater, ...)
- m : weight of equipment (ton)

圖八、日本 JAEA 發展除役人力工時預估數學模式

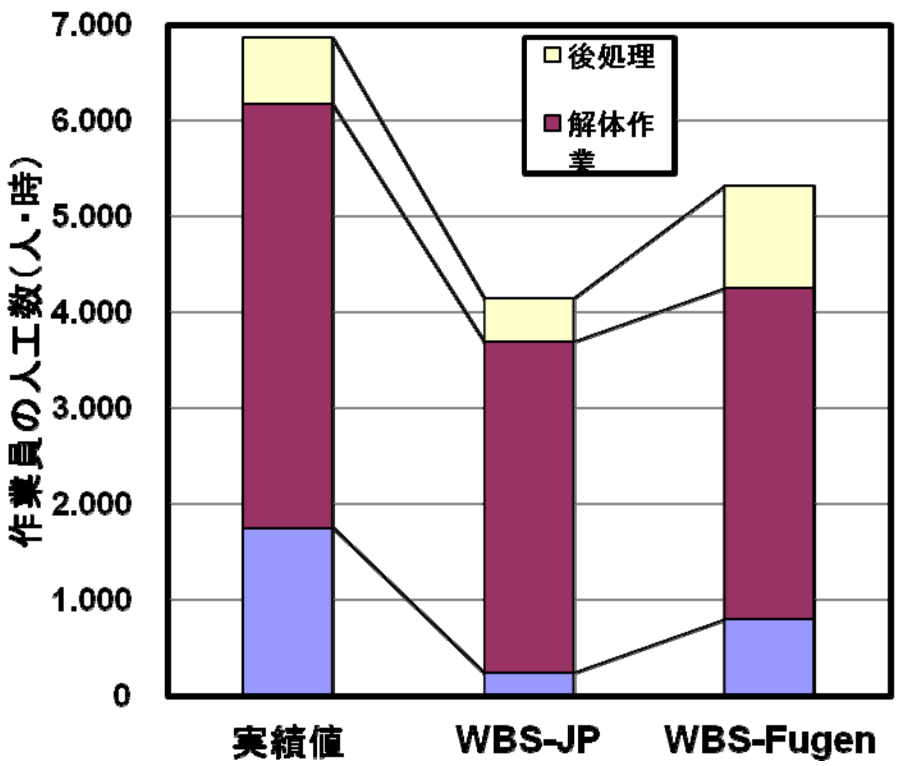


圖九、日本 JAEA 發展除役人力工時預估初步結果

經由數學模式預估及實際工作人力工時統計比較，目前仍有相當大的差異。準備工作及除污清理工作可以達到超過 90%的估算準確度，但是拆除工作則準確度差異非常大。到目前爲止，整體工時預估，應用於 Fugen 電廠的預估，比使用原有 JPDR 發展的參數預估準確度提高，但是與實際統計值仍有相當大差異。

表七、日本 JAEA 發展除役人力工時預估分析數據表

	Actual Data	Model-JPDR	Model-Fugen
Supervisor	2327.5	643.2	932.7
Worker	6862.3	4150.5	5326.2
Radion Woker	911.7	643.2	932.7
Total	10101.5	5436.9	7191.6



圖十、日本 JAEA 發展除役人力工時預估分析數據圖

除役經費預估一向是除役規劃中一個重要議題，基於除役工作本質的差異性，除

役經費預估非常困難。日本 JAEA 經由 JPDR 除役，到目前執行中的 Fugen 電廠除役，希望藉由實際工作進行，收集數據，發展除役經費預估模式，更期望將來能應用至大型核能電廠除役經費預估。

3.4 CPD 專題研究—遙控技術於除役工作之應用

除了定期專家會議如 TAG 之外，CPD 亦經由 TAG 會議長期討論，聚焦於除役及廢棄物領域重要技術及議題，從 TAG 成員中成立小組，進行專題研究。”REMOTE HANDLING TECHNIQUES”專題報告於 2011 年一月完成初稿，將提送 Management Board 會議完成審核程序後發表。報告章節目錄如附錄六。

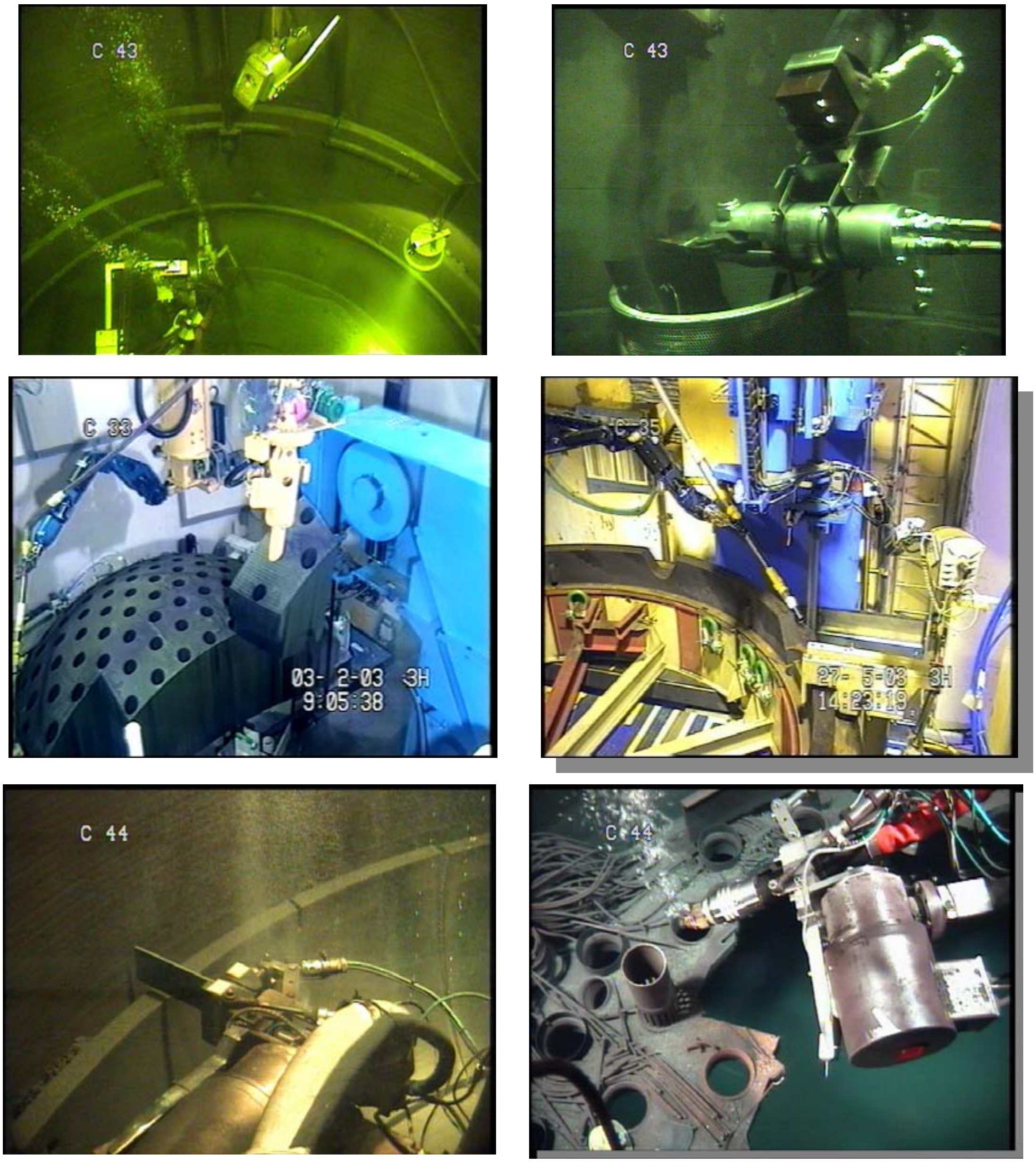
本專題主持人爲法國 CEA 的 Pierre Valentin。本報告著重於彙整遙控拆除技術的應用，並收錄國際上各除役計畫的應用經驗。提供應用經驗的計畫包括比利時 BR3，英國 WAGR 及 Sellafield，德國的 KGR、KKR、KNK2、WAK，法國的 AT1，美國的 CP5，及日本的 Tokai 1。遙控技術應用則分爲切割工具、機械臂、載具三部分分別討論。

核設施除役工作需求沒有一定的作業模式可以依循，作業需求差異很大，因此如生產線般全自動化的遙控技術應用非常困難。從歷次參加 TAG 會議，彙整各計畫執行核設施除役工作的作業模式，可以分爲直接人力作業、小型機械臂、大型專用載具三種模式。

直接手動模式爲人員配備應有的防護具，在控制環境下，直接從事較精細的除污、拆裝、檢整等作業。如下圖法國 ATUE 之電漿切割。

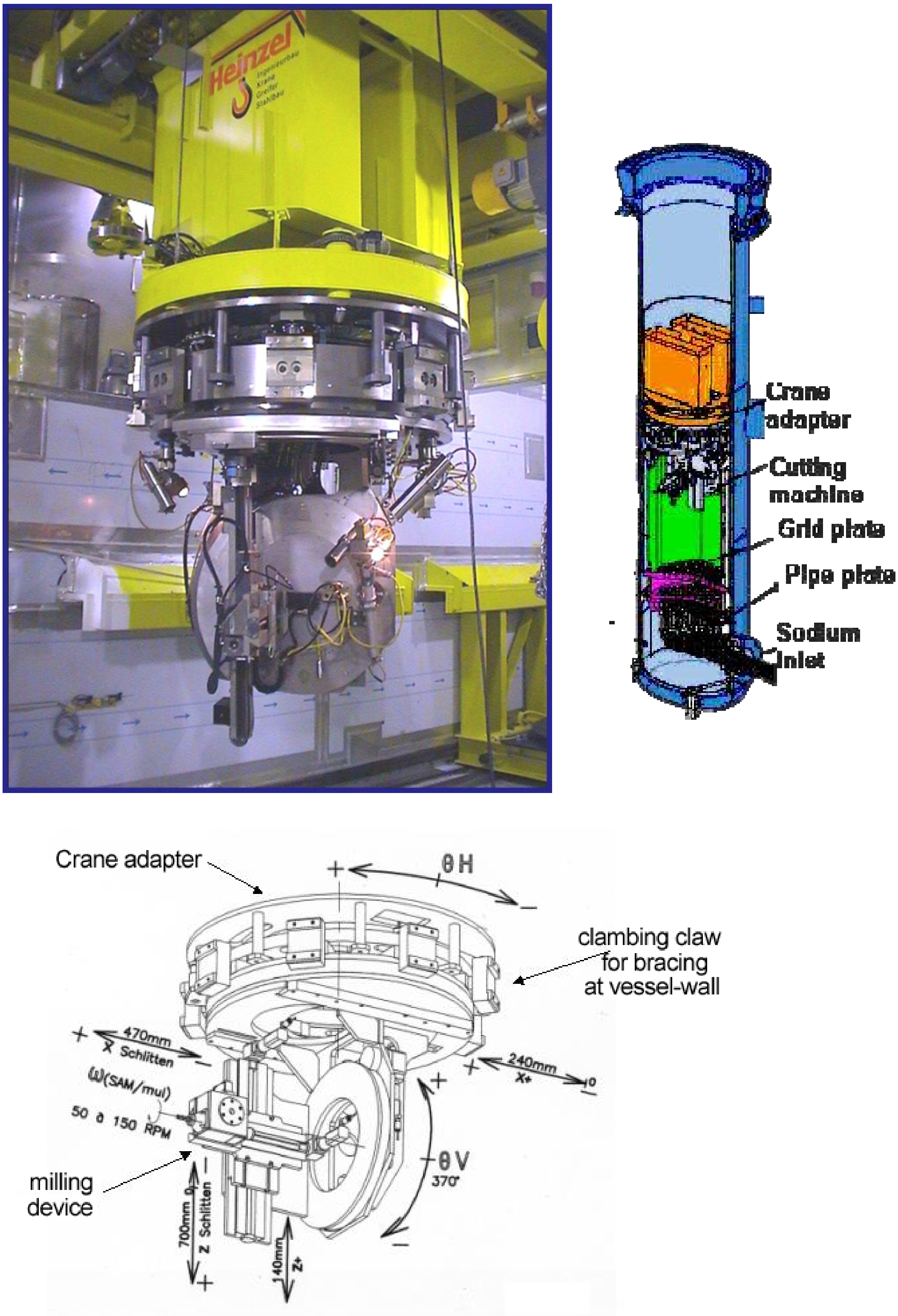
圖十一、除役手動拆除作業

小型機械臂模式，多用於水下作業或人員無法接近。例如 MZFR 研究用反應器組件拆除過程中，其 RPV 拆除過程反覆使用乾式及濕式遙控拆除。水下遙控拆除作業如圖十二。

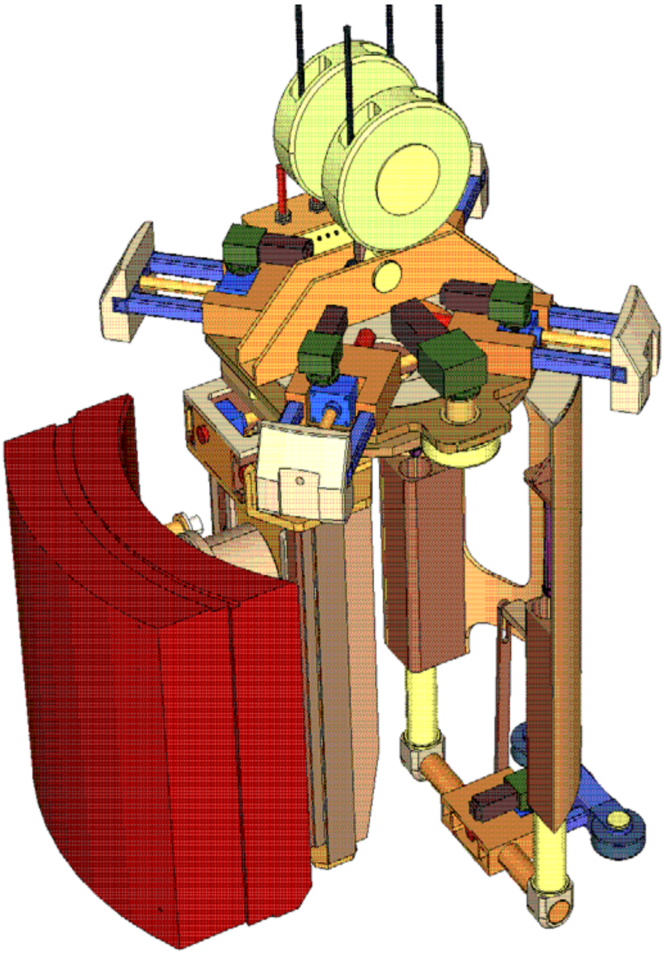


圖十二、小型機械臂水下作業模式

大型專用載具模式則專爲拆除環境及拆除作業，建造大型載具固定於現場，有些具有有限度的移動能力，多數可以更換多種終端工具。如德國 KNK 電廠爐內組件拆除，載具大小約如爐體空間，承載切割工具進入爐內切割組件。



圖十三、德國 KNK 電廠爐內組件拆除遙控切割設備

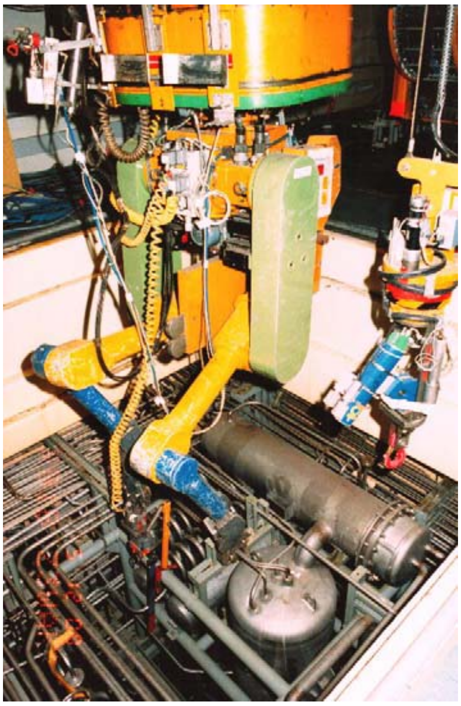


圖十四、德國 KNK 電廠爐內組件拆除遙控吊運設備

再如德國 WAK 爲燃料再處理廠，運轉期間爲 1971 年至 1990 年。從 1996 年至 2010 年規劃執行程序設備拆除。其 α 汙染之程序設備以遙控拆除保障輻射安全。遙控拆除控制室如圖十五。主要吊車如圖十六，在遙控指揮下吊掛拆除用機械手，如圖十七

圖十五、德國 WAK 遙控拆除控制室

圖十六、德國 WAK 遙控拆除主要吊車



圖十七、德國 WAK 遙控拆除機械手

遙控技術在除役的應用經驗中，並非無往不利。本報告收錄十篇國際上大型除役計畫的應用經驗。多份報告提及遙控技術應用的極限性，以及不可靠性。除役計畫因爲等待及配合遙控工具的開發而遷延時程者必比比皆是。同時應用遙控技術投入的經費亦非常可觀。核研所 TRR 爐體拆除工作勢必須要借助於遙控技術，尤其是目前仍超過 7Sv/h 的高輻射劑量率爐內組件的拆除。拆除方法的研究需及早投入資源規劃。

四、建議事項

(1) 經過會員討論，TAG 會議舉辦頻率仍維持一年兩次。我國以非 NEA 成員能參與 CPD，應對於會籍之維護持續審慎。建議一年派員與會一次。

(2)本次會議中各國專家均表示我國 TRR 除役工作中，燃料池清理盡速清理完成應爲明智策略，可以大量降低風險，尤其是經過日本福島事件之後。同時記取韓國實驗用反應器爐水洩漏之教訓。建議投入足夠資源以保持燃料池清理速度。

(3) 日本 Fugen 電廠與本所 TRR 同樣具有重水系統，Fugen 電廠除役發展尤其是其重水系統之除污、拆除等過程及技術特別值得國內參考。

(4) CPD 場地復育相關議題討論現況參考文件如附錄五。CPD 關注核設施場地復育議題，持續於各種國際場合推動技術合作，TAG 亦開始考量是否成立新的專案研究，針對核設施場地復育議題匯集資訊及國際經驗。我國執行核設施除役工作後期亦將面臨場地復育程技術需求，值得注意國際發展趨勢。

附錄一、**CPD 官方網頁**

http://www.oecd-nea.org/jointproj/decom.html

Home > Joint projects

International Co-operative Programme on Decommissioning (CPD)

The International Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects began in 1985. Initially consisting of 10 decommissioning projects in eight countries, the programme has since grown to the present number of 43 projects (27 reactors and 16 fuel cycle facilities) in 11 NEA member countries and one non-member economy. A new agreement to reflect changes in the CPD's operating methods and financing was signed in 2004. Altogether 49 decommissioning projects have benefited from the information exchange framework provided by the CPD. The information exchange includes biannual meetings of the Technical Advisory Group (TAG), during which the site of one of the participating projects is visited, and where positive and less positive examples of decommissioning experience are openly exchanged for the benefit of all. In 2005, TAG meetings were held in Tsuruga, Japan, and in Cadarache, France. In 2006, TAG meetings were held in Karlsruhe, Germany and in Higham Hall, United Kingdom.

The forum offered by the programme is valuable in ensuring that the safest, most economic and environmentally friendly options for decommissioning are employed. For some members, who have less experience in this area, the benefit in not having to go through an expensive learning and development programme is invaluable. Of particular importance in this period is not just the increase in membership and projects from OECD member countries, but the active participation of other international organisations such as the IAEA and the European Commission. This shows that the increasing importance of decommissioning for the future success of the nuclear industry is now recognised.

The programme reports to the NEA Radioactive Waste Management Committee (RWMC) and has strong ties to the NEA/RWMC Working Party on Decommissioning and Dismantling (WPDD). A report giving basic information on the participating projects, their modus operandi and summarising the first twenty years of experience accumulated within the project was published in 2006.

Participants

Decommisioning project(s) are in brackets. Links to project websites are provided where available.

- Belgium (BR3-PW, Eurochemic Reprocessing Plant)
- Canada (Gentilly-1, NPD, 204 A/B Bays, Tunney's Pasture facility; 204A/204B Bays, Chalk River)
- France (PHENIX, EL4, G2/G3 Marcoule, Rapsodie Cadarache, Basic Nuclear Facility No. 57, ELAN IIB, AT1 La Hague, UP1 reprocessing plant, Bugey 1, APM Marcoule, Melusine, ATUE)
- Germany (Lingen, MZFR Karlsruhe, KKN Neideraichbach, Greifswald, HDR, WAK, AVR, KNK)
- Italy (Garigliano, Latina)
- Japan (JPDR Tokai, JRTF Tokai, Fugen, Tokai 1 NPP, JAPCO plutonium fuel fabrication facility)
- Republic of Korea (KRR1 and KRR2 research reactors, KAERI uranium conversion facility)
- Slovak Republic (Bohunice A-1)
- Spain (Vandellos 1, PIMIC project)
- Sweden (Studsvik Active Central Laboratory)
- United Kingdom (Co-precipitation Plant Sellafield BNFL 204, Primary separation plant Sellafield, Prototype Fast Reactor Dounrey)
- Chinese Taipei (Taiwan Research Reactor)

附錄二、TAG-50 與會名單

TAG 50　Attendees

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附錄三、TAG-50 會議內容

50th Meeting of the Technical Advisory Group

May 9th – 13th, 2011

Proposed Agenda

Note: please submit your presentation material to the TAG Chairman on a memory stick or similar device for loading on to master computer at the Sunday Registration in the Hotel or as soon as you arrive at the meeting location.

1) Welcome, round-table introduction, organisational announcements

2) Approval of agenda

3) Chairman's, Co-ordinator's Remarks and Opening Business

4) Reports from CPD Management Board, Bureau, WPDD

5) Summary Record of TAG 49

6) Status Reports from participating projects
   a) Reactor Facilities:
      i) AVR – Norbert Hess
      ii) Barseback – Hakan Lorentz
      iii) Fugen – Masanori Izumi
      iv) Greifswald – Axel Backer
      v) Jose Cabrera NPP– Manuel Ondaro
      vi) Studsvik R2 Reactor – Robert Hedvall
      vii) Triga Mk II and III – Un-Soo Chung
      viii) TRR – Horng-Bin Chen
      ix) WAGR – Steve Slater

   a) Fuel Facilities:
      i) ATUE – Eric Gouhier
      ii) B204 and B243 Intermediate Waste Recovery project – Steve Slater
      iii) Ispra – Removal of Legacy Waste – Francesco Basile

iv) SOGIN – Overview – Giuseppe Pastore
v) SOGIN Pilot U – Th Plant – Giuseppe Pastore
vi) Uranium Conversion Plant – Un-Soo Chung

2) New Projects (status)
   a) Hamaoka NPP - Chubu Electric Company – Japan - Confirmed joining CPD
   b) Kurchatov Institute/MR & FRT Reactors – Russia – Has not joined

3) Country reports (If necessary)
   a) Proposal for possible brief report on Japanese nuclear situation after Fukushima for October meeting

4) Task Groups
   a) Reports – status
      i) Remote Handling Techniques
      ii) D&D of Concrete Structures
   b) New Task Group Proposals - Review of nuclear site restoration (Proposal attached as annex).

5) Five Year Report status

6) Future meetings of the TAG
   a) October 2011 – WAK /Karlsruhe
   b) May 2012 – Enresa/Spain
   c) October 2012 - tbd

7) Discussion Session – TAG Working Methods Review and Improvement.
   a) Presentations
   b) Discussion

8) Closing remarks, meeting adjourn.

Site visits
Thursday afternoon– Pilot U – Th Re-processing Plant Rotondella

附錄四、TAG-50 會議議程

Schedule for the TAG 50 Meeting in Matera, May 9th – 13th 2011

Sunday May 8th

All day - Arrival at Bari Airport, bus transfer to ALBERGO Hotel Marinagri, Basilicata - www.hotelmarinagri.it. Transfer time will be organised to match participants arrival details – It is anticipated that there will be two transfers, for morning and afternoon arrivals.

Registration/Reception in the hotel. Please bring presentation files for uploading to computer

Be sure to fill out all the information possible on the TAG information form.

The meeting (Monday, Tuesday and Wednesday) will take place at the Hotel.

Hotel Details:

HOTEL MARINAGRI

Luxury Nature & SPA

Via S. Giusto Località Torre Mozza

Italy - 75025 Policoro (MT)

Tel. [+39] 0835.960201 [+39] 0835.960201 - Fax [+39] 0835.960200

E-mail: info@hotelmarinagri.it

Monday May 9th

09:00 - meeting begins.

Coffee break

12:00 – lunch

13:30 - meeting continues

Afternoon break

Meeting continues

<u>Tuesday May 10th</u>

09:00 - meeting begins.

Coffee break

12:00 - lunch

13:30 - meeting continues

Afternoon break

Meeting continues

Wednesday May 11th

09:00 - meeting begins.

Coffee break

12:00 - lunch

13:30 - meeting continues until agenda completed

Thursday May 12th

08:00 - Meet at bus (to be confirmed)

09:00 - site tour Pilot U – Th re-processing plant Rotondella

Friday May 13th

09:00 - Close meeting

12:00 - lunch

13:00 - bus transfer to Bari Airport – Participants should allow 2 ½ - 3 hrs to flight time.

(to be confirmed during the meeting)

附錄五、場地復育議題 **NEA** 相關動向參考文件

Annex 1:

Specification for review of nuclear site restoration by WPDD CPD – Task Group

Background

Around the world, nuclear sites are being restored for beneficial reuse. Restoration is normally considered the last step in a sequence of decommissioning steps but increasingly we are recognising the value of long-term planning and parallel remediation. It is essential that regulators know that liabilities are well understood and there is adequate financial provision. Recognising the potential issues with uncertainties in final site restoration costs is driving early site land and groundwater characterisation. Operators are also learning that early intervention to ensure prevention and minimisation of leaks of radioactivity and reducing groundwater plumes reduces overall liabilities and ensures protection of the environment. Early intervention needs to be guided by good characterisation, reliable conceptual models and quantified goals. This understanding is also required to inform final site remediation where early intervention is not considered beneficial when compared to the costs. For both early and final remediation it is important to have clarity and agreement on end states for land and groundwater. Risk based end states have been developed in the US and more recently end states have been agreed with stakeholders in the UK (NDA sites). The US EPA has been instrumental in developing an integrated approach to remediation that allows local communities a role in site specific decision making. The French Atomic Energy Commission has also significant recent experience in site remediation.

The Task

The CPD will review a number of selected case studies for 3 categories:

a) Where sites have been restored,

b) Where early intervention has occurred and

c) Where early intervention is being considered

The CPD will examine the approaches and techniques adopted in the 3 categories for characterisation, interim or end state agreements, conceptual modeling, interventions (techniques and decision making) and assumptions for liability estimates. A report of the review will facilitate learning and collaboration amongst NEA countries.

附錄六、**TAG** 遙控技術專題研究報告目錄

Remote Handling Task Group Report Catalogue

Summar y