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Flying Metal Pipe for Target Transport in IFE Reactor (Revised)

Ryusuke TSUJI

Faculty of Engineering, Ibaraki University

4-12-1, Nakanarusawa, Hitachi, Ibaraki, 316 JAPAN

tsuji@ee.ibaraki.ac.jp

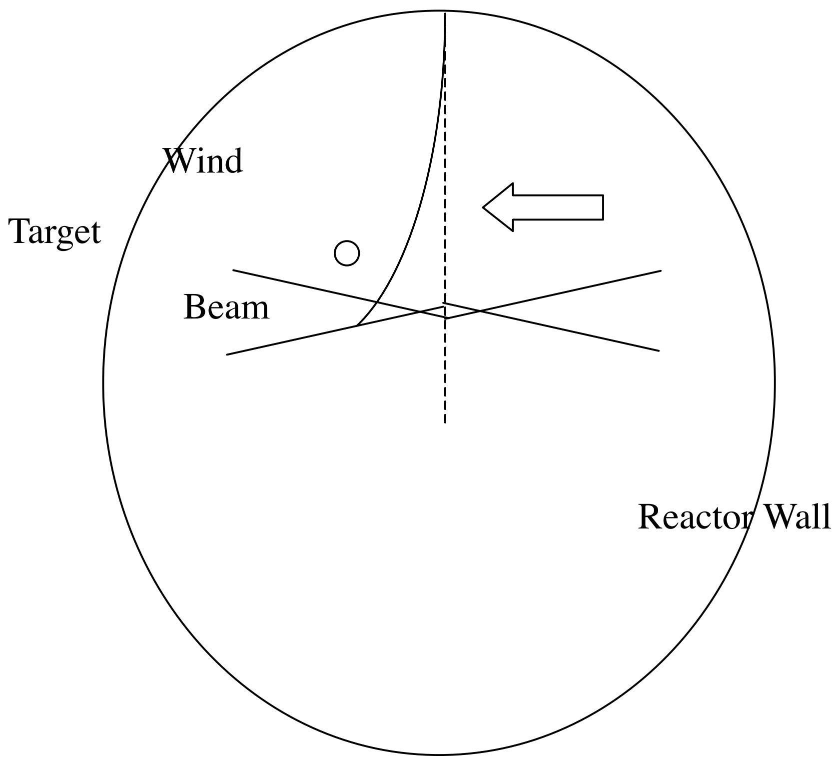
0. Introduction

The residual vapor of the liquid metal in IFE reactor chamber causes

1) **drag force to the target**
2) **deviation of the orbit of the target.**
3) **heat transport to the target**

Black body radiation from the chamber wall causes

4) **heat transport to the target**



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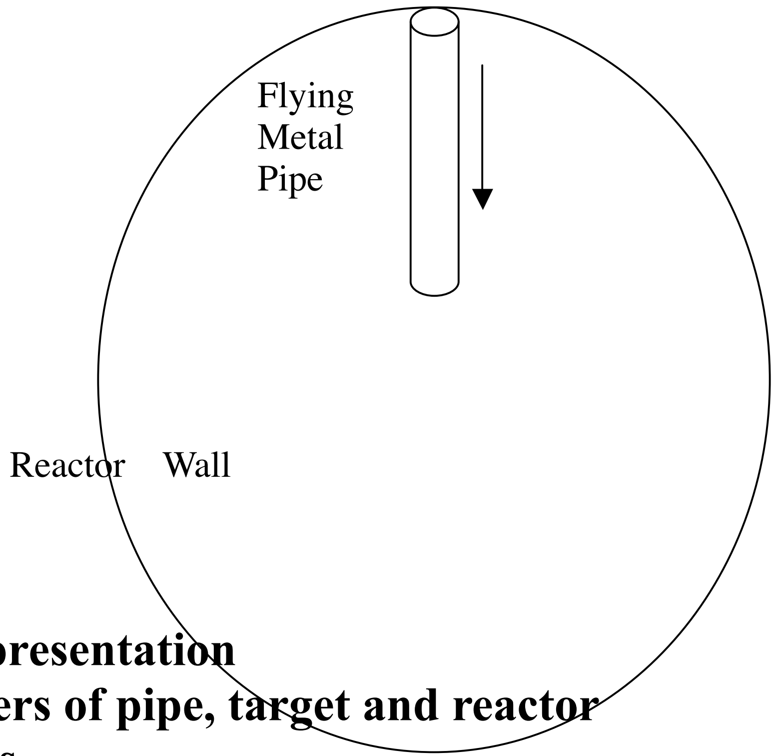


Outline of presentation

1) Parameters of pipe, target and reactor

2) Dynamics

3) Deviation of the orbit of the target

4) Heat transport to the target

5) Heat transport to the pipe

6) Summary

1. Parameters of pipe, target and reactor

Pipe

Inner radius: 0.50cm Outer radius: 0.55cm

Length: 200cm   Initial temperature: 300K

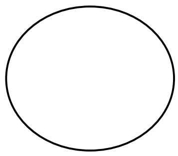
Material: Li (LiPb)

Mass: 17.6g (297g)

Injection speed: 20m/s

Injection point: top of the reactor (0, 0, 3), 3m from center

Target



Radius: 0.2cm   Mass: 5mg

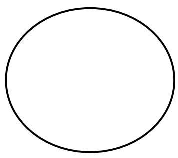
Injection speed: 100m/s   Initial temperature: 17K

Injection point: top of the reactor (0, 0, 6), 6m from center

Energy of Neutron 113MJ ($=0.5\times10^{20}\times14.1$MeV)

Energy of X-ray and Plasma 37MJ

Reactor



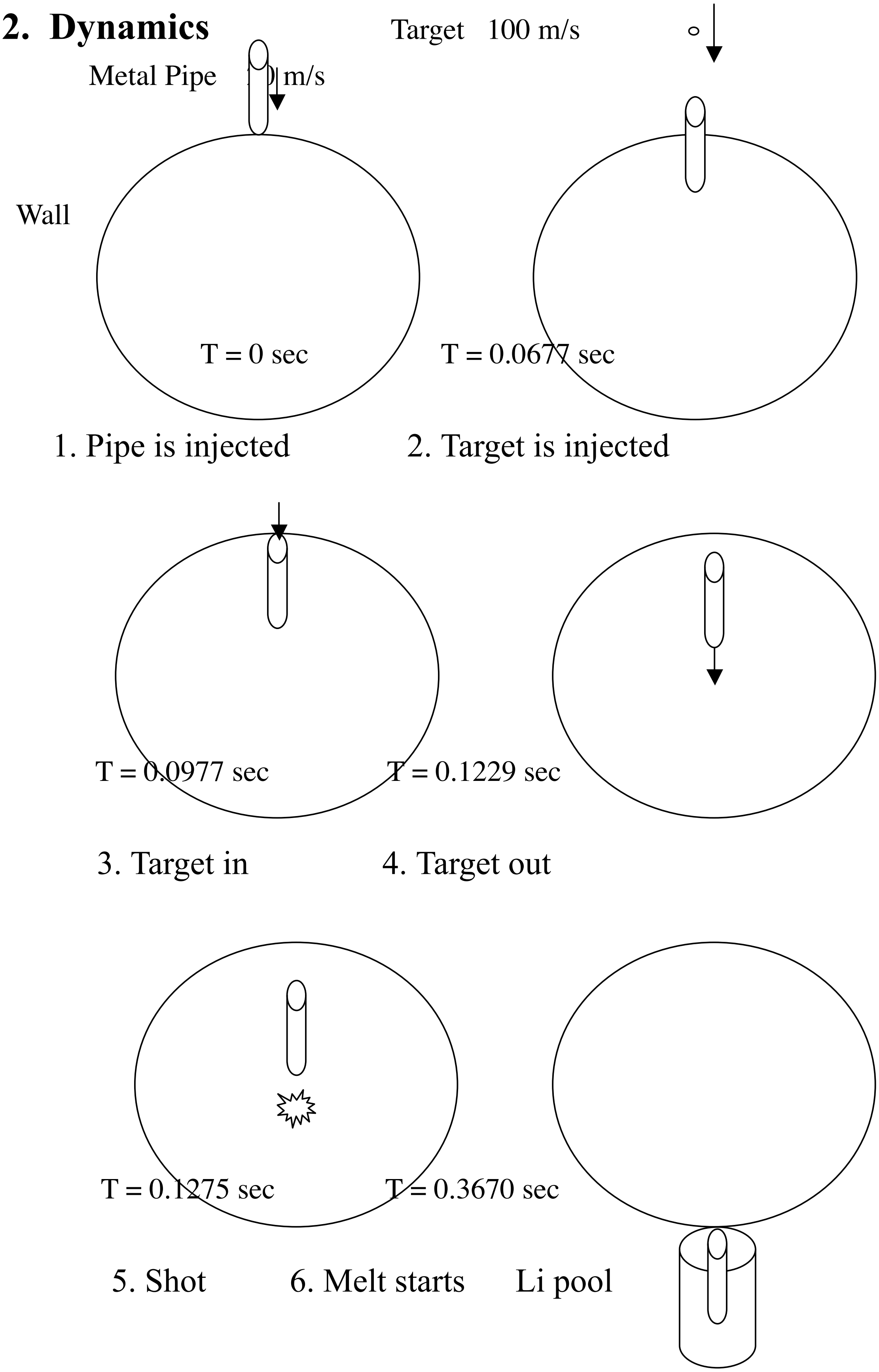
Inner radius: 300cm

Operation temperature: 800K

Li wetted wall

Gas number density 10^{21} m^{-3} (=1.1Pa = 0.08torr)

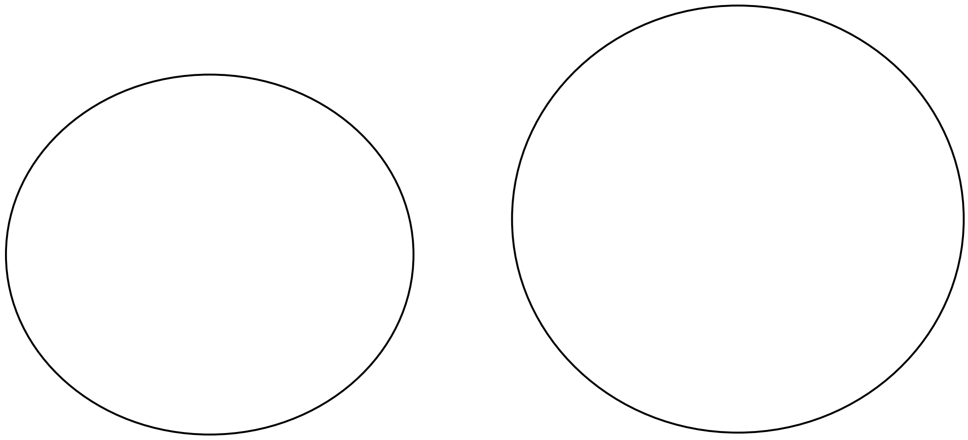
2. Dynamics



Target 100 m/s
Metal Pipe
m/s
Wall
T = 0 sec
T = 0.0677 sec
1. Pipe is injected
2. Target is injected
T = 0.0977 sec
T = 0.1229 sec
3. Target in
4. Target out
T = 0.1275 sec
T = 0.3670 sec
5. Shot
6. Melt starts
Li pool

Other causes of deviation of the orbit

Thermal expansion of structural material



T=low T=high

100 μm/K

Coliolis force

20 μm at the center

Micro vibration of structural material

? μm

Micro vibration of earth

? μm

4. Heat transport to the target

4-1 Radiation heat from reactor chamber wall

Assumption: Black body radiation

Radiation from wall $\sigma T_w^4 = 2.3226$ W/cm^2

Radiation from pipe $\sigma T_p^4 = 0.0459$ W/cm^2

Radiation from target $\sigma T_t^4 = 4.7 \times 10^{-7}$ W/cm^2

Without pipe $\sigma (T_w^4 - T_t^4) \times 0.0299$

With pipe $\sigma (T_p^4 - T_t^4) \times 0.0252 + \sigma (T_w^4 - T_t^4) \times 0.0047$

	without pipe (t_1=0.0299)	using pipe (t_2=0.0047)
Qrad	**0.0694** J/cm^2	**0.0120** J/cm^2

Radiation heat is reduced as (t_2/t_1)

4-2 Convection heat from gas

Assumption: Cryo-pump effect (no gas) in the pipe

In the pipe $Q_{conv}=0$

Out of the pipe 1.428 W/cm^2

$Q_{conv}=NC_mM(\Delta H_f+\Delta H_v+C_s\Delta T_{452\text{-}17}+C_L\Delta T_{800\text{-}452})/6$

Without pipe 1.428×0.0299

With pipe $0 \times 0.0252 + 1.428 \times 0.0047$

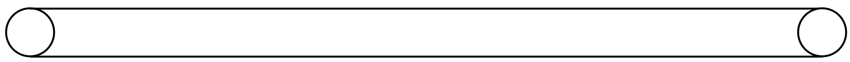
	without pipe (t_1=0.0299)	with pipe (t_2=0.0047)
Qconv	**0.0427** J/cm^2	**0.0067** J/cm^2

Heat from residual gas is reduced as (t_2/t_1)

5. Heat transport to the pipe

5-1 Neutron heating of the pipe by microexplosion

dT(0)=47.6 C   dT(200)=1.16 C



37cm from target   237cm from target

Total neutron heating = **448** J
(Calculated by ANISN-JR and GICX-40)

5-2 Plasma and X-ray heating by microexplosion

$37\text{MJ} \times (((\pi 0.5^2)/(4\pi 37^2))-((\pi 0.5^2)/(4\pi 237^2)))$
= **1648** J

5-3 Convection heating

$1.171\ \text{W/cm}^2 \times 0.2750\ \text{sec} \times 691.150\ \text{cm}^2$
= **223** J

5-4 Radiation heating

$2.3226\ \text{W/cm}^2 \times 0.2750\ \text{sec} \times 691.150\ \text{cm}^2$
= **441** J

Total heating and average temperature increase

Total: **2760**J
Maximum temperature increase ΔT: **80** K
Pipe is still **SOLID** after microexplosion

6. Summary

Flying metal pipe is proposed. The metal pipe is composed of material identical to liquid metal used in the IFE reactor such as Li. The pipe is injected into the IFE reactor chamber. Subsequently IFE target is injected and it goes into the metal pipe, goes out from other side and arrives at the center of IFE reactor chamber.

Principal results obtained in this study are following,

(1) Heat transport to the target is reduced
(2) Drag force to the target is reduced
(3) Deviation of the orbit of the target is reduced

These results relaxes the operation condition of

target injection speed (low V possible),
residual gas density (high N possible),
operation reactor temperature (high T possible)

Variation A
The method presented here is applicable in the case of other type of flying pipe made of LiPb, Flibe etc.

Variation B
Cryogenic (77K) flying metal pipe
Xe (161K:Solidification, 164K:Boiling)
Cryogenic pump effect occurs