出國報告（出國類別：洽公）

ABWR 反應爐內部組件
目視檢查之實施經驗與要領

服務機關：台灣電力公司　第四核能發電廠

姓名職稱：康力仁　核能工程監

派赴國家：日本

出國期間：**97** 年 **11** 月 **23** 日至 **97** 年 **11** 月 **29** 日

報告日期：**98** 年 **1** 月 **7** 日

行政院及所屬各機關出國報告提要

出國報告名稱：ABWR 反應爐內部組件目視檢查之實施經驗與要領

頁數 8 含附件：□是■否

出國計畫主辦機關/聯絡人/電話：台灣電力公司/陳德隆/02-23667685

出國人員姓名/服務機關/單位/職稱/電話

康力仁/台灣電力公司/第四核能發電廠/核能工程監/02-24903550 ext: 3520

出國類別：□1 考察□2 進修□3 研究□4 實習■5 其他（洽公）

出國期間：97 年 11 月 23 日～97 年 11 月 29 日　　出國地區：日本

報告日期：98 年 1 月 7 日

分類號/目：G3／電力工程；G6／機械工程

關鍵詞：反應爐內部組件、目視檢查、ABWR、IVVI、SCC、IEC、ROV

內容摘要：

早期世界各國的 BWR 電廠，大多數都是由美國 GE 公司設計與建造，所以電廠營運後，依照營運期間檢測計畫須於大修期間實施的反應爐內部組件目視檢查（IVVI）工作，亦交由 GE 公司承做。

核四廠為 ABWR 電廠，雖然仍由 GE 公司設計，但目前全世界只有日本有建廠及商轉經驗，核四廠應於商轉之前赴日本洽訪 IVVI 實施之經驗與要領，以為商轉後之 IVVI 檢測計畫預做準備。

本次洽公分別赴日本兩大製造廠日立公司及東芝公司，洽談內容包括：

一、日立公司

研討：ABWR IVVI 在日本實施之現況；

參訪：日立臨海工廠（茨城縣日立市大甕町）。

二、東芝公司

參訪：東芝 IEC（Isogo Nuclear Engineering Center）（橫濱市磯子區新杉田町）；

研討：ABWR IVVI 在日本實施之現況。

目　　次

一、目的

早期世界各國的 BWR 電廠，絕大多數都是由美國 GE 公司設計與建造，所以電廠營運後，依照 IST 計畫須於大修期間實施的反應爐內部組件目視檢查（IVVI）工作，概由 GE 公司承做。

核四廠為 ABWR 電廠，雖然仍由 GE 公司設計，但目前全世界只有日本有建廠及商轉經驗，而日本 ABWR 電廠的 IVVI 工作，皆是由日立與東芝兩家公司承做。

核四廠未來的 IVVI 工作已不一定再委由 GE 公司執行，故應於商轉之前赴日本洽訪 IVVI 實施之經驗與要領，以為商轉後之 IVVI 檢測計畫預做準備。

二、過程

（一）出國行程

本次洽公之廠家為日本的兩大核能製造公司，日立（Hitachi）與東芝（Toshiba）公司，此二家公司屬核島區主要設備供應商 GE 公司的分包商，日立公司負責製造核四廠一號機的反應爐壓力容器，東芝公司則負責製造二號機的反應爐壓力容器。

本次任務從 97 年 11 月 23 日到 97 年 11 月 29 日止為期七天，出國行程表列如下：

起始日	迄止日	前往機構名稱	國家城市名稱	詳細工作內容
971123	971123			往程（台北→東京）
971124	971126	日立公司	日本東京	洽訪 ABWR 反應爐內部組件目視檢查（IVVI）之實施經驗與要領
971127	971128	東芝公司	日本橫濱	洽訪 ABWR 反應爐內部組件目視檢查（IVVI）之實施經驗與要領
971129	971129			返程（橫濱→東京→台北）

（二）洽公內容

本次洽公主題為「ABWR 反應爐內部組件目視檢查之實施經驗與要領」，洽訪內容包括：

1. 日立公司

(1) 聽取日立計畫經理簡報「Hitachi 集團與 Hitachi-GE 核能公司之沿革與產品介紹」，簡報內容請參閱附錄 A。

(2) 聽取日立資深工程師簡報「日本 BWR 反應爐內部組件 SCC 之現場經驗」，簡報內容請參閱附錄 B。

(3) 聽取日立主任技師簡報「日本 BWR 反應爐內部組件 SCC 之檢查技術」，簡報內容請參閱附錄 C。

(4) 參觀日立臨海工廠：位於日本茨城縣日立市大甕町。

(5) 洽談 ABWR IVVI 在日本實施之現況：併同與東芝公司洽談內容總述於後。

2. 東芝公司

(1) 聽取簡報「東芝公司磯子核能工程中心（IEC）沿革與產品介紹」，簡報內容請參閱附錄 D。

(2) 聽取簡報「東芝公司自行研發之遙控水底攝影機（ROV）原理與功能」，簡報內容請參閱附錄 E。

(3) 參觀東芝 IEC (Isogo Nuclear Engineering Center)：位於日本橫濱市磯子區新杉田町。

(4) 洽談 ABWR IVVI 在日本實施之現況：併同與日立公司洽談內容總述於後。

3. 洽談 ABWR IVVI 在日本實施之現況

本次洽公行程聯繫時，即設定十項研討主題，請 GE 公司代為安排，故與各公司進行研討時，皆有深入與詳細之討論，收穫頗多，研討交流內容摘述如下：

(1) ABWR 核能現況交流

- 建造中 ABWR 電廠：島根電廠三號機（Shimane-3）
  - 預定時程：西元 2011 年燃料裝填（Fuel Loading），西元 2012 年商業運轉（Commercial Operation Date, COD）。
  - 第一灌漿到燃料裝填工期：40 個月。
  - 第一次灌漿到 COD 工期：48 個月（日立公司建造 ABWR 之標準工期）。

- 柏崎-刈羽（Kashiwasaki-Kariwa, KK）電廠兩部 ABWR 機組何時重新運轉？
  - 柏崎-刈羽電廠七號機（K7）原訂西元 2008 年 12 月運轉，但因汽機葉片問題延宕。
  - 柏崎-刈羽電廠六號機（K6）預定西元 2009 年 3 月運轉。

(2) 日本電廠 IVVI 法規要求

- 日本核能電廠皆遵循 JSME 法規，該法規乃由日本版 BWRVIP 指引（J-BWRVIP Guidelines）、JEAC4205 與其他指引所組成，JSME 法規原則上是參考 ASME 法規制定，但其內容較 ASME Section XI 更爲具體，有利業主遵循。
- 日本電廠執行 IVVI 作業乃按 JSME 之”Rules on Fitness-for-Service for Nuclear Power Plants“, ”Codes for Nuclear Power Generation Facilities“要求實施，檢查要求分爲兩部分：
  - 「標準檢查」部份：相當於 ASME Section XI 對主要組件之檢查要求（Class 1/MC/2, 3, Support Structure, In-vessel Components）。
  - 「個別檢查」部份：對以上各項提供額外與詳細的要求。

(3) ABWR 須執行 IVVI 之組件及檢查週期

- JSME 法規有關 BWR 形式反應器之規範並未延伸至 ABWR 特定組件之檢查要求，目前日本業主皆自行參照 JSME 對類似組件之規範實施 IVVI 檢查。
- 檢查週期亦自行參照 BWR 之檢查週期。

(4) 執行 ABWR IVVI 使用之設備及技術

- BWR 內部組件較複雜，故除使用傳統水底攝影機之外，對爐心底板以下（Lower Plenum）區域使用遙控操作工具（Remote Operated Vehicle, ROV）進行檢查。
- 由於 ABWR 內部組件較單純，且空間較大，故使用傳統水底攝影機即可執行 IVVI。

(5) 執行 ABWR IVVI 之困難點

- 由於 ABWR 內部組件較單純，且空間較大，故並無窒礙難行之處。

(6) 執行 ABWR IVVI 至今發現之缺陷／瑕疵

- 從柏崎-刈羽（KK）電廠六號機（K6）與七號機（K7）之歷次大修 IVVI 檢查紀錄查閱，截至目前爲止並無發現任何缺陷。

(7) 使用超音波檢測（Ultra-sonic Testing, UT）對 ABWR 爐心側板（Core Shroud）執行檢查之經驗

- 因爐心側板之 IVVI 檢查並未發現瑕疵，故尚不需使用 UT 追蹤檢查。

(8) 有關 ABWR 特有之爐內循環泵導軌（RIP Guide Rails）之檢查

- 討論重點：
  - 日本法規對爐內循環泵導軌檢查之要求與檢查週期。
  - 10 條爐內循環泵導軌係銲接於爐心側板外壁，在執行 IVVI 時是否視爲爐心側板的一部份而必須以 EVT-1 之要求執行。
  - 檢查方式、可接近性與檢查困難點之討論。
- 日本電廠現行作法
  - 日本法規並無要求，但可視爲「內部組件支撐塊（Internal Brackets）」，僅需執行「抽樣或代表性檢查（Sample/ Representative Inspection）」即可。
  - 爐內循環泵導軌非重要結構，故無特定檢查週期，目前 K6 及 K7 僅各做過一次 VT-3，並無發現瑕疵。

(9) 內部組件之營運前檢查（Pre-Service Inspection, PSI）要求

- 法規並無對反應爐內部組件之 PSI 要求。
- 日立公司曾於 K7 建造完成後，對可接近組件以 VT-3 方式攝影記錄，並對部分重要組件之銲道抽樣拍攝照片留存。
- 東芝公司則未對 K6 執行 Pre-IVVI。

(10) 分享：核四廠目前正進行反應爐內部組件所有已完工銲道之照片拍攝、Pre-IVVI 攝影、內部組件 3D 圖形、360 度全景照片與銲道資料庫之建置。

- 日立公司與東芝公司均表示此種作法爲「良好典範（Good Practice）」。

三、心得

（一）藉由本次洽公機會，參觀了日立公司的臨海工廠與東芝公司的核能工程中心，發現兩家國際級大公司的共通特點爲廠房空間規劃乾淨、寬敞、明亮，使用中工具擺設整齊，得以瞭解其廠務管理已落實到每一位工作者，成爲工作人員的工作習性，未來核四廠推動核安文化，亦應向兩家公司看齊。

（二）本次洽公也參觀了東芝公司的核能展示中心，該中心陳設了與 ABWR 相關的各式模型並有詳細解說，包括廠房鋼筋混凝土截面、1:1 模擬爐心地板、反應爐內部組件積木模型、以電鍋爐模擬蒸汽產生與推動汽輪機、微調控制棒控制反應度之模擬操作、汽機葉片實體與爐內循環泵葉輪軸組件實體等，讓民眾可充分瞭解 ABWR 運轉之安全與可靠，消除對核能電廠之恐懼與疑慮。

（三）本次洽公期間，有機會與日立公司及東芝公司的反應爐內部組件專業工程師共同研討 IVVI 的檢查週期、執行技術及相關適用法規，獲益良多，對未來的反應爐內部組件目視檢查之規劃有更深刻的了解。

（四）日立公司及東芝公司在日本核能界皆擁有設計、建造、維修及核能級備品供應的能力，故日本核能電廠在維護方面無需仰賴國外原廠，在備品準備方面無須向國外採購，忍受冗長交貨期，令人羨慕。若台灣也能培植國內公司的核能專業能力，必能降低龐大備品庫存量的壓力，與機組大修的維護費用。

（五）本次洽公期間，安排與日立公司及東芝公司的 IVVI 專業人員深入研討後，深覺 ABWR 實爲一進步之設計，故營運至今，反應爐內部組件並無發現任何重大瑕疵，相信未來核四廠營運後，必能如同日本 ABWR 電廠一樣擁有優異的營運績效。

四、建議

（一）本次出國洽公前，先進行資料收集，包括友廠 IVVI 之作法、檢查週期等資料。於行程聯繫時，即設定十項研討主題，請 GE 公司先行通知廠家準備，並將本廠目前進行之研發案成果相關資料攜帶出國與廠家進行交流，故在赴廠家洽公期間，與各公司進行研討時，皆有深入與詳細之討論，收穫頗多。建議出國人員在出國前應做充分準備，方能有效達成任務與目標。

（二）日本爲現今全世界唯一有 ABWR 電廠建造、試運轉測試、起動測試及營運實績的國家，目前也有多部 ABWR 機組正在規劃與建造中，核四廠在民國 98 年下半年即將陸續進行設備移交與試運轉測試，建議可透過 WANO-TC 之協助，於試運轉測試前派員至日本電廠學習試運轉測試與起動測試之工作規劃與管理知能，以減少摸索時間，順利完成各項測試，使台灣首座 ABWR 機組能及早發電營運。

（三）日立公司與東芝公司在反應爐內部組件維護與 IVVI 的檢測技術上皆不斷研發與精進，目前已廣泛使用遙控水底攝影機（ROV）於各電廠的反應爐內部組件維護與 IVVI 上，而此種 ROV 之設計與製作並無特別困難之技術，建議本公司可委託國內學術或研究機構（如核能研究所、工業技術研究院等）協助研發此類 ROV，未來若能成功使用於反應爐內部組件之維護與 IVVI，將可增加大修維護作業的自主性。

（四）ABWR 型式反應爐的內部組件比 BWR 型式反應爐的內部組件構造簡單，空間較大，故其 IVVI 作業也相對單純。建議本公司可以將 ABWR 的 IVVI 作爲核能工業本土化的第一步，與國內有興趣的公司或研究機構合作，發展國內自行執行 IVVI 的能力，建立專業團隊，如此既可培植國內產業，又可幫公司節省可觀的大修委外技術服務費用。

附錄

A. 日立公司簡報「Hitachi 集團與 Hitachi-GE 核能公司之沿革與產品介紹」

B. 日立公司簡報「日本 BWR 反應爐內部組件 SCC 之現場經驗」

C. 日立公司簡報「日本 BWR 反應爐內部組件 SCC 之檢查技術」

D. 東芝公司簡報「磯子核能工程中心（IEC）沿革與產品介紹」

E. 東芝公司簡報「遙控水底攝影機（ROV）原理與功能」

附錄 **A**

Hitachi 集團與 Hitachi-GE 核能公司之沿革與產品介紹

HITACHI | GE

Commercial in confidence

Welcome to Hitachi-GE Nuclear Energy, Ltd.

Overview of Hitachi & Hitachi-GE Nuclear Energy, Ltd.

November 26, 2008

Overview of Hitachi Group

HITACHI | GE

Founded in 1910 in Ibaraki, Japan

Net Sales:	11,227 Billion Yen (US $112,267 Million)
Total Assets:	10,531 Billion Yen (US $105,308 Million)
Total Employees:	389,752
Number of Subsidiaries:	911 (419 Japan/452 Overseas)

Founder Namihei Odaira

Etsuhiko Shoyama
Chairman of the Board and Director

Kazuo Furukawa
President and Chief Executive Officer

Original Repair Shop Ibaraki 1910

(US$1=100yen, As of March 31, 2008)

Hitachi Group Sales Ratio in FY2007

HITACHI

(US$1=100yen, As of March 31, 2008)

Organization of Hitachi Group

HITACHI

- Board of Directors / Chairman of the Board
- President
- Senior Executive Committee

Business Groups

- Power Systems

Akira MARU
President and CEO, Power Systems
Vice President, Hitachi, Ltd.

- Industrial Systems
- Urban Planning and Development Systems
- Information and Telecommunication Systems
- Consumer Business Group
- Automotive Systems

Group Companies

- Hitachi-GE Nuclear Energy, Ltd. (HGNE) 2007
- Hitachi Construction Machinery
- Hitachi Metals, Ltd.
- Hitachi Cable, Ltd.
- Hitachi High-Technologies Corporation

Commercial in confidence

Overview of Hitachi-GE Nuclear Energy, Ltd.

Establishment of New Companies

HITACHI

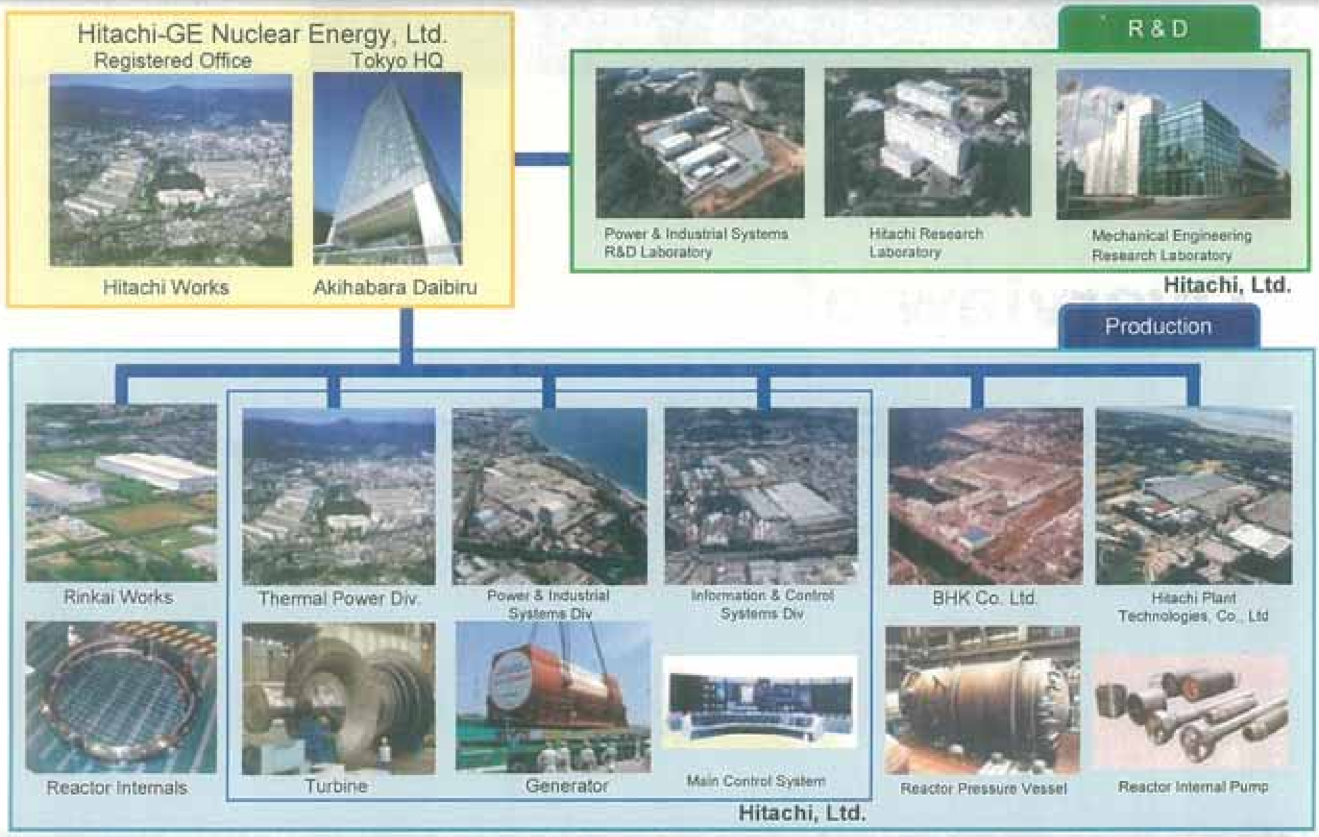
HITACHI
Inspire the Next

Joint Press Conference in New York City (July 9, 2007)

- Hitachi and GE have collaborated in nuclear businesses for more than 50 years.
- Hitachi/GE started the first alliance for comprehensive BWR technology in 1967, and have contributed to the evolution of BWR technology.
- "GE-Hitachi Nuclear Energy LLC (GEH)" in US and "Hitachi-GE Nuclear Energy, Ltd (HGNE)" in Japan were established in June-July 2007.
- GEH and HGNE consolidate synergy effect and offer high-quality and consistent business of nuclear systems from R&D, design, manufacturing, construction to operation and maintenance in nuclear business fields worldwide.

Major Facilities and Product Lines

HITACHI



Major Milestones of Hitachi Nuclear Business

HITACHI

1950 Start of Nuclear business

BWR technology licensed by General Electric

1967 First "made in Japan" NPP completed by Hitachi

1974 *Shimane # 1*

First ABWR(Advanced BWR) started operation

1996 / 97 *Kashiwazaki - Kariwa # 6 / 7 (International J/V)*

First ABWR completed by Hitachi

2006 *Shika # 2 (Full EPC Scope except civil)*

Hitachi-GE Nuclear Energy Ltd. (HGNE)

2007 *Shareholders*

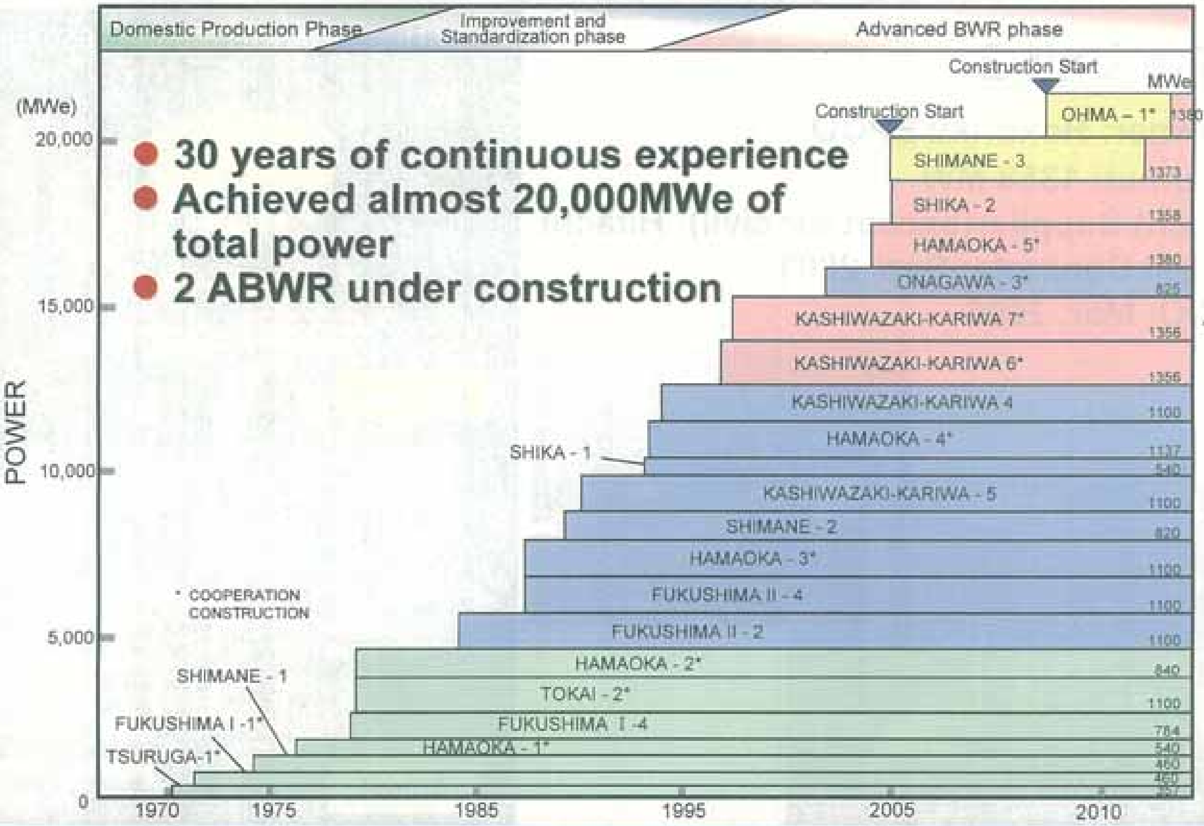
: Hitachi, Ltd. : 80.01%

: General Electric Company:19.99%

BWR: Boiling Water Reactor
ABWR: Advanced BWR

Nuclear Plant – Uninterrupted Construction Experience (1/2)

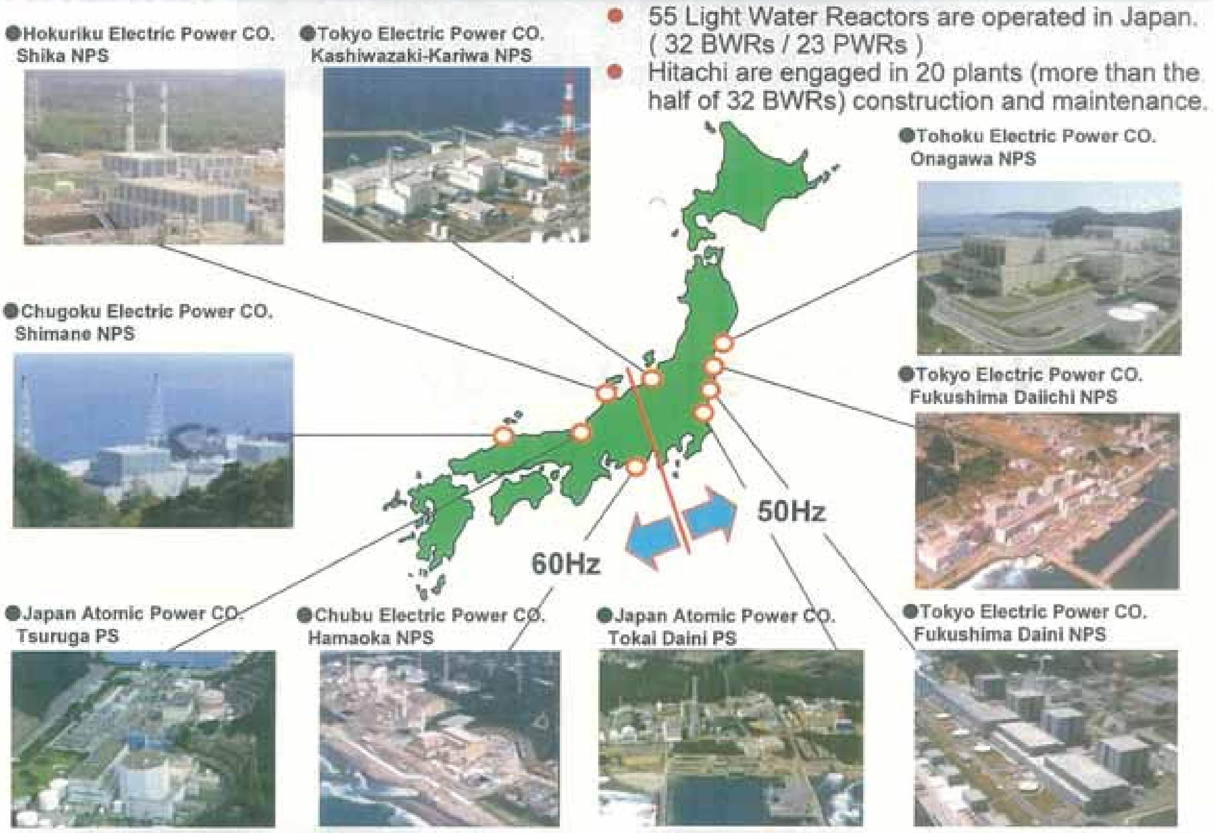
HITACHI



Nuclear Plant – Uninterrupted Construction Experience (2/2)

HITACHI

- 55 Light Water Reactors are operated in Japan. (32 BWRs / 23 PWRs)
- Hitachi are engaged in 20 plants (more than the half of 32 BWRs) construction and maintenance.



Latest Construction Status in Japan

HITACHI

Shika Unit-2

- Owner: Hokuriku EPCO
- Output: 1358 MW
- Plant Supplier(except for civil): Hitachi
- First Concrete: Sep, 2001
- C/O: Mar, 2006

RCCV Upper Drywell Module (650 ton)

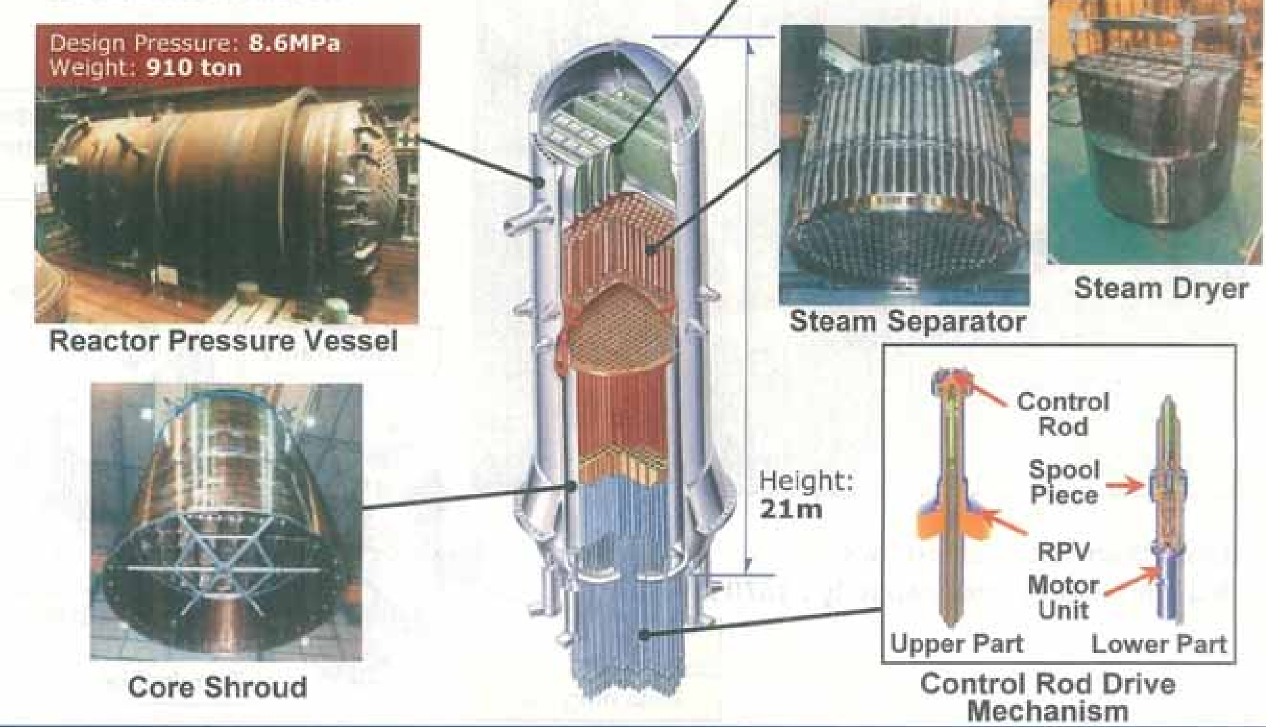
HITACHI

Nuclear Technology

Detail Design & Manufacturing
- Reactor Pressure Vessel and Internals -

HITACHI | GE

HGNE continues to produce highly reliable nuclear key components for worldwide market.



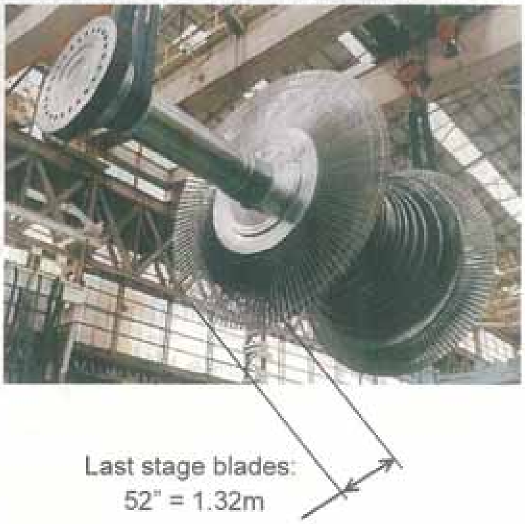
Detail Design & Manufacturing
- Turbine and Generator -

HITACHI | GE

HGNE supported by Hitachi Ltd. and its subsidiaries, supplies major equipment for nuclear power station, such as steam turbines, generators, main control room and instrument & control components, by our own technology.

Nuclear Turbine

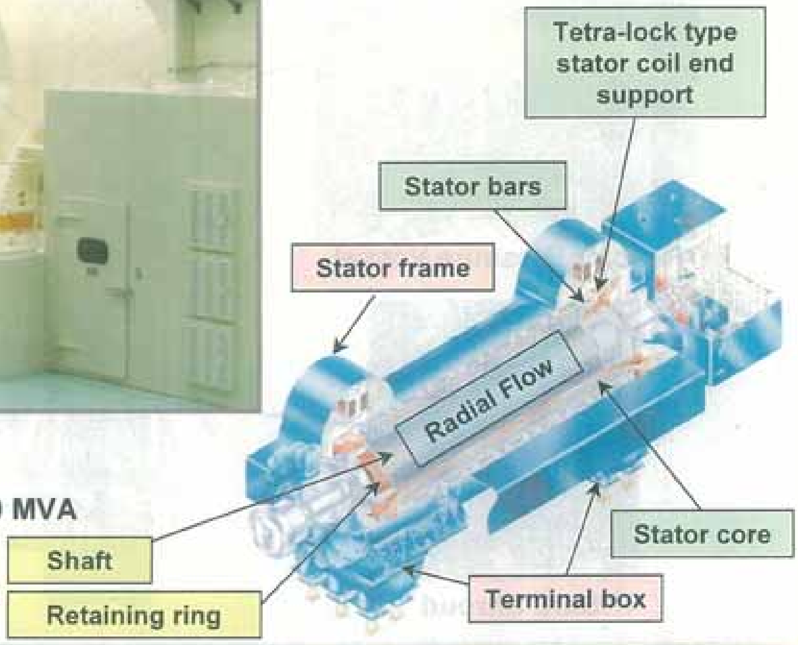
Low Pressure Turbine Rotor



- **Total number of units :**
  21 (nuclear), 1736 (all steam turbines)
- **Total generating capacity : 110GW (all steam turbines)**
- **Maximum single unit capacity : 1380 MW**

Detail Design & Manufacturing
- Turbine and Generator -

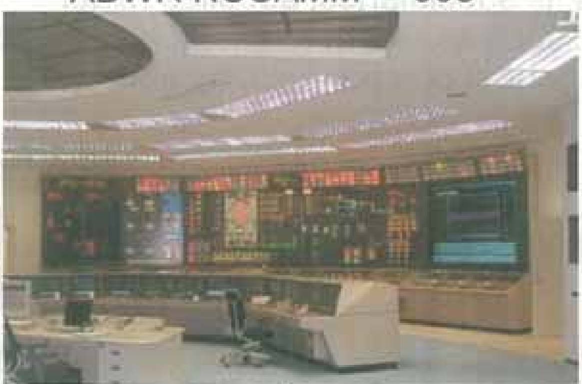
Generator



- More than 1,000 generators
- Maximum generator capacity : 1570 MVA

Detail Design & Manufacturing
- Main Control Room and I&C System-

ABWR NUCAMM(*1)-90e



- Main control console – 7.8m
  Wide display panel – 12m
- Automated sequences with user interface via touch screen
- New digital technology utilization
- Hitachi platform for Distributed Control System: G-HIACS

Safety Related System Digitalization	Non Safety Related System Digitalization	Major Control System Digitalization
Since 1997	Since late 1980s	Since early 1980s

⇨ **13 RY experience**

Qualification
By third party etc.

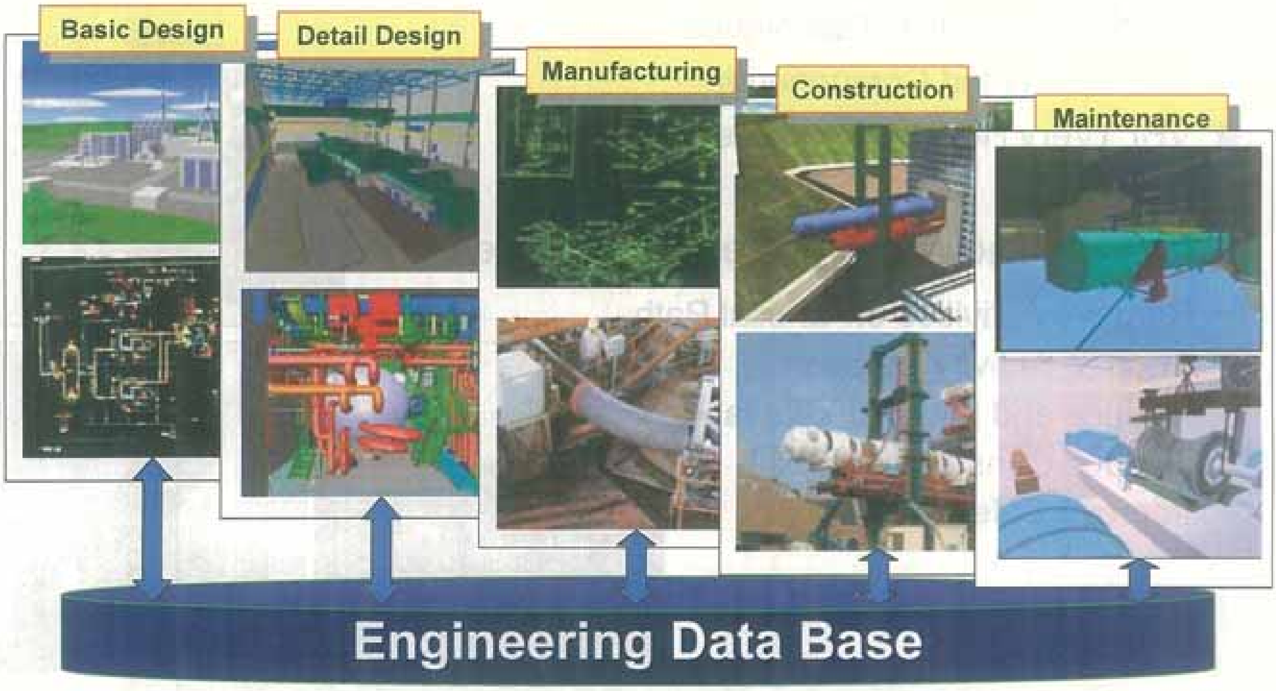
Compliant with global standard such as IEC and IEEE

*1: Nuclear Power Plant Control Complex with Advanced Human-Machine Interfaces

Plant Engineering & Construction
- Hitachi Plant Integrated CAE System -

HITACHI

HGNE Plant Integrated CAE System provides optimized design, visualization, and information management throughout the plant life

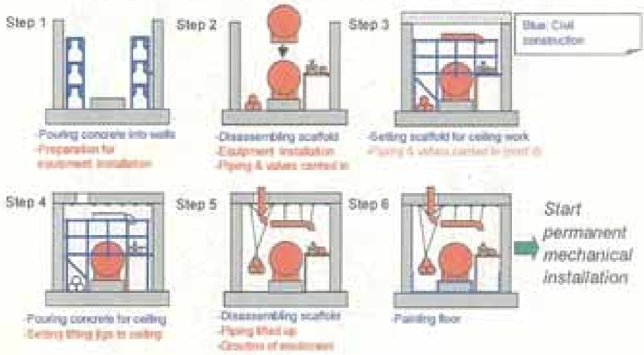


Construction - Engineering and Management -

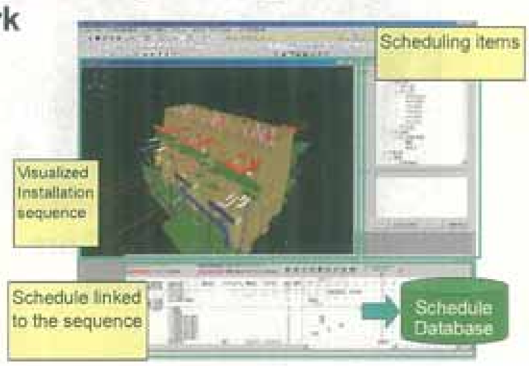
HITACHI

Modularization with Large Crawler Crane

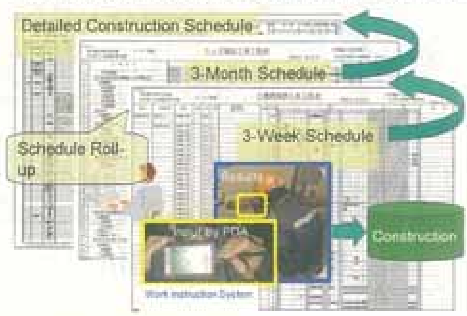
Open-top & Parallel Construction



Detailed Engineering Before On-site Work



Construction Support System



Construction - Modularization technology -

HITACHI

What is Modularization?

- Plant Construction Techniques
- Pre-assembled Components
- VHL (Very Heavy Lift) at Site

What are the Advantages of Module?

- Remove Activities on Critical Path
- Shorten Activity Duration
- Reduce and Level-off Site labor
- Reduce Construction Cost
- Improve Safety and Quality

Maintenance - Repair and Replacement -

HITACHI

Replacement of Shroud

- To achieve efficient plant operation, HGNE is supporting customers in various maintenance activities.
- Those activities include replacement of major equipment

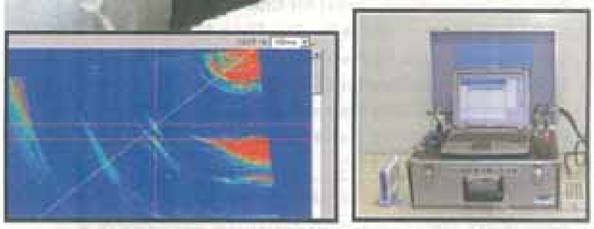
Replacement of In-Core Monitor Housing

Maintenance - Inspection -

HITACHI

Various types of Remotely Operated Vehicle

- Inspection Technology is a key to realize efficient maintenance



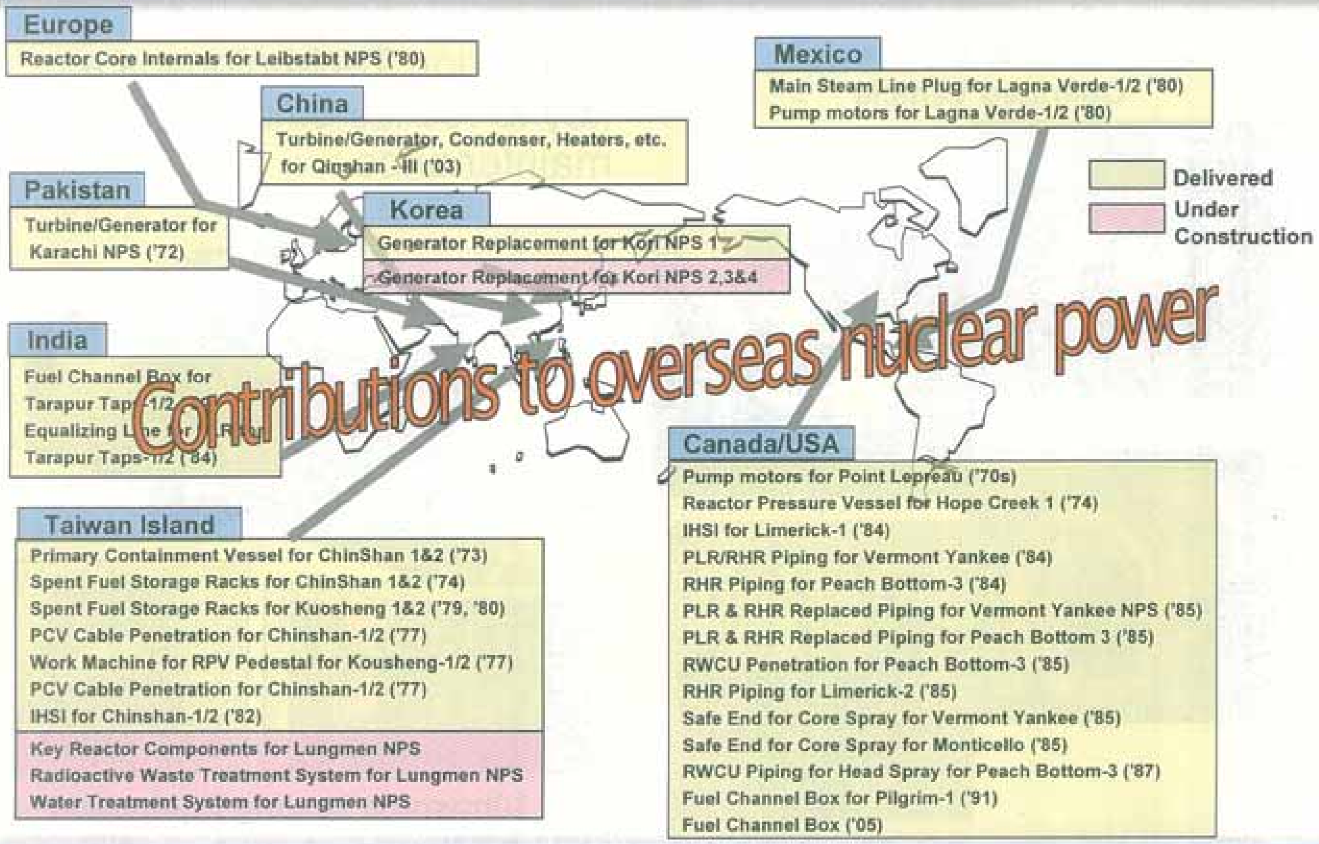
Ultrasonic Testing Equipment

HITACHI

Overseas Nuclear Business

Deliveries to Overseas Nuclear Projects

HITACHI



Third Qinshan Nuclear Power Co. NPS

HITACHI

Canada – 685
Korea – 715
Qinshan – 728

TPC Lungmen Nuclear Power Station

HITACHI

TPC

A/E

GEH

Other Vender

T/G

HITACHI

Radioactive Waste Treatment Facility

HITACHI

Makeup Water Treatment System

HGNE

Other Vender

(Unit 1)
RPV
RIN
FMCRD*
(*Unit ½)

Reactor Pressure Vessel (RPV) Transported to Storage House

Notes:
TPC: Taiwan Power Company

Latest ABWR Deployment Strategy

HITACHI

Certified Design + Constructability

ABWR

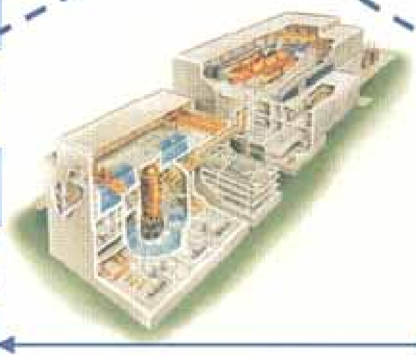
U.S. ABWR

- Minor changes (e.g., remove H2 Recombiners; Aircraft impact assessment; Bypass capacity)

Lungmen 1&2 ABWR

- Tier 1&2 DCD Departures
- Design detailing & implementation

Certified ABWR (DCD 1997)



Incorporate Japan experience and construction techniques into U.S. ABWR

Japan ABWR (Hamaoka 5; Shika 2; Shimane 3)

- Construction planning
- Modularization & Advanced Construction Technology
- 60Hz 52" LSB STG

Kashiwazaki 6&7 ABWR

- Severe Accidents
- US Codes & Standards
- EPRI URD Requirements
- NRC Regulations

Design & Licensing Basis

Japan Construction Experience

附錄 **B**

日本 BWR 反應爐
內部組件 SCC 之現場經驗

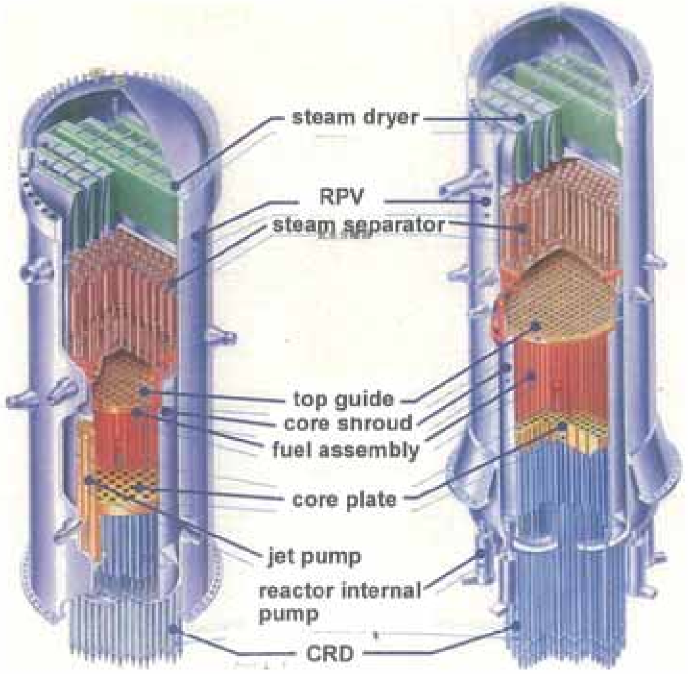
HITACHI

Field Experiences of SCC
in Japanese BWRs Core Internals

Structure of BWR

HITACHI

BWR **ABWR**



RPV: reactor pressure vess
CRD: control rod drive

What's SCC?

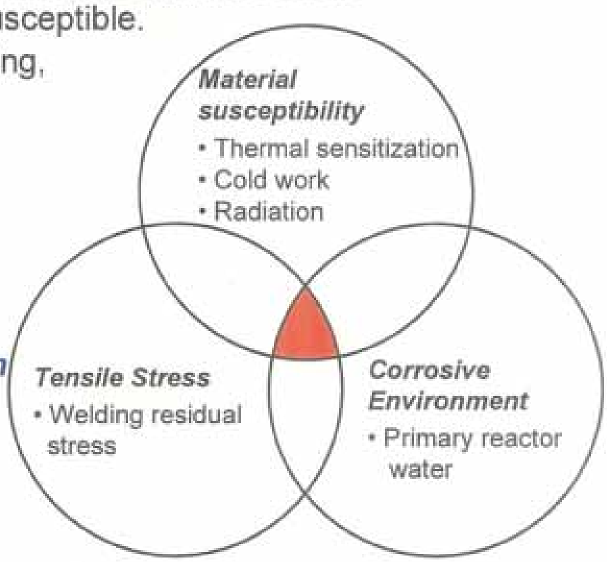
HITACHI

SCC is caused by simultaneous action of tensile stress and corrosive environment to SCC susceptible material.

- General corrosion resistant materials such as stainless steels and Ni-base alloys tend to be SCC susceptible.
  Susceptibility accelerated by welding, cold work, etc.
- Tensile residual stress is generated by welding.
- Primary reactor water becomes corrosive environment.

⇩

The major degradation phenomenon of stainless steels and Ni-base alloys in LWRs



Typical contributing factors of SCC in LWRs

SCC of low carbon SS

HITACHI

SCC of low carbon SS became apparent (2001-)

- SCC of SUS316L(NG) and 304L core shroud (2001-)

  Features
  - IGSCC without grain boundary sensitization
  - TGSCC partly observed at the surface
  - Radial (or spider net) shape cracking (core shroud)

  Factors
  - SCC initiation is accelerated by surface cold work layer due to machining/grinding and surface residual stress due to grinding.
  - SCC propagation is strongly influenced by welding residual stress.

Many BWRs stopped for inspection, evaluation and repair

⇩

Sever influence on energy supply

IGSCC: Intergranular SCC

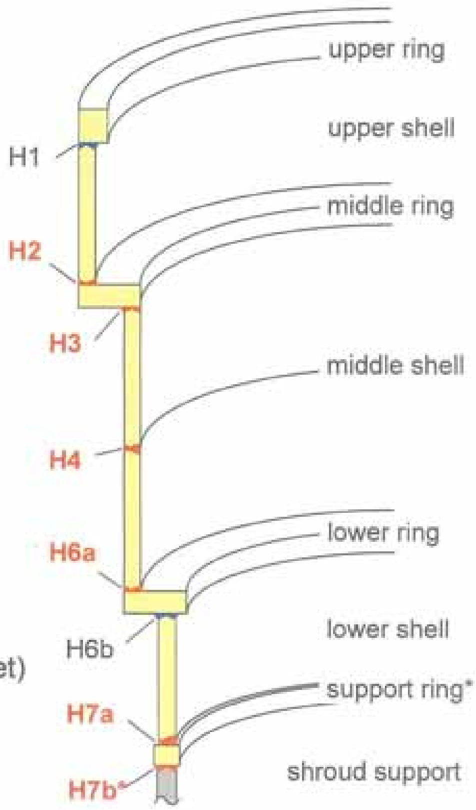
TGSCC: Transgranular SCC

Core Shroud Cracking (1)

HITACHI

Location of cracking of 316L(NG)/304L core shroud

- Middle shell welds
  Radial cracks of H3 and H4 welds
- Ring welds
  Circumferential cracks of almost full length of H2, H6a and H7a welds
- Other than the primary welds
  Radial cracks in the region far from the fusion line (one plant)
  Cracks of filet welds (T/G base, SHB bracket)



T/G: top guide
SHB: shroud head bolt

*) Some plants have no support ring and H7b weld

Welds with red letters: cracks found

Core Shroud Cracking (2)

HITACHI

Summary of core shroud cracking

- Both for Type 304L and Type 316L(NG) in various types of shroud cracking were observed in Japanese BWRs.
  - Circumferential cracking almost full length of ring
  - Circumferential cracks
  - Radial Cracks

Based on press releases from utilities

Core Shroud Cracking (3)

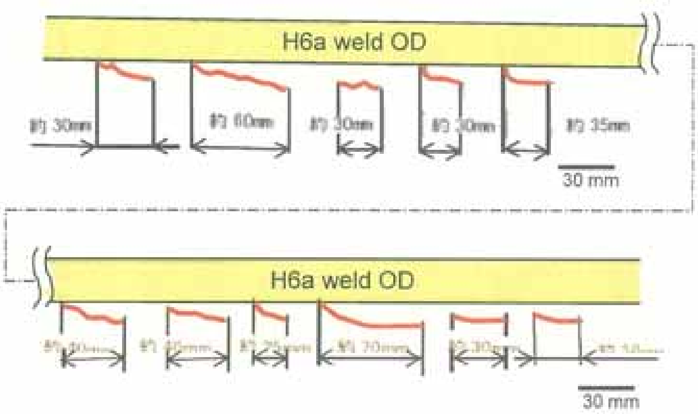
HITACHI

Characteristics of SCC of 316L(NG)/304L core shroud

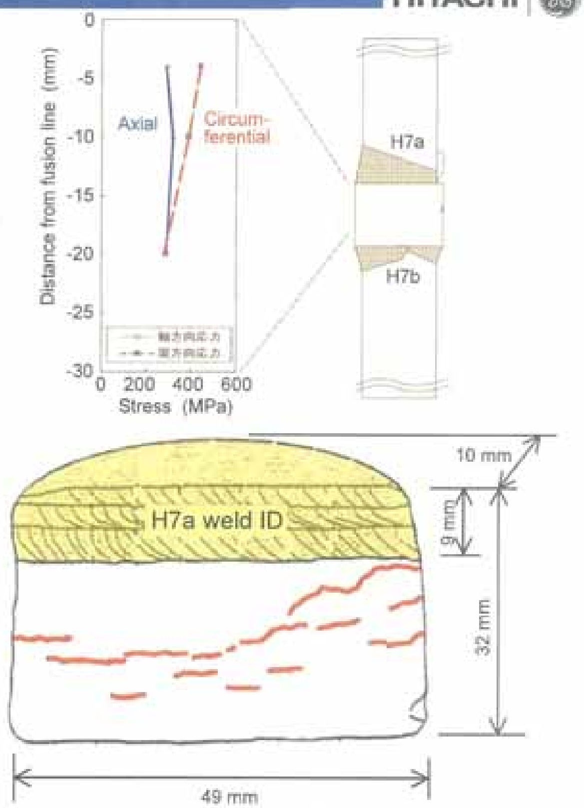
- In many cases, transgranular cracking initiated at surface cold worked layer and propagated as intergranular cracking
- Radial (or spider net) cracks of the shell welds and circumferential intermittent cracks of the ring welds
- Cracking far away from the shell welds of a hard grinding applied core shroud.

Core Shroud Cracking (4)

HITACHI



H-4 H6a weld (316L(NG))



K-3 H7a weld (316L(NG))

Circumferential cracks of the ring weld

- slightly inclined, intermittent cracks

From Home Page of NISA

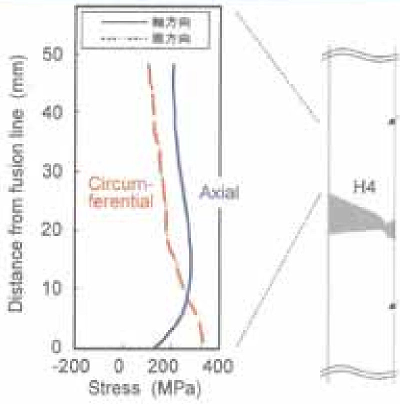
Core Shroud Cracking (5)

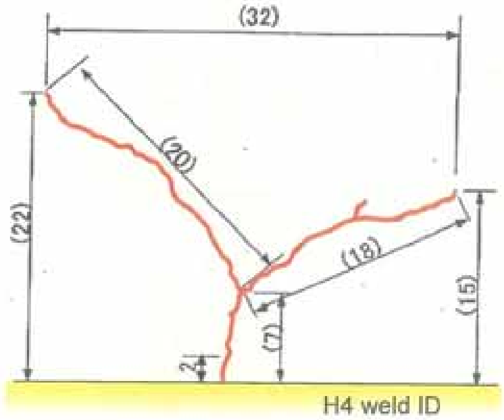
Cracking of the shell weld

- Initiation by transgranular (TG) cracking
- Propagation by intergranular (IG) cracking
- Cold worked layer at the surface
- No grain boundary sensitization

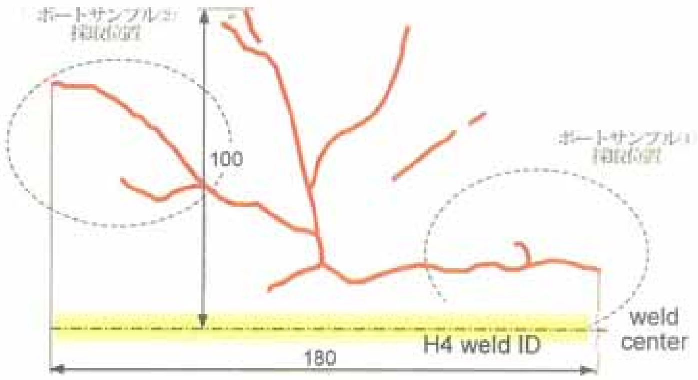
From Home Page of NISA

Core Shroud Cracking (6)





K-1 H4 weld (316L(NG))



1F-4 H4 weld (304L)

Radial cracks of the shell weld

•Radial (or spider net) cracks

From Home Page of NISA

Core Shroud Cracking (7)

Cracking of the shell weld

Observations

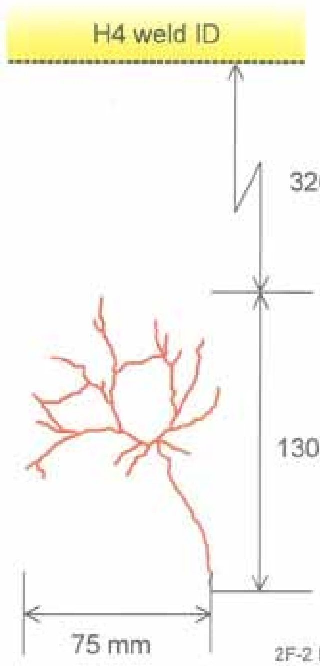
- Intergranular cracking with fine branching
- Oxidation along cracking

From Home Page of NISA

Core Shroud Cracking (8)

Example of cracking far away from the shell weld

- Intergranular cracking with fine branching
- Residual stress and cold worked layer at the surface by hard grinding are considered to accelerate SCC initiation
- At location of temporal jig weld, the weld residual stress becomes driving force of deep propagation



2F-2 H4 weld (316L(NG))

K. Takamori, et al., Proc. of JSCE Materials and Environments 2006.

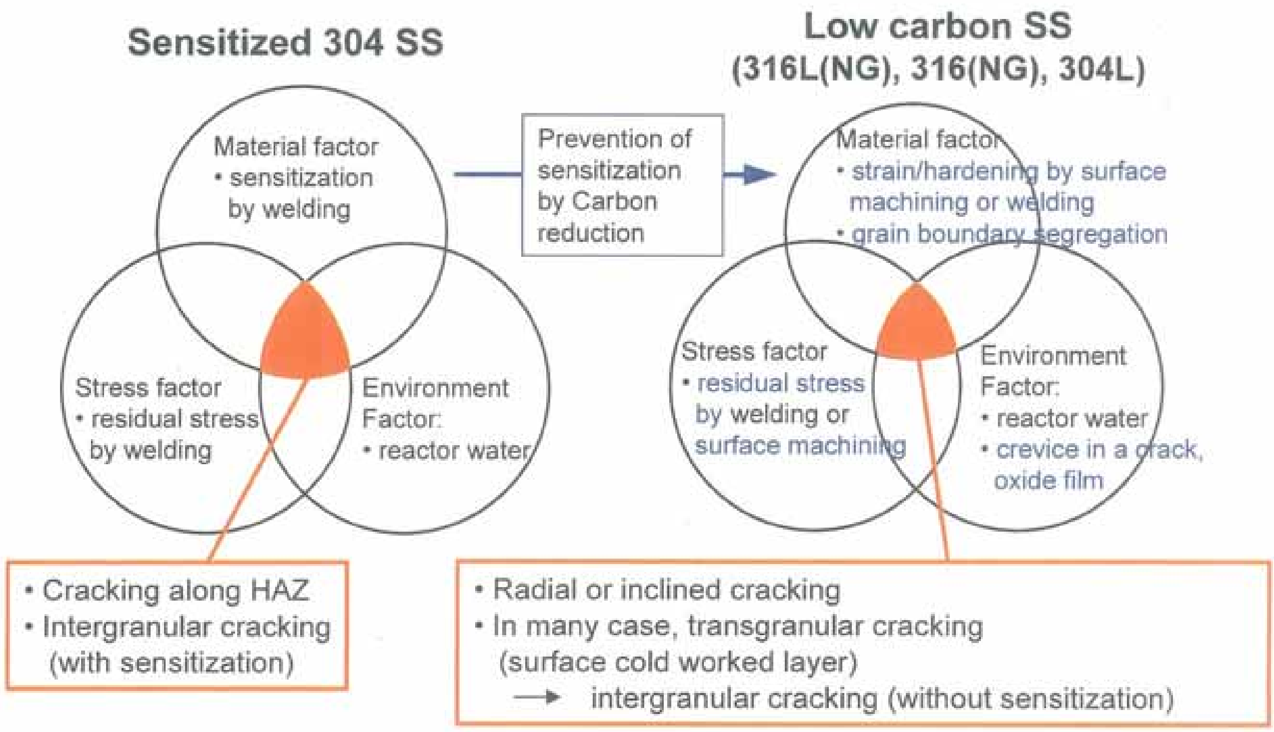
Core Shroud Cracking (9)

Summary of core shroud cracking repair

Various type of repair or countermeasure were taken such as:

- Rmv: Crack removal,
- Pol: Polishing
- WJP: Water jet peening,
- LP: Laser peening
- TR: Tie Rod repair
- Eval: Continued operation by flaw evaluation

Possible SCC Factors of Low Carbon SS



• Mechanism needs further investigations

SCC of Ni-base Alloy

HITACHI

SCC of Ni-base alloys has been found in several BWRs.

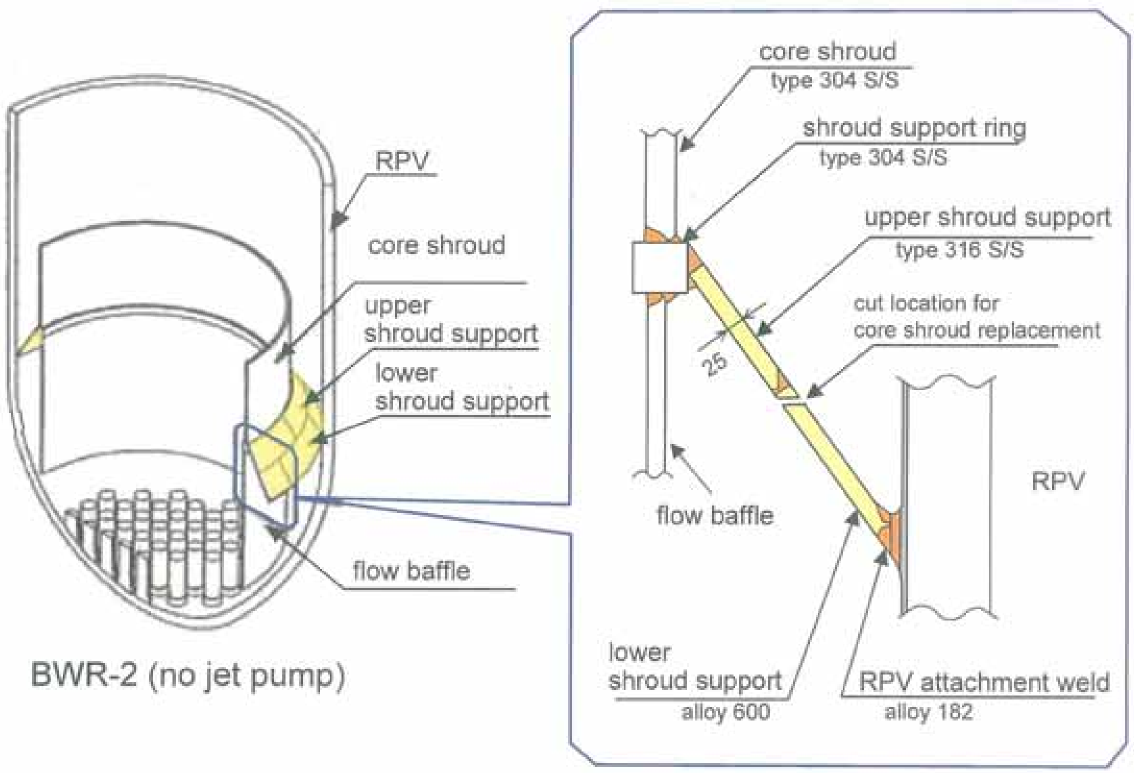
- Cracking of Alloy 182 weld metal in shroud support and CRD stub tube.

  SCC potential of shroud support welds is a recent concern of BWRs

- Deliberate inspection/mitigation is necessary because of poor accessibility of RPV bottom repair. Ni-base alloy

Shroud Support Cracking (1)

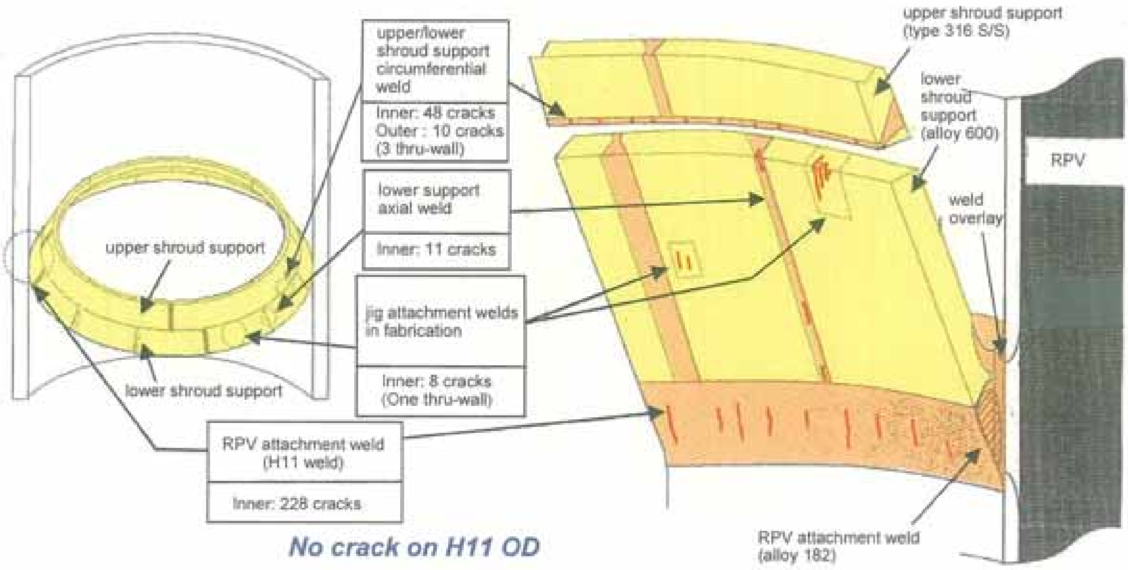
HITACHI



Shroud support structure ("A" Plant)

From Home Page of JAPC

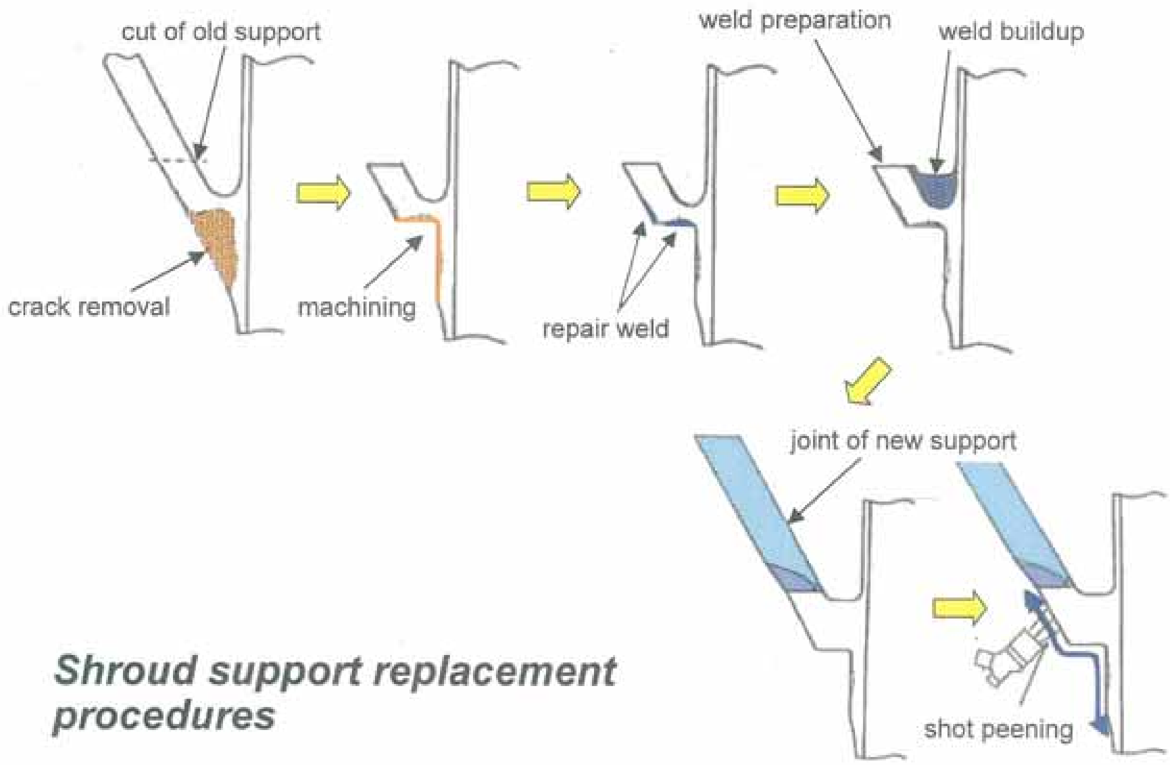
Shroud Support Cracking (2)



Cracking location

From Home Page of JAPC

Shroud Support Cracking (3)



Shroud support replacement procedures

From Home Page of JAPC

Shroud Support Cracking (4)

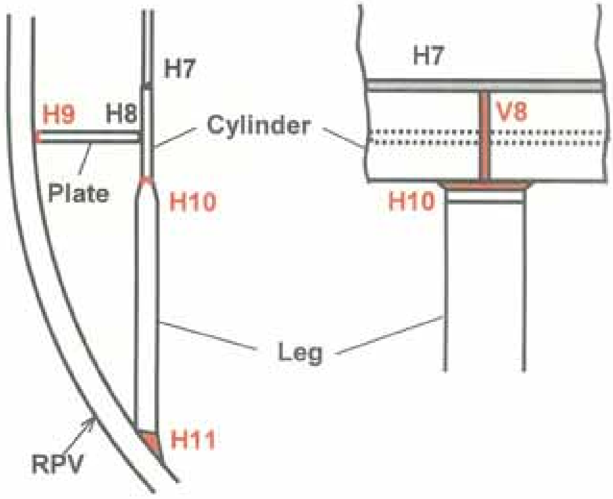
HITACHI

IGSCC of Alloy 182 welds has been found in four BWRs except for "A" Plant.

All cracks are vertical cracking in H9, H10, H11 or V8 welds.

Action to cracking

- Continued operation by crack evaluation in two plants
- Other two plants in evaluation



Welds with red letters: cracks found

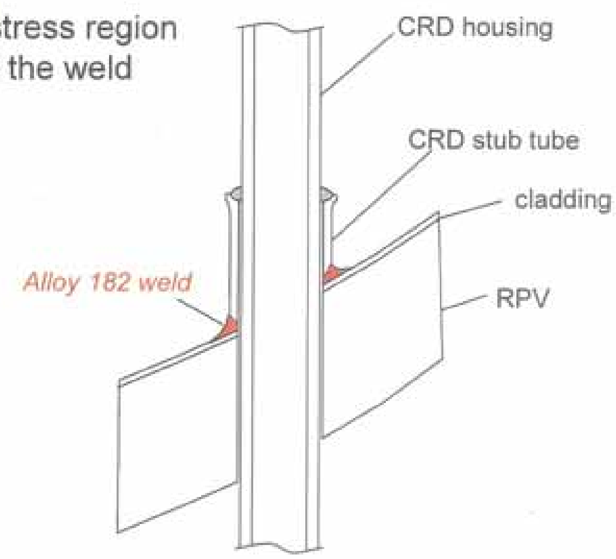
CRD Stub Tube Leakage

HITACHI

Leakage occurred at CRD stub tube weld to RPV by IGSCC of Alloy 182 (one plant)

Hamaoka

- Cracking at rather high residual stress region due to specific bead sequence of the weld
- Action to cracking
  - Replacement
- Prevention/Mitigation
  - Peening (WJP, LP)
  - HWC/NMCA
  - Nb controlled Ni-base alloy



Summary

- SCC of 316L(NG)/304L core shroud has been found in many BWRs.

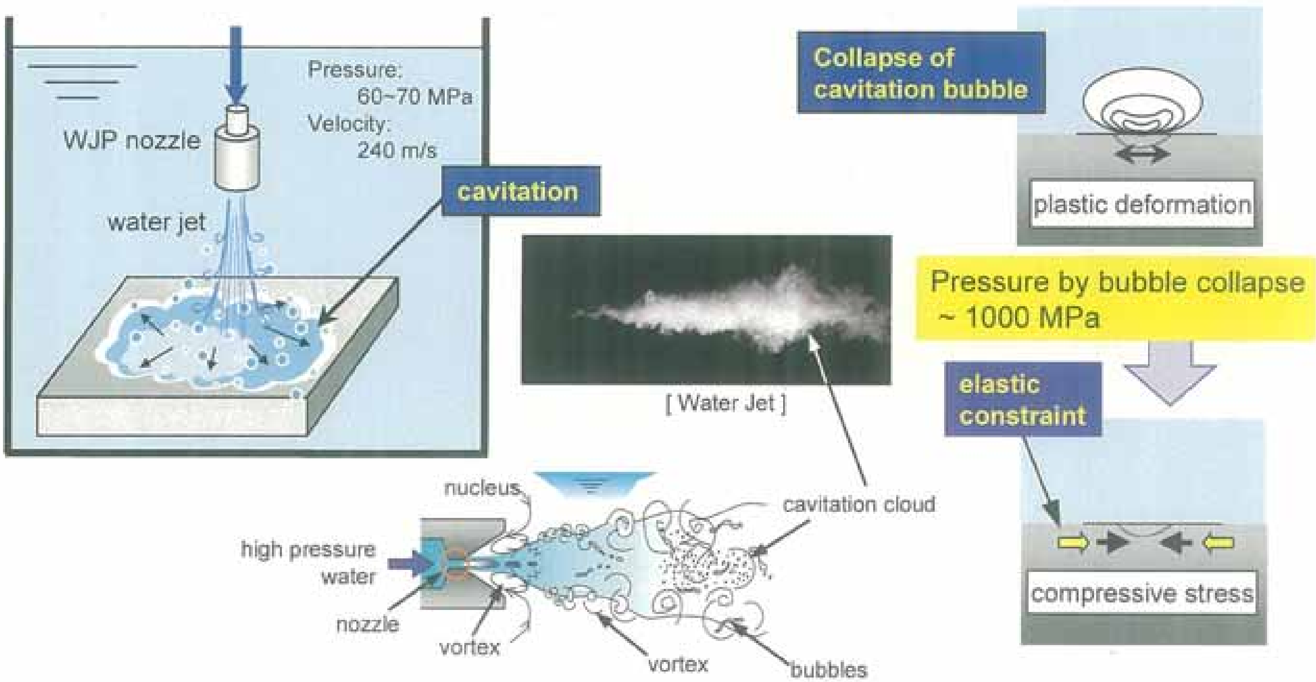
  Suppression of surface cold work layer is important in fabrication process with stainless steels

- SCC of Alloy 182 welds of shroud support has been found in several BWRs.

  Deliberate inspection/mitigation will be planned for RPV bottom

Appendix: Water Jet Peeing (1) - Principle -

- High pressure pulse generated by collapse of cavitation bubbles gives compressive stress on the surface.
- Advantage in application to complicated structure such as the RPV bottom



Appendix: Water Jet Peeing (2)

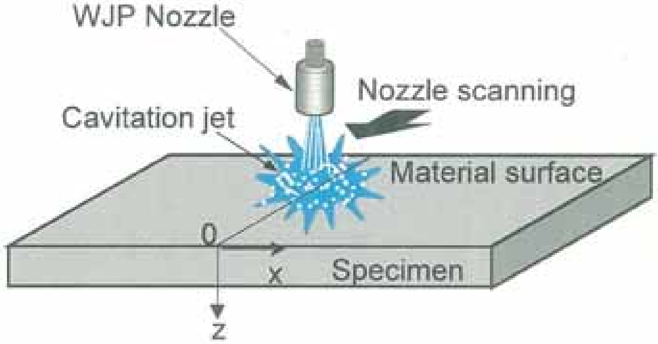
Characteristics of WJP

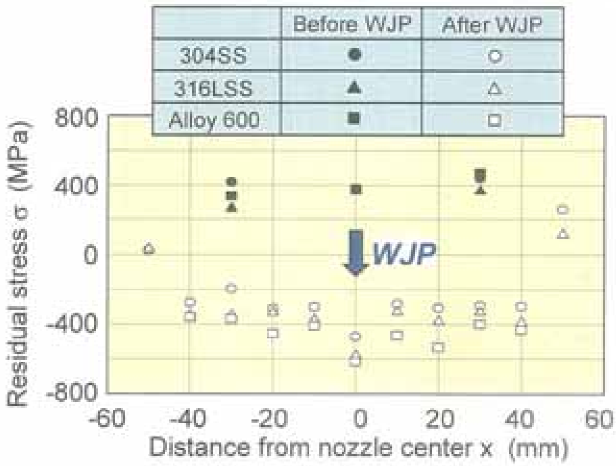
- Use only pure water for treatment
  - => No foreign material into the reactor
  - => No heat influence to the material
- Simple water transfer line
  - => Easy implementation
  - => Simply controlled equipment
  - => High reliability
- Wide range in the execution condition – jet distance/angle, etc.
  - => Applicable to complicated/narrow structures
  - => Robust execution
- No stress-induced martensitic transformation, etc.
  - => No harmful influence to the material

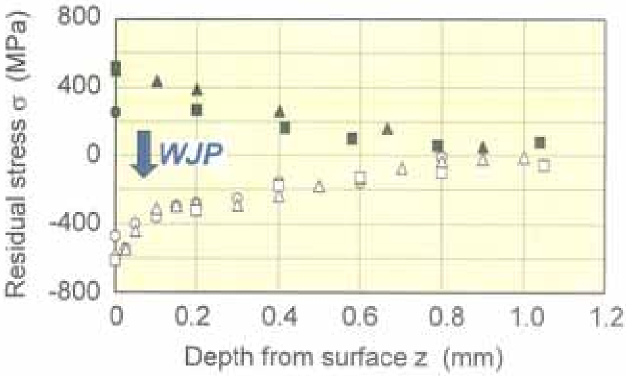
Appendix: Water Jet Peeing (3)

Stress improvement by WJP

- Surface stress decreased to -500 MPa
- Compressive stress region reached 1 mm in depth and 100 mm in width

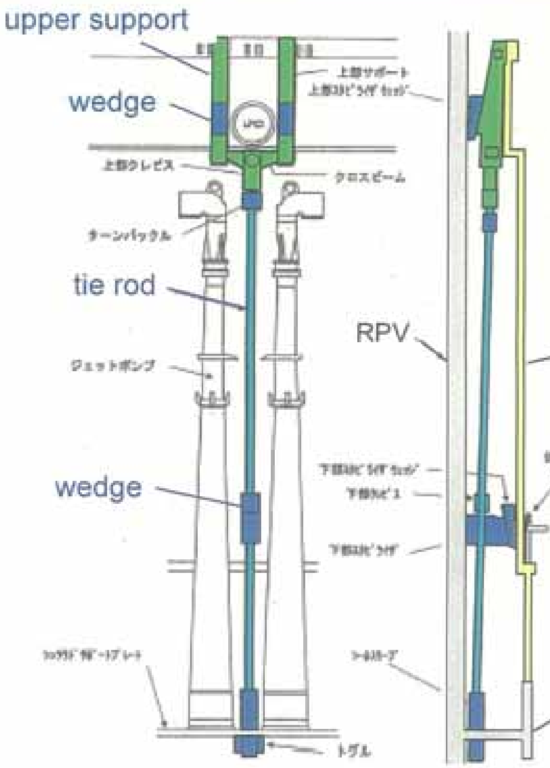






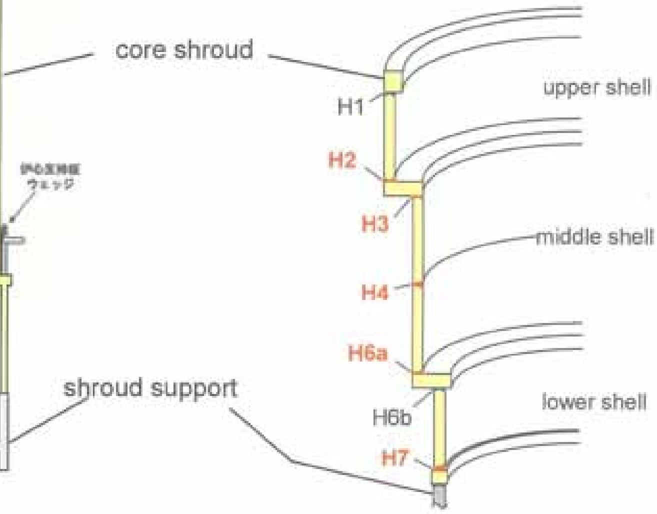
Appendix：Tie Rod Repair of Core Shroud

- Four tie rods substitute for all horizontal welds of core shroud
- Tie rod repair has been applied in four BWRs



Schematic view of tie rod
(One tie rod per quadrant)

From TENPES Report JBWR-VIP-04



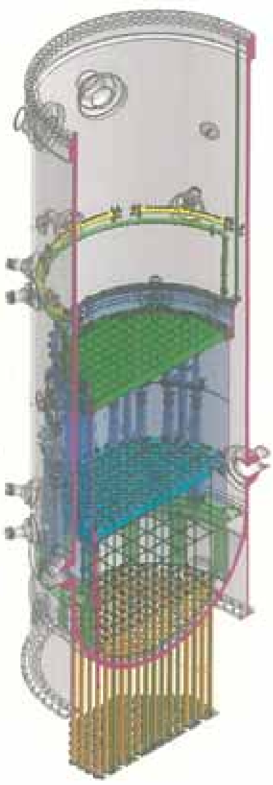
附錄 C

日本 BWR 反應爐內部組件 SCC 之檢查技術

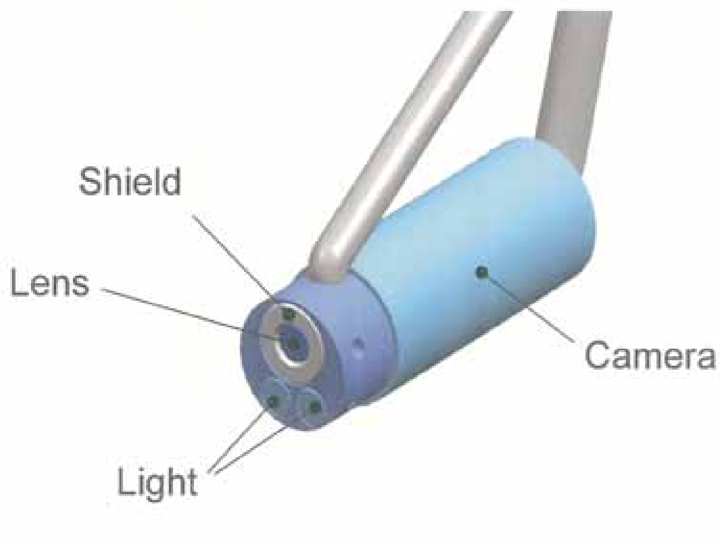
Inspection Technologies
for BWRs Core Internals SCC

Visual Inspection by TV Camera

1



In-Vessel visual inspection for SCC crack detection is generally performed by TV camera.

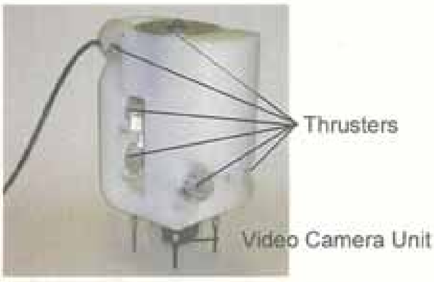


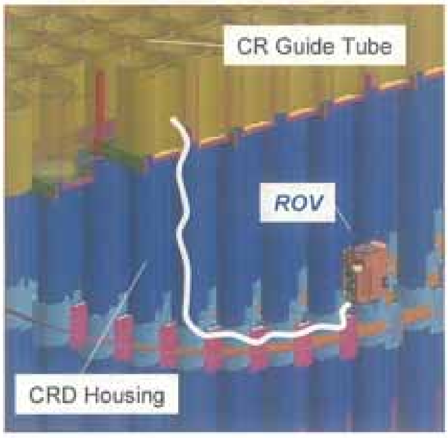
ROV for In-vessel Inspection

2

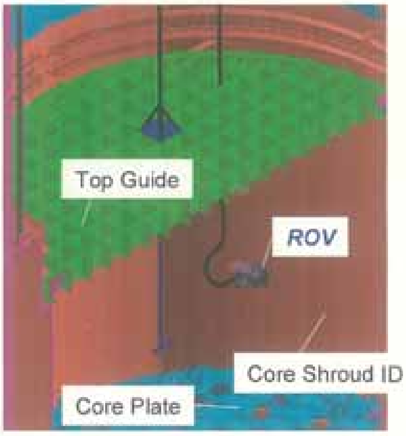
HITACHI

VT for RPV bottom





UT/ECT of core shroud/ shroud support

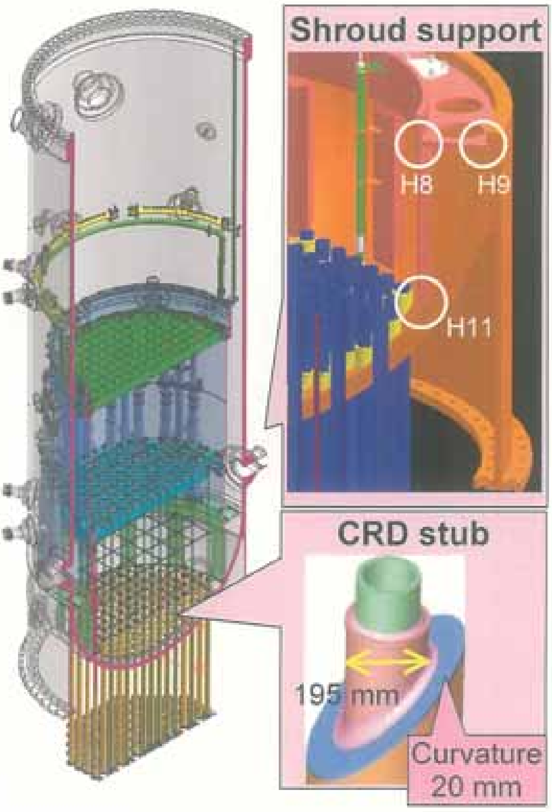


K. Kodaira, et al., Hitachi Hyoron, Feb, 2008

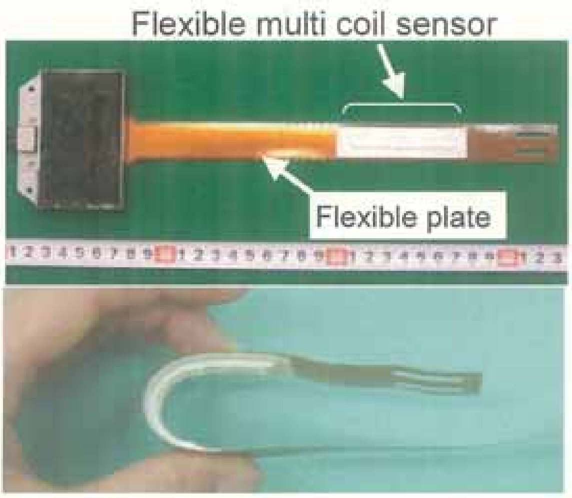
Flexible Multi ECT Sensor (1)

3

HITACHI



Flexible multi ECT sensor can be applicable to complicated structures such as shroud support and CRD stub.



A. Nishimizu, et al., 5th Int. Conf. on NDE (2006)

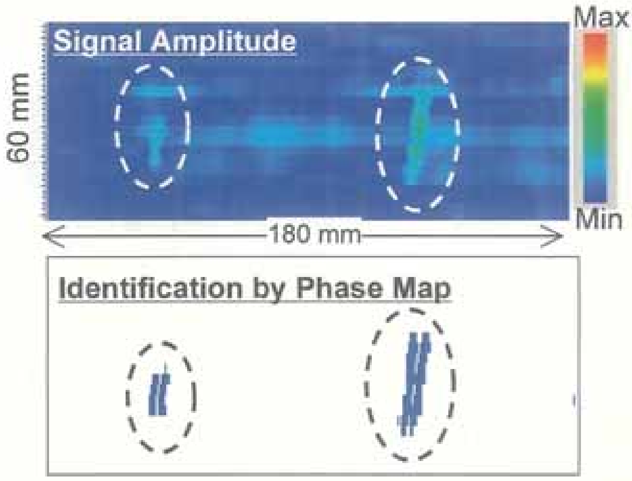
Flexible Multi ECT Sensor (2)

HITACHI

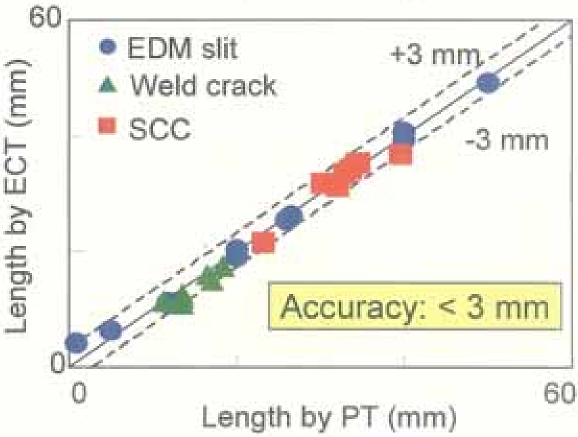
Performance of flexible multi ECT sensor

H9 weld mockup with SCC cracks

Crack indentification



Sizing Accuracy



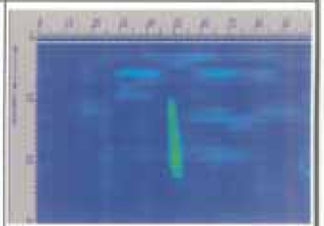
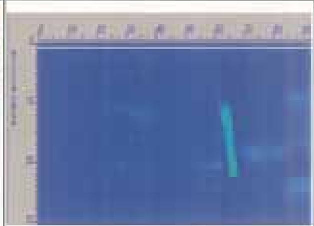
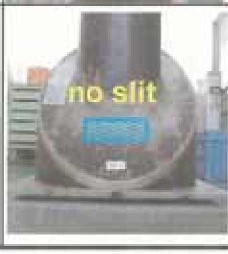
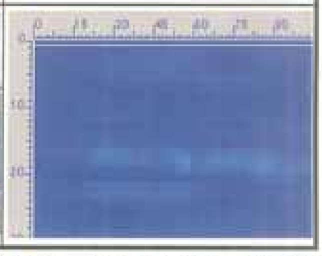
K. Kodaira, et al., Hitachi Hyoron, Feb, 2008

Flexible Multi ECT Sensor (3)

HITACHI

ECT Scanner for CRD Stub Weld

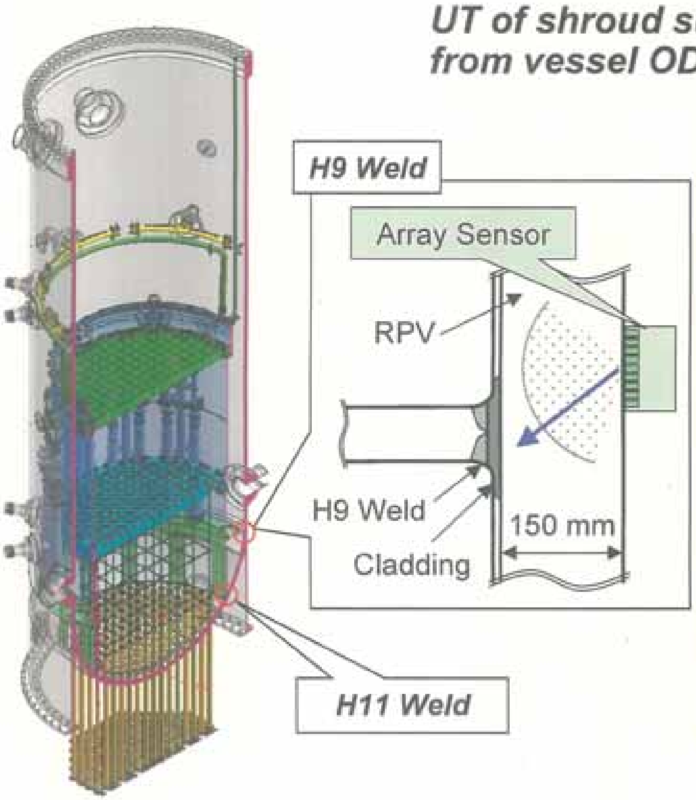
ECT scanner for CRD stub weld

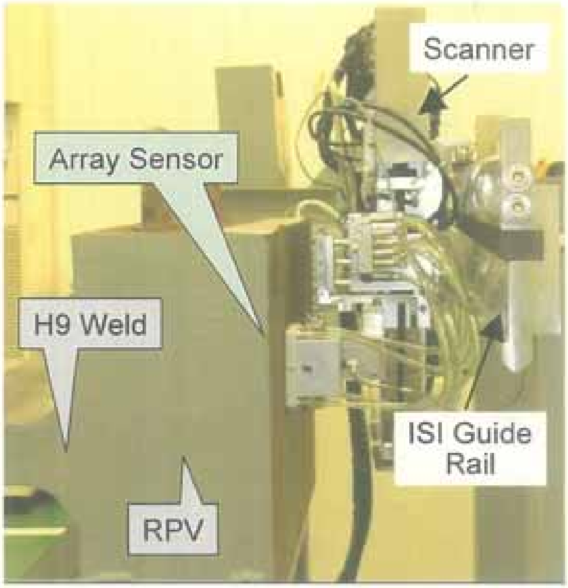
	Imaging area	C-scope image (Y-mode)
hill side		
middle side		
valley side		

K. Kodaira, et al., Hitachi Hyoron, Feb, 2008

UT through RPV (1)

UT of shroud support H9 and H11 welds from vessel OD

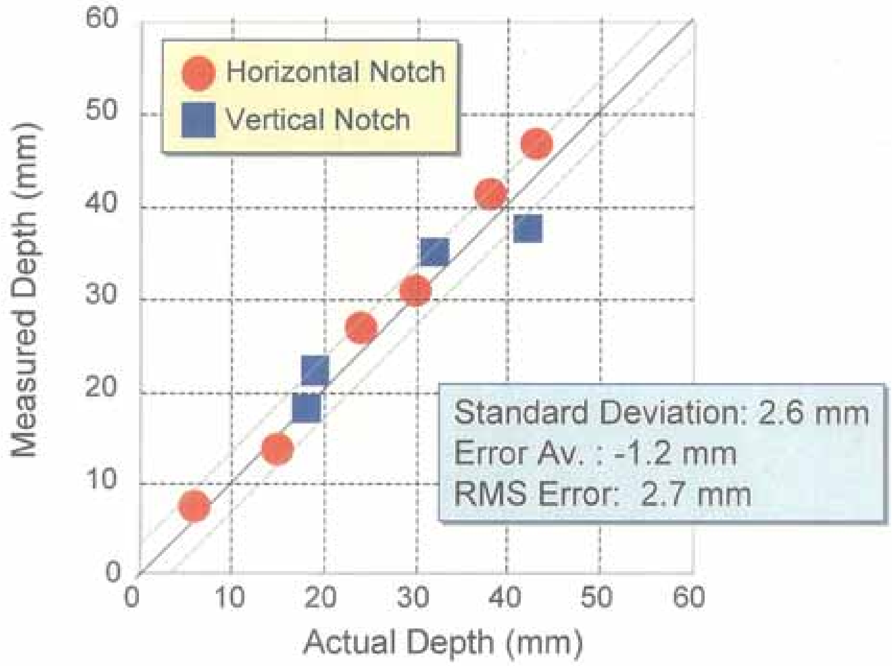




N. Kono, et.al, Proceedings of 15th ICONE (2007)

UT through RPV (3) – Sizing Accuracy -

Sizing accuracy for horizontal and vertical notches: less than 3mm



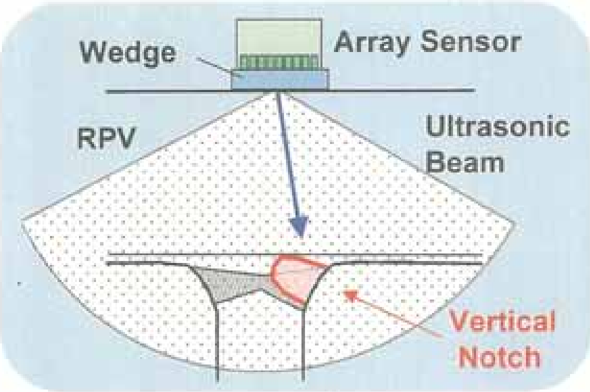
RMS: Root Mean Square

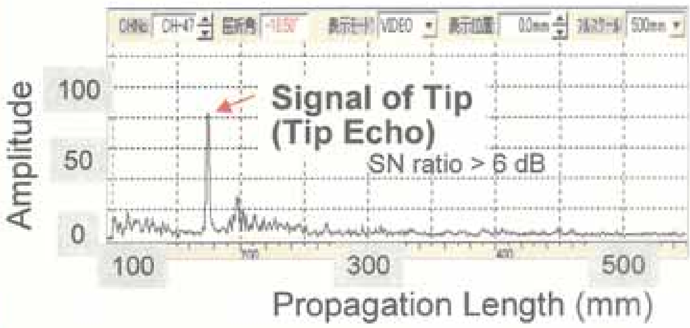
N. Kono, et.al, Proceedings of 15th ICONE (2007)

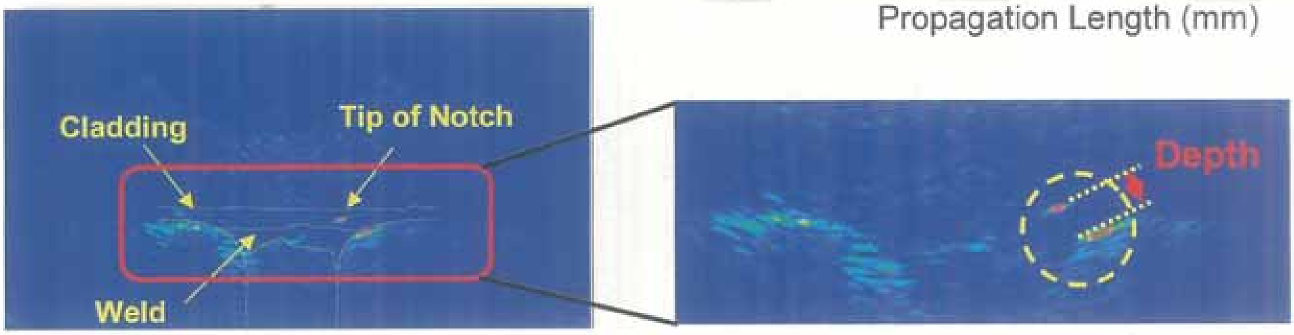
UT through RPV (2) - Detectability -

HITACHI

Detectability of vertical notch at H9 weld







N. Kono, et.al, Proceedings of 15th ICONE (2007)

附錄 **D**

磁子核能工程中心（IEC）
沿革與產品介紹

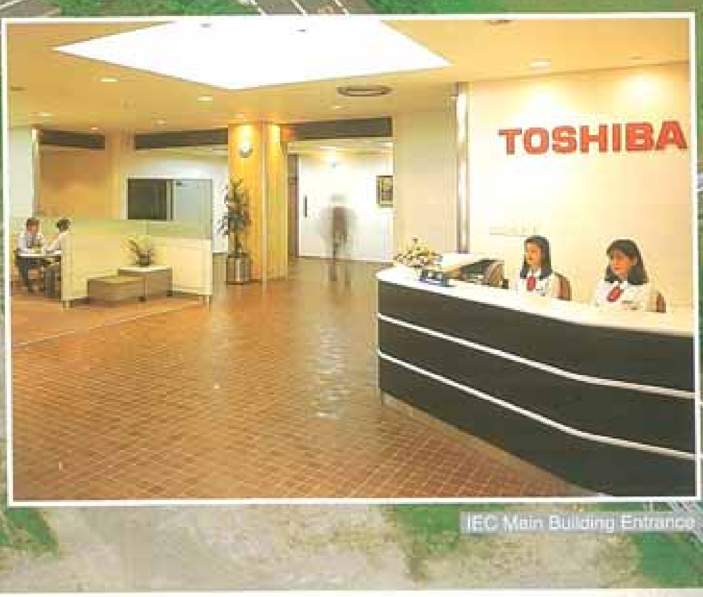
TOSHIBA

ISOGO NUCLEAR ENGINEERING CENTER

Contributing to Safe and Stable Global Electric Power Supply and Distribution:

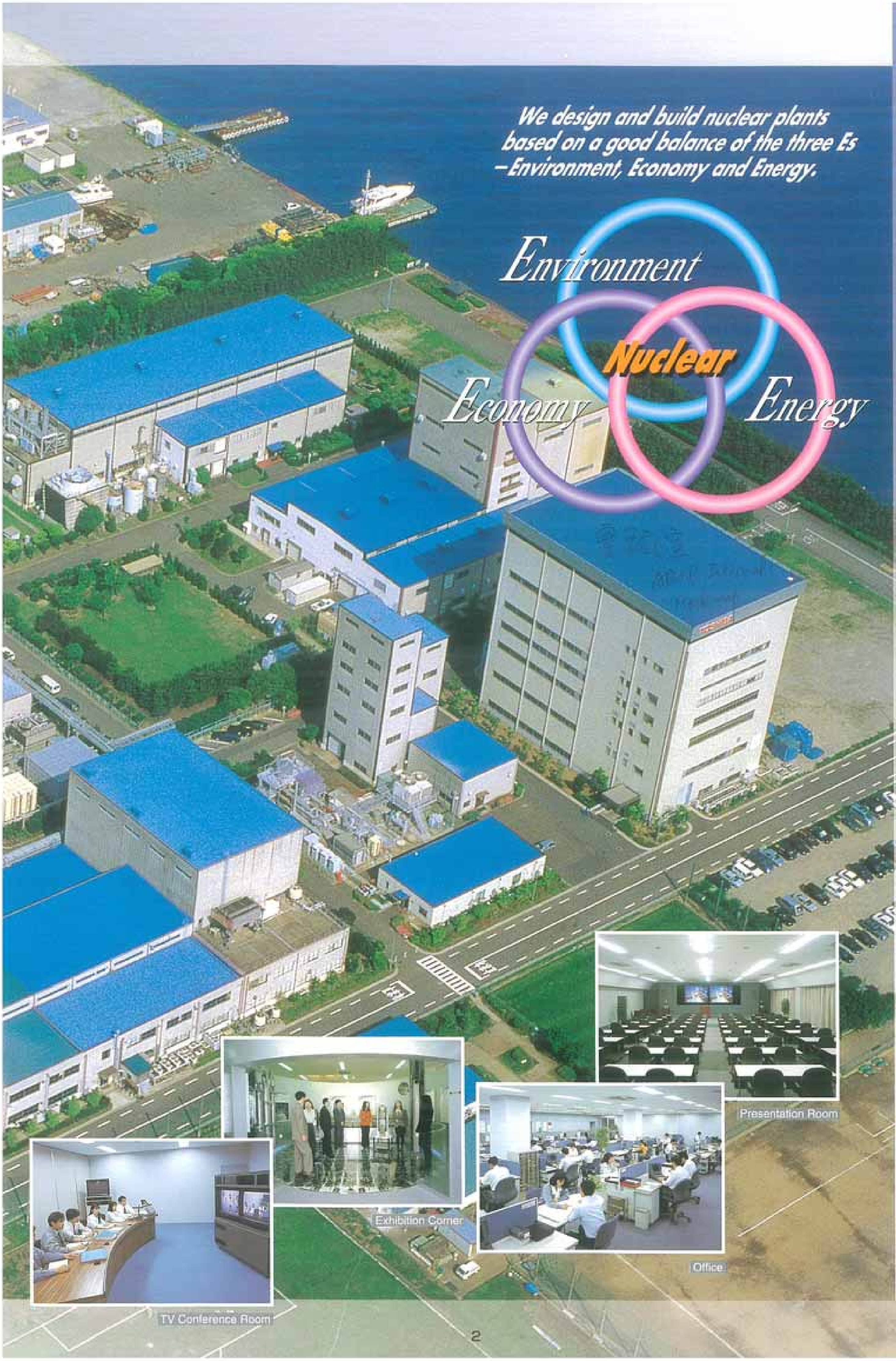
ISOGO NUCLEAR ENGINEERING CENTER

To balance the needs of economic development with environmental burden, society must consider a new mix of current and new energy sources centered around nuclear power. Based on its past successful technical developments and unique experience, Isogo Nuclear Engineering Center (IEC) can handle all facets of developing, planning, designing, constructing, testing, commissioning and maintaining turnkey nuclear power plants.



IEC Main Building Entrance

We design and build nuclear plants based on a good balance of the three Es –Environment, Economy and Energy.



Presentation Room

Exhibition Corner

Office

TV Conference Room

Tohoku Electric Power Co., Inc.
Higashidohri Nuclear Power Station

Tohoku Electric Power Co., Inc.
Onagawa Nuclear Power Station

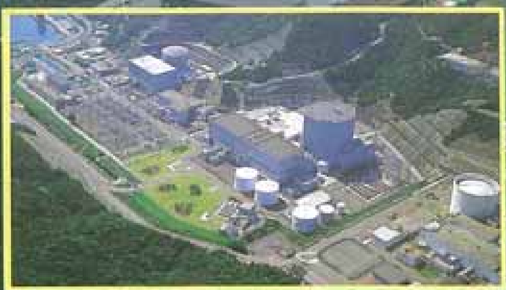
SCOPE O

Toshiba currently promotes
one of the most widely used
facilities and developing futu
(Our newly developed ABW
Techniques Grand Prix (the

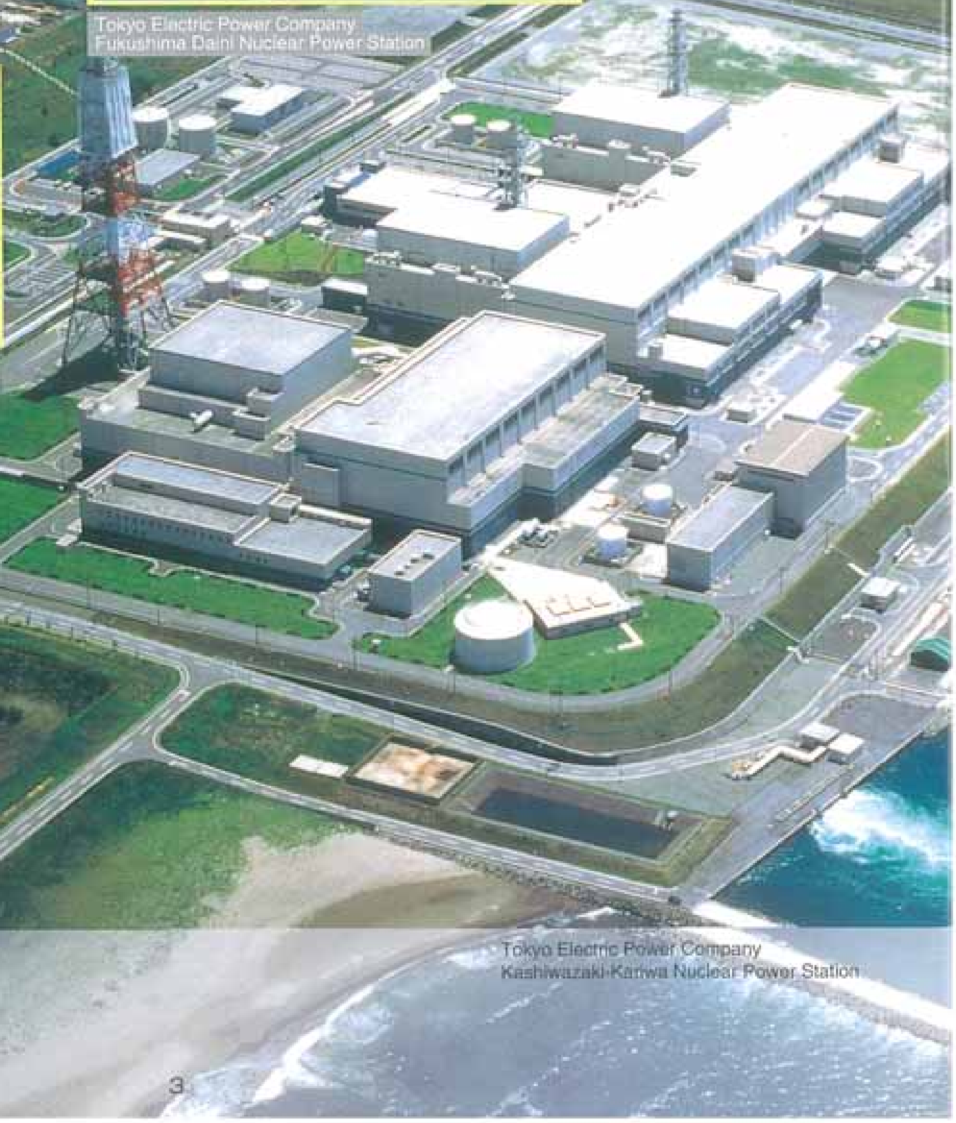
Tokyo Electric Power Company
Fukushima Daiichi Nuclear Power Station

Chubu Electric Power Co., Inc.
Hamaoka Nuclear Power Station

Tokyo Electric Power Company
Fukushima Daini Nuclear Power Station



Japan Atomic Power Co.
Tsuruga Power Station



Tokyo Electric Power Company
Kashiwazaki-Kariwa Nuclear Power Station

F IEC ENGINEERING WORK

&D, design, manufacturing, construction and services of Boiling Water Reactors (conventional BWRs and ABWRs),
actors in the world . Toshiba also devotes itself to commercializing Fast Breeder Reactor (FBR) and nuclear fuel cycle
reactors and their element technologies such as fusion reactor and accelerators technology.
was awarded the Japan Society of Mechanical Engineering Medal 1997 and the 28th Japan Industrial
999 Prime Minister's Prize))

NUCLEAR FUEL CYCLE FACILITIES

Reprocessing Plant (Rokkasho Mura)
(Photo: Courtesy of Japan Nuclear Fuel Limited)

Rokkasho Uranium Enrichment Plant
(Photo: Courtesy of Japan Nuclear Fuel Limited)

FAST BREEDER REACTOR

Prototype Fast Breeder "Monju"
(Photo: Courtesy of Japan Nuclear Cycle Development Institute)

Japan Integrated Fast Reactor

High Temperature Engineering Test Reactor

FUSION REACTOR AND ACCELERATORS

International Thermonuclear Experimental Reactor(ITER)
(Photo: Courtesy of Japan Atomic Energy Institute)

Super Photon Ring 8Gev (SPring-8)
(Photo: Courtesy of Japan Synchrotron Radiation Research Institute)

Economic and Well-Balanced Plant Engineering Using CAE

PLANNING /DESIGNING

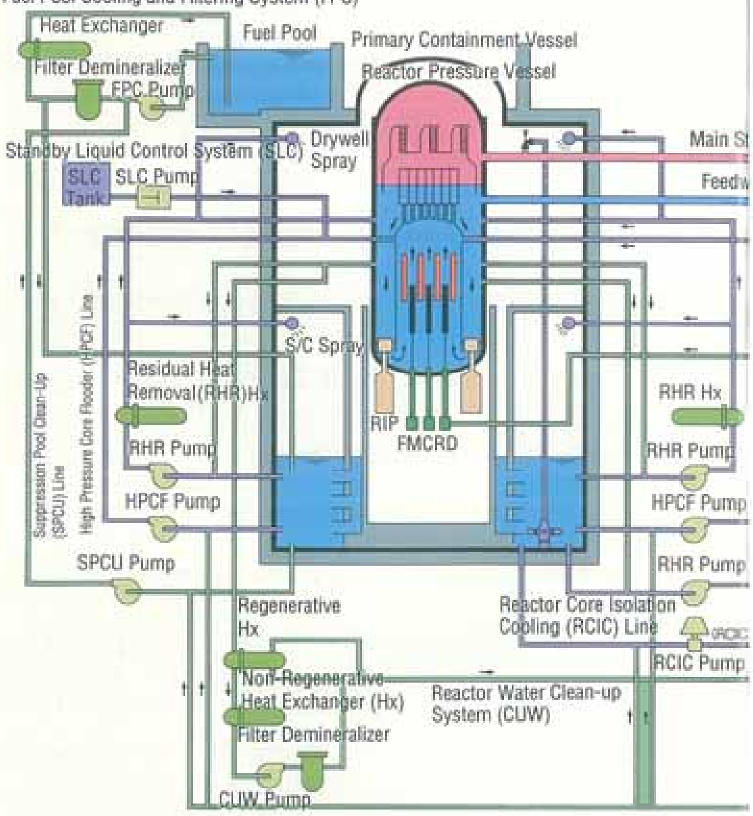
IEC handles total engineering of nuclear power plants by making full use of Computer Aided Engineering (CAE) for planning and basic design of the plant, design of components, integrated systems, control and electrical systems, buildings etc. and design analysis including aseismic evaluation.

PLANT CONCEPT DESIGN BASIC SYSTEM DESIGN

Advanced BWR

SYSTEM DESIGN OF BWR AND ABWR

ABWR System



NEXT GENERATION REACTOR

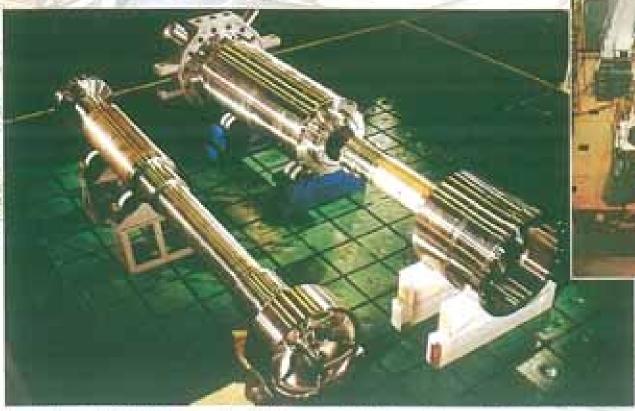
Next generation ABWR (AB1600)

Compact Containment BWR (CCR)

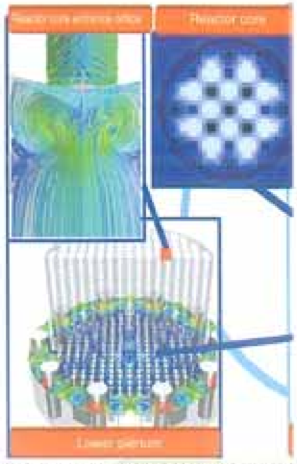
EQUIPMENT DESIGN

Reactor Pressure Vessel

Turbine & Generator



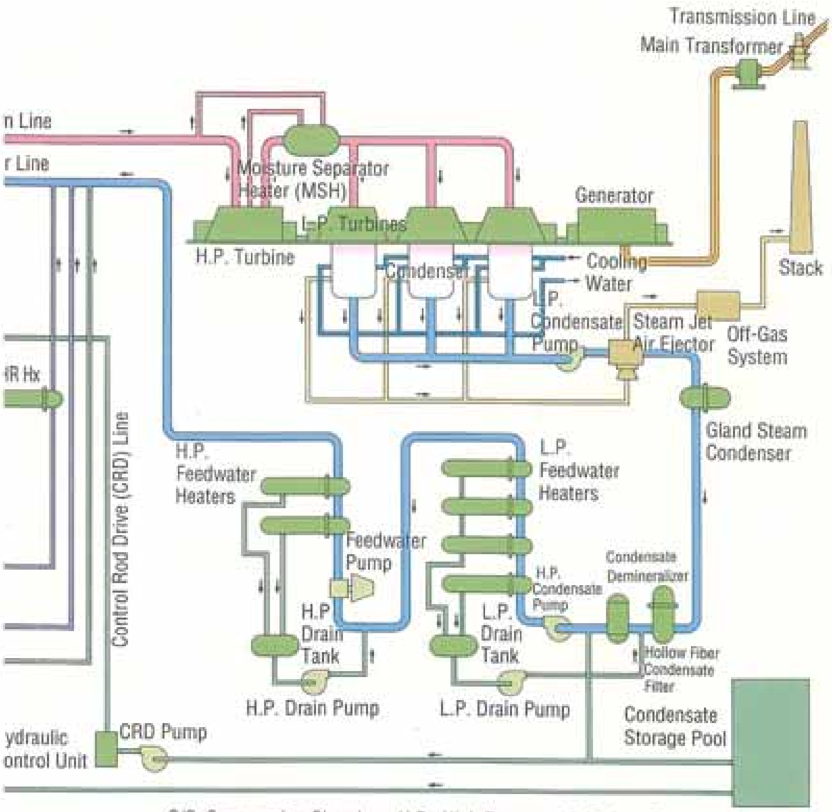
Impeller and Shaft Assembly / Diffuser and Motor of Reactor Internal Pump



Integrated Analysis Simulated for tl
(Associate Calculation by Coupl

3D Computer Aided Design (CAD) is used to design and layout easy-to-operate and user-friendly plants with due consideration for construction, operation and maintenance.

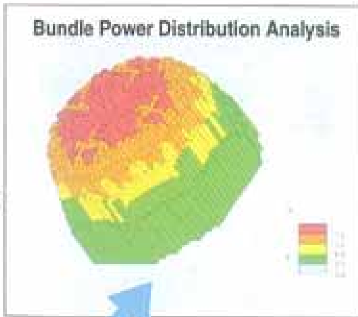
Arrangement Design of Primary Containment Vessel with 3D CAD



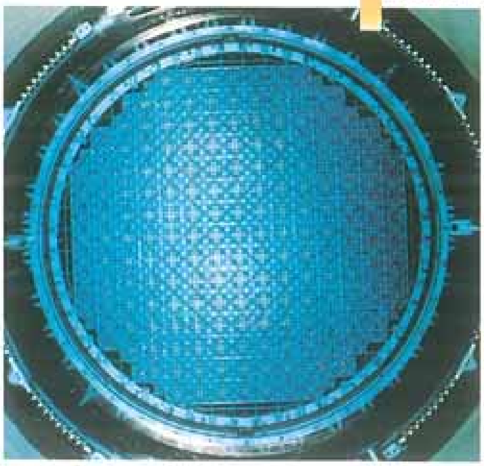
S/C: Suppression Chamber H.P.: High Pressure L.P.: Low Pressure

CONTAINMENT VESSEL DESIGN
GENERAL ARRANGEMENT
ASEISMIC DESIGN
ARCHITECTURAL DESIGN

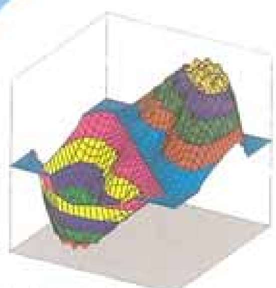
Landscape Simulation



CONTROL & DYNAMICS DESIGN
SHIELDING DESIGN
SAFETY DESIGN

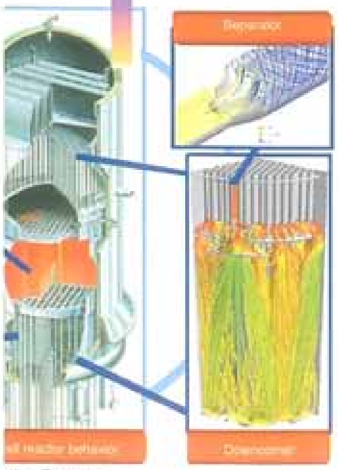


Reactor Core



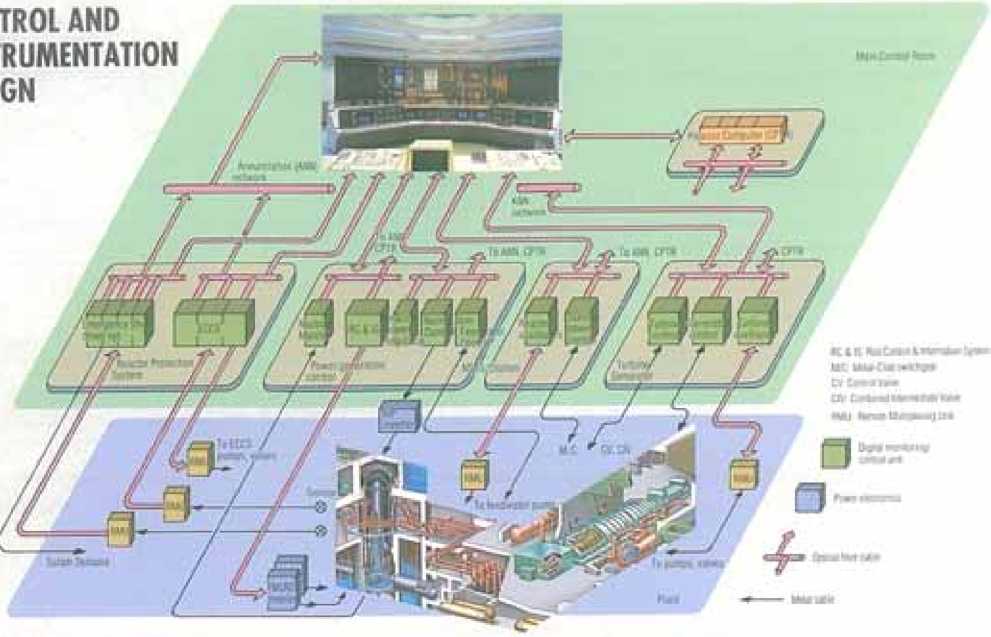
Stability Analysis
(Example of Regional Oscillation)

INTEGRATED ANALYSIS



ntire Reactor
dividual Component Models)

CONTROL AND INSTRUMENTATION DESIGN



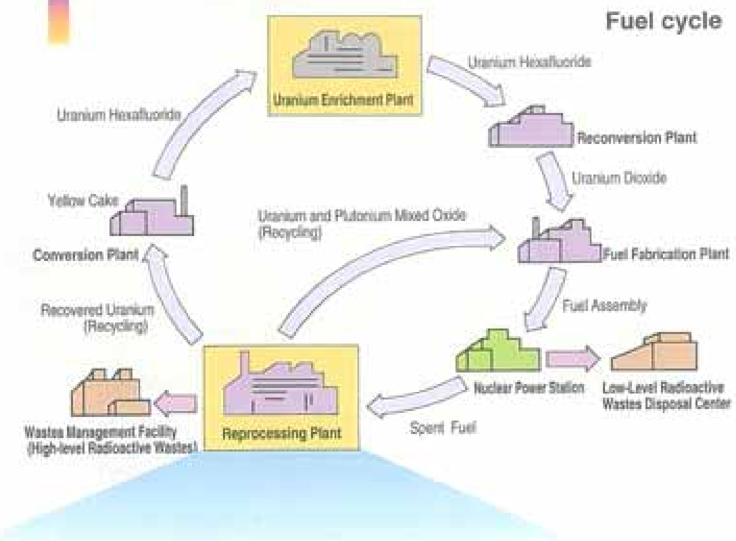
DESIGN AND ENGINEERING OF RADIOACTIVE WASTE TREATMENT SYSTEM

Advanced Cement Solidification System

Hollow Fiber Filter

Centrifugal Clarifier

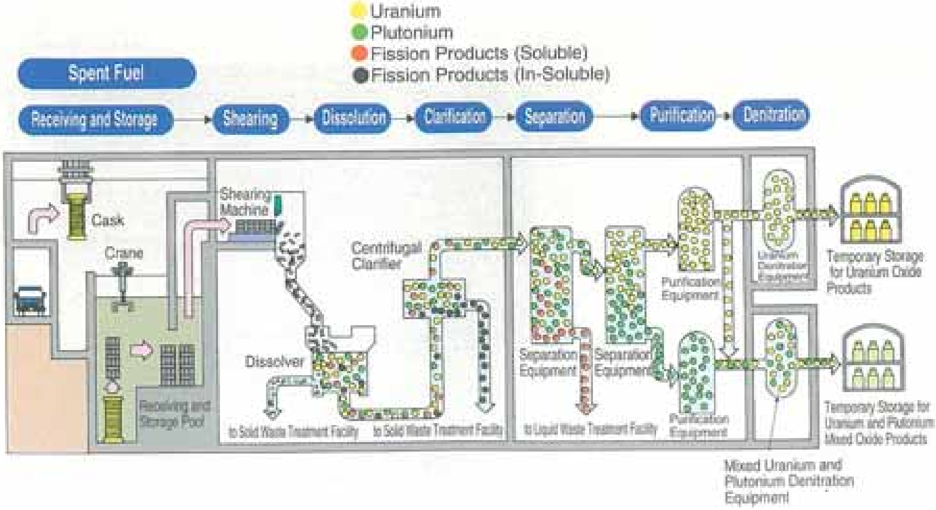
PLANNING, DESIGNING AND CONSTRUCTING NUCLEAR FUEL CYCLE FACILITIES



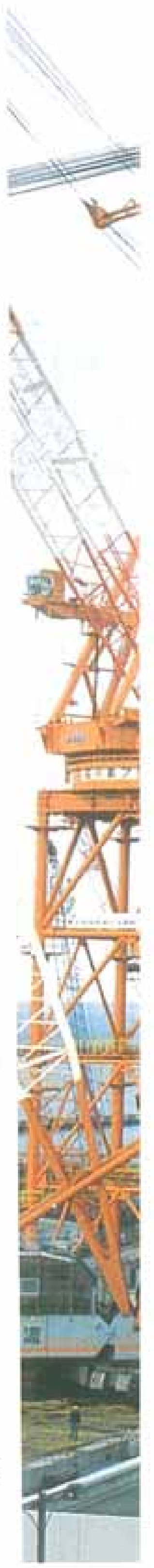
NEXT GENERATION FUEL REPROCESSING

Molten Salt Electrolysis Machine

Recovered Metallic Uranium



Reprocessing Plant Processes



Building Highly Reliable Plant within Reasonable Construction Period

CONSTRUCTION & PRE-OPERATION TEST

IEC provides total plant construction management services. Prior to construction, a schedule is drawn up and detailed plans are established to define construction, transportation, equipment carry-in, planning of temporary equipment, establishment of site organization, etc.

IEC also manages various activities after the construction start, including management overall plant construction, adjustment of schedule, control of safety, health, and radiation exposure, quality assurance of equipment and construction, management of pre-operational test , management of site office, etc.

PLANNING & MANAGEMENT OF CONSTRUCTION WORK

REBAR OF FOUNDATION MAT

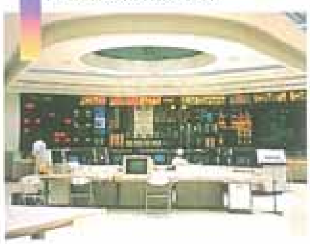
ASSEMBLY, TRANSPORTATION, INSTALLATION

LIFTING REACTOR PRESSURE VESSEL

ASSEMBLING TURBINE

TESTING

PRE-OPERATIONAL TEST



IMPROVED MAINTENANCE ENGINEERING

IEC focuses
IEC puts stre
radiation exp

OPERATION SUPPORT & EFFECTIVE USE OF OPERATION AND MAINTENANCE DATA

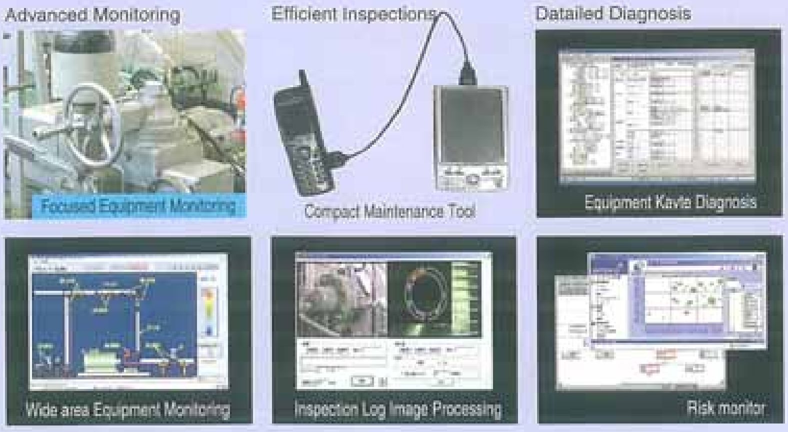
★We improve operation support and use of maintenance data by integrating plant operating data to respond quickly and with full background knowledge to anyabnormalities. We:

- Provide better technical support services
- Develop more reliable plant monitoring and diagnostic systems
- Develop and use new equipment and area diagnostic devices
- Develop more effective and efficient maintenance information systems

ASSURING SAFE
IMPROVED CA

Condition Monitoring

Advanced Monitoring | Efficient Inspections | Datailed Diagnosis

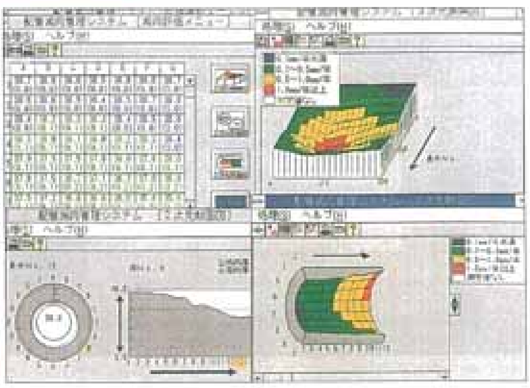


MAINTENANCE PLANNING

★To ensure safe operation, we implement assured maintenance based on the following:

- Implementing trouble-prevention activities
- Taking measures against aging to extend plant life
- Responding appropriately to ongoing and future restrictions
- Establishing medium- and long-term maintenance plans
- Proposing improvement and refurbishing plans

Further Improvement of Main Control Room Function



Piping Thickness Management System

ɔreventive plant maintenance to guarantee safe stable operation and to improve the capacity factor.
us effort into operation support and use of operation/maintenance data, annual inspection support and
re reduction, development of maintenance technology, and plant maintenance planning.

'ERATION AND ɩCITY FACTOR

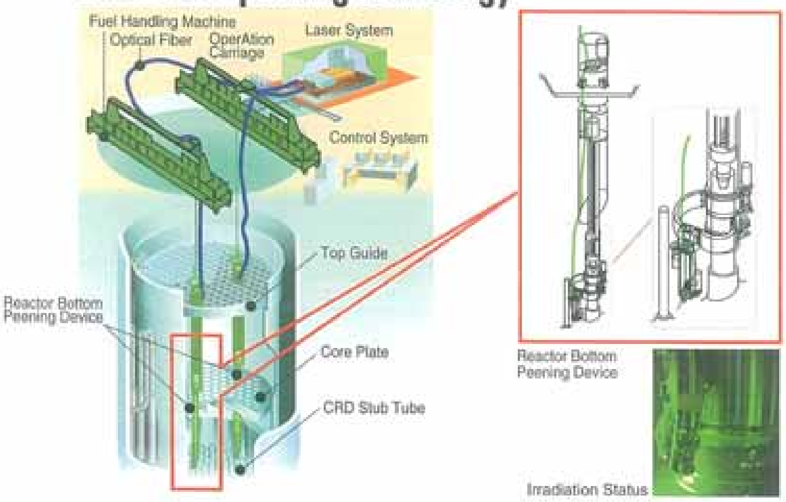

Core Shroud Replacement

DEVELOPING IMPROVED MAINTENANCE TECHNOLOGY

★We are reviewing and improving our maintenance technology to retrofit plant and facilities through:

- **Development of repair and inspection technology**
- **Development and demonstration of equipment by using plant refurbishment technological development facilities**

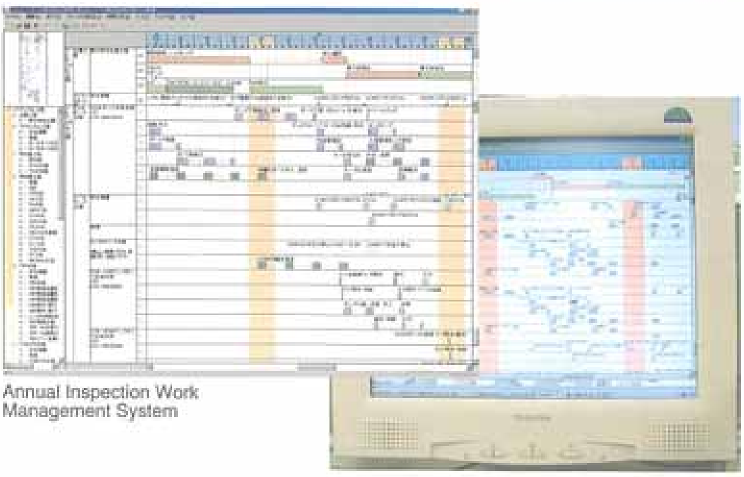
Fiber laser peening technology



SUPPORT FOR ANNUAL OUTAGE AND REDUCED RADIATION EXPOSURE

★To shorten the annual inspection outage, we endeavor to assure better periodic inspection work by:

- **Reducing refueling outage**
- **Making annual inspection more efficient**
- **Developing better annual inspection management system**
- **Reducing radiation exposure at annual inspection**


Annual Inspection Work Management System

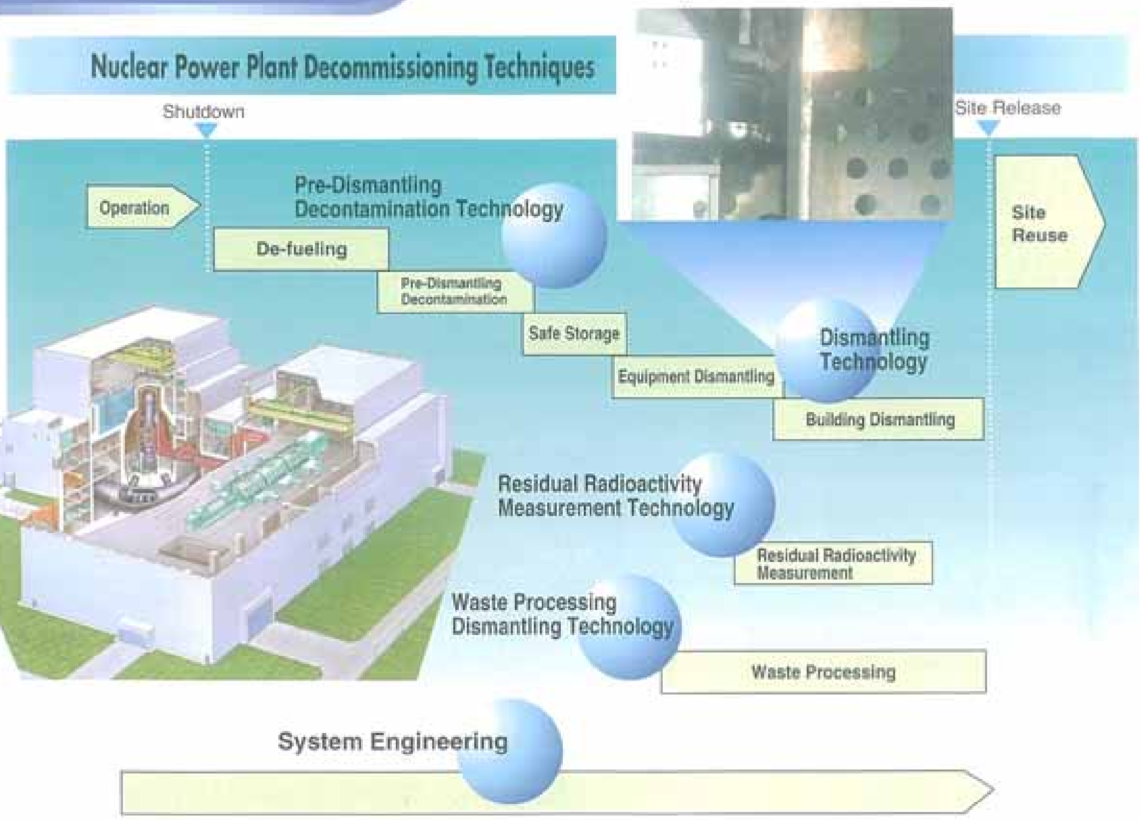

Underwater Dryer/separator Handling Device

For Nuclear Power Plant (NPP) which finished its role

DECOMMISSIONING TECHNOLOGY

Japan's first commercial nuclear power plant (NPP) started operation in 1966. However, when a nuclear power plant reaches the end of its design life, it must be decommioned and demolished as quickly as possible.
Our rich knowledge of maintenance technology obtained over many years of hands-on experience has enabled us to develop advanced technologies for decommissioning nuclear plants as cost-effectively as possible.

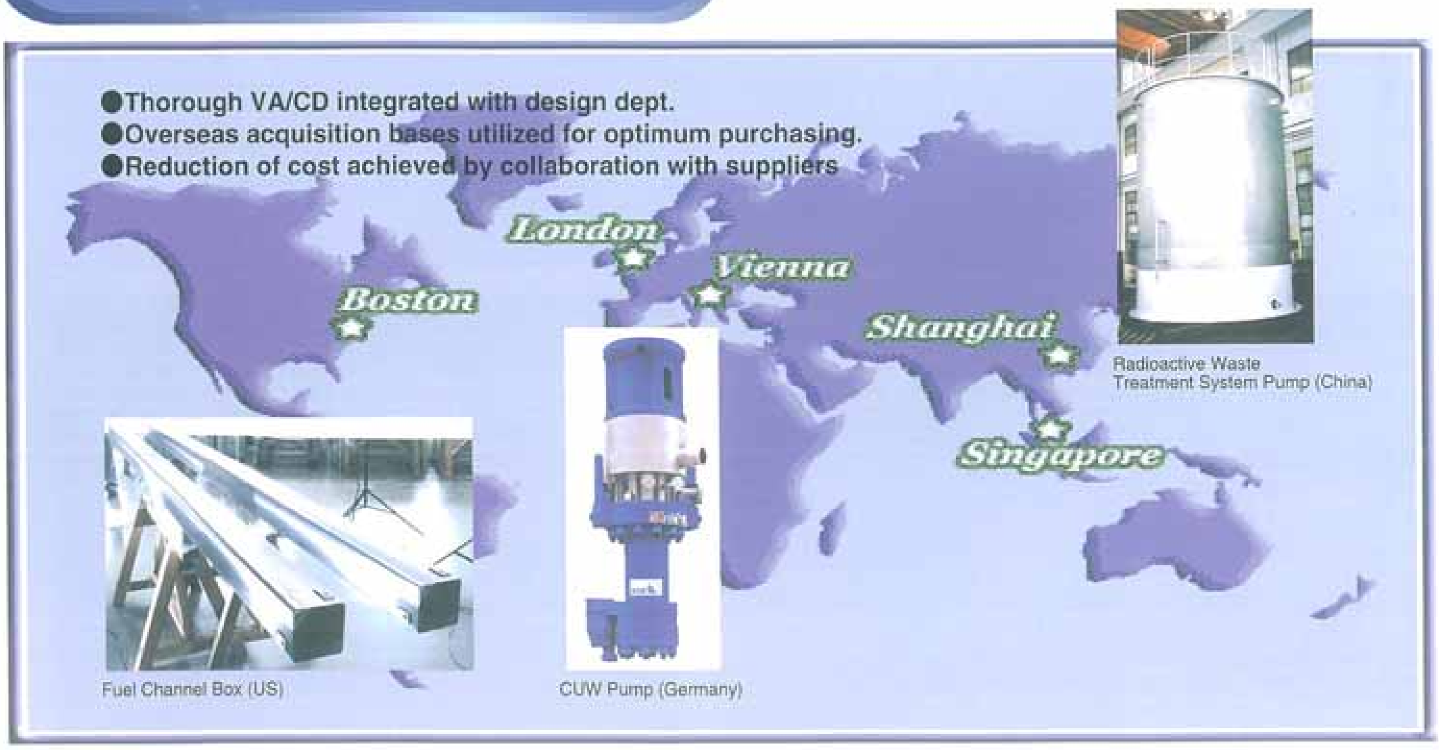
Underwater laser cutting
Offers of the most suitable cutting technology by the abundant results such as maintenance technology.



Purchasing World's Best Equipment

PROCUREMENT ACTIVITIES

- Thorough VA/CD integrated with design dept.
- Overseas acquisition bases utilized for optimum purchasing.
- Reduction of cost achieved by collaboration with suppliers



Radioactive Waste Treatment System Pump (China)

Fuel Channel Box (US)

CUW Pump (Germany)

GOAL FOR IEC

Targeting World Market with

ASSURED QUALITY

Aiming to establish Global Quality Assurance System for Nuclear Plants

ISO9001 Certificate

In February 1997, Toshiba's Nuclear Energy Systems & Services Division obtained the ISO9001 Quality Management System Standards certificate.
Toshiba is the first company awarded this recognition through head office, Isogo Nuclear Engineering Center Shop and Site in the nuclear industry in Japan.

The Quality Management System is applicable to:

Engineering, design, manufacturing, repair / refurbishment, commissioning, maintenance and management of installation of nuclear power plants, nuclear fuel cycle facilities and equipment, nuclear reactor components and equipment with their auxiliaries, nuclear fusion equipment, super conducting magnets and accelerators, nuclear power plant control and computer systems and nuclear instrumentation systems including the internal procurement of application software.

ASME Certificate

Certificate that we comply with the requirements of the American Society of Mechanical Engineers (ASME), for oversea's nuclear business was obtained in Mar. 2001.
We are the first engineering organization to obtain ASME certification in Japan. We globally offer high quality design, products, construction/maintenance through quality assurance activities in compliance with the laws and agreements of the various countries of the world.

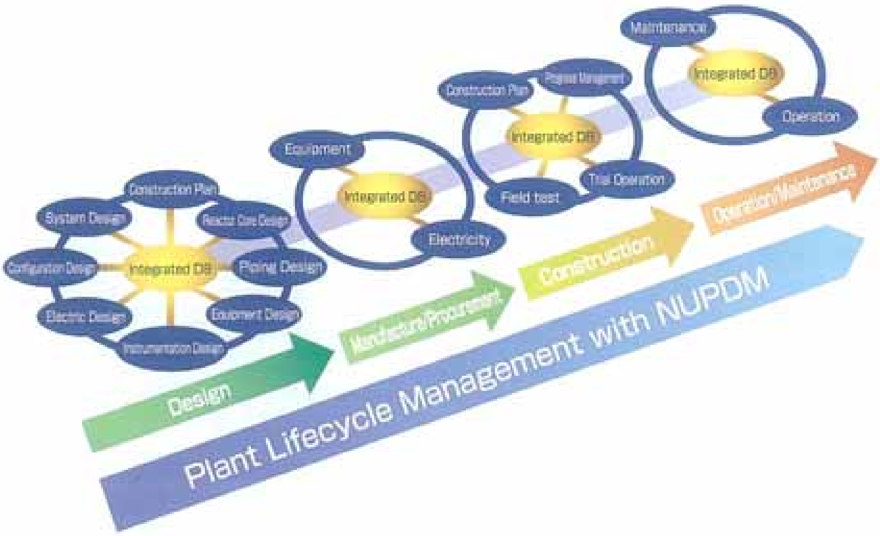
Scope of certification:

Construction of section III, division 1 components for which overall responsibility is retained and for which fabrication and installation are subcontracted to appropriate of authorization holders and as a material organization supplying ferrous & nonferrous material at the above location only.

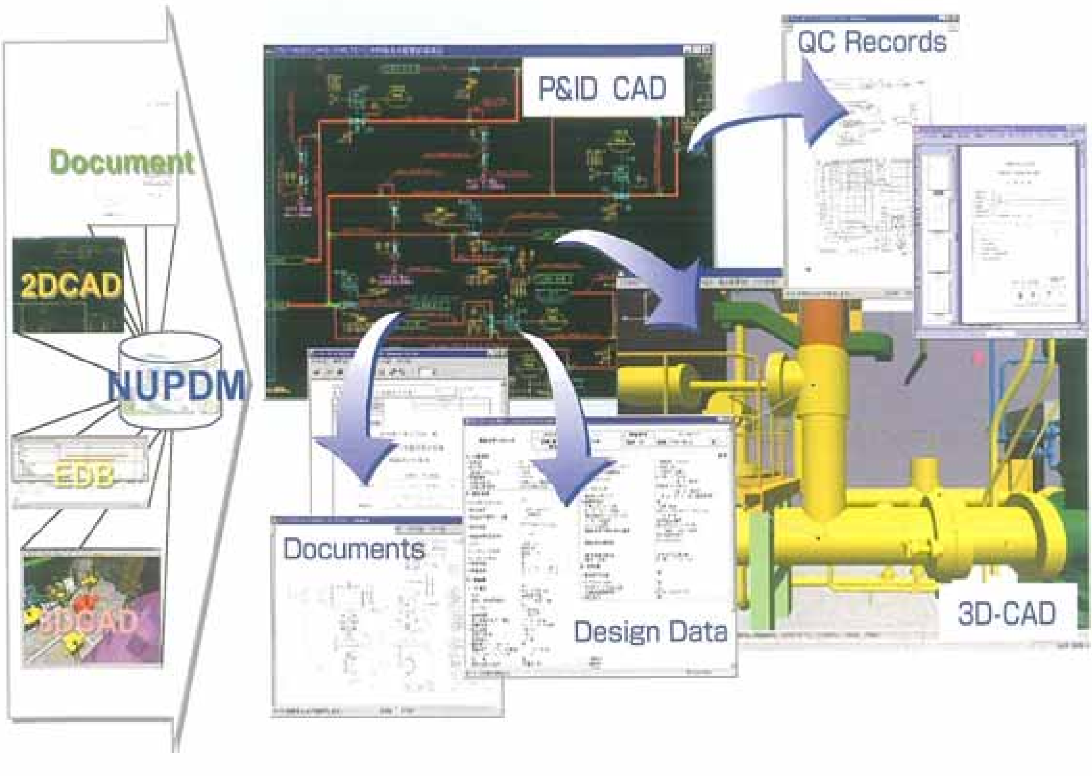
INTEGRATED INFORMATION CONTROL WITH NUPDM ACHIEVING BEST

For sustained improvement of quality over the plant life cycle

Enormous amounts of technical information are produced throughout the "plant life cycle", i.e. design, manufacture, procurement, construction, operation and maintenance in nuclear power engineering.
At Toshiba, we developed NUPDM (Nuclear Plant Data Management System) as a platform for the unified management of this technical information, and perform high quality, high-reliability engineering with IEC.



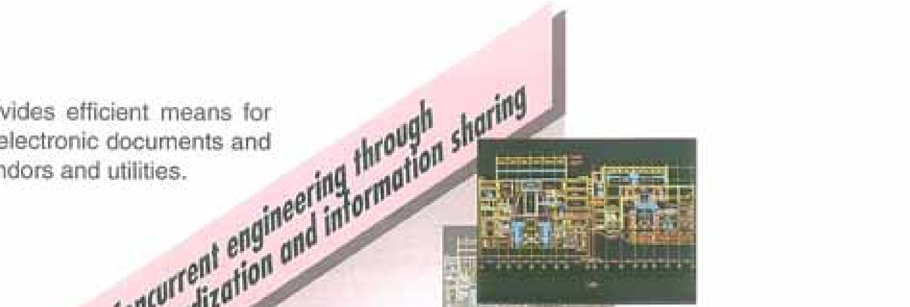
Sharing design information through integrated database

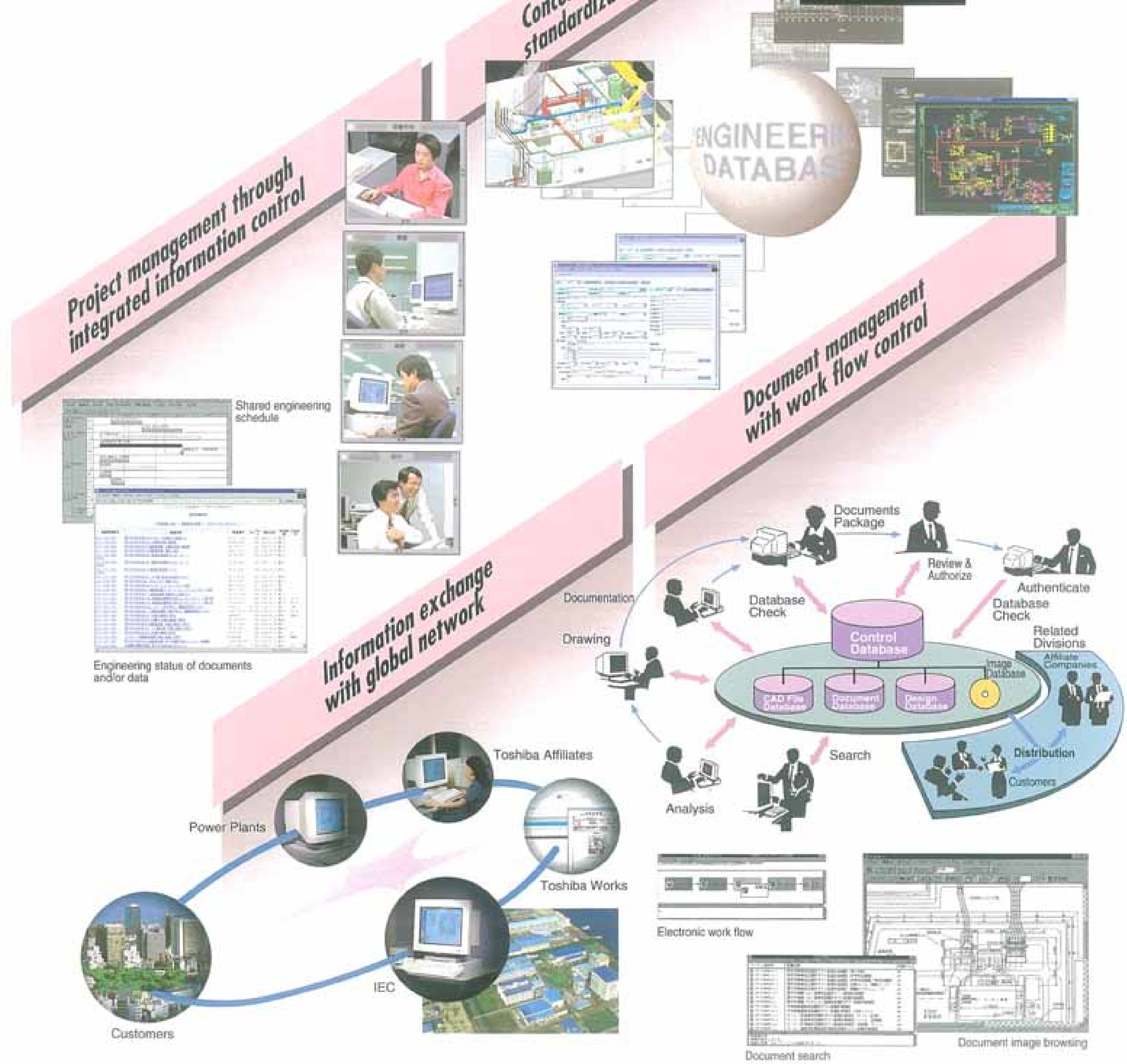


CLEAR POWER PLANT LIFECYCLE SUPPORT

NUPDM is an integrated electronic platform to control and manage engineering schedules, documents and drawings as well as databases, to support responsive and reliable information exchange, and to reduce data administration tasks.

NUPDM provides efficient means for exchanging electronic documents and data with vendors and utilities.

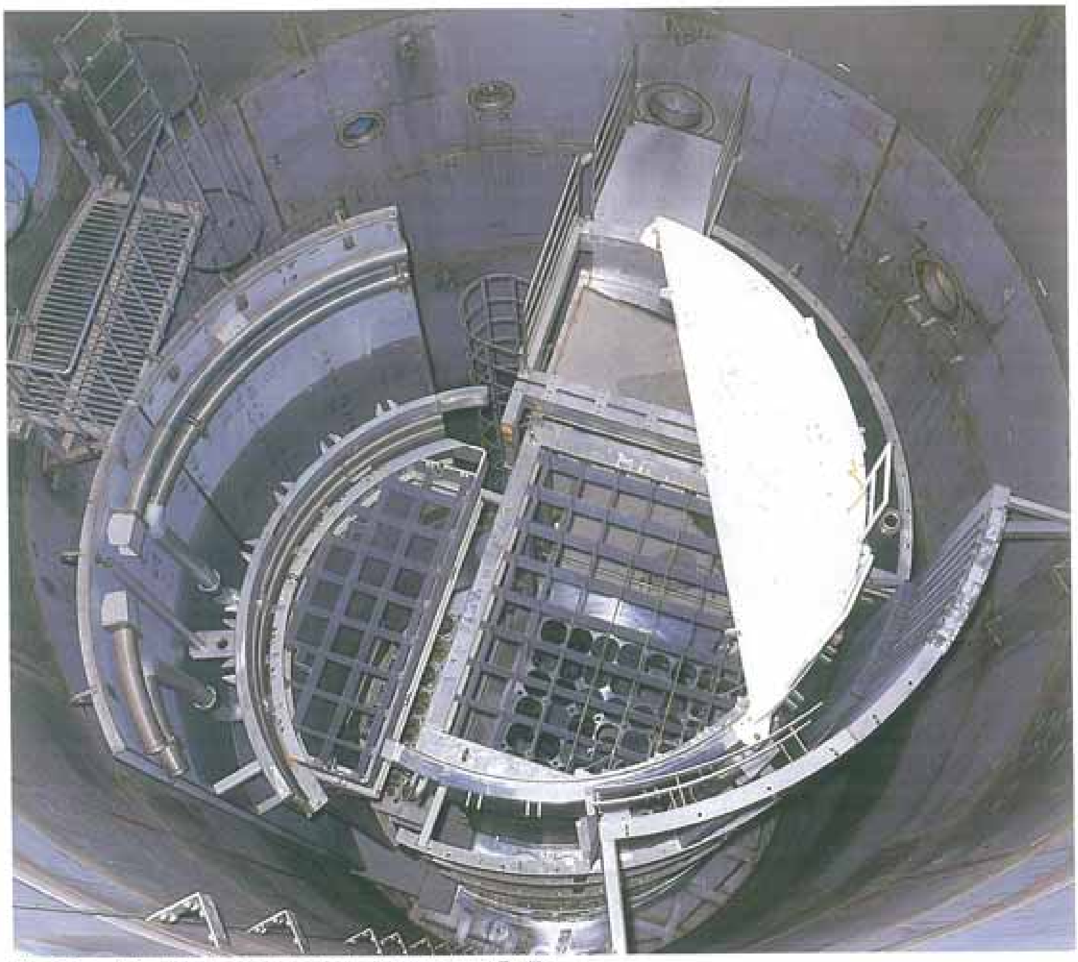




R&Ds Accurately Responding to Needs and Their Applications

INTEGRATION OF DESIGN WORK AND R&D

The large-scale R&D facilities of the Nuclear Engineering Laboratory are located next to IEC to closely link R&D and design engineering.The advanced control rod drive mechanism of BWRs is under further improvement and advanced maintenance technology such as laser peening is also under development using full-scale mockup facilities. R&D and design also integrate various uses of robotics, diagnostics and laser technology in advanced maintenance systems.



Plant Preventative Maintenance Technology Development Facility

Laser Peening
(Reactor Bottom Peening Device)

Underwater inspection robot (for inspecting inside reactor vessel narrow spaces)

Small Vehicle

Flat Vehicle

Laser Peening Test Overview

Yokohama Area

SCC Growth Rate Evaluation Equipment

Reactor Flow Test Facility

Innovative Safety Systems Research Facility

Thermal-Hydraulic Transient Test Facility

High Temperature Flow Test Facility

*Shot peening: preventive maintenance based on stress improvement of reactor internal structures

IEC PUBLIC ACCEPTANCE ACTIVITIES

To achieve better acceptance of nuclear energy by the public, a scale model of a nuclear power plant, a full-scale model of reactor internals, an engineering model of a containment vessel, etc., are on display in the Exhibition Corner. IEC also arranges tours that include a demonstration of nuclear power plant layout using 3D CAD, and a visit to the large-scale R&D facility and mock-up pressure vessel.

Full-Scale Nuclear Reactor Internal Equipment

Mock-up of ABWR Reactor & Containment

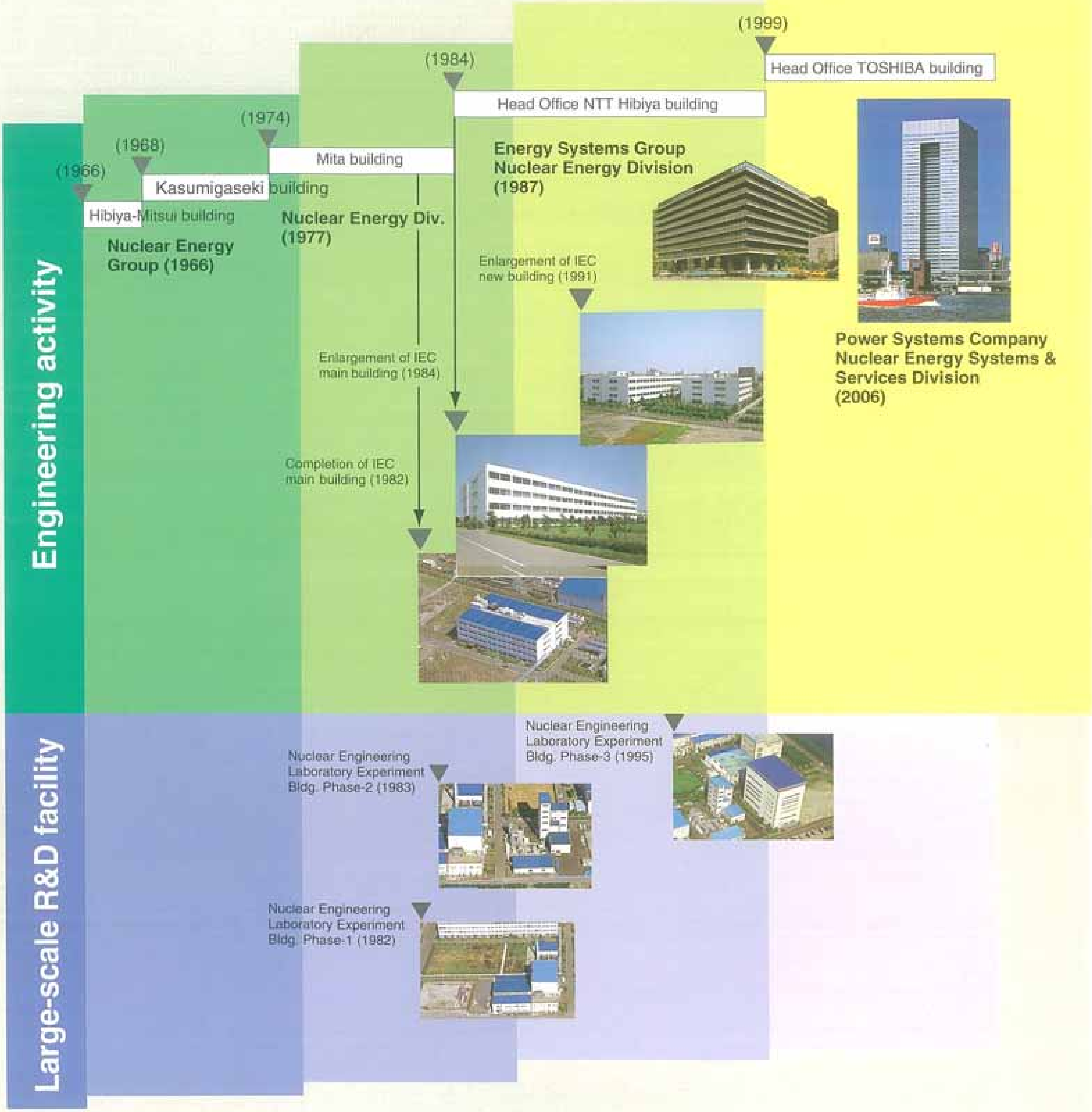
Internal Pump Disassembled Parts

Facility for Developing Plant Preventative Maintenance Technologies and Full-scale Mock-up of Reactor Pressure Vessel

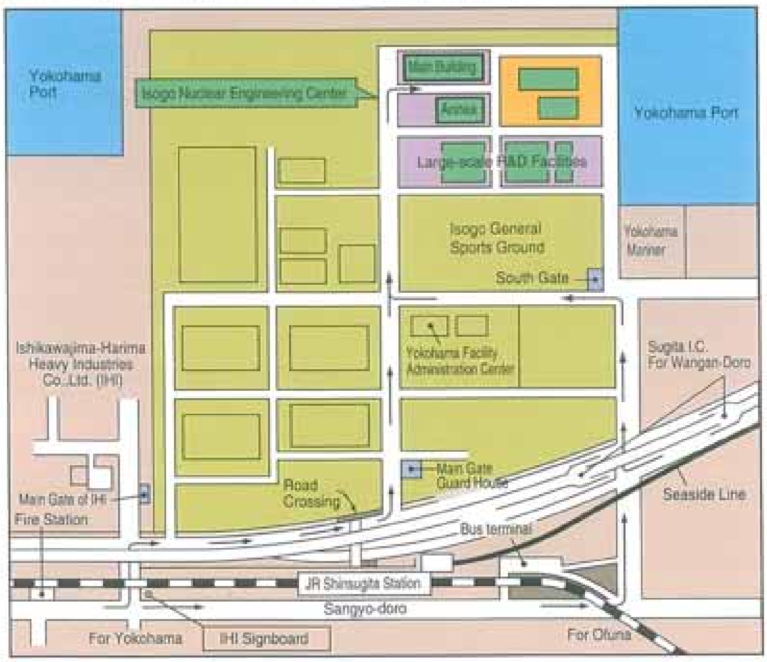
Lecture of Radiation using Radiation Measurement Kit

History of Nuclear Energy Systems & Services Division

Toshiba Nuclear Energy Systems & Services Division is well organized to provide consistent services based on its considerable experience, ranging from planning, designing, constructing, and maintaining nuclear plants to manufacturing equipment, training operators and R&D.
IEC is making steady progress toward commercialization of Fast Breeder Reactor and the nuclear fuel cycle facilities.



Guide to Isogo Nuclear Engineering Center



TOSHIBA

TOSHIBA CORPORATION

POWER SYSTEMS COMPANY
NUCLEAR ENERGY SYSTEMS & SERVICES DIVISION
1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105-8001, JAPAN
PHONE: +81(3)3457-3717 FAX: +81(3)5444-9191

Isogo Nuclear Engineering Center
8, Shinsugita-cho, Isogo-ku, Yokohama 235-8523, Japan
PHONE: (045)770-2092 FACSIMILE: (045)770-2396

2112-3 '06-4A/A-1

附錄 **E**

遙控水底攝影機（ROV）
原理與功能

Contents of Presentation

- Problem and Solution
- ROV for Sophisticated Inspection
- Compact ROV
- Flat type ROV
- Clawer ROV
- Conclusion

Problem and Solution

Problem

Visual inspection operated by underwater technicians･･･

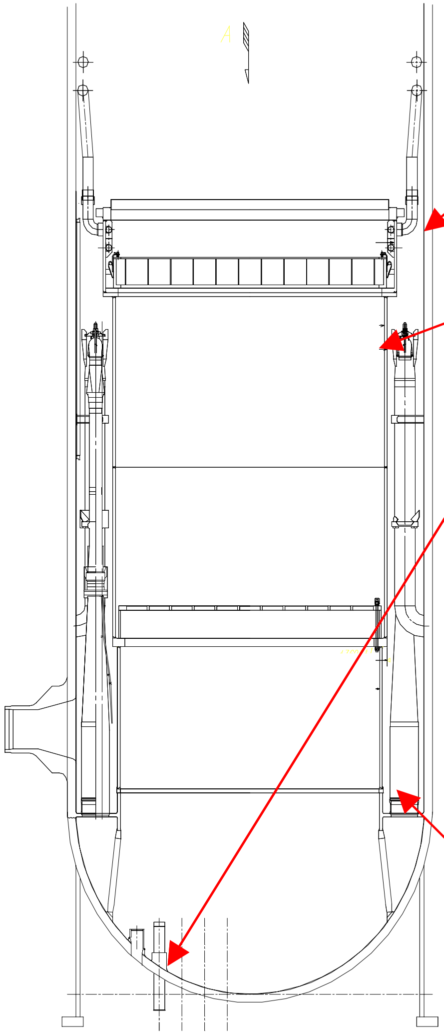
- Could not inspect surface below overhang by simple drop camera
- Will need more time to disassemble components (for example Control Rod Guide Tube:CRGT etc.)
- Might waste time and tools(CCD cameras, Lights etc.), if underwater technician's technique is poor

Solution

Proposes to introduce ROV for Internals Inspection･･･

- Will inspect larger area more speedily
- Will decrease inspection process by a few disassembled components
- Will apply for detail inspection(UT, etc.)

ROV for Sophisticated Inspection



RPV

Shroud

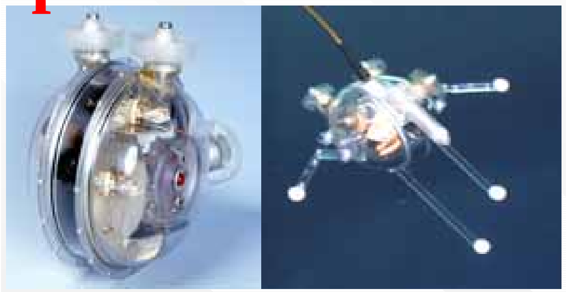
CRD housing

Shroud Support

BWR Reactor Internals

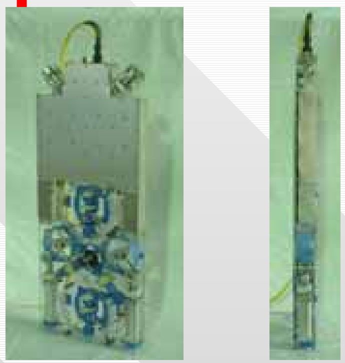
Compact ROV

VT



Flat type ROV

VT,
UT,
etc.



Crawler ROV

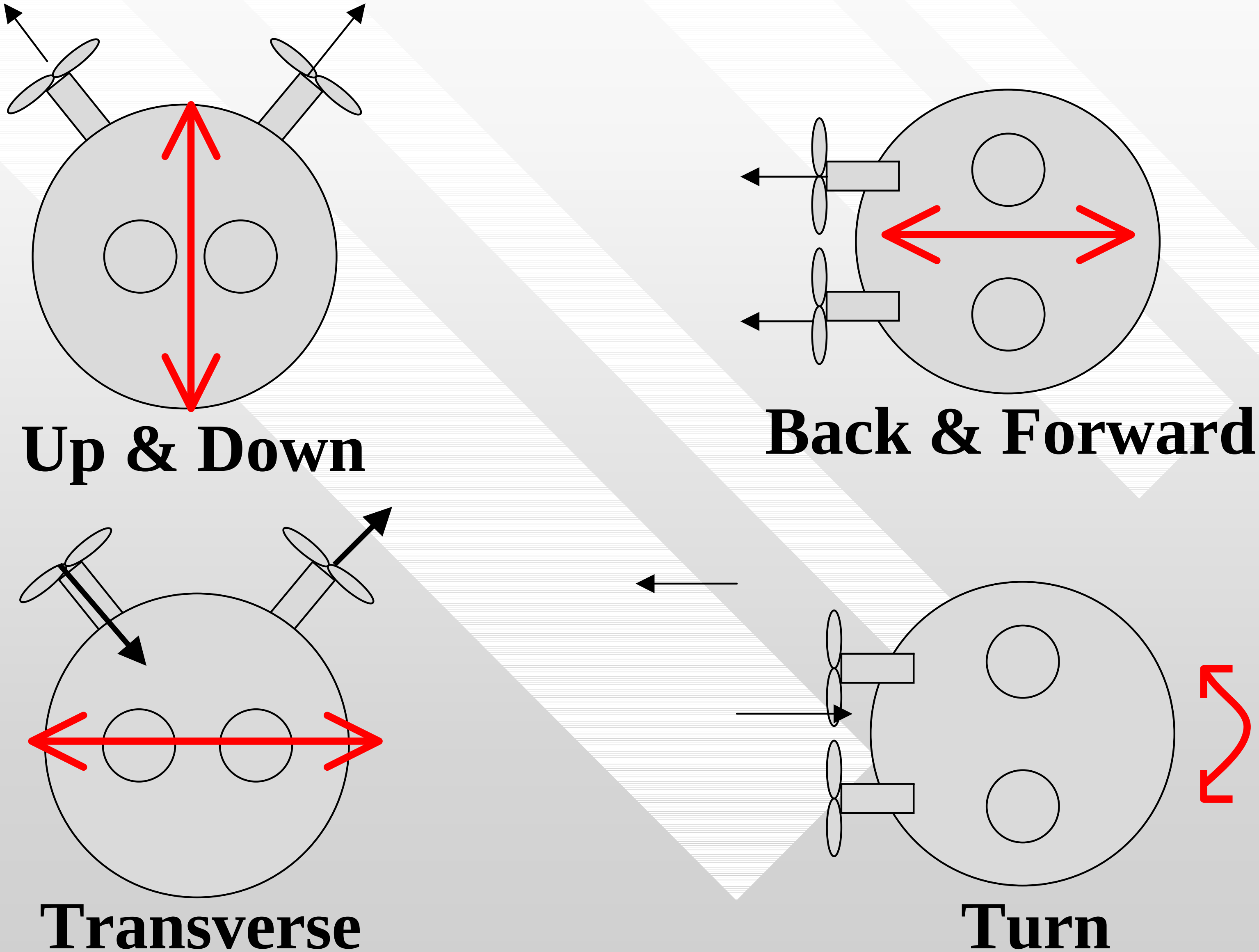
Vacuum Cleaning
VT

Compact ROV

Design Concept

- ◆**Large Inspection Area**
  - ➢**Compact & Round Shape**
- ◆**Motion**
  - ➢**Up & Down,**
    Forward & Backward,
    Turn, Transverse
  - ➢**Neutral Buoyant Cable**
- ◆**Applicability**
  - ➢**Several Option Tools**

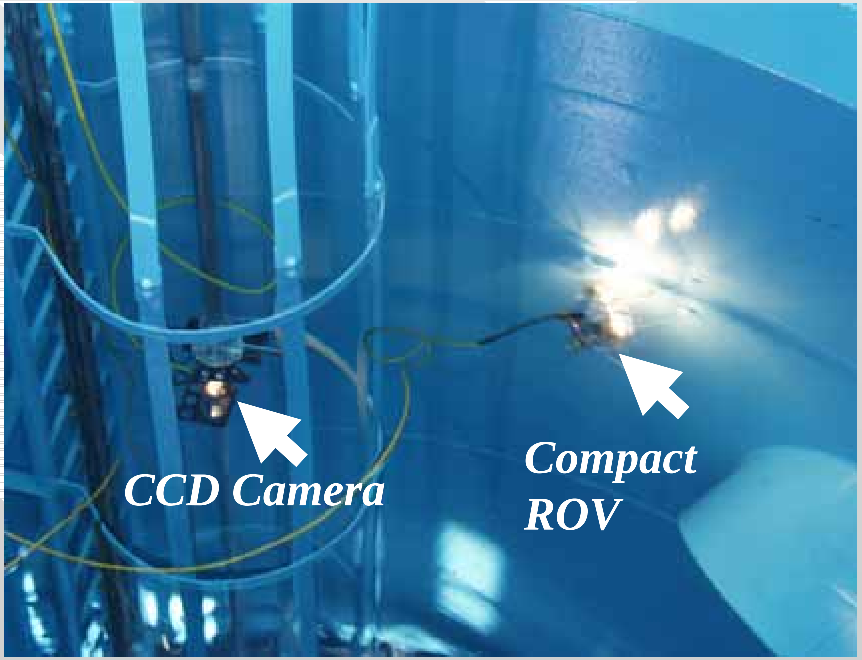
Maneuverable



Compact ROV

Specification

- Dimension : W 120 x L185 x H185
- Motion : up,down,back, forward,
  turn left & right, Transverse
- Camera: 380,000 pixel color CCD
  on tilt mechanism
- Lights : 20W x 6
- Mass : 1.5kg
- Speed : 0.15m/sec Max.
- Water Depth : <30m
- Temperature: <52℃



Compact ROV

Evolution

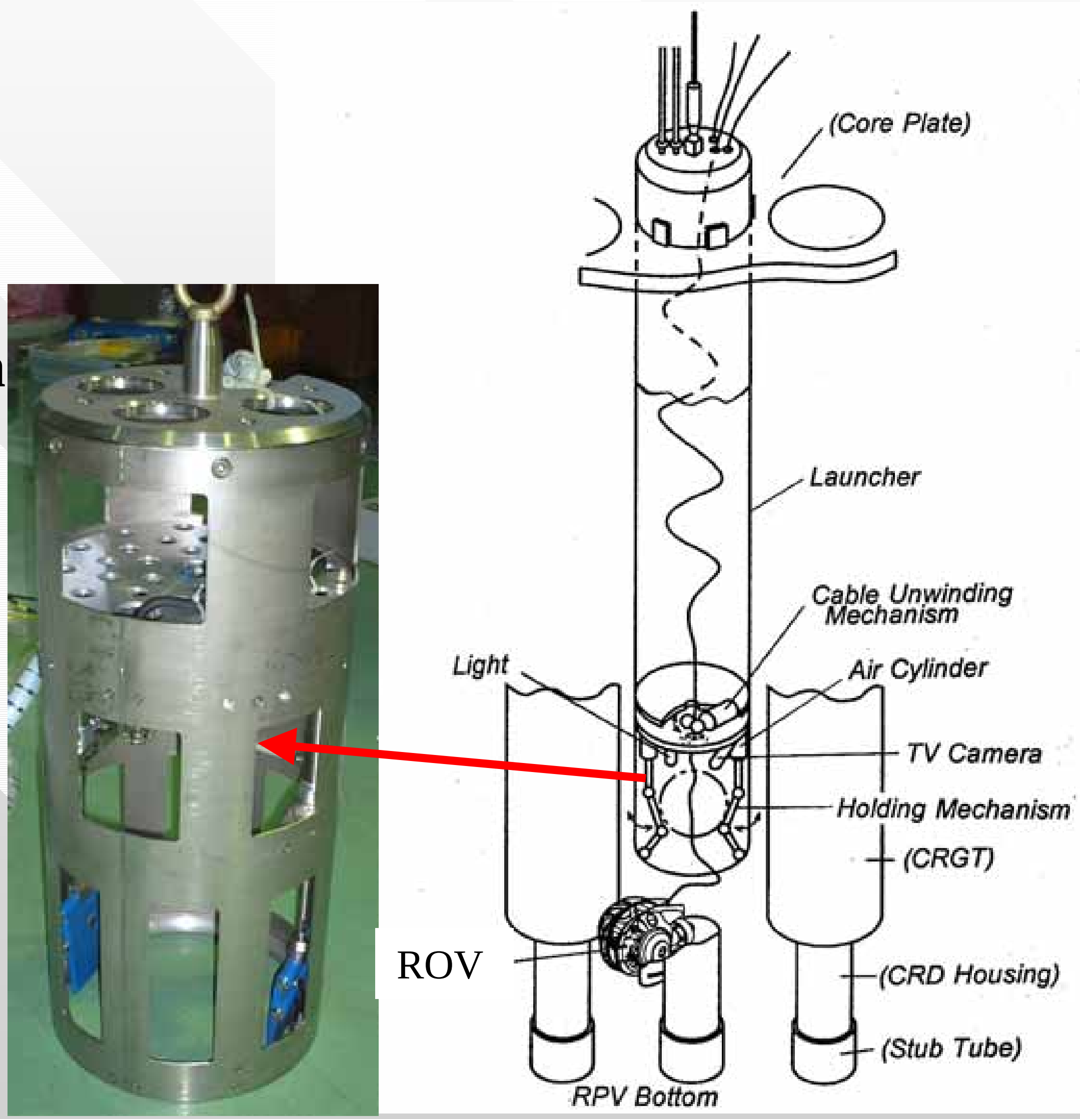
Items	Initial type	Latest type
Appearance		  A)For Internals B)For Tank Inner Wall
Dimensions [mm]	W150×L220 ×H170	**W120**×L185×H185・・・A)
Move	Up and Down, Back and Forward, Turn,	Up and Down, Back and Forward, Turn, **Transverse**
Picture	Unstable picture	**Stable picture** ・・・B)

Compact ROV
Access Support Device(Option Tool)

Specification

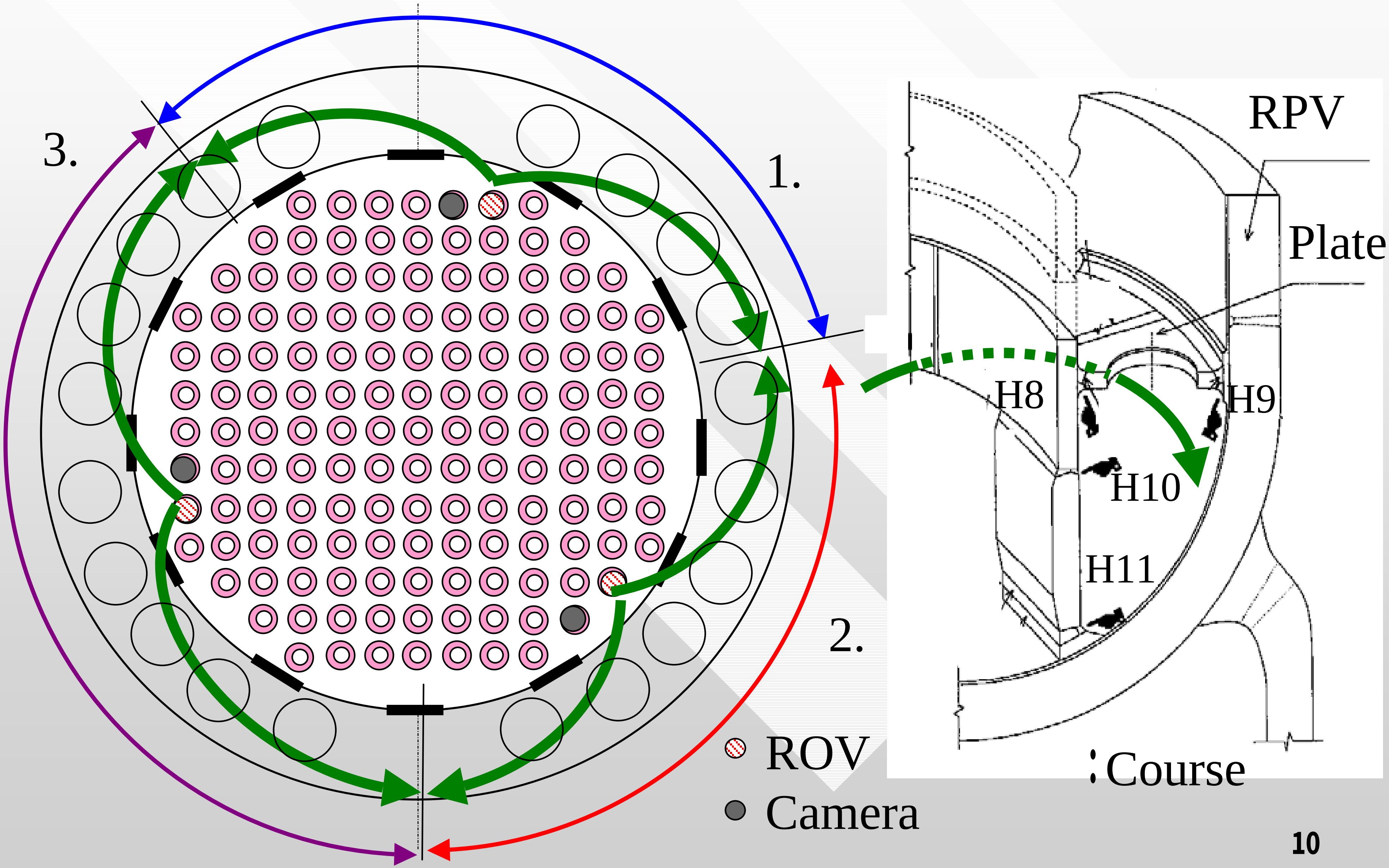
- Dimensions : ϕ270 x H4,600mm
- CCD Camera x 2,Light x 1
- Cable Support Mechanism
- ROV Hold Mechanism

<u>Guides ROV to RPV Bottom smoothly</u>



Compact ROV

How to Access under Shroud Support Plate



Compact ROV

Field Experience

- Effectiveness

Inspection Area	Drop Camera		Compact ROV	
	time *	Coverage	time *	Coverage
Shroud H9 weld line	impossible		3 hours 6 CRGT**	**100%**
CRD Housing :for 26 sets	4hours 4 CRGT**	39% Average	2 hours 2 CRGT**	40% Average

*:not include time for disassemble and assemble of CRGT

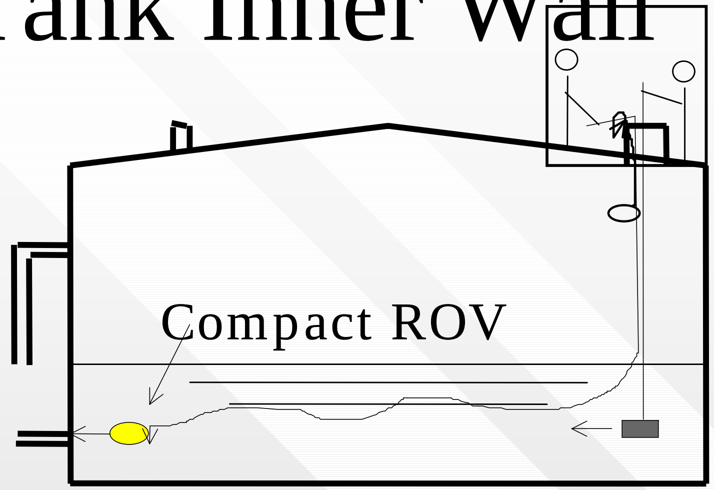
**:shows the number of disassembled CRGT

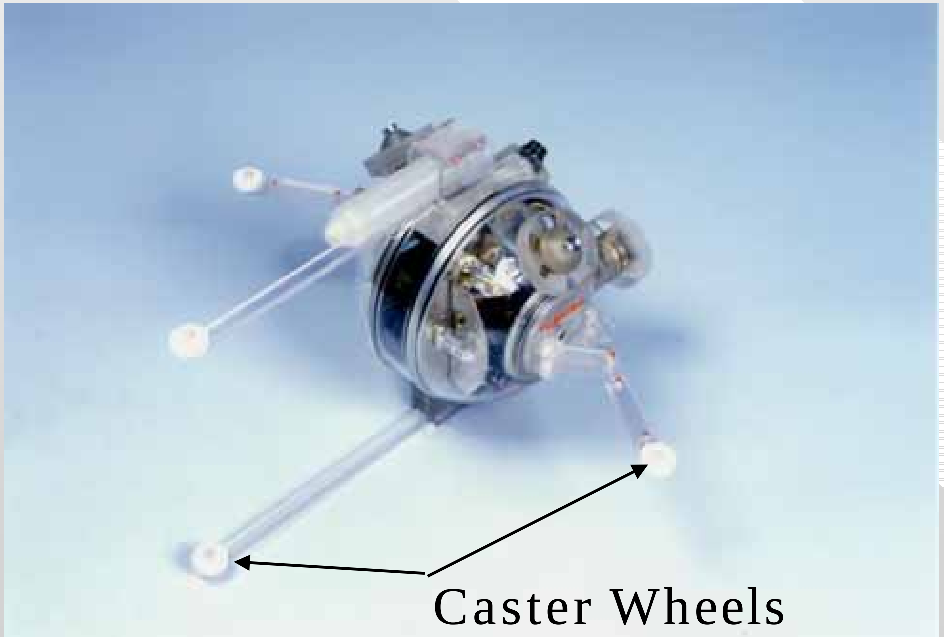
Compact ROV

Visual Inspection on Tank Inner Wall

Effectiveness

- High quality picture
- Approximately 3days for 30m^2 VT (not included preparation and finish)

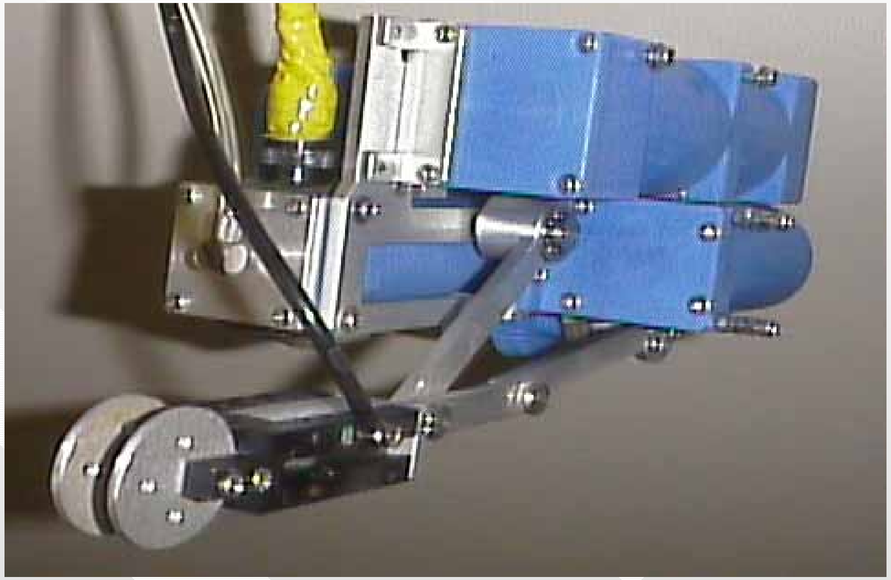




Compact ROV for paint inspection on tank inner wall

Compact ROV

Griper(Option Tool)

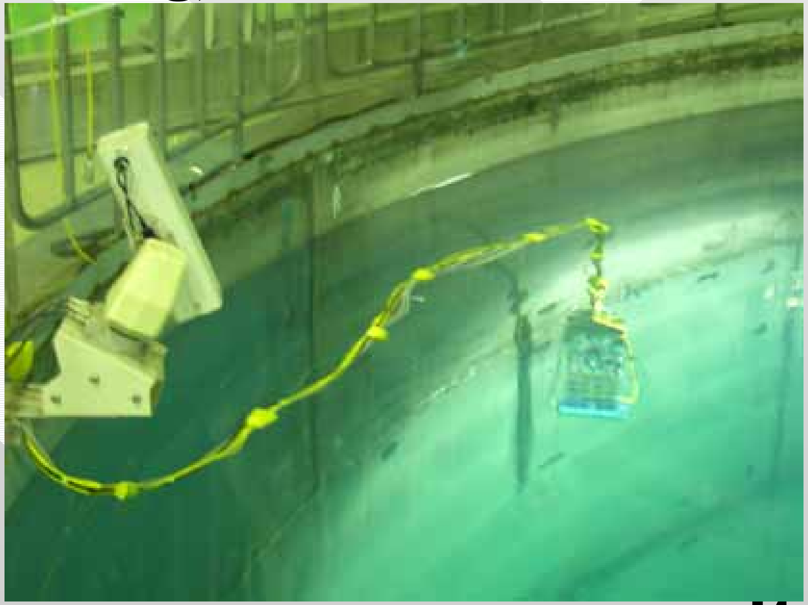


- **DOF : 2**
- **Water Depth : 30m**
- **Size : W90 x L185 x H70mm**
- **Weight : 600g(in air)**
- **Actuator : Air Cylinder**
- **Load Capacity: 5g**
- **Stroke : 10mm**

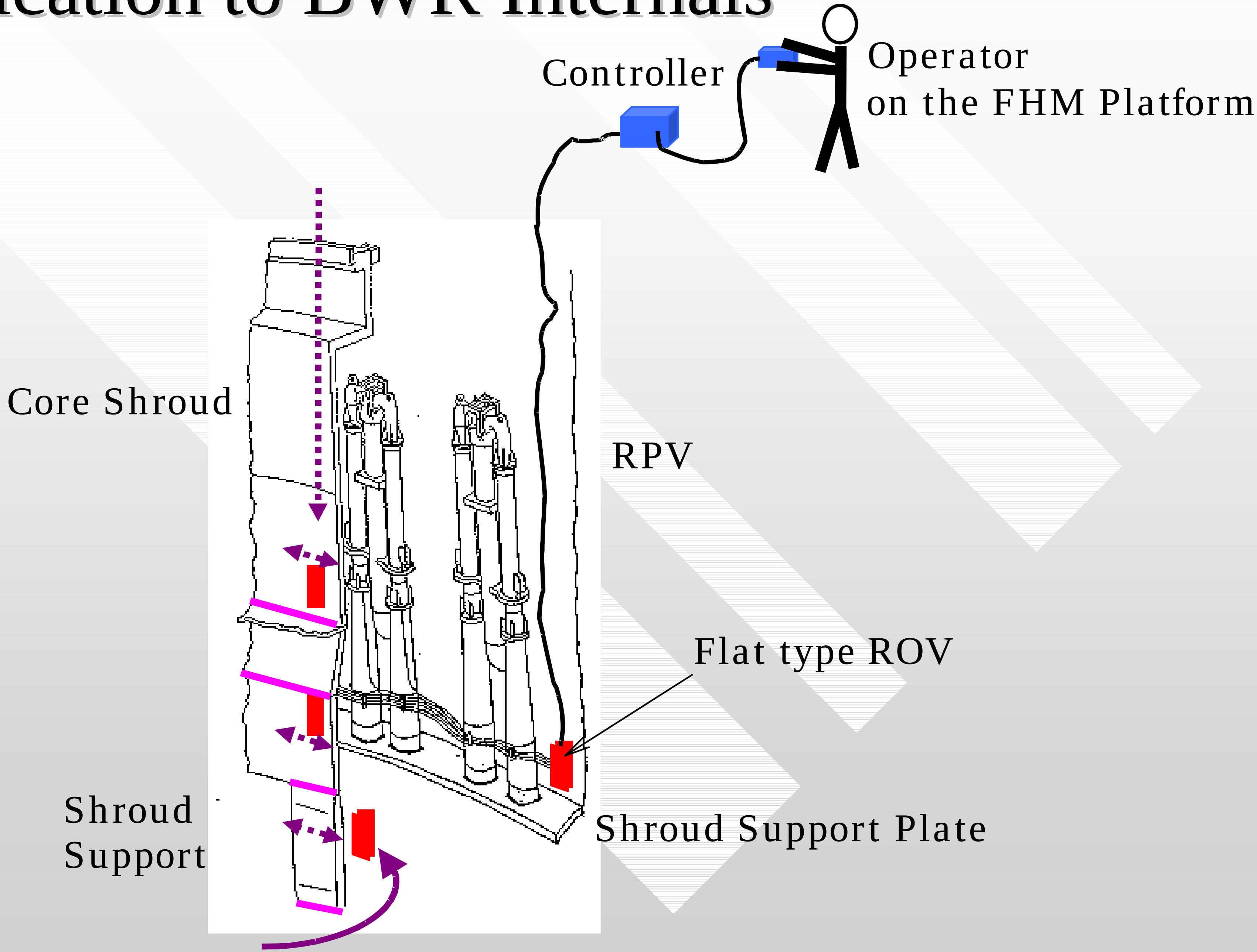
Flat type ROV

Concept Design

- ◆**Large Inspection Area**
  - ➢**Flat Shape**
  - ➢**Neutral Buoyant Body**
  - ➢**Goes through 50mm gap between structures (For example: Core shroud and jet pump)**
  - ➢**Goes below overhang by natation (For example: shroud support leg)**
- ◆**Motion**
  - ➢**Natation**
  - ➢**Clings and Drives on Wall**
  - ➢**Neutral Buoyant Cable**
- ◆**Applicability**
  - ➢**Several Option Tools**

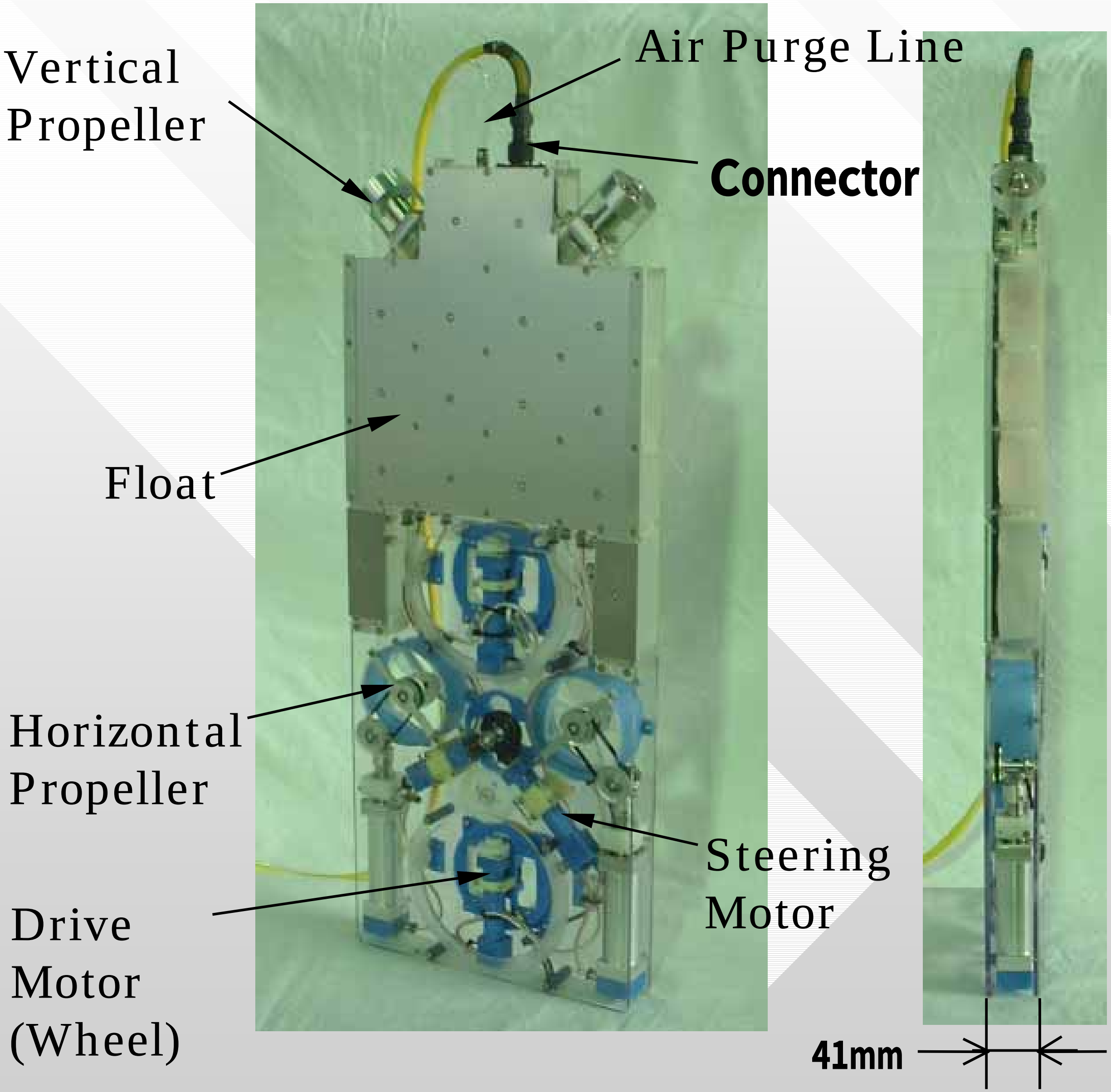


Flat type ROV
Application to BWR Internals



Flat Type ROV

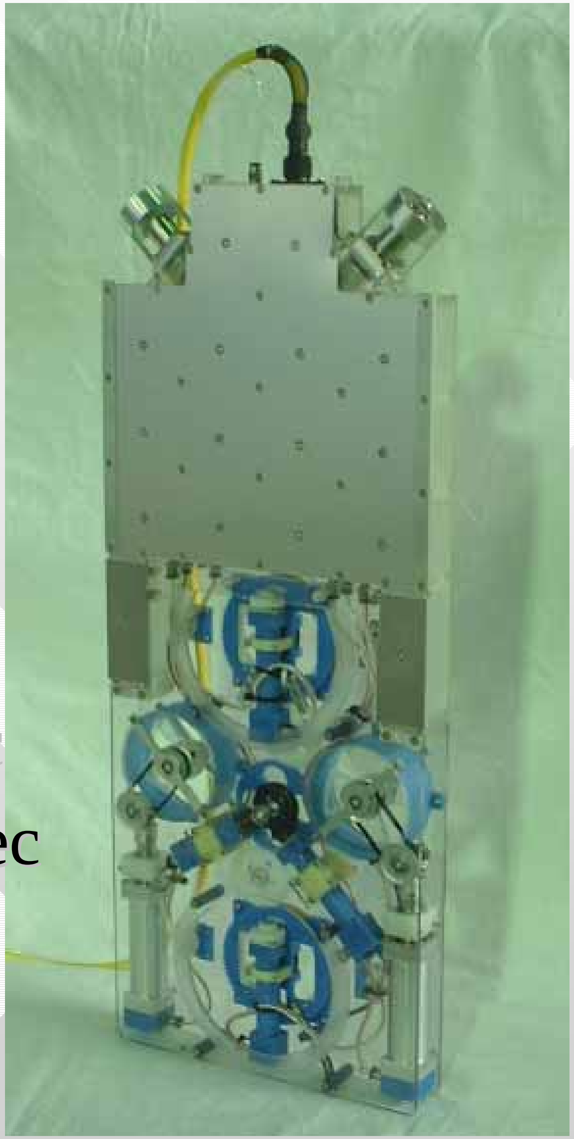
Configuration



Flat Type ROV

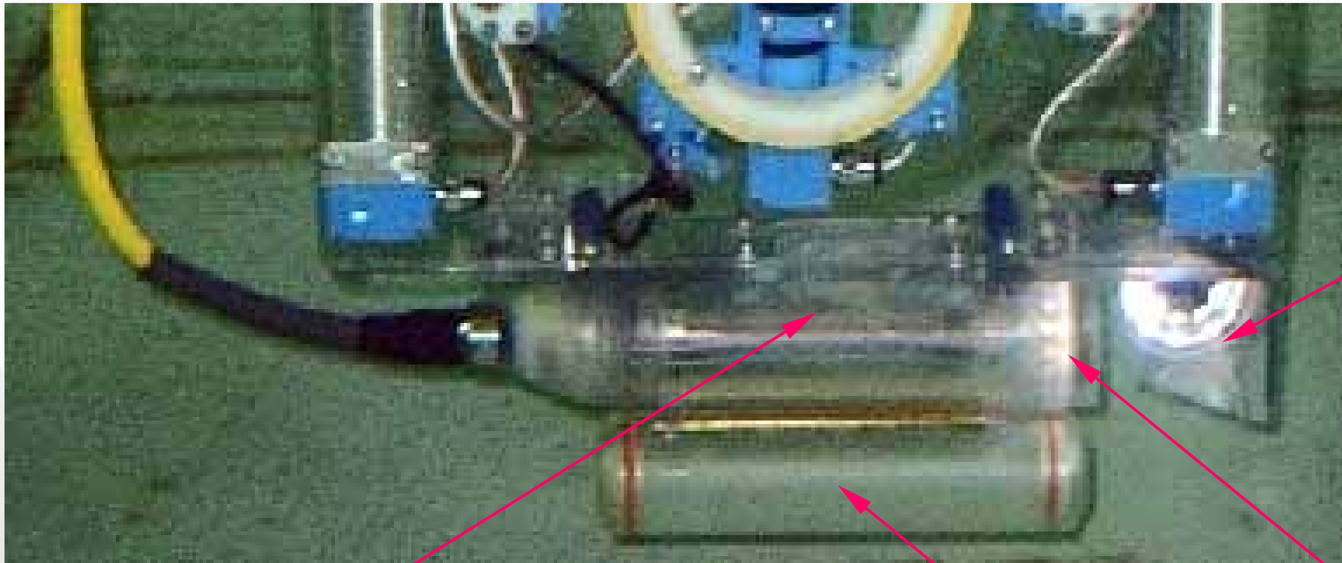
Specification

- Dimension : W 41 x L570x H230[mm]
- Motion :
  - Natation:up & down,back & forward,
    turn left & right, Transverse
  - Drive: up & down, Transverse
- Mass : 2.9kg
- Speed :
  - Natation:back & forward・・・ 0.1m/sec
    Transverse・・・0.07m/sec
  - Drive: 0.1m/sec
- Water Depth : <30m
- Temperature: <52℃



Flat Type ROV

VT Head



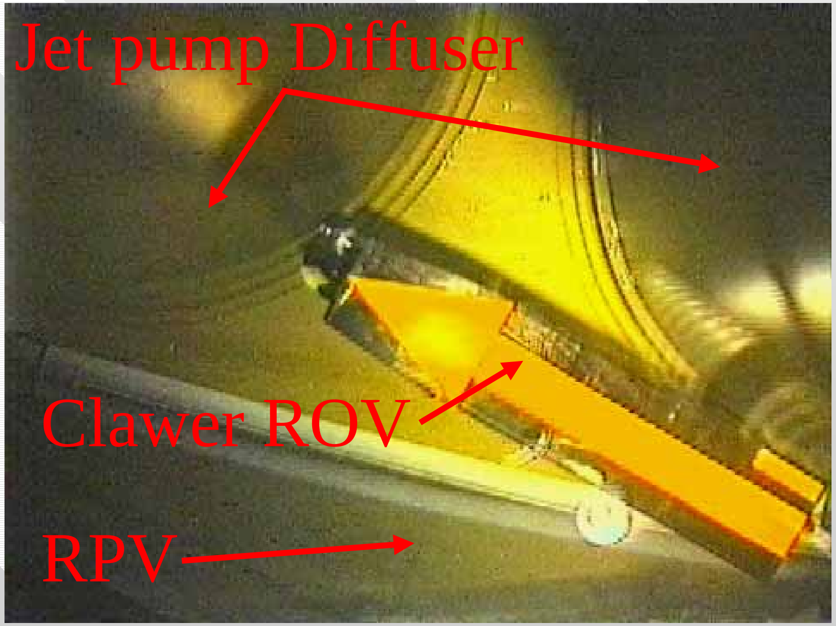
Features

- Remote focus adjustment
- 410,000 pixel CCD --- 1 mil wire resolution
- Remote light adjustment separated in 4 sectors
  ---easily discriminates flaw

Clawer ROV

Concept Design

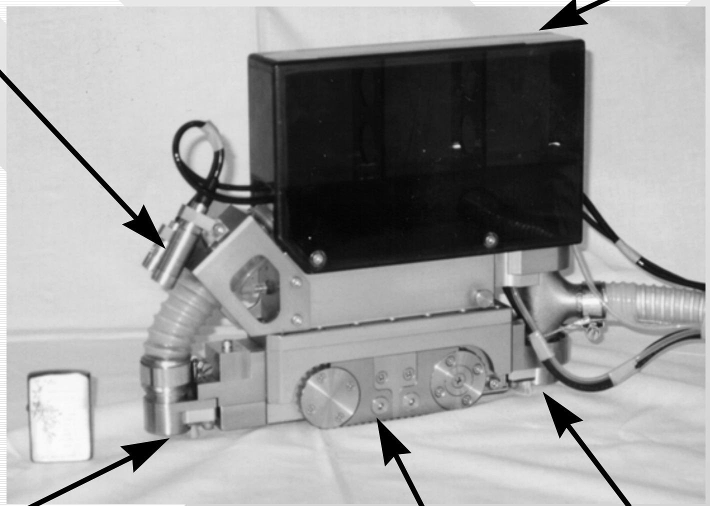
- ◆**Large Inspection Area**
  - ➢**Flat Shape**
  - ➢**Goes through 60mm gap between structures**
  - ➢**Goes below overhang by Clawer (For example: shroud support plate)**
- ◆**Motion**
  - ➢**Back & Forward, Turn,**
- ◆**Applicability**
  - ➢**Vacuum cleaning**
  - ➢**Visual inspection**



Clawer ROV

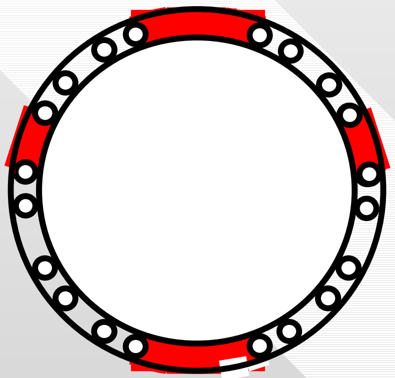
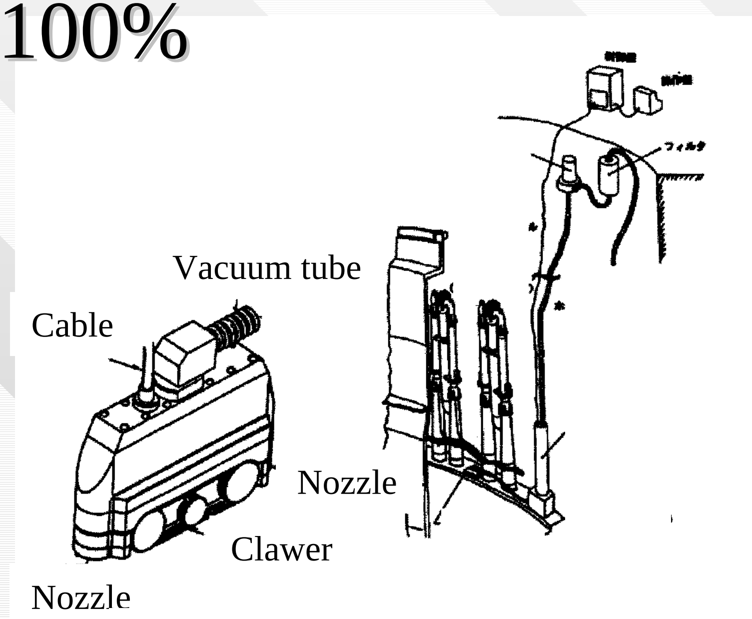
Specification

- Dimension : W50 x L248 x H250mm
- Motion : back & forward, turn left & right
- Camera: 380,000 pixel color CCD
- Mass : 4.6kg
- Water Depth : <30m
- Temperature: <52℃



Clawer ROV

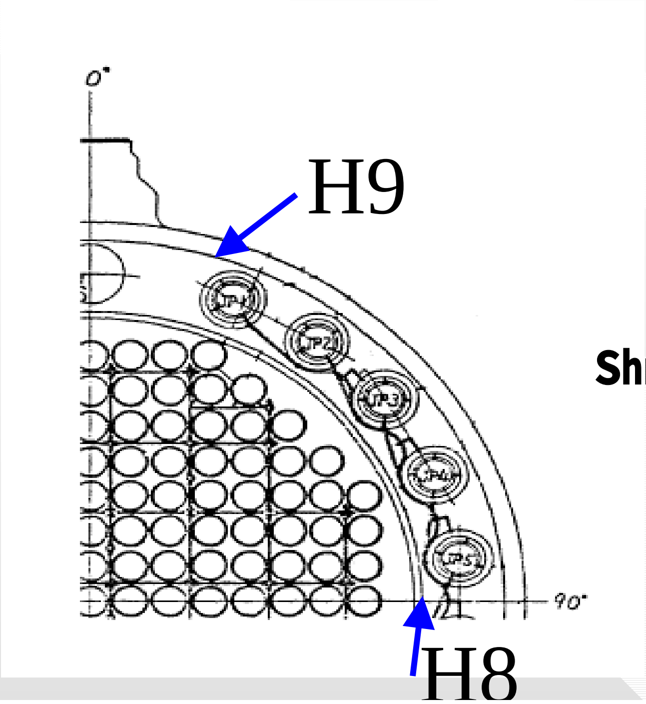
Comparison

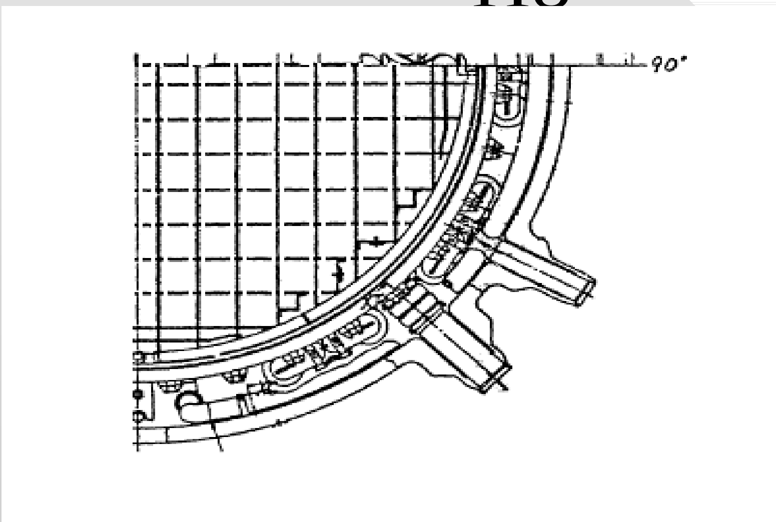
Items	Former method	Latest method
Tool	Vacuum tools	Clawer ROV
Coverage	20% 	100% 
Critical time	1day	1day

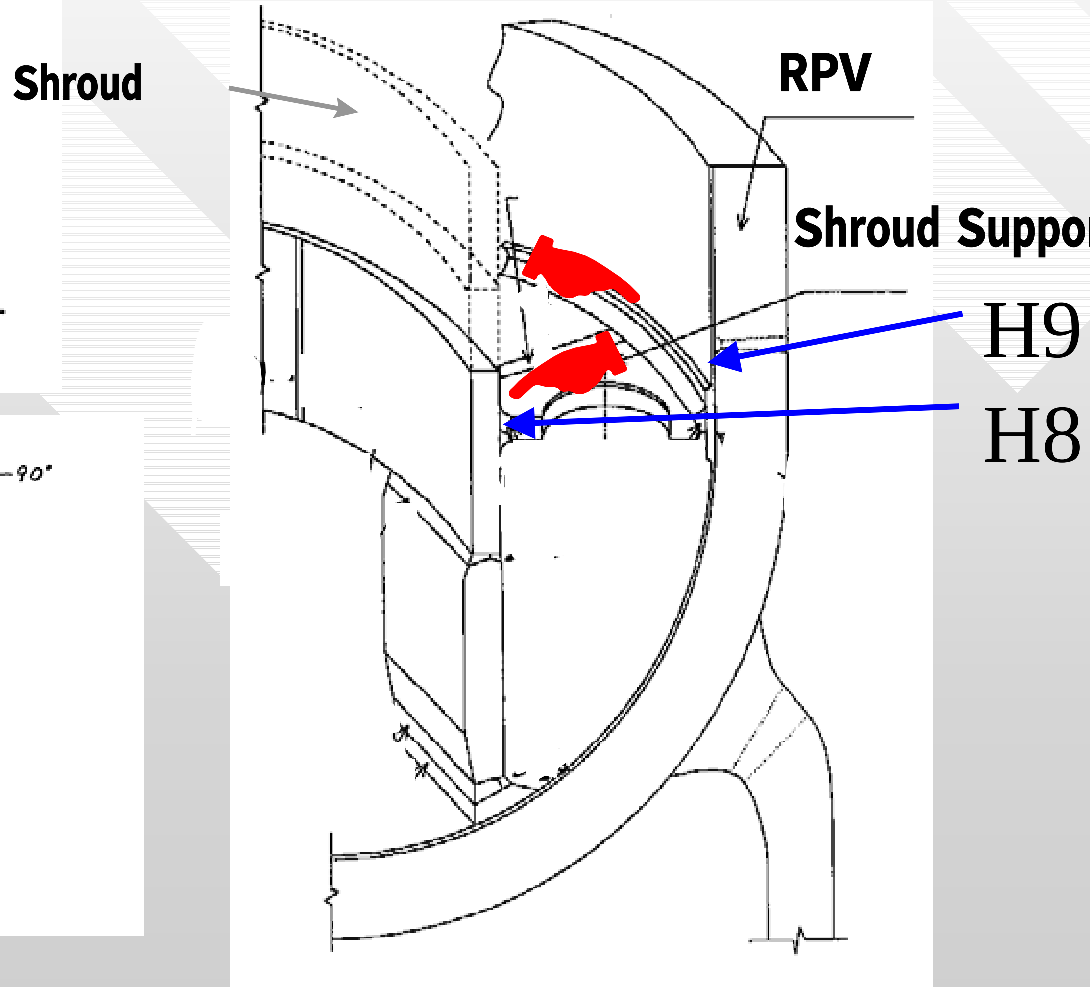
Clawer ROV

VT for Upper surface Shroud Support Plate

Picture range：70mm x50mm

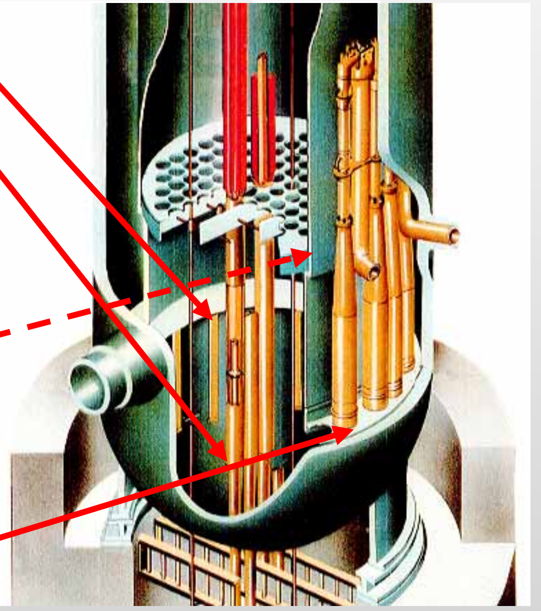






Practical Use

No.	ROV	Inspection	Target / times
1	**Compact ROV**	VT	・Shroud Support VT / 5 ・CRD housing VT / 4 ・Tank VT / 3 ・PWR Core Former Bolts VT /1
2	**Flat type ROV**	VT (UT)	・Core shroud VT / 1
3	**Clawer ROV**	VT	・Vacuum cleaning on Shroud Support plate/ 9



Conclusion

Proposes underwater inspection by ROV

- Inspects larger area more speedily
- Decreases inspection process by few disassembled components
- Applies for detail inspection(UT, etc.)

ROV family used practically in internals inspection and cleaning

- Compact ROV for shroud support and CRD housing
- Flat type ROV for core shroud and shroud support
- Clawer ROV for upper shroud support plate