JAERI-Review
2004-008

MINUTES OF THE IFMIF TECHNICAL MEETING DECEMBER 4-5, 2003, KYOTO, JAPAN

March 2004

IFMIF International Team

日本原子力研究所
Japan Atomic Energy Research Institute

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JAERI-Review 2004-008

Minutes of the IFMIF Technical Meeting
December 4-5, 2003, Kyoto, Japan

IFMIF International Team

Department of Fusion Engineering Research
(Tokai Site)
Naka Fusion Research Establishment
Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken

(Received January 30, 2004)

The IFMIF Technical Meeting was held on December 4-5, 2003 at Shiran-kaikan, Kyoto University. The main objectives are i) to finalize the Comprehensive Design Report (CDR), ii) to discuss IFMIF cost and organization, iii) to review technical status of major systems, transition phase activities and EVEDA plan. This report presents a brief summary of the results of the meeting. Agenda, participants list and presentation materials are attached as Appendix.

Keywords : IFMIF, Fusion Material, Neutron Source, Irradiation Facility, Transition Phase, EVEDA, Engineering Validation, Engineering Design, Comprehensive Design Report

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This report was edited by members of Office of Fusion Materials Research Promotion as follows; H.Nakamura, M.Takeda, M.Ida, S.Maebara, T.Yutani, M.Sugimoto

国際核融合材料照射施設 (IFMIF)技術会合報告書
2003 年 12 月 4 日- 5 日、芝蘭会館、京都

那珂研究所核融合工学部
IFMIF 国際チーム

(2004 年 1 月 30 日受理)

国際核融合材料照射施設(IFMIF)の技術会合が 2003 年 12 月 4 日、5 日に、京都大学の芝蘭会館で開催された。技術会合の主な目的は、i) 総合設計報告書の最終内要、ii)IFMIF のコストおよび組織、iii)主要システムの技術検討の現状、移行期活動の現状、工学実証・工学設計期活動案の審議である。本報告書では、これらの技術会合の要約を取り纏めた。本技術会合のアジェンダ、参加者リスト、発表資料は、付録に掲載した。

本報告書は、核融合炉材料開発推進室の以下のメンバーにより、編集された。
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Accelerator
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Target
Nakamura Hiroo*(JAERI, JA), Ara K.(JNC, JA), Arnol'dov M. (IPPE, RF), Dell' Orco G. (ENEA, EU), Ezato K.(JAERI, JA), Fedotovsky V.(IPPE, RF), Horiike H.(Osaka Univ. , JA), Ida M.(JAERI, JA), Kakui H. .(IHI Co., Ltd. , JA), Kondo H. (Osaka Univ. , JA), Loginov N.(IPPE, RF), Miccichè G.(ENEA), Mikheyev A.(IPPE, RF), Morozov V.(IPPE, RF), Muroga T.(NIFS, JA), Riccardi B.(ENEA, EU), Shishulin V.(IPPE, RF), Suzuki A.(NIFS, JA), Tanaka S.(Univ. Tokyo, JA), Yamamura T.(IHI Co., Ltd. , JA), Yamaoka N. (Osaka Univ. , JA), Yoneoka T.(Univ. Tokyo, JA)

***Group Leader**

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1. Introduction

IFMIF is a joint effort of the European Union (EU), Japan, the Russian Federation (RF), and the United States of America (USA) within the framework of the Fusion Materials Implementing Agreement of the International Energy Agency (IEA). A reference conceptual design and a detailed cost estimate for IFMIF were developed during the "Conceptual Design Activity (CDA)" phase (1995-96). That design was the basis for the "Conceptual Design Evaluation (CDE)" phase (1997-98). In January 1999, the IEA Fusion Power Coordinating Committee (FPCC) requested a review of the IFMIF design, and directed that it focus on cost reduction without changing the original mission. In addition, the concept of staged deployment of the facility was also suggested to reduce the initial investment and to lower the annual expenditures during construction.

The "Key Element Technology Phase" (KEP) during 2000-2002 was carried out with the objectives of reducing some of the key technology risk factors on the path to achieving a CW deuteron beam with the desired current in the accelerators, of verifying relevant component designs on a laboratory scale and of validating design codes.

It is recognized that some development activities and some detailed preliminary design efforts are still required to provide the basis for making a decision on IFMIF construction. Therefore, a new phase, the Engineering Validation and Engineering Design Activity (EVEDA), is planned to focus on the detailed engineering design and the associated prototypical component tests. EVEDA will be organized under a new organizational structure to allow for enhanced joint team design work and for a smooth transition to subsequent construction. Prior to the EVEDA, "Transition Phase" during 2003-2004 is being in progress to perform preparations to enter the EVEDA.

This report presents a brief summary of the objectives and results of the IFMIF technical meeting. Detailed information on the agenda and presentation materials is attached in the Appendixes.

2. Meeting Objectives

The purposes of the IFMIF Technical Meeting are i) to finalize the Comprehensive Design Report (CDR), ii) to discuss IFMIF cost and organization, iii) to review technical status of major systems, transition phase activities and EVEDA plan.

3. Brief Summary of the IFMIF Technical Meeting

CDR publication and Cost Estimate report

Thorough examination of the draft of the Comprehensive Design Report was made and agreement on final details of the CDR was obtained after minor revisions to the text and tables. Technical writing and editing was almost complete. Project schedule and organization of CODA was discussed assuming "ITER-like" organization for preliminary planning and cost estimates. Cost estimate was made based on the assumption above and agreement was reached on all aspects of total project cost estimates.

Phase	EVEDA	CODA							Total
		Construction	Installation & Checkout	Startup & Commissioning	Operation			Decommissioning	
					125-mA Operation	250-mA Operation			
						Annual	Total		
Cost	88.4 1)	539.2 2)	116.7 3)	115.4 4)	141.2 5)	78.5	1,570 6)	50.0 7)	2,620.9

1) Cost including Joint Team operation and supporting staffs
2) Cost for 10 years;
3) Cost for 10 years;
4) Cost for 8 years beginning 2 years later than start of construction;
5) Cost for last 3 years of 10 years construction time;
6) Cost for 20 years after completion of construction;
7) Total decommissioning cost in 5 years

The structure of the project management created based on meetings with ITER and SNS project members was discussed and harmonized agreement was obtained. The details are to be identified by participating parties to CODA.

Technical Status of Major Project Systems

Technical Status of Major Project Systems was presented by each group leader. The status of accelerator team was presented by Jameson. Majority of accelerator systems is well positioned for start of EVEDA, and focus is placed on high energy beam transport and diagnostics in 2004. Target system activity was presented by Nakamura. Wake on Li surface formed by irregularity due to Li-sludge may be an issue. The sludge is formed by oxidation or nitrification of lithium due to residual impurities. Therefore, better impurity control of the atmosphere may mitigate this issue. Heinzel presented the status of the Test Facilities. Since the environment to which structural materials of test module are exposed is severe, structural materials specification needs to be examined in more detail. The structural design to accommodate internal He coolant pressure also needs to be done in more detail. Design integration works related to updates of safety issues and design database were presented by Sugimoto.

Status and Plans for Transition Tasks

Milestones in the Transition Phase were discussed and are listed below:

1. Start discussion of EVEDA participation and Agreement at the government level (depends on ITER decision time).
2. Submission of EVEDA Agreement to a next FPCC meeting.

3. Make technical evaluation based on IFMIF-CDR in each party (before summer in 2004)
4. Prepare preliminary EVEDA task description (2004)
5. Need to strengthen management.

Task descriptions and Cost of EVEDA

After the completion of the KEP, it was recognized that some development activities and some detailed preliminary design were still required to provide the basis for making a decision on IFMIF construction. Subsequently, a new phase, the Engineering Validation and Engineering Design Activity (EVEDA), is planned to focus on the detailed engineering design and the associated prototypical component tests. This will be under a new organizational structure to allow for enhanced joint team design work and for a smooth transition to subsequent construction. Task list on accelerator, target, test facilities and design integration was proposed and was agreed upon by participants.

Acknowledgements

Appreciation is given to all members of the international IFMIF team on their contributions to this work. The IFMIF executive subcommittee has been highly impressed with dedication and enthusiasm of the IFMIF team. Also, appreciation is given to for the continued Interest of the IEA-FPCC.

Appendix-A

Agenda of IFMIF Technical Meeting, December 4-5, 2003, Kyoto, Japan

December 4

10:00-10:10	Welcome and Review of Agenda	Matsui Shannon
10:10-10:20	Status of CDR publication and Cost Estimate Report	Sugimoto Heinzel
10:20-10:30	Review/discuss schedule plans for Transition, EVEDA and CODA	Sugimoto
10:30-12:00	EVEDA organization and cost issue	Group Discussion
12:00-13:00	Lunch	
13:00-15:00	Review Plans for ILE of IFMIF construction	Group Discussion
	- Coffee break -	

Technical presentations
Group Leaders will present an overview of the CDR Design, discuss major issues, review plans for the Transition and EVEDA leading to CODA. Identify project management needs. Status of ongoing R&D will be discussed with additional speakers.

15:10-17:00	Accelerator Facility	Jameson Rathke Maebara Sugimoto

December 5

Technical Presentations, Continued

9:30-10:20	Target Facility	Nakamura Riccardi
	- Coffee break -	

10:30-11:30	Target Facility Activities	Loginov Ida
	- Lunch -	
12:30-14:30	Test Facilities	Heinzel Matsui Shimizu Yutani
14:30-15:10	Design Integration	Sugimoto Ida Riccardi
	- Coffee break –	
15:20-16:40	Discussion on technical details of EVEDA Tasks	Shannon
16:40-17:00	Summary/Action Items	
17:30-19:30	Reception	

Appendix-B Participants List

EU

- **R.Andreani (EFDA)**
- **J.Chen (EFDA)**
- **V.Heinzel (FZK)**
- **R.Laesser (EFDA)**
- **B.Riccardi (ENEA)**

Japan

- **M.Ida (JAERI)**
- **H.Kakui (I.H.I)**
- **S.Maebara (JAERI)**
- **H.Matsui (Tohoku Univ./JAERI)**
- **H.Nakamura (JAERI)**
- **K.Nakamura (JAERI) (only Dec.5)**
- **A.Shimizu (Kyusyu Univ.) (only Dec.5)**
- **M.Sugimoto (JAERI)**
- **M.Takeda (JAERI)**
- **T.Yutani (JAERI)**

RF

- **M.Arnoldov (IPPE)**
- **N.Loginov (IPPE)**

US

- **R.Jameson (ORNL)**
- **J.Rathke (AES)**
- **T.Shannon (Univ. Tennessee)**

Appendix-C

Minutes of IFMIF Technical Meeting, 1 October 2003, EFDA-CSU, Garching,Germany

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Minutes of IFMIF Technical Meeting
1 October 2003
EFDA-CSU, Garching, Germany

Attendees:

EU,	J. Chen (EFDA), E. Diegele (EFDA), R. Lässer (EFDA), R. Ferdinand (CEA Saclay), H. Klein (Univ. Frankfurt), W. Bahm (FZK), V. Heinzel (FZK), A. Möslang (FZK), B. Riccardi (ENEA Frascati)
Japan	H. Matsui (JAERI/IMR Tohoku Univ.), H. Takatsu (JAERI), H. Takeuchi (JAERI), M. Sugimoto (JAERI), H. Nakamura (JAERI)
USA	T. Shannon (Univ. Tennessee), R. Jameson (ORNL), J. Rathке (Adv. Energy Sys.)
Russia	V. Chernov (Bochvar Inst.), N. Loginov (IPPE)

Prof. H. Matsui gave a welcome talk at the beginning of the meeting, and the overall status about transition phase and CDR preparation work was described. The agenda consisting of five sessions was reviewed by participating IFMIF team members and agreed.

1. In the general discussion, it was emphasized that the wider international participation to the EVEDA is a key to get support from each government and scientific communities. An idea to review the project management in CDR by the people outside the IFMIF or fusion communities before its publication was raised by Dr. R. Jameson, however the time constraint only allows to perform the review by ITER team as a realistic solution.
2. The draft of cost estimate was explained by Dr. H. Takeuchi and a new cost structure consisting of base and option parts of construction cost was proposed. Such classification was introduced to be indicative that the base part would be consistent with the explanation for getting a support of EVEDA participation in the community of Japan a half year ago. After a discussion, the other reasoning for classification was employed to indicate that both of base and option parts are necessary to build the facility. The possible categories for separation were "construction" and "installation & checkout", and it was agreed to get a solution for cost breakdown of two categories by each subsystem leaders.

   For ILE organization and its management cost, there was a doubly difference between the estimates performed by Japan and USA, so that it was recommended to inquire such a structure in ITER by EU and Japan independently within ~one week, as an action item after this meeting. The review of cost packages in conventional facility was another action item because the present cost is higher than that obtained in CDA cost estimate by EU, where the building volume was larger than now. These review would result in the revision of Cost Estimate report.

3. CDR draft should be edited in English by Dr. F. Wiffen till early November, and it will be published at end of November when the draft is transfered to FzK in the first week of November. It was agreed to send the figures in CDR with high quality to Dr. A. Moeslang and immediately to send the manuscripts of CDR for starting the English edit.
   The missions of IFMIF written in sections 1 and 2.1 were heavily revised by Prof. H. Matsui to clarify the priority of each objecectives. Some numbers in the table of users' requirements, like neutron flux gradient or upper limit of irradiation temperature of SiC/SiC, were also revised to reflect the recent discussion in users group.
4. Prof. H. Matsui introduced the perspective of budgetary situation for EVEDA phase in Japan and Dr. H. Takeuchi presented an idea of task allocation based on the prioritization of the tasks to start them. As a conclusion, it was agreed that the required resources woule be almost provided by gathering the contribution form each participant parties and corectly taking into account the cost of personnel employed by laboratories.
5. Nothing particular issue was discussed as the other items.

Distibuted materials:

(1) CDR 2nd draft, 29th August, 2003

(2) Comments to CDR 2nd draft, sections 1, 2, 3-1, and 5.

(3) Cost Estimate Report, draft, 29th August, 2003

(4) Revision proposal to Cost Estimate with base and option categories in construction phase

Appendix-D

Documents presented in the IFMIF Technical Meeting,
Dec.4-5 2003, Kyoto, Japan

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Status of CDR Publication and Cost Estimate Report

M. Sugimoto, JAERI

IFMIF Technical Meeting

December 4-5, 2003

Shiran-Kaikan, Kyoto, Japan

1

Status of IFMIF Comprehensive Design Report

- Mar. 19, '03: 15th IFMIF SubCom. (Tokyo) – contents & responsibilities
- Jul. 1-2, '03: 16th IFMIF SubCom. (Lausanne) – first draft
- Jul. 28 & Aug. 7, '03: Video conferences
- Aug. 29, '03: Second draft circulated
- Oct. 2, '03: 17th IFMIF SubCom. (Garching) – second draft
- Nov. 25, '03: Final draft (ILE issue unresolved)
- Dec. 6, '03: 18th IFMIF SubCom. (Kyoto) – final (?) draft
- Dec. '03 (?): Publication

FINAL DRAFT is put in JAERI FTP server and it is not transferred to FzK yet because ILE issue is not resolved yet.

2

Status of IFMIF Cost Estimate Report

- Apr. '03: Initiate international discussion
- May '03: Inputs from AES about accelerator sys. & proj. mgt.
- Jun. '03: Inputs from JAERI
- Jul. 28 & Aug. 7, '03: Video conferences – cost difference issues are discussed
- Oct. 2, '03: 17th IFMIF SubCom. (Garching) – draft 29 Aug.
- Oct. '03: Inputs from ITER team about ILE structure
- Nov. '03: Input from Moeslang about EVEDA structure; Input from US about ILE cost based on SNS proj.
- Dec. 6, '03: 18th IFMIF SubCom. (Kyoto) – final (?) draft

3

Issues to be resolved for finalizing drafts of CDR & cost report

- EVEDA structure and associated cost
  - Last draft on Nov. 20 prepared by A. Moeslang
- ILE organization and cost at Construction phase
  - Feedback from EU and Japan ITER teams
  - Japanese proposal based on ITER-like organization
  - US proposal based on SNS organization
- ILE organization and cost at Operation phase
- Cost related to Conventional Facilities (WBS 5.0)

4

IFMIF
International Fusion Materials Irradiation Facility

Cost Estimate Report

JAERI

IFMIF Technical Meeting, Kyoto Japan, 4-5 December, 2003

Summary of IFMIF Project Cost

■ **Total Project Cost (TPC)**

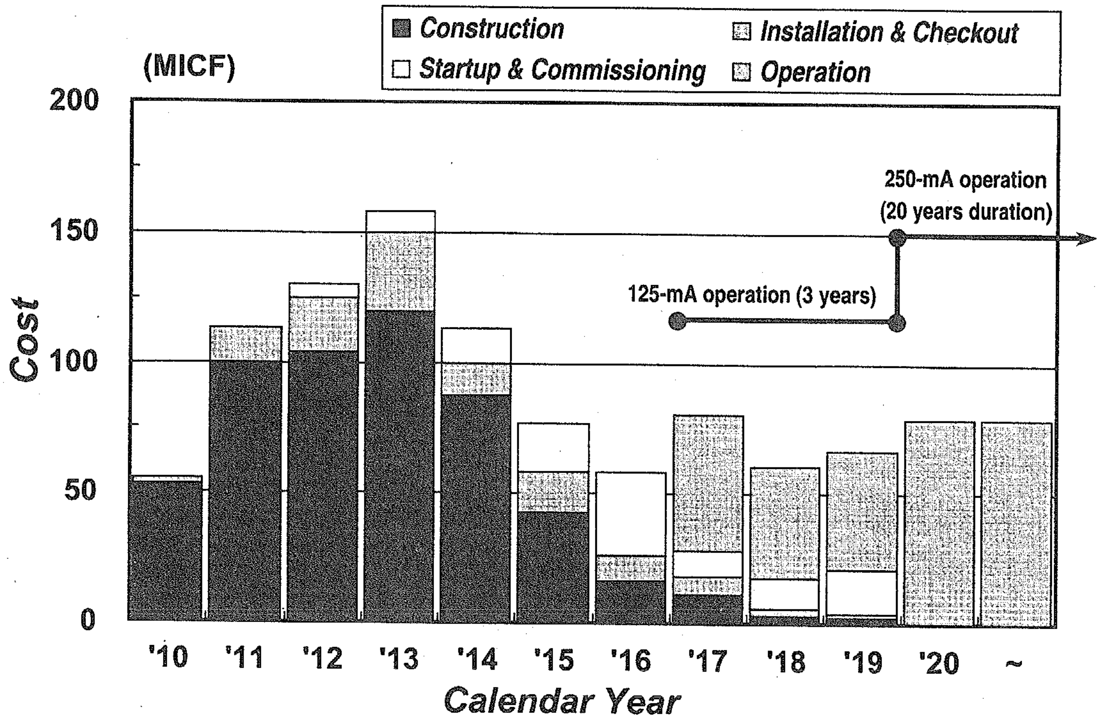
Unit: MICF

Phase	EVEDA	CODA							Total
		Construction	Installation & Checkout	Operation				Decommissioning	
				Startup & Commissioning	125-mA Operation	250-mA Operation			
						Annual	Total		
Cost	85.6 1)	539.2 2)	116.7 3)	115.4 4)	141.2 5)	78.5	1,570 6)	50.0 7)	2618.1

1) Cost including Joint Team operation and costs (based on the EVEDA Joint Team organization Ver.24-Nov-2003);
2) Cost for 10 years; 3) Cost for 10 years;
4) Cost for 8 years beginning 2 years later than start of construction;
5) Cost for last 3 years of 10 years construction time;
6) Cost for 20 years after completion of construction;
7) Total decommissioning cost in 5 years

Annual Cost Profile

(Construction ~ Operation)



EVEDA Cost

Ver. 24-Nov-2003

Unit: MICF

	Home Team		Joint Teams	Total
	Engineering Validation	Engineering Design		
Accelerator Facility	21.0	10.8	1.76	**32.5**
Target Facility	17.0	4.5	1.76	**22.7**
Test Facility	9.1	4.5	1.76	**15.7**
Joint Team - Conventional Facilities, CC&CI	-	-	2.64	**2.64**
Joint Team - QA, Safety, System Engineering	-	-	3.52	**3.52**
Joint Team - Project leader, Administrators, Supporting Staffs	-	-	6.62	**6.62**
Joint Team - Office Operation	-	-	0.63	**0.63**
Total	**47.1**	**19.8**	**18.69**	**85.59**

* **Staff:** **1 Manager @ 235kICF/yr + 15 Professionals @ 176 kICF/yr + 8 Support Personnel @92 kICF/yr**

Cost of Construction Phase

Unit: MICF

WBS	Subsystem	Construction	Installation & Checkout	Total	ratio
1.0	Project Management	54.5	21.1	75.6	11.5%
2.0	Test Facilities	88.3	1.7	90.0	13.7%
3.0	Target Facility	43.5	7.8	51.4	7.8%
4.0	Accelerator Facility	259.2	52.4	311.7	47.5%
5.0	Conventional Facilities	81.5	33.2	114.7	17.5%
6.0	Central Control & Common Instrumentation	12.0	0.5	12.5	2.0%
Total		539.2	116.7	655.9	100%

Cost of Operation Phase (1)

- Startup & Commissioning -

Unit: MICF

CY	12	13	14	15	16	17	18	19	Total
ILE personnel	3.17	5.65	9.19	14.01	25.27	5.42	7.43	9.51	79.6
Electrical Power	0.54	0.77	0.76	1.28	3.59	1.24	1.37	3.85	13.4
Maintenance	1.31	1.32	3.24	3.26	3.35	3.26	3.27	3.36	22.4
Total	5.01	7.73	13.20	18.55	32.21	9.93	12.07	16.71	115.4

- ILE personnel rates: Manager @ 235 kICF/y, Engineer @ 176 kICF/y, Technician @ 138 kICF/y, Support / Shop @ 92 kICF/y
- Electrical Power Rates: 0.0855 ICF/kWh
- Maintenance: Including Spare parts, Ar & He gas, Cooling & Service water, etc.

Cost of Operation Phase (2)

- 125-mA Operation & 250-mA Operation –

Unit: MICF

CY	17	18	19	20-39 (annual)	Total (23 years)
ILE personnel	14.2	14.2	14.2	20.3	449.4
Electrical Power	13.0	13.0	9.3	26.3	561.1
Maintenance	15.8	15.8	21.8	31.8	690.1
Target Equipments	10.0	-	-	-	10.0
Total	52.9	43.0	45.3	78.5	1710.6

- ILE personnel rates: Manager @ 235 kICF/y, Engineer @ 176 kICF/y, Technician @ 138 kICF/y, Support / Shop @ 92 kICF/y
- Electrical Power Rates: 0.0855 ICF/kWh
- Maintenance: Including Spare parts, Ar & He gas, Cooling & Service water, etc. Annual maintenance cost is approximately 5% of construction costs
- Target Equipments: Cost of Spare Trap, Remote Handling System for Purification System

Modified point of Construction Phase Cost

➢ Total Estimate Cost (TEC) was separated
  ⇒ ***Construction cost*** and ***Installation & Checkout cost***

➢ Increased Project Management Cost
  ⇒ ***ILE structure is consisted of Central Team & Local Team.***
  (Central Team:352PY & Local Teams:200PY for 10 years)
  ⇒ ***Management cost ratio 6.5% →11.5%***

➢ Changed the definition of personnel rates
  ⇒ ***Off –Site rates → personnel rates for subsystem*** (off / on –site)
  ⇒ ***On –Site rates → personnel rates for ILE***

➢ The HVAC cost of Conventional Facilities was partly modified. ***(error of ventilation volumes)***

Review/discuss Schedule Plans for Transition, EVEDA and CODA

M. Sugimoto, JAERI

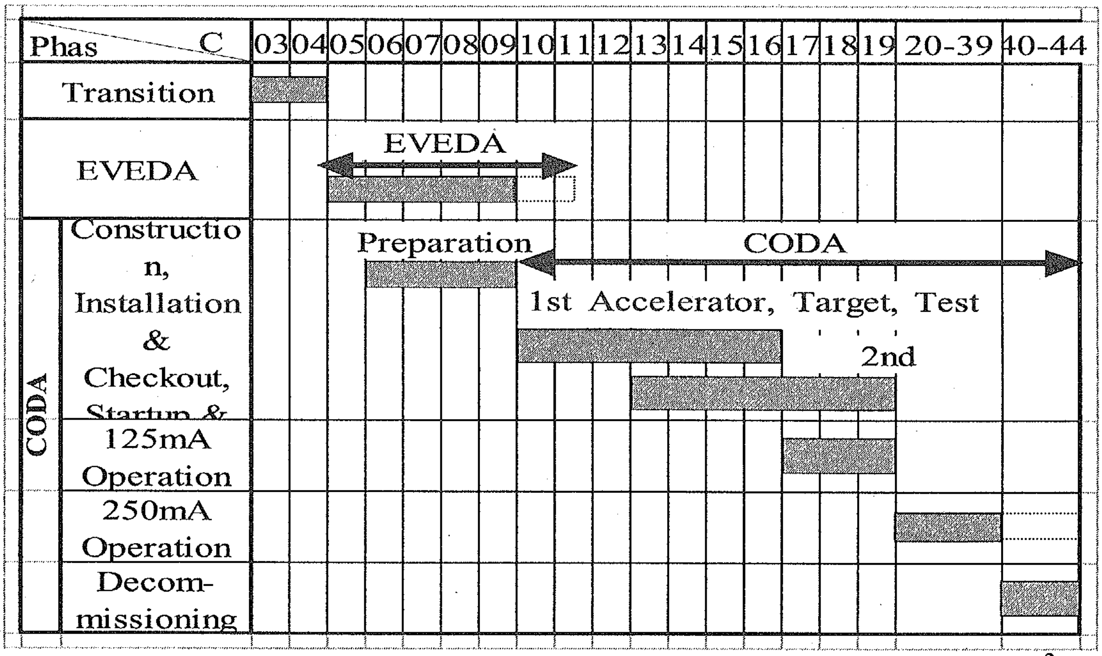
IFMIF Technical Meeting

December 4-5, 2003

Shiran-Kaikan, Kyoto, Japan

1

Schedule of Transition, EVEDA and CODA (CDR, Nov. '03)



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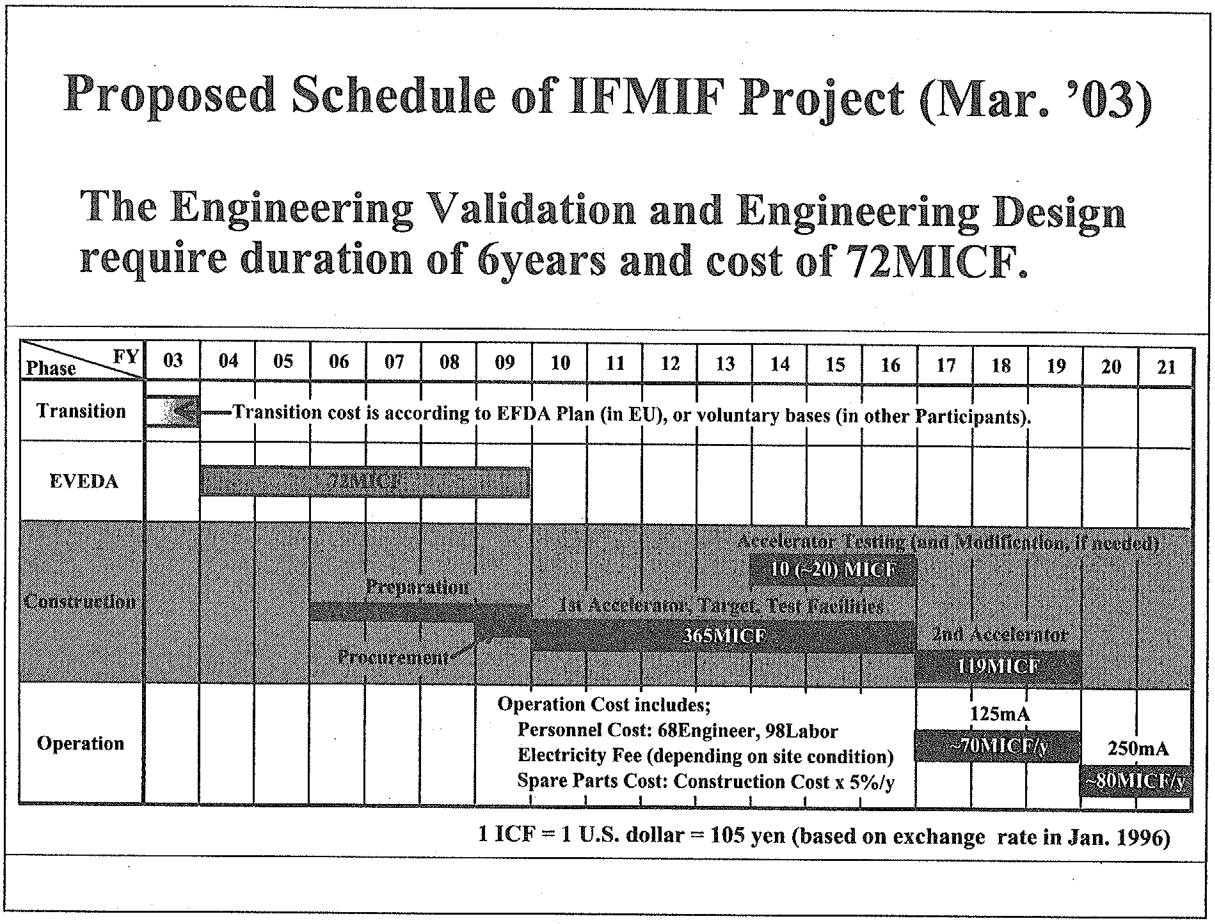
Proposed Schedule of IFMIF Project (Mar. '03)
The Engineering Validation and Engineering Design require duration of 6years and cost of 72MICF.
Phase
FY
03
04
05
06
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08
09
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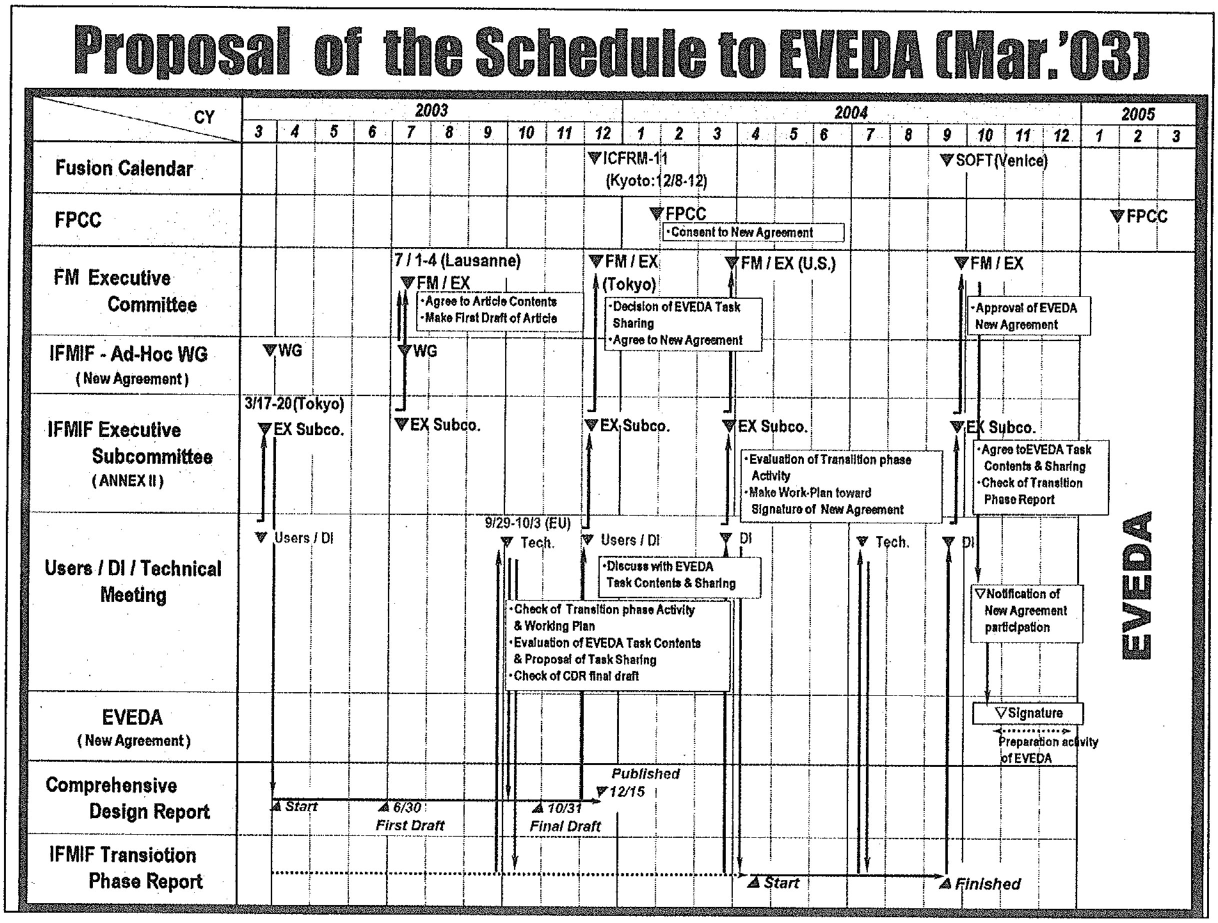
21
Transition
Transition cost is according to EFDA Plan (in EU), or voluntary bases (in other Participants).
EVEDA
72MICF
Construction
Accelerator Testing (and Modification, if needed)
10 (~20) MICF
Preparation
1st Accelerator, Target, Test Facilities
365MICF
Procurement
2nd Accelerator
119MICF
Operation
Operation Cost includes;
Personnel Cost: 68Engineer, 98Labor
Electricity Fee (depending on site condition)
Spare Parts Cost: Construction Cost x 5%/y
125mA
~70MICF/y
250mA
~80MICF/y
1 ICF = 1 U.S. dollar = 105 yen (based on exchange rate in Jan. 1996)


Proposal of the Schedule to EVEDA (Mar.'03)
CY
2003
2004
2005
Fusion Calendar
ICFRM-11
(Kyoto:12/8-12)
SOFT(Venice)
FPCC
FPCC
·Consent to New Agreement
FPCC
FM Executive Committee
7/1-4 (Lausanne)
FM / EX
·Agree to Article Contents
·Make First Draft of Article
FM / EX
(Tokyo)
·Decision of EVEDA Task Sharing
·Agree to New Agreement
FM / EX (U.S.)
FM / EX
·Approval of EVEDA New Agreement
IFMIF - Ad-Hoc WG (New Agreement)
WG
WG
IFMIF Executive Subcommittee (ANNEX II)
3/17-20(Tokyo)
EX Subco.
EX Subco.
EX Subco.
EX Subco.
·Evaluation of Transition phase Activity
·Make Work-Plan toward Signature of New Agreement
EX Subco.
·Agree to EVEDA Task Contents & Sharing
·Check of Transition Phase Report
Users / DI / Technical Meeting
Users / DI
9/29-10/3 (EU)
Tech.
Users / DI
·Discuss with EVEDA Task Contents & Sharing
DI
Tech.
DI
·Check of Transition phase Activity & Working Plan
·Evaluation of EVEDA Task Contents & Proposal of Task Sharing
·Check of CDR final draft
Notification of New Agreement participation
EVEDA (New Agreement)
Signature
Preparation activity of EVEDA
EVEDA
Comprehensive Design Report
Start
6/30 First Draft
10/31 Final Draft
Published 12/15
IFMIF Transiotion Phase Report
Start
Finished

Milestones in Transition Phase

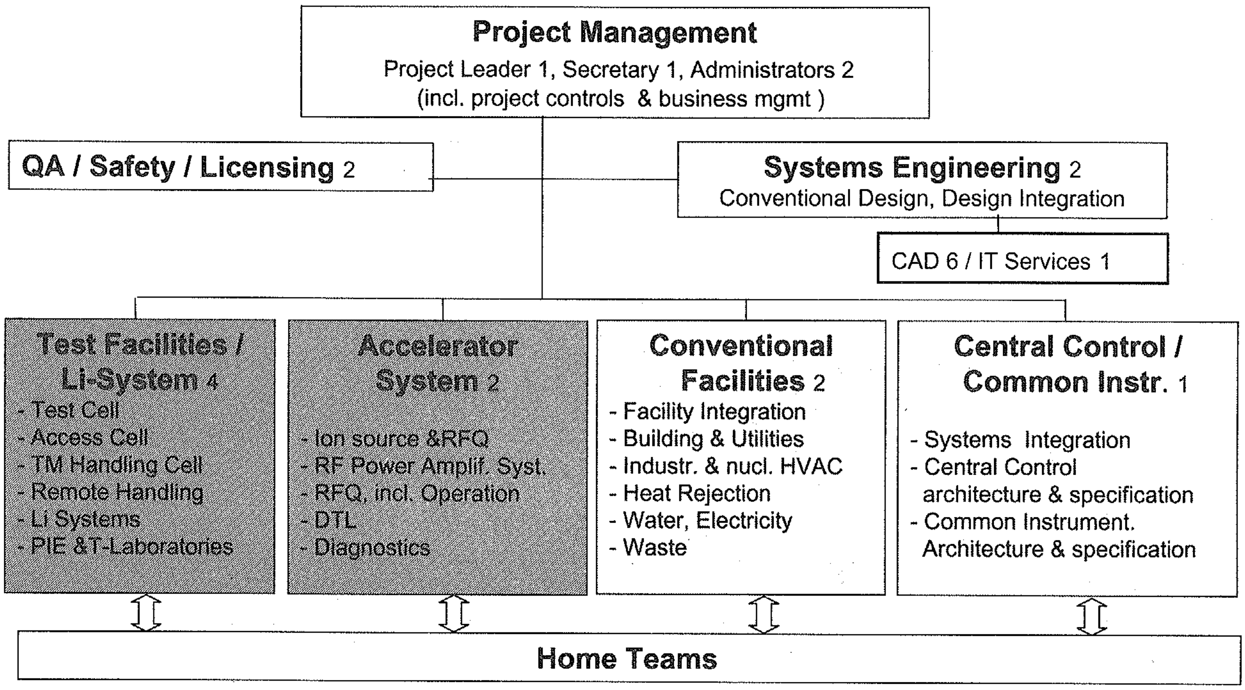
- Start discussion of EVEDA Agreement at the government level (depends on ITER decision time)
  - Extra FPCC meeting in summer-fall in 2004 ?
- Finish technical evaluation based on IFMIF-CDR in each parties (before summer in 2004)
- Prepare EVEDA task description in some details (early 2004)

5

EVEDA organization and cost issue

IFMIF Technical Meeting, Kyoto Japan, 4-5 December, 2003

IFMIF: EVEDA Central Team Harmonized Version 24-Nov-2003

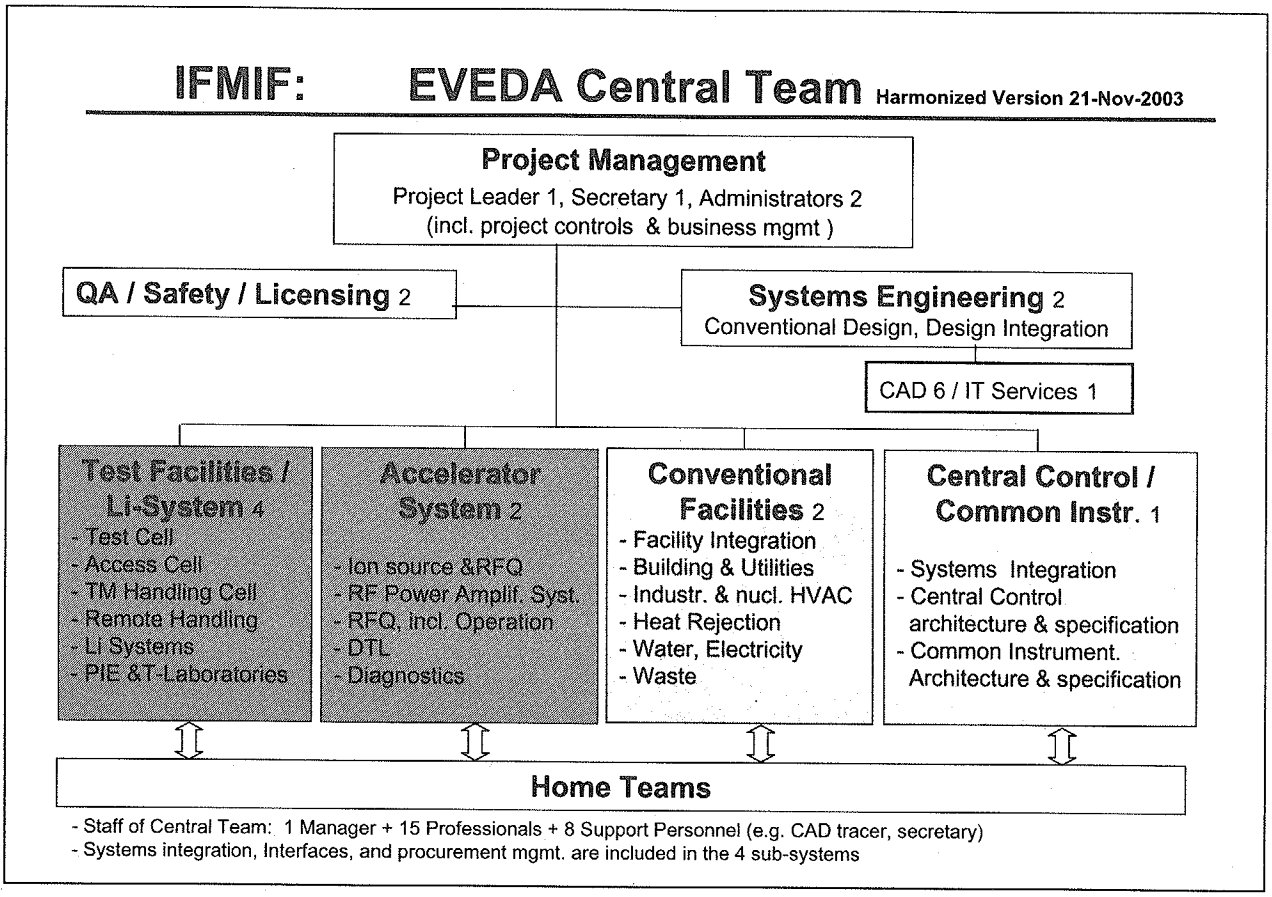


- Staff of Central Team: 1 Manager + 15 Professionals + 8 Support Personnel (e.g. CAD tracer, secretary)
- Systems integration, Interfaces, and procurement mgmt. are included in the 4 sub-systems

IFMIF: Cost of EVEDA (harmonized version 24-Nov-2003) Unit: MICF

	Home Teams		Central Team	Total
	Engineering Validation	Design		
Accelerator Facility	21.0	10.8	1.76	33.56
Target Facility	17	4.5	1.76	23.26
Test Facility	9.1	4.5	1.76	15.36
CT: Convent. Facils, CC&CI	-	-	2.64	2.64
CT: QA, safety, Site, SE	-	-	3.52	3.52
CT: Mgt, Adm. Asst.	-	-	2.94	2.94
CT: Office operation 8 Supporting Personnel	-	-	0.63 3.68[1]	0.63 3.68[1]
Total	66.9		15.01 3.68[1]	81.91 3.68[1]

•Staff: 1 Manager @ .235MICF/yr + 15 Professionals @ .176 MICF/yr + 8 Supporting Personnel @0.092MICF/yr
•Note 1: cost born by hosting country



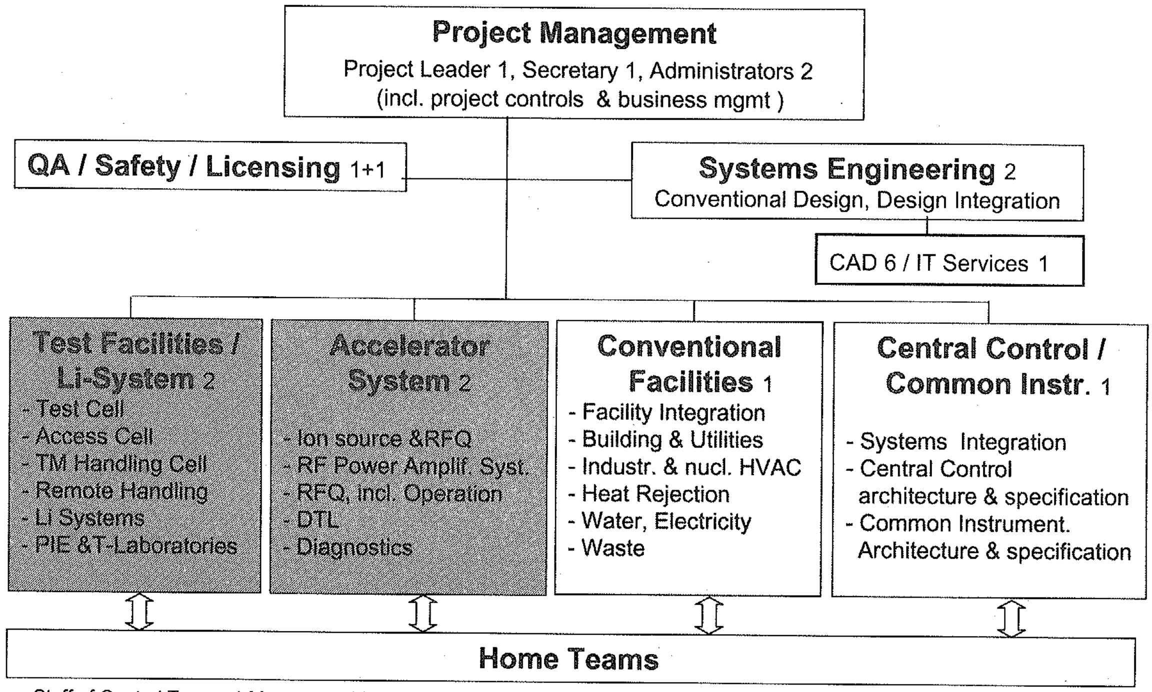
IFMIF: Cost of EVEDA (harmonized version 21-Nov-2003)

Unit: MICF

	Home Teams		Central Team	Total
	Engineering Validation	Engineering Design		
Accelerator Facility	21	10.9	1.76	33.66
Target Facility	17	4.0	1.76	22.76
Test Facilities	9.1	4.9	1.76	15.76
Central Team – Project Leader, administration, SE, QA, Safety, Conventional Facilities, CC&CI, etc.	-	-	9.1	9.1
Central Team – Office operation – 8 Supporting Pers.	-	-	0.63 3.68	0.63 3.68
Total	47.1	19.8	18,69*	85.59

* Staff: 1 Manager @ .235MICF/yr + 15 Professionals @ .176 MICF/yr + 8 Supporting Personnel @92MICF/yr

IFMIF: EVEDA Central Team EFDA suggestion 18-Nov-2003



- Staff of Central Team: 1 Manager + 11 Professionals + 8 Support Personnel (e.g. CAD tracer, secretary)
- Systems integration, Interfaces, and procurement mgmt. are included in the 4 sub-systems

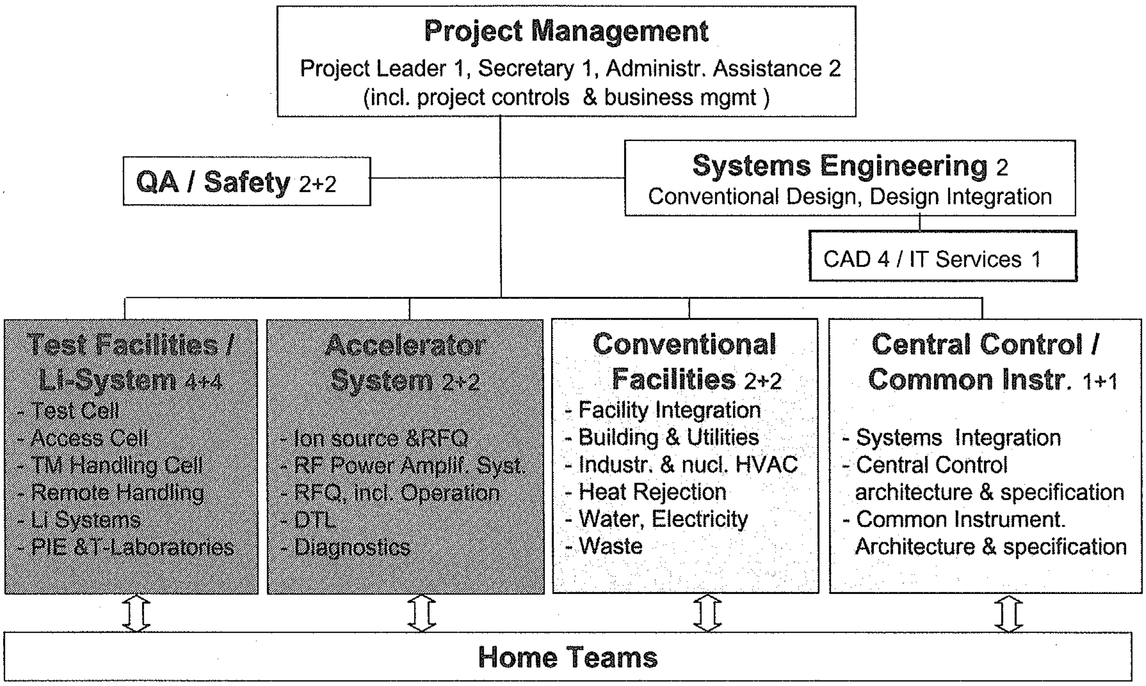
IFMIF: Cost of EVEDA (EFDA suggestion 13-Nov-2003) Unit: MICF

	Home Teams		Central Team		Total	
	Engineering Validation	Design	*	**	Internatnl	Local
Accelerator Facility	22.6	11.8	1.76		36.16too much ok	
Target Facility	17	5.0	0.88		22.88	
Test Facility	9.1	5.9	0.88		15.88	
CT: Convent. Facils, CC&CI	-	1.0	1.76		1.76	
CT: QA, safety, Site, SE	-	1.0	2.64		2.67	
CT: Mgt, Adm. Asst.	-	-	2.94		3.36	
CT: Office operation Supporting Personnel**	-	-	0.63	3.12	0.63	3.12
Total	73.4		14.61		84.89	3.12

** Born by Local Host of Central Team 8 Supporting Personnel @78MICF/yr (Local Host)

IFMIF: EVEDA Central Team

13-Nov-2003



- Staff of Central Team: 1 Manager + 15 Professionals + 17 Support Personnel (e.g. CAD tracer, secretary)
- Systems integration, Interfaces, and procurement mgmt. are included in the 4 sub-systems

IFMIF: Cost of EVEDA (13-Nov-2003)

Unit: MICF

	Home Teams		Central Team	Total
	Engineering Validation	Design		
Accelerator Facility	20	9.8	2.68	32.48fine
Target Facility	17	3.0	2.68	22.68
Test Facility	9.1	3.9	2.68	15.68
CT: Convent. Facils, CC&CI	-		4.02	4.02
CT: QA, safety, Site, SE	-		6.74	6.74
CT: Mgt, Sec., Adm. Asst., Proj. Cont., Bus. Mgmt.	-	-	3.40	3.40
CT: Office operation	-	-	0.63	0.63
Total	62.8		22.83*	85.63

* Staff: 1 Manager @ .235MICF/yr + 15 Professionals @ .176 MICF/yr + 17 Support Personnel @ .92 MICF/yr

IFMIF EVEDA: Comments to Structure & Cost (1/2) (13-Nov-2003)

Structure:

- The suggested structure of EVEDA is based on IFMIF meetings, subsequent discussions with EFDA and FZK Fusion Project management, and includes experience from ITER. The 4 sub-systems have been categorized on the basis of major WBS elements. Systems integration, Interfaces, and procurement mgmt. are included in the 4 sub-systems
- As EVEDA is not yet IFMIF construction, the majority of commentators suggested a significant budget cut of " Project controls & business management". In the most recent plan, this activity has been included in the Project management.
- "ITER people" confirmed that the size of this Central Team should not fall below the staff defined in the tables (1 manager, 15 scientists/engineers, 17 supporting personnel)
- In agreement with some sub-system leaders, and also suggested by ITER experts, a fraction of the "Engineering Design" of the home teams was moved to the Central Team

Cost:

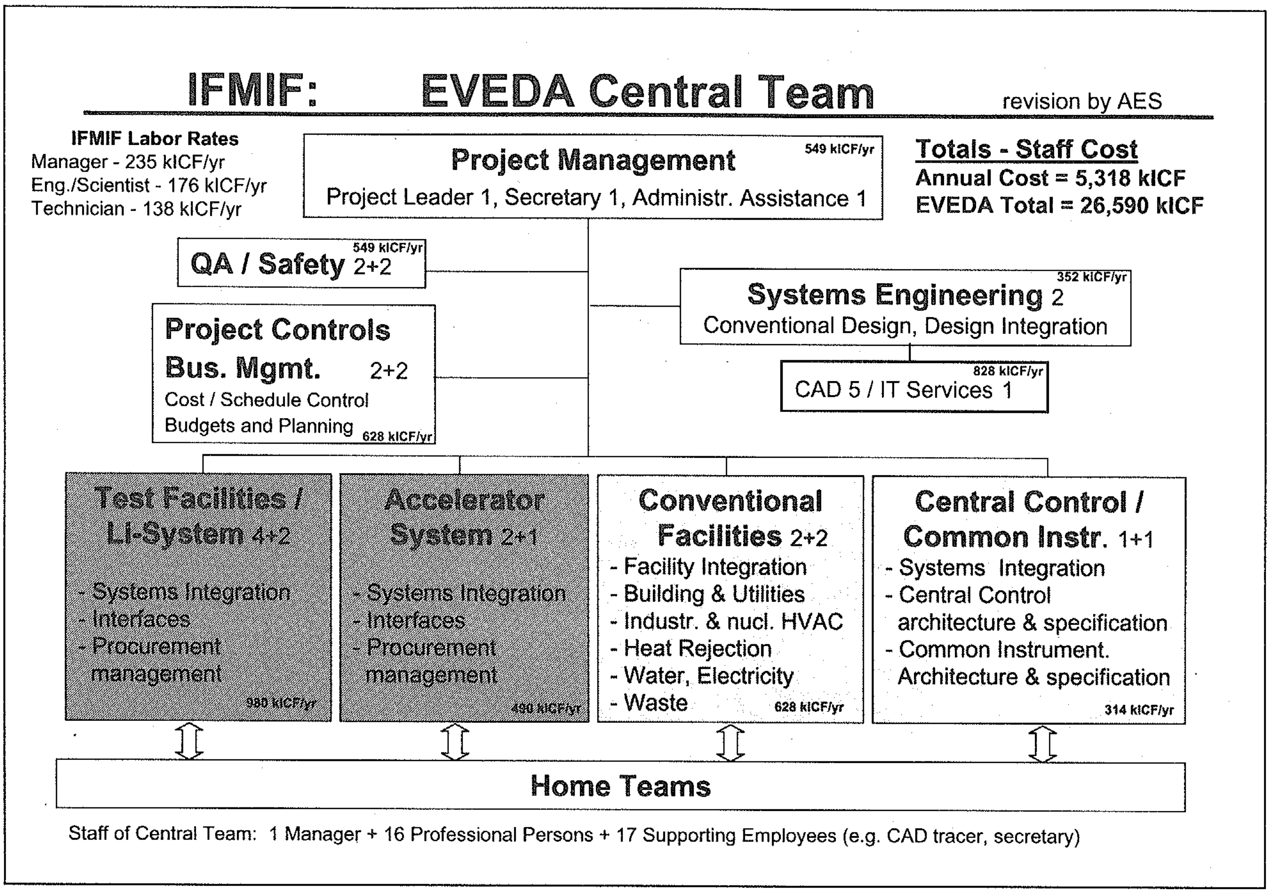
- Due to general boundary conditions, it has been originally tried to keep the budget below ~80 and 82 KICF, respectively.
- This requirement can be kept (see table next page), if domestic personal costs are allowed for the cost evaluation of the Central Team.

IFMIF EVEDA: Comments to Structure & Cost (1/2) (13-Nov-2003)

Cost (continued):

- However, also EFDA requests now to take for the evaluation of the EVEDA Central Team the international cost mix specified earlier this year. The argument is, to provide a self consistent basis for the domestic CDR assessment. In Europe, such an assessment is presently being prepared.
- At the bottom line, it is suggested to implement in chapter 6 (Cost estimate) of the CDR the following information:
  - EVEDA structure: Page 1 (or a minor modification) of this power point slide
  - EVEDA cost: Page 2 (or a minor modification) of this power point slide
- Can we defend in EU and JA the higher EVEDA cost ?
  Likely yes. In order to avoid serious problems later during the set-up of EVEDA, a self consistent grand total is needed today (e.g. EFDA position). In addition, any domestic assessment is going to use also domestic personal costs. Compared to the IFMIF On-site cost in kICF, the real costs in JA and EU have become smaller also due to the different conversion rates: While for the IFMIF cost assessment 1 Euro =1 $ has been defined, the present conversion rate is 1 Euro = 1.17 $. Similar changes happened to the ratio between Yen-$. Therefore, the "real" costs in Japan and Europe of EVEDA can be likely kept significantly below 86 M.

Category	IFMIF on-site cost (internat. mix, specified spring 2003)	EFDA (official basis, Nov 2003)
Manager	236 kICF	Not specified on EFDA level
Engineer/Scientist	176 KICF	149 kEuro
Technician	138 kICF	96 kEuro
Shop, Craft, CAD tracer,.....	92 KICF	Not specified on EFDA level; Each Association takes its individual numbers



IFMIF: Cost of EVEDA (with Taxes, revision by AES)

Unit: MICF

	Home Teams		Central Team	Total
	Engineering Validation	Design		
Accelerator Facility	22.6	9.2	2.45	34.25
Target Facility	18	4.0	2.45	24.45
Test Facility	10.1	4.9	2.45	17.45
CT: Convent. Facils, CC&CI	-	-	4.71	4.71
CT: QA, safety, Site, SE	-	-	7.26	7.26
CT: Mgt, Sec., Adm. Asst., Proj. Cont., Bus. Mgmt.	-	-	5.89	5.89
CT: Office operation +2 CAD	-	-	0.42 1.38	1.8
Total	68.8		27.0*	95.8

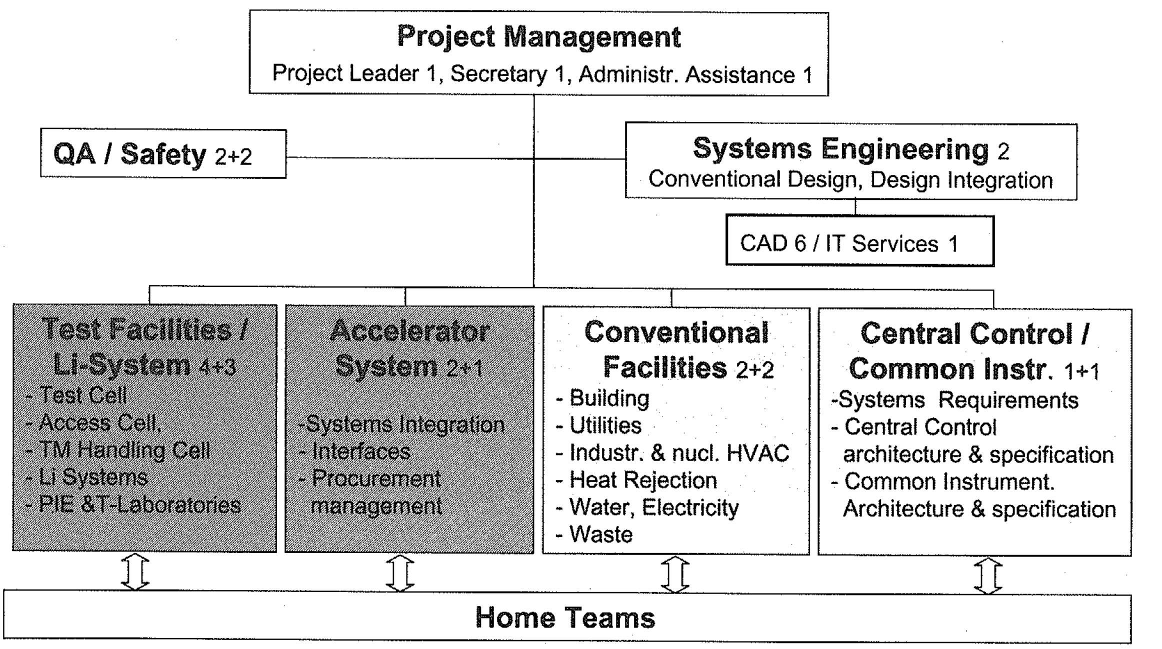
* Staff - 1 Manager @ .235MICF/yr + 16 Professionals @ .176 MICF/yr + 17 Support Personnel @ .138 MICF/yr

IFMIF: Cost of EVEDA (without Taxes, revision by AES) Unit: MICF

	Home Teams		Central Team	Total
	Engineering Validation	Design		
Accelerator Facility	20.15	9.2	2.45	31.80
Target Facility	15.55	4.0	2.45	22.0
Test Facility	7.65	4.9	2.45	15.0
CT: Convent. Facils, CC&CI	-	-	4.71	4.71
CT: QA, safety, Site, SE	-	-	7.26	7.26
CT: Mgt, Sec., Adm. Asst., Proj. Cont., Bus. Mgmt.	-	-	5.89	5.89
CT: Office operation +2 CAD	-	-	0.42 1.38	1.8
Total	61.35		27.0*	88.35

* Staff - 1 Manager @ .235MICF/yr + 16 Professionals @ .176 MICF/yr + 17 Support Personnel @ .138 MICF/yr

IFMIF: EVEDA Central Team (Oct. 2003) - draft-



Staff of Central Team: 15 Professional Persons + 17 Supporting Employers (e.g. CAD tracer, secretary)

IFMIF: Cost of EVEDA (Oct. 2003)

Unit: MICF

	Home Teams		Central Team	Total
	Engineering Validation	Design		
Accelerator Facility	20	9.8	2.0	31.8
Target Facility	17	3.0	2.0	22.0
Test Facility	9.1	3.9	2.0	15.0
CT: Convent. Facils, CC&CI	-	-	3.0	3.0
CT: QA, safety, Site, SE	-	-	4.0	4.0
CT: Mgt, secretary, CAD	-	-	2.0	2.0
CT: Office operation+2 CAD	-	-	1.8	1.8
Total	62.8		16.8*	79.6

* 15 Professionals are included (15 x 5yr x 0.2MICF/yr = 15 MICF); each professional includes a CAD tracer
This revision is based on Garching Meetings (1-2 Oct 2003; 29 Oct 2003), and a proposed central team structure

IFMIF
International Fusion Materials Irradiation Facility

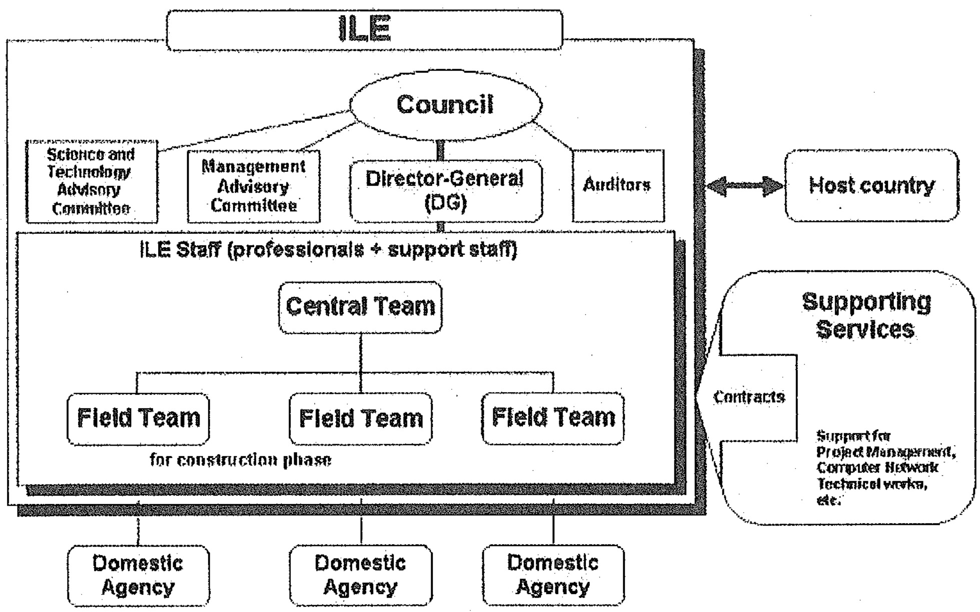
ILE of IFMIF Construction

JAERI

IFMIF Technical Meeting, Kyoto Japan, 4-5 December , 2003

LTER–ILE Organization (hearing by JP)

- ILE consist of Central Team and Field Teams
- Central Team: 840PPY during 10 years (1 Professional with 1 Support)
- Field Teams : 960PPY during 10 years (1 Professional with 2 Support)



LTER–Management Cost (hearing by JP)

			Cost (kIUA)	Ratio	Personnel
1) Project Management			477	14.5%	
	Central Team	Professional	126	3.8%	840PY
		Support	63	1.9%	840PY
	Field Teams	Professional	144	4.4%	960PY
		Support	144	4.4%	1920PY
2) Direct Capital Cost			2755	83.7%	-
3) R&D during construction			60 (-80)	1.8%	-
Total			3292	100%	4560PY

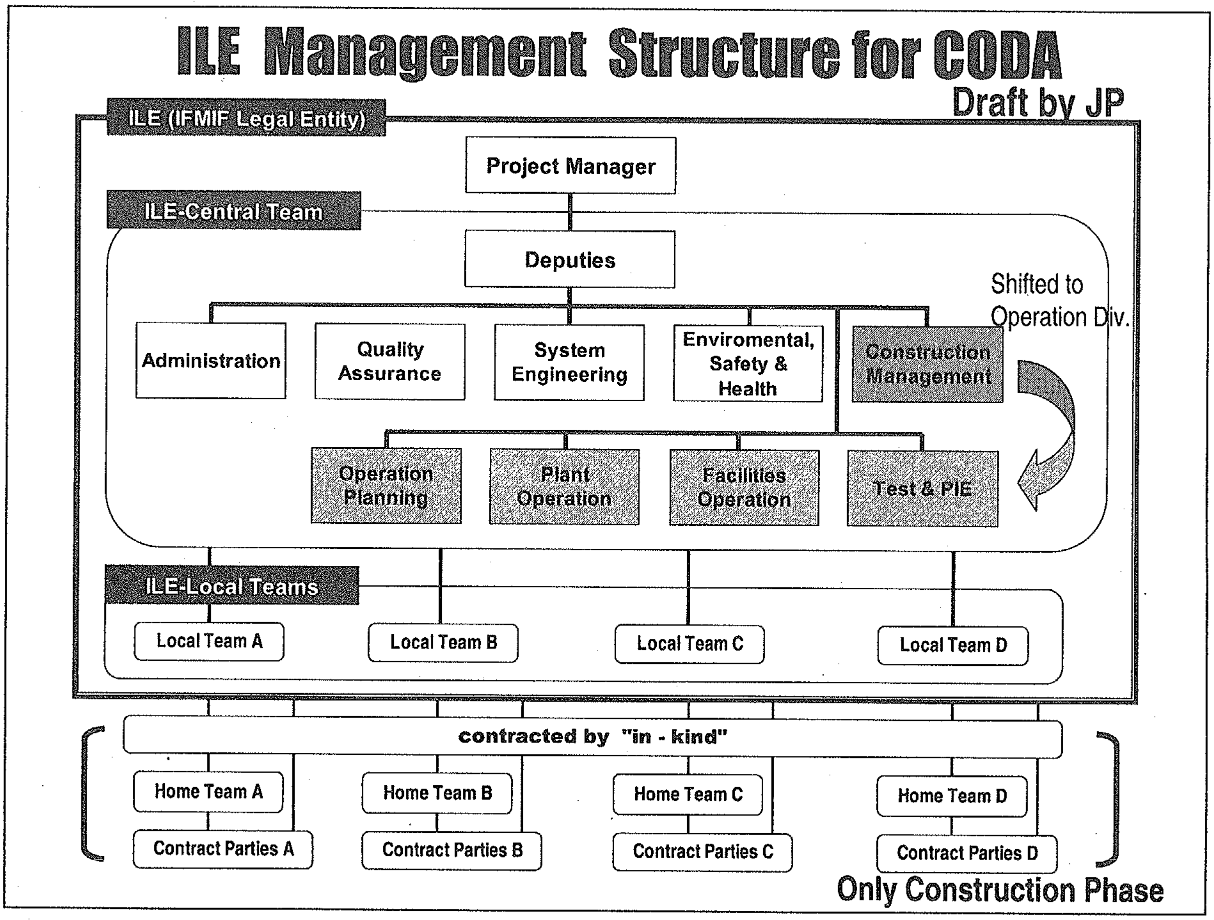
Personnel rates: Professional @ 150 IUA / y, Support @ 75 IUA / y

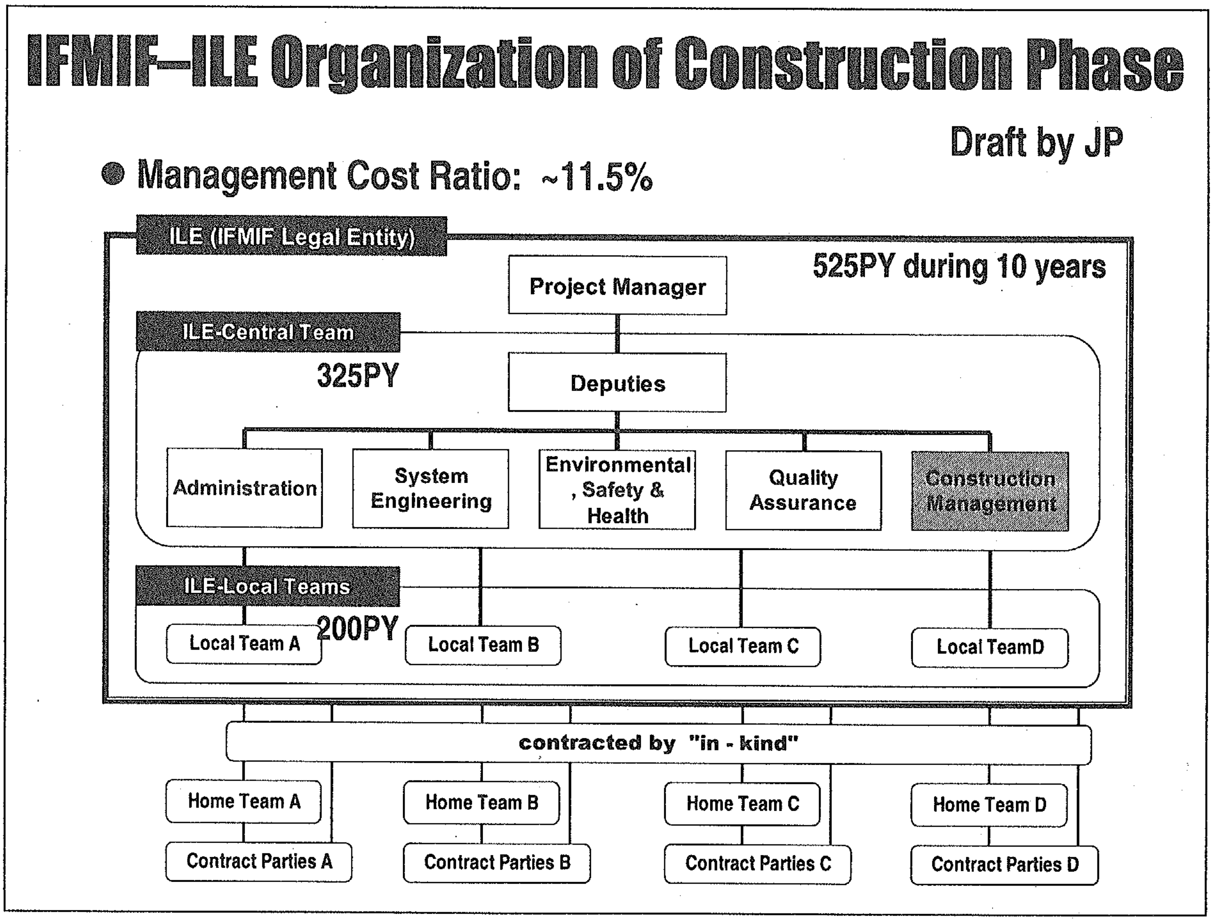
For IFMIF-ILE, Management cost ratio is 10~12%

LTER–ILE Management Cost (hearing by EU)

		Cost (kIUA)	Ratio	Personnel
1) Project Management		714	19.1%	
	Central Team	338		4517
	Field Teams	376		5060
2) Direct Capital Cost		3025	80.1%	-
3) R&D during construction		-	-	-
Total		3739	100%	9577PY

For IFMIF-ILE, Management cost ratio is 10~20%


ILE Management Structure for CODA
Draft by JP
ILE (IFMIF Legal Entity)
Project Manager
ILE-Central Team
Deputies
Shifted to Operation Div.
Administration
Quality Assurance
System Engineering
Enviromental, Safety & Health
Construction Management
Operation Planning
Plant Operation
Facilities Operation
Test & PIE
ILE-Local Teams
Local Team A
Local Team B
Local Team C
Local Team D
contracted by "in - kind"
Home Team A
Home Team B
Home Team C
Home Team D
Contract Parties A
Contract Parties B
Contract Parties C
Contract Parties D
Only Construction Phase


IFMIF-ILE Organization of Construction Phase
Draft by JP
Management Cost Ratio: ~11.5%
ILE (IFMIF Legal Entity)
Project Manager
525PY during 10 years
ILE-Central Team
325PY
Deputies
Administration
System Engineering
Environmental, Safety & Health
Quality Assurance
Construction Management
ILE-Local Teams
200PY
Local Team A
Local Team B
Local Team C
Local TeamD
contracted by "in - kind"
Home Team A
Home Team B
Home Team C
Home Team D
Contract Parties A
Contract Parties B
Contract Parties C
Contract Parties D

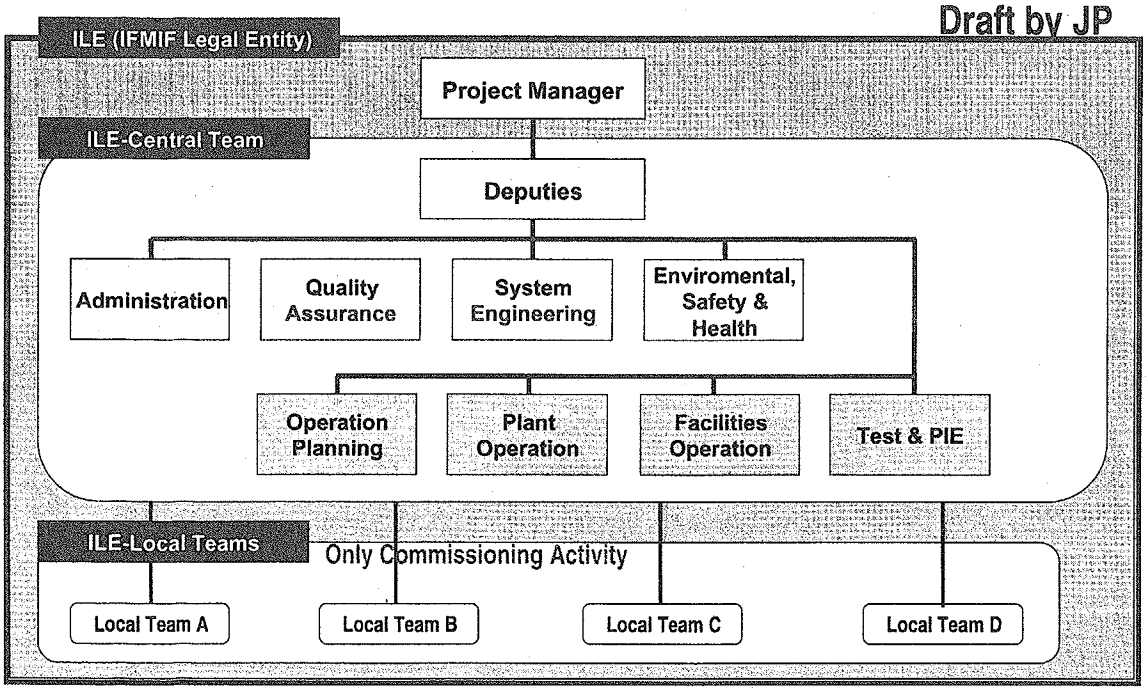
Staffing Plan of Construction Phase ILE

Description	1 '10	2 '11	3 '12	4 '13	5 '14	6 '15	7 '16	8 '17	9 '18	10 '19	Total
	Construction and Installation & Checkout										
			Startup & Commissioning								
								125mA Operation			
Project Manager	4	4	4	4	4	4	4	2	2	2	34
Director & Deputy	2	2	2	2	2	2	2	1	1	1	17
Support	2	2	2	2	2	2	2	1	1	1	17
Administration	6	7	7	7	6	6	4	4	4	4	55
Professional Officer	3	3	3	3	3	3	2	2	2	2	26
Support	3	4	4	4	3	3	2	2	2	2	29
System Engineering	4	5	6	6	6	5	4	3	3	0	42
Manager	1	1	1	1	1	1	1	1	1	0	9
Engineer	2	3	4	4	4	3	2	1	1	0	24
Support	1	1	1	1	1	1	1	1	1	0	9
Environmental, Safety & Health	4	4	5	5	5	4	4	2	2	2	37
Engineer	2	2	3	3	3	2	2	1	1	1	20
Support	2	2	2	2	2	2	2	1	1	1	17
Quality Assurance	4	4	4	4	4	4	4	2	2	2	34
Engineer	2	2	2	2	2	2	2	1	1	1	17
Support	2	2	2	2	2	2	2	1	1	1	17
Construction Management	16	17	18	18	17	12	12	5	5	3	123
Manager & Deputy	2	2	2	2	2	2	2	1	1	1	17
Engineer	10	10	10	10	9	6	6	2	2	0	65
Support	4	5	6	6	6	4	4	2	2	2	41
Central Team Total	38	41	44	44	42	35	32	18	18	13	325
Manager & Deputy	5	5	5	5	5	5	5	3	3	2	43
Engineer	19	20	22	22	21	16	14	7	7	4	152
Support	14	16	17	17	16	14	13	8	8	7	130
Local Teams Total	20	24	28	28	28	20	20	12	12	8	200
Engineer	10	12	14	14	14	10	10	6	6	4	100
Support	10	12	14	14	14	10	10	6	6	4	100

IFMIF–ILE Organization of Operation Phase

(Startup & commissioning, 125-mA & 250-mA Operation)

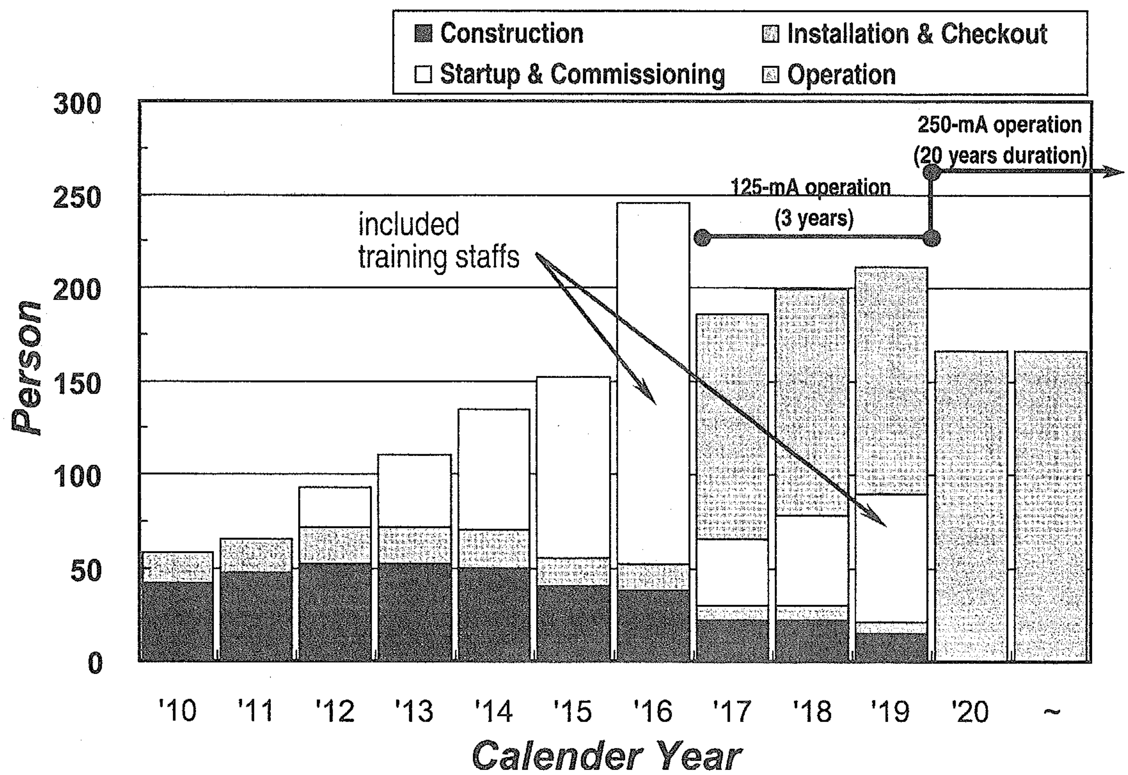
Draft by JP



ILE Staffing Plan for Operation Phase

Description			1 '10	2 '11	3 '12	4 '13	5 '14	6 '15	7 '16	8 '17	9 '18	10 '19	11~ 20~39 (annual)	Total1 '10~'19 (10 years)	Total2 '10-'39 (30 years)
			Construction and Installation & Checkout												
					Startup & Commissioning										
										125mA Operation					
Project Manager		Startup & Commissioning			2	2	2	2	2	1	1	1		13	
		125mA & 250mA Operation								1	1	1	4	3	83
Administration		Startup & Commissioning			2	2	4	4	4	2	2	2		22	
		125mA & 250mA Operation								2	2	2	6	6	126
System Engineering		Startup & Commissioning			3	3	4	4	4	3	3	3		27	
		125mA & 250mA Operation								3	3	3	6	9	129
Environmental, Safety & Health		Startup & Commissioning			2	2	2	2	2	2	2	2		16	
		125mA & 250mA Operation								3	3	3	4	9	89
Quality Assurance		Startup & Commissioning			2	2	2	2	2	2	2	2		16	
		125mA & 250mA Operation								2	2	2	3	6	66
Operation Planning		Startup & Commissioning					3	3	5	2	2	2		17	
		125mA & 250mA Operation								3	3	3	5	9	109
Test & PIE		Startup & Commissioning						4	23	3	3	10		43	
		125mA & 250mA Operation								20	20	20	30	60	660
Plant Operation		Startup & Commissioning			3	7	14	14	29	3	3	5.5		78.5	
		125mA & 250mA Operation								28	28	28.5	34	84.5	764.5
	Plant Operation	Startup & Commissioning			3	3	6	6	13	1.5	1.5	3		37	
		125mA & 250mA Operation								12.5	12.5	13	16	38	358
	Central Control	Startup & Commissioning				4	4	4	12	1	1	2		28	
		125mA & 250mA Operation								12	12	12	14	36	316
	Maintenance	Startup & Commissioning					4	4	4	0.5	0.5	0.5		13.5	
		125mA & 250mA Operation								3.5	3.5	3.5	4	10.5	90.5
Facilities Operation		Startup & Commissioning			4	6	16	20	65	6	6	14.5		137.5	
		125mA & 250mA Operation								59	59	58.5	74	176.5	1656.5
	Accelerator Facility	Startup & Commissioning			4	6	8	8	36	3	3	11.5		79.5	
		125mA & 250mA Operation								33	33	32.5	45	98.5	998.5
	Target Facility	Startup & Commissioning					4	8	15	1.5	1.5	1.5		31.5	
		125mA & 250mA Operation								13.5	13.5	13.5	15	40.5	340.5
	Test Facilities	Startup & Commissioning					4	4	14	1.5	1.5	1.5		26.5	
		125mA & 250mA Operation								12.5	12.5	12.5	14	37.5	317.5
Central Team Total					*18*	*24*	*47*	*57*	*140*	*26*	*26*	*44*		*382*	
Startup & Commissioning		Manager & Deputy			3	3	4	5	5	2.5	2.5	2.5		27.5	
		Engineer			7	8	16	22	40	14.5	14.5	15.5		137.5	
		Technician			2	6	8	8	8	2	2	4		40	
		Support			6	7	19	22	87	7	7	22		177	
Local Teams Total					*3*	*14*	*18*	*40*	*54*	*9*	*22*	*25*		*185*	
Startup & Commissioning		Engineer			1	7	8	21	30	5	13	14		99	
		Technician			1	4	5.5	8.5	10	2.5	5.5	3		40	
		Support			1	3	4.5	10.5	14	1.5	3.5	8		46	
Central Team Total										*121*	*121*	*121*	*166*	*363*	*3,683*
125mA & 250mA Operation		Manager & Deputy								2.5	2.5	2.5	6	7.5	128
		Engineer								27.5	27.5	27.5	43	82.5	943
		Technician								9	9	9	13	27	287
		Support								82	82	82	104	246	2,326

Annual Personnel Profile of ILE



Comparison of ILE Organization

(Construction and Installation & Checkout)

(JAERI proposal 10/2003)

Project Manager & Administration			**89**
	Director & Deputy	M	17
	Support(Secretary)	S	17
	Professional Officer	E	26
	Support Office Staffs	S	29
ES&H			**37**
	Enginner	E	20
	Suport Staffs	S	17
Quality Assurance			**34**
	Enginner	E	17
	Suport Staffs	S	17
System Engineering			**42**
	Manager	M	9
	Enginner	E	24
	Support(Secretary)	S	9
Construction Management			**123**
	Mananger & Deputy	M	17
	Engineer	E	65
	Support Staffs	S	41
Local Teams			**200**
	Engineer	E	100
	Support	S	100
TOTAL			**525**

M : Manager
E : Engineer, Seientist
T : Technician
S : Secretary, Support, Clew, Craft

(AES proposeal 11/2003)

Project Office			**295**
	Project Director & Deputy	M	20
	Administrative & Technical Assoc.	E	20
	Project Control & MIS	T	72
	Businees Mgt.	E	70
	Information Technology	E	47
	Human Resources	T	30
	Secretarial & Office Staff	S	36
ES&H			**40**
	Manager	E	10
	Technical Staff	T	20
	Secretarial & Office Staff	S	10
Quality Assurance			**40**
	Manager	E	10
	Technical Staff	T	20
	Secretarial & Office Staff	S	10
Subconstracts & Procurement			**90**
	Manager	E	10
	Technical Staff	T	70
	Secretarial & Office Staff	S	10
Construction Management			**80**
	Manager	M	10
	Material Control	T	26
	Engineering / Logistics	E	34
	Secretarial & Office Staff	S	10
TOTAL			**545**

System Engineering			**130**
	SE Manager	M	10
	Secretarial & Office Staff	S	19
	Configuration Control	E	20
	Systems Requirements & Specs.	E	14
	Sysyem Analysis	E	16
	System Integration	E	17
	Test and Evaluation	E	18
	RAMI & FMEA	E	16

1. PROJECT MANAGEMENT

The IFMIF project management organization is structured with two levels, overall IFMIF Project Management (level-1), and Facility Systems Management (level-2). The filled boxes of Figure-1 represent level-1, which are considered "on-site" or "home team" functions and have more recently been termed the IFMIF Legal Entity (ILE); and the unfilled boxes represent level-2, which may be "off-site" functions and are part of the Facility Systems organizations. The project is structured so that all Facility Systems project phases (design through commissioning) come under the "on-site" ILE Construction Management function that is to be provided by a commercial A&E type management team. Once the IFMIF facility achieves full operational status, this A&E management team is dissolved. Prior to complete phase-out of Construction, a new "on-site" Operations organization will begin functioning and will transition to conduct all Facility Systems operations over a 20+year period. This management approach is typical of large projects in the US and has been derived from the SNS project management organization, which represents an applicable model. The SNS model is relevant to IFMIF by the fact that it is made up of a number of different national laboratories, each with their own management for their facility systems, and that ORNL represents the "home team", with equivalent top-level management. Furthermore, SNS is a green field operation as expected with IFMIF.

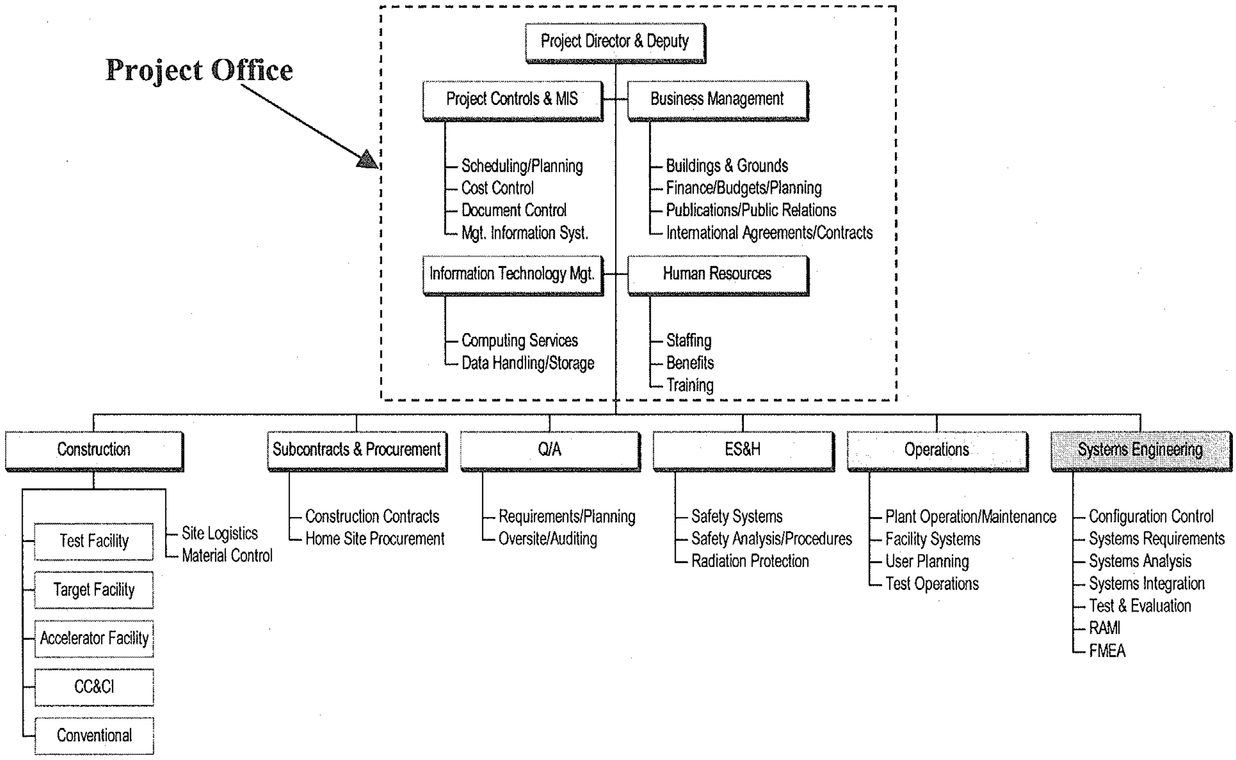


Figure 1: Proposed IFMIF Project Management Organization (ILE)

Although Systems Engineering is shown on the organization chart as part of the "home team", it is generally not considered a management cost. Instead it is carried under a separate WBS to reflect the fact that the associated costs are mote technical than management.

1.1 Level-1 Project Management or ILE (WBS 1.0)

This element includes all top-level project management and associated costs for the management, administration and control for the overall IFMIF project. The level-2 management of the Facility design, construction, testing and installation activities is included in the Facility Systems costs. This project management team should begin to form before completion of EVEDA, so that it is in place by construction approval, and will continue through full acceptance of IFMIF as an operational system in 2019. The peak employment years will be between start of Final Design at the beginning of the year 2010 and the completion of the major construction and commissioning elements of the first accelerator at the end of the year 2016. Since level-1 Project Management is considered an "on-site" task, it will be performed in the host country. The level-1 management functions are described in the following paragraphs. This organization is flexible in that it should remain in effect during the Operations phase; however, the Construction Management team will dissolve while Operations Management will take over, under the same project office. Project office staffing may also be modified for the operational phase. Systems Engineering, which is traditionally not part of the project management cost (usually it is costed under a separate WBS), will continue during the operational phase but will need to be re-organized to a lower staffing level and with some new functions to support operations and test.

1.1.1 Project Office

The Project Office includes the Project Director (PD) and Deputy PD, Project Controls and Management Information Systems, Business Management, Information Technology, Human Resources and General Office Staff (administrative & clerical). The PD has overall control over technical development of the IFMIF as well as the business aspects of running the program. Associate directors as required also support the PD from time to time.

The PD interfaces with the Contracting/International Government Agencies through the Business Management team. This team also facilitates all Government Agencies to Project business, and legal issues as well as Public Relations, and Buildings and Grounds.

The Project Controls & MIS team includes allocation of budgets to all managers, collection of monthly status and reporting of actual vs. planned costs, presentation of corrective planning for unacceptable deviations, and maintenance of an updated Cost to Complete. Scheduling and Tracking, also in this team, provides monthly status tracking of work accomplished against planned milestones, and also maintains a continually updated Plan to Complete.

The Information Technology team is responsible for setting up and maintaining all computing services, data handling and storage.

The Human Resources team oversees staffing and all employee related issues and benefits as well as providing training.

1.1.2 ES&H

ES&H includes personnel responsible for establishing and maintaining in ES&H policy that includes, procedures, conducting inspections and audits, and is structured in accordance with the regulations of the contracting agencies as well as the country responsible for the IFMIF Facility. A significant part of this effort is Radiation Safety and handling of Facility Waste. The ES&H activity reviews the IFMIF Facility Systems design evolution to determine consistency with safety guidelines that may influence the design for the site location of the host country. These guidelines by means of the subcontracting policy will be conducted to "off-site" suppliers of materials and services. As the IFMIF design matures, the ES&H activity will transition into establishment of procedures for conduct of work in the host country. This will be followed by observation, inspection and auditing the workplace staff and conditions to assure personnel and environmental safety.

1.1.3 Quality Assurance

Q/A includes the management and supporting personnel responsible for establishing and maintaining a quality assurance program that includes procedures, conducting inspections and audits of Q/A policy function, in accordance with the regulations of the contracting agencies as well as the host country responsible for the IFMIF facility. These functions by means of the subcontracting policy will be conducted to "off-site" suppliers of materials and services. The staff that is used to perform the day to day functions of performing material inspections and/or witnessing tests, identifying material and processes, logging statistical and test data, are not part of this management function.

1.1.4 Subcontracts and Procurement

Included in this function are Subcontract Managers assigned to oversee the business and legal points of large dollar subcontracts for the Construction Management team. The Procurement Manager and support staff is responsible for setting project procurement policy guidelines and requirements, as well as providing formal review and approval for procurement. This management activity must be in place prior to the time of authorization for long lead procurement and will continue at various levels of staffing until all subcontracts and purchase orders are complete. This also includes the staff that is used to perform the day-to-day functions of obtaining quotations from prospective suppliers, preparing purchase orders, and following up on invoices for the "on site" activities to support the Construction Management. This does not include the procurement effort under the level-2 Facility Systems. Instead, that part of the activity is treated as an indirect charge at level-2 and is built into the estimated direct labor rates of the IFMIF project.

1.1.5 Construction Management (CM)

CM provides planning, tracking, and day-to-day supervision over ALL construction activities, which include Material Control, and Facility Systems Construction (level-2). This function continues until the IFMIF Facility Systems are fully installed. As manufacturing and procurement phases down, this management function decreases to a sustaining level until the project enters the fully operational phase. It is assumed that a commercial A&E type firm will carry out the CM function.

- Material Control: this management function includes the establishment of procedures, monitoring of their compliance and corrective action as required to provide a smooth flow of material on the IFMIF project. This includes inventory control as well as material tracking functions for purchased, manufactured, and government agency provided material. Accountability for portable instrumentation and test equipment is also part of this activity. This management activity begins after approval for long lead procurement and continues at various levels of staffing until the IFMIF begins the full operation phase.

- Site Logistics: this function includes the planning, and supervision of all operations necessary to provide a smooth flow of "on site" construction activities. Such operations are handling of heavy equipment and components (transport, storage, etc.), scheduling and interleaving construction and installation activities so as not to interfere with each other as well as to be sequenced for maximum effcieincy.

- Facility Systems Management: make up the 2nd level of management as listed below:
  - Test Facility Manager
  - Target Facility Manager
  - Accelerator Facility Manager
  - Central Control and Common Instrumentation Facility Manager
  - Conventional Facility Construction Manager (A&E)

  These managers are not part of the level-1 organization; however, they report through the Construction Manager to the IFMIF Project Office. Their function is discussed under Level-2 Project Management.

1.1.6 Operations

This management team will begin to function late in the construction phase and primarily after the first accelerator is accepted. This team will take over planning for users and appropriate operation of the Facility Systems to support the experimental/test schedule. The team will function until the end of the operations phase, after which decommissioning will take place.

1.1.7 Systems Engineering (SE)

Traditionally, costs for SE functions are included under a separate WBS because the function is not specifically part of Project Management. In the IFMIF CDA report (1996) and some of the most recent work updating IFMIF, SE functions were included as part of Project Management. Subsequently, the overall cost of IFMIF Project Management could appear somewhat higher than the typical parametric (10 to 15% of Construction cost) for such projects. In this model we have kept with the tradition of a separate WBS for SE.

SE activities include development and flow down of System Requirements, Systems Analysis (system performance analysis, system trade-off studies, RAMI and FMEA analysis), Systems Integration (management of systems interfaces), and System Test (test planning, test execution, data acquisition and analysis, and performance validation) and Configuration Control. The actual conduct of testing functions will depend largely upon the staff that is in place for installation and commissioning of the Facility Systems. The System Test activity under the PM organization is more oversight and post-test review than actual conduct. During the early stages of the project, SE will have a strong influence upon the configuration and design detail of the Facility Systems that is conducted under Construction Management. SE will also provide Engineering Review Board (ERB) and Change Control Board (CCB) functions as a means of maintaining Design Control once a specified level of design is achieved.

The SE team should stay in place to support Operations; however, it should be re-organized in terms of staffing and function.

1.1.8 Staffing Plan and Estimated Cost of Level-1 Project Management

Development of the IFMIF staffing plan was performed by first examining each labor category from the SNS project to conduct an evaluation for applicability to IFMIF. Tailoring each labor profile in time with the IFMIF schedule was then performed. Consideration was given to the fact that the SNS staffing numbers are presently in the middle of the project time period, most probably at peaked values. Labor rates were applied using good judgments with the internationally agreed "on-site" values.

		FTE PER YEAR											
	Rate	10	11	12	13	14	15	16	17	18	19	FTE	COST
DESCRIPTION	**kICF/yr**											**Totals**	**kICF**
Project Management		**57**	**59**	**59**	**59**	**59**	**59**	**52**	**49**	**46**	**46**	**545**	**82262**
Project Office		32	32	32	32	32	32	27	26	25	25	295	46,200
Project Director & Deputy	235	2	2	2	2	2	2	2	2	2	2	20	4,700
Administrative & Technical Assoc.	176	2	2	2	2	2	2	2	2	2	2	20	3,520
Project Controls & MIS	138	8	8	8	8	8	8	6	6	6	6	72	9,936
Business Mgt.	176	8	8	8	8	8	8	6	6	5	5	70	12,320
Information Technology	176	5	5	5	5	5	5	5	4	4	4	47	8,272
Human Resources	138	3	3	3	3	3	3	3	3	3	3	30	4,140
Secretarial & Office Staff	92	4	4	4	4	4	4	3	3	3	3	36	3,312
ES&H		4	4	4	4	4	4	4	4	4	4	40	5440
Manager	176	1	1	1	1	1	1	1	1	1	1	10	1,760
Technical Staff	138	2	2	2	2	2	2	2	2	2	2	20	2,760
Secretarial & Office Staff	92	1	1	1	1	1	1	1	1	1	1	10	920
Quality Assurance	138	4	4	4	4	4	4	4	4	4	4	40	5440
Manager	176	1	1	1	1	1	1	1	1	1	1	10	1,760
Technical Staff	138	2	2	2	2	2	2	2	2	2	2	20	2,760
Secretarial & Office Staff	92	1	1	1	1	1	1	1	1	1	1	10	920
Subcontracts & Procurement		9	10	10	10	10	10	9	8	7	7	90	12340
Manager	176	1	1	1	1	1	1	1	1	1	1	10	1,760
Technical Staff	138	7	8	8	8	8	8	7	6	5	5	70	9,660
Secretarial & Office Staff	92	1	1	1	1	1	1	1	1	1	1	10	920
Construction Management		8	9	9	9	9	9	8	7	6	6	80	12842
Manager	235	1	1	1	1	1	1	1	1	1	1	10	2,350
Material Control	138	2	3	3	3	3	3	3	2	2	2	26	3,588
Engineering/Logistics	176	4	4	4	4	4	4	3	3	2	2	34	5,984
Secretarial & Office Staff	92	1	1	1	1	1	1	1	1	1	1	10	920

		Systems Engineering Is Not Part of Project Management Cost											
Systems Engineering		14	15	16	15	15	15	12	10	9	9	130	12,995
SE Management	235	1	1	1	1	1	1	1	1	1	1	10	2,350
Secretarial & Office Staff	92	2	3	3	2	2	2	2	1	1	1	19	1,748
Configuration Control	176	2	2	2	2	2	2	2	2	2	2	20	3,520
Systems Requirements & Specs.	176	2	2	2	2	2	2	1	1			14	2,464
Systems Analysis	176	2	2	2	2	2	2	1	1	1	1	16	30
Systems Integration	176	2	2	2	2	2	2	2	1	1	1	17	32
Test and Evaluation	176	1	1	2	2	2	2	2	2	2	2	18	35
RAMI & FMEA	176	2	2	2	2	2	2	1	1	1	1	16	2,816

1. Rates are international averages as of Sept., 2003, on-site burdened, no fee
2. The costs of SE are not part of PM.

1.1.9 Comparison With SNS

Construction Phase	SNS	US Revised IFMIF	
		w/o Systems Engineering	With Systems Engineering
Duration (years)	7.75	10	
Total Est. Cost of Level-1 Mgt. (MICF)	91 (1)	82.3	95.3
Total Est. Construction Cost w/o Mgt.	798.4 (1)	578	
Mgt. Cost as % of Construction Cost	11.4	14.2	16.5
Average Person Loads Over Duration	73.5 (2)	54.5	67.5
Project Office	*43*	*29.5*	*29.5*
Systems Engineering			*13*
ES&H	*5.5*	*4*	*4*
Q/A	*4*	*4*	*4*
Subcontracts & Procurement	*11*	*9*	*9*
Construction Management	*10*	*8*	*8*

Notes:

(1) Cost in US dollars CY2003
(2) Present staff on SNS approximately midway in the project (not averaged over duration)
(3) Estimated average staff based upon expected project cost over the duration

The comparison shown above illustrates that the proposed management cost ratio for IFMIF is somewhat higher than for SNS. This is due in part to the fact that IFMIF is not a fast track project and in many cases a minimum staffing level is necessary to carry out the given functions over time. Building and installing both accelerators simultaneously would result in a lower management cost ratio. This is further exacerbated by the fact that the construction number of 587 does not include pre-operational testing which is covered under the same management organization within the same time frame. Pre-operational testing for the 1st and 2nd accelerators is now 21.2 MICF and 15.5 MICF respectfully. Updated spreadsheets for these values are included in Appendix-A. We must also add the cost of the supporting Facility Infrastructure during the period from 2012 to 2016. This amounts to 24.4 MICF as shown in Appendix-B. The total project cost under the proposed management team is 639.1 MICF, bringing the parametric for management to 12.9%.

Based upon this recent evaluation with its caveats, it is believed that the proposed management effort is realistic, especially given the international coordination that will be necessary for such a project.

APPENDIX-A

1st ACCELERATOR PRE-OPERATIONAL TESTING (single shift)								ICF	
STAGE >	**Pre.**	**Inj.**	**RFQ**	**DTL #1**	**DTL #10**	**HEBT**	**Accept.**	**Monthly Rate**	**Total Labor Cost**
OPERATING PERIODS (Months) >	**3**	**3**	**9**	**9**	**12**	**9**	**3**		
SKILL	**STAFF TOTALS**								
								15.00%	<<Field Diff.
ADMINISTRATION	**3**	**3**	**3**	**3**	**3**	**3**	**3**	Note 1	
Plant Manager	1	1	1	1	1	1	1		
Office Support	1	1	1	1	1	1	1		
Visitor Control	1	1	1	1	1	1	1		
PLANT OPERATIONS	**12**	**13**	**15**	**17**	**19**	**19**	**19**	Note 1	
Shift Superintendent	1	1	1	1	1	1	1		
Plant Operators	1	1	2	3	4	4	4		
Plant Protection (3 shifts)	9	9	9	9	9	9	9		
Safety Officer	1	1	1	1	1	1	1		
HP Technicians		1	2	3	4	4	4		
TEST OPERATIONS		**0**	**0**	**0**	**0**	**0**	**4**	Note 1	
Experiment Control							2		
Operations Labor							2		
TARGET OPERATIONS		**0**	**0**	**0**	**0**	**0**	**2**	Note 1	
Supervision							2		
ACCELERATOR OPERATIONS		**13**	**20**	**24**	**27**	**29**	**29**		
Physics		2	2	4	4	4	4	Note 2	
Theoretical		1	1	2	2	2	2		
Experimental		1	1	2	2	2	2		
Operations Labor		5	9	10	13	15	15	Note 3	9,332,864
Cognizant System Eng.		1	2	3	3	4	4	15,547	2,360,035
Test Operations		1	2	2	3	4	4	15,547	2,199,123
Cont'l. Hardware Maint. Eng.		1	1	1	1	1	1	15,547	804,557
Software Maintenance Eng.		1	1	1	1	1	1	15,547	804,557
Diagnostics Eng.		1	1	1	1	1	1	15,547	804,557
RF Systems Eng.			1	1	2	2	2	15,547	1,180,017
RF Control (LLRF) Eng.			1	1	2	2	2	15,547	1,180,017
Technician Staff		3	5	6	6	6	6	Note 3	3,442,824
Electrical Power		1	1	1	1	1	1	11,880	614,790
Electronic/Instrumentation		1	1	1	1	1	1	11,880	614,790
Mechanical		1	1	1	1	1	1	11,880	614,790
Vacuum			1	1	1	1	1	11,880	573,804
RF			1	2	2	2	2	11,880	1,024,650
Craft/Shop		3	4	4	4	4	4	Note 3	1,791,240
Mechanical		1	1	1	1	1	1	8,800	455,400
Electrical		1	1	1	1	1	1	8,800	455,400
Machinist		1	2	2	2	2	2	8,800	880,440
MAINTENANCE		**2**	**2**	**3**	**3**	**3**	**3**	Note 1	
Maintenance Mgr.		1	1	1	1	1	1		
Shop Labor		1	1	2	2	2	2		
CENTRAL CONTROL		**2**	**2**	**2**	**4**	**4**	**4**	Note 1	
Central Control Operators		1	1	1	2	2	2		
Data Acquisition		1	1	1	2	2	2		
TOTALS		**33**	**42**	**49**	**56**	**58**	**64**		**14,566,928**
Electrical Use (MW-Hr)>>		**9.6**	**2081**	**1989**	**3389**	**3444**	**2254**	0.0855	**1,125,744**
							AFI Rate>	35.00%	**5,492,435**
GRANDE TOTAL									**21,185,108**

Note 1: Included in WBS 7
Note 2: Included in WBS 4.2.2 per the CDA
Note 3: Rates taken from the most recent international data as of Sept., 2003

2nd ACCELERATOR PRE-OPERATIONAL TESTING (single shift)								ICF	
STAGE >		Inj.	RFQ	DTL #1	DTL #10	HEBT	Accept.	Monthly Rate	Total Labor Cost
OPERATING PERIODS (Months) >		3	6	6	9	6	3		
SKILL	STAFF TOTALS								
								15.00%	<<Field Diff.
ADMINISTRATION		**3**	**3**	**3**	**3**	**3**	**3**	Note 1	
Plant Manager		1	1	1	1	1	1		
Office Support		1	1	1	1	1	1		
Visitor Control		1	1	1	1	1	1		
PLANT OPERATIONS		**13**	**15**	**17**	**19**	**19**	**19**	Note 1	
Shift Superintendent		1	1	1	1	1	1		
Plant Operators		1	2	3	4	4	4		
Plant Protection (3 shifts)		9	9	9	9	9	9		
Safety Officer		1	1	1	1	1	1		
HP Technicians		1	2	3	4	4	4		
TEST OPERATIONS		**0**	**0**	**0**	**0**	**0**	**4**	Note 1	
Experiment Control							2		
Operations Labor							2		
TARGET OPERATIONS		**0**	**0**	**0**	**0**	**0**	**2**	Note 1	
Supervision							2		
ACCELERATOR OPERATIONS		**13**	**20**	**24**	**27**	**29**	**29**		
Physics		2	2	4	4	4	4	Note 2	
Theoretical		1	1	2	2	2	2		
Experimental		1	1	2	2	2	2		
Operations Labor		5	9	10	13	15	15	Note 3	6,811,918
Cognizant System Eng.		1	2	3	3	4	4	15,547	1,716,389
Test Operations		1	2	2	3	4	4	15,547	1,609,115
Cont'l. Hardware Maint. Eng.		1	1	1	1	1	1	15,547	590,009
Software Maintenance Eng.		1	1	1	1	1	1	15,547	590,009
Diagnostics Eng.		1	1	1	1	1	1	15,547	590,009
RF Systems Eng.			1	1	2	2	2	15,547	858,194
RF Control (LLRF) Eng.			1	1	2	2	2	15,547	858,194
Technician Staff		3	5	6	6	6	6	Note 3	2,500,146
Electrical Power		1	1	1	1	1	1	11,880	450,846
Electronic/Instrumentation		1	1	1	1	1	1	11,880	450,846
Mechanical		1	1	1	1	1	1	11,880	450,846
Vacuum			1	1	1	1	1	11,880	409,860
RF			1	2	2	2	2	11,880	737,748
Craft/Shop		3	4	4	4	4	4	Note 3	1,305,480
Mechanical		1	1	1	1	1	1	8,800	333,960
Electrical		1	1	1	1	1	1	8,800	333,960
Machinist		1	2	2	2	2	2	8,800	637,560
MAINTENANCE		**2**	**2**	**3**	**3**	**3**	**3**	Note 1	
Maintenance Mgr.		1	1	1	1	1	1		
Shop Labor		1	1	2	2	2	2		
CENTRAL CONTROL		**2**	**2**	**2**	**4**	**4**	**4**	Note 1	
Central Control Operators		1	1	1	2	2	2		
Data Acquisition		1	1	1	2	2	2		
TOTALS		**33**	**42**	**49**	**56**	**58**	**64**		**10,617,544**
Electrical Use (MW-Hr)>>		**9.6**	**1506**	**1296**	**2693**	**2296**	**2254**	0.0855	**859,668**
							AFI Rate>	35.00%	**4,017,024**
GRANDE TOTAL									**15,494,237**

Note 1: Included in WBS 7

Note 2: Included in WBS 4.2.2 per the CDA

Note 3: Rates taken from the most recent international data as of Sept., 2003

APPENDIX-B

	ACCELERATOR INST'L. & PRE-OPERATIONL TESTING (single shift)								
STAGE >	**Pre.**	**Inj.**	**RFQ**	**DTL #1**	**DTL #10**	**HEBT**	**Accept.**		
TOTAL DURATION (Months) >	**3**	**3**	**12**	**12**	**18**	**9**	**3**		
SKILL	**FTE TOTALS**							**RATE per MO.**	**COST kiloICF**
								Note 1	
ADMINISTRATION	**3**	**3**	**3**	**3**	**3**	**3**	**3**		**2,099**
Plant Manager	1	1	1	1	1	1	1	19.58	1,175
Office Support	1	1	1	1	1	1	1	7.70	462
Visitor Control	1	1	1	1	1	1	1	7.70	462
PLANT OPERATIONS	**12**	**13**	**15**	**17**	**19**	**19**	**19**		**12,024**
Shift Superintendent	1	1	1	1	1	1	1	14.67	880
Plant Operators	1	1	2	3	4	4	4	11.50	2,139
Plant Protection (3 shifts)	9	9	9	9	9	9	9	11.50	6,210
Safety Officer	1	1	1	1	1	1	1	11.50	690
HP Technicians		1	2	3	4	4	4	11.50	2,105
TEST OPERATIONS		**0**	**0**	**0**	**0**	**0**	**4**		**157**
Experiment Control							2	14.67	88
Operations Labor							2	11.50	69
TARGET OPERATIONS		**0**	**0**	**0**	**0**	**0**	**2**		**88**
Supervision							2	14.67	88
ACCELERATOR OPERATIONS		**13**	**20**	**24**	**27**	**29**	**29**		Note 2
Physics		2	2	4	4	4	4		
Theoretical		1	1	2	2	2	2	14.67	
Experimental		1	1	2	2	2	2	14.67	
Operations Labor		5	9	10	13	15	15		
Cognizant System Eng.		1	2	3	3	4	4	14.67	
Test Operations		1	2	2	3	4	4	11.50	
Cont'l. Hardware Maint. Eng.		1	1	1	1	1	1	14.67	
Software Maintenance Eng.		1	1	1	1	1	1	14.67	
Diagnostics Eng.		1	1	1	1	1	1	14.67	
RF Systems Eng.			1	1	2	2	2	14.67	
RF Control (LLRF) Eng.			1	1	2	2	2	14.67	
Technician Staff		3	5	6	6	6	6		
Electrical Power		1	1	1	1	1	1	11.50	
Electronic/Instrumentation		1	1	1	1	1	1	11.50	
Mechanical		1	1	1	1	1	1	11.50	
Vacuum			1	1	1	1	1	11.50	
RF			1	2	2	2	2	11.50	
Craft/Shop		3	4	4	4	4	4		
Mechanical		1	1	1	1	1	1	7.67	
Electrical		1	1	1	1	1	1	7.67	
Machinist		1	2	2	2	2	2	7.67	
MAINTENANCE		**2**	**2**	**3**	**3**	**3**	**3**		**1,415**
Maintenance Mgr.		1	1	1	1	1	1	11.50	656
Shop Labor		1	1	2	2	2	2	7.67	759
CENTRAL CONTROL		**2**	**2**	**2**	**4**	**4**	**4**		**2,277**
Central Control Operators		1	1	1	2	2	2	11.50	1,001
Data Acquisition		1	1	1	2	2	2	14.67	1,276
TOTALS		**33**	**42**	**49**	**56**	**58**	**64**		**18,059**
							AFI Rate>	35.00%	
GRANDE TOTALS									**24,380**

Notes: 1) Rates taken from the most recently received international data as of Sept., 2003
2) Total labor cost for pre-operational testing excludes accelerator facility labor which is covered under a sepa
3) Electrical power cost for commissioning is included in the Pre-Operational spread sheet

Transition Tasks 2003 - Saclay

H2+ Ion Source Development
ECR source to be reoptimized for H2+.
- Emittaance measurement unit and Wien filter will be ready soon; then testing work will begin.

High Energy Beam Transport Beam Optics Design
- The HEBT task is almost finished, and they are preparing the report.
It is a difficult line, and they have worked a lot on the design, looking at different scheme, including duodecapoles etc...Today they are not able to achieve the requirement on the beam edges, and the line is too sensitive to the tuning. They are working on optimising the sensitivity, but nothing much can be done on the beam edges. We will have to transmit this information to the target people, or to switch to a raster scanner...(that we don't want up to now).

End-to End Study of Errors on the Beam Optics
The error studies from the RFQ entrance to the target spot is going to be made, but not started yet; still waiting for the HEBT. It will also include all the errors not included on the previous calculation.

RFQ Design Activities
The 2D cavity cross-section evolution along the 12.5m long RFQ is started but not finished (optimised on the reference cell, but needed to apply the shape on all the others...). The 3D calculation of the RFQ extremities is almost finished. The calculation of the number of coupling gap needed is almost done. The mathematical tools are OK and have been used for SPIRAL2. They need to apply it on the IFMIF design to understand the number of needed coupling, but also the number of tuners and their size.

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Transition Tasks 2003 - Japan

(Will be presented by Dr. Sugimoto/Dr. Maebara)

RFQ Design Activities

- Built and measured an RFQ cold-model cavity, using MAFIA to analyze frequency, modes. Find that steering modes should not be a problem, and that 3-section RFQ is satisfactory.

- Design of RFQ vacuum ports and evaluation of rf properties

- Design of rf power coupler

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Transition Tasks 2003 - IAP, Uni. Frankfurt

(Yearly Report, July 2002-June 2003, 15 pages)

Ion Source, LEBT, Diagnostic and RFQ Development

- H2+ Ion Source Development - investigating H2- option
- Determination of compensation degree within fringe fields in the LEBT.
- Non interceptive diagnostics development - CCD Camera improvement
-Diagnostic chamber and vacuum system design for the LEBT
- Investigation of beam injection into a RFQ by a Gabor lens LEBT

Investigation of the 4-Rod RFQ

Scheme of a 175 MHz IH/SuperconductingCH-DTL

- Detailed beam dynamics modeling, including errors, has been done.
- Low-power copper scaled test module has been built and used for field checks.
- Superconducting prototype 350 MHz cavity under construction.

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Transition Tasks 2003 - US

Summary of Activities from the US Effort for IFMIF During CY2003
IFMIF Meeting, October, 2003, Garching, Germany

Updated the accelerator and beam transport configuration

- Updated "Reference" Accelerator with 10 tank DTL (1 RF system per tank) per latest Saclay design
- Updated High Energy Beam Transport (HEBT) per 2002 AES analysis
- Revised power budget (next chart)

Does Not Include:

- Layout of the Diacrode based "Reference" RF System
  - However, all components have been identified, sized, and costed
  - Physical form factor of components does not impact building design
  - Requires further work to determine optimum layout (possible CY2004 work)

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Transition Tasks 2003 - US

Provided updated cost information for WBS 4 (accelerator facilities)

- Independently reviewed and restructured lower level WBS 4 elements to be more representative of the revised accelerator configuration.

- Independently reviewed and re-estimated all WBS 4 elements in ICF units

- US developed cost data spreadsheet is included herein

- Participated in reviewing international cost estimates as well, to assist the team in arriving at the most representative costs for IFMIF. Final IFMIF costs will be a blend of the US, European and Japanese inputs

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Transition Tasks 2003 - US

Provided extensive support to the EVEDA and CODA management, schedule and costing definition and detailing

- Provided a structure for revised project management, schedule and costs , and a structure for revised costing ground rules.

- Provided a structure and proposed that costs should be estimated by use of updated international averages for labor rates (including the addition of French rates)
  - Since different labor categories have changed more than the value of inflation over time, a current review was suggested and then accepted
  - Initially 6 labor categories were proposed. In the final analysis 4 categories were accepted
  - It was also proposed and agreed that "off-site" rates would be fully burdened thru fee and that "on-site" rates would not have fee

- Use of an international average electrical rate was also proposed and agreed upon (0.08554 ICF/kWhr)

- It was agreed that International average inflation of 10% will only be used where there is insufficient data to re-estimate costs

- US Inputs to IFMIF CDR Management Section, Prepared by J. Sredniawski, AES – November 5, 2003
  - Contents include comparison with SNS

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Transition Tasks 2003 - US

Developed a plan and costs for accelerator commissioning

- US proposed staffing plan generally adopted by the international team
  - –Approach employs a team buildup as each section of the accelerator is installed
  - –This team is used for both installation and commissioning steps
  - –Plan includes IFMIF facility infrastructure

- Commissioning steps represent new costs not accounted for in the CDA

- Costs have been separated
  - –Installation and checkout remains in WBS 4
  - –Commissioning (pre-operational testing) has been placed into WBS 7
  - –Operations costs remain in WBS 7

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11th International Conference on Fusion Reactor Materials December 7-12, 2003, Kyoto, Japan

IFMIF Accelerator Facility

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J. Rathke [d], J. Sredniawski [d], M. Sugimoto [e]

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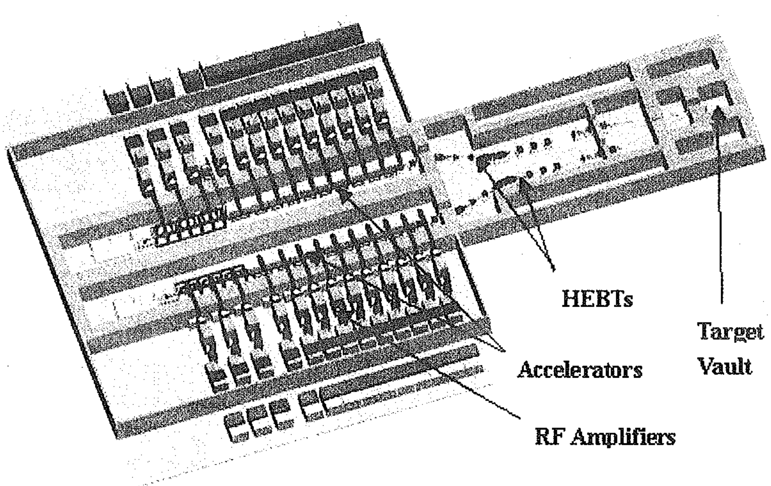
Isometric View of the IFMIF Accelerator Facility



IFMIF uses two Continuous Wave (CW) 175MHz linear accelerators, each providing a 125 mA, 40 MeV deuteron beam.

The accelerator reference design assumes utilization of conventional, room-temperature, RF linear accelerator (RF linac) technology.

Many aspects of the design are driven by the requirement for hands-on maintenance.

The IFMIF accelerators have been defined and detailed sufficiently for rough manufacturing and cost estimates.

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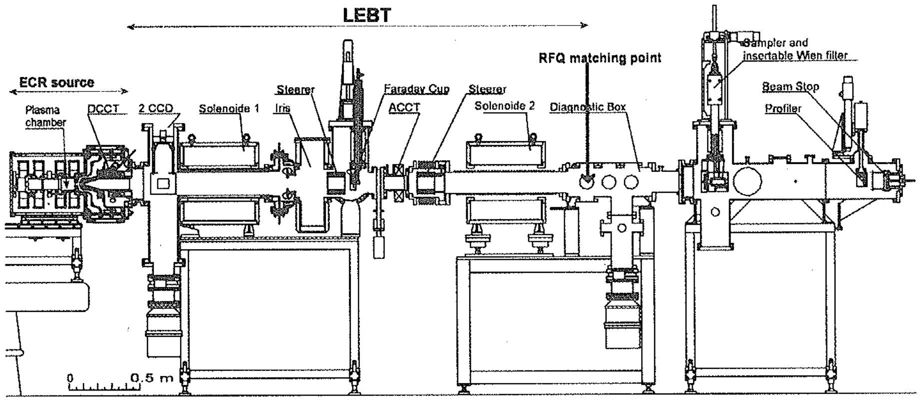
CEA Saclay IPHI injector configuration is the basis for the IFMIF injector.



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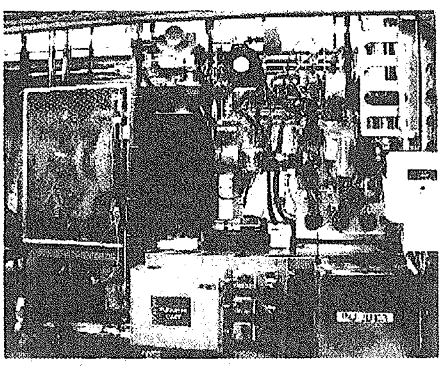
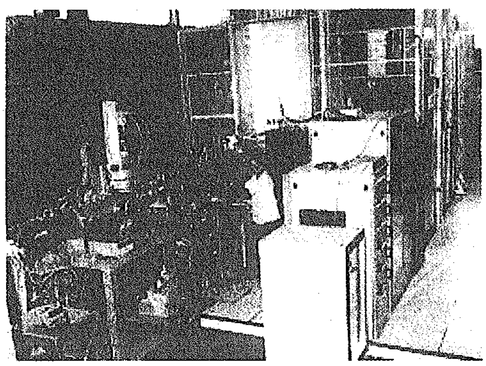
ECR Ion Sources at Los Alamos & Saclay





Status of IFMIF Injector

Extensive H^+ operational experience with the ECR ion source type has been obtained at CEA-Saclay (Fig. 2), with several very long runs of up to 1000 hours accumulated duration, with availability of >95% achieved [4].

LANL has also achieved long-term reliable operation from a similar ECR source.

Operation with a pulsed D^+ beam at CEA Saclay has also been demonstrated showing that IFMIF beam performance requirements can be achieved.

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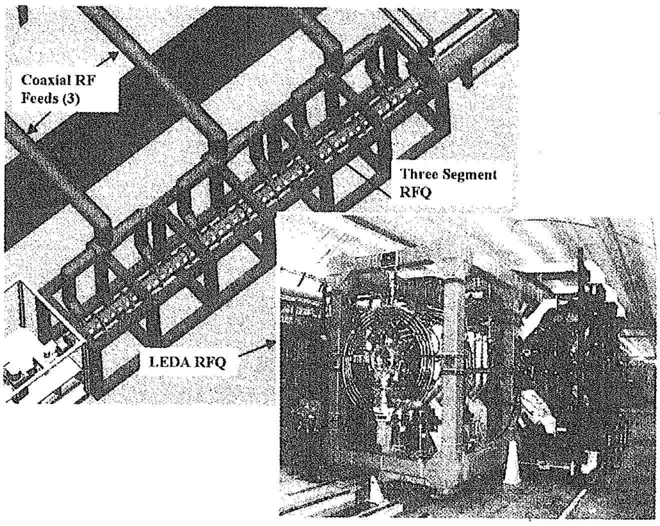
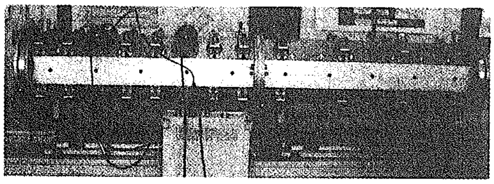
Conceptual Design of the IFMIF 12.5 Meter Long RFQ Compared to the LEDA RFQ.



LEDA Radio-Frequency Quadrupole (RFQ) accelerator with injector rolled back

The CEA Saclay IPHI RFQ & IFMIF RFQ Status



Agreement between measurements, 3d simulations and model validates mathematical formalism

Tuning procedures have been developed and experimentally validated.

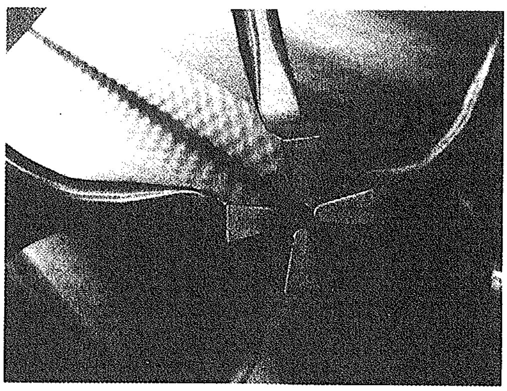
Now under construction,

IFMIF RFQ Status

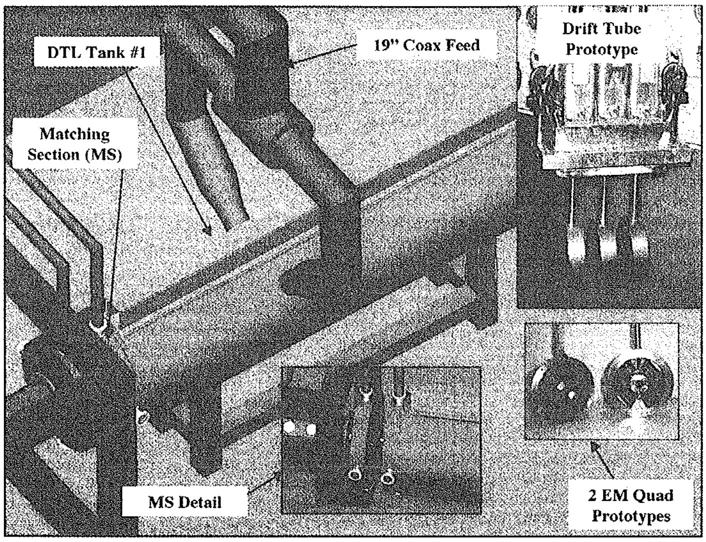
LANL 350 MHz prototype has operated for many hours.

Saclay 352 MHz prototype under construction.

Scalable to IFMIF 175 MHz frequency. Requires development of manufacturing methods.



Conceptual design of the IFMIF matching section and first Drift Tube Linac (DTL) tank.



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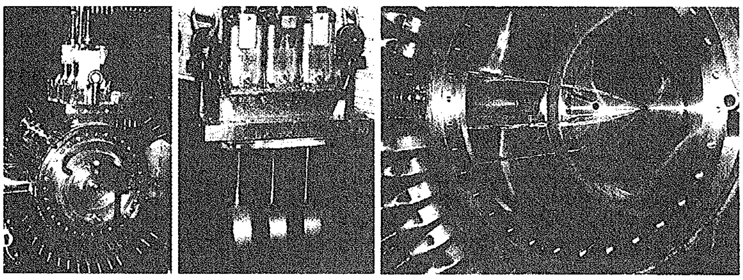
CEA Saclay DTL Hot Model & DTL Status



Left: the hot model fully assembled.

Middle: girder supporting the three drift tubes.

Right: interior view of the copper-plated stainless steel tank (the large aperture on the left being the pumping port).

IFMIF DTL Status

Saclay 352 MHz hot model has demonstrated technique.

Quadrupole magnet development accomplished.

Scalable to IFMIF 175 MHz frequency. Requires development of manufacturing methods.

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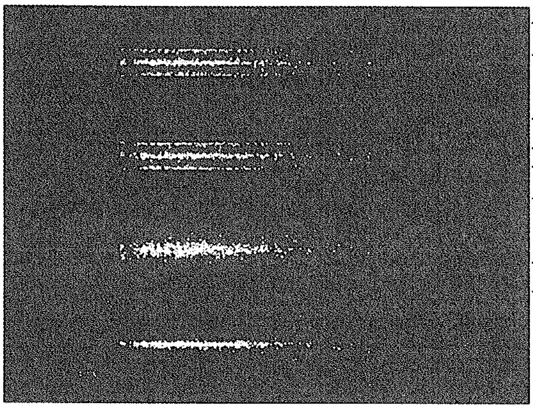
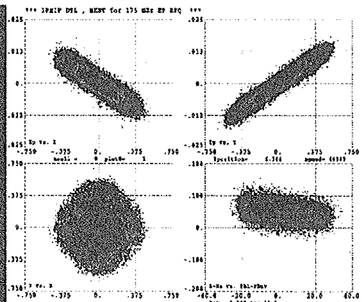
RFQ Beam Dynamics Design & Simulation





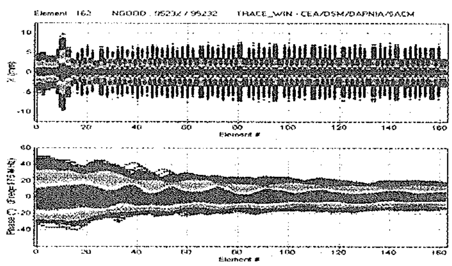
Right - output distribution of the RFQ at 5 MeV (input distribution of the DTL).

Left - transverse and longitudinal beam profilealong the four-vane-RFQ.

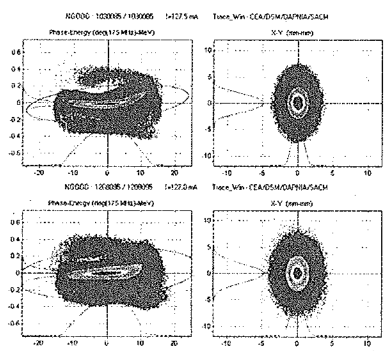
Status

Extensive design development by two groups. Designs meet IFMIF requirements.

DTL Beam Dynamics Design & Simulation



Transverse beam size and beam phase distribution along the DTL.



Above -Output distribution of the DTL at 40.3 MeV(without error simulation).
Below - Output distribution of the DTL at 40.3 MeV (with error simulation).

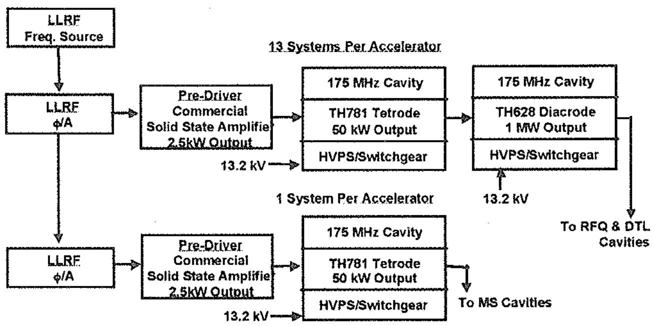
DTL Design & End-to-End Simulation Status

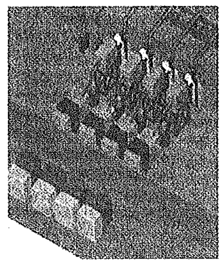
DTL Design and end-to-end particle dynamics simulations have been done by two groups.

Overall performance meets IFMIF requirements.

No losses are observed in the DTL.

IFMIF 175 MHz RF power system block diagram and conceptual design.





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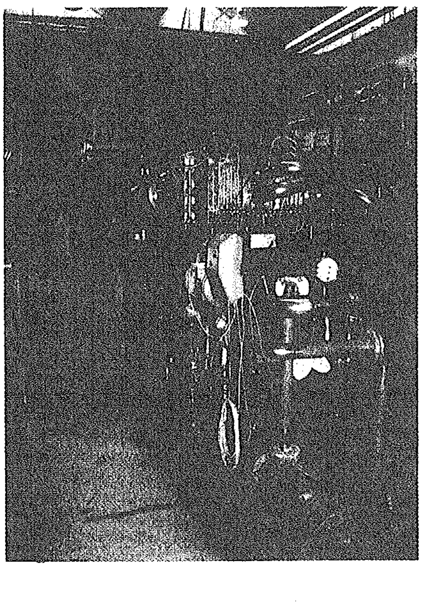
RF Power Amplifier Demonstration



Thales Electron Devices has developed a new kind of gridded tubes called DIACRODE which can overcome the limitations of the conventional tetrode, mainly the RF losses.

Endurance tests with a 200 MHz TH 628 Diacrode were performed during the IFMIF KEP, with over 1,047 hours at full cw power in the range of 1,010-1,030 kW into a resistive load, with a remarkably stable operating point.

This test fully demonstrating the diacrode's capability to operate at IFMIF relevant conditions (200 MHz and 1 MW CW).

The diacrode can be scaled to the IFMIF 175 MHz frequency

As the rf system is the most expensive accelerator subsystem, this demonstration of a reliable power amplifier is of utmost importance to the readiness for IFMIF construction.

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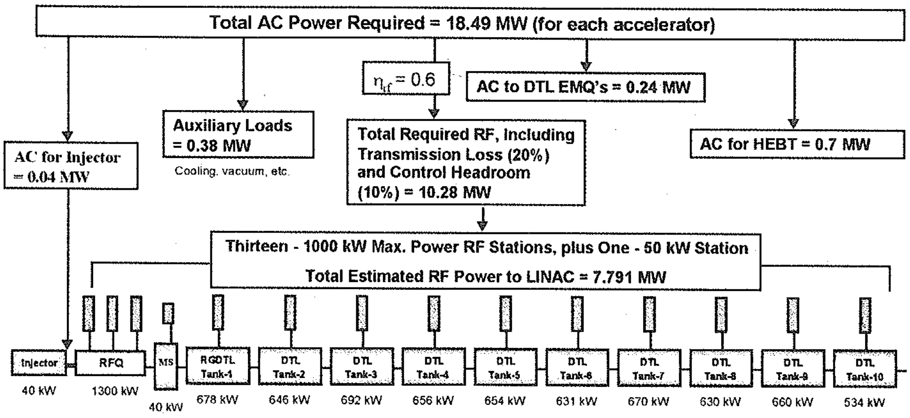
Electrical power requirements of a single IFMIF accelerator.



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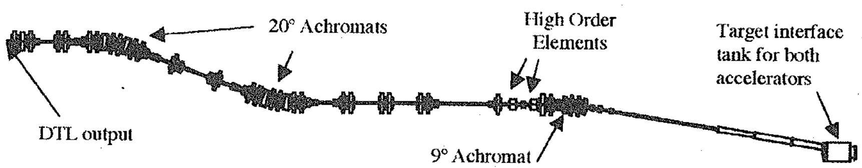
High-Energy-Beam-Transport (HEBT) layout for one accelerator.



The HEBT conveys a 40 MeV, 125 mA beam some 55 meters to the target and incorporates two twenty degree achromatic bends, FODO transport, a final focus and a final nine degree achromatic bend followed by a 17 meter drift to the target. On target, the requirement is for a beam uniformly illuminating a rectangle 20 cm in width by 5 cm in height. The beam footprint can be adjusted using different magnet settings; it should be possible, for example, to focus to a 10 x 5 cm footprint.

Design work to meet target requirements is in progress.

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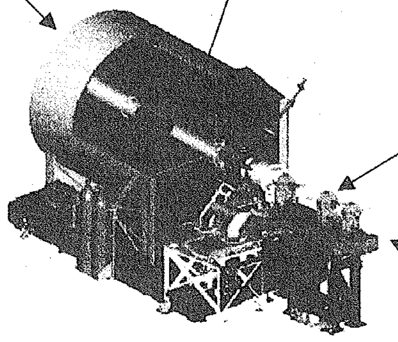
LEDA beam dump is the design basis of IFMIF beam calibration station.



Beam Diagnostics

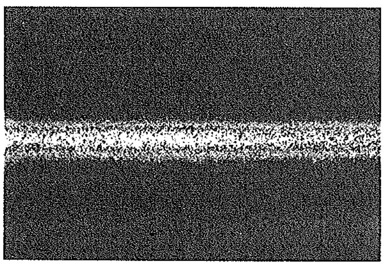


Image of a 2.5 mA proton beam interacting with hydrogen at 2.5 x 10^{-5} hPa observed 15cm after the iris with an intensified camera. The diameter of the beam is 9 mm.

CEA Saclay has conducted R&D on the measurment of the transverse beam profile of a high power beam.

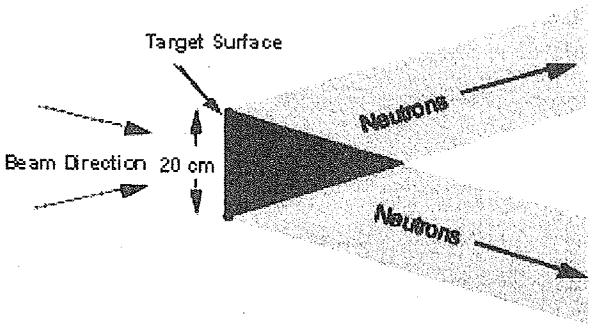
The current induced in a wire intercepting the beam could give a profile measurement. Unfortunately such a wire scanner would melt under CW operation in high power accelerators.

A proven way to measure the transverse beam profile under CW operation is based on the luminescence process and measurement of beam induced light. However, this method is very difficult to calibrate and is not sensitive enough at higher beam energy.

Absorption of laser light could be another method to measure transverse beam profile. Very preliminary results have been obtained.

These and other methods are under development.

Divergence geometry of neutron source for selected beam bending angle.



The angle at which the beam intercepts the target represents a compromise between maximizing the high flux volume in the test cell (favors smaller angle), and minimizing machine activation due to neutron back-streaming into the active beamline components (favors larger angle). A 9° beam-bending half-angle is acceptable.

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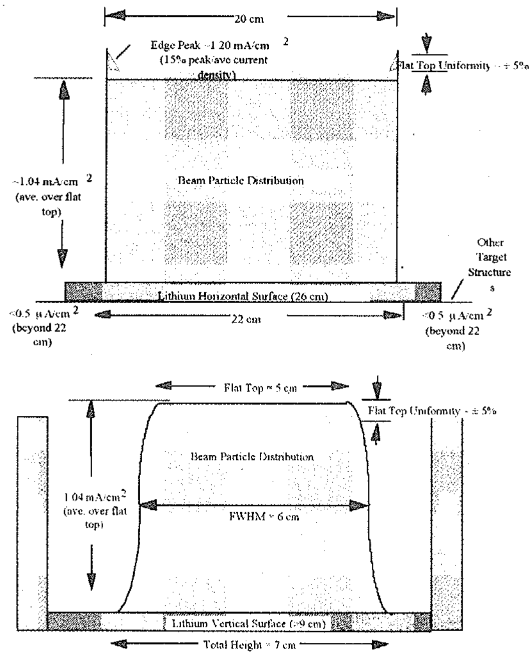
Requirements for Beam Profile on the Lithium Target



Horizontal - 20 cm

Vertical - 5 cm

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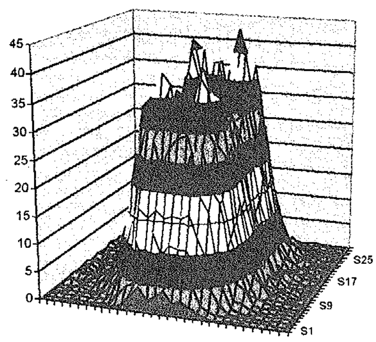
High Energy Beam Transport (HEBT) Simulation



Conceptual capability is demonstrated. Further design work is required to achieve desired flatness, edge peak minimization, and adequate tuning insensitivity.

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IFMIF Accelerator Facility RAM

The accelerator system and its components shall be designed to minimize the system's downtime and to assure minimum availability of 88 % during normal operation.

(From the overall availability budget for the IFMIF facility of 80.7 %, the test cell system allocation of 97.5 % and the target system allocation of 95 %, one obtains for the accelerator system an 87.1 % availability requirement.

It is assumed that both accelerators are always directing the beam to the target. Failure of one of the accelerators does not constitute an unavailability event for the IFMIF facility. In computing the total availability, half credit for operating with half of the current was taken. With this assumption, through application of the binomial theorem, the requirement for each accelerator was derived as 87.1 %.)

Detailed modeling tools for accelerator system RAM are available.

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Next Steps - Transition and EVEDA Phases

The IFMIF room-temperature accelerator technology reference design is at an advanced conceptual level, with proof-of-principle operation already demonstrated of the principal injector, RFQ and rf power amplifier subsystems. With an experienced team, the accelerator could proceed immediately to a construction project.

In the planned Engineering Validation and Engineering Design Activity (EVEDA):

- Complete the design for the accelerators to insure overall consistency of the conceptual design and to bring the overall accelerator design to the construction approval level for all components, sub-systems and support structure, including specifications, thermal/structural analysis, system activation, safety, and interface issues. Prepare detailed design for long lead time and staged contract procurements on critical path.
- beam validation tests with an IFMIF qualified injector, LEBT, RFQ transport cavity and diacrode rf amplifier are planned.
- beam diagnostics development will continue.
- investigation of potential advantages of superconducting accelerator technology will continue.

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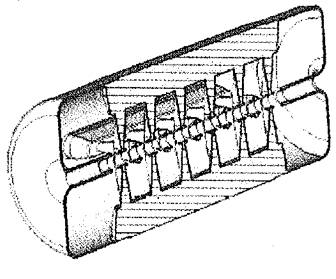
Technology alternatives

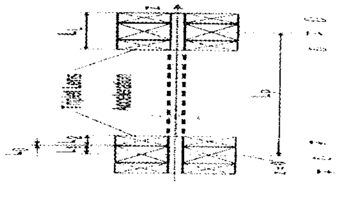
As accelerator technology continuing develops, new techniques may become advantageous to IFMIF before the construction project begins.

Evaluation of these also helps attract young persons to the project.

During the past decade, the technical and operational advantages of superconducting RF linacs have made them the technology of choice for many electron and heavy-ion beam applications. A similar set of advantages is currently being considered for the next generation of high-intensity ion linacs for tritium production, transmutation facilities and spallation neutron sources.

This technology base, including prototype tests planned by various institutions during the next five years, indicate that, after extensive study and prototyping, a superconducting linac could be an alternative for the 8 to 40 MeV portion of the IFMIF accelerator by the time it is actually built.





View of a superconducting CH mode cavity and lattice

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EVEDA task list for Accelerator Facilities.

		ID	Task	Contents
Accelerator Facilities	Engineering Validation	AF-1a	Develop H_2^+ ion source	Development of H_2^+ ion source for beam commissioning
		AF-1b AF-1d AF-1e	High power RFQ load cavity and engineering prototypes to support design	Design and construction high power RFQ-type load cavity used for high power RF test and as a beam matching diagnostic for the injector test stand prepared by Task AF-1g
		AF-1c	Complete RF power system to one coupler	Design, construction and integration of complete RF power system including one RF window/coupler and RF controls
		AF-1f	Beam diagnostics and instrumentation	Development of beam diagnostics, instrumentation
	Eng. Design	AF-2a AF-2b AF-2c AF-2d AF-2e	Engineering design activity	Complete design to the construction approval level of accelerator components, sub-systems and support structure, including specifications, thermal/structural analysis, system activation, safety, and interface issues. Prepare detailed design for long lead time procurements on critical path.

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Conclusion

The IFMIF Accelerator Facility Conceptual Reference Design is fully ready for progression into the EVEDA and constructions phases of the IFMIF project.

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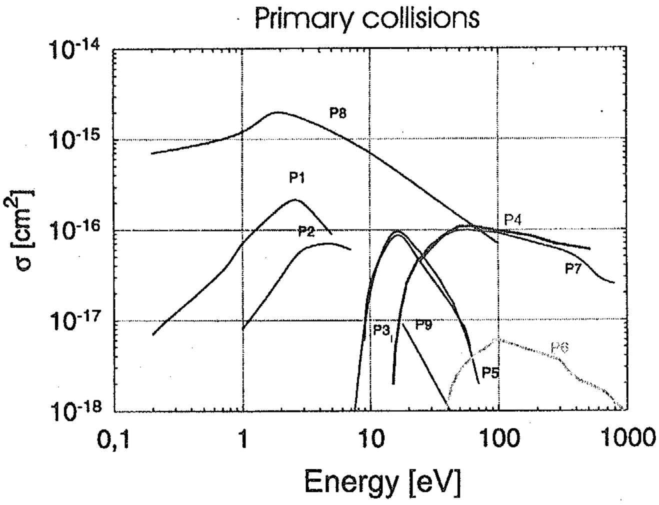
TTMI-001
IFMIF-Accelerator Facilities

I Ion Source, LEBT, Diagnostic and RFQ Development

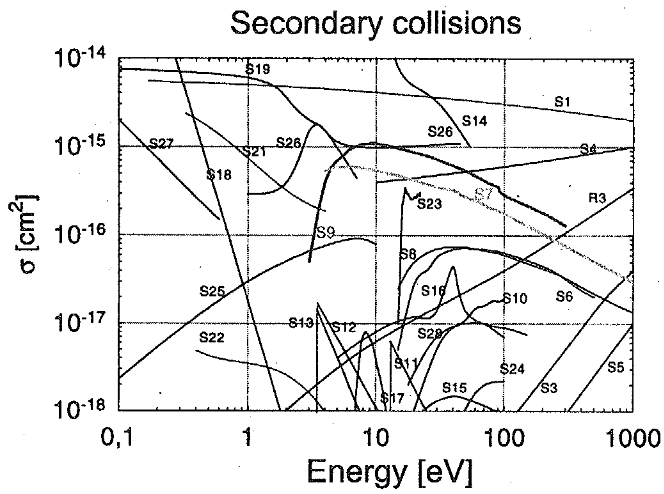
I.1 Ion source

At the University of Frankfurt, a high current H^+/D^+ source was developed and tested. The ion source is an arc discharge driven volume source. It is equipped with a solenoid for the plasma confinement and a variable filter magnet to control the electron energies in the plasma. In operation with an arc power of 10 kW a beam current of 200 mA was extracted [1] using an emission opening radius of 4 mm. This corresponds to the required D^+ current of 140 mA.
Because of problems with the safety in our ion source lab, source operations with hydrogen are not allowed. Before a reconnection of the lab the installation of an exhaust system above the ion source is required. Moreover, different safety lights have to be installed and an operation manual for the use of the test facility has to be written. The installation of the exhaust system will be performed in October 2003.
In the meantime a small hydrogen source has been used to test a CCD camera for a two-dimensional ion beam diagnostic. For the next stage of development it is planed to increase the ion source lifetime. In operation with one tungsten filament (1.8 mm thickness), an arc power of 10 kW dc and a beam current of 200 mA, the ion source lifetime is about 100 h. In order to increase this value the ion source will be equipped with four filaments. After commissioning and optimisation of the source it is planned to measure the beam emittance at full beam current. For this reason a new high power slit grid emittance measurement device was bought and has been tested. This device is ready for operation. Parallel to the emittance measurements a beam investigation using the CCD camera will be performed. This delay is not essential for the IFMIF project, since the source has always achieved the IFMIF - requirements. It is a back up solution for the chosen ECR – source anyway.
From great importance is the development of a high current H_2^+ ion source, which is inevitable for the run in of the accelerator. The use of the D^+ ion source for this action is impossible, the particle losses, which are unavoidable in this phase, would lead to a intolerable activation by the neutrons. This H_2^+ ion source turned out to be more difficult as expected. Our intensive studies showed, that the use of the D^+ ion source for the production of high current H_2^+ ion beams is not possible. Therefore a new source has to be designed. Detailed studies lead us to following design parameters: The cross sections show **(see fig. 1 and 2**, P_3, P_4, P_6, S_7, S_9), that the integral cross section for the H_2^+ production are very small and the electron energies must lie in a small energy bandwidth (~10 – 30 eV). The plasma density has to be small, the volume large (to achieve the high current), the distance between the filaments and the extraction opening shall be short, the number of filaments 2 – 4. The use of a solenoid is not appropriate, the source has to have a multicusp field. An important question concerns the necessary H_2^+ beam current. So far, an emission current density of 50 mA/cm^2 has been achieved in Berkeley with an H_2^+ fraction of 80 %. But the diameter of the extraction hole was only 1 mm. This best result (0.4 mA) is far away from the required current of about 100 mA. Therefore also a multiaperture extraction system will be considered. But the much larger emittance of such a system may be unacceptable. As a result we can state, that we have got a good overview of the necessary basis parameters of this source, but much more work has to be invested to come to a detailed layout and realisation.



primary collision	reaction	energy [eV]	reference
P1	$e + H_2 \rightarrow H_2^*$ (rot) + e	< 0,1	[Iti, Hun, Iti 2]
P2	$e + H_2 \rightarrow H_2^*$ (vib) + e	< 0,1	[Iti, Hun, Kie, Iti 2]
P3	$e + H_2 \rightarrow H_2^*$ (elec) + e	< 5	[Iti, Hun, Ha, Iti 2]
P4	$e + H_2 \rightarrow H_2^+ + 2e$	15.4	[Kie, Taw 2, Chan]
P5	$e + H_2 \rightarrow 2H + e$	< 5	[Kie, Chan, Taw]
P6	$e + H_2 \rightarrow H^+ + H + 2e$	< 20	[Taw 2]

Fig. 1 : Cross sections for primary collisions as a function of electron energy. For H_2^+ production the reactions P4 and P6 are relevant.



secondary collision	reaction	energy [eV]	reference
S1	$H^+ + H \rightarrow H + H^+$	< 0,2	[Taw, Sa]
S2	$e + H_3^+ \rightarrow H_2 + H^+ + e$		[Chan 2]
S3	$H_2 + H \rightarrow H^+$	< 100	[Nak]
S4	$H^- + H_2 \rightarrow H + ...$	< 10	[Nak]
S5	$H^- + H_2 \rightarrow H^+ + ...$	< 300	[Nak]
S6	$e + H \rightarrow H^+ + 2e$	13,6	[Kie, Ch, Taw 2]
S7	$e + H_2^+ \rightarrow H^+ + H + e$	< 1	[Step, Chan]
S8	e + H (1s) → H (2p)+ e	< 13,6	[Cou, Cal]
S9	e + H (2s) → H^+ + 2e	< 2	[Taw 2]
S10	$e + H_2^+ \rightarrow 2H^+ + 2e$		[Kie, Step]
S11	hν + H (1s) → H^+ + e	13,6	[Cro]
S12	hν + H (2p) → H^+ + e	3,5	[Cro]
S13	hν + H (2s) → H^+ + e	3,5	[Cro]
S14	e + H (1s) → H (1s) + e		[Cal, Kie 2]
S15	e + H (1s) → H (3s) + e	< 15	[Cal, Kie 2]

Fig. 2 : Cross sections for secondary collisions as a function of electron energy. For H_2^+ production the reactions S7 and S9 are relevant.

I.2 Determination of compensation degree within fringe fields in the LEBT.

The beam transport of high perveance ion beams is mainly influenced by space charge forces. For compensated transport as proposed for IFMIF the detailed knowledge of the degree of compensation along the beam axis is essential to determine the beam transport properties of the LEBT including losses and emittance growth. The processes defining the compensation degree in drift sections are well known and the compensation degree within the solenoids where the magnetic fields are dominant, can be estimated with adequate precision. The transition between these two states in the fringe fields of the solenoids are still under investigation. To measure the degree of compensation within fringe fields, a residual gas ion energy analyser will be installed in the LEBT system between the two solenoids. Three experiments on space charge compensation in fringe fields are planned:

1.) both magnetic fields of the solenoids have the same polarity (B_z (z=0)~$5*10^{-3}$ T), only heavy and energetic particles can escape between the solenoids.
2.) solenoids have opposite polarity to reduce fringe fields between them (B_z (z=0)=0 !)), a loss channel for all particles between the solenoids is open.
3.) drift between both solenoids with magnetic shielding

In a first step the magnetic field strength in transversal and longitudinal direction was determined. The results of the measurements are shown in fig. 3. They show that the magnetic field between the solenoids is small enough to extract compensation particles form the beam in transversal direction. Now a residual gas ion energy analyser will be installed between the solenoids to determine the degree of compensation and the influence on beam transport for the different field configurations.

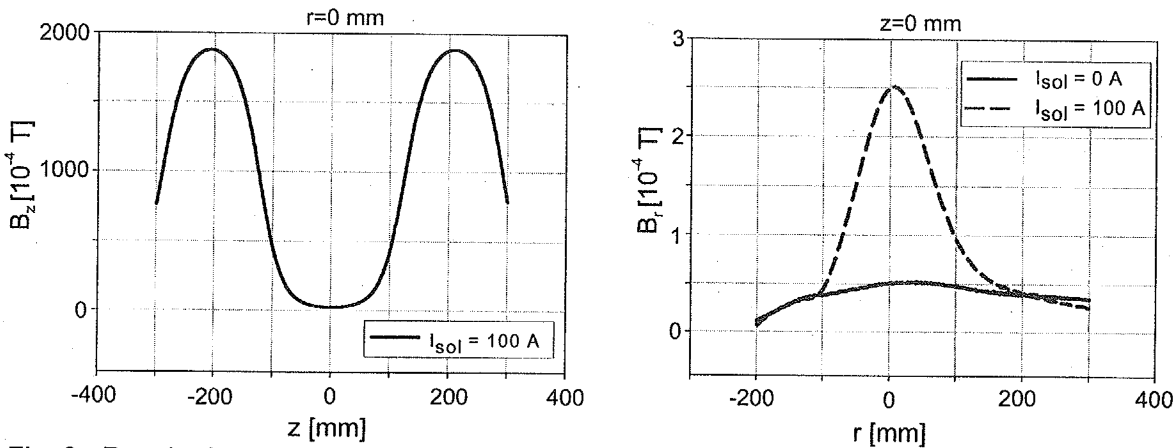


Fig. 3 : Result of a magnetic field measurements (field polarity equal) for determination of the compensation degree within the fringe fields. The solid line in the right picture shows the residual magnetism of the solenoids (B_z (I=0)<$5*10^{-5}$ T).

I.3 Non interceptive diagnostics development

To improve the spatial resolution available by optical profile measurements a new intensified slow scan CCD camera will be used. The advantages of the new system compared with the one already in use are:

1.) Doubling of the number of pixels in both transversal planes improving the total pixel number by a factor of 4.

2.) Identical Pixel size of CCD chip and residual light amplifier (6 μm) to reduce Moire effects.

3.) Coupling between intensifier and CCD chip by glass interconnects instead of lens coupling to reduce vignetation.

4.) Peltier cooling instead of liquid nitrogen cooling for flexible use within the experiment.

The two systems together allow simultaneously the determination of the beam profiles in both transversal planes. This is necessary due to the different starting conditions for the ions in both transversal planes caused by the magnetic dipole filter field needed to improve the source plasma performance. The new diagnostic system has been set up and successfully tested using a printed target. Fig. 4 shows the images of the target gained from both cameras under identical conditions. For the given experimental set up the transversal resolution is 136 μm/pixel for the old camera (pixel structure on the lower right picture visible) compared with 68 μm/pixel. The new optics allows a smaller minimum distance between camera and the target (ion beam) and therefore the resolution limit for the new camera is 20 μm/pixel. The angular resolution improved from 2°mrad to 1°mrad simultaneously.

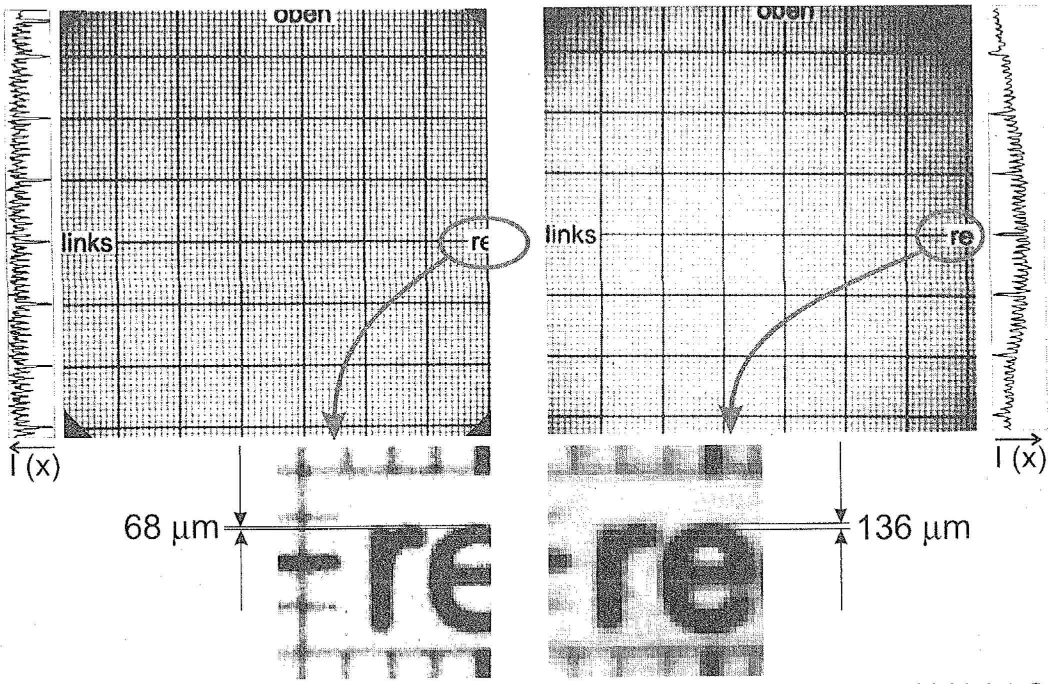


Fig. 4 : Comparison between the results gained from the new (left) and the old (right) CCD camera. The overall pictures (above) demonstrated the reduction of the vignetation error. The detailed view (below) demonstrates impressively the resolution enhancement.

The suppression of vignetation effects (upper left picture has a more homogeneous light distribution than the right one) are clearly visible. This new technique will improve the results of the transversal beam diagnostic and simplifies data interpretation and reduces errorbars.

I.4 Diagnostic chamber and vacuum system for the LEBT

The residual gas pressure in the LEBT is dominated by the gas flow from the ion source. On the other hand a residual gas pressure above $5*10^{-5}$ hPa has only a small improvement of the degree of space charge compensation for DC beams. Therefore to reduce particle losses due to interactions between residual gas and the beam ions, the residual gas pressure in the LEBT has to be reduced to be below $5*10^{-5}$ hPa. An effective way to reduce the gas pressure is the use of a differential pumping system. Therefore the first vacuum chamber is divided in two independently pumped chambers connected only by an aperture slightly bigger than the beam diameter. To study experimentally the different aspects of the first LEBT chamber after beam extraction (beam dynamics, vacuum aspects, beam diagnostics, etc.) the chamber with included differential pumping system has been constructed, built in the workshop and successfully vacuum tested. Figure 5 shows the new device on the vacuum test bench. Flanges for three pumps, a replaceable aperture between both vacuum stages, a Faradaycup, optical beam analyses and residual gas spectroscopy are available. In a next step the device will be installed in the LEBT system between the ion source and the first solenoid and experiments on pumping efficiency and pressure separation in both stages for different apertures will be performed.

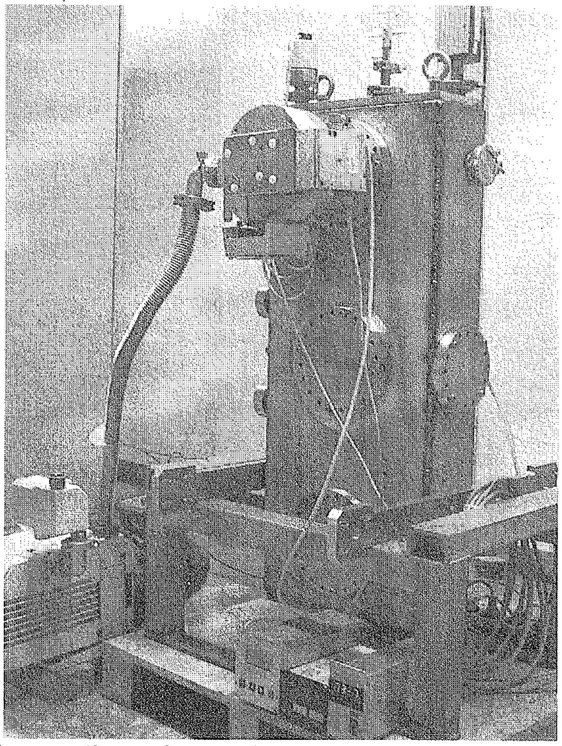


Fig. 5 : First diagnostic and pumping chamber for LEBT measurements.

I.5 Investigation of beam injection into a RFQ by a Gabor lens LEBT

To investigate the injection of an high perveance ion beam into a RFQ and the Gabor lens option for IFMIF as well, an low power experiment is under construction. The actual status of the experimental set up is shown in fig. 6. The ion source of volume type and the LEBT system are operational, and the beam at the injection point into the RFQ is characterised. The RFQ has been installed and vacuum tested. Low power tests for surface conditioning have been performed successfully as well as measurements of the resonance frequency of the RFQ-cavity and the reflected power (-25 dB). The tuner is installed, successfully tested and operational. The beam diagnostic behind the RFQ is tested and will be installed at the beam line in the near future. High power tests and beam injection into the RFQ is scheduled for autumn 2003.

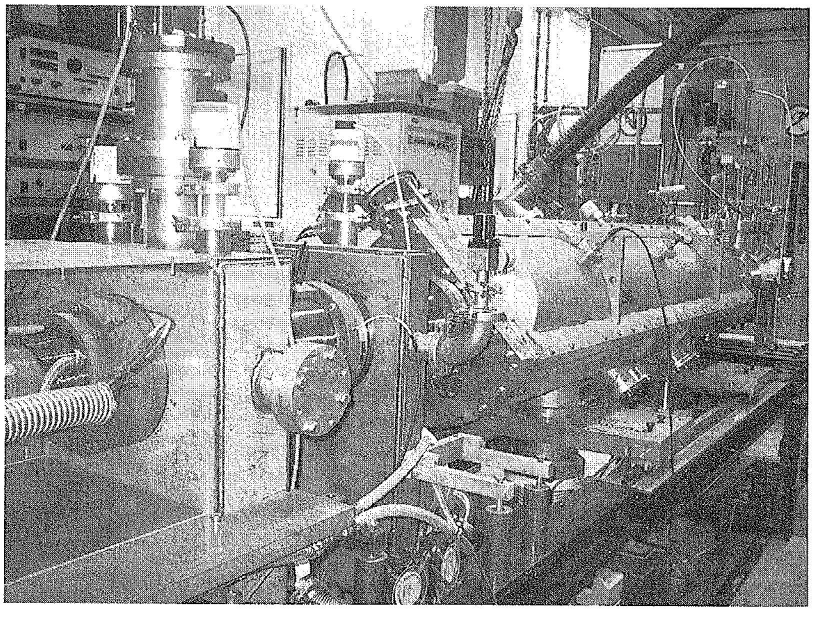


Fig. 6 : Experimental set up for investigation of RFQ injection. A volume source(leftmost) injects into an LEBT consisting of two Gabor lenses (left to center) connected directly to an RFQ (center to right).

I.6. Investigation of the 4-Rod RFQ

The 4-Rod RFQ is an alternative solution to the complex 4-Vane structure. The fields are concentrated on the resonating stem structure and with roughly the same power consumption the power density is higher by a factor 2-3.

The RFQ design for the IFMIF accelerator requires a RFQ at 175 MHz and cw-operation. Extrapolating from our experience from existing pulsed machines at 200 MHz and cw RFQs at 108 MHz we have concentrated in rf-modelling of a suitable 175 RFQ resonator. MAFIA and MWS simulations have been done to optimize the design. Shunt impedances of up to 90kOm have been achieved.

The electrode voltage in the design is as high as 120kV, which results in a power consumption of 160 kW/m. Our rf-structure has 10 stems per m. The rf-simulation gave a 65% part of the power losses on the stems, which corresponds to a power density of 36 W/cm^2 , with peak values at the transition from stems to eletrode supports of up to 120 W/cm^2 . We have started simulations of the thermal distribution, possible cooling schemes and and the resulting mechanical deformations.

To test solutions we preparing a short high power test tank to test the critical peak power density effect at the frequency of 175 MHz

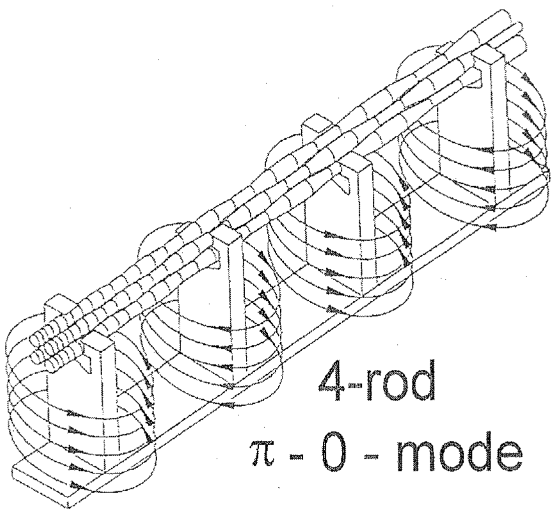


Fig II.1: Scheme of the 4-Rod RFQ insert

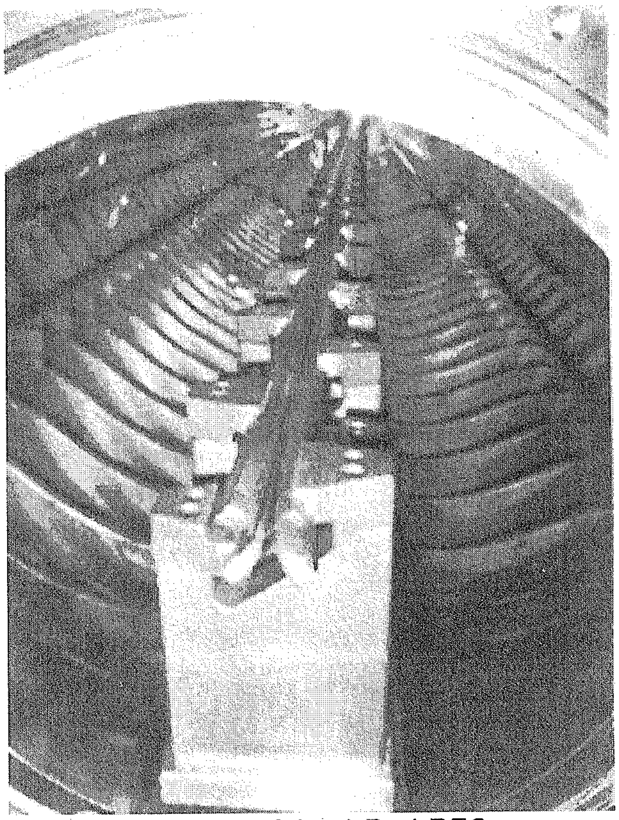


Fig. II.2: View of the 4-Rod-RFQ

I.7 References

[1] R. Hollinger, P. Beller, K. Volk, M. Weber, H. Klein, *The Frankfurt 200 mA Proton Source*, Rev. Sci. Instrum., 71, Volume II, 836-838, 2000

II. IFMIF LINAC DEVELOPMENT

The IFMIF project (International Fusion Materials Irradiation Facility) requests two cw linacs operated in parallel. Each one is designed to provide a 5 MW 125 mA deuteron beam at 40 MeV for the production of an intense neutron flux with an energy around 14 MeV. This paper presents a drift tube linac design for this project, which is completely based on H-type cavities. The room temperature (rt) RFQ and a short IH-DTL (Interdigital-H-DTL) are followed by 4 superconducting (sc) CH-DTL (Crossbar-H) cavities. The operating frequency is 175 MHz, the designed section lengths are 13 m for the RFQ (Radio-Frequency-Quadrupole) (5 MeV), 1 m for a compact MEBT (Middle Energy Beam Transport), 2 m for the IH-cavity (10 MeV) and 9 m for the sc CH-DTL (40 MeV). The structure parameters and end-to-end multiparticle beam dynamics calculations with and without DTL errors for the whole linac will be presented and the results will be discussed.

Extended particle dynamics investigations of the reference IFMIF DTL layout (RFQ+Alvarez-DTL) showed a very robust beam behaviour for the Alvarez-type DTL. Even with the reduction of the input energy – to reduce the length of the RFQ - and with a favourable lower input power per tank the calculations gave in all cases stable solutions, good emittance conservation, strong transverse and longitudinal focusing, no particle losses and sufficient large aperture factors also, when standard quadrupole and rf errors and mismatched input beams were included [1]. This layout has an overall length of 46 m. The rf power consumption per linac is estimated to around 7.5 MW. Technical challenges in case of the Alvarez-DTL are the high thermic load per meter in combination with a quadrupole singlet channel where each magnet is housed in a drift tube on a slim stem. Beam dynamics studies for a corresponding rt IH-type DTL showed its capability for high intensity acceleration with good power efficiency. Investigations on beam stability against matching, field and quadrupole errors showed however, that the IH-DTL is due to the KONUS-dynamics (Kombinierte – Nullgrad - Struktur) more sensitive to errors than the Alvarez [2,3]. Both rt structures showed in combination with a special compact MEBT no particle loss and smooth beam behaviour, but the RFQ+Alvarez-DTL combination gave higher aperture factors and lower emittance growth [1].
Due to the mandatory cw operation mode of the IFMIF facility the combination of a short rt IH structure and a chain of sc CH resonators with inter tank focusing has been proposed in addition, which fulfills the requirements for a high current IFMIF DTL. The sc CH DTL part provides very high rf and acceleration efficiency and due to its special cell geometry high mechanical robustness. The sc drift tube linac has a total length of ≈ 11 m only, the cryostat length is ≈ 8 m. The estimated total plug power (including all cryostat losses) per meter of this design study is ≈ 1.5 kW/m (for comparison the rt linacs need ≈ 50 kW/m assuming 50 % amplifier efficiency), which demonstrates the high rf efficiency of the sc CH modules. In connection with large drift tube apertures the risk of particle losses in the sc part is reduced. Detailed simulations showed also a low sensitivity of the beam behaviour and beam quality against all combinations of statistic and mechanical errors, i.e. transverse quadrupole triplet displacement errors ± 0.1 mm and a rotation of ±1 °, rf phase errors ± 1 °, rf amplitude errors ± 1 % and quadrupole gradient errors ± 1 % [1].

For all DTL studies the same reference design of an RFQ has been used to be comparable between all design versions for the IFMIF linac. Table 1 gives a summary of the RFQ structure and beam parameters. The main goal was a lowered Kilpatrik factor of 1.7 to reduce the sparking probability due to the required cw operation. Nevertheless the transmission should be high as well as the beam quality at the RFQ output to allow good matching to the following DTL. In the design the recipe of equipartitioning has been applied leading to a parameter set, which fulfills the IFMIF requirements [4].

Table 1: Structure parameters of the RFQ for IFMIF.

RFQ-Parameters	Values
A/q	2 (D^+)
Rf-frequency f [MHz]	175
In / Out energy W [MeV]	0.1 / 5.0
P_{tot} [MW]	1.506
Peak field E_{peak} [MV/m]	23.77
Cells / length [m]	659 / 12.31
In / Out current [mA]	140 / 132.7
In / Out $\varepsilon^{N,rms}$trans [cm×mrad]	0.020 / 0.023
In / Out $\varepsilon^{N,rms}$long [cm×mrad]	0 / 0.043

In Fig 1. the output beam distribution in phase space at 5.0 MeV of the RFQ is plotted, calculated with PARMTEQM® (multipole effects and image charges included) and 50,000 macro particle were used. The transmission is about 94 % with good beam quality. The transverse rms emittance growth is less than 10 % and the beam is well confined with a few halo particles only.

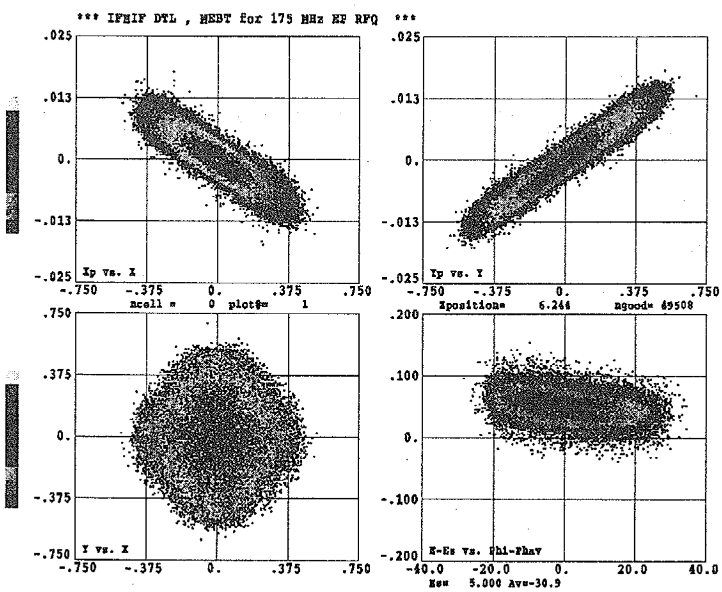


Fig. 1: Output beam distribution in phase space at 5.0 MeV of the Four-Vane-RFQ from table 1 calculated with PARMTEQM® and 50,000 macroparicles were used.

The calculations were repeated with the new full 3D RFQ program called TOUTATIS® to validate the agreement of the used RFQ codes [5]. Fig. 2 compares the transmission efficiency of the IFMIF RFQ from table 1 calculated with PARMTEQM® and TOUTATIS®. The differences are significant and the reasons for the remarkable reduction in transmission efficiency in TOUTATIS® are up to now under detailed discussion [6].

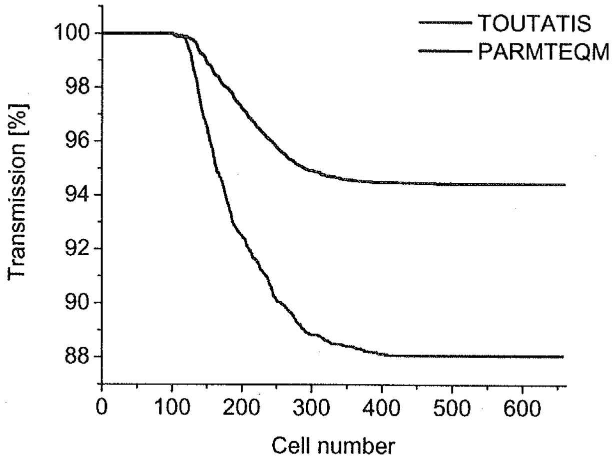


Fig. 2: Transmission efficiency along the RFQ calculated with PARMTEQM® (black line) and TOUTATIS® (red line).

In addition preliminary electromagnetic rf design studies of a 175 MHz 1.7 Kilpatrick Four-Vane resonator were performed with the rf field solver SUPERFISH®. Fig. 3 shows the simulation results of the first quadrant in TE_{210} mode of the resonator with the cell parameters of table 1 and a Kilpatrick factor of 1.7.

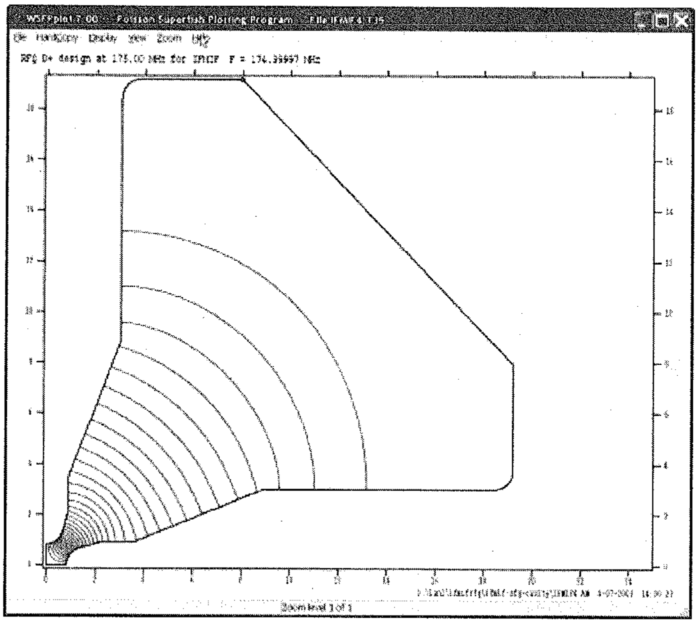


Fig. 3: First quadrant in TE_{210} mode with the electric field lines of an 1.7 Kilpatrick 175 MHz IFMIF Four-Vane RFQ resonator calculated with SUPERFISH®.

The matching to the RFQ can be accomplished by a partly space charge compensated magnetic LEBT (Low Energy Beam Transport) with low influence on transmission and beam quality. Therefore the output emittances of Fig. 1 have been taken for the beam dynamics simulations through the DTL, aiming for preliminary results for the beam behaviour from source to 40 MeV to ensure stable and loss free operation in the whole IFMIF accelerator facility.

The superconducting CH-version (design and structure parameters of table 2 and Fig. 4 made with LORASR©) turned out to be superior to the rt IH-design with respect to the following critical issues: a) no cooling problems in cw operation b) reduced linac length and less tanks, i.e. higher efficiency and lower structure periods c) larger drift tube diameters up to 8 cm. The beam behaviour is smooth, no losses along the linac occurred and a good safety margin could be reached in the sc linac against losses due to mismatch and standard DTL errors. Extended electromagnetic simulations have been performed with Microwave Studio® to optimize the parameters of the first and last superconducting CH cavity for IFMIF. It was possible to further reduce the electric and magnetic peak fields to modest values which is important for reliable routine operation. Fig. 5 gives a realistic 3D sketch of the optimized 175 MHz sc CH tanks 1 in the critical low energy part and 4 at the high energy end of the DTL, calculated with Microwave Studio®.

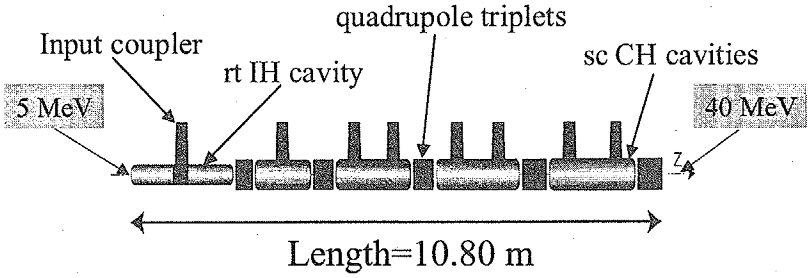


Fig. 4: Scheme of a 175 MHz sc IH/CH-DTL.

Table 2: Design parameter of a 175 MHz sc IH/CH-DTL for IFMIF + Cavity parameters of sc CH tank 1 and 4.

Design parameters	SC CH-DTL		Units
A/q	2 (D^+)		
In-/out current	125.0 / 125.0		MA
Frequency	175.0		MHz
Number of tanks	5 (1NC+4SC)		
P_{tot}	4.44		MW
W_{in} / W_{out}	5.0 / 40.1		MeV
Cells / Length	73 / 10.8		M
A_0 of DT	NC:1.5 SC:2.4 - 4.0		Cm
In- / Out rms ε^n_{trans}	0.035 / 0.091		cm×mrad
In- / Out rms ε^n_{long}	0.070 / 0.097		cm×mrad
Cavity parameters	**CH 1**	**CH 4**	**Units**
Beta	0.1	0.2	
Frequency	175.00	175.00	MHz
E_{acc} (=E_0)	5.00	4.3	MV/m
Tank length	1.20	2.30	M
Tank diameter	52.9	67.3	Cm
Gaps	12	12	
E_{peak}/E_{acc}	4.01	3.75	
B_{peak}/E_{acc}	7.73	8.46	mT/MV/m

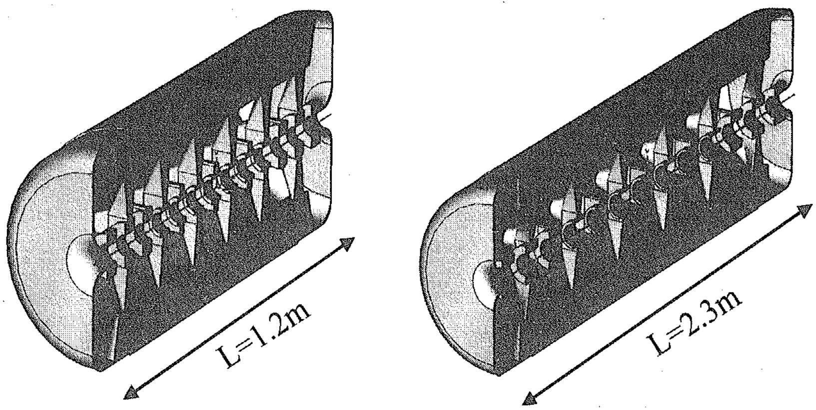


Fig.5: 3D view of the first and last 175 MHz sc CH-cavities (tank 1 and 4) calculated with MicroWave Studio®.

For testing the overall stability of the complete injector facility against particle losses integrated multi particle simulation studies through the whole 25 m long sc linac (RFQ+MEBT+sc IH/CH-DTL) were performed with the programs PARMTEQ® and LORASR©. Fig. 6 shows the 100 % transverse beam envelopes along the whole linac in the nominal case without assuming mechanical and rf tolerances. The beam behaviour is smooth, no losses after the RFQ occurred, a good safety margin could be reached throughout the sc part of the H-DTL against losses. The output distribution is well confined with a quasi elliptic dense core.

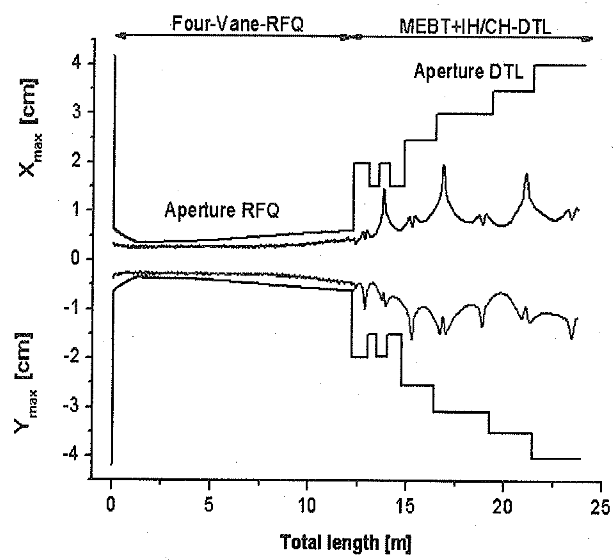


Fig. 6: 100 % transverse beam envelopes along the whole linac (RFQ+MEBT+H-DTL) in the nominal case.

The overall simulations were repeated with applied combined, statistically distributed standard mechanical, rf and quadrupole triplet gradient errors for the MEBT and the following H-DTL, i.e. transverse quadrupole triplet displacement errors ± 0.1 mm and a rotation of ±1 °, rf phase errors ± 1 °, rf amplitude errors ± 1 % and quadrupole gradient errors ± 1 %. Figs. 7 and 8 show the results of the simulations for the IFMIF linac in this case. The 100 % beam envelopes are still smooth. No further losses occur after the RFQ and the phase space at the exit of the H-DTL at 40.1 MeV is still quasi elliptic and well confined.

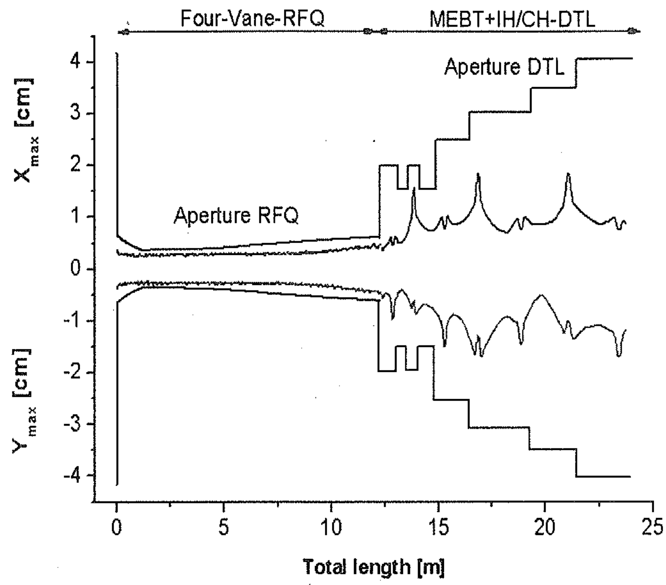


Fig. 7: 100 % transverse beam envelopes along the whole linac with combined errors for the MEBT and H-DTL.

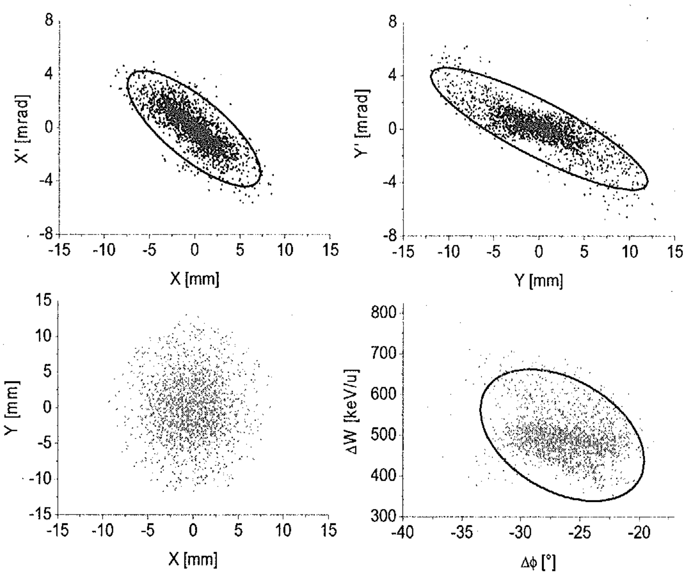


Fig. 8: Output distribution of the linac at 40.1 MeV with combined errors of the MEBT and H-DTL, 2,000 macro particles used.

A down scaled copper model (1:2) has been built to study the basic rf properties of a CH-structure. The model has been modified and new drift tubes have been fabricated. The corresponding particle-beta is now 0.08. By changing the length of the drift tubes and therefore the local capacitance it was possible to obtain a flat field distribution [7]. In addition, a preliminary Higher Order Mode analysis has been performed. The first 15 modes could be identified experimentally and the R/Q-values have been measured. The agreement between the electro-dynamic simulations and the measurement are excellent [7]. Figure 9 shows the field distribution of the first 12 modes. The black curves represent the measurements and the colored curves the simulations.

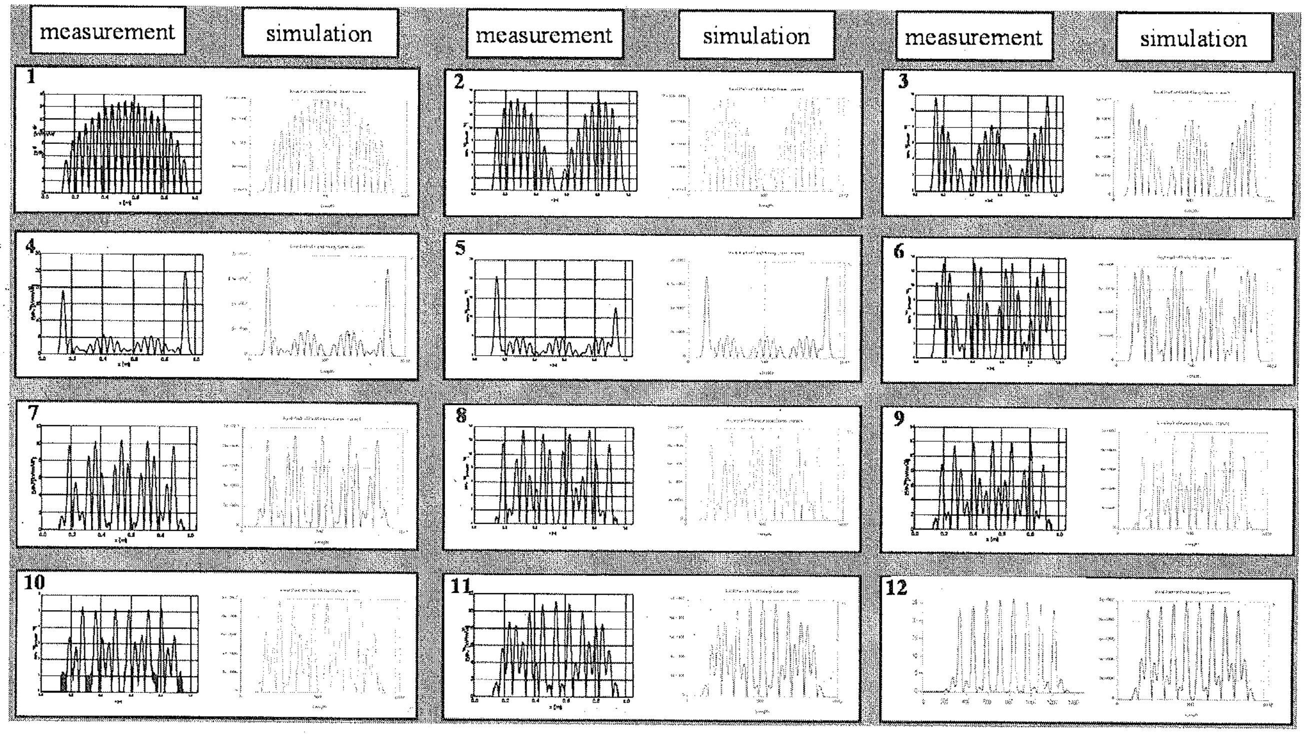


Fig. 9: Comparison of the field distribution of the first 12 modes. The black curves are measurements and the colored curves are simulations.

In a next step we introduced a beta profile in the model cavity. Due to the large number of gaps and the corresponding high energy gain per cavity it is necessary to increase the cell length from cell to cell. Figure 10 shows this modified model with beta profile. The distance between the stems which is correlated to the cell length increases from left to right. By changing the length of the drift tubes keeping the right cell length it was also possible to obtain a flat field distribution. Figure 11 shows the comparison between the simulated (blue) and the measured field distribution. Again, the agreement between simulation and measurement is excellent [8]. The input beta is 0.085 and the output beta 0.12. Additionally, first studies of tuning methods have been performed with very promising results [8].
A superconducting CH-cavity (1:2) has been optimized. This niobium cavity has been ordered and is already under fabrication. The cavity with a beta of 0.1 is expected to be delivered in 2004. To test this superconducting cavity, a cryo-lab has been equipped with a 3m vertical cryostat, a class 100 laminar flow box, transport dewars and a magnetic shielding. First tests will be performed in 2004.

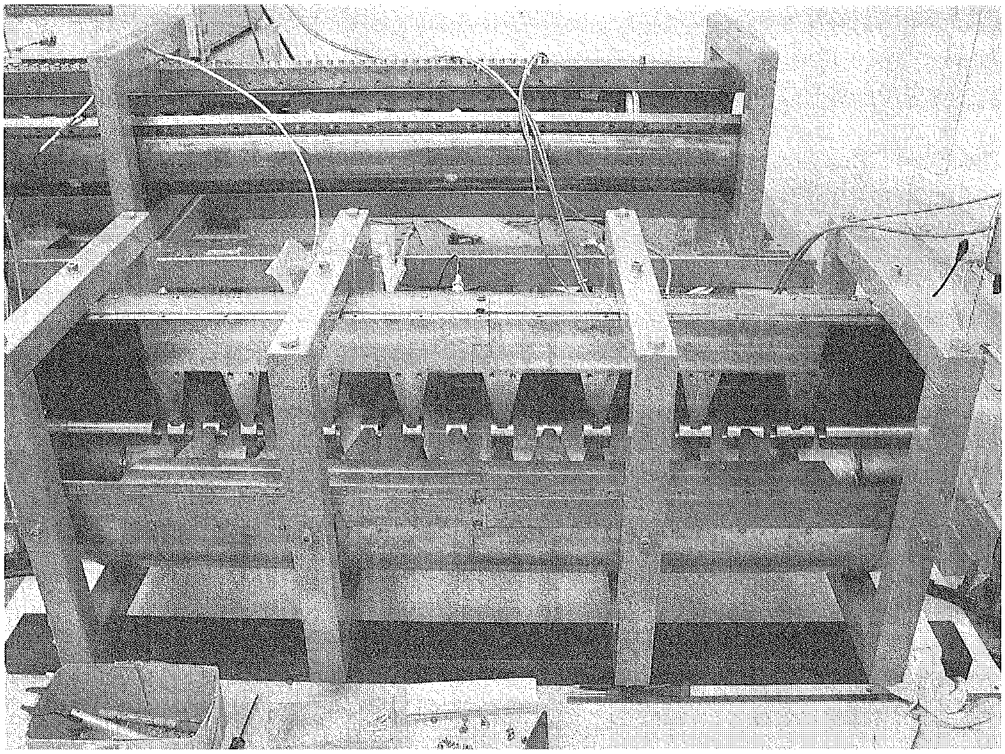


Fig. 10: Copper model with beta profile.

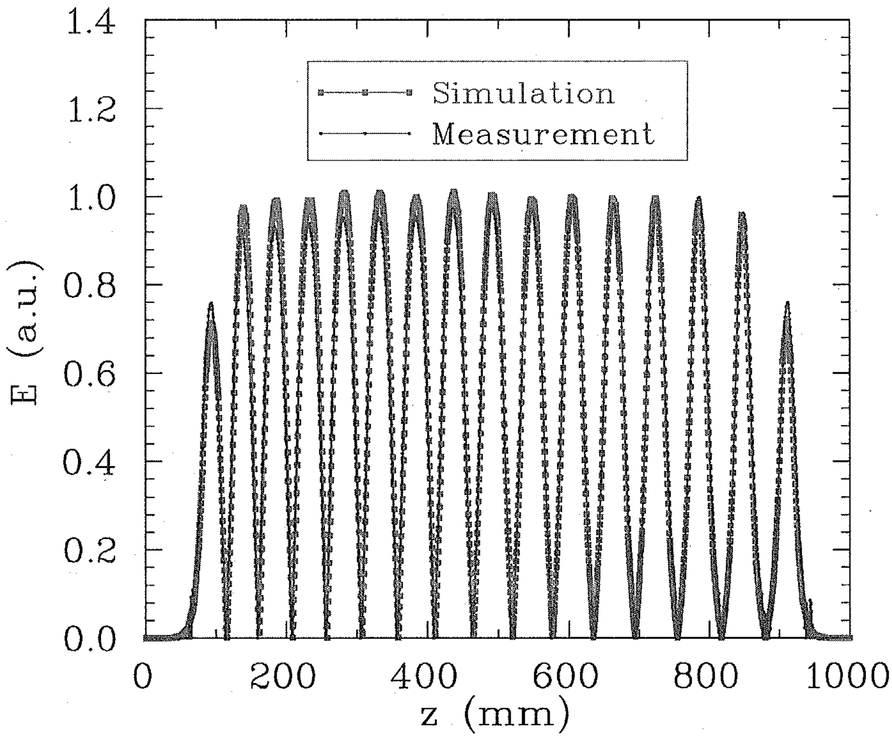


Fig. 11: Measured (blue) and simulated (red) field distribution of the copper model with beta profile.

The superconducting CH-structure in combination with the KONUS beam dynamics layout is well suited for the efficient acceleration of intense light ion beams. Extended beam dynamics simulations gave high transmission, also in case of statistically distributed mechanical, rf, quadrupole gradient and matching errors due to a low number of rf and structure periods of the H-DTL with KONUS dynamics. Also integrated overall simulations of the whole linac (RFQ+H-DTL) with and without mechanical and optical tolerances showed a smooth beam behaviour, moderate emittance growth and a non-chaotic beam behaviour without particle loss. A downscaled 1:2 room temperature copper model has been built and tested in order to investigate basic rf properties, tuning methods and to validate the simulations. There was an excellent agreement between the simulations and the measurements [7][8][9]. The order for a 350 MHz superconducting prototype of bulk niobium has been placed and the delivery is scheduled at the beginning of the year 2004. In addition, further electromagnetic design optimization procedures with MicroWave Studio® of the Four-Vane-Cavity and the CH-Resonators will be made to optimize the rf properties in the view of rf power supply, field flatness, peak fields and thermal distribution of the resonators due the cw operation mode and high beam intensity.

II.2 References

[1] A. Sauer, Ph.D. Thesis, J. W. Goethe-Universität Frankfurt a. M., Germany, March 2003.
[2] A. Sauer et al., "Investigation of a normal conducting 175 MHz Linac design for IFMIF", EPAC 2002, Paris, France, June 2002.
[3] U. Ratzinger, "Effiziente HF-Linacs für leichte und schwere Ionen", J. W. Goethe-Universität Frankfurt a. M., July 1998.
[4] R. A. Jameson, "Some Characteristics of the IFMIF RFQ KP1.7 Designs", Int.-Rep. Institut für Angewandte Physik, Frankfurt a. M., Germany, May 2000.
[5] R. Duperrier, Ph. D. Thesis nr. 6194, University of Orsay, France, June 2000.
[6] R. A. Jameson, A. Sauer, R. Ferdinand, R. Duperrier, private communication.
[7] H. Podlech et al., "Higher Order Mode Investigation of Superconducting CH Structures and Status of the CH Prototype Cavity, PAC 2003, Portland, USA, May 2003.
[8] H. Podlech et. al, "Status of the Development of a Super Conducting 352 MHz CH-Prototype Cavity ", Proceedings of the SRF2003, Travemünde, Germany, September 2003
[9] H. Liebermann et al., "Design of a Superconducting CH-Cavity for Low and Medium Beta Ion and Proton Acceleration", PAC 2003, Portland, USA, May 2003.

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R&D of IFMIF RFQ

Sunao MAEBARA, JAERI
JAPAN

KEP Activities

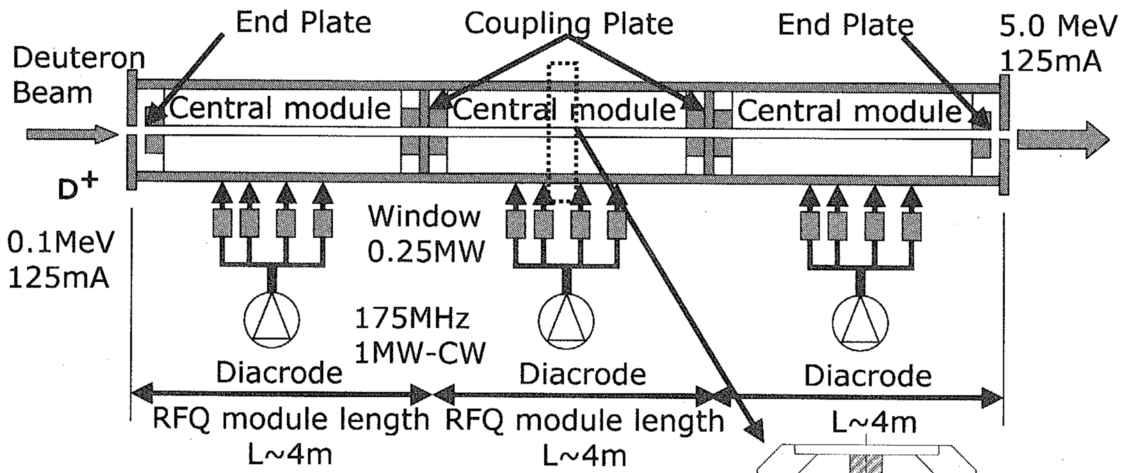
- Preliminary RFQ design by MAFIA code & Low Power Test for 4m-Long RFQ module
- 175MHz Window design & fabrication for 500kW-CW

Transition Phase Activities

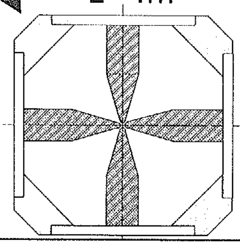
- Improved RFQ design & Low Power Test
- Low Power Test for Vacuum ports
- Low Power Test for Loop Antenna

Conceptual Design of IFMIF RFQ

JAPAN



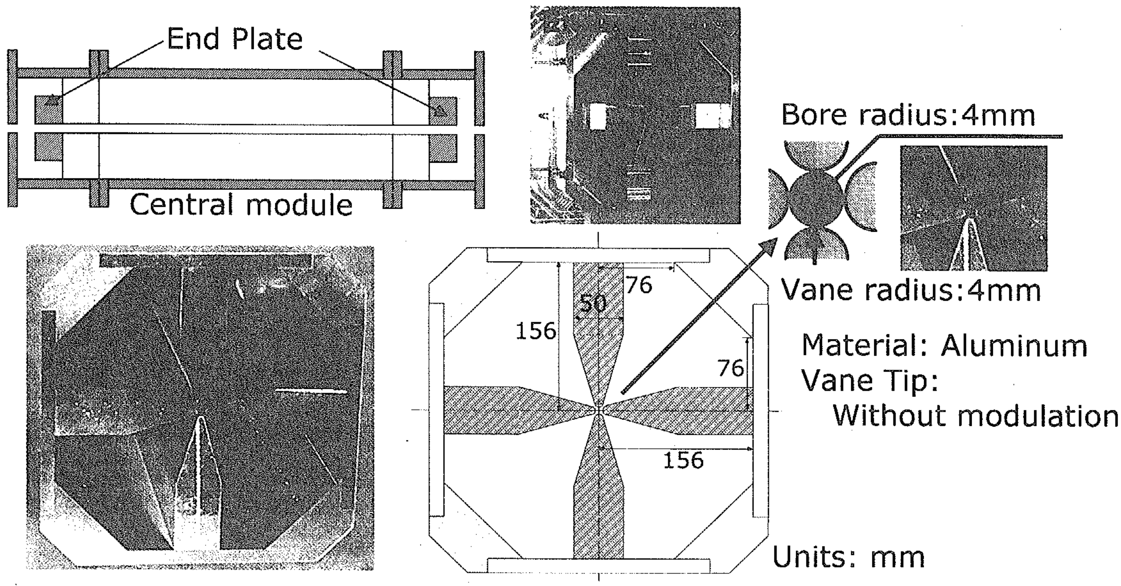
12m-Long RFQ is needed, Coupling plate technique is indispensable.



Preliminary RFQ design

JAPAN

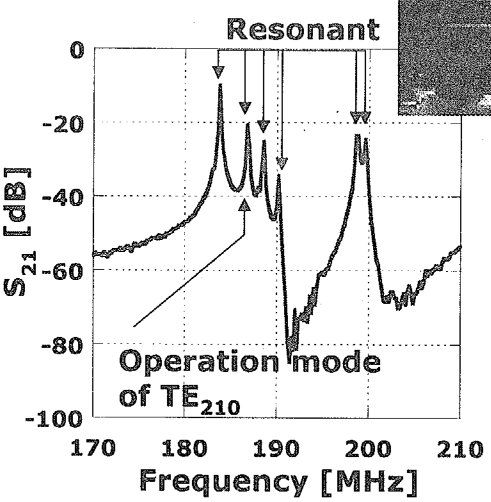
KEP Designed by MAFIA code

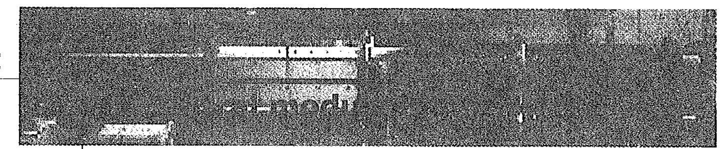


Low Power Test for 4m-Long RFQ Module

JAPAN

KEP TE_{210} mode is not affected by higher modes in 4m-Long RFQ Module





- Resonant frequency of 187MHz for TE_{210} was measured, but the design was 175 MHz by MAFIA code. Mesh Size at End plate was optimized to agreed with measured values.

175MHz Window design

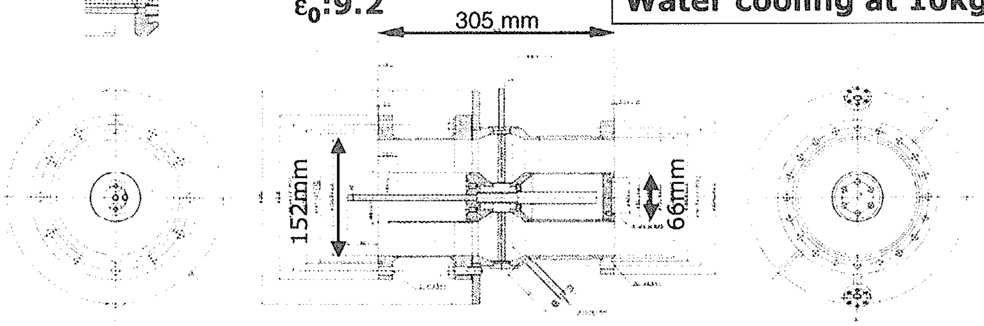
JAPAN

KEP Based on the E4268 window developed by KEK and Toshiba.

RF loss and Temp. rise of ceramic were estimated to be 50W and 20 ℃ with Water cooling at 10kg/cm³.

Material: 95% Al_2O_3

ε_0:9.2



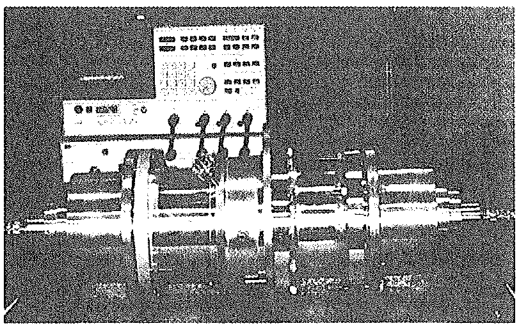
Inner surface: Copper plated to reduce ohmic loss

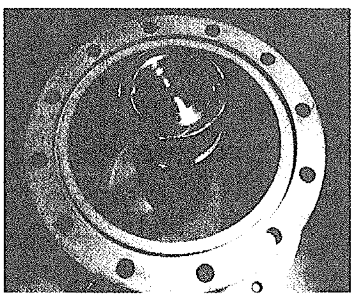
Ceramic disk: TiN of 0.1mm coated to reduce electron yield in multipactoring discharge

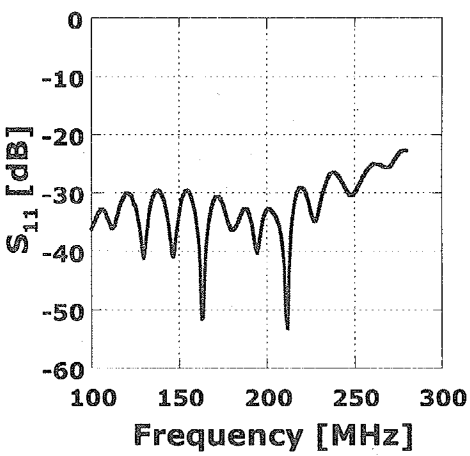
175MHz 500kW-CW Window

JAPAN

KEP







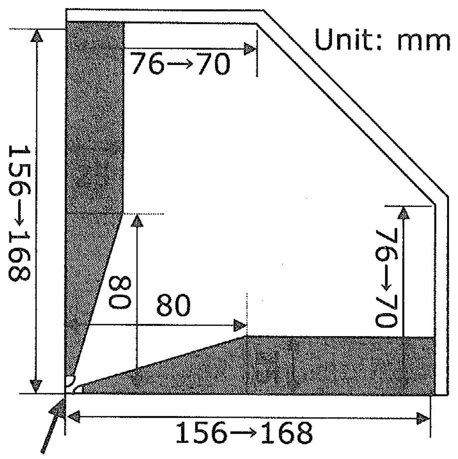
A good RF properties of S_{11}<-30dB and S_{21}<-0.1dB were measured by Network Analyzer.

Improved RFQ design

JAPAN

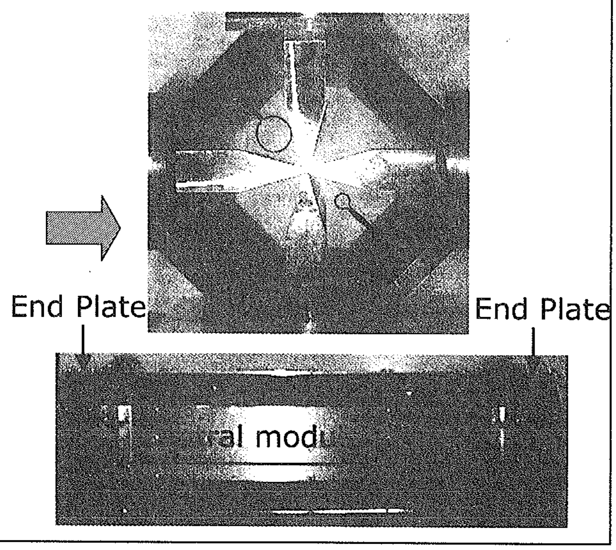
Transition Phase

175MHz RFQ was redesigned using optimized Mesh size.



Bore Diameter: ϕ8 mm
Vane Tip Radius: 4mm

Improved central module

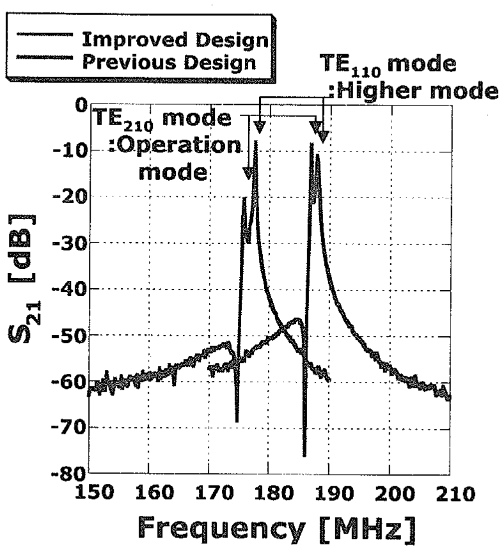


Low Power Test of Improved RFQ

JAPAN

Transition Phase

Module Length :1.1m



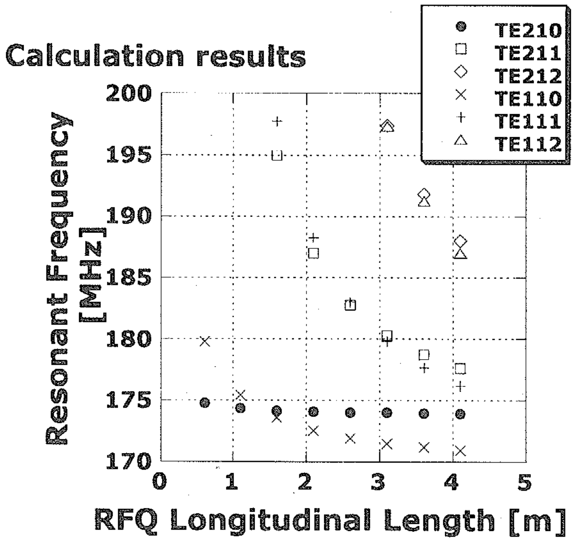
The resonant frequencies of 175.65MHz for TE_{210} was measured, which was in a good agreement with calculated one of 174.36MHz.

This difference will be caused by misalignment of the connection between End-plate and central module.

Evaluation of Higher modes

JAPAN

Transition Phase



In case of 4.1m-Long RFQ Module, the resonant freq. of TE_{210} and TE_{111} are 173.91 and 176.18MHz.

The difference is 2.27MHz, TE_{210} is not affected by TE_{111}.

Summary of Preliminary RFQ design

JAPAN

Transition Phase

- For remodeled RFQ module, measured mode frequency was in a good agreement with the calculated one.
- MAFIA code was useful to analyze modes accurately.
- In higher mode analysis by MAFIA code, it is found that the operation mode is not be affected by TE_{111} mode in the RFQ length of 4.1 m.

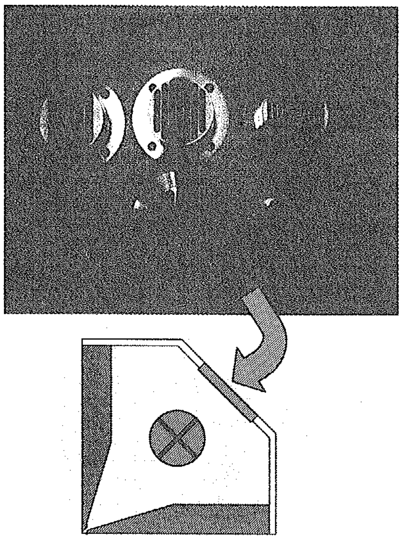
As a result, it is feasible to employ three ~4m RFQ sections with two coupling plates to realize the 12m-Long IFMIF RFQ.

Design of Vacuum Ports

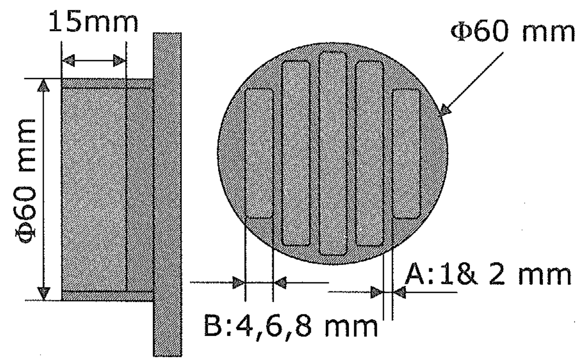
JAPAN

Transition Phase

RFQ Vacuum Pressure of < 10^{-4} Pa is required.



Dimension



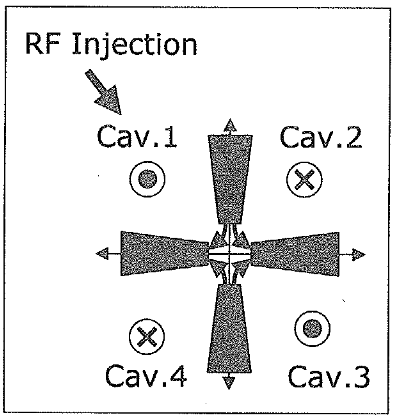
Φ60mm:221~246l/s:N2,25℃

Low Power Test for Vacuum Ports (I)

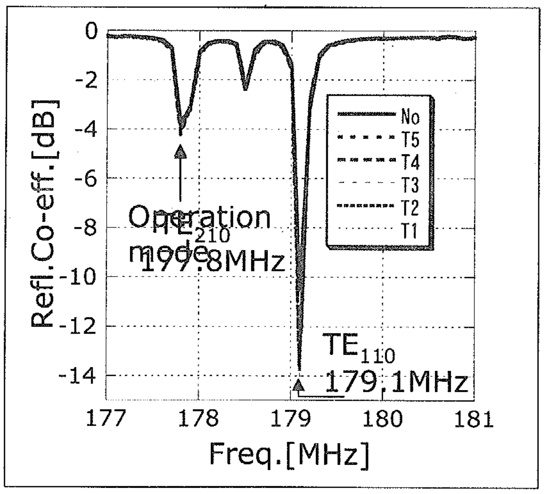
JAPAN

Transition Phase

Reflection Co-efficient & Phase difference are measured.



Operation Mode

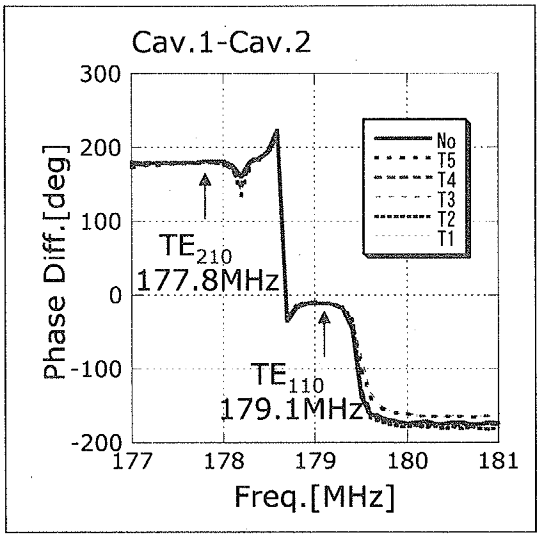


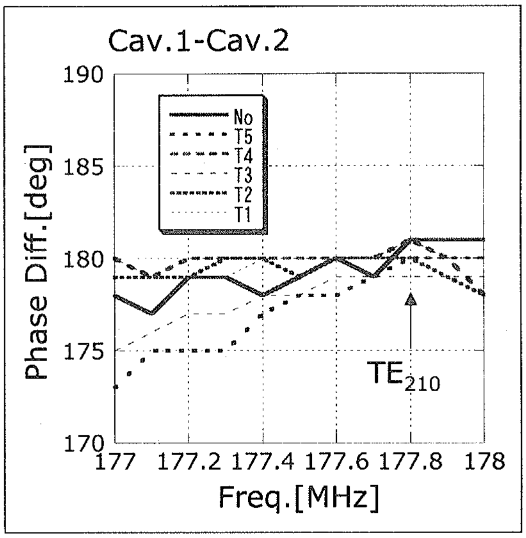
No change for Refl.Co-eff.

Low Power Test for Vacuum Ports (II)

JAPAN

Transition Phase



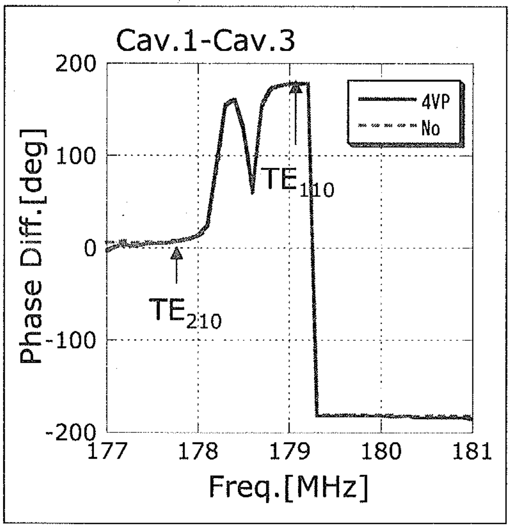


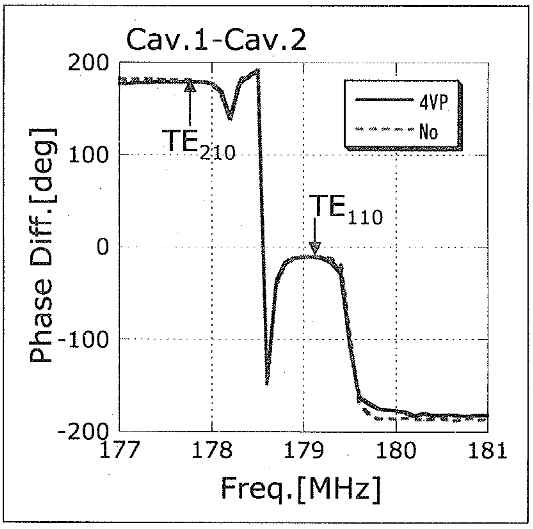
No RF property defects measured for any case.

RF Properties by 4 vacuum ports

JAPAN

Transition Phase





No change !

RF Input Coupler for 175MHz RFQ

JAPAN

Transition Phase

Assumption: Outgassing rate from RFQ material is 1×10^{-7} Pam^3/sm^2 at 100℃

Equation: $V\frac{dP}{dt}=C(P_1-P_0)$

S~0.57m^2, (V~1.68x10^{-2} m^3)
5.7x10^{-8}~2.46x10^{-4} (P_1-P_0) Pam^3/s

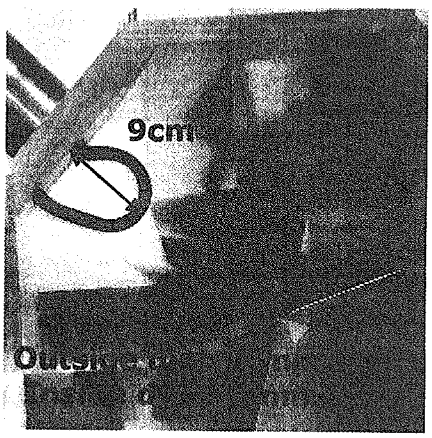
Pressure: $P_1-P_0\sim2.3\times10^{-4}$ Pa

Next Technical Issue :
Cooling Method of Slit parts

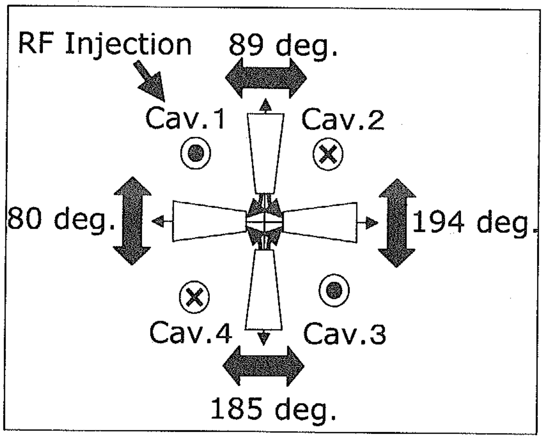
Large Loop Antenna

JAPAN

Transition Phase



Operation mode(TE_{210})



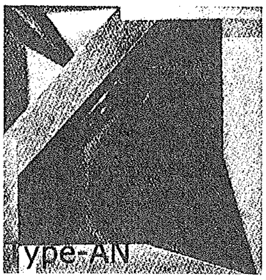
<PD>=137.0 deg.

Phase is affected by Large Loop Antenna.

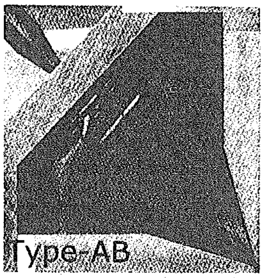
Small Loop Antenna

JAPAN

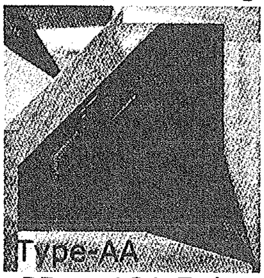
Transition Phase



<PD>=174.5 deg.

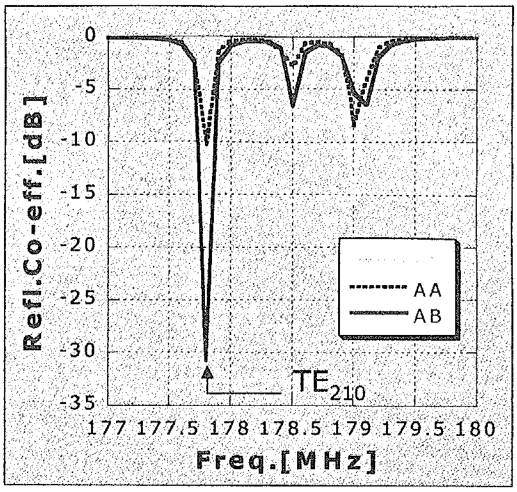


<PD>=180.0 deg.



<PD>=181.5 deg.

Quite good !

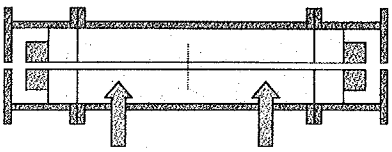


A proper phase difference is obtained by a smaller loop antenna.

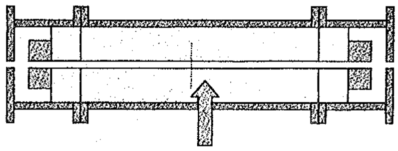
Next Step for Loop Antenna

JAPAN

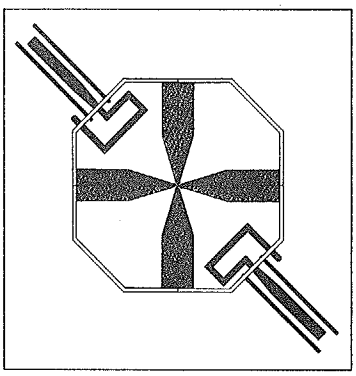
Transition Phase

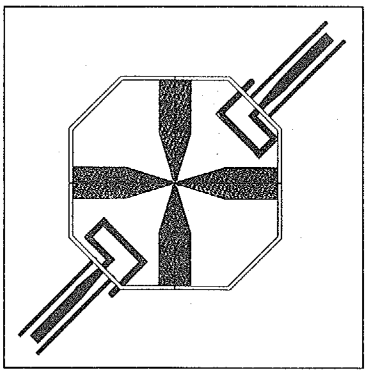


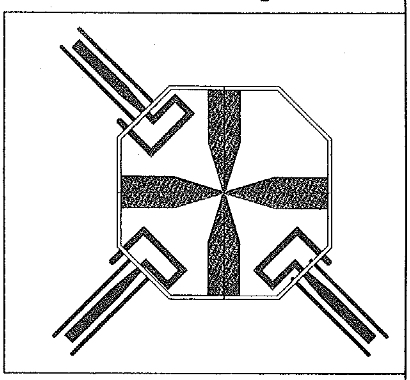
2-2 Ports Injection



1-4 Ports Injection



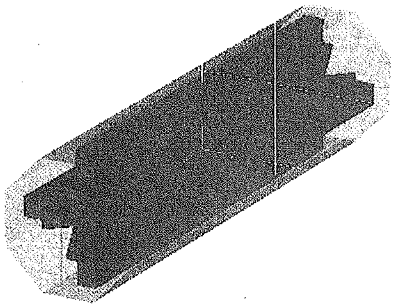


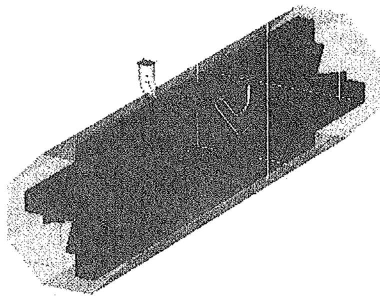


Analysis by MW-Studio

JAPAN

Transition Phase





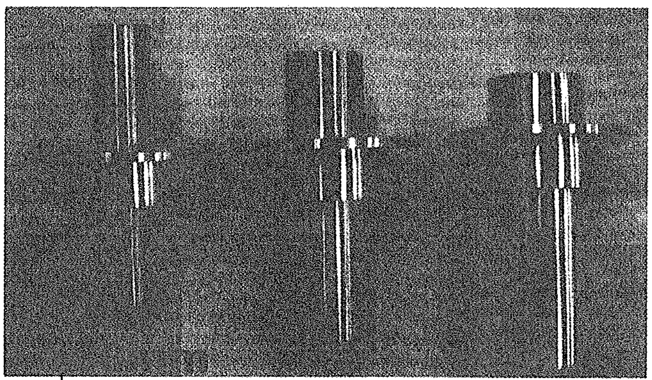
Q-value & RF Losses by Eigenmode Solver

Coupling factor by Transient Solver

RF Properties by Stub Tuner

JAPAN

Transition Phase



ϕ40mm **ϕ50mm**

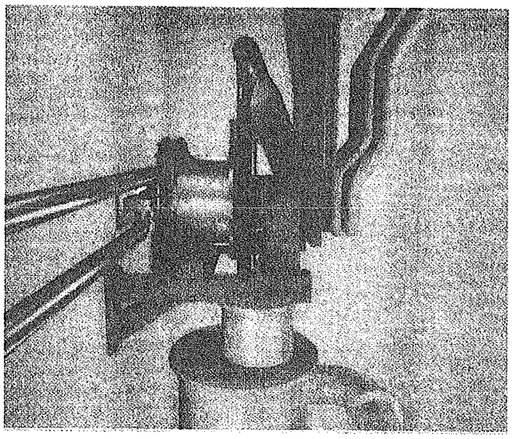
Δf & Δϕ will be evaluated by low power test.

The End

Thank you for you kind attention.

IFMIF 国際核融合材料照射施設

Transition phase activities - Target System -



Hiroo Nakamura
for IFMIF Target Group

IFMIF Technical meeting
Kyoto, December 4-5, 2003

IFMIF 国際核融合材料照射施設

Tasks in transition phase ('03-'04)

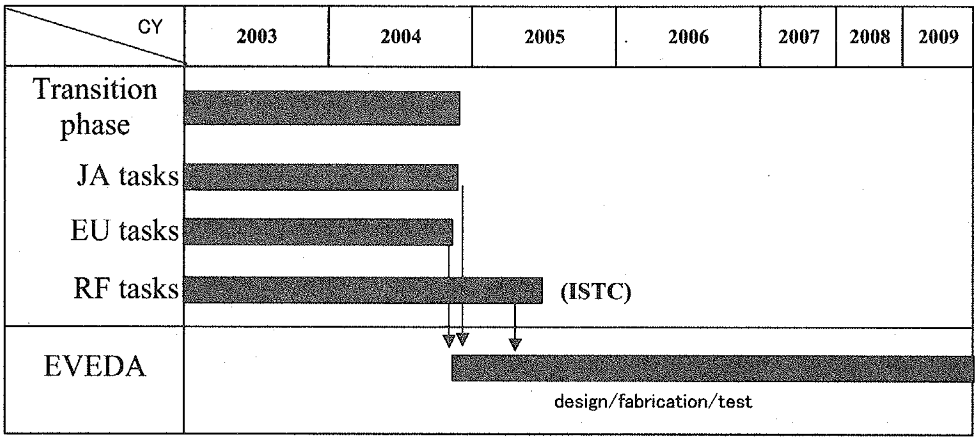
Target Tasks in Transition Phase

Task ID	Task Title	Overview of Task Content	Justification	Contributing Party EU	JA	US	RF
TG-1	Flow stability in Li and water experiment	- Long term Li loop experiment - Water exp at different curvature - Diagnostics for Li/Water exp.	Obtain additional data for EVEDA to reduce uncertainty margins	X	X		X
TG-2	Li purification/ monitors/ corrosion/ erosion	- Characteristics of impurity trap systems - Material selection of monitors	Obtain additional data for EVEDA to improve reliability	X	X		X
TG-3	Engineering Design (include RH test)	- Examination of interface items - EVEDA Li test loop - Remote handling system	Establish base design for EVEDA phase	X	X		

(IFMIF Ex.subcommittee, EFDA CSU-Garching, Nov. 2002)

Schedule (2003 and beyond)

The following schedule is expected based on 2 years transition period.



H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

Transition phase activities in Japan

Transition Phase Activities (Target System)

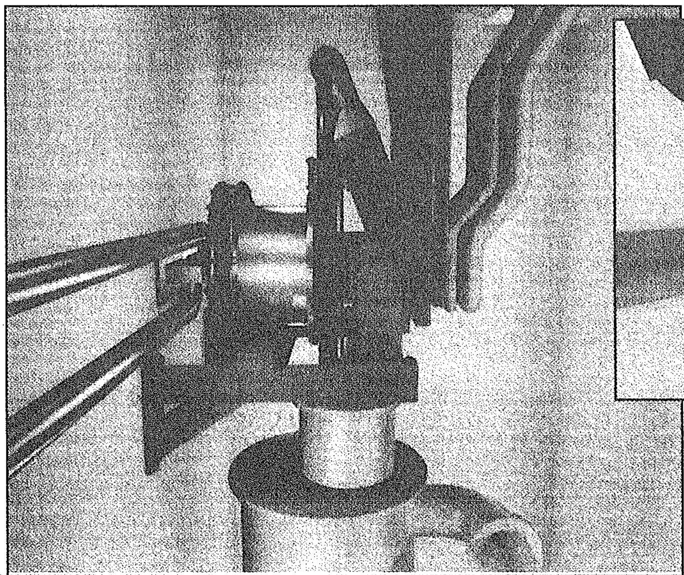
Task ID	Task Title	Contributing Party EU	JA	US	RF	Overview of Task Content	Japanese Activities: Universities(Draft)	JAERI(+JNC)
TG-1	Flow stability in Li and water experiment	X	X		X	i) Long term Li loop experiment	-Deatiled surface mesurement by fast camera (Osaka Univ.) -Effect of evaporation on components -Long term exp.(up to 100hrs)	Participation to Osaka Li exp. (Fast camera, Contact sensor)
						ii) Water exp at different curvature		Optimization of flow guide of quench tank
						iii) Diagnostics for Li/Water exp.	-Updated ultra sonic sensor (Osaka Univ.) -Laser sensor (Nagoya Univ.)	JNC type ultra sonic sensor (JNC)
TG-2	Li purification/ monitors/ corrosion/ erosion	X	X		X	i) Characteristics of impurity trap systems	-Evaluation of tritium getter material and alternative N2 getter material (Univ.Tokyo)	Consideration of Li purification system based on the KEP
						ii) Material selection of monitors		Consideration of monitor concept
						iii)Examination of corrosion/erosion		Survay of corrosion data
TG-3	Engineering Design	X	X			i) Examination of interface items		Preliminary design and interface definition
						ii) EVEDA Li test loop		Design of Li test loop
						iii) Remote handling system		Test of lip seal welding

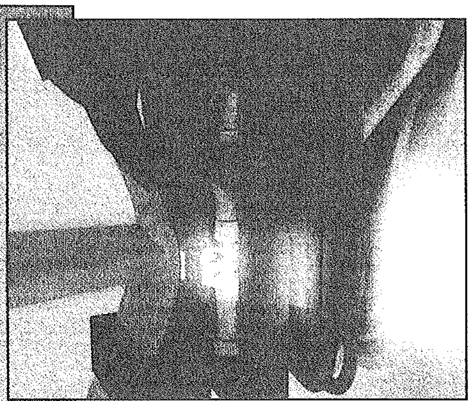
H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

IFMIF

3D view of Target assembly

3D CAD model has been established based on the KEP design. Design improvement is in progress.





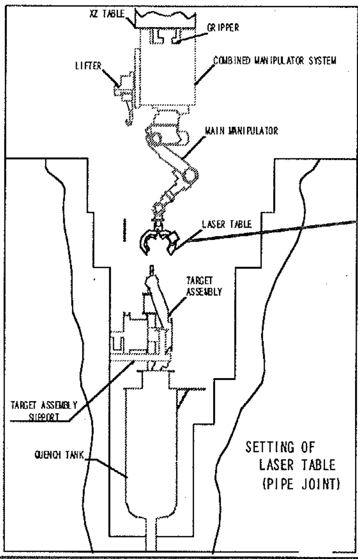
(Top) Magnified view
(Left) Target assembly and Test cell

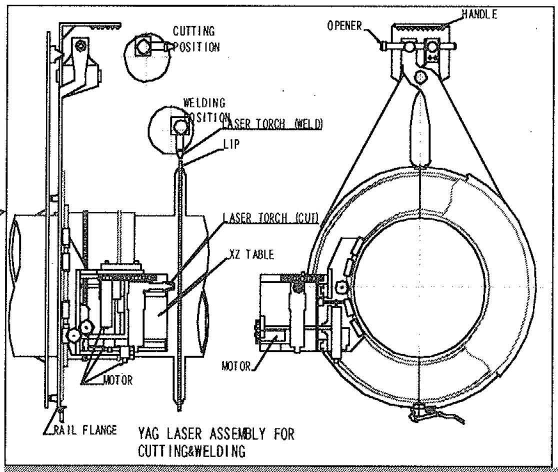
H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

IFMIF

Laser Table for Cutting/Re-welding

Welding/cutting of lip seal is done by laser table attached to RH arm.



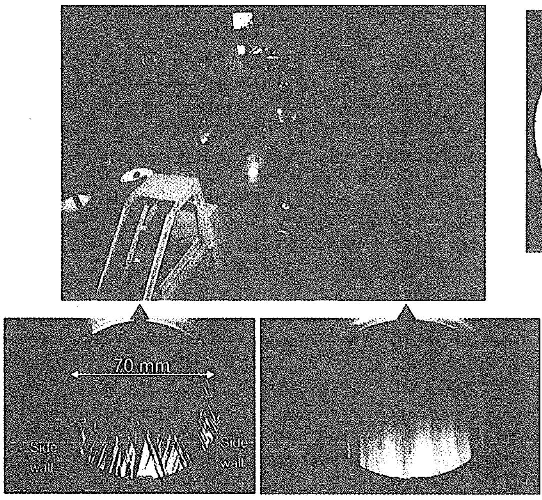


Laser Table for welding/cutting

H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

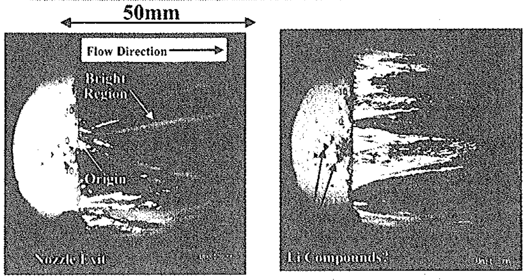
Li flow experiment in Osaka University

Osaka Li loop



2.2 m/s   13 m/s

Latest results on surface wakes



5m/s   10m/s

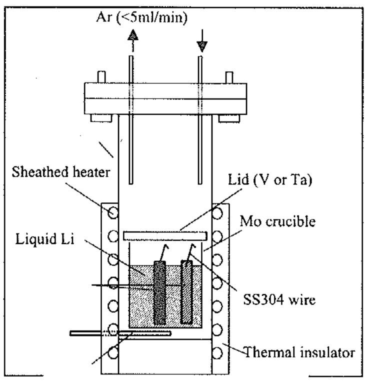
Picture of Free Surface after a several several weeks of operation

Wakes will not arise fatal effect on Li free surface on beam foot print. Study of origin of the wakes is under investigation.

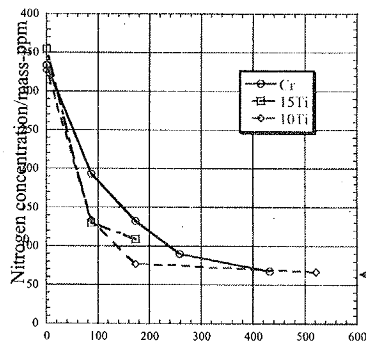
H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

Nitrogen control study in University of Tokyo

As candidate hot trap material, characteristics of Cr and V-Ti alloy has been measured. Uses of Cr in high N region and V-Ti alloy in low N region are recommended.



Experiment setup



65 ppm

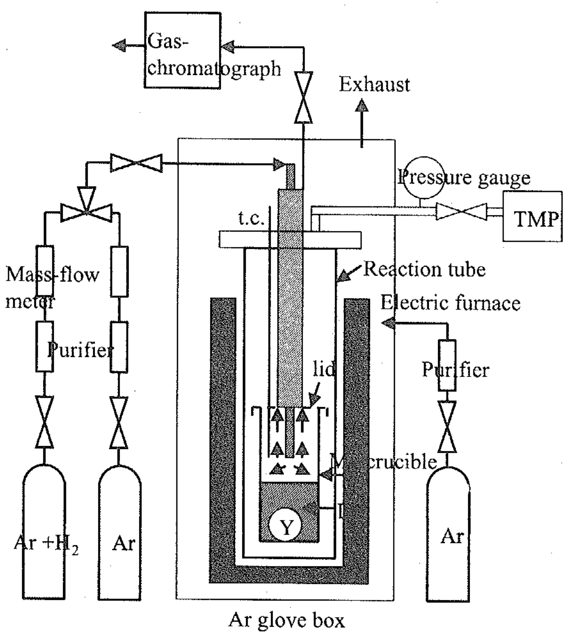
In case of Cr, 65 wppm is limit due to Li-Cr-N Formation

Temporal behavior of Nitrogen in Li (Cr, V-10%Ti, V-15%Ti)

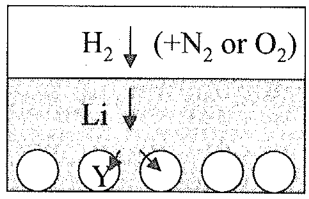
-> In IFMIF, 135 m^3 of hot trap area is needed.
- >Optimization of V-Ti alloy, Test of Fe-Ti-V alloy

H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

Tritium control study in Kyushu University



Experimental setup of hydrogen isotope Recovery (H_2-Li-Y)



Schedule

FY2003

(1) H_2 absorption in Li or Y

(2) H_2 absorption in Li + Y without nitride or oxide

FY2004

(3) H_2 absorption in Li + Y with nitride or oxide (from U. Tokyo)

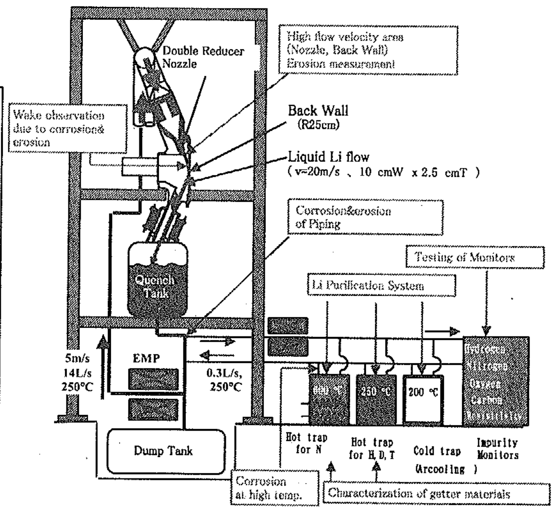
H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

EVEDA Li test loop

- Re-evaluation of Li test loop has been done.
- Using existing components, 30% cost reduction may be possible.

Specification of EVEDA Li test loop

Nozzle exit shape : 10 cm^W x 2.5 cm^T
(26 cm^W x 2.5 cm^T: IFMIF TG)
Li velocity : 10 to 22 m/s
Li flow rate : 50 l/s (133: IFMIF TG)
Impurity content : <10 wppm
Li purification : Cold trap, Hot traps
Diagnostics : High speed camera,
Ultra-sonic sensor, Imp.monitors



H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

Tasks in transition phase ('03-'04)

**Tasks in transition phase have been defined.
(IFMIF Ex.subcommittee, EFDA CSU-Garching, Nov. 2002)**

Target Tasks in Transition Phase

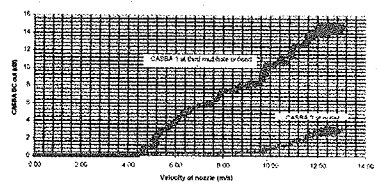
Task ID	Task Title	Overview of Task Content	Justification	Contributing Party			
				EU	JA	US	RF
TG-1	Flow stability in Li and water experiment	- Long term Li loop experiment - Water exp at different curvature - Diagnostics for Li/Water exp.	Obtain additional data for EVEDA to reduce uncertainty margins	X	X		X
TG-2	Li purification/ monitors/ corrosion/ erosion	- Characteristics of impurity trap systems - Material selection of monitors	Obtain additional data for EVEDA to improve reliability	X	X		X
TG-3	Engineering Design (include RH test)	- Examination of interface items - EVEDA Li test loop - Remote handling system	Establish base design for EVEDA phase	X	X		

H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

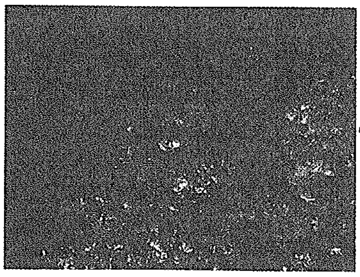
1st Result of Water Jet Exp. in ENEA

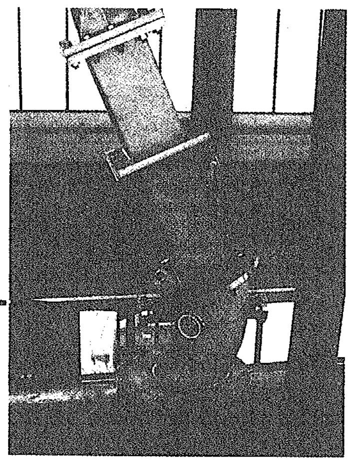
To evaluate joint gap effect on surface behavior and cavitation behavior, water exp. is being performed.

Cavitation signals



Free surface Wave at 10 m/s



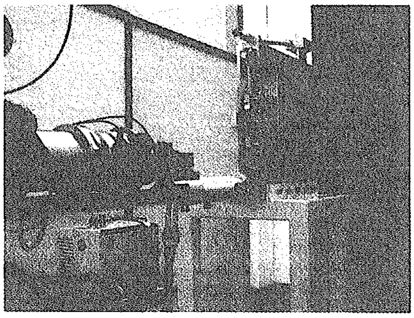


H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

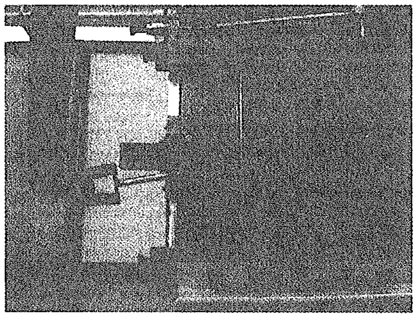
IFMIF RH of bayonet type back plate in ENEA

Both installation and removal procedures have been carried out using the tools shown below.

To complete this activity, delivery of the final bolting tool is awaited, although improvement to the mock-up will continue.



First step of the bolting procedure



Completion of bolting procedure on the back-plate

H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

IFMIF Tasks in transition phase ('03-'04)

Tasks in transition phase have been defined.
(IFMIF Ex.subcommittee, EFDA CSU-Garching, Nov. 2002)

Target Tasks in Transition Phase

	Task ID	Task Title	Overview of Task Content	Justification	Contributing Party			
					EU	JA	US	RF
	TG-1	Flow stability in Li and water experiment	- Long term Li loop experiment - Water exp at different curvature - Diagnostics for Li/Water exp.	Obtain additional data for EVEDA to reduce uncertainty margins	X	X		X
	TG-2	Li purification/ monitors/ corrosion/ erosion	- Characteristics of impurity trap systems - Material selection of monitors	Obtain additional data for EVEDA to improve reliability	X	X		X
	TG-3	Engineering Design (include RH test)	- Examination of interface items - EVEDA Li test loop - Remote handling system	Establish base design for EVEDA phase	X	X		

H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

Li loop experiment in IPPE

Objectives

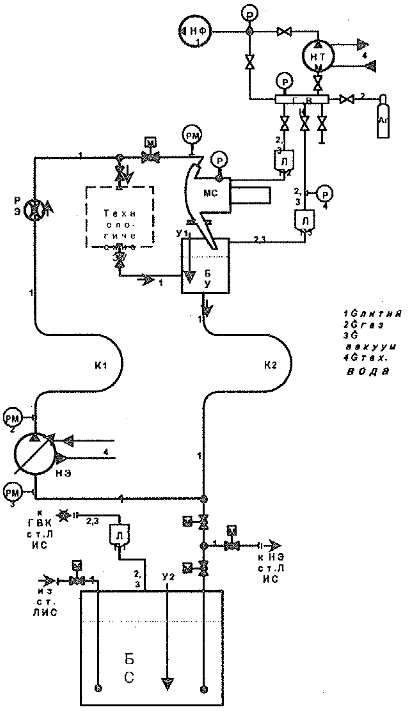
Evaluate Li hydraulic behavior in curved vertical Li flow.

Specifications

-Li flow: 7 cm wide,1 cm thick
-Velocity:20 m/s
-Flow rate:0.8 m^3/min

Schedule

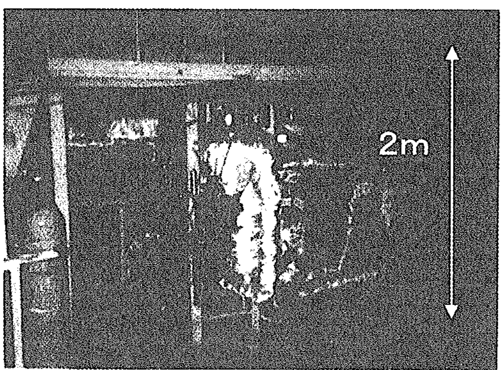
-Design,Fabrication: - early 2004
-Experiment : Spring 2004 -



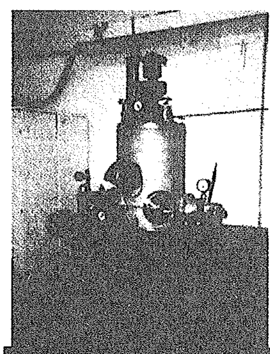
H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

Li purification and Erosion/corrosion

3 year Li target program (June 2002-June 2005) is on going under ISTC project.



Li Loop for Impurity Monitor and Li Purification System



Rotating Target for Corrosion Test (15 cm ϕ for 20 m/s)

H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

1st results of soluble getters (IPPE)

In soluble getter, IFMIF specification (<10 wppm) has been satisfied using oxygen getter of Ca and nitrogen getter of Al.

Soluble getter	Impurity	Tempera-ture, °C	Initial concentration % mass.	End concentra-tion, % mass.
Calcium Ca	Oxygen O	350	$(1\text{-}2).10^{-3}$	$(1\text{-}2)\cdot10^{-4}$
Aluminium Al	Nitrogen N	350	$(5\text{-}10).10^{-3}$	$(2\text{-}5)\cdot10^{-4}$

H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

Milestones of Major Options

The following major options shall be evaluated prior to EVEDA.

Design Items	Options	Interim Assessment	Evaluation
Back-wall (attachment method)	Lip seal welding /cutting method	Mar.04	mid 2004
	Bayonet type method		
Hot trap material (N2 removal)	Ti,Zr,Cr, V-Ti alloy	Mar.04	mid 2004
	Al(soluble getter)		
Hot trap material (T2 removal)	Yttrium	Mar.04	mid 2004
	Zr, La		
Monitors	Off-line	Mar.04	mid 2004
	On-line		

H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

Summary

In transition phase, the following target tasks are being conducted by EU, Japan and RF.

- Flow Stability in Li and Water Experiments
- Li Purification, Monitors, Corrosion/Erosion
- Design of EVEDA Li test loop
- Design of IFMIF Li target system

These activities will promote EVEDA program with smooth start of the tasks.

H. Nakamura, IFMIF Technical mtg, Kyoto, December 4-5, 2003

IFMIF Technical meeting - Kyoto 4,5 Dec 2003

Abstract on EU-Transition year task on IFMIF Li Target

At ENEA, water experiments are being in progress on a quasi full-scale simulacrum, called HY-JET, of a double reduced (SHIMA) nozzle with a curved replaceable back plate vertical target flow. Tests performed with a back wall curvature of 45 cm and a roughness of 0.8 μm and no stair at nozzle-back wall joint have been carried out. It was demonstrated that in laminar flow, below 2.5 m/s, some diagonal wakes remain attached to the lateral tray walls and these wakes disappear above the transition to turbulent flow. At higher velocity, approaching 10 m/s, the flow assumed the fully developed turbulence pattern with sparkling bubbles on the bulk, remaining well attached to the back plate. In the turbulence flow region, the lateral instabilities have procured overcoming of flow beyond the lateral tray walls. The Gortler vortexes are not clearly evidenced due to superimposition with the lateral instabilities. Cavitation noises on both the flow straightener-orificed plates and at the outlet the nozzle respectively at 5 m/s and 10 m/s have been detected by ENEA CASBA-2000 patented accelerometer, with the resonance signal resulting almost linear with the nozzle velocity.

The activity on lithium corrosion and chemistry has been continued. The ENEA Brasimone lithium loop adaptation has been almost completed. Actually basic chemistry results are expected from Nottingham University (GB): they will provide the base for the set up of impurity monitoring and purification systems to be implemented in the Li loop.

The activity devoted to the design, manufacturing and testing of the removable back-wall bayonet concept has been continued at ENEA Brasimone. The back-wall prototype has been manufactured. Tests have been carried out in order to verify working and sealing capability. The sealing capability has been checked also at 270°C. During year 2003 remote handling tests have been performed at room temperature and in atmosphere. The prototype RH capability has been proven and the tests allowed for a further optimization of the design.

INTERNATIONAL FUSION MATERIAL
IRRADIATION FACILITY

EU Lithium Target Tasks

B.Riccardi (ENEA Frascati)

ENEA Frascati

B.Riccardi, IFMIF Meeting - Kyoto Dec 2003

Li Target Tasks

- Support to test for the cavitation investigation
- Water experiments
- Lithium corrosion and chemistry
- Design, construction and remote handling test of the removable back plate

Support to test for the cavitation investigation

Objectives

- Monitoring of the cavitation occurrence near the nozzle and the orificed flow straighter of the HY-JET mock-up at ENEA Brasimone.

- Monitoring of the cavitation occurrence on the OSAKA University lithium loop (near the electromagnetic pump and the orificed flow straighter pressure drop control device).

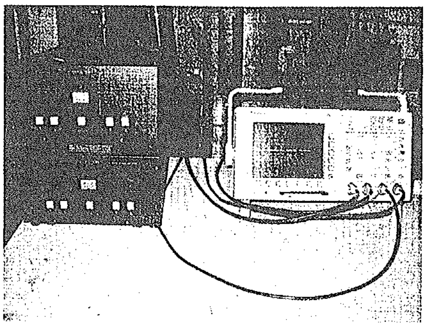
The CASBA monitors the bubble re-implosions due to cavitation or boiling phenomena.

The CASBA acoustic detection of bubble re-implosions is based on vibration frequency spectra obtained from an accelerometer operating in its non linear resonance region.

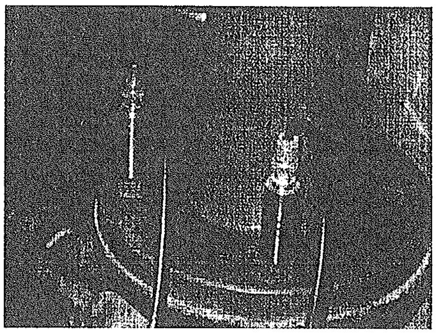
The CASBA accelerometer has a resonant frequency of 38-40 kHz, much higher those generated by mechanical or hydrodynamic vibrations. Therefore, it magnifies the bubble noise emissions at a frequency close to its resonance.

CASBA accelerometer Main features

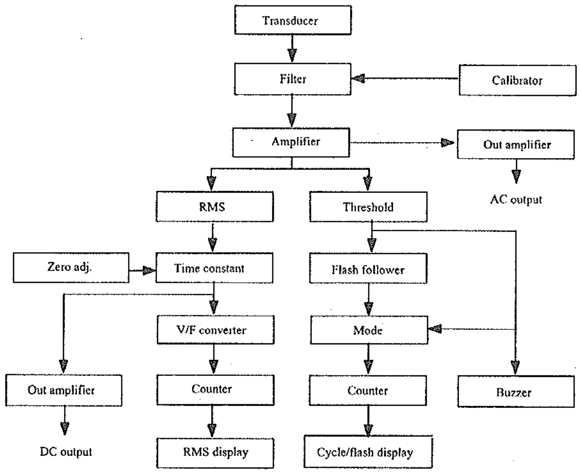
•Accelerometer resonance	38-40 kHz;
•Temperature max	60 ° C;
•Filter Pass Band	35-45 kHz;
•Signal gain	-20 +30 dB;
•AC Out	Filtered trasducer signal;
•DC Out	50 mV/dB – max 4 V
•Time constant	single shot, 1.5, 2.5, 10 s
•Signal	Floating / ground
•Display indication	dB=20Log(DC Out/0.05) ± GAIN (dB)



CASBA 2000 unit



CASBA 2000 gauge



CASBA FLOW CHART

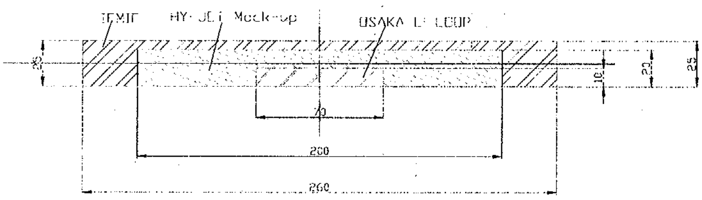
Water experiments

Task objectives

– evaluation of the stability of the IFMIF Lithium jet flow on the target by water experiments on HY-JET a simulacrum of double reduced nozzle with a concave replaceable back plate;

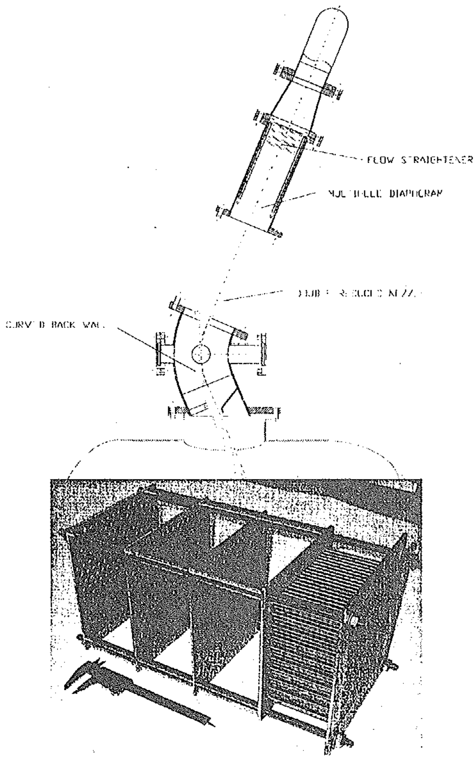
– monitoring of the cavitation occurrence near the nozzle, the flow straightener and the orificed pressure drop control device of the HY-JET mock-up.

NOZZLE CROSS SECTION							
IFMIF Real scale				HY-JET MOCK-UP Scale ratio = 0.8			
Width [m]	**Height [m]**	**Area [m^2]**	**Hydr.Diam. [m]**	**Width [m]**	**Height [m]**	**Area [m^2]**	**Hydr.Diam. [m]**
0,26	0,025	0,0065	0,045614035	0,200	0,020	0,00416	0,036491228
Out. velocity [m/s]		15		**Out. velocity [m/s]**		10	
				flow rate [l/s]		41,6	
				pressure drop [Pa]		4,99E+04	
HYDRAULIC SIMILITUDE BETWEEN LITHIUM/WATER							
LITHIUM				**WATER**			
Temperature [°C]	**density [kg/m3]**	**dynamic viscosity [Pa s]**	**Reynolds**	**Temperature [°C]**	**density [kg/m3]**	**dynamic viscosity [Pa s]**	**Reynolds**
250	**510,0**	**5,01E-04**	**6,96E+05**	0	999,8000	1,79E-03	2,04E+05
300				10	999,0000	1,31E-03	2,78E+05
400	**490.0**	**4.,20E-04**	**7,98E+05**	20	998,2000	1,00E-03	3,64E+05
500				30	995,4000	7,97E-04	4,56E+05
				40	992,4000	6,53E-04	5,55E+05
				50	990,5000	5,47E-04	6,61E+05
				60	**980,7000**	**4,65E-04**	**7,70E+05**
				70	975,5000	4,11E-04	8,66E+05
				80	971,8000	3,55E-04	1,00E+06
				90	965,0000	3,17E-04	1,11E+06
				100	957,1000	2,82E-04	1,24E+06

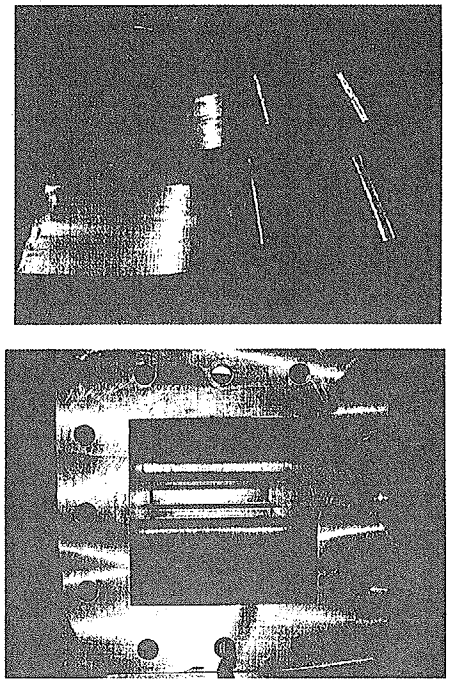


Parameter	IFMIF Li loop	Water Exp. JAERI	Osaka Li loop	Water Exp. ENEA
Nozzle Geometry	Double Reducer Nozzle	Double Reducer Nozzle	Double Reducer Nozzle	Double Reducer Nozzle
Back wall Geometry	Concave (R=250 mm)	Straight	Straight	Concave (R=250 mm)
Jet Thickness (mm)	25	10	10	20
Jet Width (mm)	260	100	70	200
Li Speed (m/s)	20	20	15	10-20
Flow Rate (l/s)	133	TBC	13	30-80
Vacuum Condition (Pa)	10^{-3}	10^4 - 10^5	100-1000 (TBC)	Pressure $5\ 10^5$ (Pa)
Nozzle Material	RAF	acrylic resin	304 SS	304L SS

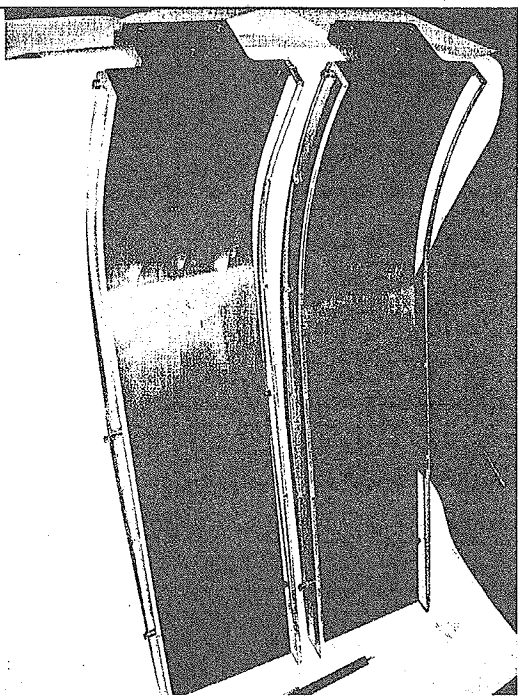
Comparison among IFMIF, Osaka and ENEA Brasimone mock-ups



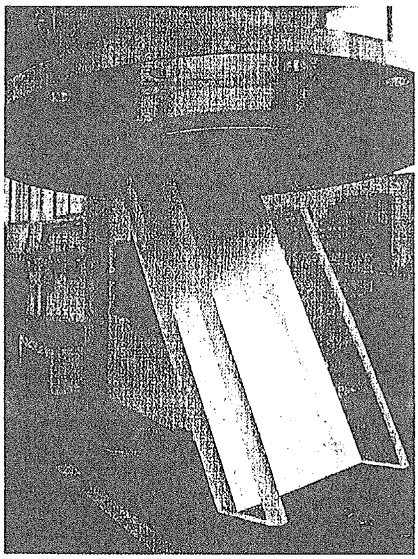
Flow-straightener and multi holes orificed grids

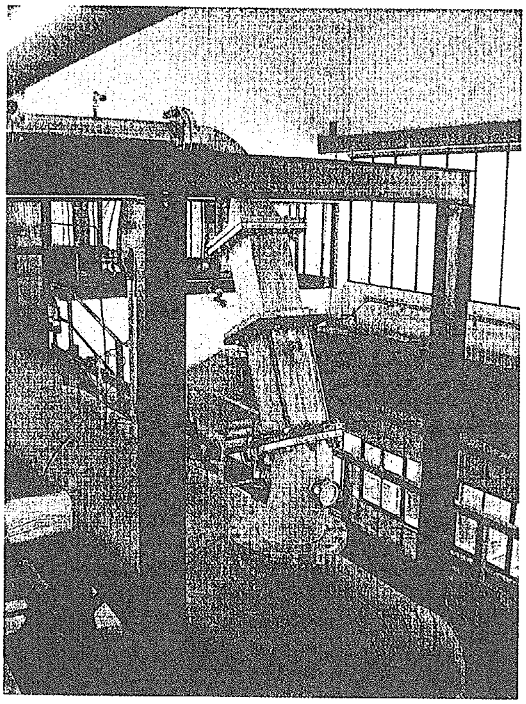


Nozzle plates after machining and after welding

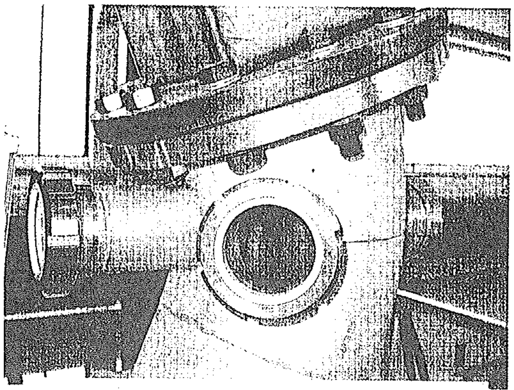


Concave back plates 250 mm 450 mm

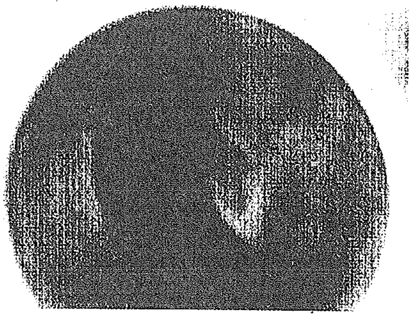




Final assembly of hy-jet mock-up



Flanged windows on the concave back wall



Status

First tests performed with a back wall curvature of 45 cm and a roughness of 0.8 μm without stair

in laminar flow below 2.5 m/s some diagonal waves (12 ° from the axes) remain attached to the lateral tray walls.

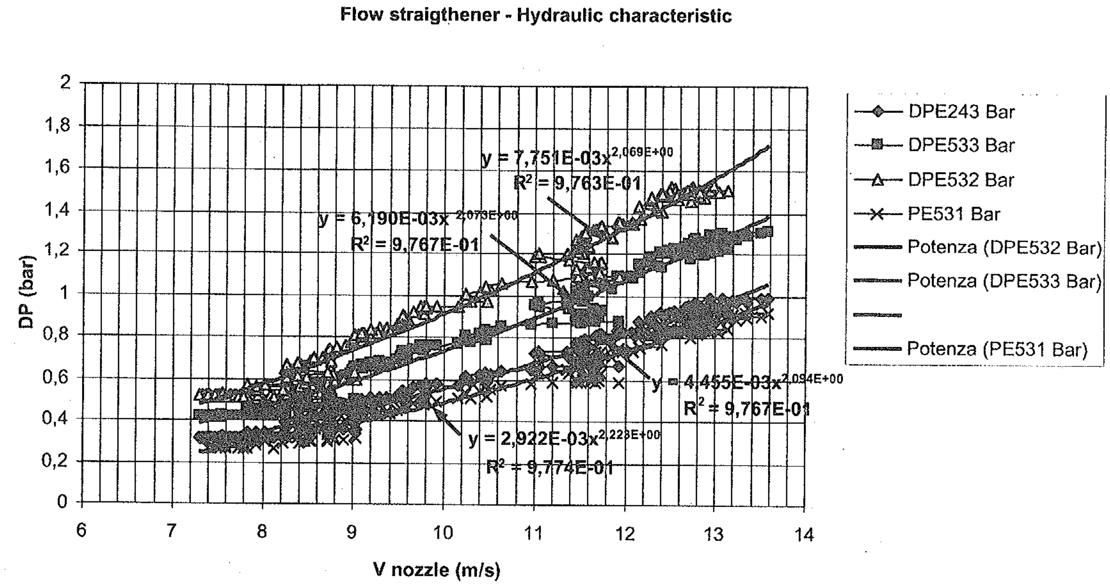
These wakes disappear above the transition to turbulent flow with the persistence of the flow detachment and instabilities and accumulation of flow on the lateral tray walls.

At higher velocity, approaching 10 m/s, the flow assumed the fully developed turbulence pattern remaining well attached to the back plate with lateral instabilities procuring the overcoming of flow beyond the lateral tray walls.

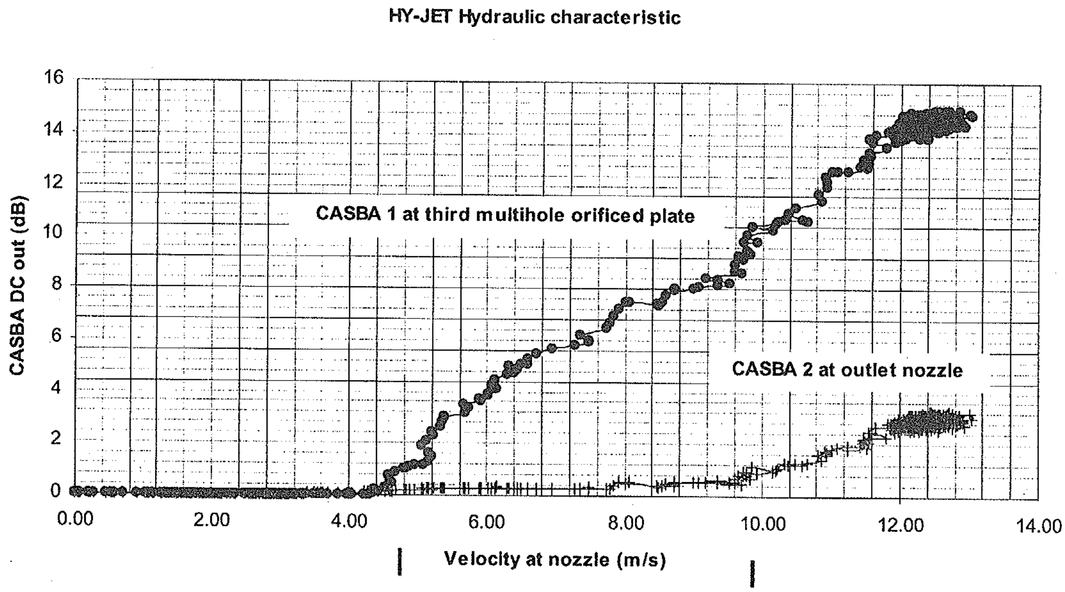
The Gortler vortexes not clearly evidenced due to superimposition with lateral instabilities.

The overall pressure drop for the flow straightener and three orificed plates at nozzle velocity of 10 m/s is about 0.09 MPa with a extrapolated value of 0.38 MPa at 20 m/s.

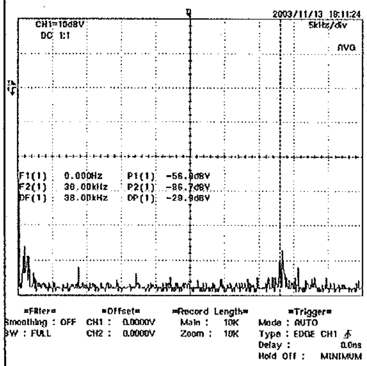
ENEA CASBA-2000 accelerometer detected the onset of cavitation noises on both the flow straightener-orificed plates and at the nozzle outlet respectively at 5 m/s and 10 m/s.



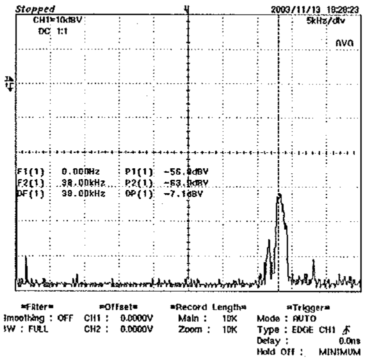
Hydraulic characteristic of the flow straightener and three orificed plates



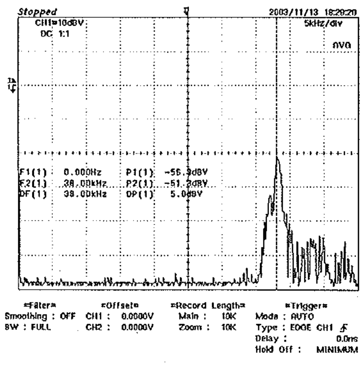
CASBA-2000 signals vs. nozzle water velocity



CASBA-2000 signal at the third orificed plate at 7.75 m/s

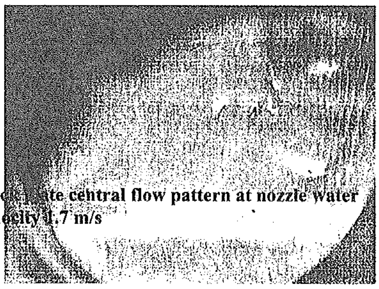


CASBA-2000 signal at the third orificed plate at 12.7 m/s



CASBA-2000 signal at the third orificed plate at 14.5 m/s

Cavitation noises on both the flow straightener-orificed plates and at the outlet the nozzle detected respectively at 5 m/s and 10 m/s.



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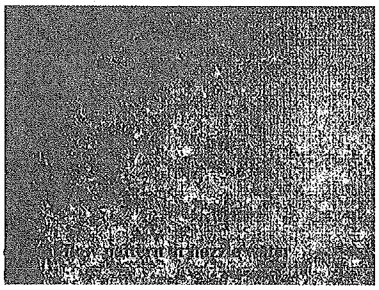
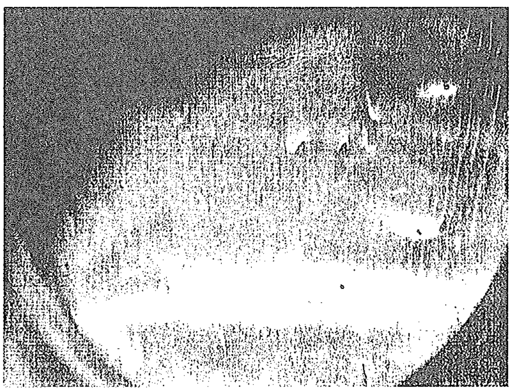
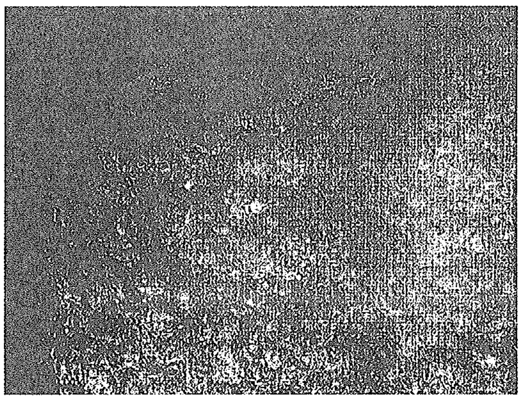


Back plate

velocity 10

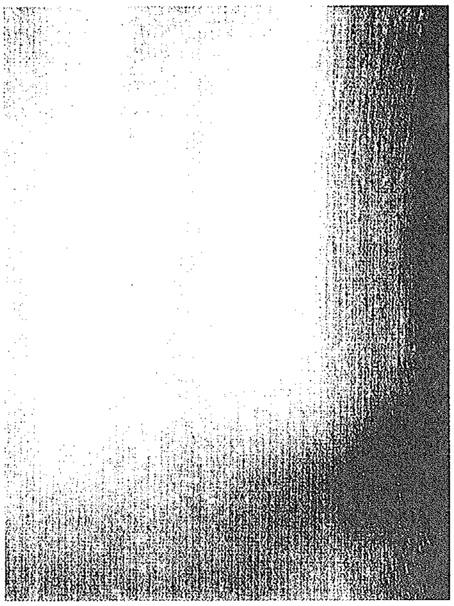


Back plate central flow pattern at nozzle water velocity 1.7 m/s



Back plate central flow pattern at nozzle water velocity 10 m/s

Back plate lateral flow pattern at 3.2 m/s nozzle water velocity



Back plate lateral flow pattern at 10 m/s nozzle water velocity

Lithium corrosion and chemistry

Aim of the task is the development of a Li purification strategy, including monitoring and removal systems

Impurity monitoring systems that could be considered in principle:

electrochemical sensors for N, C and H;

resistivity meter for N;

diffusion carbon meter;

analytical techniques.

For the **removal of impurities** two systems will be investigated in detail:

cold trap

hot trap.

Experimental evaluation of the corrosion rate of different materials (namely austenitic and martensitic steels) in flowing lithium.

Task sub-deliverables

Basic tests of Cold trap, Hot Trap and on-line monitoring.

4.a Selection of the most promising on-line monitoring methods (for N, C, H/D) for the successive development. *31/03/2002*

Preparation of the specifications for those meters and beginning the tests for N meters in stagnant Li. Intermediate report. *30/11/2002*

4.b Development of meters and conclusion of tests in stagnant conditions. Development of hot and cold trap systems and first tests. Intermediate report. *31/12/2004*

4.c Final tests in dynamic loop with impurities control for the metres and the traps. Final report.

Lithium corrosion tests for the loop components and back wall materials. *31/12/2001*

4.d Modification of the existing loop for the new experiments. Specifications preparation, test section design and components purchase. Intermediate Report *31/12/2002*
4.e Loop re-adaptation and compatibility tests beginning. Intermediate Report *31/12/2004*
4.f Conclusion of the tests – Final report

Analysis for the behaviour of some impurities in the primary loop. *31/12/2004*

4.g The main impurities will be evaluated and a strategy for trapping will be defined. This analysis will concern mainly C,N, O – Conclusion and final report

SOLUBILITIES OF THE NON METALLIC ELEMENTS IN Li

Solubility data in wppm

T [°C]	O	N	C
200	7.4	1450.4	0.4
300	86.7	8621.2	8.5
400	488.5	30172.8	79.8
500	1760.2	76365.8	417.5
600	4728.3	156240.2	1496.0
700	10366.6	275919.3	4123.0

Hydrogen monitoring (direct pressure measurement)

The selected method is based on diffusion meter by using a **Nb or Nb-Zr membrane.**

Nitrogen monitoring

N concentration measurement by resistivity technique (not specific).

The reference N monitoring technique is the electrochemical one by using solid state nitride conducting electrolyte

- Candidate : nitride compounds
- **Alcaline earth metal nitride halides A_2NX** (A=Mg,Ca, Sr or Ba; X=F, Cl, Br and I)
- **Thernary Li nitride compounds Li_3AlN_2 and LiMgN**

Oxygen monitoring

Electrochemical method < Reference

Amalgamation (Not on line) Back up

Carbon monitoring

Diffusion meter : Harwell carbon meter which use a Fe membrane.
Compatibility issue with Li to be assessed <Reference

Amalgamation : (Not on line) Back up

Impurity purification

200° C cold trapping should maintain impurities down to 63 wppm (**hydrogen**), 7 wppm (**oxygen**) and 2 wppm (**carbon**) – scravenger on stainless steel mesh.

For **Nitrogen** in addition to cold trap (Al or Ca) a hot trap is necessary Candidate materials: Ti or Ti-V alloy.

If it is found that hydrogen cannot be maintained at low level a hot trap made of Yttrium spounge may be employed

LITHIUM LOOP IN ENEA: LIFUS

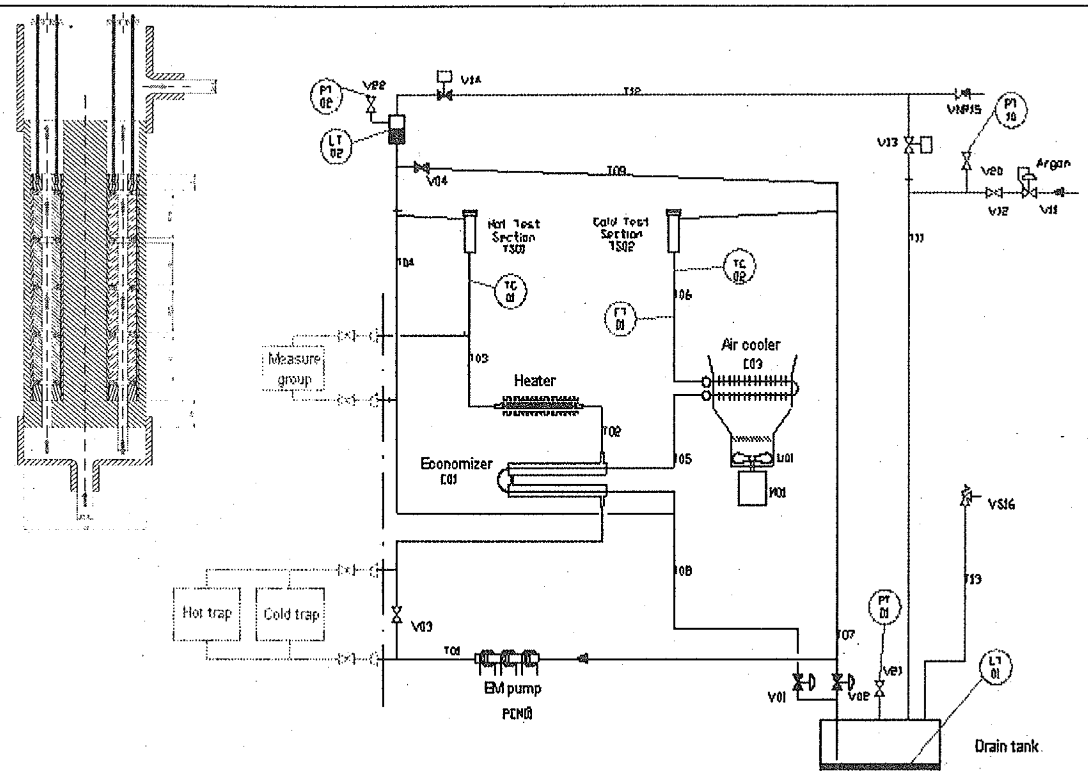
OPERATING LIMITS OF THE LITHIUM LOOP (LIFUS III)

Li inventory	30 liters
Temperature hot section	450 °C
Temperature cold section	300 °C
Maximum velocity test section	10 m/s

HEATER

Maximum power	34 kW
Heat flux	5.7 W/cm

Status : Loop re-adaptation completed



Remote handling of the removable back-plate

Task objectives

Design and manufacture of the back-plate mock-up;

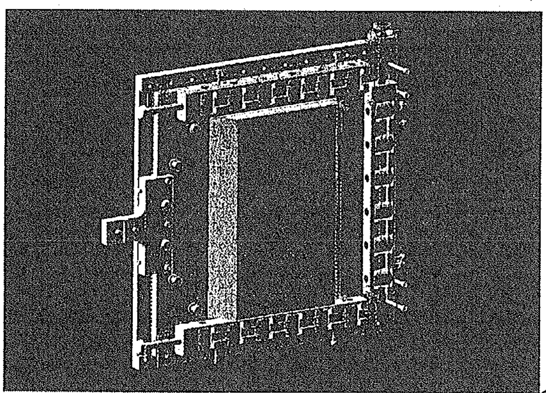
Testing of the proposed back-plate to validate the design;

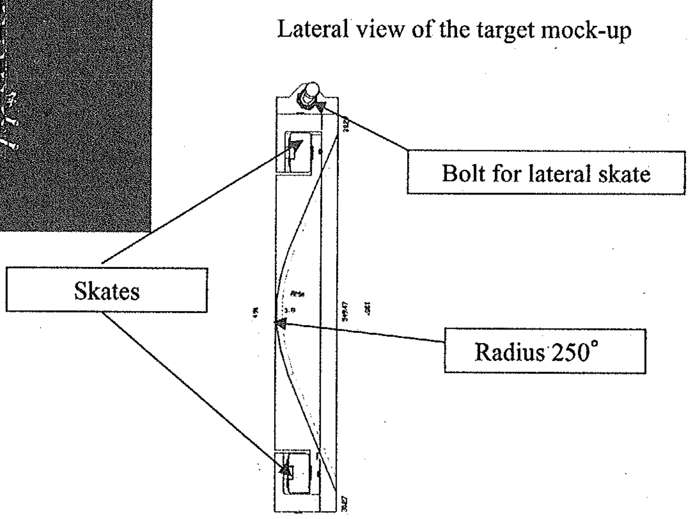
Definition and validation of the remote handling procedures.

The reference requirements for the target design are as follows:

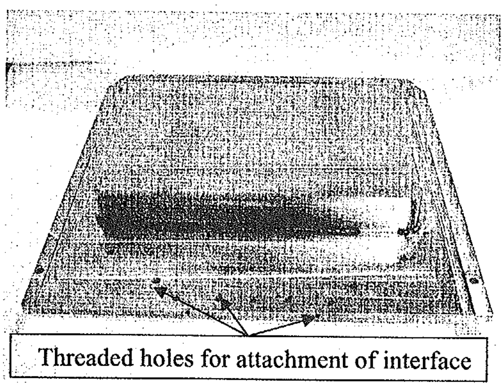
- ✓ Vacuum of 10^{-3} Pa in the target chamber;
- ✓ Vacuum of 10^{-1} Pa in the test cell – outside the target chamber;
- ✓ Leak rate 10^{-10} mbar l/s (10^{-11} Pa m^3/s);
- ✓ Lithium inlet and outlet temperatures 250° C and 300° C respectively;
- ✓ Temperature peaks up to ~ 400° C;
- ✓ Metal gasket seal.

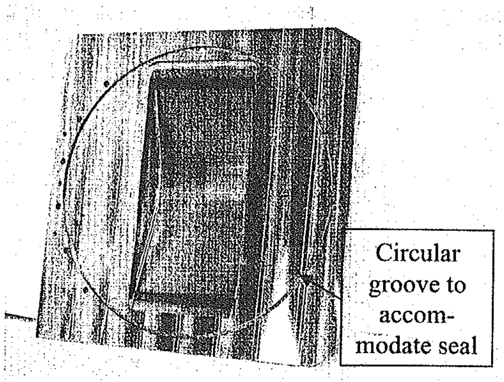
Back-plate mock-up assembly



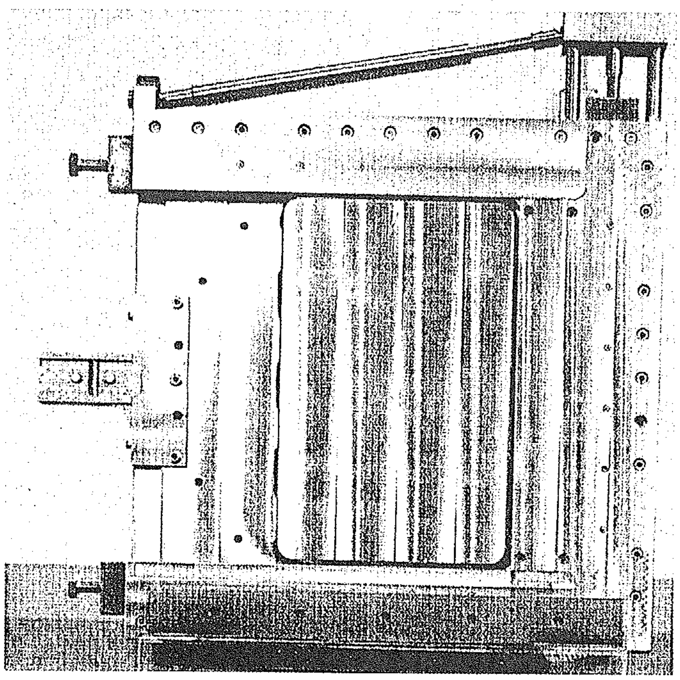


Removable back-plate:
- ✓ **Width: ~550 mm**
- ✓ **Height: ~550 mm**
- ✓ **Weight: 60 Kg**
- ✓ **Material: Stainless Steel Aisi 316L**





General view of the replaceable back-plate mock-up

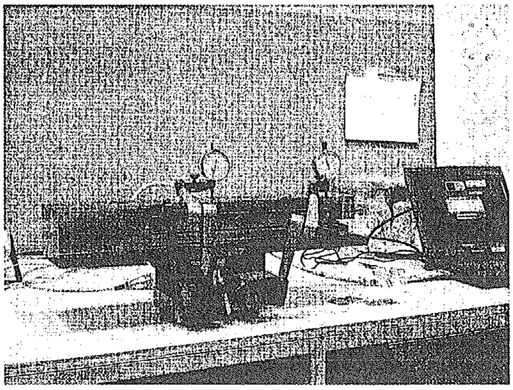


Locking systems verification and determination of the working parameters

Preliminary tests were aimed at checking validity of the locking system concept.

The trials have enabled verification of the working parameters – the torque and force transmitted to the plate – and general performance of the locking system.

The verification trials were carried out at room temperature and at 270 ° C.



Measures of force and torque

Use of:

✓ Load Cell up to 10 Ton ;

✓ Torque cell ;

✓ Two mechanical dial gauges ;

✓ Dynamometer.

Vacuum tests

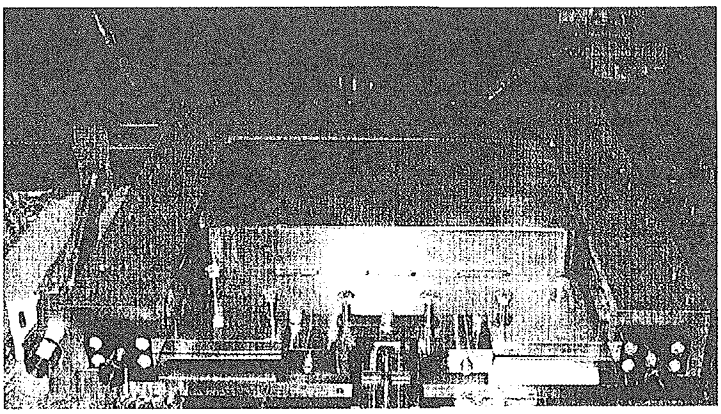
The reference parameters for these trials are:

✓Leak rate 10^{-10} mbar*l/s

✓Vacuum of 10^{-3} Pa in the target chamber;

✓Vacuum of 10^{-1} Pa in the test cell outside the target chamber;

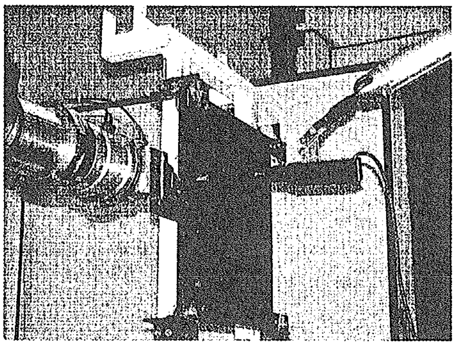
The trials have been carried out successfully at room temperature and at 270° C

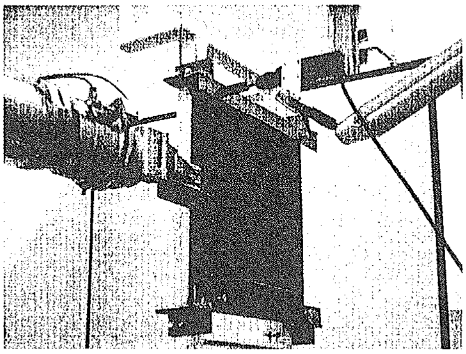


Remote handling

The remote handling activity of the removable backplate will be carried out in the existing DRP facility at the ENEA Research Centre at Brasimone.

This facility was originally conceived to test the refurbishment operations of the ITER divertor cassette and it is generic enough to accommodate demonstration of a wide variety of R.H. procedures. Therefore, preliminary tests aimed at establishing the suitability of this facility to the task were carried out in June 2002.





TOOLING

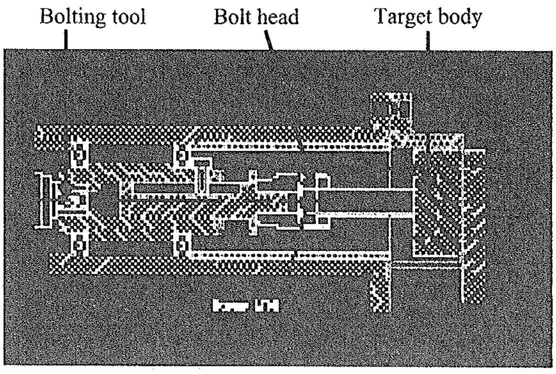
For the RH activities it was necessary to develop a number of dedicated tools and interfaces:

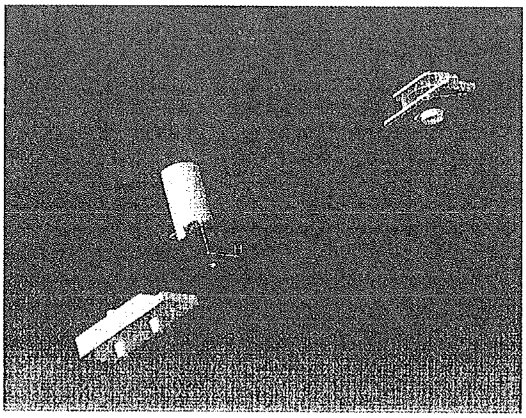
- Tools for bolting the upper, lower and lateral skates (tool + mechanical interface with the back-plate itself).
- A tool to complete the back-plate bolting sequence to the specified torque (a simple ratchet spanner with a mechanical interface to the light manipulator), as well as initial loosening.

The latter two tools are going replaced by a new dedicated bolting tool

Tools

Interface between HM and Atlas Copco Bolting tool;

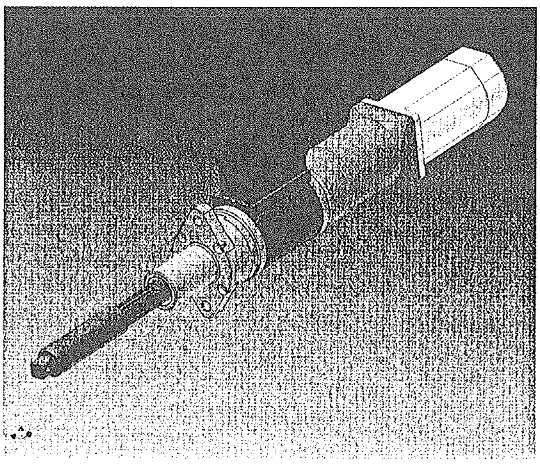


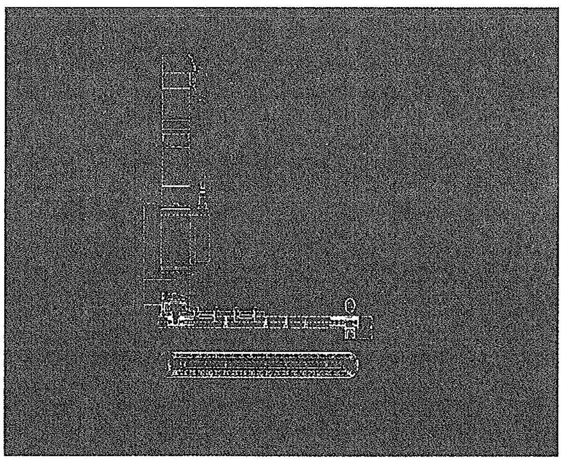


3D view of simple bolting tool

Tools

- Bolting tool for the bolts on the back-plate (delivered October 2003)

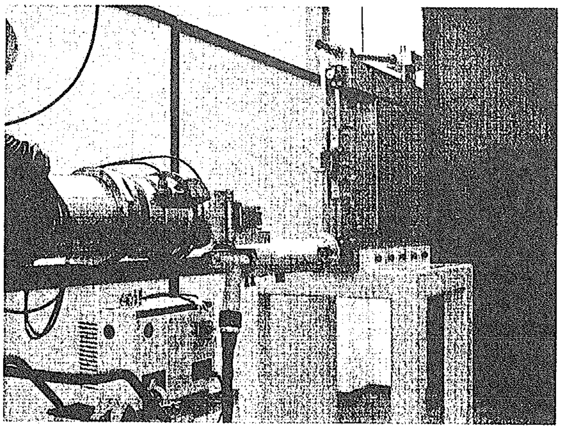




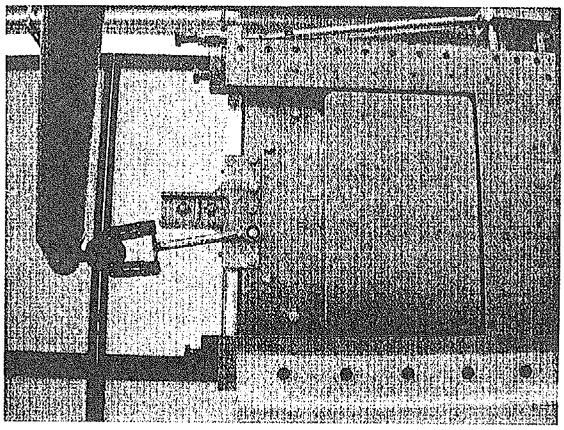
RH Trials

The RH activities began in May 2003 and are completed.
Both installation and removal procedures have been carried out using the tools previously described.
The activity is completed. With the delivery of the final bolting tool and the improvement to the mock-up will continue.

First step of the bolting procedure



Completion of bolting procedure on the back-plate



Results

A cycle of back-plate installation and removal sequences has been completed successfully with the following results;

- Removal appears more difficult than the installation:
- The time necessary to free the pins on the back-plate from the holes on the frame is more than is expected.
- Some damage to the internal surface of the frame, where the back-plate slides, was found.

Design Improvement and Advice

Improvements:

- The geometry of the back-plate pins must be changed;
- The lower part of the back-plate should be made using a low friction material; (100Cr6)
- The same material could be used for the lower part of the frame in the area where the back-plate slides;

Advice:

- Particular attention must be paid to the alignment between the Heavy Manipulator and the back-plate interface;
- Care must be taken to limit the torque applied to the back-plate skates and bolts to within the planned values.

ISTC
МНТЦ

Status of #2036 ISTC Project

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4-6.12.03

ISTC project #2036

THE THERMAL-HYDRAULIC AND TECHNOLOGICAL INVESTIGATIONS FOR VALIDATION OF THE PROJECT OF LITHIUM CIRCULATION LOOP AND NEUTRON LITHIUM TARGET FOR IFMIF

Main tasks

- Analysis of simulation conditions of IFMIF target lithium jet (TG12K)
- Research of lithium jet thermohydraulics (TG14K)
- Research of lithium evaporation from a free jet surface and lithium deposition on the vacuum line mock-up walls (TG41K)
- Investigation of lithium flow interaction with structural materials (TG15K, TG16K, TG22E, TG23E)
- Development of devices and methods for impurity concentration monitoring and lithium purification from impurities (TG31K, TG71K)
- Preparing of the final report for the project on the whole

Task 1

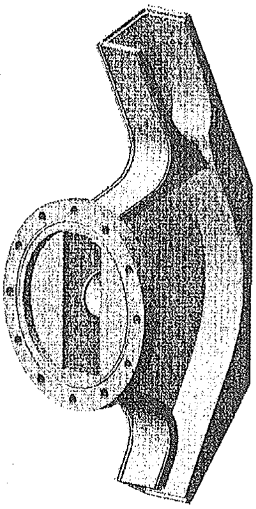
Simulation conditions:

- conditions of interfacial waves appearance;
- velocity profiles at the nozzle exit and in the jet;
- pressure distribution along the nozzle;
- state of surfaces contacting with lithium and its change during lifetime;
- limitations of possible change of the main parameters (power and current of deuteron beam, velocity profile of lithium flow, amplitude of interfacial waves);
- tolerance level of the target assembly vibration;
- conditions of nucleation and growth of hydrogen bubbles in lithium jet ;
- statistical parameters of turbulence

Mathematical model of Li jet

Task 2

Target assembly mock-up



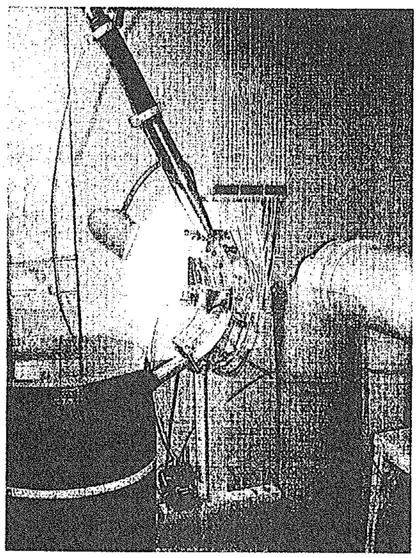
Straightener:
- tube bundle diameter of 4x0.3 mm

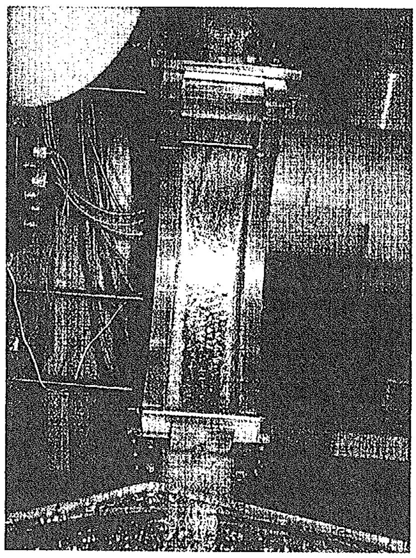
Double-reducer nozzle:
- model Shima;
- symmetric;
- 1st step 100→25 mm,
  2nd step 25→10 mm

Back wall:
- curvature radius of 250 mm

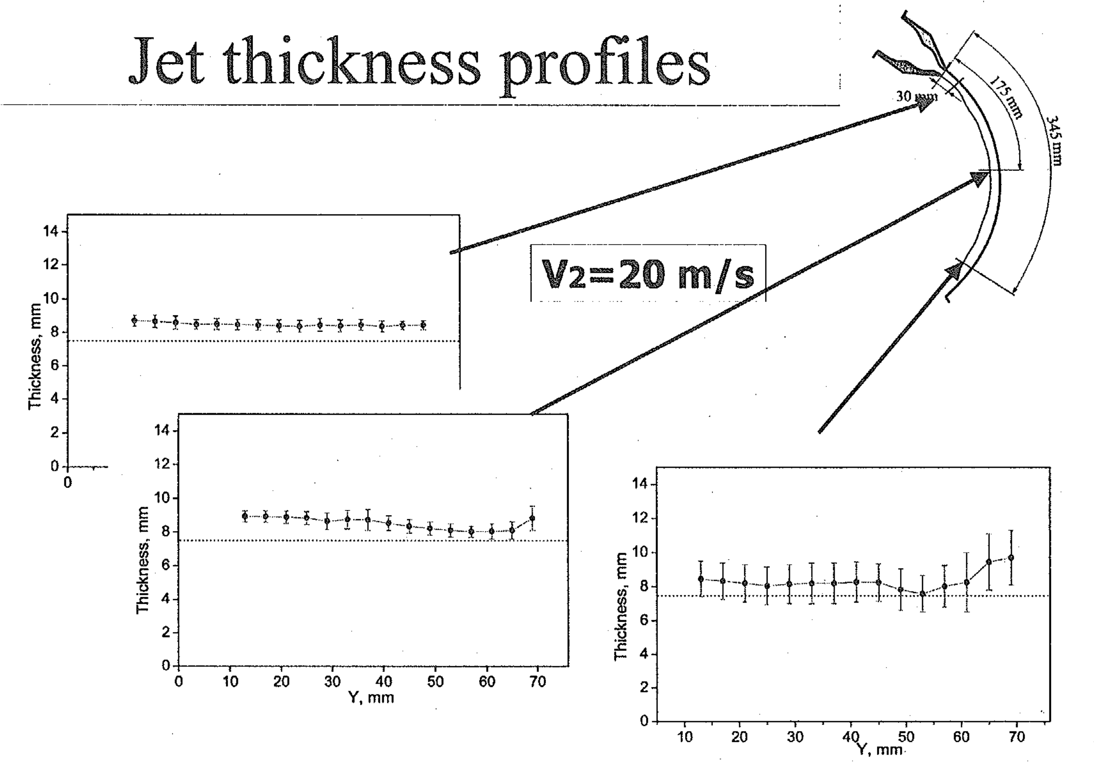
Lithium jet:
- rectangular cross section of 70x10 mm^2;
- velocity – up to 20 m/s;
- temperature – up to 300 °C

Water experiments

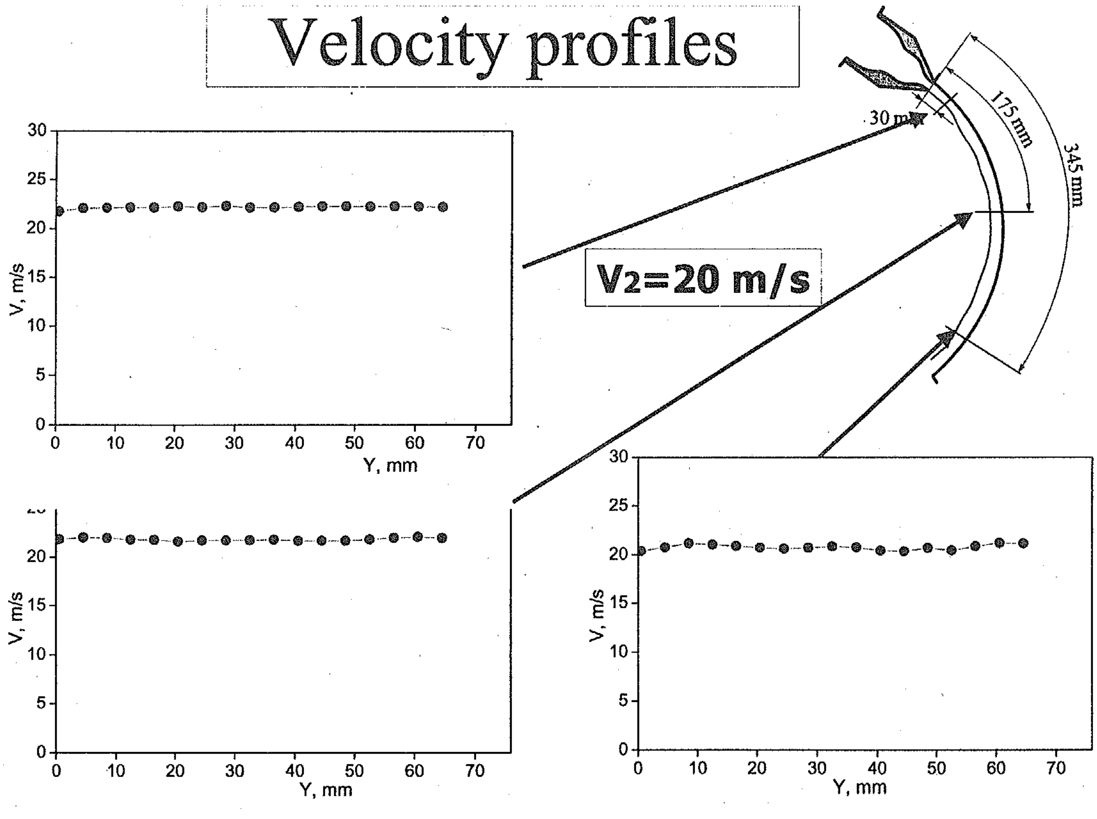




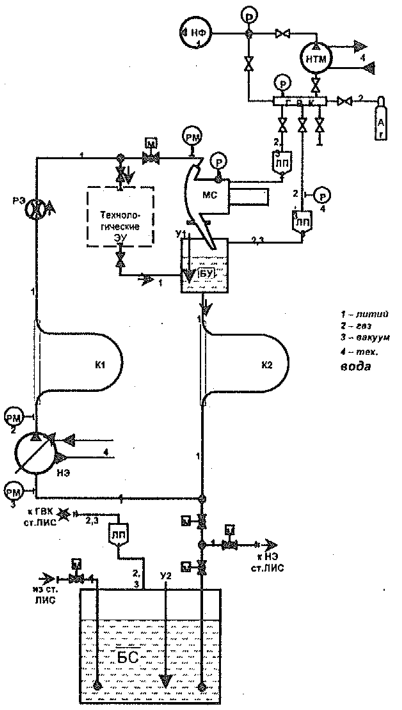
Jet thickness profiles



Velocity profiles



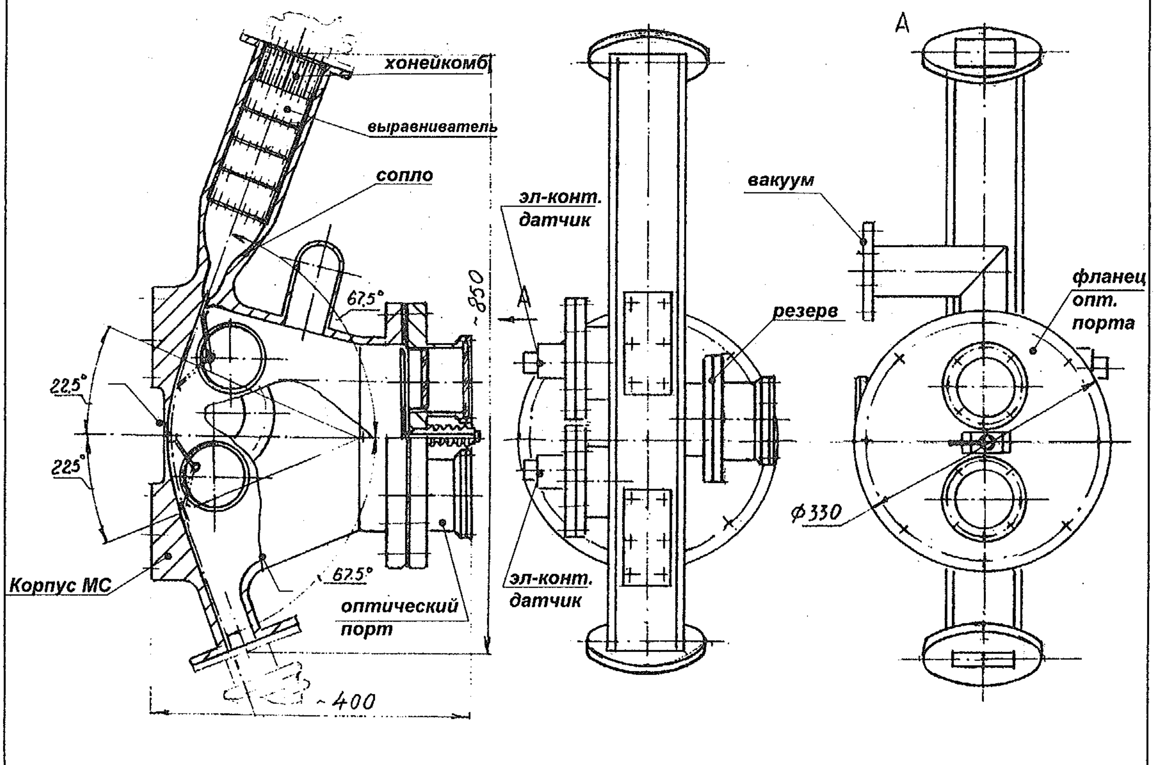
Task 2



Lithium target loop:

- flow rate up to 50 m^3/h;
- temperature up to 300 ^{o}C;
- hydrostatic head 12 m;
- tubing 62 (79) mm ;
- pressure 10^{-3}-10^5 Pa;
- lithium volume 200 l;

Equipment are acquired and manufactured. Assembling the LTF-M is stated.



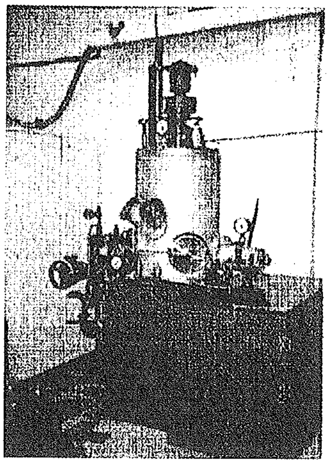
Target assembly mock-ups

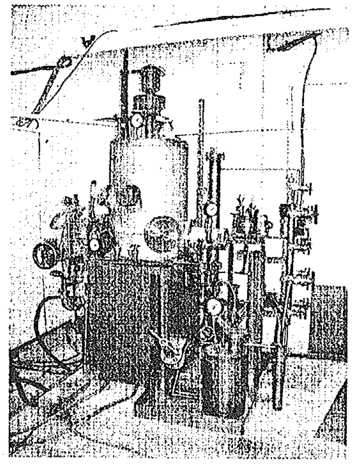
Parameter	FMIT	JAERI Phase 1	JAERI, Phase 2	Osaka	IPPE	Prototype	IFMIF
Coolant	Lithium	Water	Water	Lithium	Lithium	Lithium	Lithium
Nozzle geometry	1 stage	2 stages	2 stages	2 stages	2 stages	2 stages	2 stages
Back-wall	Concave R=100mm R=269mm	Concave R=250mm	Straight	Straight	Concave R=250 mm	Concave R=250 mm	Concave R=250 mm
Jet thickness, mm	19	25	10	10	10	25	25
Jet width, mm	100	240	100	70	70	100	260
Jet speed, m/s	17	1.2-17	2.5-20	Up to 15	Up to 20	20	20
Flow rate, l/s	40	102	20	13	13	50	133
Vacuum conditions, Pa	10^{-3}	10^{5}	10^{4}-10^{5}	10^{2}-10^{3}	10^{-3}-10^{5}	10^{-3}	10^{-3}
Working temperature°C	250	20	20-30	300-550	250-300	250-280	250-280
Nozzle material	304 SS	Acrylic resin	Acrylic resin	304 SS	12X18H10T	RAS	RAS
Lifetime, hours	9000	-	-	500	>1000*	>5000*	175200*
State	Shut-down in 1982	Tested in 1997	Tested in 2001-2002	Tests with 2002	Operation with 2004	Designing	Designing

Task 3

- Analytical investigations of evaporation and mass transfer from the target free surface are carried out.
- Intensity calculations for non-equilibrium evaporation of melt components were performed using kinetic ratios brought together into the system of two differential equations of mass transfer in gas phase .

Task 4

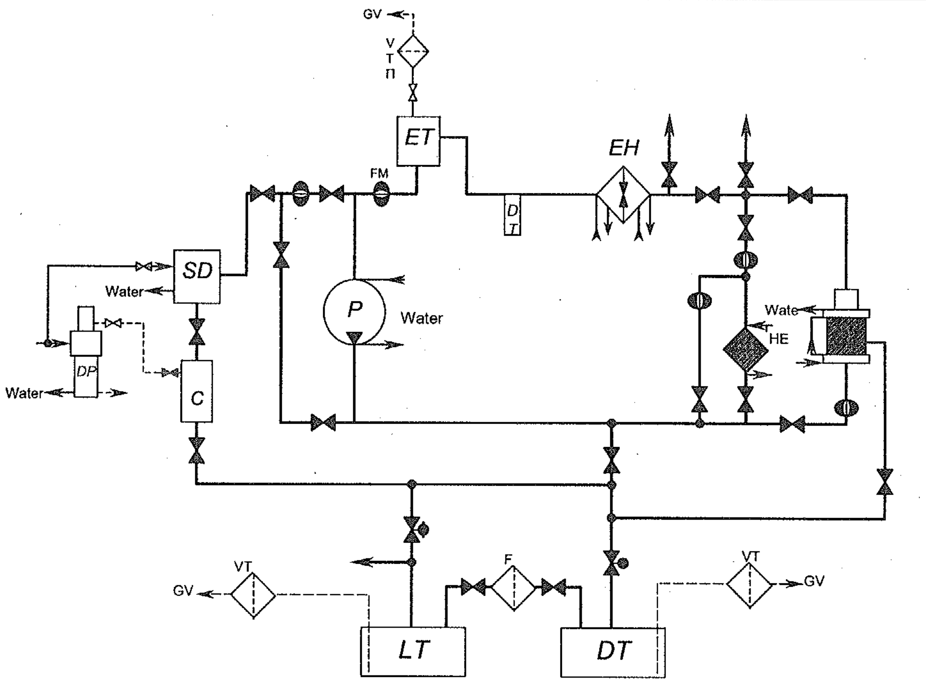




Problems of physical and chemical interaction Li with structural materials is analyzed:

Rotating disk facility is modernized.

Task 5



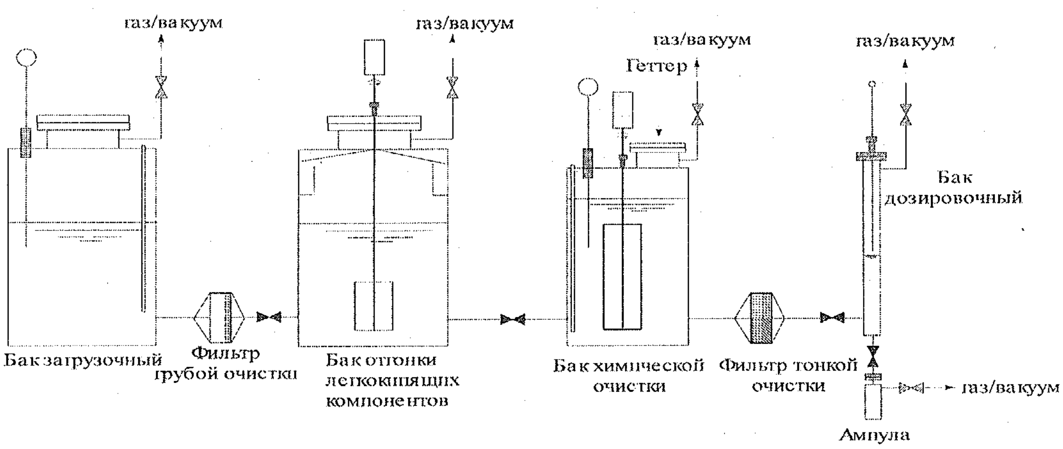
Test of cold trap and plug indicator is under way

Task 5

- Measurements of empty and filled existing loop outgassing are made;
- Sampler distiller precommissioning;
- Investigation of lithium purification by soluble aluminium is carried out.;
- Oxygen electrochemical cell is manufactured;
- Possibility of purification Li from Na is analyzed;
- Other methods of monitoring are developed.

Task 5

Технологическая схема установки



Nearest plans

1.Manufacturing the target assembly – 02.2004

2.Assembling LTF-M – 12.2003-03.2004

3.Startup of LTF-M – 06.2004

4.Startup of "Rotating disk" facility – 01.2004

5.Water experiments to be continue

High Speed Lithium Flow Experiments for IFMIF Target

(Transition Task **TG-1: Flow stability in lithium and water experiment)**

H. Kondo, A. Fujisato, N. Yamaoka, S. Inoue, S. Miyamoto, F. Sato, T. Iida, H. Horiike (Osaka Univ.), I. Matushita (Shinryo High Technologies, Ltd.), M. Ida, Hideo Nakamura, Hiroo Nakamura (JAERI), and T. Muroga (NIFS)

A lithium flow experiment simulating IFMIF target was carried to investigate behavior of wakes on free-surface of high-speed flow. A lithium loop in Osaka University was modified to have free-surface test section, where liquid lithium flows in a horizontal flat channel. The lithium flow with width 70 mm, thickness 10 mm and flow velocity up to 14 m/s was generated through a double reducer nozzle with the same shape as that validated to well generate stable and high-speed flow up to 20 m/s through water experiments in JAERI.

While a free-surface of the lithium flow was smooth in initial experiments, wakes on the free-surface (Fig. 1) were observed after several-weeks experiment in 1.5 year. This type of wake was observed also in FMIT experiments. The shape of wake observed in Osaka lithium loop was compared with that predicted by a theory as an isophase line of wave caused by disturbance source moving at a constant velocity on a still water surface. The experimental result well agreed with the theoretical one (Fig. 2), thus, the theory is applicable to high-speed lithium flow.

After lithium drain, some fouling with thickness up to about 1 mm (Fig. 3) were founded on the inside-wall near the nozzle exit. These fouling are source of the observed wakes, and they were considered to be made of lithium compound (its analysis is under preparation). This type of disturbance source is negligible in case of IFMIF lithium target under the condition of well-controlled impurity. Other disturbance source of nozzle corner between the nozzle edge and side-wall is unavoidable even in the IFMIF target. However, the wake region would not exceed the width margin of 30 mm in IFMIF target, applying the experimental and theoretical results.

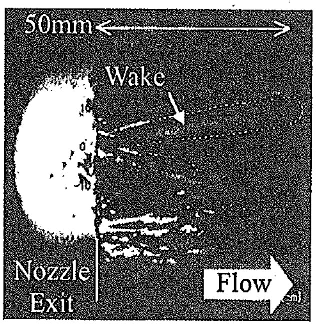


Fig. 1. Li surface near nozzle exit

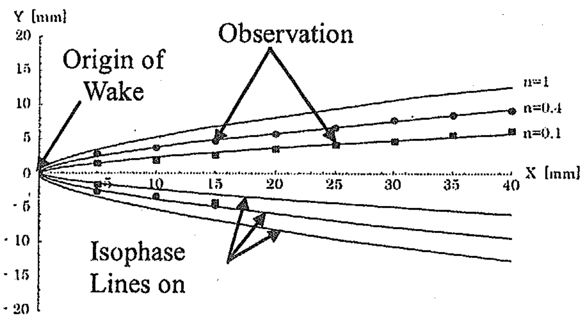


Fig. 2. Wakes in experiment and theory

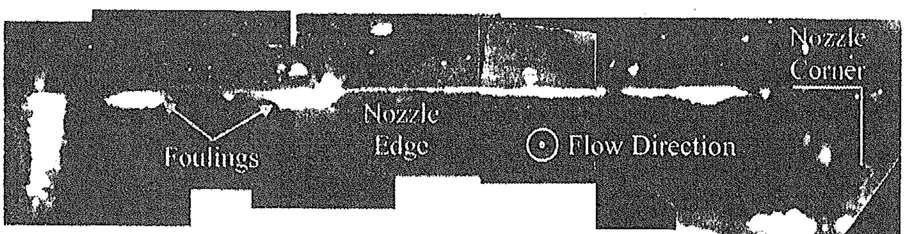


Fig. 3. Nozzle exit after Li drain

High Speed Lithium Flow Experiments for IFMIF Target
(TG-1: Flow stability in Li and water)

H. Kondo, H. Horiike (Osaka Univ.),
M. Ida, H. Nakamura (JAERI), et al.

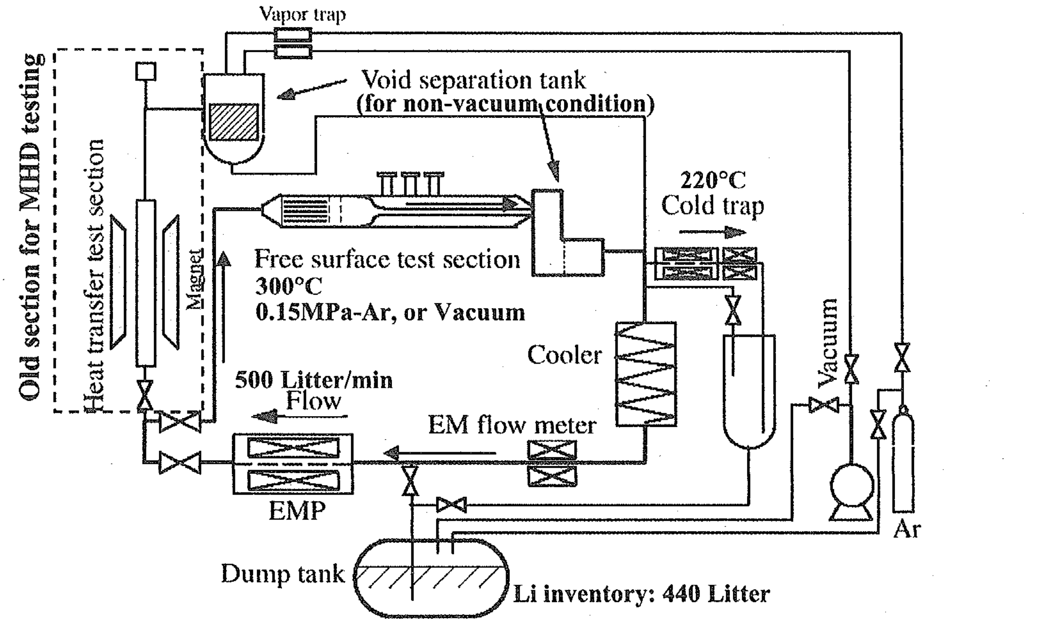
IFMIF Technical Meeting
Dec. 4 - 5, 2003
Kyoto

Objectives

- Examination on characteristics of wake on Li free-surface originated at nozzle exit
- Evaluation of surface stability in IFMIF Target affected by the wake

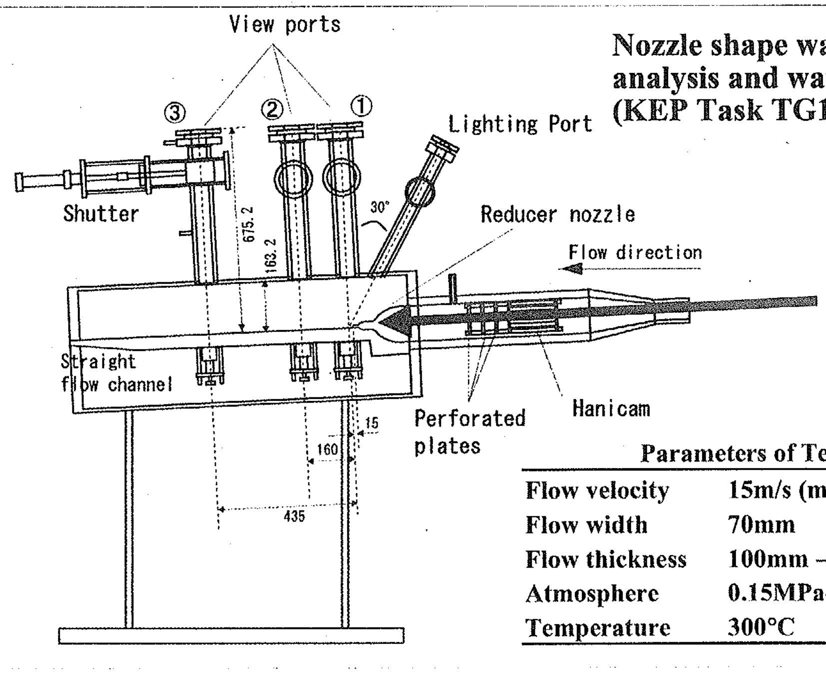
Experimental Setup (Schematic of Li Loop)

Modified to examine free-surface behavior



Experimental Setup (Test Section)

Li flow up to 14m/s was generated.



Nozzle shape was determined by analysis and water experiment (KEP Task TG11B)

Parameters of Test Section

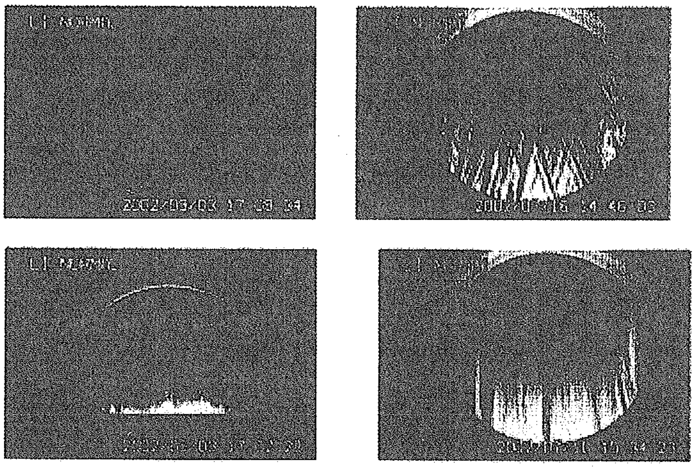
Flow velocity	15m/s (max.)
Flow width	70mm
Flow thickness	100mm → 10mm (by Nozzle)
Atmosphere	0.15MPa-Ar or Vacuum
Temperature	300°C

Results of Former Experiment

High-speed lithium flow with smooth free-surface was successfully generated.

5m/s

10m/s



Flow Direction

Nozzle Exit 150mm Downstream

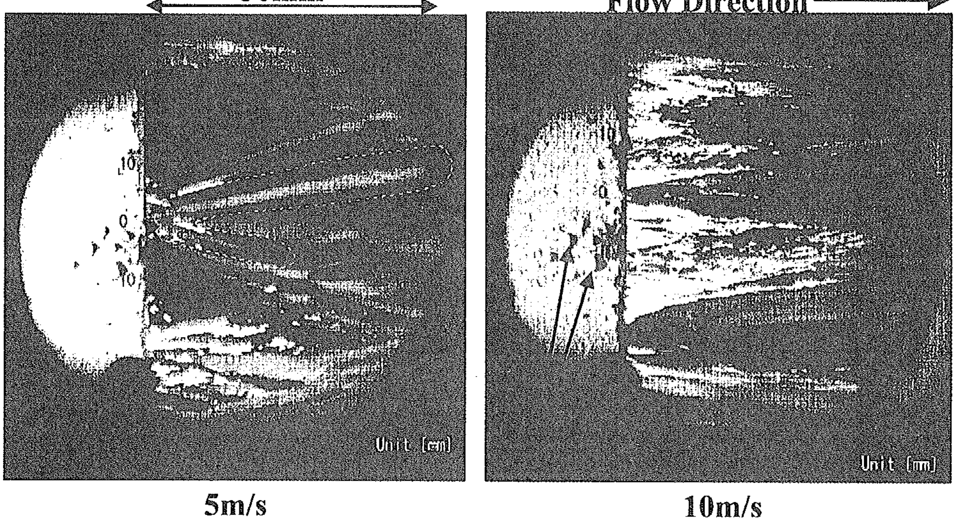
Picture of Free Surface after a few weeks of operation

Results of this Experiment

Wakes originated from several points at nozzle exit.

50mm

Flow Direction



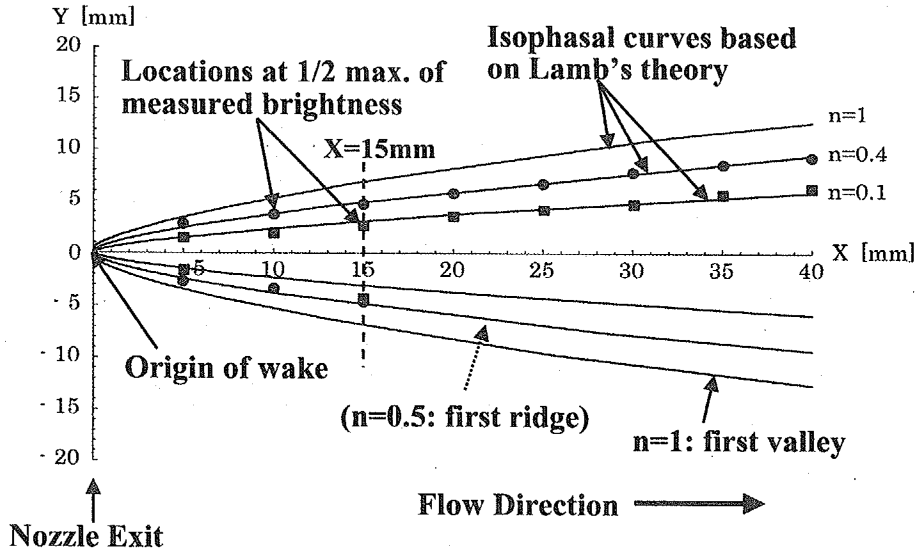
5m/s 10m/s

Picture of Free Surface
after a several several weeks of operation (in 1.5years)

Discussion

- Comparison with theoretical prediction -

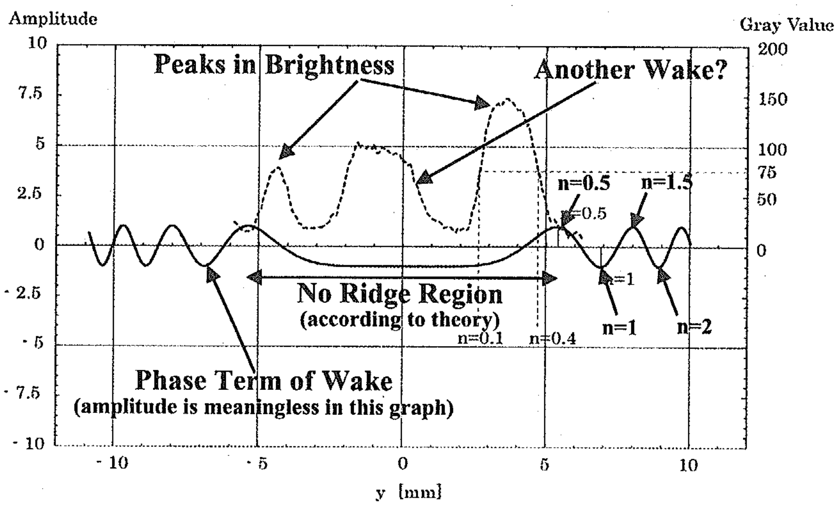
Observed wake location well fit theoretical isophases.



Discussion

- Comparison with theoretical prediction -

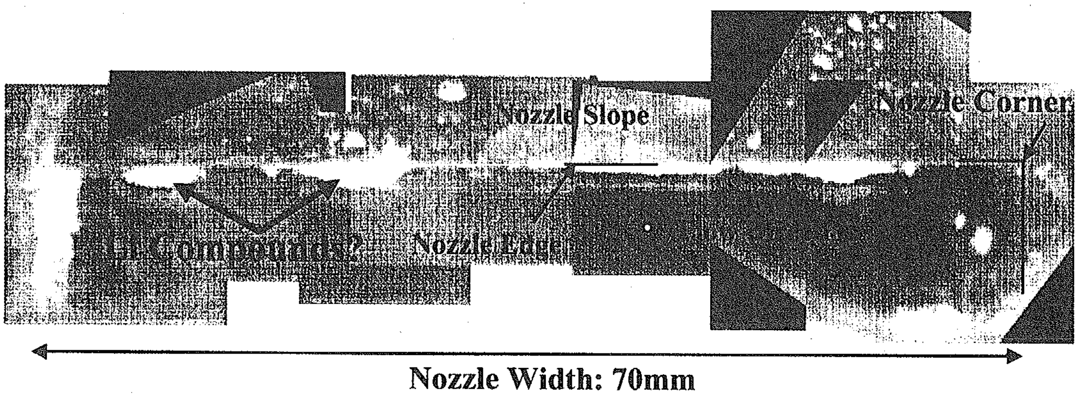
Two peaks in brightness were considered to corresponds to phases n=0.1-0.4



Theoretical Wake Phase and Measured Brightness (X=15mm)

Discussion
- Cause of wake -

Origins of observed wake is considered to be Li compound due to N_2 and O_2 from Ar cover gas and maintenance.



Picture of Nozzle Exit after Li Drain
(viewing in the direction opposite to flow)

Discussion
- Extension to IFMIF Target stability -

- **Wakes due to Li compounds would not occur in case of IFMIF with vertical target and under condition of impurity control.**
- **Wake would occur only at the both corners of nozzle exit between nozzle edge and side-wall in IFMIF.**
- **However, with extension of the experimental and theoretical results to IFMIF case, any wake would not spread beyond width margin of 30mm in IFMIF target.**

Conclusion

1) Observed location of wake well agreed with that predicted by the theory.

2) No instability due to wake on beam footprint: 200mm x 50mm would occur because of margin 30mm x 2 from side walls

Future Plan

1) Analysis of Li compound is under preparation.

2) Measurements of wake/wave amplitude are under preparation.
   - Resistivity method (Fork type)
   - Ultrasonic method
   - Laser interference method

V. Heinzel, FZK

Optimised design of the High-Flux-Test-Module

The High-Flux-Test-Module was optimised towards „maximum space for specimen“ which means on the other hand „minimum space for equipments for temperature control like heaters, temperature sensors, helium channels for cooling etc.“. The main components of the HFTM are the container with the integrated lateral reflector and the rigs with material specimens. The specimens are housed in capsules which are inserted into the rig casing. The space between the specimens in the capsules is filled up with sodium or a sodium/potassium eutectic alloy. Electric jacket wire heaters are wrapped around the capsule. Thermocouples within the specimen stack provide information for temperature control and heater power adjustment. Helium flows upward through channels between the rigs with a width of 1 mm at the longer side and 0.5 mm at the smaller sides. It removes the power from nuclear reactions and from the electric heaters. The electric heater system of each capsule is subdivided into three heaters which are controlled independently. They have to keep the temperature distribution within the specimen stack within a given tolerance during beam on periods as well as during beam off situations. The heaters have to compensate the vertical power profile of the nuclear power density within the specimen stack, the temperature increase of the helium along the channel and changes of the heat transfer coefficient due to the boundary layer development in flow direction. The heat conduction in the specimen stack limited the rig width to about 10 mm. Following specimen arrangement studies the rig geometry comes to most reasonable dimensions for the stack width of 9.3 mm and a height of 81 mm. Between the capsule and the rig walls a gap with stagnant helium is installed. This reduces the heat transfer from the capsule to the rig wall so far that the power from the heaters can compensate the heat losses. Further, the rig wall temperature is kept close to the helium temperature.

The lay-out of the HFTM was done by means of the CFD code STAR-CD. In case of the proper arrangement of the electric heaters the temperature of the specimen stack can be adjusted at about 450 °C with a tolerance of 30 °C. Over a stack height of 66 mm the temperature is within 15 °C. Temperature distributions analyses at 650 and 330 °C were presented too, showing comparable tolerances.

The turbulence model used with the STAR-CD simulation calculations was compared to experimental data with good agreement. However these data were measure in a tube with 27 mm, which was much larger than the IFMIF channel, and with air. Experiments with smaller channels in a helium loop at FZK are taken up. First pressure loss measurements with a not yet heated channel revealed that the different pressure loss effects have to be recorded separately in order to provide data apt for the code validation. The validation of the code concerning pressure loss and heat transfer must by available before an integral full scale test of the HFTM.

The final design of the HFTM was postponed for preparing a first step towards a design integration of the test cell. A further reason was the neutronic repercussion of the Medium-Flux-Text-Module to the HFTM. A design optimisation of the MFTM was started. Stress analyses may also require design amendments. The results will be the input to a repetition of the nuclear calculations followed by an iterative redesign of HFTM and MFTM

Major work to be done during the EVEDA phase will be dedicated to the full scale test of the HFTM and later of the MFTM. The experimental work will comprise the testing of the loop component in respect of the operational helium loop for IFMIF.

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Optimised Design of the High-Flux-Test-Module for the International-Fusion-Material-Irradiation-Facility

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Or
New Reference Design:

He-cooled HFTM with Rectangular-Plate-Shaped Rig and Triple-Heater-Capsule

Design Goal:
Maximum Space for Specimen

Minimum space for: heaters, cooling channels, structure and ......

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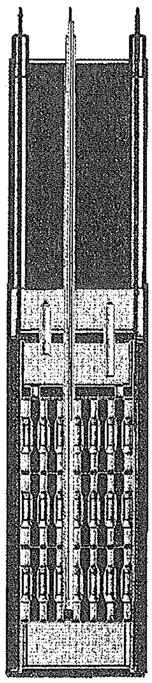

Specimens and the space between filled with sodium and thermocouples in

capsules with electric jacket heaters

Specimen stack height 81 mm

Inserted in rigs

Weld seams out of high flux field

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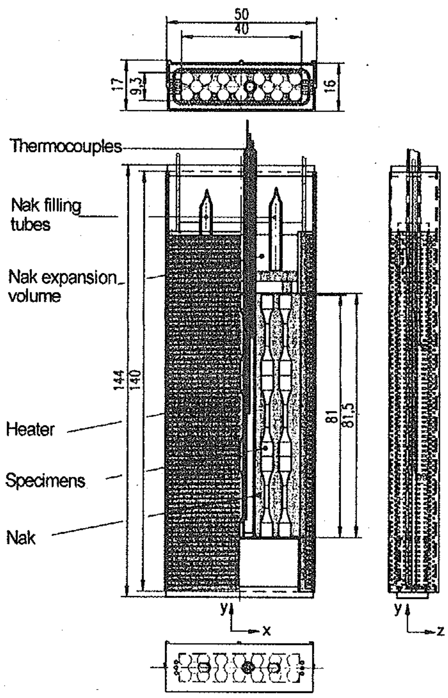

Elevation cut off of the capsule with the Specimens

The triple heater system is wound around the capsule

The power of each heater can be adjusted independently

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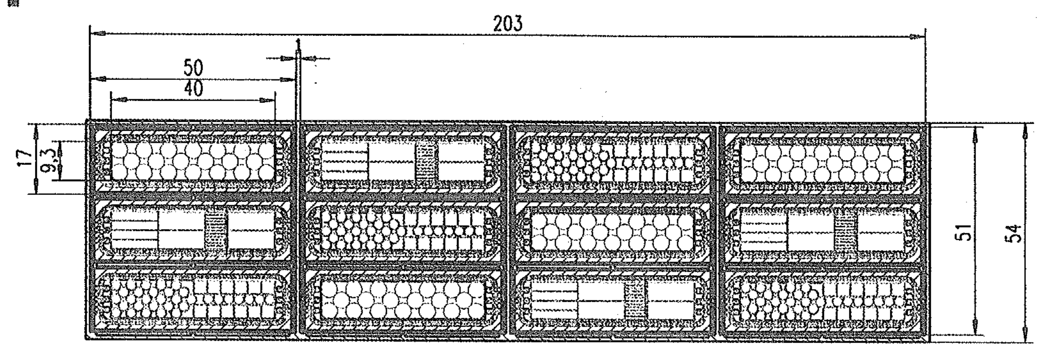

Container with three compartments each with three rigs;
Main Helium channels with a width of 1mm between the rigs and 0.5 mm between the rig and compartment walls

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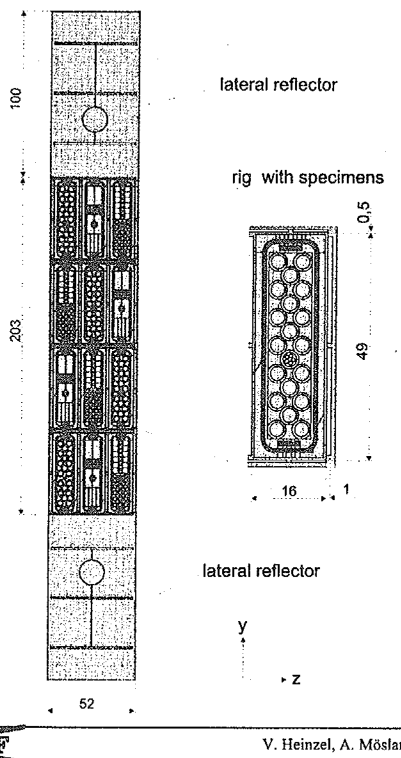

Horizontal cut off the HFTM container with integrated lateral reflector
The rig size is optimised for several specimen arrangements

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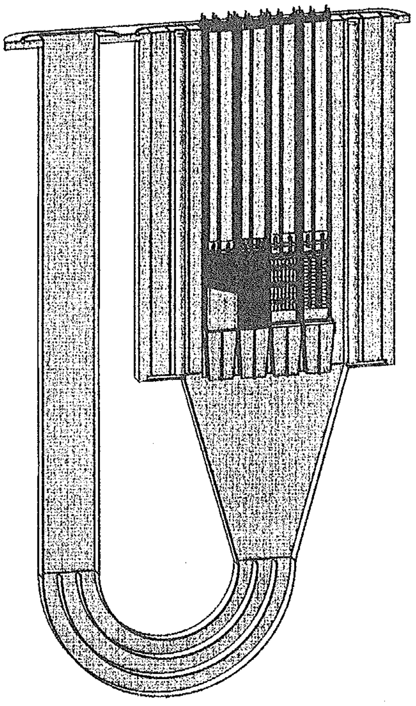

HFTM container cut-off with the helium inlet duct

The container is enlarged at the upper end giving space for the back plate flansh

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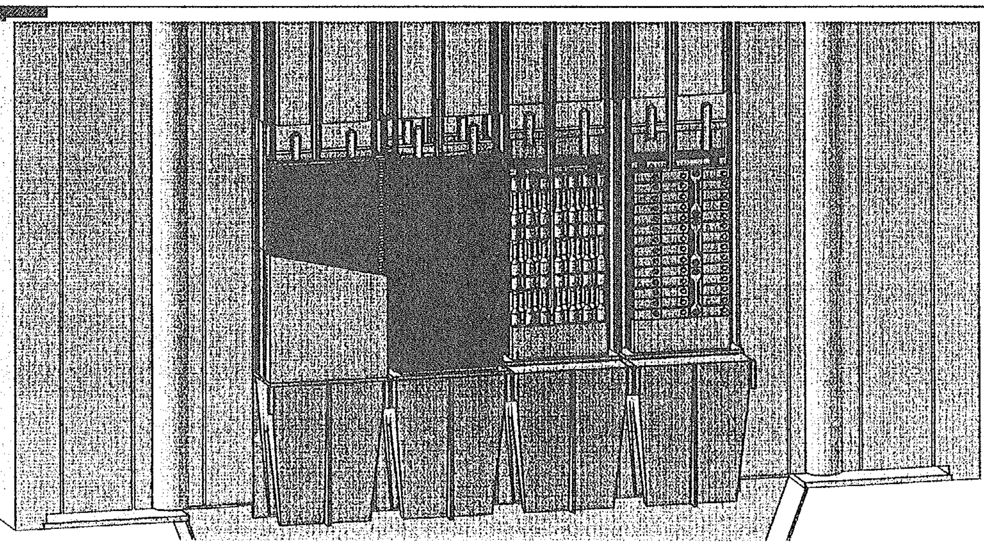

Container, compartment and rigs cut-off with cooling channels in the reflector

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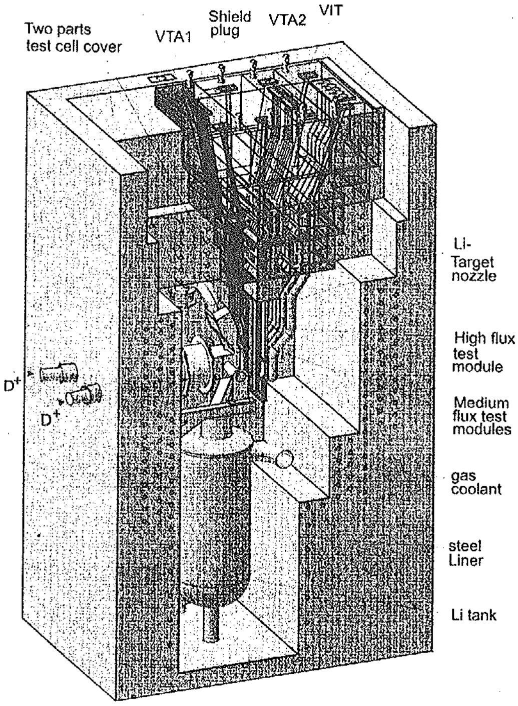

IFMIF test cell with the main inserts
This design studies initiated agreements of several dimensions

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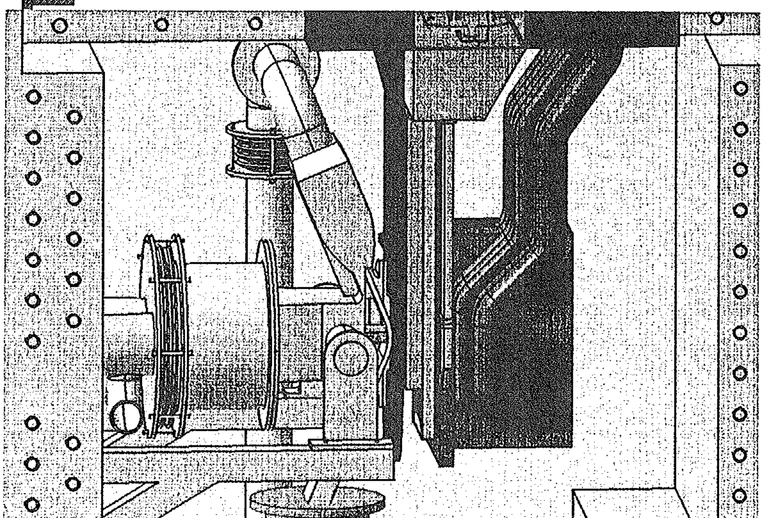

IFMIF test cell with the target and the test modules
This design studies helped to find the zones of inter-rogations

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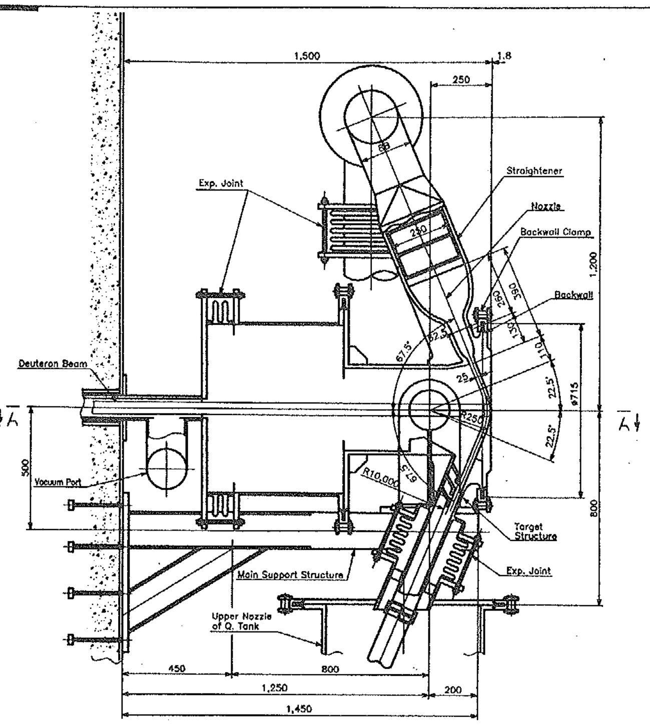

The back plate flansh caused an extension of the HFTM container

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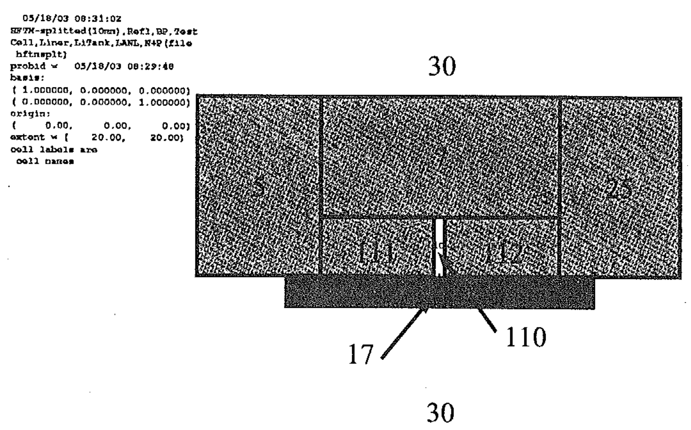

Material distribution for the neutronic calculations for showing the repercussion to the specimens within the MFTM from gaps penetrating the HFTM

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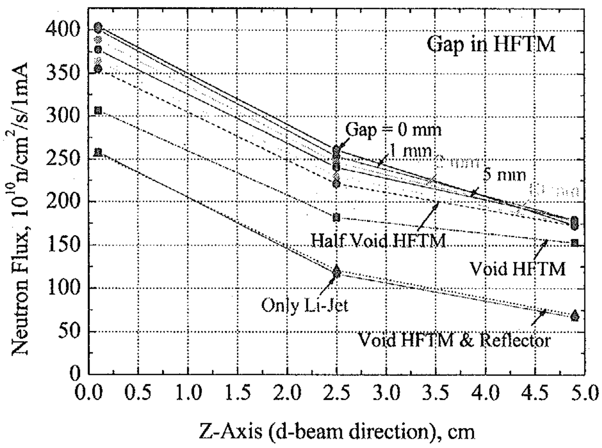

Material gaps cause flux reductions within the HFTM revealing by this the repercussion of the MFTM

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Cases of different design temperatures investigated

Case	1a	1b	2	3a	3b	4a	4b	5a	5b
Parameter									
Eff. He gap size (mm)	0.5	0.5	0.5	0.5	0.5	**0.8**	0.8	**0.25**	**0.25**
Lower cap	thin	**thick**	thick	thick	thick	thick	thick	thick	thick
Heating	nucl.	nucl.	**nucl./el.**	nucl./el.	**el.**	el.	**nucl./el.**	nucl./el.	**el.**
El. power in section									
upper (W/cm^3)	-	-	71	**149**	194	147	108	65	111
middle (W/cm^3)	-	-	-	**90**	199	148	39	-	118
lower (W/cm^3)	-	-	74	**158**	206	154	110	70	124
results									
Max. spec. temp.(^{0}C)	403	404	465	650	655	650	650	337	339
Max. temp. diff. in specimens (K)	121	121	30	31	35	13	22	33	33
Max. Helium velocity (m/s)	478	479	504	550	547	514	518	501	499
Stat. press. drop (MPa) (rig only)	0.053	0.053	0.056	0.06	0.06	0.057	0.058	0.055	0.055

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Heating	Nucl	Nucl	Nucl + el	Nucl + el	el	el	Nucl + el	Nucl + el	el
upper			71	149	194	147	108	65	111
middle				90	199	148	39		118
lower			74	158	206	154	110	70	124
Max Temp. °C	403	404	465	650	655	650	650	337	339
Max Temp. Diff. °C	121	121	30	31	35	13	22	33	33

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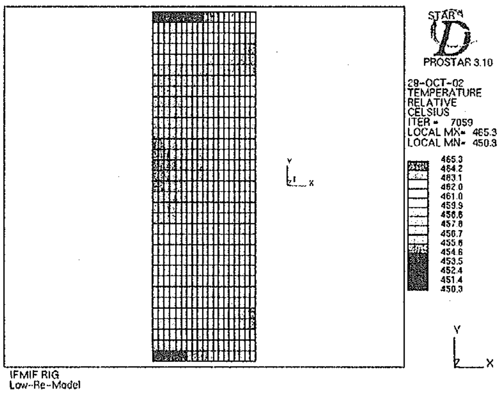

Temperature distribution in the specimen stack at nuclear heating and addition electric heater power; with an adapted power level of the tree electric heaters the temperature can be kept within a tolerance of 15°C over a stack height of 66mm.

Nevertheless there remain small regions with lager temperature deviations. This deviations can be reduced by addition heaters. This heater on the other hand will require addition space. It has to be considered carefully whether the specimen in those regions are rejected or specimen have to be removed in order to give space for addition heaters.

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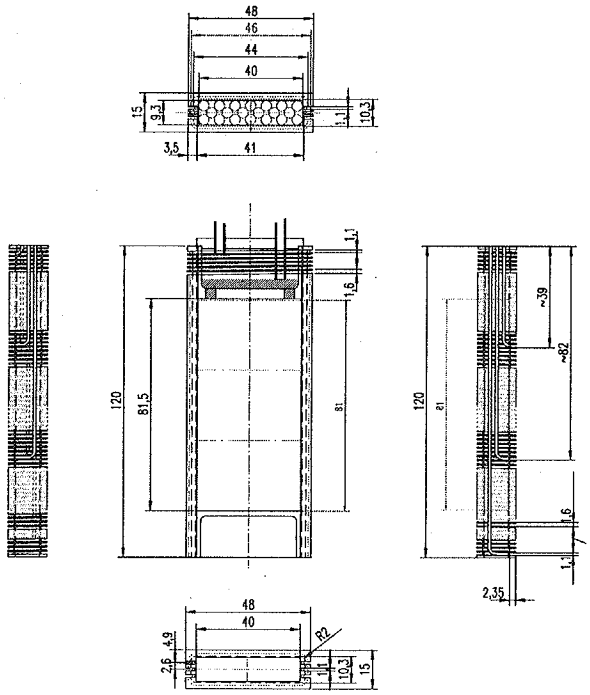

Electric Jacket Heater arrange-ment

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The electric heaters have to compensate:

a) The vertical temperature increase of the helium

b)Local heat transfer coefficient variations due to boundary development in flow direction

c)Local heat transfer coefficient variations in rectangular channels

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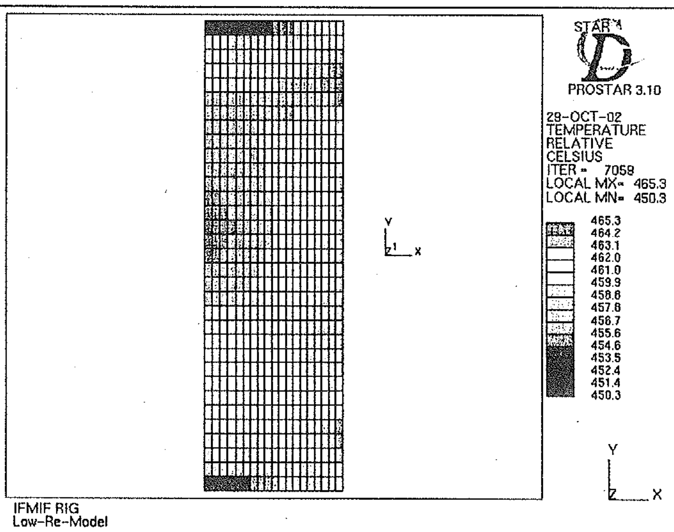

Temperature distribution within the specimens stack with nuclear and electric heatung

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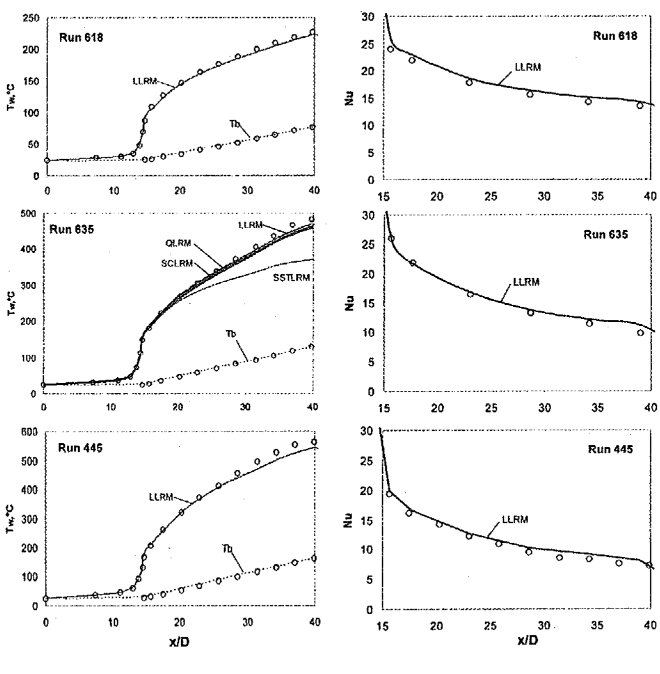
The lay out with STAR-CD decides on the triple heaters system subdivision of the heaters and the individual power of the heaters:

This requires validation of CFD code



Comparison of STAR-CD low-Reynolds turbulence model with air flow in a 27 mm diam. tube

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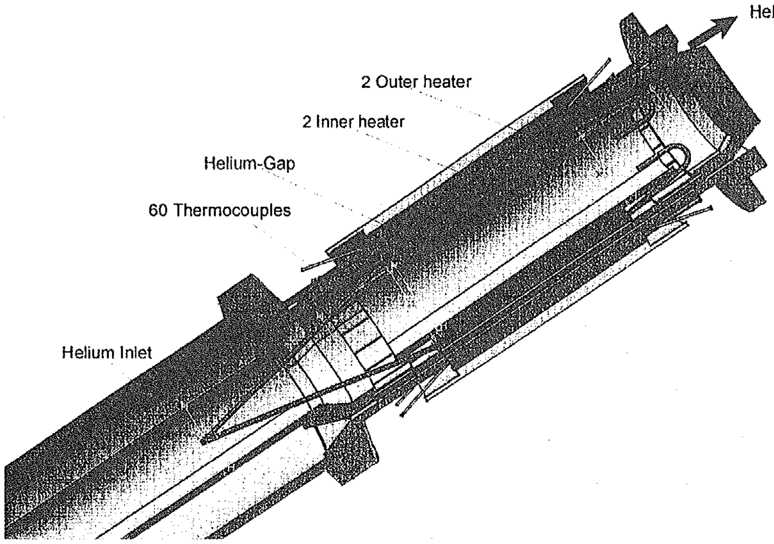

ITHEX test section designed with CATIA V5

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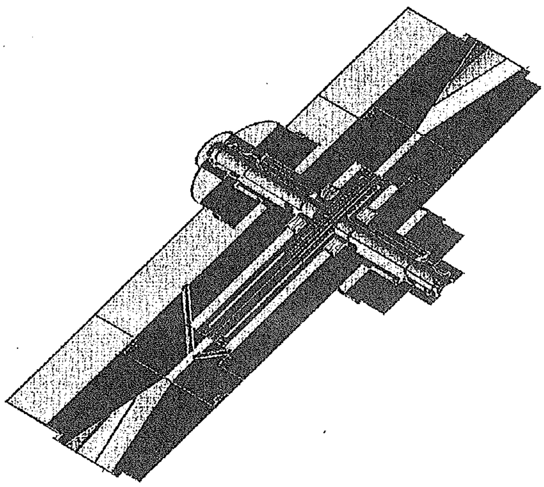

ITHEX test section rectan-gular channel

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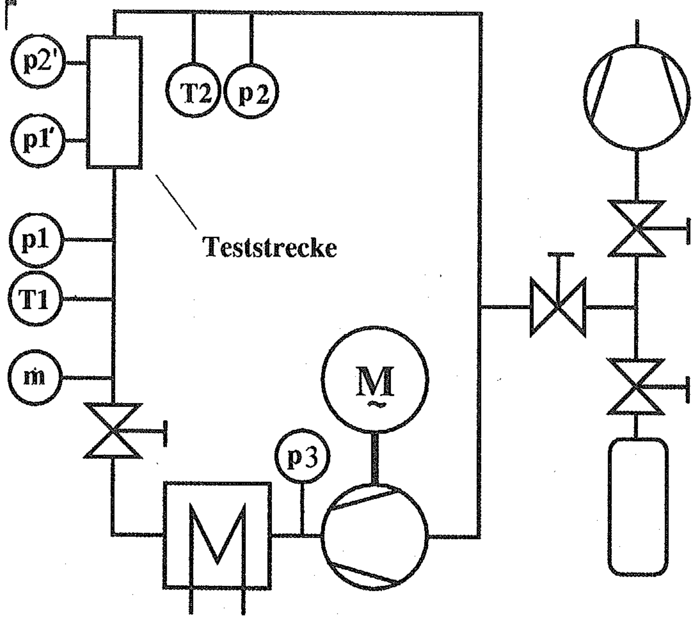

ITHEX helium loop for adia-batic pressure loss measure ments

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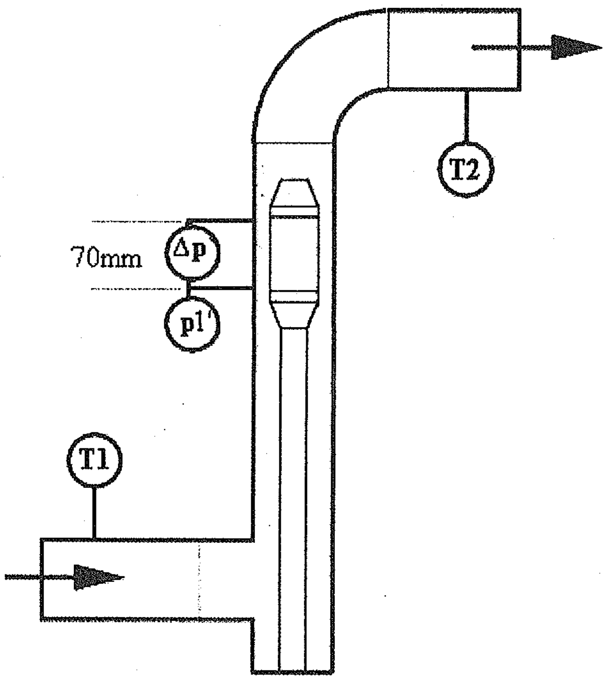

Positions of pressure sensors

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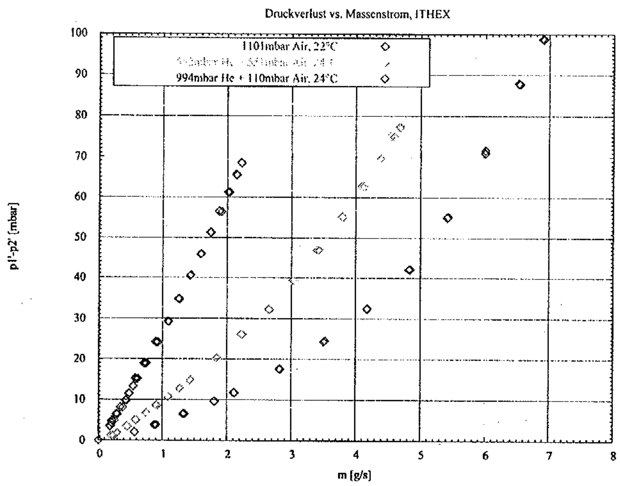

Small percentages of air changes decisively the material data

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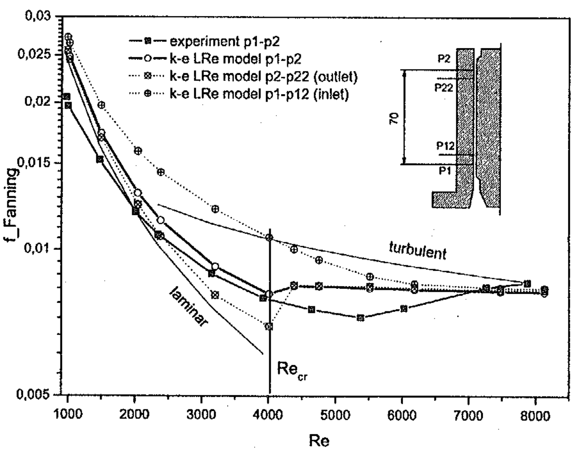

Integral data are not apt for validation

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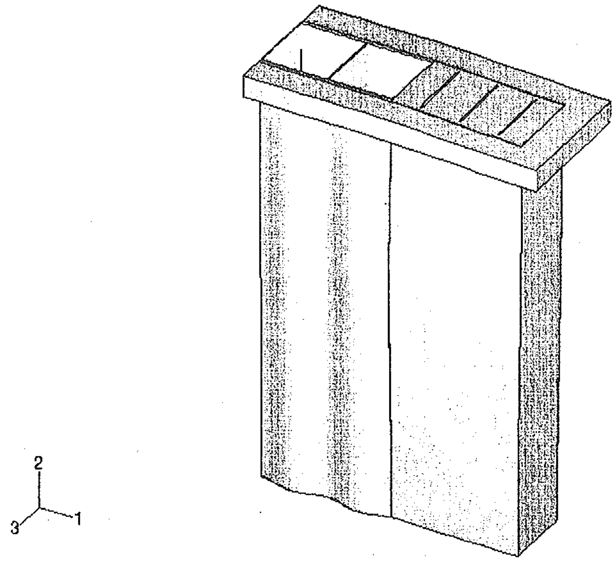

Container model for the stress analyses

50 % of the container is shown

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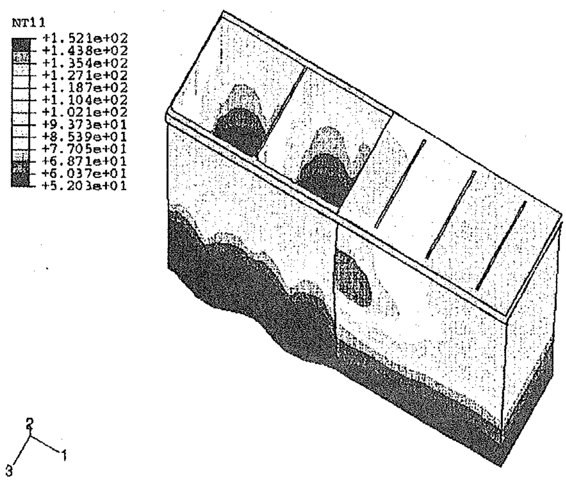

Temperature distribution in the container wall

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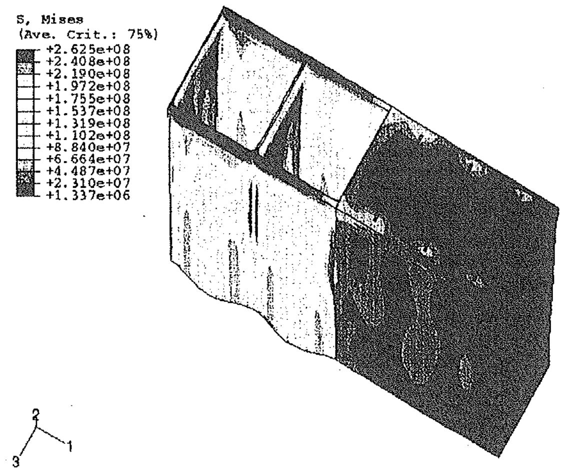

Mieses stresses in the container wall due 0.3 MPa internal pressure and thermal stresses

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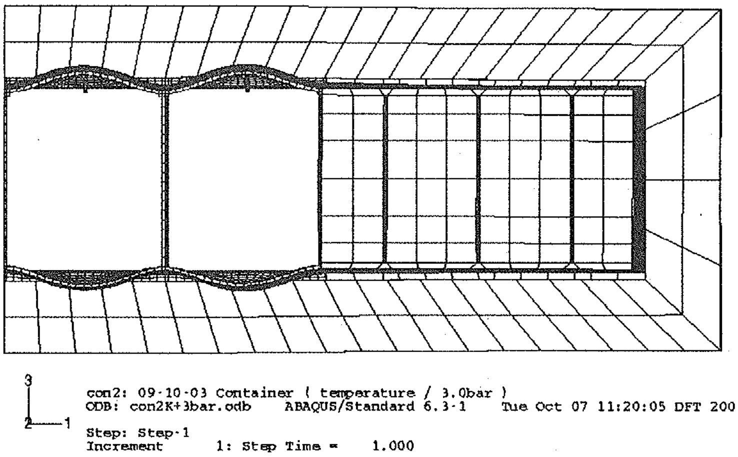

Elongations according to 0.3 MPa and thermal stresses

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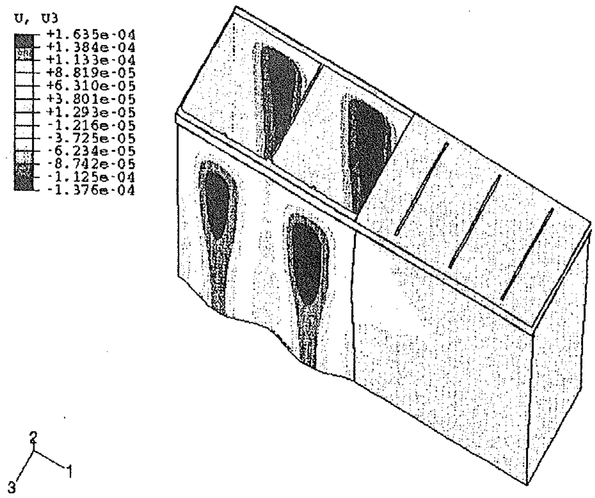

Strains in direction (3) in the container wall

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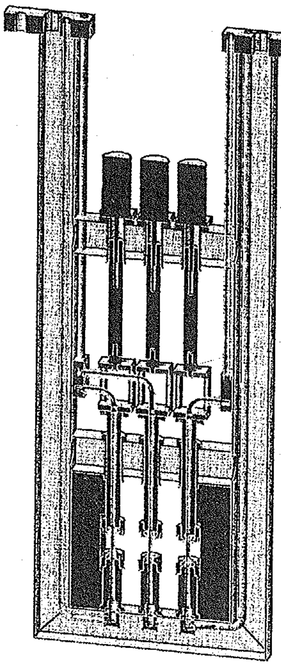

Medium Flux Test Module with the creep fatigue test unit

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IFMIF Technical Meeting
December 4-5, 2003
Kyoto, Japan

SSTT

b)Fracture Toughness CT)

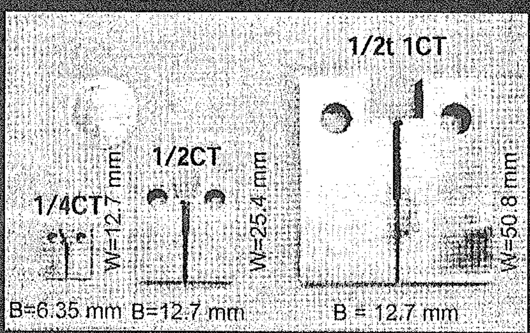
A. Kimura[1)], R. Kasada[1)], H. Ono[1)], H. Kubo[1)], M. Narui[2)], Y. Kohno[3)], K. Shiba[4)]

1) Institute of Advanced Energy, Kyoto University
2) Institute for Materials Research, Tohoku University
3) Muroran Institute of Technology
4) Japan Atomic Energy Research Institute

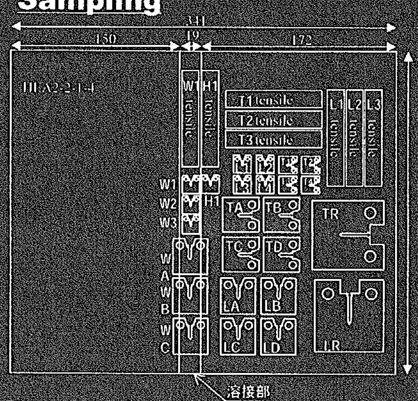
CT Specimens

IAE, Kyoto University

Geometry



Sampling

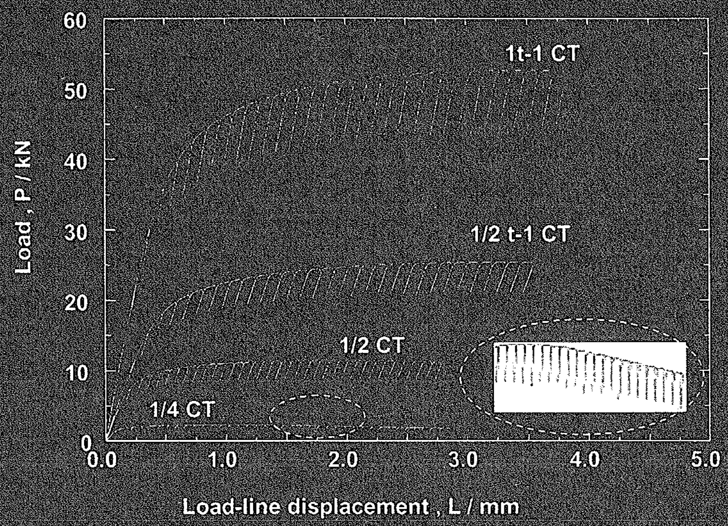


Specifications of ASTM standard

試験片サイズ	W	B	a_0	Side Groove	判定
ASTM E1820-99a	2=< W/B =< 4		0.45W-0.70W	<0.25B	
1/2t 1CT	50.8	12.7	29.60	0.2B	○
1/2CT	25.4	12.7	14.70	0.2B	○
1/4CT	12.7	6.35	7.85	0.2B	○

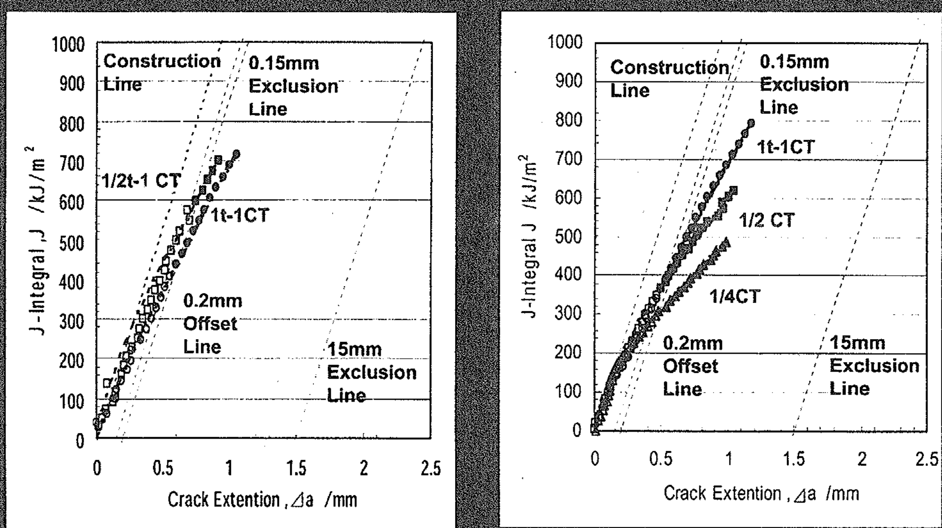
Load-Load line Displacement Curves

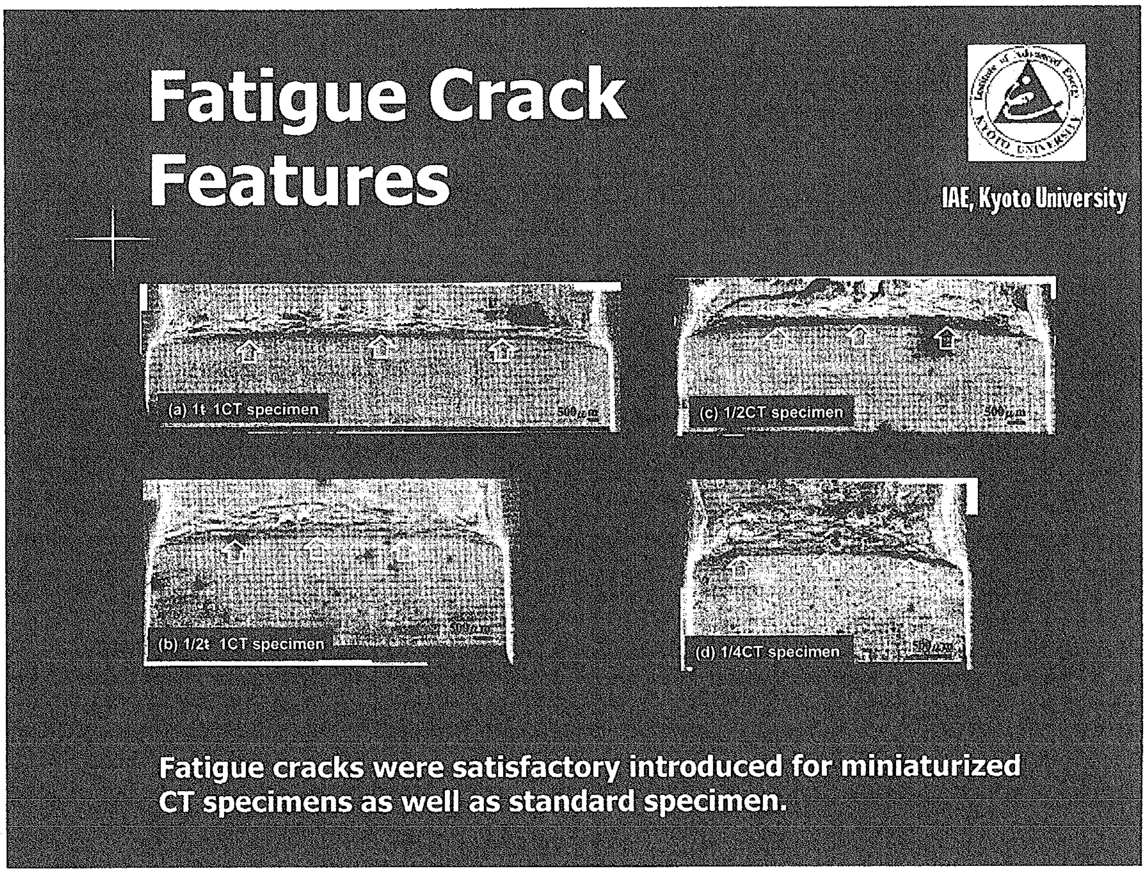
IAE, Kyoto University

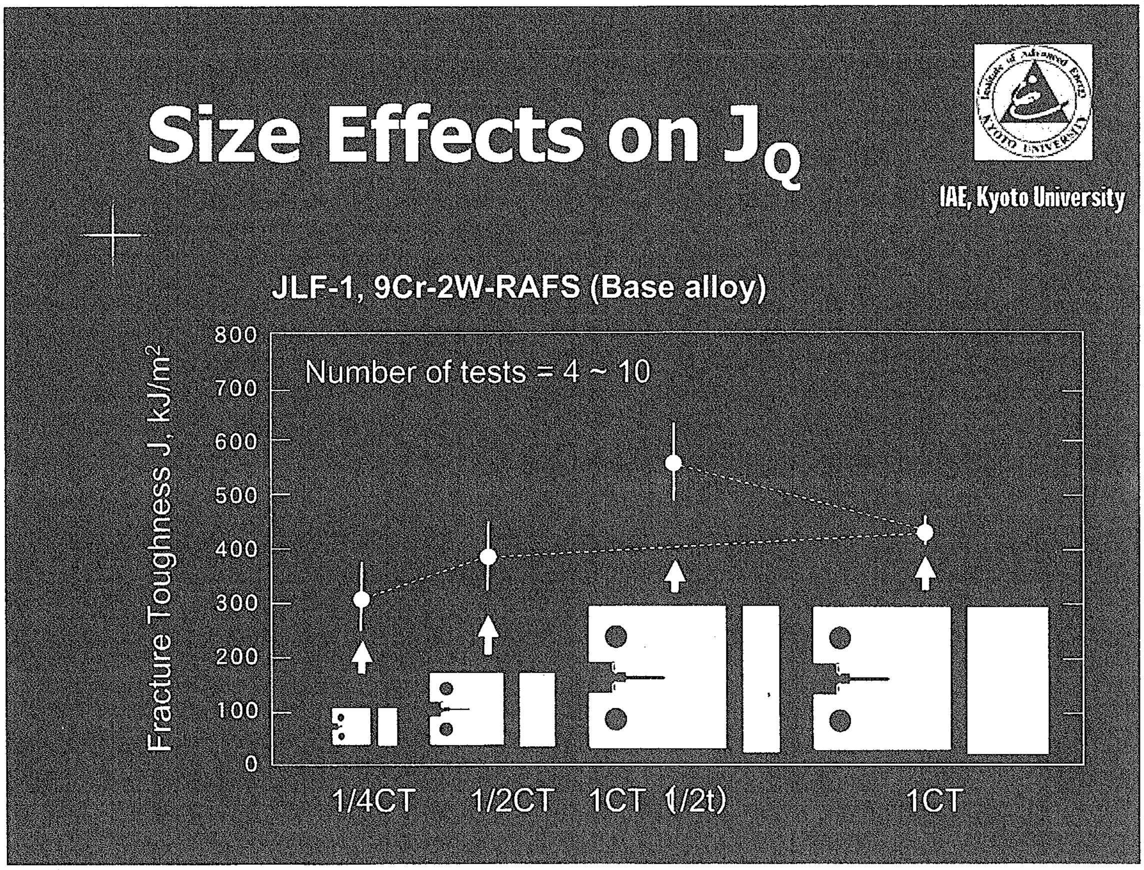


J_Q – R Curves

IAE, Kyoto University

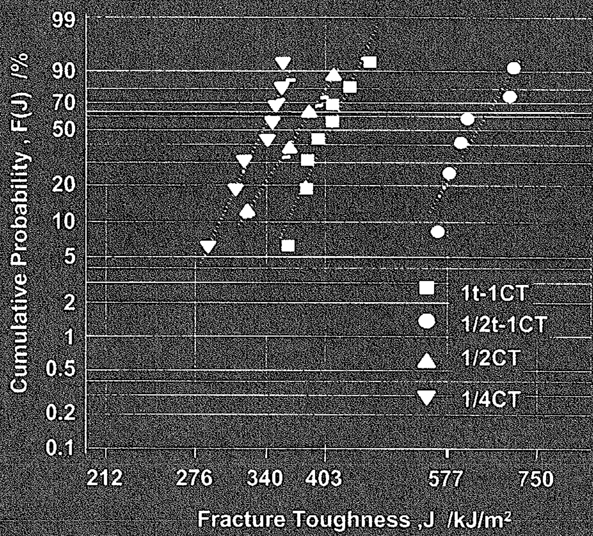



Fatigue Crack Features
IAE, Kyoto University
(a) 1t 1CT specimen
(c) 1/2CT specimen
(b) 1/2t 1CT specimen
(d) 1/4CT specimen
Fatigue cracks were satisfactory introduced for miniaturized CT specimens as well as standard specimen.


Size Effects on JQ
IAE, Kyoto University
JLF-1, 9Cr-2W-RAFS (Base alloy)
Fracture Toughness J, kJ/m2
Number of tests = 4 ~ 10
800
700
600
500
400
300
200
100
0
1/4CT
1/2CT
1CT (1/2t)
1CT

Weibull Distribution

IAE, Kyoto University



10 < m < 15

Valid-invalid Evaluation

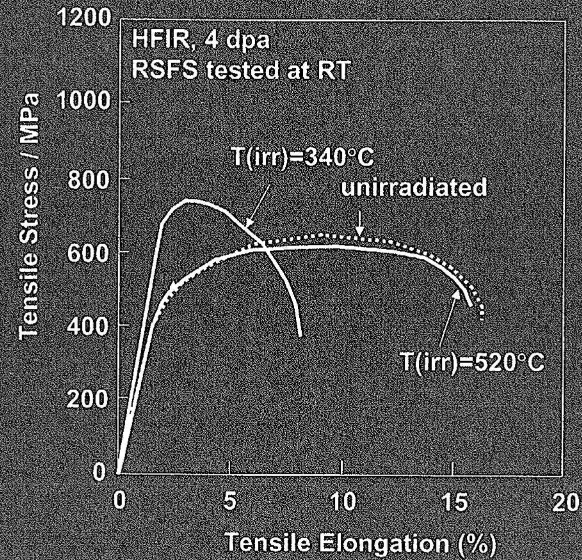
IAE, Kyoto University

J_{IC} Valid 基準 : B and $b_0 > 25J_Q / \sigma_Y$

Specimen size	B and b_0	$25J_Q/\sigma_Y$	Valid/invalid
1CT	25.4 mm	22.9	valid
1/2t-1CT	12.7 mm	33.5	invalid
1/2CT	12.7 mm	20.6	invalid
1/4CT	6.4 mm	19.5	invalid

Irradiation Effects

IAE, Kyoto University



- Tirr. < 400°C
  1) Hardening
  2) Loss of ductility
- Tirr. > 400°C
  1) No hardening
  2) Loss of ductility

Valid-invalid Criteria Estimation

IAE, Kyoto University

J_{IC} Valid - invalid : B and $b_0 > 25J_{IC}/\sigma_Y$

Specimen	B and b_0 (mm)	Unirradiated		Irradiated			
		$25J_{IC}/\sigma_Y$	Valid/ invalid	$25J_{IC}/\sigma_Y$ 350℃	Valid/ invalid	$25J_{IC}/\sigma_Y$ 520℃	Valid/ invalid
1CT	25.4	23.33	valid	8.40	valid	17.50	valid
1/2t-1CT	12.7	26.48	invalid	9.53	valid	19.86	invalid
1/2CT	12.7	27.59	invalid	9.93	valid	20.69	invalid
1/4CT	6.4	28.61	invalid	10.30	invalid	21.46	invalid

Reduction of fracture toughness : 0.6 (350℃), 0.75 (520℃)
Irradiation hardening : 1.67 (350℃), 1 (520℃)

J_Q Evaluation for Thin Plates of Fusion Blanket

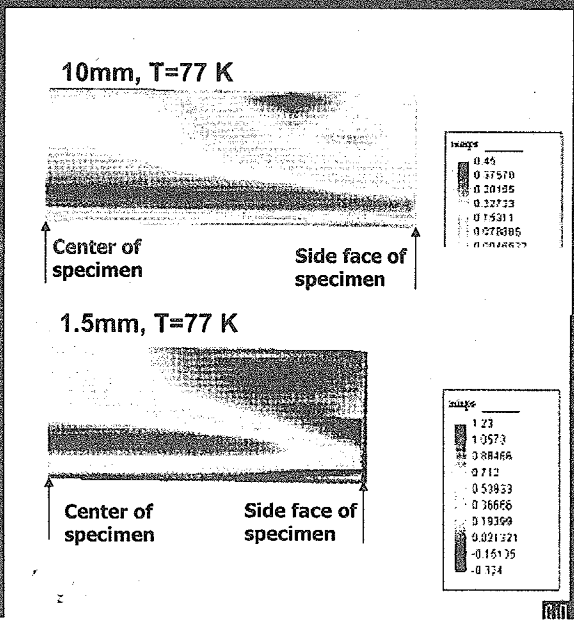
IAE, Kyoto University

- Thin plate < 5mmt
  - ○Plain stress state condition
  - ○Enhancement of shearing rupture

- ●Valid-invalid criteria specialized for fusion blanket materials
- ●Application to the other area

Minimum Principal Stress at Fracturing

IAE, Kyoto University



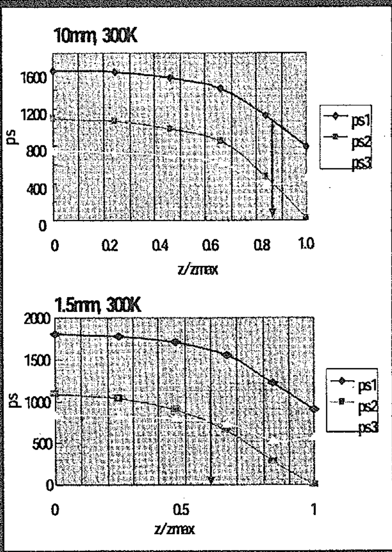
An FEM simulation study indicates a plain stress state was developed at near surface area in miniaturized specimen.

⇩

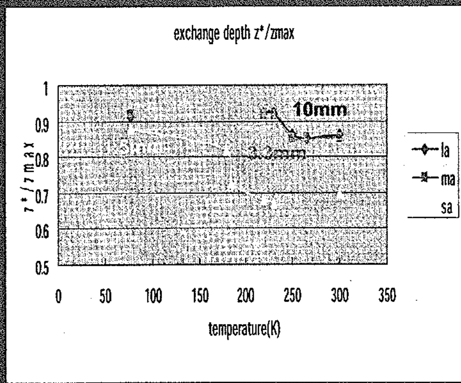
Temperature Dependence

Distribution of 3 Min. Principal Stresses

IAE, Kyoto University



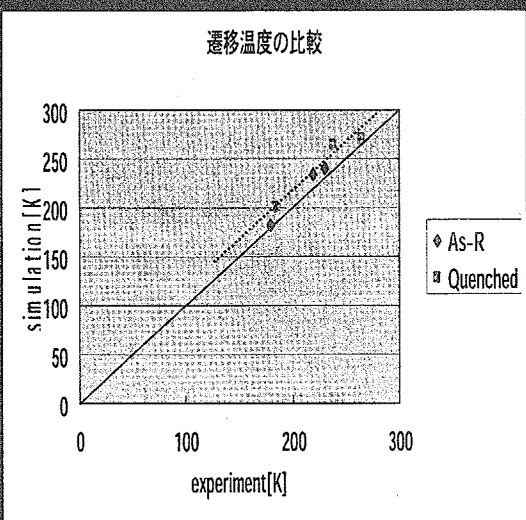
Cross point of the 2nd and 3rd Principal Stress



Transition Behavior

Comparison between Exp. and Analysis

IAE, Kyoto University



There is a linear relationship between the DBTTs obtained by experiment and FEM analysis, although the simulated values are always 20K higher than those of experimental values.

Expectation of Size Effect

Summary

IAE, Kyoto University

Fracture toughness measurement of a RAFS (JLF-1Steel)

1. Fatigue pre-crack was satisfactory introduced into miniaturized CT specimen.
2. J_Q increased: 1CT ⇒ 1/2t-1CT
3. J_Q decreased: 1CT ⇒ 1/2CT ⇒ 1/4CT
4. J_{1C} (valid) was obtained for only 1CT.
5. Valid-invalid criteria specification for fusion material would be necessary.

IFMIF Techinical Meeting
2003, 12, 4-5, Kyoto

Fracture Toughness Evaluation of Reduced Activation Materials

- 3PB Miniaturized Specimens -

H. Kurishita, T. Yamamoto[1)], T. Nagasaka[2)], A. Nishimura[2)], T. Muroga[2)] and S. Jitsukawa[3)]
Tohoku Univ., UCSB[1)] , NIFS[2)], JAERI[3)]

Background

- Limited irradiation volume in IFMIF
  ~ 500 cc for >20 dpa/year
- Thin wall structures (several millimeters thick) of reduced activation materials

↓

- Need of small specimen test technology (SSTT)

Fracture toughness : a key engineering property

Compact tension (CT), 3-point bending (3PB) specimens

Standard size CT and 3PB specimens : very large

IFMIF ~ 500 cc : *6* standard CT, *2~3* standard 3PB

SSTT for fracture toughness testing

Elastic-plastic fracture toughness tests : CT specimen

Background and Objective

Comparison of CT and 3PB Specimens

	CT	3PB
Data precision	Very good	Good
Data availability	Very good	Good
Specimen miniaturization	Good	Very good
Specimen preparation	Good	Very good
Specimen setting for testing	Good	Very good
Control of testing condition	Good	Very good

MCVN

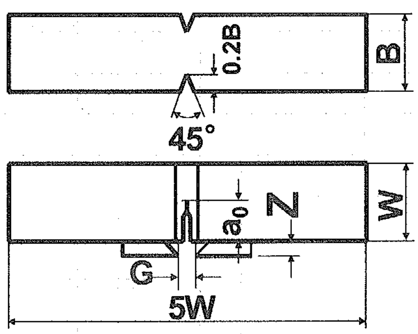
Objective

To establish SSTT for fracture toughness testing of reduced activation materials using miniaturized 3PB specimens

Material : Japanese low activation ferritic steel, JLF-1

Experimental

3PB Specimen



W = B or 1.5B

W	10	5	5	3.3
B	7	5	3.3	3.3

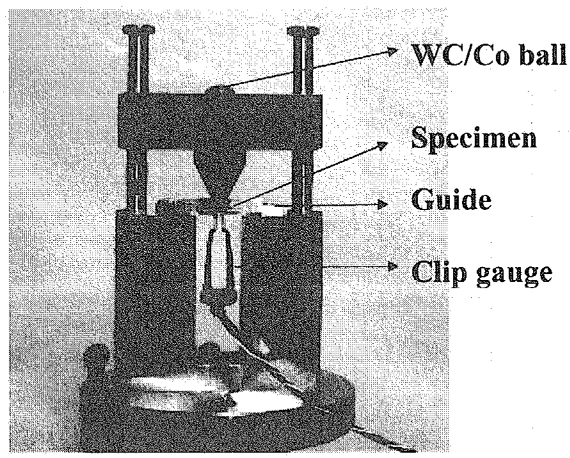
(mm)

a_0 = 0.5 W, Z = 1 or 0 mm

G = 2 mm, Span = 4 W (40, 20, 13)

Fixture

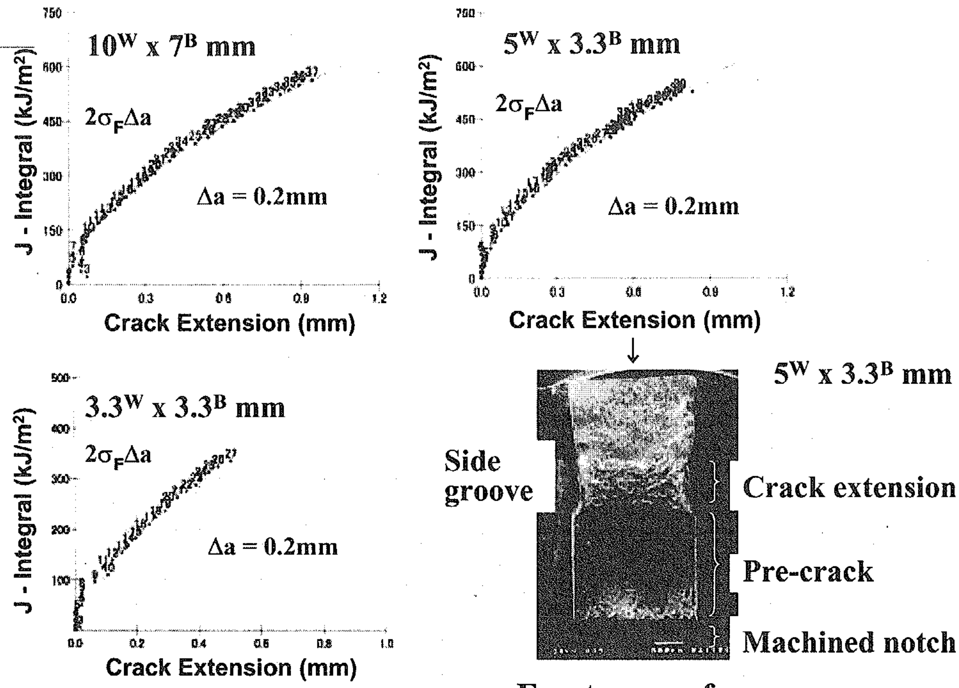
Span 20mm



Test

- Elastic-plastic fracture toughness test (single-specimen method) at RT
- Plane strain fracture toughness test at 77K

J-integral vs Crack Extension Curves at RT



Fracture surface

Fracture Toughness of JLF-1 at RT

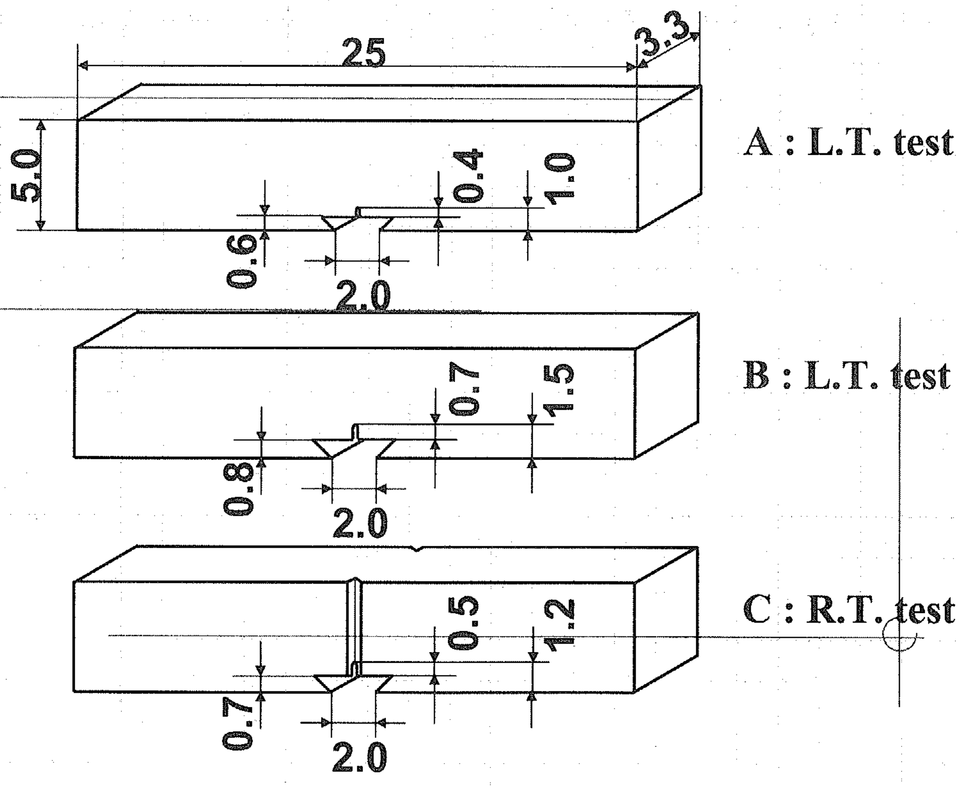
	W (mm)	B (mm)	B_N (mm)	a_0 (mm)	J_Q^{ASTM} (kJ/m²)	J_Q 1) (kJ/m²)	J_{IN} 2) (kJ/m²)
1	10.0	7.0	4.2	5.18	431	251	117
2	5.0	5.0	3.0	2.89	467	273	123
3	5.0	3.3	2.0	2.82	443	261	116
4	3.3	3.3	2.0	1.84	336	222	103

1) **Blunting line : fit through the initial portion of the data**
   2nd line : parallel to the blunting line but offset by $\Delta a = 0.2$ mm
2) **Blunting line : same as the above**
   2nd line : a linear approximation of the data falling between approximately 0.1 and 0.3 mm of crack extension

Fracture Toughness Evaluation at Low Temperatures

- Careful pre-cracking will be needed to satisfy the requirement of $K_{f(max)} \leqq 0.6(\sigma_{y1}/\sigma_{y2}) \cdot K_Q$
- The values of σ_{y1} and σ_{y2} measured for JLF-1 were 521 MPa (at RT) and 1120 MPa (at 77K), respectively, resulting in a small value of $\sigma_{y1}/\sigma_{y2} = 0.47$.
- Plane-strain fracture toughness values at 77K for JLF-1 were re-evaluated using carefully pre-cracked, miniaturized 3PB specimens with proposed geometry.

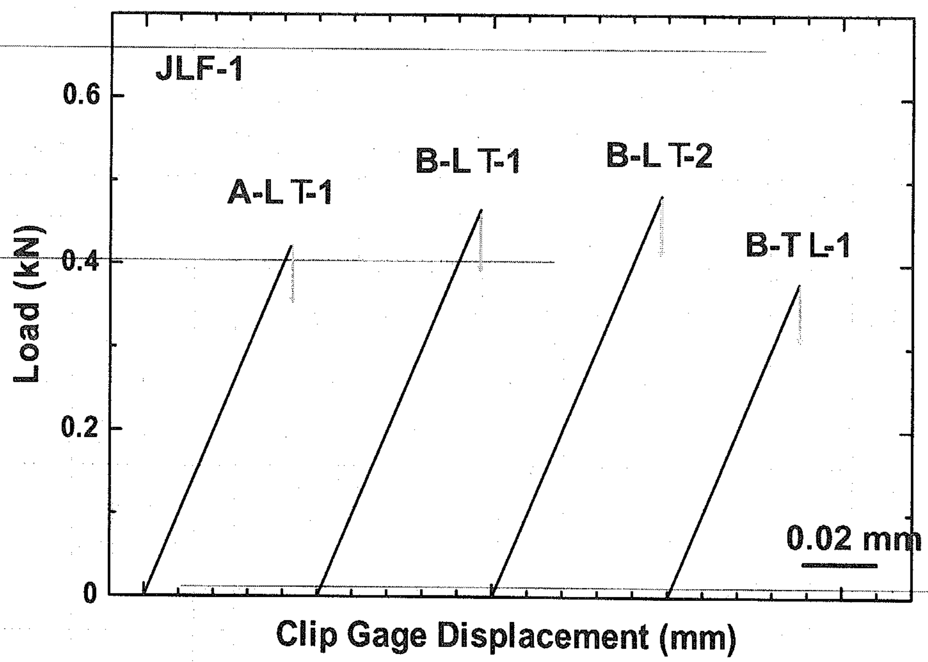
3PB Specimen Geometry for IFMIF Irradiation



Pre-Cracking Data for A and B Specimens

Type	Spec.	K_{max} ($MPam^{1/2}$)	ΔK_f ($MPam^{1/2}$)	$K_{f(max)}(3\%)$ ($MPam^{1/2}$)	$P_{f(max)}$ (kN)	$P_{f(min)}$ (kN)	Total cycles (f=20c/s)
A	LT-1	22.42	5.06	5.65	0.122	0.012	465760
A	LT-2	22.42	5.99	6.68	0.144	0.014	336170
B	LT-1	23.08	6.38	8.13	0.158	0.015	300000
B	LT-2	22.96	8.05	8.97	0.193	0.019	193969
B	LT-3	23.89	7.02	7.83	0.168	0.017	210768
B	TL-1	22.87	4.83	5.38	0.120	0.012	599998
B	TL-2	22.57	5.98	6.67	0.144	0.014	357764

Test Results for A and B Specimens at 77K



Plane-Strain Fracture Toughness of JLF-1 at 77K

Spec.	W, B (mm)	a_0 (mm)	W-a_0 (mm)	P_Q (kN)	K_Q ($MPam^{1/2}$)	2.5 $(K_Q/\sigma_{ys})^2$ (mm)
A-LT-1	5.01, 3.28	2.71	2.30	0.421	22.4	0.40
B-LT-1	5.03, 3.30	2.74	2.29	0.466	25.1	0.50
B-LT-2	5.01, 3.31	2.69	2.32	0.482	25.3	0.51
B-TL-1	5.04, 3.32	2.77	2.27	0.377	20.0	0.32

σ_{ys} = 1120 MPa at 77K

$$K_{IC} = 20 \sim 25\ MPam^{1/2}$$

Conclusions

1. The elastic-plastic fracture toughness test at room temperature for 3PB miniaturized specimens of JLF-1 gave J_{IN} values of 103~123 kJ/m². J_{IN} is defined as the J value for the onset of crack extension.
2. For IFMIF irradiation an appropriate specimen geometry for 3PB miniaturized specimens was proposed.
3. For the proposed specimen geometry, the plane-strain fracture toughness test at 77K was performed using carefully pre-cracked specimens because of the requirement of $K_{f(max)} < 0.6(\sigma_{y1}/\sigma_{y2}) \cdot K_Q$, where σ_{y1} and σ_{y2} for JLF-1 were 521MPa at RT and 1120MPa at 77K, respectively. The values of K_{IC} obtained were 20-25MPam$^{1/2}$.

Measurements of Neutron Emission Spectra and ^{7}Be Production in Li(d,n) and Be(d,n) Reactions for 25 and 40 MeV deuterons

Cyclotron and Radioisotope Center (CYRIC), *Tohoku University, Japan*

Hagiwara Masayuki, Baba Mamoru, Kawata Naoki, Itoga Toshiro, Hirabayashi Naoya

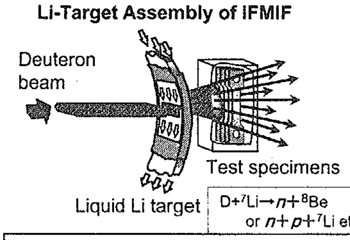
in collaboration with NIFS (National Institute for Fusion Science)

1. Introduction

- For optimization & operation of high-intensity neutron production source; e.g. IFMIF(International Fusion Material Irradiation Facility)
  detailed knowledge is required on
  - *Neutron energy-angular distribution*
    (-Double differential cross-section)
  - *Radio activity accumulation*
    (- Activation cross-section)

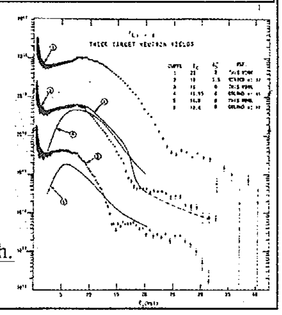
  for the ^{nat}Li(d,x) and ^{nat}Be(d,x) reaction

Li-Target Assembly of IFMIF



E_d: 40 or 32MeV, I_d: 250mA (=10MW max)
Flux-volume: 500 cm^3 (@> 10^{14} n/cm^2/s)

- Data status are very poor
  as shown by discrepancies
  among experiments & calculations



$^7Li_{thick}$(d,n) spectra

M. A. Lone et al.
Nucl. Instrum. And Meth.
143 (1977) 331-344

1-2. The present study

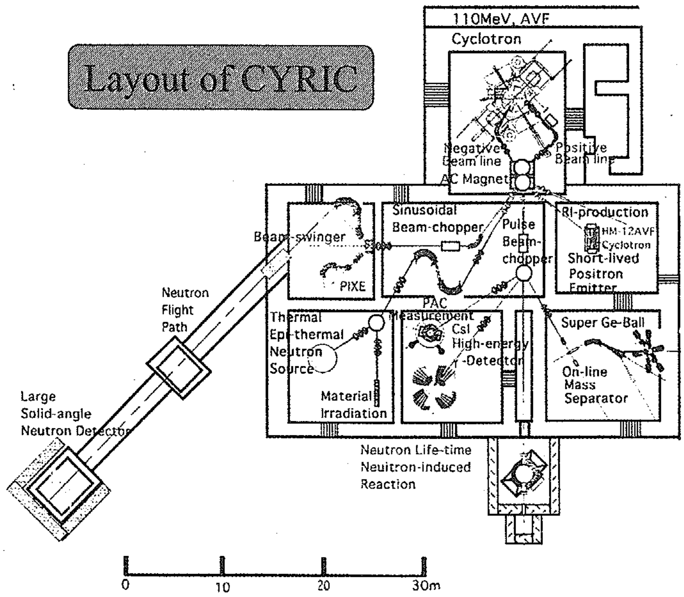
Measurements of

1. *Neutron energy-angular distribution* for thick target ^{nat}Li(d,n), ^{nat}Be(d,n) reaction
2. *Accumulation of ^{7}Be activity* in the thick ^{nat}Li, ^{nat}Be target for Ed=25, 40 MeV
3. *Neutron energy-angular distribution* for thin target ^{nat}Li(d,n), reaction for Ed= 40 MeV
4. *Accumulation of ^{7}Be activity* in the thin ^{nat}Li target for Ed= 40, 38.6, 29.7, 28.2, 19.7, 17.7, 10, 7.05 MeV with stack method

at *Tohoku Univ., Cyclotron & Radio Isotope Center* (CYRIC) [http://www.cyric.tohoku.ac.jp]

2. Experimental Apparatus

2-1.Cyclotron and Radioisotope Center, Tohoku University (CYRIC)



Performance of K=110 AVF cyclotron

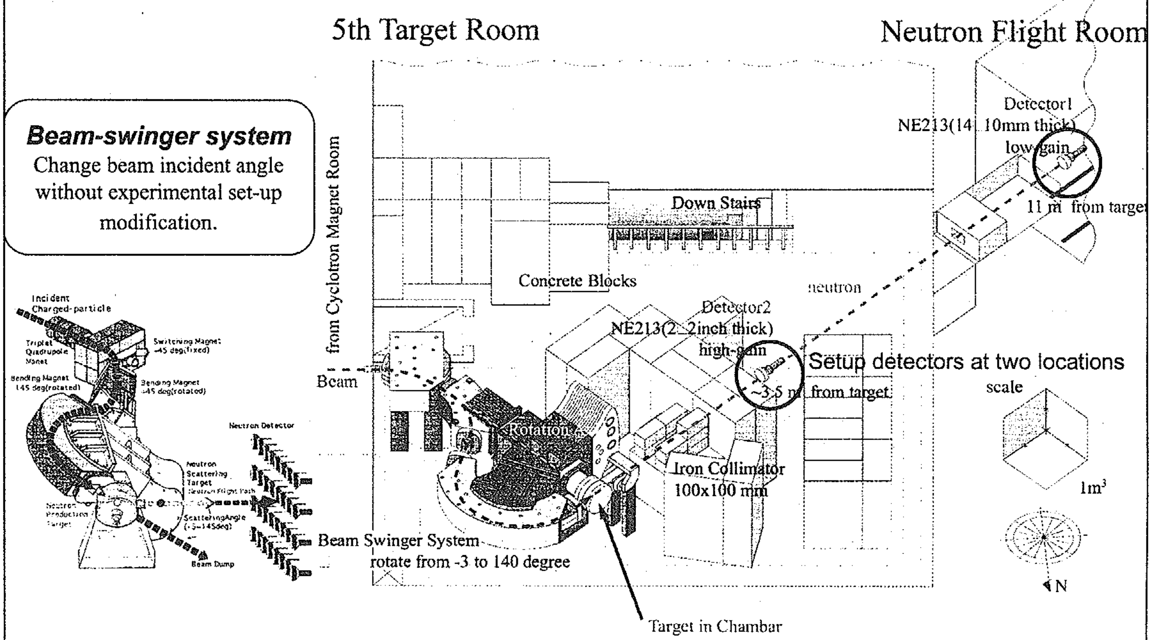
•Protons	10-90 MeV
•Deuterons	10-65 MeV
•^{3}He	20-170 MeV
•^{4}He	20-130 MeV
	etc.

This measurements

Deuteron 25, 40 MeV ~5nA
at Target-room NO.5
with Beam-swinger system

2-2. Target Room 5 (TR.5)

Beam-swinger system & Well collimated TOF channel

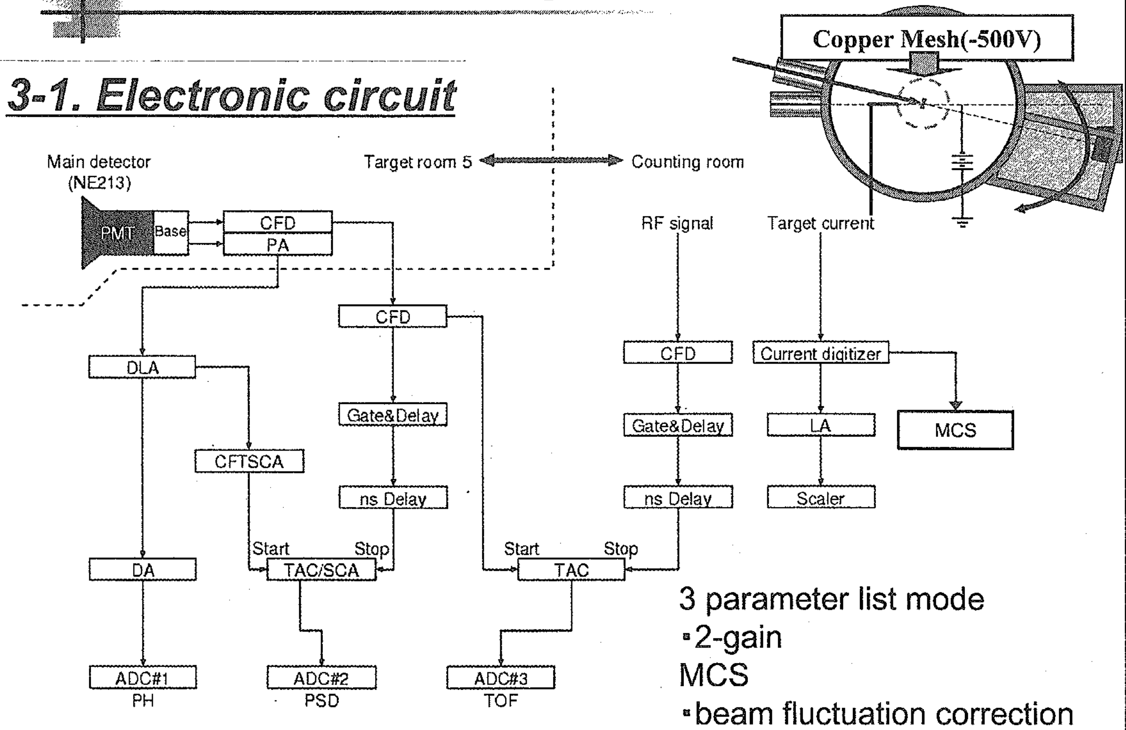


2-3. Outline of experiments

- E_d : 25, 40 MeV
- Angle : 0~110 deg
- Flight path : 3.5 m (for high-gain: NE213 (2inchf × 2inch)),
  11m (for low-gain : NE213 (14cmf × 10cm))
- Targets : Metallic Li (7.5 mm thick) for Ed= 25 MeV
  (~21 mm thick(total), 8 stack targets) for Ed= 40 MeV
  (~0.85 mm thick), for Ed = 40 MeV thin target
  : Metallic Be (2.4 mm thick) for Ed= 25 MeV
- Beam current : ~5nA
- Measurement time : ~30 min.
- RF frequency : ~1.168 MHz

3. Neutron spectra

3-1. Electronic circuit



3 parameter list mode
- 2-gain

MCS
- beam fluctuation correction

3-2. Data reduction

1. Separate neutron events from γ-ray events by PSD gate.
2. Set soft-bias (~0.6 MeV for high-gain, ~3.5 MeV for low-gain).
3. Conversion into energy spectra by the following equation:

$$E_n(i) = mc^2 - m_0c^2 = m_0c^2\left(\frac{1}{\sqrt{1-\beta^2}} - 1\right) \qquad \beta = \frac{v_n(x)}{c} = \frac{L}{c \cdot T_n(i)}$$

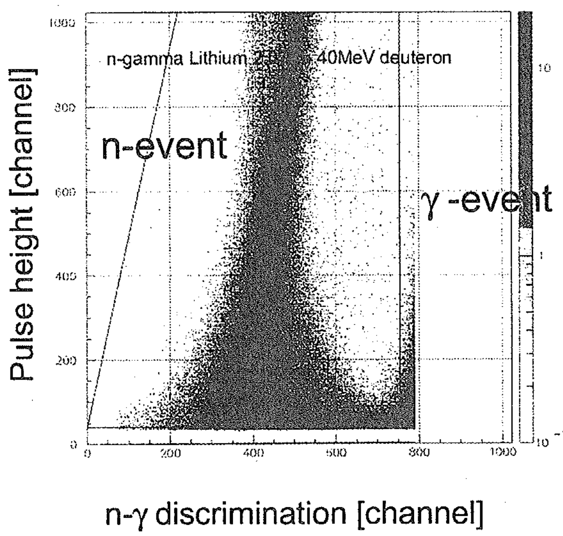
m_0 : Rest mass of a neutron
i : Channel number of the events
L : Flight path
c : Light velocity.

4. Conversion energy spectra into differential yields by dividing by *detector efficiency and solid angle.
5. Normalize by the current integrated.
6. Correction of attenuation (air:LA150, Li:Abfalterer et al.)

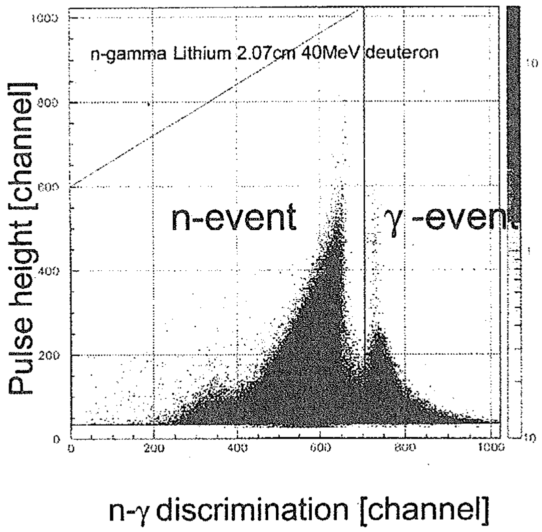
*Efficiency : Calculated by SCINFUL code.

3-3. Raw data

3-3.1. high-gain raw data



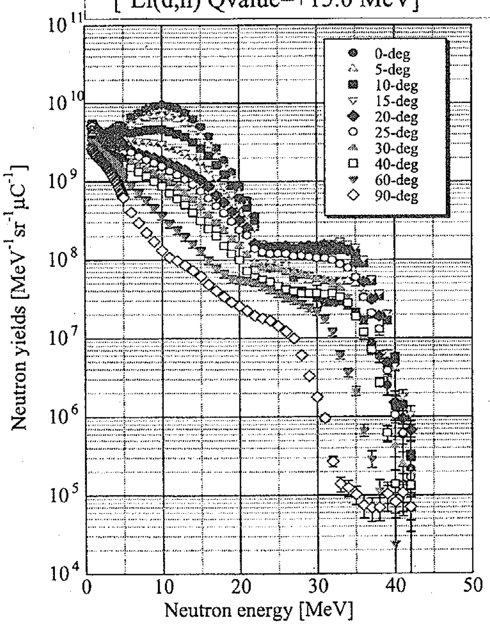
3-3.2. low-gain raw data



3-4. Result for Ed = 25 MeV

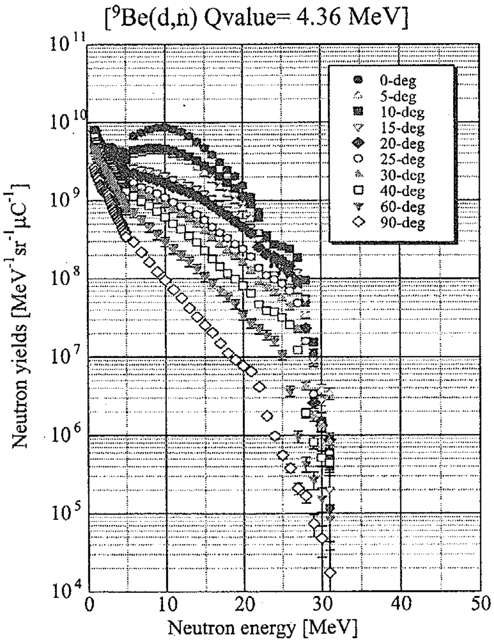
3.4.1 ^{nat}Li(d,xn) for Ed= 25 MeV

[^{7}Li(d,n) Qvalue=+15.0 MeV]



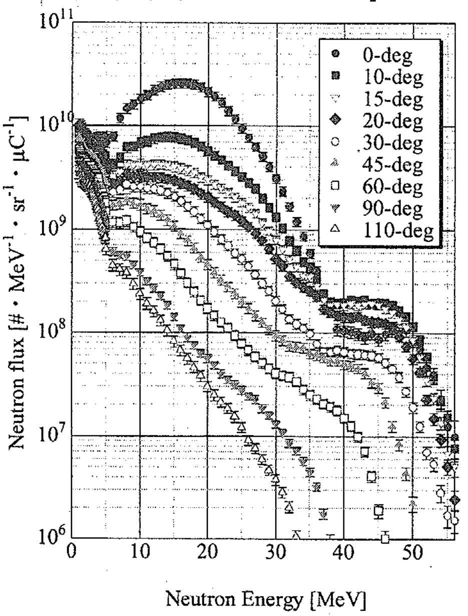
3.4.2 ^{nat}Be(d,xn) for Ed= 25 MeV

[^{9}Be(d,n) Qvalue= 4.36 MeV]

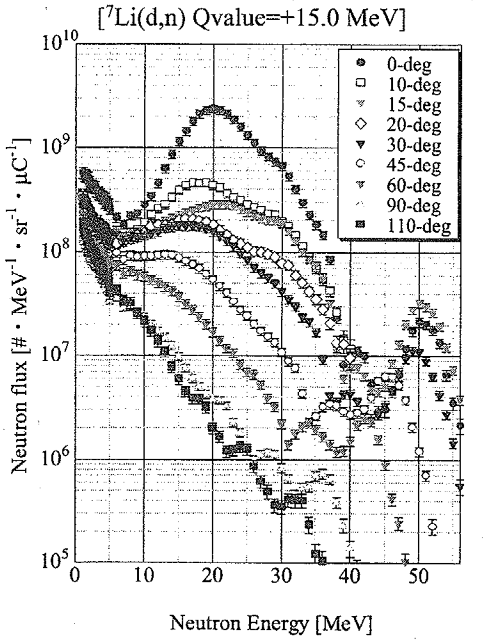


3-5. Results for Ed = 40 MeV

3.5.1 thick ^{nat}Li(d,xn) for Ed= 40 MeV
[^{7}Li(d,n) Qvalue=+15.0 MeV]



3.5.2 thin ^{nat}Li(d,xn) for Ed= 40 MeV
[^{7}Li(d,n) Qvalue=+15.0 MeV]



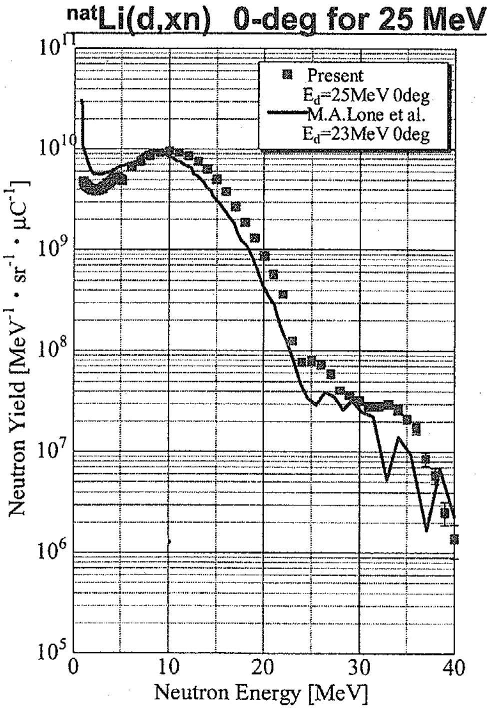
3-6. Comparison with other data

3-6-1. Comparison with Lone's data

■ Present data
Ed = 25 MeV 0-deg
TOF method
— M.A.Lone et al.
Ed = 23 MeV 0-deg
TOF method

·> 5 MeV
good agreement in the curve and yield
·< 5 MeV
large difference
→problem of efficiency ?

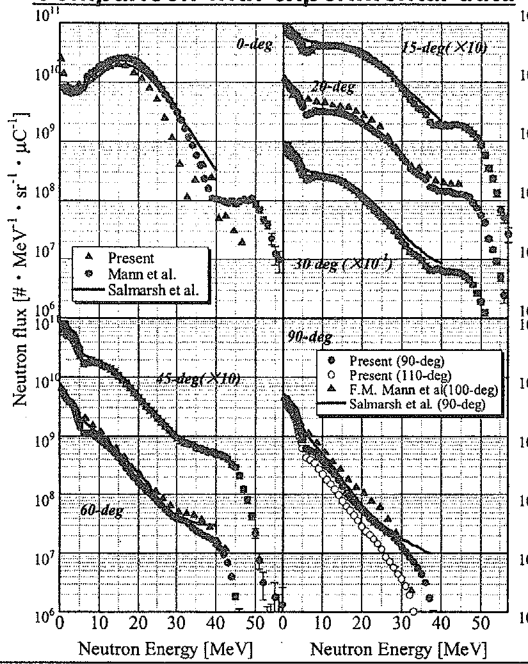
^{nat}Li(d,xn) 0-deg for 25 MeV



3-6-2. Comparison with experimental and calculation data

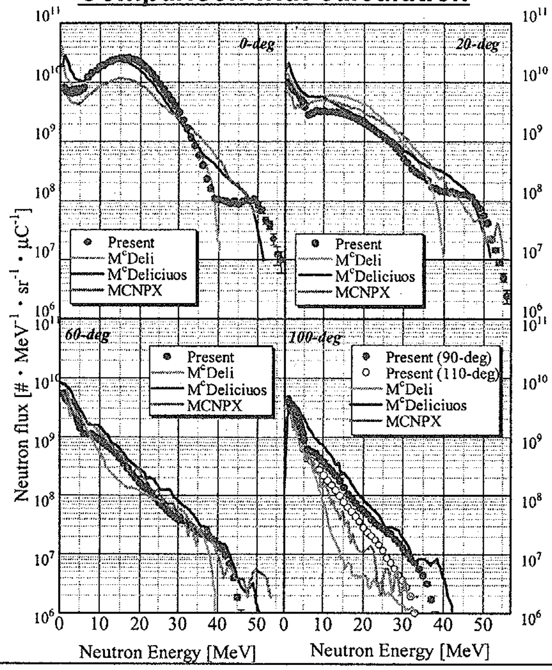
natLi(d,xn) for 40 MeV

Comparison with experimental data



natLi(d,xn) for 40 MeV

Comparison with calculation



3-6-3. Comparison with DDX

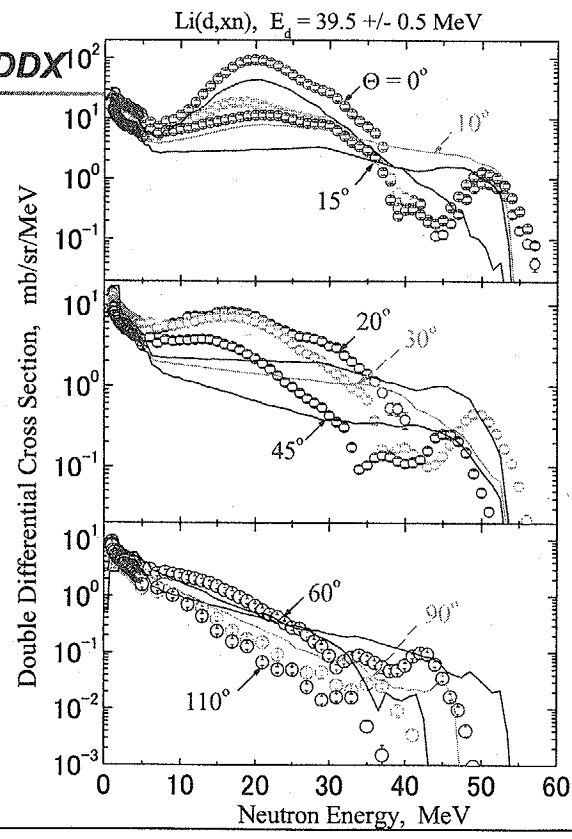
- Present
- M^CDeLicious code
  (S.P.Simakov,U.Fischer)

Disagreement among present and calculation data

Peak by 2 body reaction

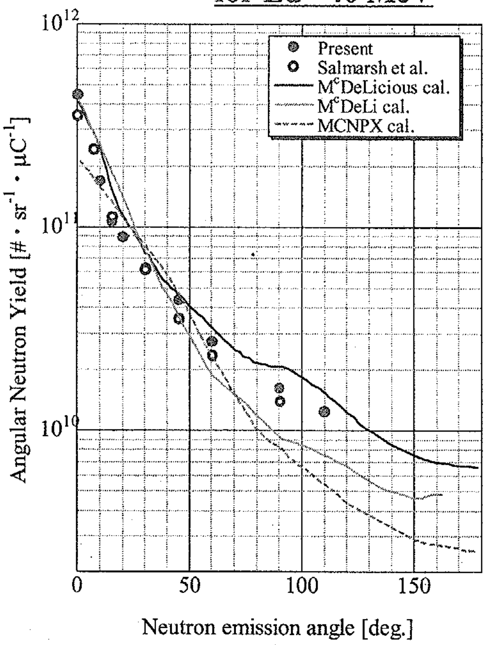
[^{7}Li(d,n)^{8}Be : Q-value +15.03 MeV]

[^{6}Li(d,n)^{7}Be : Q-value +3.38 MeV]

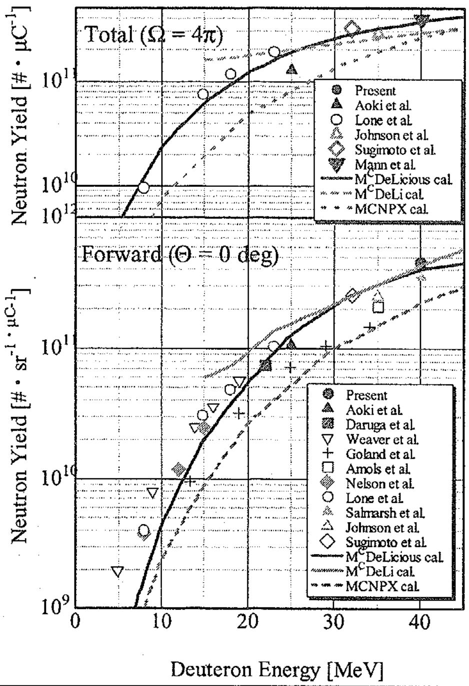


3-6-4. Comparison with ADX and total yield

Thick $^{nat}Li(d,xn)$ ADX for Ed= 40 MeV



Thick $^{nat}Li(d,xn)$ Total yield

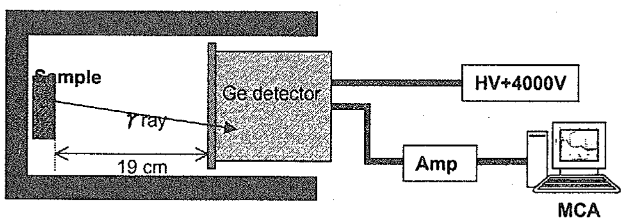


4. ^{7}Be activity

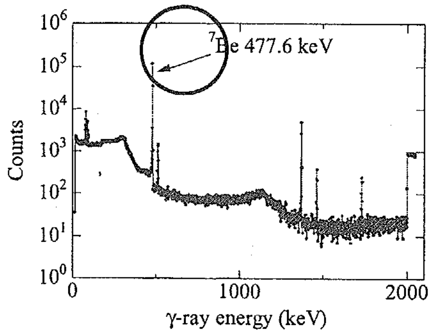
After neutron measurement

Measurement of ^{7}Be activity from the Li,Be targets using a pure Ge detector

4-1. Gamma-ray *measurement* set-up



4-2. Measured gamma-ray spectrum

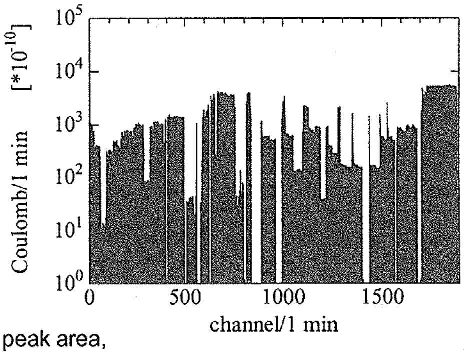


4-3. Data reduction

1) Reaction rate

$$R = \frac{\lambda \cdot C}{\varepsilon \cdot \gamma \cdot e^{-\lambda \cdot T_c} \cdot (1 - e^{-\lambda \cdot T_m}) \cdot \sum_{i=1}^{n} \{Q_i \cdot e^{-\lambda \cdot (n-i) \cdot \Delta t}\}}$$

Beam fluctuation with MCS



2) Number of products

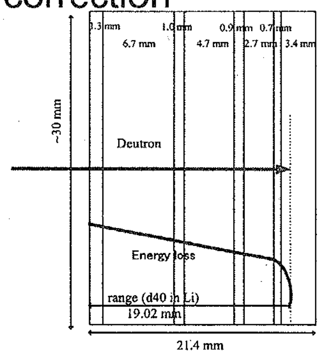
$$N = R \cdot Q_{total}$$

3) Activity

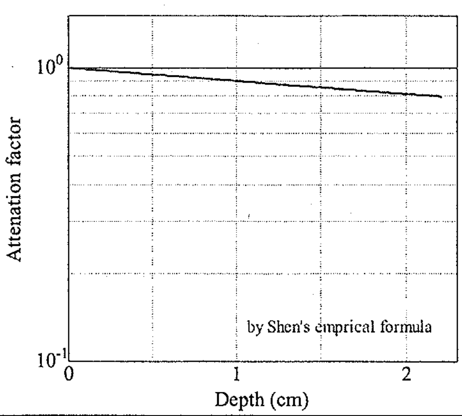
$$A = \frac{\lambda \cdot N}{I \cdot t}$$

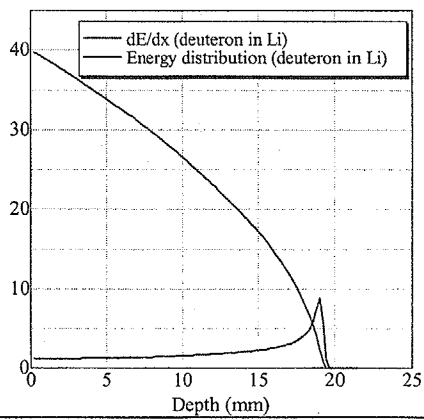
λ : decay constant (s^{-1}),
C : total counts of gamma-ray peak area,
ε : peak efficiency,
T_c: cooling time (s),
γ : branching ratio of gamma rays,
T_m: counting time (s),
Q_i : beam current (Coulomb) for irradiation time interval Dt (s) [using Multi Channel Scaler : MCS]
N : number of produced atoms in the target (atom),
A : dps/(μA·h)
I : beam current (μA)
T : irradiation total time (h)

Energy determination & attenuation correction



1. Energy of each stack sample
   -TRIM code
2. Attenuation
   -Shen's empirical formula

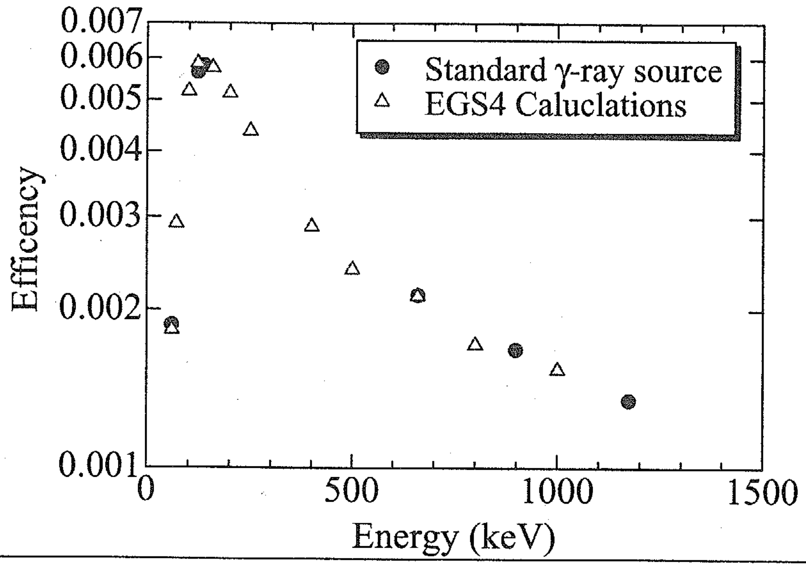




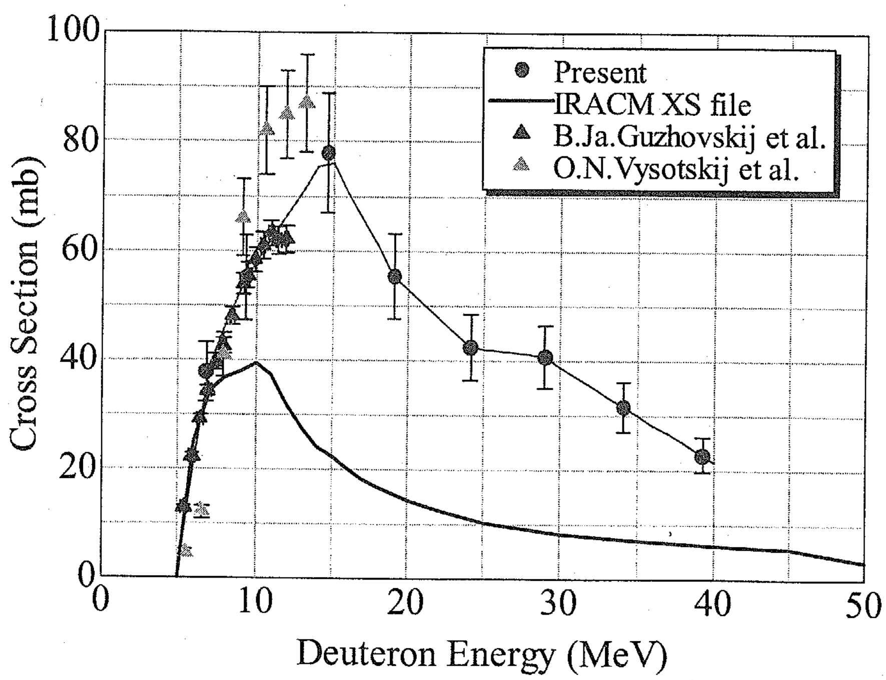
4-4. Ge detector absolute efficiency

EGS4, "Monte Carlo code" ➡ Efficiency + Correction

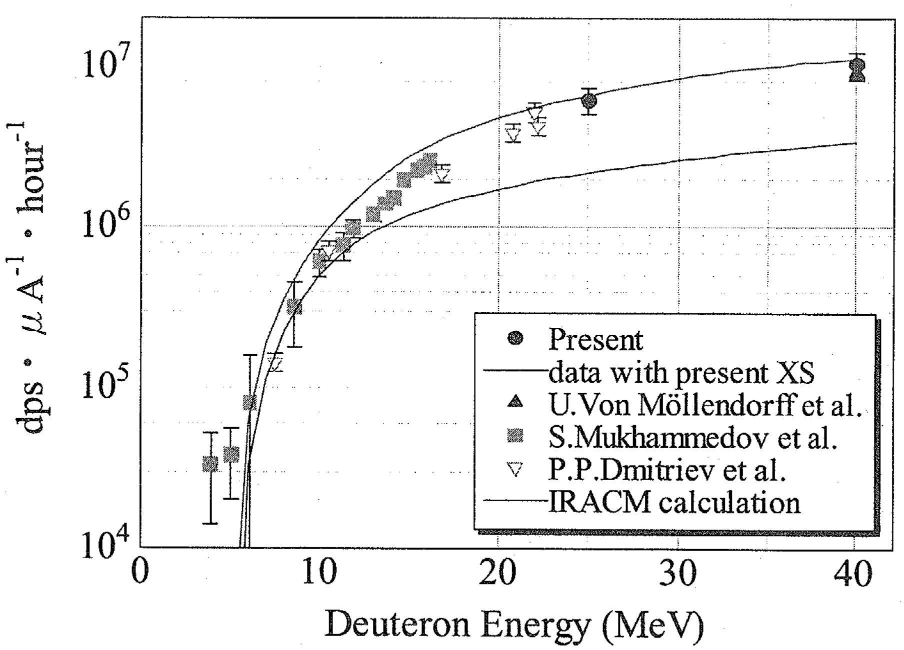
- Confirmation of the calculation in comparison with experimental value at 15 cm distance



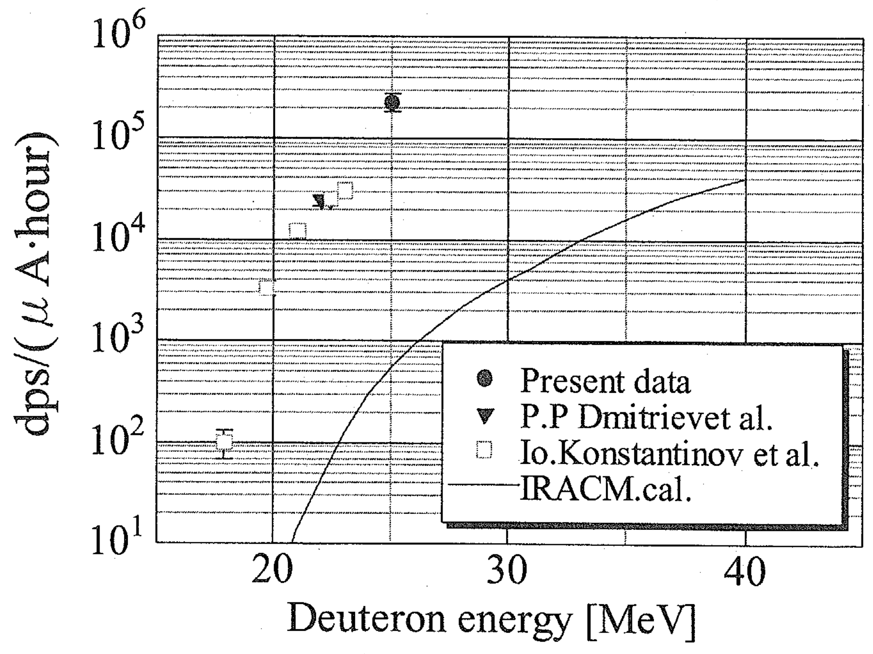
4-5. ^{7}Li(d,2n)^{7}Be results



4-6. Thick $^7Li(d,2n)^7Be$ Results

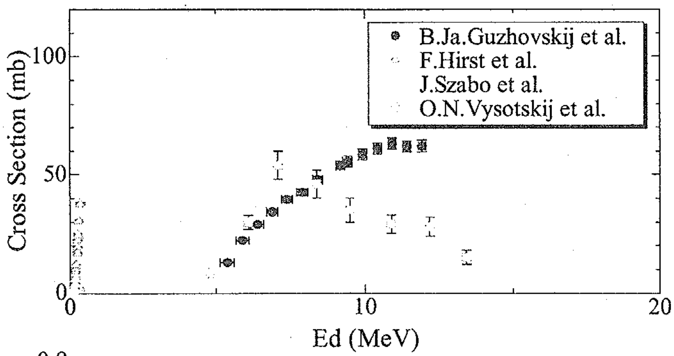


4-7. Thick $^9Be(d,x)^7Be$ Results



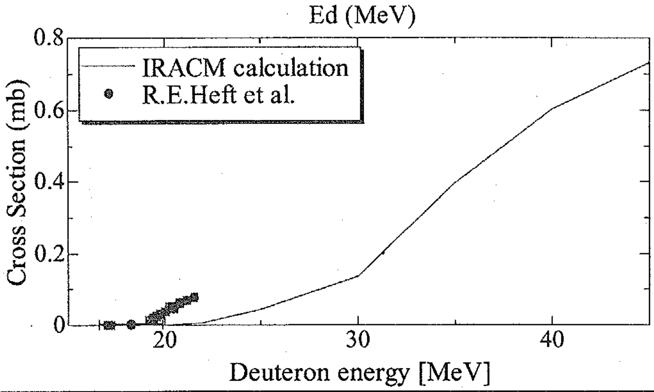
4-8. Reference cross-section

^{6}Li(d,x)^{7}Be Cross-section



^{9}Be(d,x)^{7}Be Cross section

- IRACM cross section (ALICE code) →underestimation



5. Summary

1. Measurements were done for
   - A) Neutron energy-angular distribution
   - B) ^{7}Be accumulation

     for ^{nat}Li(d,n), ^{nat}Be(d,n) reaction with thick and thin targets,
2. Spectrum data
   - almost entire energy measurement at many angle - first time
   - clearly show the high energy tail, and
   - in fair agreement with Lone's data for 25 MeV and Saltmarsh data for 40 MeV
   - calculations did not support present data in the high energy tail.
3. ^{7}Be data
   - In high energy, the present data - first time
   - much larger than IRAC estimation
   - Probably due to underestimation of ^{7}Li (d,n) cross-section and lack of ^{6}Li(d,n) cross-section

Reference

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- [12]U.Von Möllendorff, H.Feuerstein and H.Giese, Proc. 20th Symp., on Fusion Technology (Marseille, France, 7-11 Sept.1998) pp.1445

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Structural analysis on high flux test module of IFMIF

A.Shimizu @Kyushu Univ.

Kyushu University — Advanced Energy Engineering Science

Some issues to be solved in transition phase for test module

- Reliability of measurement by T.C. under irradiation conditions
- Alternative bonding between T.P. and capsule,
  - NaK or liquid metal
- More accurate estimate for nuclear heating,
  - so far supposed to be 5W/g
- Effect of Irradiation embrittlement and thermal stress on structural material (2003)
- Matching with the whole design
  - taking a consistent operationinto account ,irradiation-extraction-examinaiton,

2003 f.y. strategy

- Structural Analysis
  - Channel wall also undergoes nuclear heating
- Experiment for verification
- Coupling 3D neutron tracking code and stress analysis code with thermofluid simulation
- Effect of high energy spectrum of neutron and γ-ray on nuclear heating
  - Spatial non-uniformity of nuclear heating effects cooling performance and thermal stress load

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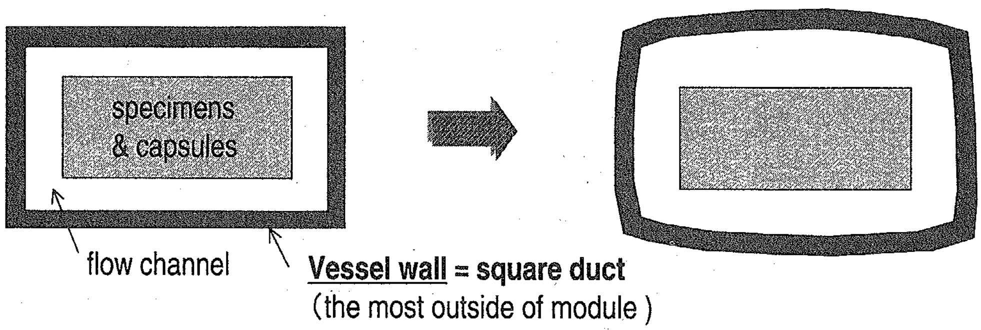
Vessel wall of high flux test module



Inside of vessel wall	; ~ 0.5MPa (He)
Outside	; ~ 0.1Pa (low vacuum)

⇒ deformation of vessel wall
(change in flow channel width)
⇒ un-uniformity of flow rate
⇒ large influence upon cooling performance
(⇒ destruction in the worst case)

∴ Verification of suitability of square duct is nessecary !!

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- Pressurization experiment of *square duct*
- Structural analysis considering *large deformation*

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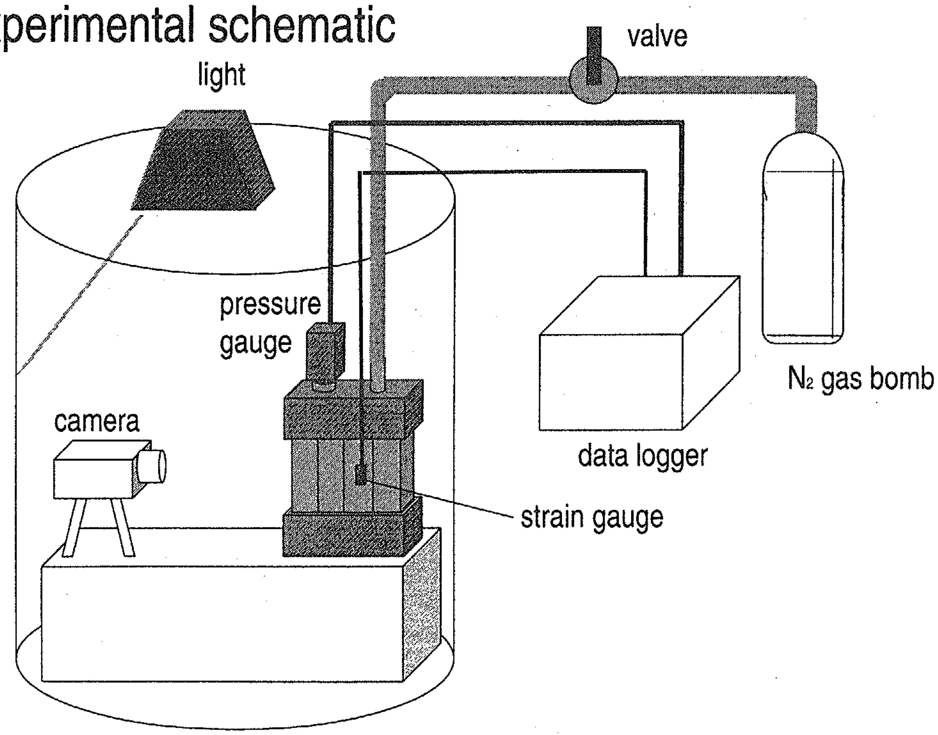
Experimental schematic



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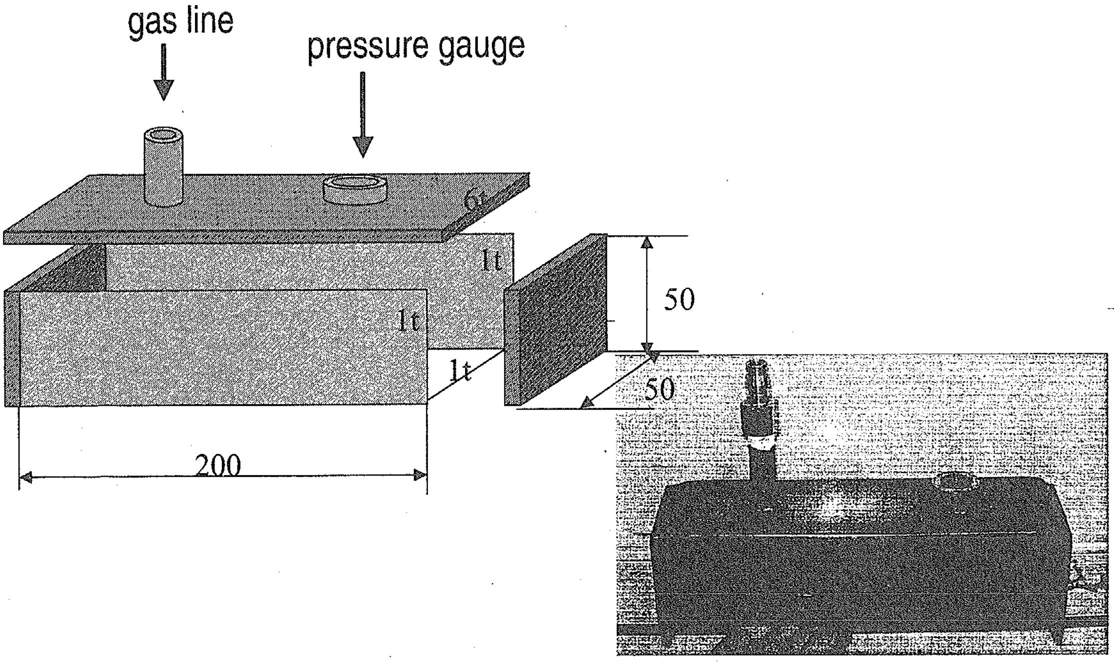
Test section of preliminary experiment



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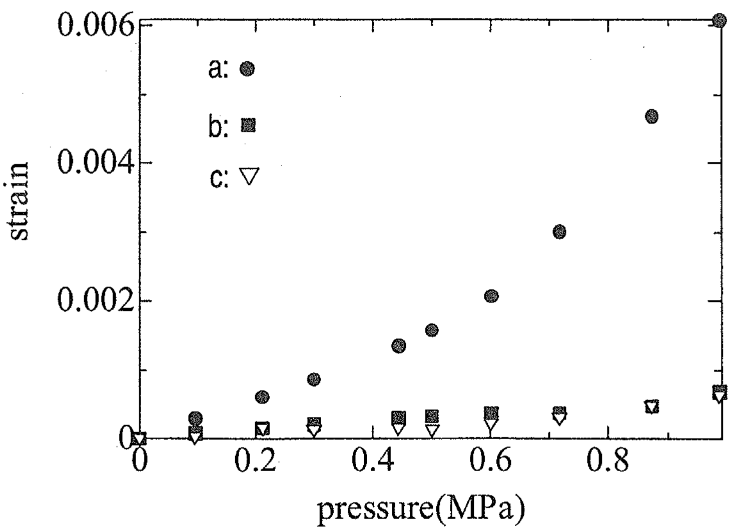
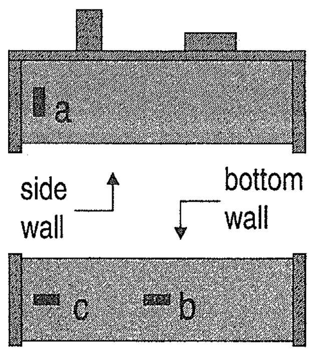
Experimental results-1

Relation between pressure and strain





position of strain gauge

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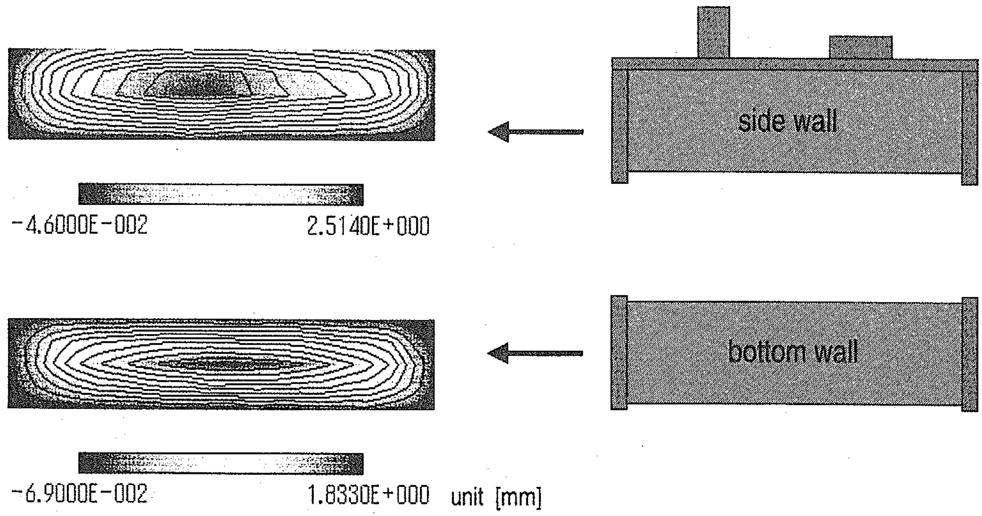
Experimental results-2

Deflection of surface wall after pressurization of 1 MPa



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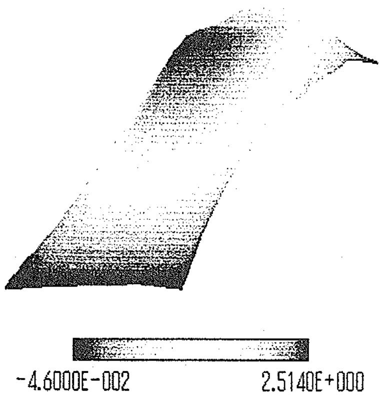
Deflection of channel surface



Measured deflection of surface at 1MPa;
Max.displacement =2.5 mm

Estimated displacement from strain gauge =2.37 mm

(1.2 mm at 0.5 MPa)

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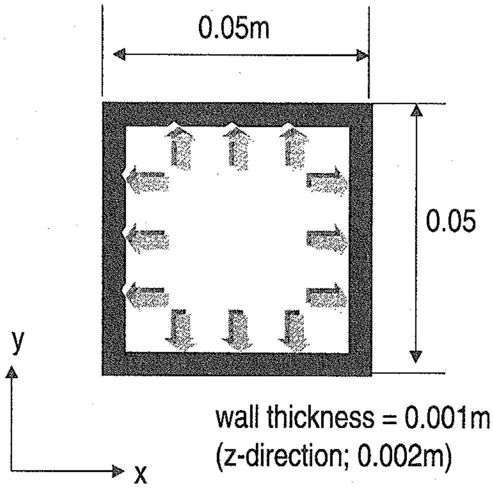
Numerical simulation



wall thickness = 0.001m
(z-direction; 0.002m)

Δp; pressure difference between insede & outside

Uz = 0

NUMERICAL CONDITION

Young's modulus; 209.0 x 10^9 [N/m^2]
Poisson's ratio; 0.29
shear modulus; 81.0 x 10^9 [N/m^2]
hardening coef.; 2.0 x 10^9 [N/m^2]
Yield stress 2.0 x 10^8 [N/m^2]

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Numerical procedure

Elasto-plastic finite element analysis

- virtual work formulation

$$\int_{{}^t v} {}^t_t\dot{\mathbf{S}} : \delta \mathbf{A}_{(L)} \, d\,{}^t v + \int_{{}^t v} {}^t\mathbf{T} : \tfrac{1}{2}\left(\delta {}^t_t\mathbf{F}^T \cdot \mathbf{L} + \mathbf{L}^T \cdot \delta {}^t_t\mathbf{F}\right) d\,{}^t v$$
$$= \int_{{}^t s_t} {}^t_t\dot{\mathbf{t}}^* \cdot \delta \mathbf{u} \, d\,{}^t s_t + \int_{{}^t v} {}^t\rho \, {}^t\dot{\mathbf{g}}^* \cdot \delta \mathbf{u} \, d\,{}^t v$$

- rate constitutive equation

$${}^t_t\hat{\mathbf{T}}^{(J)} = {}^t_t\mathbf{C} : \mathbf{D}$$
${}^t_t\hat{\mathbf{T}}^{(J)}$; Jaumann rate of Kirchhoff stress

${}^t_t\dot{\mathbf{S}}$; Truesdell stress rate; ${}^t_t\dot{\mathbf{S}} = {}^t_t\hat{\mathbf{T}}^{(J)} - \mathbf{D}\cdot\mathbf{T} - \mathbf{T}\cdot\mathbf{D}$

- stress integration ;
  backward Euler integration (elastic predictor- radial corrector method)

- incremental analysys;
  Newton-Raphson method using consistent tangent stiffness matrix

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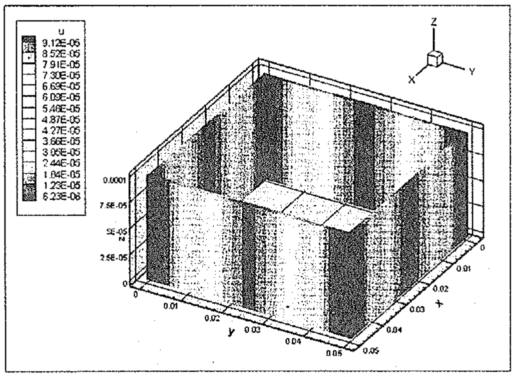
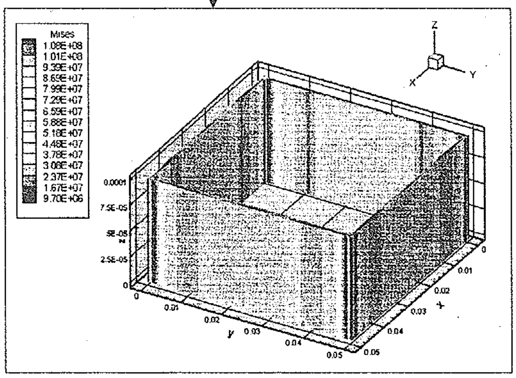
Example of Numerical result

Δp=0.13[MPa]
1334 nodes & 576 elements

displacement profile →



Mises stress profile ↓



Large deflection appears at center region.

Stress concentrates on corners.

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Near future plan

- Conduct pressurization experiment of full-scale version
- Examine elasto-plastic FEM code with various Δp
- Introduce thermal effect to the FEM code

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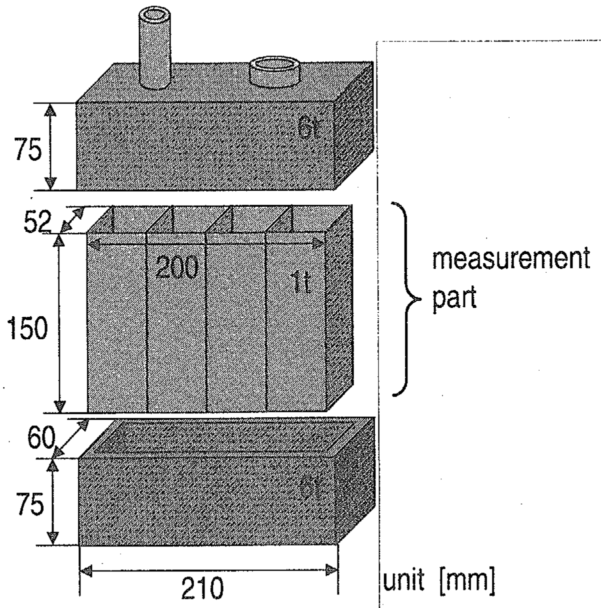
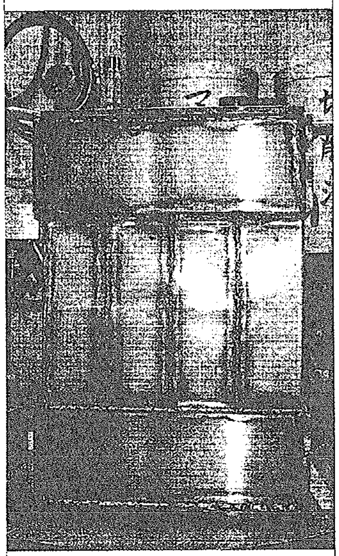
Detail of test section of full-scale version





IFMIF 国際核融合材料照射施設

Status of Transition Phase Activity for Test Facilities in JAERI

T. Yutani
JAERI

IFMIF Technical Meeting
Dec. 4-5, 2003, Kyoto, Japan

IFMIF 国際核融合材料照射施設

Transition Phase Activity for Test Facilities in JAERI

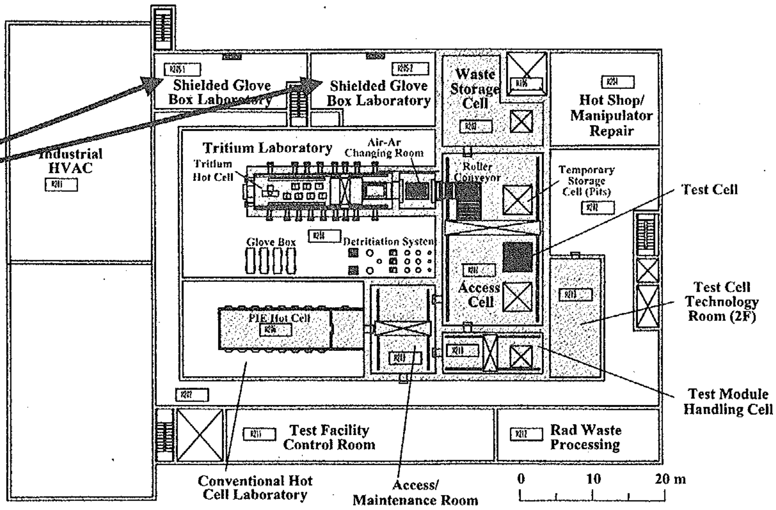
JAERI is carrying out preparation for layout of PIE facilities as a part of 'Update Design of the Test Cell subsystems'.

Task ID	TASK TITLE	OVERVIEW OF TASK CONTENT	JUSTIFICATION	CONTRIBUTING PARTY			
				EU	JA	US	RF
TF-1		Test Facility Design					
TF-1a	Improve reference design of High Flux Test Module	Validation of capsule fabrication technology; detailed thermo-fluid dynamics calculations	Incorporate KEP results into the reference design	X	X		
TF1b	He gas prototype facility	Definition of He has prototype facility and evaluation of existing EU loops	To perform tests on 1:1 sized test module prototypes an adequate He-loop is necessary	X			
TF-1c	Updated Design of the Test Cell subsystems	Establish updated reference design outline for (i) the test cell configuration, (ii) the HFTM high performance version, (iii) the MFTM with integrated neutron moderator/reflector	Incorporate KEP results into the reference design	X	X		
TF-2		Test Facility Development					
TF-2a	Miniaturized neutron/gamma monitors	Specification of reference design	Incorporate KEP results into the reference design	X			
TF-2b	Micro-tomography system	Specify reference design and perform underlying tests for confirmation	The reference assembly is based on KEP findings and additional experiments performed during 2003	X			
TF-3		Test Facility Neutronics					
TF-3a	D-Li reaction: Evaluation of source term	Experimental and theoretical verification of the D-Li source term	Reduce significantly the current neutron yield uncertainties of 20%	X	X		
TF-3b	Provide nuclear data above 20 MEV	Completion of data file preparation and neutron transport benchmark tests between 20-50 MeV	Indispenseable input for neutron transport and nuclear inventory calculations (long term activity)	X	X		
TF-3c	Detailed 3D-calculations of the nuclear response	Provide complete nuclear response based on detailed geometry of revised test modules	The nuclear respose is the important information for designers and users (long-term activity)	X	X		
TF-4		Specimen Development					
	SSTT; CT specimen development	Development of specimens and testing methodology for Fracture toughness tests	CT specimen and testing technology development is inevitable for the fusion community	X	X		

Preparation for layout of PIE facilities

Layout of Test Facilities (2F) at July 2003

After that, Shielded Glove Box Laboratory for micro-structural analyses has been removed, as it is assumed that a similar laboratory will already exist at the IFMIF host site.

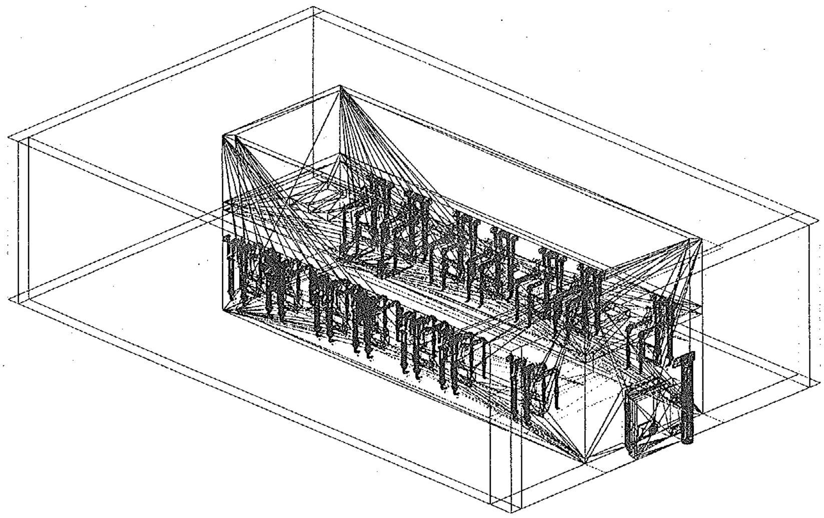


Many examinations may be required, to decide layout of PIE facilities.

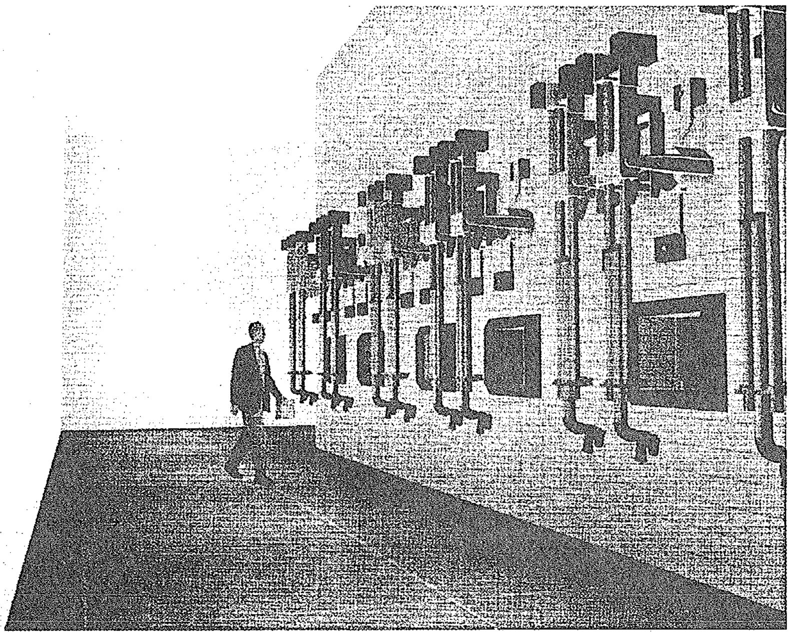
Then, JAERI is preparing the drawings of components.

Preparation for layout of PIE facilities

CAD Drawing of Conventional Hot Cell Lab.

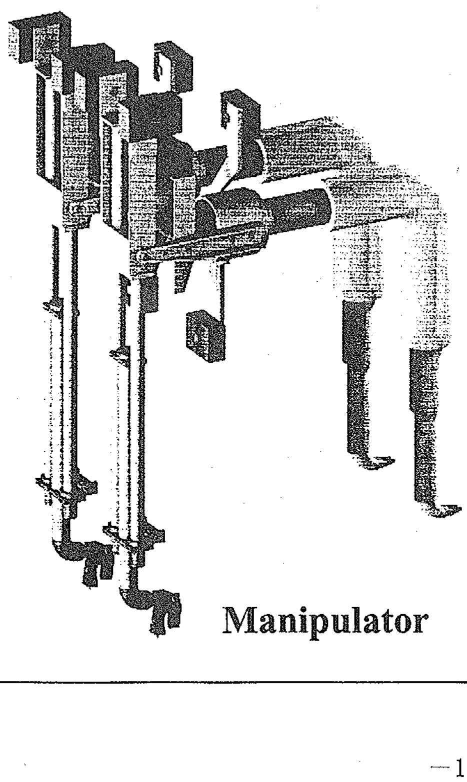


Preparation for layout of PIE facilities
3-D View of Conventional Hot Cell Lab.

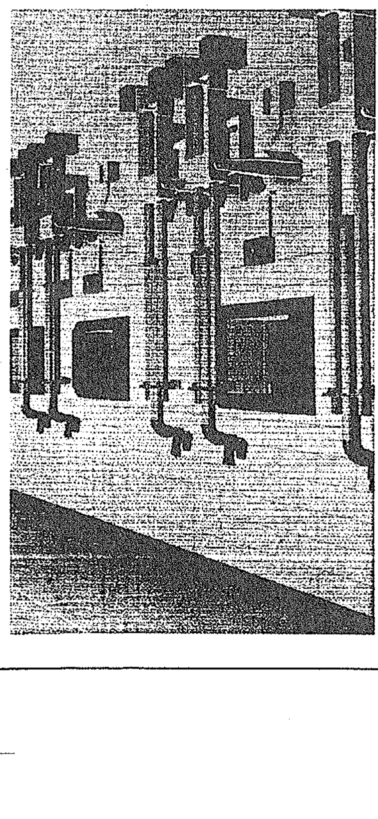


Note: The clothes of a person are not realistic.

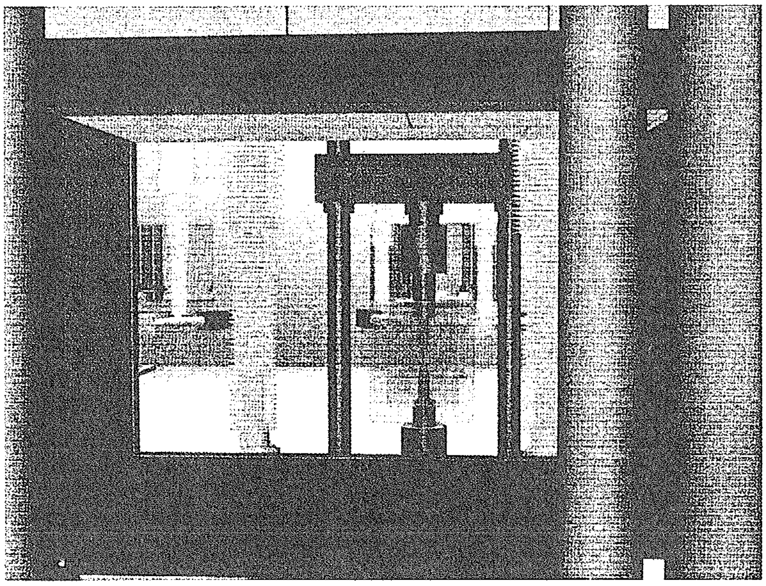
Preparation for layout of PIE facilities
3-D View of Conventional Hot Cell Lab.



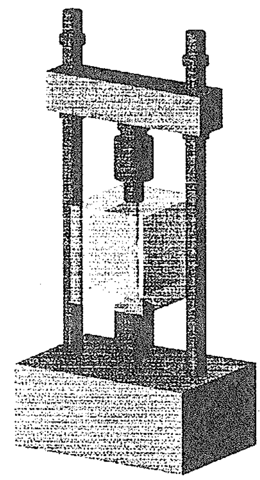
Manipulator



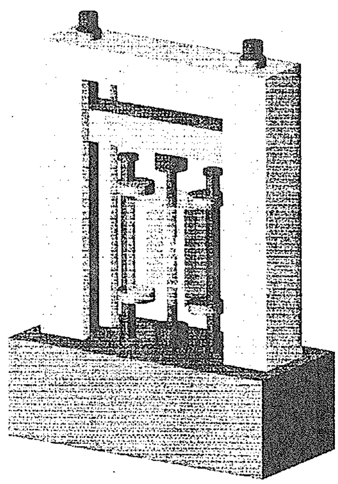
Preparation for layout of PIE facilities
Inside View of Hot Cell through Window



Preparation for layout of PIE facilities
Drawings of Equipment for PIE



Fatigue Testing Machine



Universal Testing Machine

To decide the layout of PIE facilities, more drawings (Impact Tester, Profilometer, etc.) need to be prepared.

IFMIF

Future Plan

- Continuation of Preparation for layout of PIE facilities
- Evaluation for neutronics (D-Li source term, nuclear data, nuclear response) in cooperation with FZK, if possible
- And, Participation in several tasks in EVEDA

Status of Design Integration Tasks in 2003

M. Sugimoto, JAERI

IFMIF Technical Meeting
December 4-5, 2003
Shiran-Kaikan, Kyoto

1

DI Activity in Transition Phase

DI activity is concentrated on the following four tasks.

1) Examining the present concept of operation to clarify the interface issues,
2) Surveying regulation concept to start negotiation with authority, which may needs long duration,
3) Establishing IFMIF data base to efficiently exchange information among IFMIF team, and
4) Updating reference design by 3D-CAD system and data communication to efficiently prepare Engineering Design in EVEDA.

2

Design Integration Tasks in Transition Phase

	Task ID	Task Title	Overview of Task Content	Justification	Contributing Party EU	JA	US	RF
Design Integration	DI-1	Basic Concept of Operation	- Examination of specification for the whole system control - Consistency check among all subsystems	In order to perform system design, a basic concept is needed.	X	X		
	DI-2	Survey for regulation concept	- Worker & Public Safety Assessment - Examination of guidelines and collection of data for licensing - Estimation of Test Cell shielding performance	To start the negotiation with authority, a regulation concept is needed.	X	X		
	DI-3	IFMIF data base	Set up of IFMIF web-site	To facilitate information exchange	X	X	X	
	DI-4	Reference Design	Update Ref. Design by 3D-CAD system and data communication	To efficiently prepre Engineering Design in EVEDA.	X	X	X	

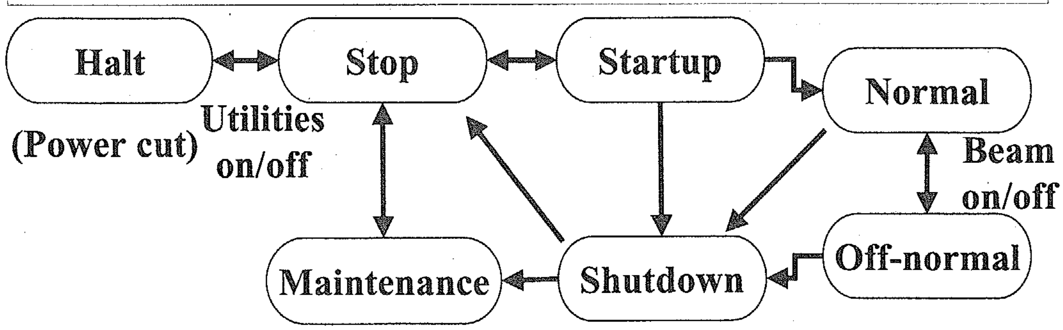
3

DI-1 Basic concept of operation

Update operation requirements (JAERI)

The present concept of operation requirements is re-examined to clarify the interface issues among each subsystems.

Transitions among states of facility are considered.



4

DI-2 Survey of regulation concept

Reference Accident Sequence analysis (ENEA Frascati)

1) Eleven sequence families of Plant Damage States were identified with respective reference scenarios.
2) Two accident sequences (beam overpower, Li intrusion to beamline & reaction with cooling water) are studied in 2003.

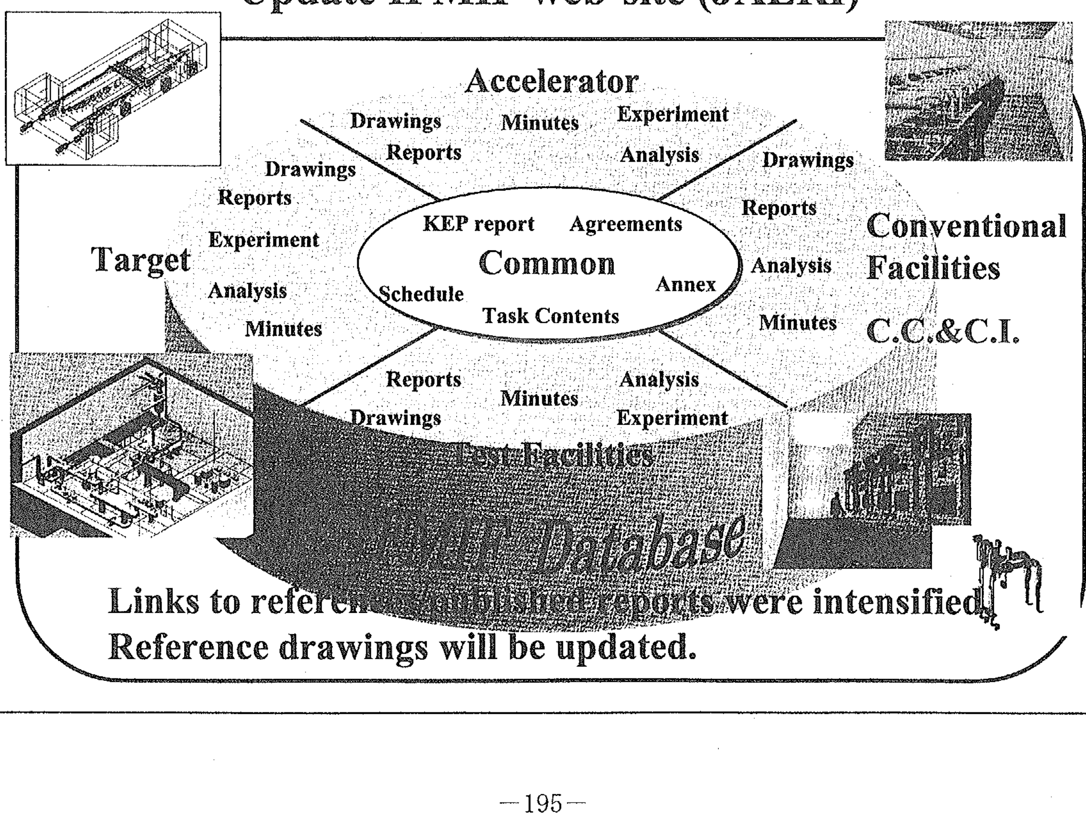
Evaluation of shielding performance of Test Cell (ENEA Frascati)

1) 3 dim. Radiation transport calculations using Monte Carlo and Sn codes with decay gamma rays are in progress to evaluate dose rates.

5

DI-3 IFMIF database: set up web-site

Update IFMIF web-site (JAERI)



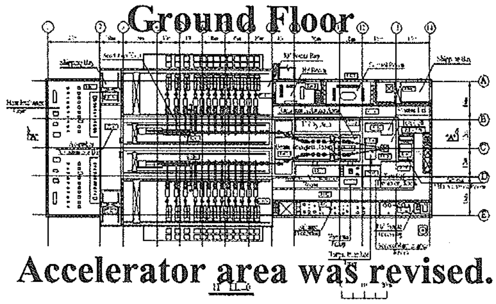
Links to refe[illegible] published reports were intensified.
Reference drawings will be updated.

6

DI-4 Reference design

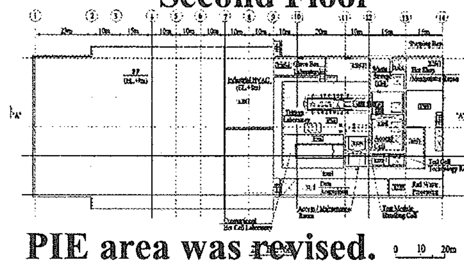
Update component designs (JAERI)

Ground Floor



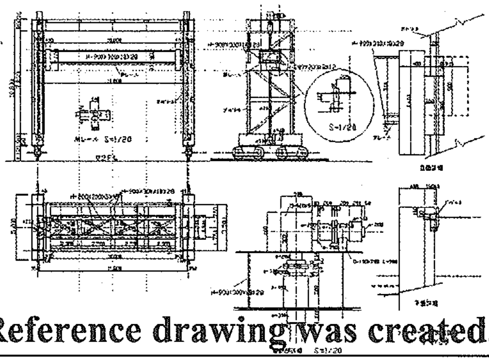
Accelerator area was revised.

Second Floor



PIE area was revised.

Universal Robot System



Reference drawing was created.

7

Summary

1) The selected four tasks are in progress to move smoothly to the activity carried out in EVEDA phase.

2) The details of engineering design tasks during EVEDA need to be clearly identified in next year transition activity.

8

IFMIF
International Fusion Materials Irradiation Facility

Overview of CDR design

Design Parameter of Conventional Facilities

JAERI

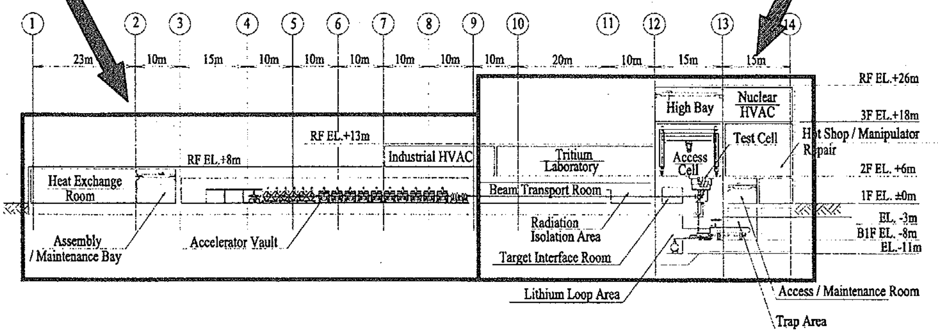
IFMIF Technical Meeting, Kyoto Japan, 4-5 December, 2003

1

Main Building

- Accelerator building
  - 100m x 60m x 8~13 m
  - for Seismic: General Industry Building Level

- Target & Test building
  - 70m x 60m x -11~26 m
  - for Seismic: Atmic Facility Building Level



Assumptions

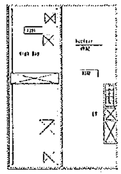
- Located within existing nuclear research facility
- Supported on the Bedrock directly

2

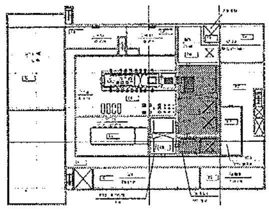
Heating Ventilation & Air Conditioning

Classification

- Industry HVAC
- Active Nuclear HVAC (I-1)
- Nuclear HVAC (I-2)
- Nuclear HVAC (I-3)
- Nuclear HVAC (I-4)
- Nuclear HVAC (II)

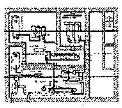


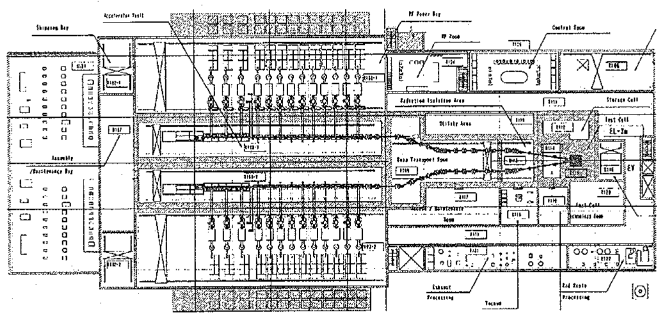
3F



2F

B1F





1F

3

Heating Ventilation & Air Conditioning

Design Parameters

Classification		Gas	Room Volume (m³)	Flow rate (m³/h)	Pressure (Pa(gage))
Industry HVAC	-	Air	14,000	42,000	-100
Active Nuclear HVAC	I-1	Air	4,800	50,000	-400
Nuclear HVAC	I-2	Ar / Air	1,500	4,500	-300
	I-3	Ar	100	-	0.1 / -400
	I-4	Air	4,000	15,000	-300
	II	Air (Ar)	66,900	191,000	-200

4

Electrical System & Water Supply System

●Electrical System

- Power Capacity : 50MVA
- Supply Voltage to IFMIF Site : 66 kV

●Water Supply System

1) Cooling Water
   - Heat rejection capacity : 40 MW
   - Temperature : 30°C, 35°C
   - Condition : < 1 μS/cm^2
2) Service Water
   - Industrial water : 70 m^3/h
   - Primary cooling water for Accelerator : 10 L/min

5

Distribution of Heat Rejection Capacity

		Supply Temp.	Capacity (MW)	
			external loop	internal loop
Acclerator	RF Power	30 / 50°C	-	16.72
	Ion Sauce, LEBT	30 / 50°C	-	0.60
	RFQ	35 / 38°C	-	2.24
	DTL	35 / 38°C	-	5.60
	HEBT, RF	30 / 50°C	-	1.36
	Aux. eq. HVAC	-	0.02	-
Li-Loop		-	13.00	-
Total			13.02	26.52
			39.54	

6

Radioactive Waste Treatment System

- **Liquid waste**
  - Storage volume : $10\ m^3 \times 2$
  - Treatment capacity : 150 kg/h
  - Discharged level : $\leq 4.0 \times 10^{-4}$ Bq/cm^3 (unknown radioactivities)
    ≤ 6.0 Bq/cm^3 (tritium)
- **Gaseous waste**
  - Processing capacity : 100 m^3/h
  - Discharged level : $\leq 5.0 \times 10^{-4}$ Bq/cm^3 (tritium)
- **Solid waste**
  - Released weight : ≤ 1.0 ton/year

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Central Vacuum System, etc.

- **Central Vacuum System**
  - Accelerator : 0.1 mPa
  - Target surface : 1.0 mPa
  - Test Cell : 0.1 Pa
- **Radiation Shielding**
  - Test Cell Room : wall thickness ~ 4.3 m
    (< 10 μS/h in the adjacent area)
- **Gas Supply**
  - Ar, He, Air(10 kg/cm^{2}G), Liquid N

8

Crosscheck of Conventional Facilities Cost

performed by ENEA and Japan

- Checked about following 3 Elements
  1) Building Cost
     → *Cost difference is around 10%, two cost estimate are alike.*
  2) HVAC System Cost
     → *Design condition of two cost estimate is different.*
     → *Assumption for cost reduction is considered in JP estimate.*
  3) Heat Rejection Cost
     → *Heat rejection capacity of ENEA estimate is incorrect. The concluding value become similar.*

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(1) Building Cost

WBS items	2003 cost ENEA	2003 cost Japan	Remarks *[Difference]*
Unit:	MEuro	MICF	In 2003 cost estimate: 1 ICF = 1Euro
BUNKER & INDUSTRIAL BUILDING	20.8	29.8	ENEA estimate only includes the cost for the buildings of Accelerator Building (WBS5.2.1.5), and Target Building / Test & Exam. Complex / High Bay (all included in WBS5.2.2.1).
ENGINEERING	2.0 (10%)	0	No cost breakdown is given in Japanese estimate. They are considered to be included in 29.8 MICF.
AFI	4.2 (20%)	0	
TOTAL BUILDINGS	***27.0***	**29.8**	***[+2.8MICF (+10%)]***

◆The whole of the building cost needs to make addition of various equipments cost **22.3 MICF** to the above total.

10

[2] HVAC System Cost

WBS items	2003 cost ENEA	2003 cost Japan	Remarks [Difference]
Unit:	MEuro	MICF	In 2003 cost estimate: 1 ICF = 1Euro
HVAC System	12.6 → 18.1	11.4 → 9.6	•Nuclear HVAC price /m³: $117 (Japan) vs. $230 (ENEA); (37,300→72,573 m³) •Active HVAC price /m³: $130 (Japan) vs. $288 (ENEA); (4,798→4,790 m³) •Industrial HVAC price /m³: $36 (Japan) vs. $33 (ENEA); (65,300→14,063 m³)
ENGINEERING	1.3 (10%)	0	No cost breakdown is given in Japanese estimate. They are considered to be included in 11.4 MICF. It seems to be no ambiguity in design when building size is fixed.
AFI	1.9 (15%)	0	
TOTAL HVAC	***15.8*** → 22.6	11.4 → 9.6	***[-4.4MICF (-28%)]*** → ***[-13.0MICF (-58%)]***

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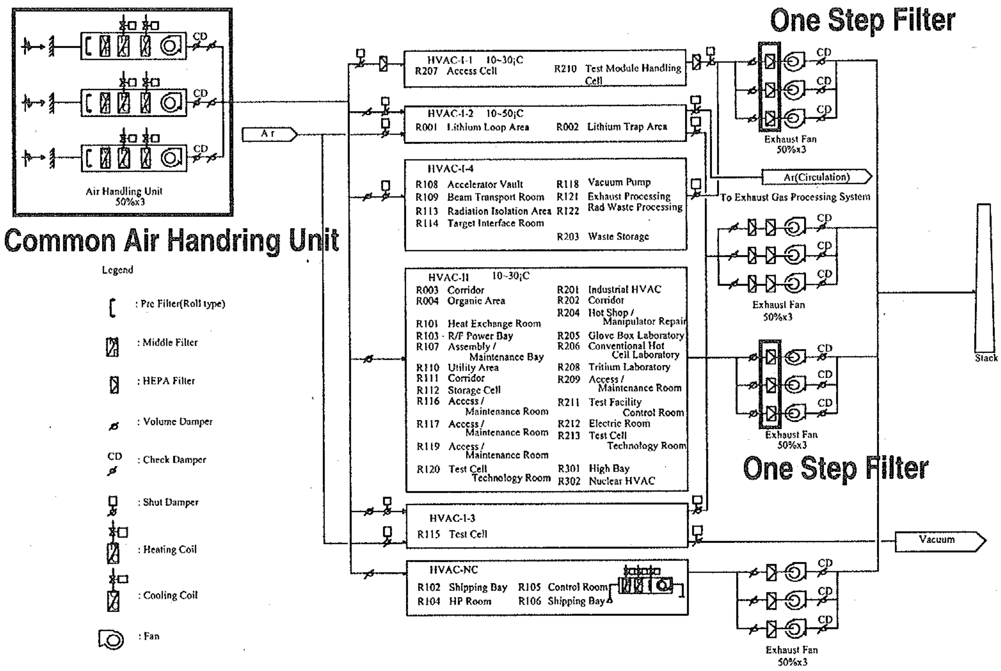
Design Condition of HVAC System

	ENEA		Japan (in KEP Report)	
	volume served (m^3)	air change / h	volume served (m^3)	air change / h
Industrial HVAC	65,317	2~3	14,063	2
Nuclear HVAC	37,319	3~5	72,573	3.5
Active Nuclear HVAC	4,798	40	4,790	10

12

HVAC System of JP Cost Estimate

(assumptions for cost reduction)



13

(3) Heat Rejection System Cost

WBS items	2003 cost ENEA	2003 cost Japan	Remarks *[Difference]*
Unit:	MEuro	MICF	In 2003 cost estimate: 1 ICF = 1Euro
Heat Rejection System	7.4 → 13.9	18.4	Capacity: 40MW (Japan, including Li loop cooling) vs. 14MW (ENEA) → 40MW (assuming power law: C~kP$^{0.6}$)
ENGINEERING	0.8 (10%)	1.1	
AFI	1.5 (20%)	1.3	
TOTAL H.R.S	***9.7*** → 18.1	**20.9**	***[+11.2MICF (+115%)]*** → ***[+2.8MICF (+15%)]***

$$C = 1.46xP^{0.6} \approx 1.46 \times 14^{0.6} = 7.1 \text{(MUS\$)}$$

14

EFDA Technology Workprogramme
Field: Tritium Breeding and Materials
Task TTMI-004: Estimation of Test Cell shielding performance
Principal Investigator : D.G.Cepraga

Backgroung (KEP Phase)

The subtask is aimed at evaluating the shielding capability of IFMIF Test Cell.

This assessment has to be performed checking first the radiological protection related to beam-on operational phase to verify the compliance with the maximum allowable dose rate limit (10 μ Sv/h). Dose rate calculation outside Test Cell concrete walls has been performed via the Sn SCALENEA-1 shielding analysis sequence with the new intermediate energy coupled 256n-49γ multi-group cross-section library Vitenea-IEF. The contribute to the dose rate from decay gamma sources has been taken into account using the ANITA-IEAF activation code package. The dose rates of the IFMIF facility, Test Cell and its surrounding areas, at various configurations have been calculated for different operational phases, beam-on (start-of-cycle, end-of-cycle) and beam-off (shutdown and 1 day cooling), at various detector points.

The results analysis points out that the beam-on phase at the end-of-cycle represents the maximum exposure case. For beam-on phase the total dose rates for the Lateral, Back and Floor directions are less than the recommended one (10μSv/h) in both the start-of-cycle and end-of-cycle cases and higher than 10μSv/h for the upper direction. For beam-off phase the total dose rate is lower than 10μSv/h one day after the plant shutdown in the forward and upper directions.

Two types of radiological concerns related to the cells/rooms (outside the Test Cell) have been considered: the first (A) is related to the dose rate into the various maintenance cells and laboratories surrounding the Test Cell during beam-on and beam-off phases; the second (B) is related to the radioactivity of materials that were irradiated into the Test Cell (e. g. VTA1, VTA2 and VIT modules) and that were transferred to the various maintenance cells and laboratories.

The dose rate calculations made possible the room classification in different Radiation Access Zones: all the cells/rooms in the forward and lateral direction (with respect the beam axis) can be considered as controlled area, while the up, down and back rooms have to be considered as Controlled/Restricted areas.

The Test Module material contact dose is much higher than the hand-on-limit (assumed to be 10μSv/h) up to very long period from the end of the irradiation. Therefore, remote handling operations are requested on those materials. To reduce dose rates from the activated materials, adequate local shielding (or shielded containers) have to be foreseen (into the transfer/storage rooms).

Activities 2003

Three dimensional radiation transport calculations, both MCNP Monte Carlo family codes and DOORS deterministic Sn family codes (TORT), in order to guarantee a complete Q.A. process, and decay gamma source estimations (ANITA-IEAF activation code package) for dose rate evaluations of the Test Cell are performed, based on the 3D-architecture of the IFMIF facility.

The following activities are in progress:

Test calculations with TORT related to IFMIF Test Cell are being performed. They are related to the parametric search of broad group cross section library (starting from 256 neutron and 42 gamma energy groups) and to the check of the pre-post –processing modules produced.

Tests are performed to define the last real 3D configuration , order of quadrature, order of Fit to the Fluxes and Cross-Sections , broad energy group structure to be used in the calculations; check

between 1D spherical SCALENEA-1 and 3D calculations for fluxes on the Test Cell liner will be made.
Calculations with MCNP codes (MCNP-4C2 / MCNPX-5.2b) are in progress for the same geometrical configuration of Test Cell used for TORT to calibrate the results.
Continuous check between 1D spherical SCALENEA-1 and 3D (MCNP and TORT) results, in particular for concrete shield region, is performed.

Description of the SN Multidimensional Dose Evaluation

1) Discrete-Ordinates Difference Equations: quadratures and scattering

Search of the best set of: Order of Angular Quadrature and Order of Fit to the Fluxes and Cross-Sections.
A set of calculations, applied to an IFMIF essential Test Cell configuration, was performed for different values of Order of Angular Quadrature (Gauss-Legendre coefficients): S6, S8 and S16. For each of these values, three different Order of Fit to the Fluxes and Cross Sections (order of Legendre polynomials) were used in the calculations: P1,P3, P5 respectively.
The analysis of this parametric search shows that the best choice is P5-S16, but it creates difficulties in 3D calculations related to the convergence and especially to handle the huge data output (more than 150 millions of fine mesh group energy fluxes). The differences in the results choosing a more roughly approximation like P1-S6 are about 80% lower on surface neutron/gamma dose rates, while P3-S8 seems a sufficient choice (a difference about 20%). The first test calculations by 3D Sn TORT code using as Order of Angular Quadrature, S8, and as Order of Fit to the Fluxes and Cross-Sections, P3, have been performed reaching the convergence and the quantity of data contained in the output are easily managed by the codes ad hoc produced (see 2). A set of calculations was performed to find a reasonable spatial mesh interval set. The difference between two calculations with 140 and 70 spatial intervals in radial direction inside the biological concrete region shows that dose rate values become lower of 15%.

2) Utility modules to process input/output data files for DOORS-TORT codes

A set of programs was developed as tools to prepare and check the input and output data files for TORT (three-dimensional deterministic transport code). One code was set up able to generate the geometrical and material distribution entries for TORT and applied to IFMIF Test Cell. The main advantage of this program consists of de-coupling the geometrical model description, which must be prepared once and for all, and the mesh grid refinement options. If the user decides to create a more or less refined mesh than the he has got or to switch from an X-Y-Z grid to a R-Θ–Z one or vice versa, it is sufficient for it to change very few data entries to this program, without modifying the geometrical description of the model to be analysed. A code was also set up able to manage the huge TORT output file in order to extract the nuclear responses, i.e. neutron and gamma fluxes on a user defined mesh, and to convert them to doses, via neutron and gamma flux to dose conversion factors.

Reference Accident Sequences analysis for IFMIF-KEP design.

Task TTMI-004

The activity related to the 2003 task is devoted to:

1. Selection of Reference Accident Sequences according last updating of design solutions and reviewing last safety assessment.
2. Investigation of two representative accident sequences. Deterministic analyses are performed in order to evaluate challenging of containment's and radioactive release to the environment, as well as risks for workers due to the accidental conditions.

Activities in point 1.

Representative Accident Sequences events will be the ones that should be interested by deterministic assessment in order to verify the respect of safety limits for the facility even if accidental situations will occur. The analysis of Postulated Initiating Events and possible sequences is on going and results of the work will be produced for the end of 2003.

At the present, 11 Plant Damage States (PDS) are identified. Each PDS refers to a different accident scenario.

Sequence family	Description	Reference scenario
PDS1	Target overheating	Lithium coolant large break LOCA, followed by failure of the beam shutdown system and beam/target isolation system (including eventual manual recovery)
PDS2	Li fire in Li Cell	Li spill in the Li Cell with HVAC inoperative
PDS3	Li fire in Li Cell without isolation	Li spill in the Li Cell with HVAC inoperative and Li Cell confinement failure
PDS4	LI fire in Li Cell and Target overheating	Li spill in the Li Cell with HVAC inoperative and failure of beam shut down and isolation systems (including eventual manual recovery)
PDS5	LI fire in Li Cell without isolation and Target overheating	Li spill in the Li Cell with HVAC inoperative and failure of beam shut down and isolation systems (including eventual manual recovery) and Li Cell confinement failure*
PDS6	Radioactive impurity accumulation	Loss of Li purification followed by failure of both beam shutdown and isolation systems
PDS7	Li intrusion in the beam line	Li spill in the Test Cell due to Backwall rupture, with failure of the system which allows isolate the beam from the target (including eventual manual recovery) with beam either shutdown or not
PDS8	Li fire in the Test Cell	Li spill in the Test Cell due to Backwall rupture, with failure of the Test Cell vacuum system
PDS9	Li fire in the Test Cell without isolation	Li spill in the Test Cell due to Backwall rupture, with failure of the Test Cell vacuum system, and additional loss of integrity of the Test Cell
PDS10	Water-Li reaction	Accelerator cooling water spill in accelerator duct and consequent water-Li reaction with no intervention of the beam isolation system
PDS11	Tritiated Exhaust Gas Release	Exhaust Gas Detritiation System malfunction and failure of interlock and protection systems

Activities in point 2.

Two accident sequences have been set for the study (thermal hydraulic codes are used) to be performed in this year:

1. Accident transient due to accelerator power excursion, i.e. beam overpower above the nominal power, with secondary and tertiary circuits operating.
   The analysis is aimed at the evaluation of the target back plate material (low activation ferritic steel) resistance to the thermal stress overcoming the nominal conditions.
2. Accident transient due to the interaction between the lithium coming from the target and the water spilled from the water cooling system of the accelerator. This accident scenario could be determined by a random failure of accelerator cooling loop channel or a rupture induced by a beam deviation on the accelerator tube wall.

The first study has been already done considering 30% of beam overpower (from 10 to13 MW), while the second study is in progress.

As a conclusion of the first study we can observe that the increase of temperature for the three fluids (lithium, oil and water) is limited and does not impair the safety of the system.

If we would like to limit within 5 °C the increase of water temperature between the inlet and the outlet of the heat exchanger, as specified in the normal operation requirements, the mass flow rate should rise consequently.

In the transient analysed the mass flow rate of the fluids are maintained constant.

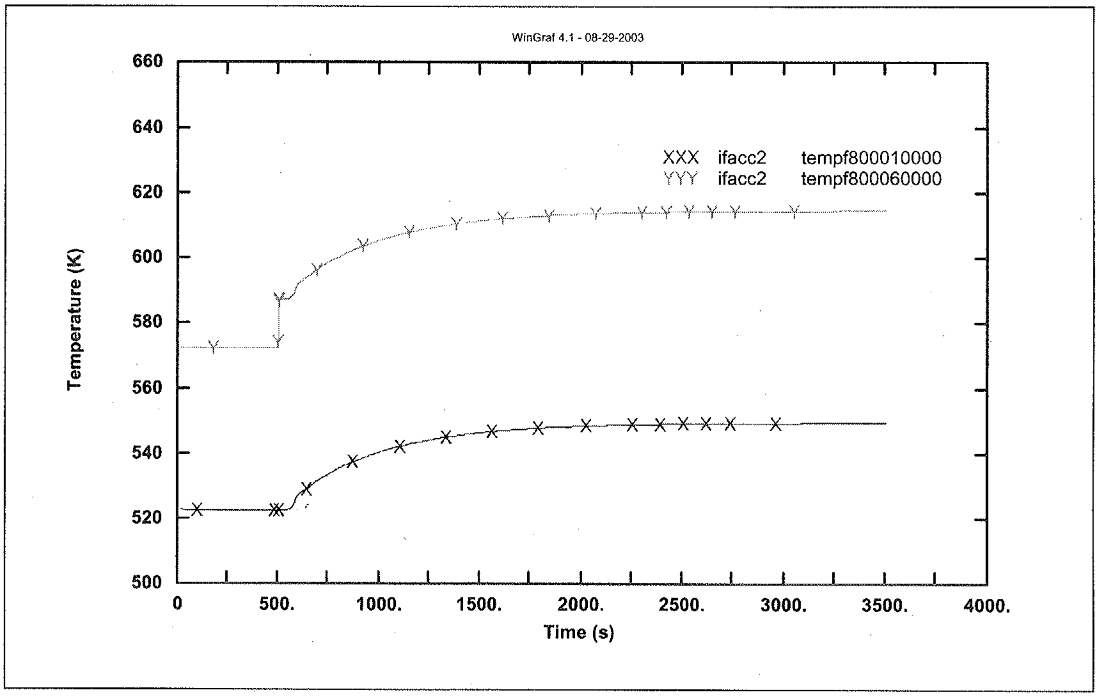


Fig. 1: Lithium temperature at the inlet (**XXX**)and the outlet (YYY) of the target

Status of Japanese DI Tasks in Transition Phase

(Transition Task **DI-1, DI-2, DI-3 and DI-4)**

M. Ida, M. Takeda, T. Yutani, H. Nakamura and M. Sugimoto (JAERI)

Japanese team is to contribute to all of four DI Tasks (DI-1 through DI-4) in IFMIF Transition Phase. In 2003, there were progress mainly in DI-3 and DI-4 as follows.

DI-1: Basic concept of operation

This task covers design of control and check of consistency for whole system. Detailed design is to be done with progress on facility design, and with progress on commercial equipment of control, communication and computer.

DI-2: Survey for regulation concept

This task covers safety assessment, guideline examination, and shielding estimation. Japanese guidelines relating radiation/radioactivity and lithium fire are under examination. Detailed estimation on radiation shielding of Test Cell is to be done.

DI-3: IFMIF database

This task covers setup of IFMIF web-site in each party. Japanese web-site is being updated. Anyone can access the web-site with address

http://insdell.tokai.jaeri.go.jp/IFMIFHOME/ifmif_home_e.html

Publications relating IFMIF, for examples,

JAERI Tech 2000-014, Reduced Cost Report;
JAERI Tech 2000-052, KEP Task Description; and
JAERI Tech 2003-005, KEP Report;

are available on this site.

DI-4: Reference design

This task covers reference design update by 3D CAD system and cost estimation. In 2003, 3D data of PIE is under preparation (Figs. 1 and 2). IFMIF total project cost from EVEDA to decommissioning was estimated through international discussion. Also organization and personnel of Joint Team in EVEDA and IFMIF Legal Entity in CODA were examined.

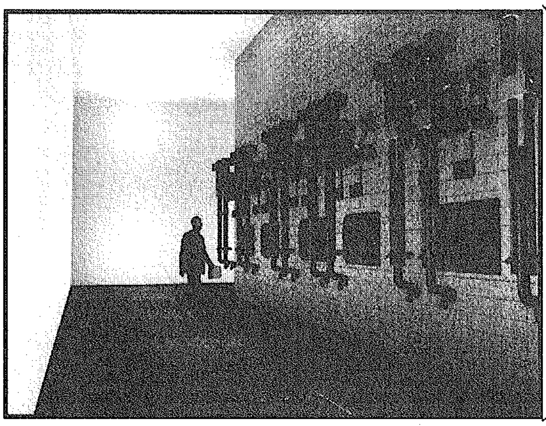


Fig. 1. Outside of Hot Cell (R206)

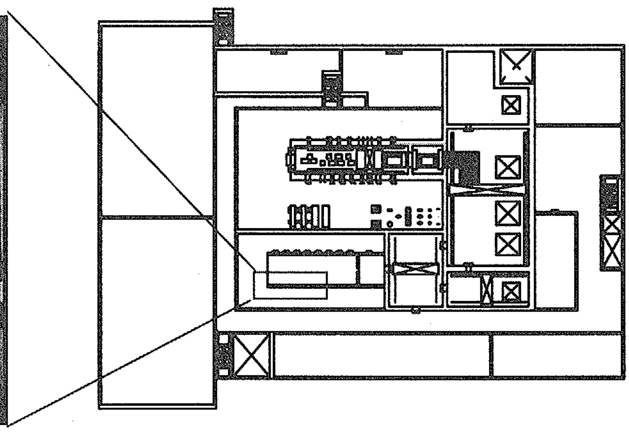


Fig. 2. Room Layout (2nd Floor)

Status of Japanese DI Tasks in Transition Phase

Mizuho Ida
JAERI

IFMIF Technical Meeting
Dec. 3 - 4, 2003
Kyoto

DI Tasks in Transition Phase

Japanese team is performing all of DI Tasks as follows:

	Task ID	Task Title	Overview of Task Content	Justification	Contributing Party EU	JA	US	RF
Design Integration	DI-1	Basic Concept of Operation	- Examination of specification for the whole system control - Consistency check among all subsystems	In order to perform system design, a basic concept is needed.	X	X		
	DI-2	Survey for regulation concept	- Worker & Public Safety Assessment - Examination of guidelines and collection of data for licensing - Estimation of Test Cell shielding performance	To start the negotiation with authority, a regulation concept is needed.	X	X		
	DI-3	IFMIF data base	Set up of IFMIF web-site	To facilitate information exchange	X	X	X	
	DI-4	Reference Design	Update Ref. Design by 3D-CAD system and data communication	To efficiently prepre Engineering Design in EVEDA.	X	X	X	

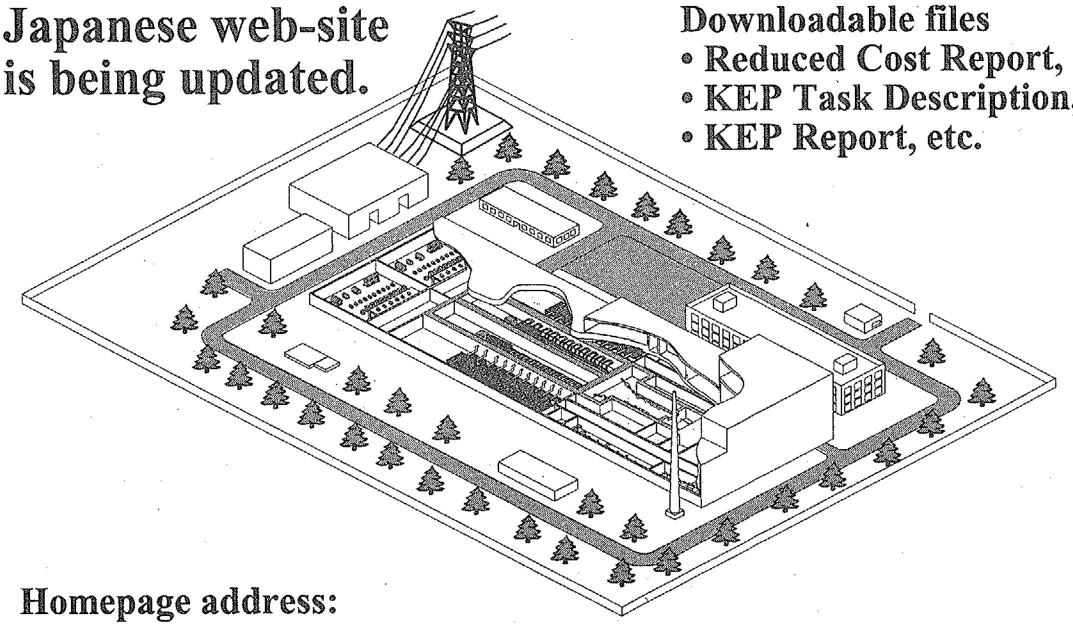
DI-3: IFMIF Data Base

- Setup of web-site -

Japanese web-site is being updated.

Downloadable files

- **Reduced Cost Report,**
- **KEP Task Description,**
- **KEP Report, etc.**

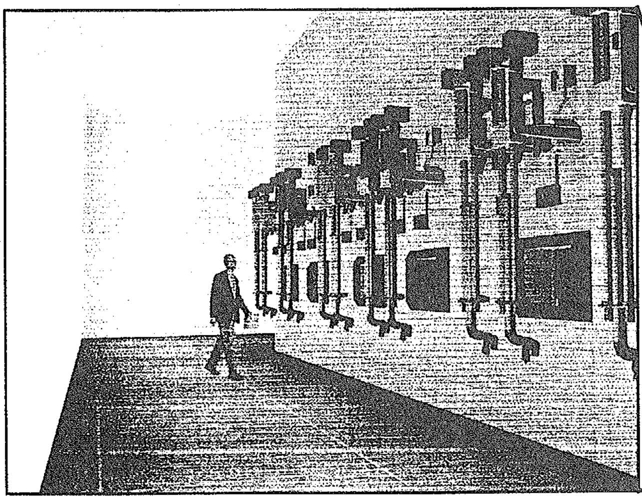


Homepage address:
http://insdell.tokai.jaeri.go.jp/IFMIFHOME/ifmif_home_e.html

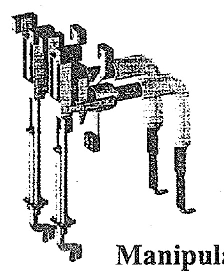
DI-4: Reference Design

- Update of reference design by 3D CAD system -

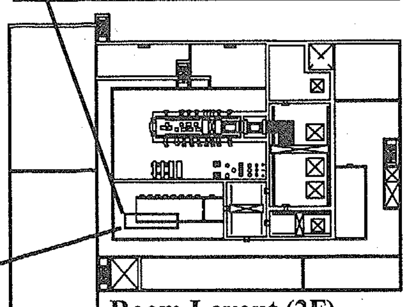
3-D data base of PIE is under preparation.



Outside of Hot Cell (R206)



Manipulator



Room Layout (2F)

DI-4: Reference Design
- Cost Evaluation -

TPC was estimated with following assumptions:

1) In-kind system in EVEDA and CODA

2) JT and HTs in EVEDA, ILE and HTs in CODA

3) Revision mainly for Accelerator and PM

4) IFMIF site in an existing nuclear facility

5) International average rates of personnel and electricity

6) Following category as each activity in IFMIF project

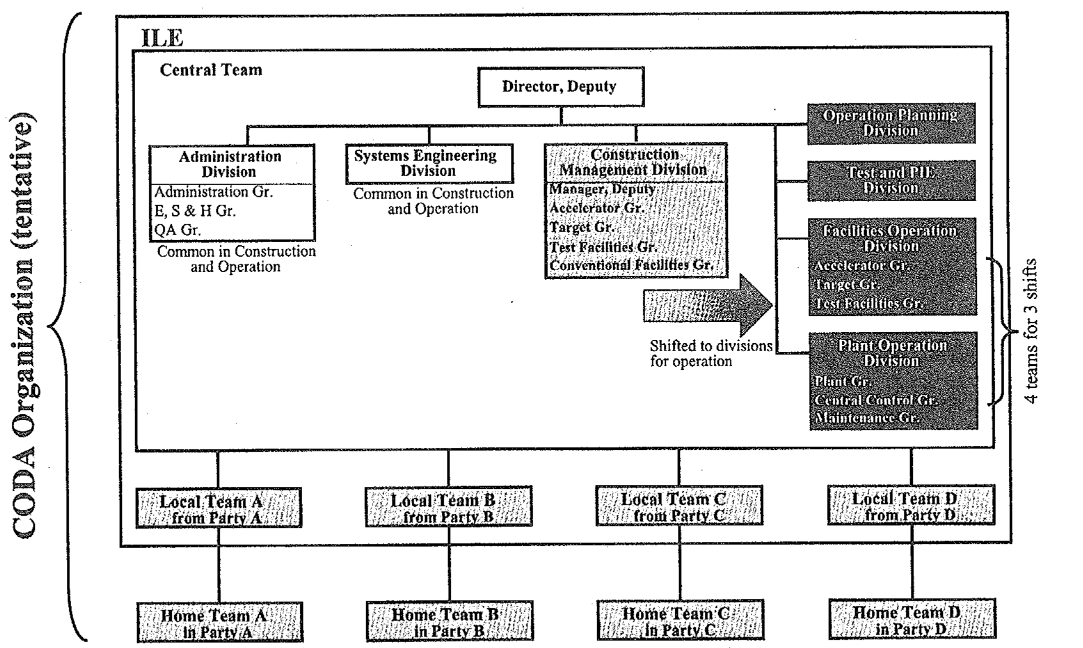
Unit: MICF

Phase	EVEDA	CODA							Total
		Construction	Installation & Checkout	Operation				Decommissioning	
				Startup & Commissioning	125 mA Operation	250 mA Operation			
						Annual	Total		
Cost	85.6 [1)]	539.2 [2)]	116.7 [3)]	115.4 [4)]	141.2 [5)]	78.5	1,570 [6)]	50.0 [7)]	2,618.1

Note: These values are tentative.

- Cost Evaluation (continued)-

IFMIF cost from construction to operation is under evaluation assuming ILE structure and personnel.



5. IFMIF PROJECT SCHEDULE AND ORGANIZATIONS

This chapter describes the proposed IFMIF schedule for the Engineering Validation and Engineering Design Activity (EVEDA) and the Construction, Operation and Decommissioning Activities (CODA). It also describes an assumed organizational structure for the IFMIF activities. The structure is modeled after concepts being considered in ITER project (still under discussion and not finalized at the time of this publication). Also it is recognized that the person responsible for managing the IFMIF Legal Entity (ILE) will likely make modifications to this model. The structure described here was used for preliminary planning and cost estimating purposes. It should not be considered as a proposal for the IFMIF project.

5.1 Main Schedule

The main schedule shown in Fig.5.1-1 is based on the international consensus among the IFMIF team members as follows:

- EVEDA Phase: 2005 - 2009
  IFMIF-EVEDA will be implemented under a new IEA Agreement. The period of the agreement will be late 2004 through late 2011, to allow sufficient time for completion of EVEDA activities.
- CODA Phases: 2010 - 2044
  IFMIF-CODA will be implemented under a new Agreement that will have some overlap in time with the EVEDA Agreement. This Agreement will also allow the Construction and Operation phases to overlap.

  * Construction to Commissioning: 2010-2019
    This activity includes procurement, design, fabrication, installation and checkout, and startup and commissioning. The first accelerator, target facility, test facilities and utilities will be constructed and commissioned during 2010-2016. The second accelerator will be constructed and commissioned by the 2019.

  * Staged Operation at 125 mA, then 250 mA: 2017-2039 (or with extension to 2049)
    A 125 mA facility will be in operation during 2017-2019 while construction and commissioning of the second accelerator is underway. Full power IFMIF operation with 250 mA is planned for the 20 years 2020-2039 and may be extended, if necessary, for an additional 10 years (to 2049).

  * Decommissioning: 2040-2044
    Decontamination, radioactive decay and dismantling/disposal of IFMIF are included in the total planning for the IFMIF project. The decommissioning duration is assumed to be five years.

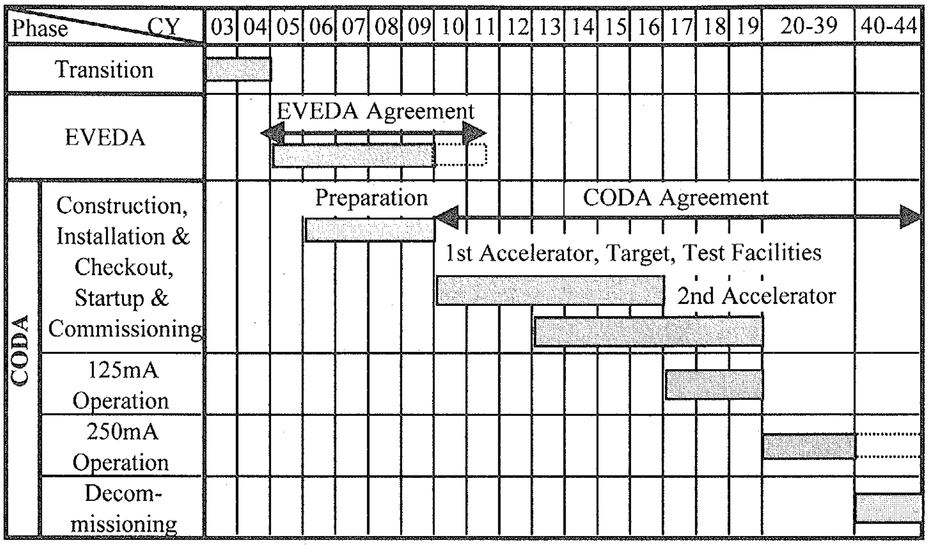


Fig. 5.1-1. IFMIF main schedule.

5.2 EVEDA Schedule and Organization

EVEDA will be implemented under a new IEA Agreement. The activity will be carried out by each participating party and at the international joint team site during the period 2005-2009.

5.2.1 EVEDA Schedule

EVEDA is planned to take five years, but the duration can be extended up to seven years under the EVEDA Agreement. The engineering design of the whole IFMIF system will be completed to a level that will support procurement. In addition to the engineering design of IFMIF, the technology for key components of each subsystem will be validated as follows:

* For the Accelerator, an H_2^+ ion source will be developed and tested. A high-power RFQ-type load cavity will be tested with a developed 1MW RF power source. Also a CW injector with a LEBT will be tested. After that, the RFQ-type load cavity, the RF power source, the CW injector and the LEBT will be integrated and tested.
* For the Target, a target model at about 1/3 scale in width and flow rate, and a circulation loop is to be designed, fabricated and tested by a participating party. The test planned for mid-2007-2009 includes validation of hydraulic stability, impurity control, and target diagnostics.
* For the Test Facilities, a full mockup of the High Flux Test Module (HFTM) will be designed, fabricated and tested by a participating party. The HFTM test is planned for mid-2007-2009 under the condition of circulating helium cooling with heaters simulating the beam heating. Other test modules are expected to be tested in the same time frame.

5.2.2 EVEDA Organization

The proposed EVEDA organization is shown in Fig.5.2-1. Functions and responsibilities of the EVEDA organization will be defined in a new IEA Agreement and an Annex covering the EVEDA activities.

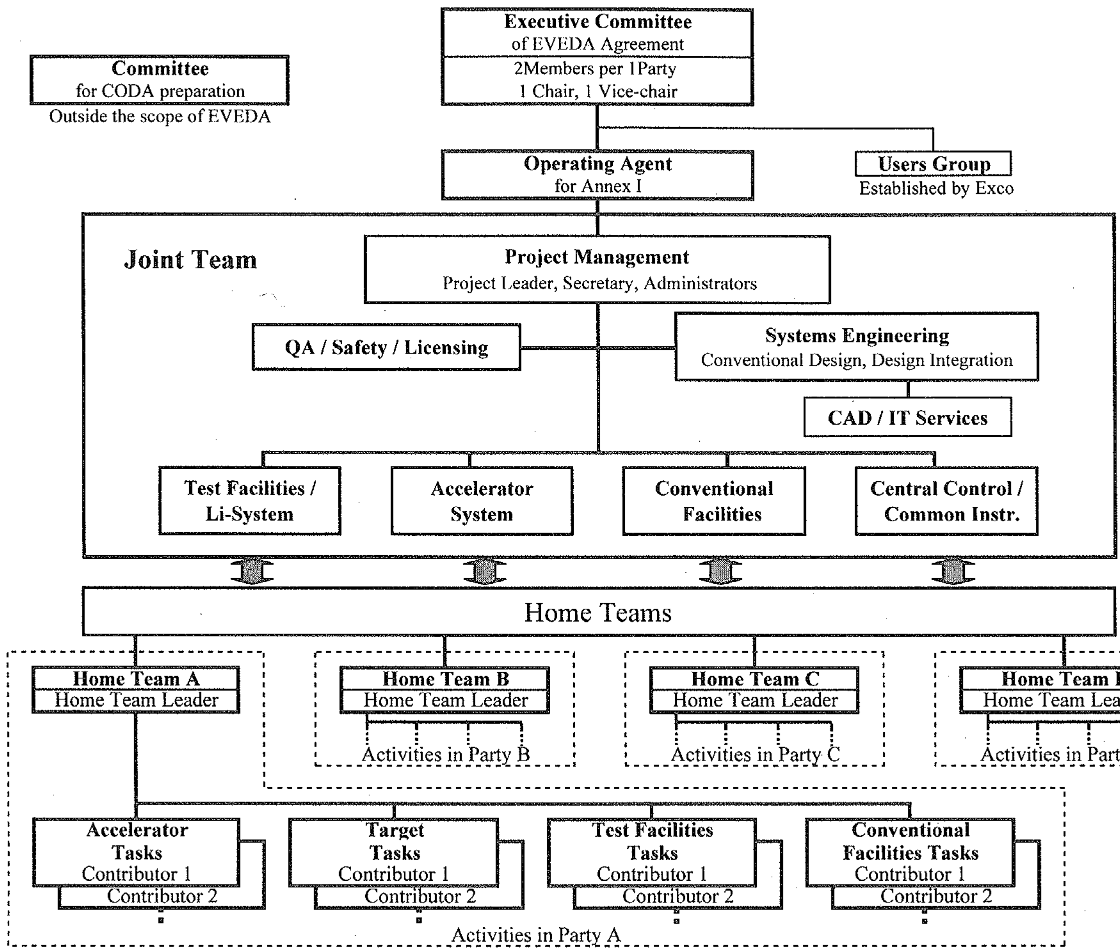


Fig. 5.2-1. EVEDA organization.

Engineering validation tasks will be performed by each Home Team in each participating party. The engineering design will be performed by a Joint Team established at the Operating Agent and by each Home Team. The Joint Team consists of the Project Leader, staff from each party, and support personnel provided by the Operating Agent. Each Home Team Leader is responsible for tasks accepted in the Accelerator, Target, Test, Conventional Facilities and Central Control work areas. There are neither fabrication nor test activities in Design Integration for the Conventional Facilities, Central Control, whole facility analyses, or project issues.

The Executive Committee of the EVEDA Agreement is responsible for supervising EVEDA and for reporting to IEA. The Executive Committee approves the Work Plan for EVEDA and the Annual Programme of Work, and adopts the procedures needed to supervise EVEDA. The Executive Committee can establish subsidiary bodies as needed, such as a Users Group for management, administration and technical matters. New Annexes, if needed, are approved by the Executive Committee.

The User Group consists of a Group Leader and members from the participating parties. The User Group will be responsible for examining and defining user requirements and test plans. The results will be reported to the Executive

Committee.

An activity that will be outside the IEA EVEDA Agreement scope is a committee established to prepare for the CODA phases of IFMIF. The preparation activities will include developing proposals for new Agreements and establishing a legal entity for CODA. Transfer of materials and property rights from EVEDA to CODA participants will be discussed. Preparations for and procurement of long-lead time items for IFMIF construction will be carried out in parallel with the EVEDA.

5.3 CODA Schedule and Organization

CODA will be conducted under a new Agreement among the parties, separate from the EVEDA Implementing Agreement. The activities will be carried out by each participating party and by an international legal entity during the period 2010-2044. An extension of the CODA will be provided for as an option, to allow operation to continue up to an additional 10 years.

5.3.1 CODA Schedule

Figure 5.3-1 shows a proposed IFMIF-CODA schedule. The CODA consists of the following overlapping project phases.

5.3.1.1 Construction

Elements of the construction work, including procurement, design and manufacturing, will be performed off-site by each Party. The manufacturing will be performed mainly by industrial organizations. Procurements related to the Buildings and Utilities start in the year 2010, since these items must be prepared early to accommodate Accelerator, Target and Test Facilities Installation. Also, procurement of RFQ, MS, RF power system and URS start in the early stages of construction. Fabrication of RF power systems requires long periods of time. Procurement of the Target Facility starts in 2010, to meet the required early installation.

All buildings will be constructed during the period 2010-2013. Half of the Accelerator Building (for the first accelerator) and part of the Target and Test Buildings will be constructed in 2010-2011. The early start on the Target and Test Buildings is needed to house utilities equipment.

5.3.1.2 Installation and Checkout

Utility equipment, except for the Liquid and Solid Radioactive Waste Treatment systems, will be installed in 2010-2011. After construction of the first half of the Accelerator Building, elements of the first accelerator will be installed in the following order: Injector, RFQ/MS, DTL and HEBT. The first accelerator will be installed in 2012-2015, and the second in 2014-2017. Some large components of the Target and Test Facilities will be installed during construction of the Target/Test Building. These include the dump tanks and coolers for liquid lithium and organic oil, and a gantry crane as part of the universal robot system.

5.3.1.3 Startup and Commissioning

Installation, checkout, and any startup and commissioning of the accelerator elements cannot overlap. The HEBT beam operation needs a flowing lithium target.

Performance of the utility equipment must be validated before any long-term test of the Target facility can be started.

5.3.1.4 Staged Operation at125 and 250 mA

IFMIF is planned to operate for 23 years from the initial operation of the first accelerator in 2017. Optional operation for an additional 10 years is possible. Most of the subsystem and components are designed to ensure 30-year operation, including scheduled maintenance. Necessary spare parts will be obtained during the operating phase.

5.3.1.5 Decommissioning

This activity consists of decontamination, radioactive decay and dismantling/disposal periods. The duration of this phase will depend on the volume of work and on the decay period for radioactive components. In the case of ITER, the decommissioning duration (excluding the decay period) was estimated to be about 11 years. The decay period has not been estimated. The estimation requires data on the quantity and quality of activated materials. For IFMIF, the decommissioning is assumed to take five years.

5.3.2 CODA Organization

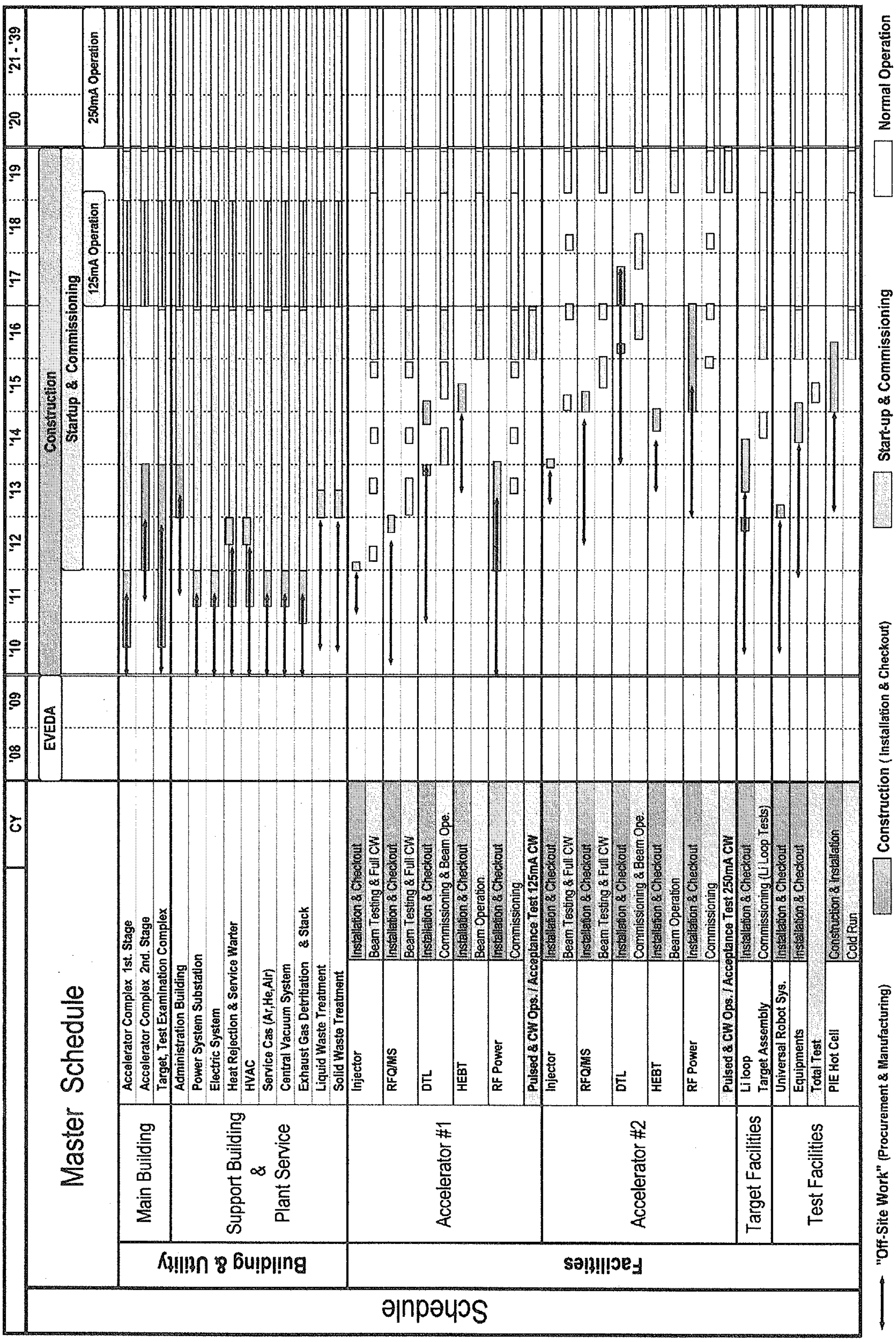
It is planned that IFMIF-CODA will be implemented by the ILE and Home Teams. The ILE and the Home Teams will be established under an Agreement for IFMIF-CODA. The ILE will be responsible for the whole duration of IFMIF, including construction, operation and decommission phases. The ILE organization will be adjusted to meet the missions of each phase, with changing numbers of personnel as shown in Table 5.3-1. Each Home Team is responsible for the activities of their Party during construction. The relationship between ILE and each Home Team is “in-kind,” without exchange of funds. The planned organizations of ILE and Home Teams are shown in Fig.5.3-2.

The ILE consists of a Central Team and several Local Teams. The number of Local Teams is equal to that number of Home Teams. The Central Team includes divisions for construction and operation, for a smooth transition from the construction phase to facility operation. It is assumed that most members in the construction division will be gradually shifted to the operation division. These staff members are expected to be able to develop and improve their operating skills through their work in the commissioning of components and systems. The Local Teams and Home Teams carry out their activities during Construction, Startup, and Commissioning phases of the project. This organization will function to meet the following needs.

Table 5.3-1. Annual profile of ILE personnel.

	Annual personnel											Total
CY	10	11	12	13	14	15	16	17	18	19	20-39	
Personnel	58	65	93	110	135	152	246	186	199	211	166	4775

Fig. 5.3-1. IFMIF-CODA schedule



5.3.2.1 Construction, Installation, and Checkout

The Construction Management Division is a joint team consisting of institutional people assigned from IFMIF participating parties. The Division will coordinate construction activities. IFMIF construction will be based on in-kind contributions, with each Party responsible for activities including design, fabrication, installation and checkout of their subsystems, elements, and components. These activities of a Party are accomplished by the Home Team in the Party. The Systems Engineering Division will maintain the design condition of IFMIF during construction. Also, an Environment, Safety and Health Group and a Quality Assurance Group will be established during CODA. The Local Teams in ILE are responsible for interfacing the activities of the corresponding Home Teams on the in-kind system. The Local Teams are also responsible for installation and checkout of their subsystems, elements, and components. The total number of CODA staff will change yearly, based on the planned activity level for each year.

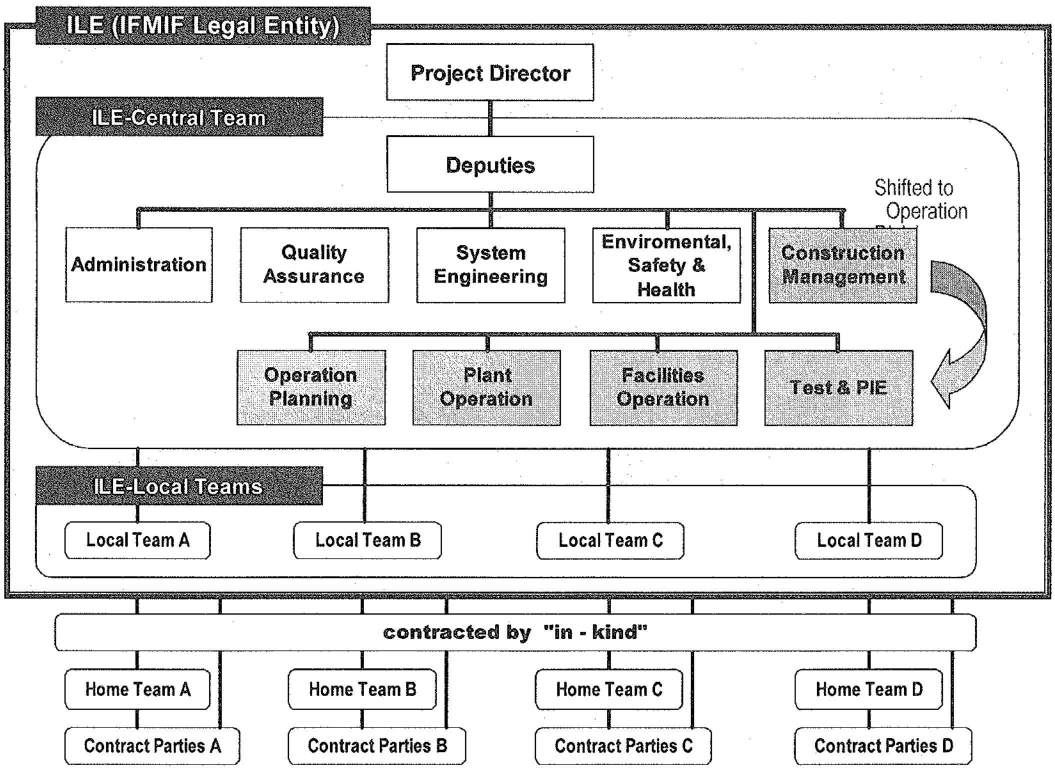


Fig. 5.3-2. CODA Organization.
(Construction Management Division is shifted to Operation Planning, Test and PIE, Facilities Operation and Plant Operation Divisions in accordance with activity shift from construction to

5.3.2.2 Startup and Commissioning - 125 mA Operation and 250 mA Operation

The operating plans developed by the Operation Planning Division will support four operating teams, staffing three shifts for the IFMIF high availability operation. The team members will be selected from staff of the Facility Operation Division and the Plant Operation Division. Maintenance Group will be responsible for providing the maintenance that assures high availability. The Test and PIE Division will be responsible for handling irradiated materials and preparing PIE equipment. The Environment, Safety and Health Group will be needed to maintain safe conditions in all operations, and the Quality Assurance Group will ensure the quality of spare parts. In normal operation at 250 mA, the total number of CODA staff will be constant or decreasing, based on growing experience and improvement of skills.

5.3.2.3 Decommissioning

This activity is assumed to be performed by the modified ILE, reorganized and staffed to meet the needs of decommissioning. In the decontamination period, a remote-handling group will remove tritium and other movable radioactive dust from components. A packing group will confine activated objects. After the decay period, the remote-handling group and supporting specialized contractors will disassemble and dismantle the components and facilities and ship to disposal or storage sites. The required number and skill of the decommissioning personnel will depend on the quality and quantity of activated materials. Furthermore, the required duration of decay depends on activation level and contained radionuclides. These estimates will be developed before requesting approval for construction.

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国際単位系（SI）と換算表

表1　SI基本単位および補助単位

量	名　称	記　号
長　　さ	メートル	m
質　　量	キログラム	kg
時　　間	秒	s
電　　流	アンペア	A
熱力学温度	ケルビン	K
物 質 量	モル	mol
光　　度	カンデラ	cd
平 面 角	ラジアン	rad
立 体 角	ステラジアン	sr

表2　SIと併用される単位

名　称	記　号
分，時，日	min, h, d
度，分，秒	°, ′, ″
リットル	l, L
トン	t
電子ボルト	eV
原子質量単位	u

$1\ \mathrm{eV}=1.60218\times10^{-19}\mathrm{J}$

$1\ \mathrm{u}=1.66054\times10^{-27}\mathrm{kg}$

表5　SI接頭語

倍数	接頭語	記　号
10^{18}	エクサ	E
10^{15}	ペタ	P
10^{12}	テラ	T
10^{9}	ギガ	G
10^{6}	メガ	M
10^{3}	キロ	k
10^{2}	ヘクト	h
10^{1}	デカ	da
10^{-1}	デシ	d
10^{-2}	センチ	c
10^{-3}	ミリ	m
10^{-6}	マイクロ	μ
10^{-9}	ナノ	n
10^{-12}	ピコ	p
10^{-15}	フェムト	f
10^{-18}	アト	a

表3　固有の名称をもつSI組立単位

量	名　称	記号	他のSI単位による表現
周波数	ヘルツ	Hz	s^{-1}
力	ニュートン	N	$m\cdot kg/s^2$
圧力，応力	パスカル	Pa	N/m^2
エネルギー，仕事，熱量	ジュール	J	N•m
工率，放射束	ワット	W	J/s
電気量，電荷	クーロン	C	A•s
電位，電圧，起電力	ボルト	V	W/A
静電容量	ファラド	F	C/V
電気抵抗	オーム	Ω	V/A
コンダクタンス	ジーメンス	S	A/V
磁束	ウェーバ	Wb	V•s
磁束密度	テスラ	T	Wb/m^2
インダクタンス	ヘンリー	H	Wb/A
セルシウス温度	セルシウス度	℃	
光束	ルーメン	lm	cd•sr
照度	ルクス	lx	lm/m^2
放射能	ベクレル	Bq	s^{-1}
吸収線量	グレイ	Gy	J/kg
線量等量	シーベルト	Sv	J/kg

表4　SIと共に暫定的に維持される単位

名　称	記　号
オングストローム	Å
バーン	b
バール	bar
ガル	Gal
キュリー	Ci
レントゲン	R
ラド	rad
レム	rem

$1\ \text{Å}=0.1\mathrm{nm}=10^{-10}\mathrm{m}$

$1\ \mathrm{b}=100\mathrm{fm}^2=10^{-28}\mathrm{m}^2$

$1\ \mathrm{bar}=0.1\mathrm{MPa}=10^5\mathrm{Pa}$

$1\ \mathrm{Gal}=1\mathrm{cm/s}^2=10^{-2}\mathrm{m/s}^2$

$1\ \mathrm{Ci}=3.7\times10^{10}\mathrm{Bq}$

$1\ \mathrm{R}=2.58\times10^{-4}\mathrm{C/kg}$

$1\ \mathrm{rad}=1\mathrm{cGy}=10^{-2}\mathrm{Gy}$

$1\ \mathrm{rem}=1\mathrm{cSv}=10^{-2}\mathrm{Sv}$

（注）

1．表1－5は「国際単位系」第5版，国際度量衡局1985年刊行による。ただし，1 eVおよび1 uの値はCODATAの1986年推奨値によった。

2．表4には海里，ノット，アール，ヘクタールも含まれているが日常の単位なのでここでは省略した。

3．barは，JISでは流体の圧力を表わす場合に限り表2のカテゴリーに分類されている。

4．EC閣僚理事会指令ではbar，barnおよび「血圧の単位」mmHgを表2のカテゴリーに入れている。

換　　算　　表

力	$N(=10^5 dyn)$	kgf	lbf
	1	0.101972	0.224809
	9.80665	1	2.20462
	4.44822	0.453592	1

粘　度　$1\ Pa\cdot s(N\cdot s/m^2)=10\ P$（ポアズ）$(g/(cm\cdot s))$

動粘度　$1\ m^2/s=10^4 St$（ストークス）(cm^2/s)

圧力	MPa(=10bar)	kgf/cm^2	atm	mmHg(Torr)	$lbf/in^2(psi)$
	1	10.1972	9.86923	7.50062×10^3	145.038
	0.0980665	1	0.967841	735.559	14.2233
	0.101325	1.03323	1	760	14.6959
	1.33322×10^{-4}	1.35951×10^{-3}	1.31579×10^{-3}	1	1.93368×10^{-2}
	6.89476×10^{-3}	7.03070×10^{-2}	6.80460×10^{-2}	51.7149	1

エネルギー・仕事・熱量	$J(=10^7 erg)$	kgf•m	kW•h	cal(計量法)	Btu	ft•lbf	eV
	1	0.101972	2.77778×10^{-7}	0.238889	9.47813×10^{-4}	0.737562	6.24150×10^{18}
	9.80665	1	2.72407×10^{-6}	2.34270	9.29487×10^{-3}	7.23301	6.12082×10^{19}
	3.6×10^6	3.67098×10^5	1	8.59999×10^5	3412.13	2.65522×10^6	2.24694×10^{25}
	4.18605	0.426858	1.16279×10^{-6}	1	3.96759×10^{-3}	3.08747	2.61272×10^{19}
	1055.06	107.586	2.93072×10^{-4}	252.042	1	778.172	6.58515×10^{21}
	1.35582	0.138255	3.76616×10^{-7}	0.323890	1.28506×10^{-3}	1	8.46233×10^{18}
	1.60218×10^{-19}	1.63377×10^{-20}	4.45050×10^{-26}	3.82743×10^{-20}	1.51857×10^{-22}	1.18171×10^{-19}	1

1 cal＝ 4.18605J（計量法）

＝ 4.184J（熱化学）

＝ 4.1855J（15℃）

＝ 4.1868J（国際蒸気表）

仕事率　1 PS（仏馬力）

＝ 75 kgf•m/s

＝ 735.499W

放射能	Bq	Ci
	1	2.70270×10^{-11}
	3.7×10^{10}	1

吸収線量	Gy	rad
	1	100
	0.01	1

照射線量	C/kg	R
	1	3876
	2.58×10^{-4}	1

線量当量	Sv	rem
	1	100
	0.01	1

（86年12月26日現在）

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