FIRE Fueling and Pumping Cost and R&D Needs

P. W. Fisher, M. J. Cole, C. A. Foster,
M. J. Gouge and B. E. Nelson
Oak Ridge National Laboratory

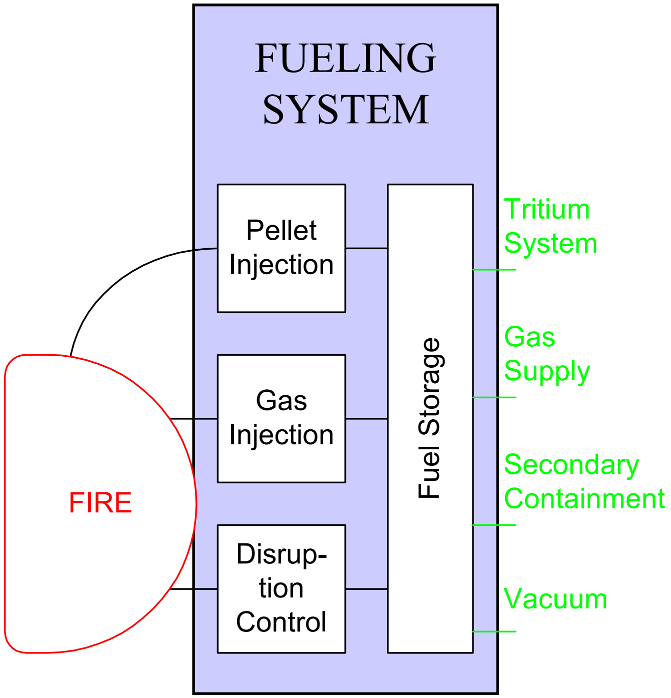
June 6, 2001

Outline

- Fueling System Cost Estimate
  - Fuel Storage
  - Pellet Fueling
  - Gas Fueling
  - Disruption Control
- Pumping System Cost Estimate
  - High Vacuum Pumping
  - Torus Rough/Backing
  - Diagnostic Rough/Backing
- Proposed Research in Support of FIRE Pumping and Fueling System Designs

Fueling System Cost Estimate

	WBS 2.1	
	Fueling System	
Cost Category	**hours**	**$k**
Engineering/Scientific	8500	1190
Shop Fab.	22500	1800
Procurement	1600	160
Equipment/Materials		2950
Travel		50
Assembly & Test Support	6500	715
Testing & Commissioning	2000	280
SUBTOTAL		7145
Contingency	20%	1429
GRAND TOTAL		**8574**



Fuel Storage Cost Estimate

	WBS 2.1.1	
	Fuel Storage	
Cost Category	**hours**	**$k**
Engineering/Scientific	936	131
Shop Fab.	3875	310
Procurement	400	40
Equipment/Materials		245
Travel		10
Assembly & Test Support	591	65
Testing & Commissioning	214	30
SUBTOTAL		831
Contingency	10%	79
TOTAL		910

Includes:

- Fuel storage skid near torus
- Valve manifold to distribute gas to torus fueling systems
- Piping between fueling systems
- Flow and pressure control
- Secondary containment
- All-welded, 316 Stainless primary piping
- Based on TFTR, ITER, …

Pellet Fueling Cost Estimate

	WBS 2.1.2	
	Pellet Fueling	
Cost Category	**hours**	**$k**
Engineering/Scientific	3500	490
Shop Fab.	8500	680
Procurement	400	40
Equipment/Materials		1900
Travel		20
Assembly & Test Support	2882	317
Testing & Commissioning	1000	140
SUBTOTAL		3587
Contingency	20%	700
TOTAL		4287

Includes:

- Repeating pneumatic injector
- Multiple guns (3)
- D-T 200 torr-L/s for 20 s
- 3-4 mm pellets @~4 Hz
- 200-1200 m/s
- Pellet diagnostics
- Injection line
- Guide tubes
- Secondary containment
- Based on TFTR, JET/DIII-D

Gas Fueling Cost Estimate

	WBS 2.1.3	
	Gas Fueling	
Cost Category	**hours**	**$k**
Engineering/Scientific	1821	255
Shop Fab.	6625	530
Procurement	400	40
Equipment/Materials		540
Travel		10
Assembly & Test Support	2291	252
Testing & Commissioning	429	60
SUBTOTAL		1687
Contingency	12%	200
TOTAL		1887

Includes:

- Multiple gas injection stations (4)
- D-T 200 torr-L/s for 20 s
- D2 200 torr-L/s for 20 s
- Impurity gases 25 torr-L/s (2)
- Independent species & rates
- Electromagnetic dosing valves
- Injection piping
- Secondary containment
- Based on TFTR & ITER

Disruption Control Cost Estimate

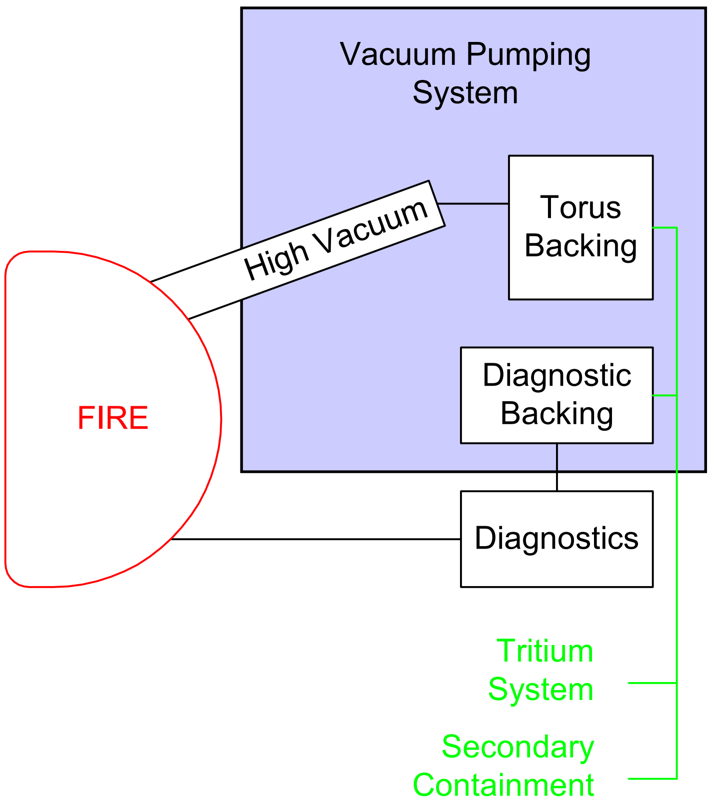
	WBS 2.1.4	
	Disruption Control	
Cost Category	**hours**	**$k**
Engineering/Scientific	2243	314
Shop Fab.	3500	280
Procurement	400	40
Equipment/Materials		265
Travel		10
Assembly & Test Support	736	81
Testing & Commissioning	357	50
SUBTOTAL		1040
Contingency	43%	450
TOTAL		1490

Includes:

- Massive gas puff
- Fast valve
- Gas reservoir
- Injection piping
- Secondary containment
- Triggering system
- Based on DIII-D

Vacuum Pumping System Cost Estimate

	WBS 2.2	
	Pumping System	
cost category	**hours**	**$k**
In-house design	17920	2240
R&D labor	7360	920
Procurement support	5360	456
Assembly / Installation	8494	722
Integrated systems testing	1952	166
M&S		
equipment/materials		4938
purchased services		
travel		100
subcontract/ matls OH	8.3%	418
SUBTOTAL		9960
Contingency	35%	3493
GRAND TOTAL	**41086**	**13453**



High Vacuum System Cost Estimate

	WBS 2.2.1	
	High Vacuum	
cost category	**hours**	**$k**
In-house design	7800	975
R&D labor	7360	920
Procurement support	2960	252
Assembly / Installation	4864	413
Integrated systems testing	320	27
M&S		
equipment/materials		3394
purchased services		
travel		50
subcontract/ matls OH	8.3%	286
SUBTOTAL		6317
Contingency	38%	2400
TOTAL	23304	8718

Includes:

- Cold duct cryopumps (16)
- Turbo/drag pumps (16)
- 200-400 torr-L/s ~10^{-2} torr for 20 s
- Base pressure
  - HDT: 10^{-7} torr
  - Impurities: 10^{-9} torr
- Based on STTR concept
- Prototype to be constructed

Torus Roughing/Backing System Cost Estimate

	WBS 2.2.2	
	Torus Rough/Backing	
cost category	hours	$k
In-house design	5420	678
R&D labor	0	0
Procurement support	1200	102
Assembly / Installation	1967	167
Integrated systems testing	960	82
M&S		
equipment/materials		887
purchased services		
travel		25
subcontract/ matls OH	8.3%	76
SUBTOTAL		2016
Contingency	30%	605
TOTAL	9547	2621

Includes:

- Four skids located near HV pumps being serviced
- Tritium compatible rough pumps
  - Scroll/diaphragm
- Valves and piping to HV system
- Instrumentation
- Secondary containment

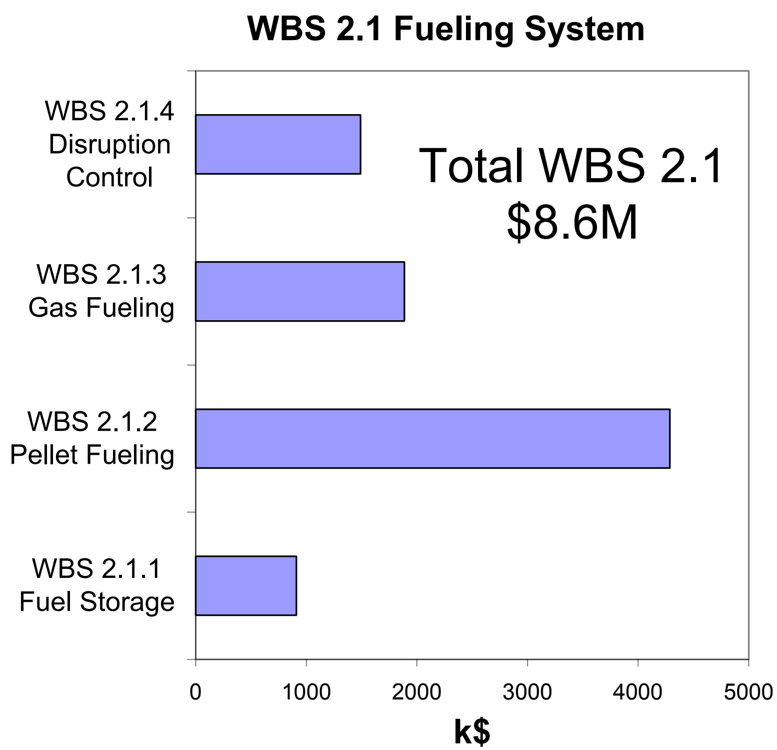
Diagnostic Roughing/Backing System Cost Est.

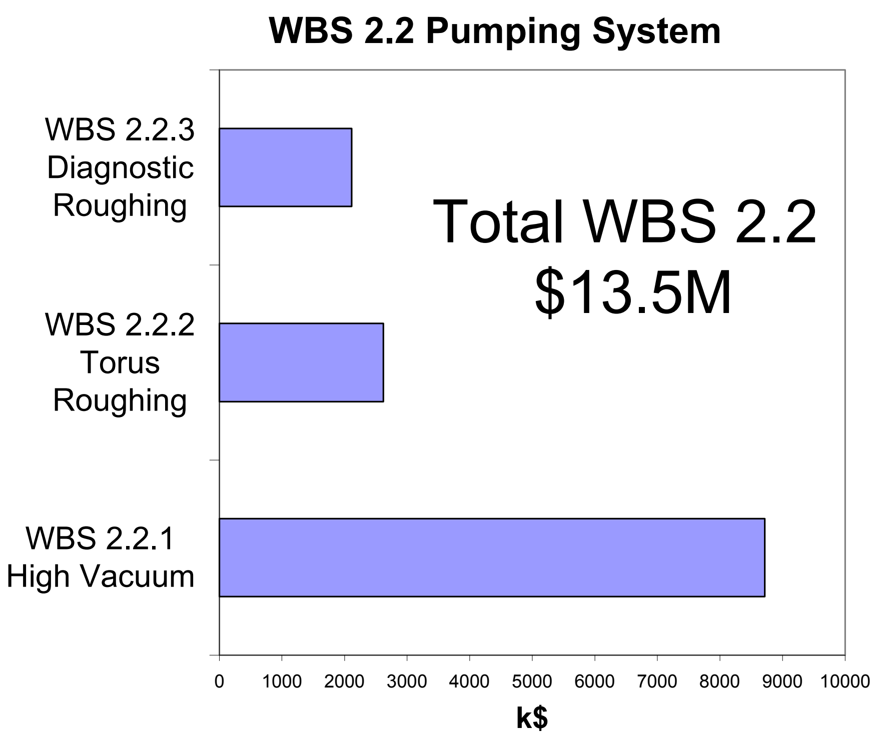
	WBS 2.2.3 Diagnostic Rough/Backing	
cost category	**hours**	**$k**
In-house design	4700	588
R&D labor	0	0
Procurement support	1200	102
Assembly / Installation	1663	141
Integrated systems testing	672	57
M&S		
equipment/materials		657
purchased services		
travel		25
subcontract/ matls OH	8.3%	57
SUBTOTAL		1627
Contingency	30%	488
TOTAL	8235	2115

Includes:

- Tritium compatible rough pumps
    - Scroll/diaphragm (2)
- Ring manifold around torus
- Instrumentation
- Secondary Containment

Fueling and Pumping Cost Summary

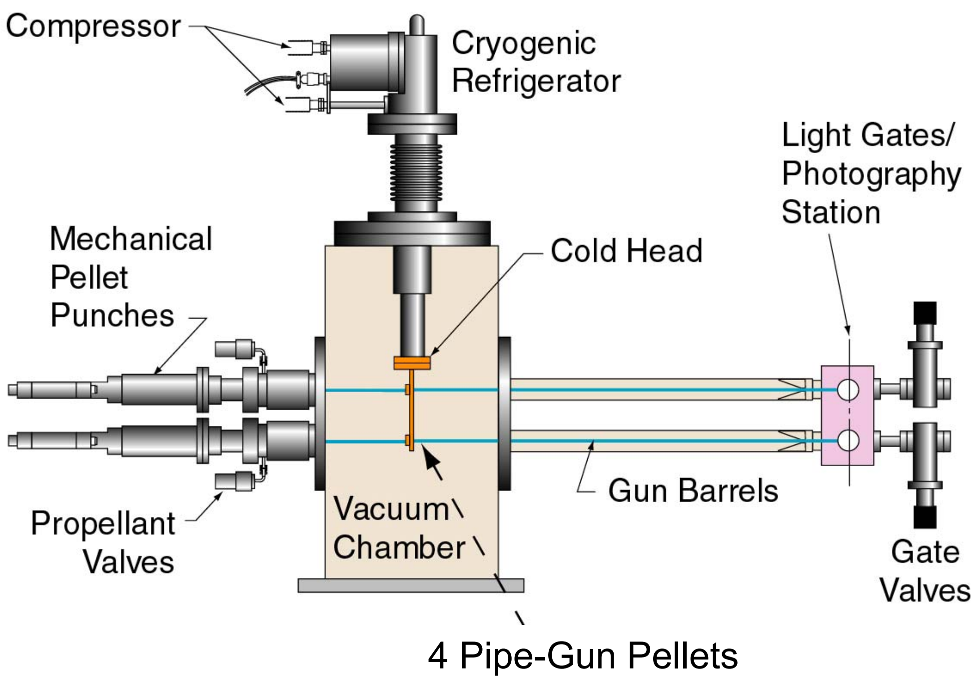




Cost and schedule: FIRE Fueling R&D

- Estimate for cost for twin screw extruder R&D ~ $200K:
  - Twin screw extruder design with cryocooler (FY-02)$45K
  - Fabricate and test with D, H (FY-03) $155K
  - Cryocoolers,sensors available from fueling program
- Schedule: complete test of twin screw extruder by Sept 2003
- FIRE Project benefit:
  - Validate a new hydrogen ice extruder with minimum tritium inventory (safety and siting flexibility)
  - Demonstrate, for the first time, extruder cooling with G-M cryocoolers: operational benefit as it eliminates reliance on LHe.

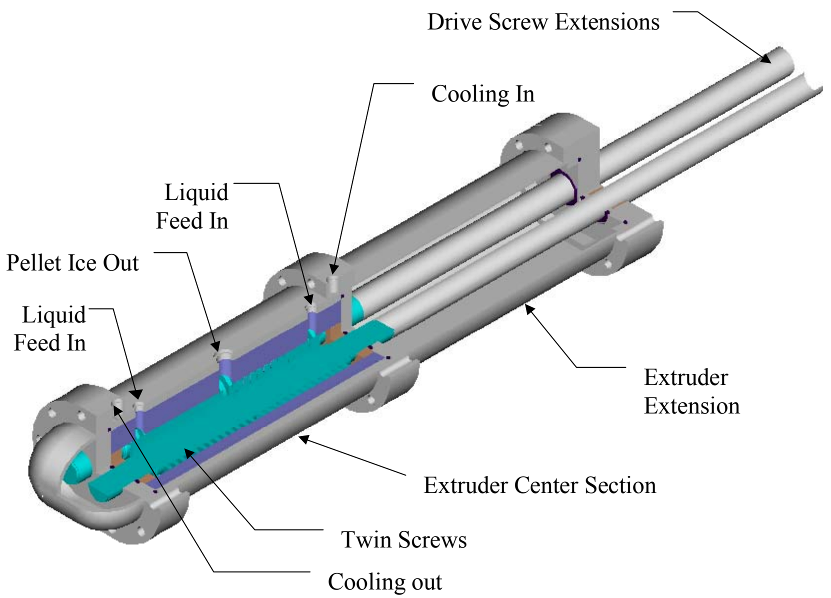
Pellet Injector in a Suitcase



- Suitcase injector presently being fabricated for MST has some features relevant to FIRE
  - Multiple guns (4)
  - Utilizes cryocooler
  - High and low speed pellets

Twin-screw extruder concept (ORNL STTR with Utron, Inc. and ITER Design)

- Dual, opposed, counter-rotating screws
- Liquid helium is fed into the extruder at one end and flows through cooling channels (alternative is G-M cryocooler)
- Deuterium is fed into the screw chamber and flows to the center of the extruder.
- As the liquid flows it freezes on the inner wall between the screw and the inner housing.
- As the screws rotate they scrape off the deuterium and force the ice to the center of the extruder were it is extruded out the center hole to the feed tube.



Cost and schedule: FIRE Pumping R&D

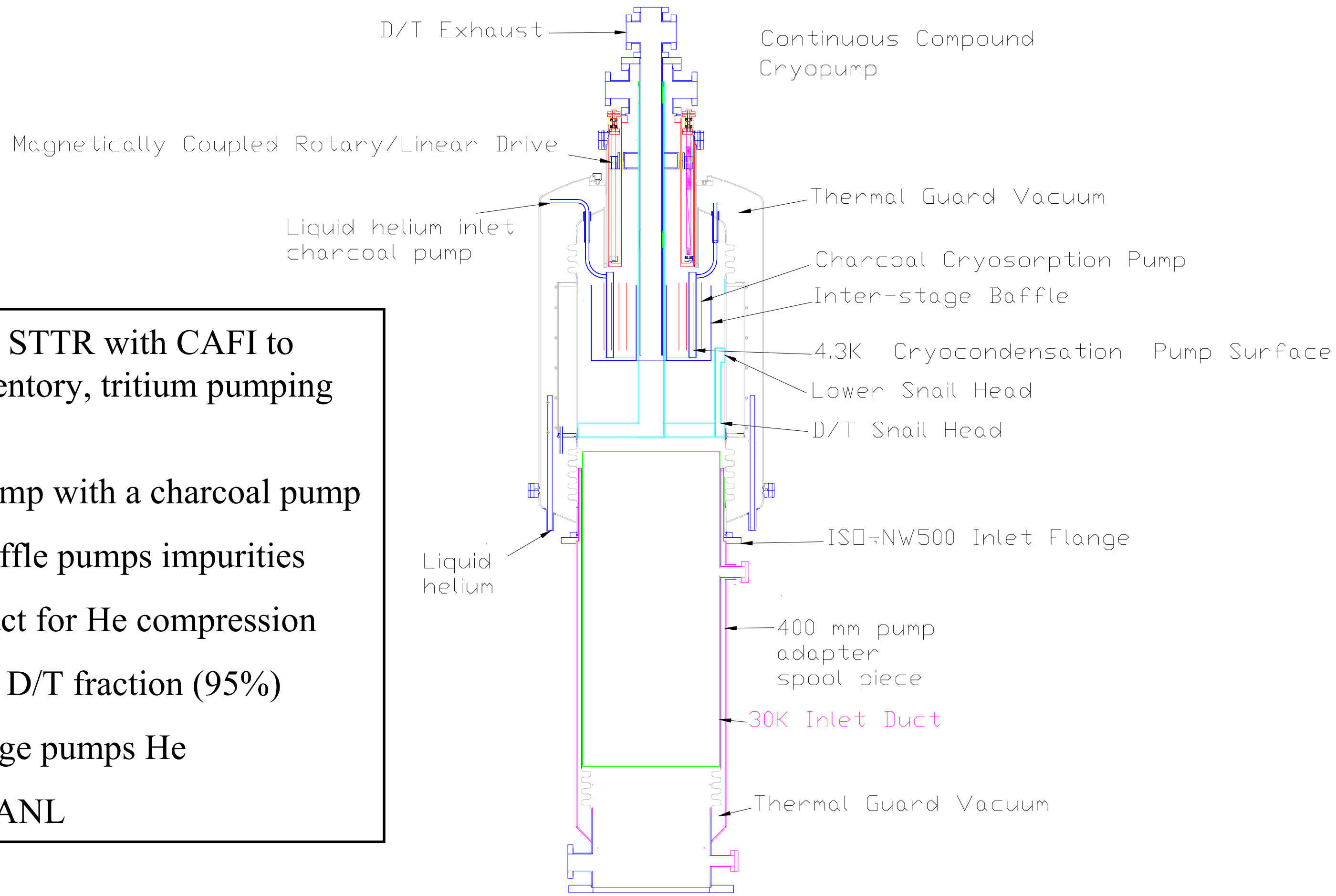
- Estimate for cost for cryopump module ~ $170K:
  - Design cryomodule and shop fabrication (FY-02) $95K
  - Assemble test with H, He inlet gas (FY-03) $65K
  - Components like mechanical pumps, sensors, RGAs, available from fueling development program

- Schedule: complete test of FIRE cryomodule by Sept 2003

- FIRE Project benefit:
  - Validate a novel cryopumping concept with He compression in the entrance duct to allow a compact, in-vessel system (validate baseline design)

DOE STTR Cryopump Work

- •1998-Present DOE STTR with CAFI to construct a low-inventory, tritium pumping system
- •Combined snail pump with a charcoal pump
    - •15K Inlet baffle pumps impurities
    - •30K Inlet duct for He compression
    - •Snail pumps D/T fraction (95%)
    - •Charcoal stage pumps He
- •Will be tested at LANL



Conclusions

- WBS 2.1 FIRE Fueling System
  - $8.6M including contingency
- WBS 2.2 FIRE Pumping System
  - $13.5M including contingency
- Base VLT fueling program continues to develop experimental and theoretical basis for designing FIRE fueling and disruption mitigation system
- DOE SBIR and STTR program continues to develop experimental and theoretical basis for designing FIRE pumping system
- Proposed research
  - Development of continuous RPI using a twin-screw extruder and cooled with closed-cycle refrigerators
  - Design and fabrication of a prototype divertor pumping duct with cold liner, cryopump and turbo/drag pump