DEPARTMENT OF MECHANICAL ENGINEERING

ENME - B6 - Nuclear Pebble Managers

Fuel Injection and Removal Device for Pebble Bed Modular Reactor (PBMR)

Taylor Berry, Emma Brown, Thomas Byrnes, YeHwan Lee, Christopher Mai, Lydia Robling

A. JAMES CLARK SCHOOL OF ENGINEERING

Motivation, Goal, Impact

Goal: Create a fuel injection and removal device for a PBMR that controls the flow of pebbles between a reserve fuel container, core, and spent fuel container.

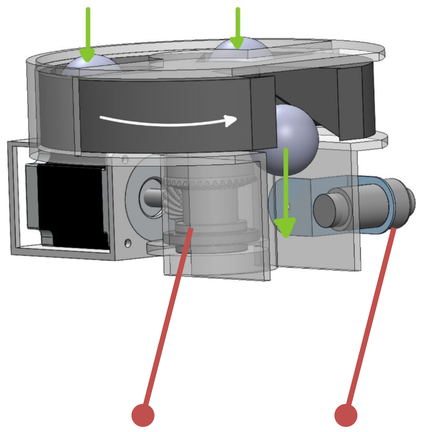
- The entire PBMR is only 2 x 2 m.
- Sold as military contracts, commercial building generators, and for off-grid energy applications.
- 10 kWe power output, can be used in series as well.
- Fully automated and designed for manual refueling only once every 3 years.
- 2200 units/year production goal.
- Automatically cycles 15-20% of the pebbles within the core every 3 months.

Requirements

- Must inject and remove an equal number of fuel pebbles into and out of the core based on a gamma detector reading within the core.
- Must have meter to measure amount of fuel injected and removed.
- Construction material should withstand max temperatures of 800 °F within the core vessel, and 200 °F outside the core.
- Must keep the spent pebbles in a detachable and transportable container for safe disposal and transport.

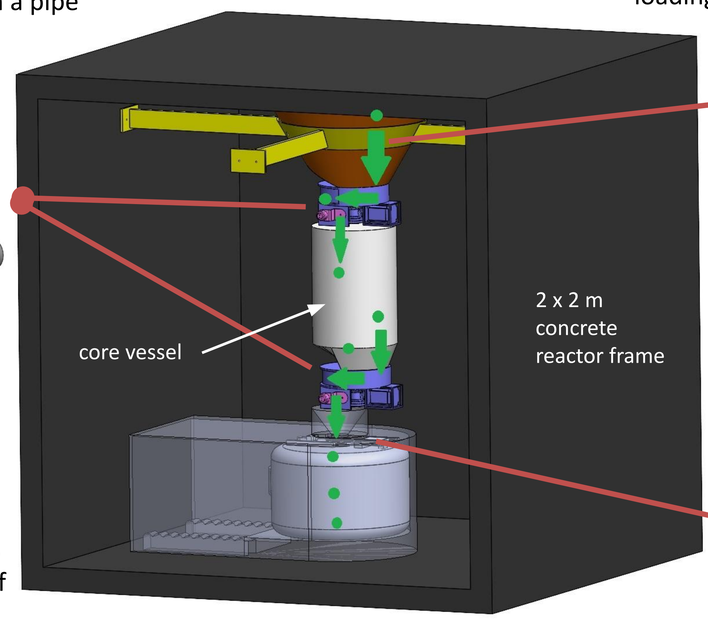
Final Design

60 mm fuel pebbles are funneled into the rotating plate and dropped through a pipe opening.



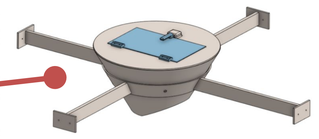
The rotating shaft is driven by a stepper motor connected to a spiral bevel gear set.

A capacitive sensor counts the number of dispensed pebbles.

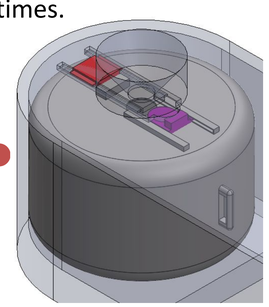


flow of fuel pebbles through all systems shown in green.

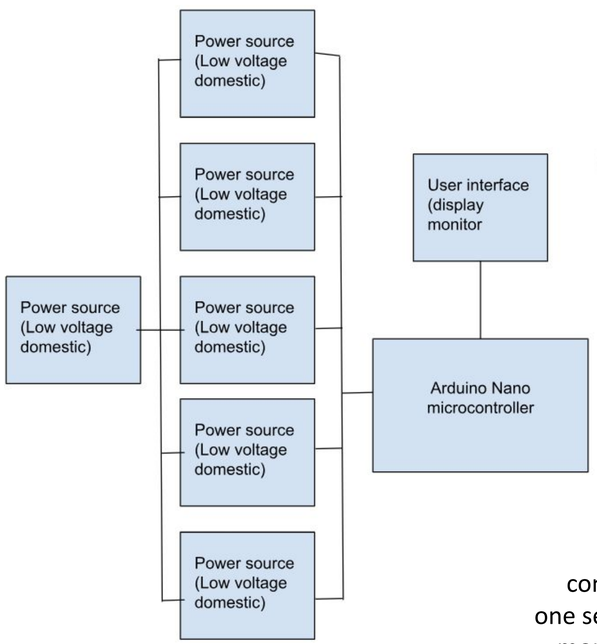
reserve fuel container with loading door and collar mount.



The spent fuel container features double spring loaded doors to ensure secure containment of nuclear waste at all times.



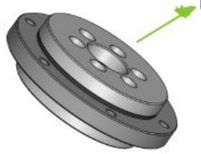
Design Calculations & Decisions



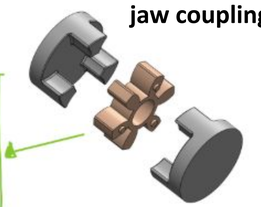
electrical system **logic diagram**

spiral bevel gear set
Driven gear teeth - 40
Driving gear teeth - 20

zero lubrication **slewing ring** - PRT-01-20-ES-H



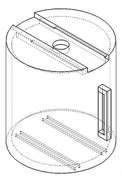
jaw coupling



stepped shaft dimensions

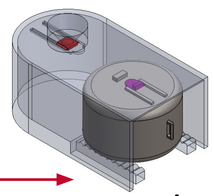
Sustainable Decisions

Old spent container has one set of tracks mounted onto base.



old spent container

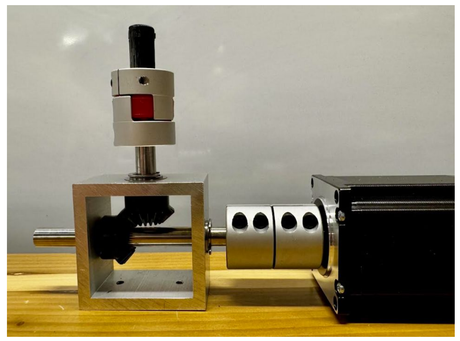
New spent container only has roller tracks, saving material and using standard parts.



new spent container assembly

Prototype & Test Results

Internal prototype assembly consists of a right angle gearbox, motor, and two shaft couplings to spin the rotating dispenser plate.



One-Factor ANOVA testing if direction reversal unclogs

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
One Direction	54	26	0.481481	0.254368		
Both Directions	54	52	0.962963	0.036338		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.25926	1	6.259259	43.0625	2E-09	3.930692
Within Groups	15.4074	106	0.145353			
Total	21.6667	107				

At a significance level of α = 0.05 with a t-critical value of 1.98, the LSD test shows a significant difference between single and double direction(s)—concluding 2 directional rotation produces more successful dispensing outcomes.

	|Δ(AVG)|	LSD	Reject if LSD < |Δ(AVG)|
single VS double direction	0.481481481	0.145466996	REJECT!

Dispensing Consistency Trails

Dispensing trails 1 and 2 clogged and stopped rotating after about 28/48 of the test pebbles were dispensed. To stop clogging from occurring, we implemented a direction switch after 1 empty rotation, resulting in 48/48 of test pebbles dispensed. This change will occur using data from the motor encoder and counting mechanism in the full design.