



Feasibility Study for the Development of a Pilot Scale Molten Salt Reactor in the UK

Presentation to Delft Symposium
17th April 2015
Rory O'Sullivan

Company & Background

Feasibility Study



Objectives:

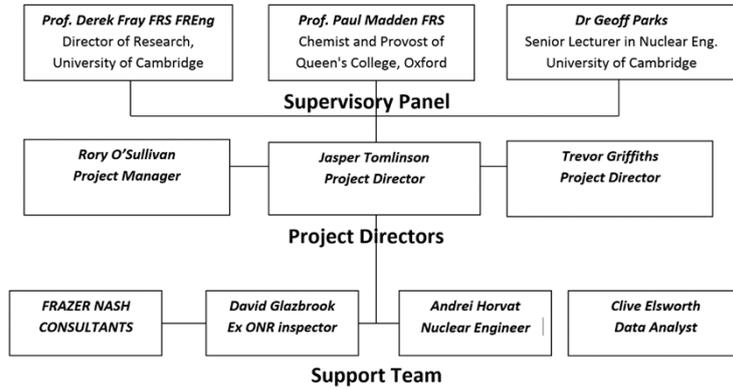
- * To validate and assess alternative MSR configurations – Not R&D
- * To formulate terms of reference for an engineering design study for a chosen configuration
- * To consider designs that can act as a test bed and as a training platform for engineers and operators.

Funding



- * £100k (€140k) Budget
- * 25% privately financed by the shareholders
- * 75% funded by Innovate UK
- * Innovate UK is a government body to drive innovation and economy
- * Funds are awarded on a competition basis

The Feasibility Study Team



External view of MSRE



Rear view of MSRE



Regulatory Assessment

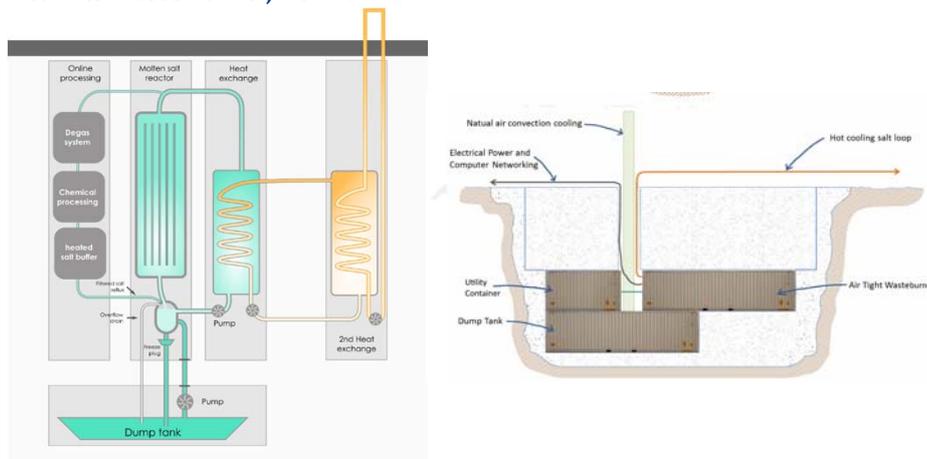
- * Existing site license needed
- * A process does exist for experiments on an existing licensed site but the last research reactors were built in the 1970's so no experience exists.
- * A recently retired regulator on our team is carrying out a full review of this.
- * Site selection assessment

MSR Designs Considered

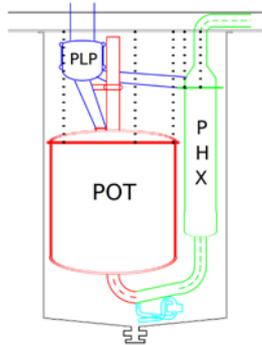
Criteria:

- * Must be exportable to UK
- * No research required
- * Active commercial team

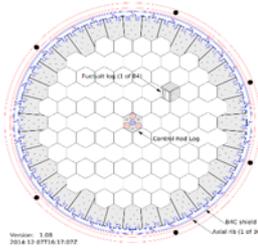
Seaborg Technologies / Copenhagen Atomics Waste Burner, Denmark



ThorCon, USA



Section through reactor vessel showing the core - 'POT', pump - 'PLP' and heat exchanger - 'PHX'

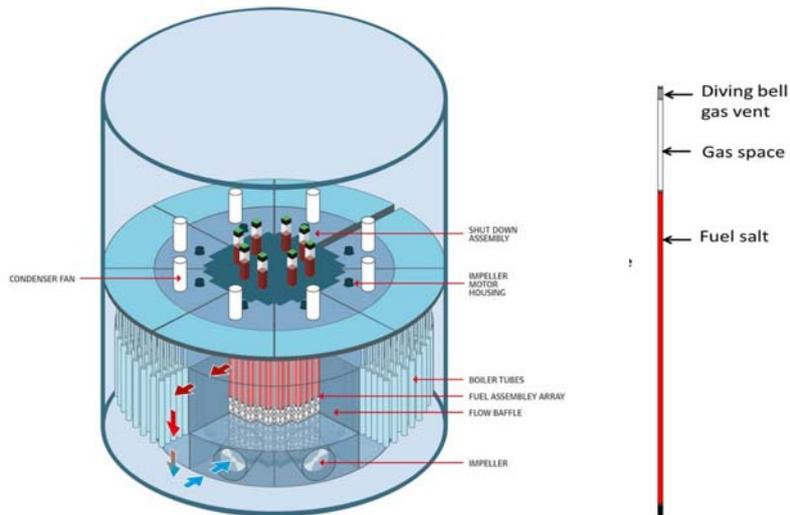


Section through core in plan view showing the graphite logs



Close up section through graphite log

Stable Salt Reactor, Moltex Energy, UK



Flibe Energy, USA

- * This prototype proposal is a 2MWth two fluid breeder design – LFTR
- * Thermal spectrum moderated by graphite. Its fissile element is uranium 233 which is bred from thorium in a blanket salt at the outer edge of the reactor core.
- * Design principle is based on ORNL MSBR design from 1968.

Terrestrial Energy, Canada

- * The Integrated MSR was again based on the MSRE work at ORNL and was amended to give a more sealed, passive approach.
- * Based in Canada with an international team.

Transatomic Power, USA

- * The TAP proposal is a 10MWth reactor which is similar to the MSRE except for its utilisation of zirconium hydride as a moderator. Its main aim is to burn spent nuclear fuel.
- * The design is from a start-up company based in the US that originated out of MIT, Boston and still has strong links there.

Assessment Process

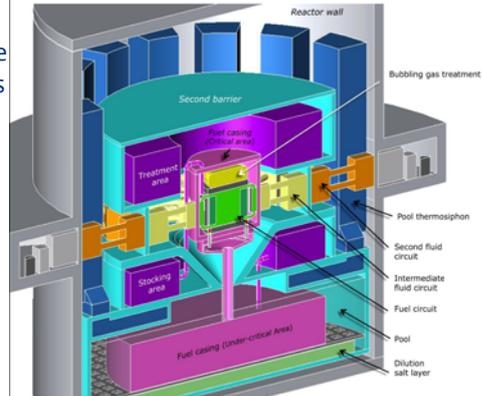


- * Simple process looking at characteristics that affect development of a pilot scale demonstration reactor only
- * People contributing to review will be **UK universities, ORNL** amongst other researchers and institutions
- * Sample assessment headings include:
 - Technology
 - Safety & Environment
 - Security
 - Simplicity
 - Licenseability
 - Reactor Characteristics
 - Cost

MSR Activity – Not Assessed

* European MSFR

- * CNRS at Grenoble coordinates a long-term development programme for a fast spectrum MSR – known as EVOL program
- * Consortium of 12 European institutes.
- * Jan-Leen Kloosterman now taking over coordination at Delft.



MSR Activity – Not Assessed

- * **Fuji MSR** is a 100-200MWe near-breeder design promoted by a Japanese, Russian and US consortium (ITHMSI) founded by the late Dr Kazuo Furukawa
- * **Thorenco** has a design for a pilot scale pool type LFTR
- * **MOSART** in Kurchatov Institute in Russia have a single fluid burner and a two fluid breeder design.
- * **Dual Fluid Reactor** Based in Berlin. A fast reactor with a fertile/fissile chloride fuel salt cooled by molten lead.

Chinese TMSR Program



- * By the far the largest program today
- * Currently 600 staff and €330m budget secured (excl. infrastructure, ancillary research)
- * Solid & liquid fuel prototype program
- * Multiple experiments
- * Necessary Program



APEC BLUE

Beijing, During APEC week (Nov. 2014)



Beijing, before or after APEC week

TMSR Timeline

1970
2015
2025
2035

Research

Demonstration

Commercialization

Project	2015	2025	2035
TMSR-SF	10MW test reactor	10MW test/100MW demo	1GW commercial reactor
TMSR-LF	2MW test reactor	2MW test/10MW online repro.	100MW demo reactor



Zero-power cold-state MSR
SINAP

CAS

project funding

request : 2.588 B
appro. : 2.172 B
(without budget for infrastructure and Utility)

(JiaDing Cite)

National & Local

project funding

request :
R&D : 1 B
Infrastructure & Utility: >1B
Demo :

(DaFeng Cite)

Partly from Industry

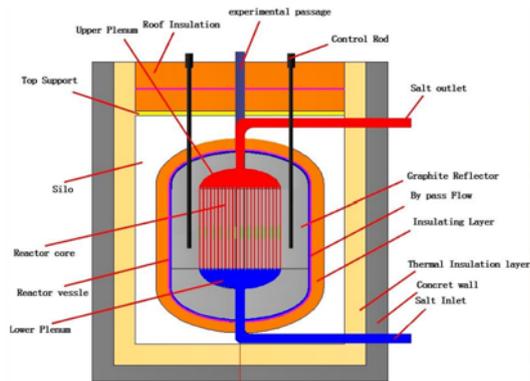
Market

project funding

Funding mainly from industry

TMSR Concept

- * As MSRE principle, Control arrangement altered to match FHR.
- * Graphite moderator and reflector.
- * FLiBe salt with 99.95% Li7
- * Construction materials are Hastelloy N and GH3535
- * LEU first, Th trials later on
- * 3 commercial versions - FHR, burner, breeder.



TMSR Activity Today

At SINAP facility:

- * Passive cooling demonstration facility
- * Several salt loops incl. purification techniques
- * Tritium separation and off gassing techniques
- * Specific TMSR supercomputer
- * Radioactive material handling facility

Other facilities:

- * Graphite fabrication facility in operation
- * Site license application
- * National equivalent of ASME code being developed
- * ^7Li enrichment facility at SIOC
- * Thorium preparation facility
- * TIG welding techniques

UK Opinion Poll

- * UK fieldwork was conducted using Ipsos MORI's i:Omnibus service among an online quota sample of adults aged 16-75 in Great Britain (n = 1007) between 27th and 31st March 2015. Data were weighted by age, gender, region, working status and social grade to the known population profile.
- * More positive response than seen in recent years.
- * OECD report from 2010 showed 28% in favour, 31% opposed within nuclear countries
- * UKERC report in 2013 showed 32% in favour, 29% opposed
- * Both showed information as important trusting scientists and NGOs over governments and industry

UK Opinion Poll

- * As part of a future energy mix:
 - * 21% prefer new nuclear of known technology,
 - * 36% prefer new nuclear that challenges old technology
 - * 43% want neither of the above
 - * Summary is 57% can be considered in favour of new nuclear
- * 41% in favour of expanding nuclear power proportion
- * 23% have heard of Gen IV reactor technology
- * 73% believe more information is needed
- * 52% believe improved nuclear is required to tackle climate change; 15% believe it is not

UK Opinion Poll

* Of these issues below which are most important to consider before building new nuclear power stations?

* - Safety	74%
* - Radioactive waste disposal	72%
* - Risk from terrorism	44%
* - Cost of electricity	36%
* - Local planning concerns	34%
* - Job creation in the UK	28%
* - Nuclear weapons proliferation	25%
* - Investment to enhance access for UK nuclear engineering to overseas markets	17%
* - None of these ...	8%

What Happens Next?



- * Increase interest in developing prototype
- * Funding
- * Full design study