Safely Dispensing Radioactive Powder for Spine-Rad™ Brachytherapy Bone Cement

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Executive Summary: On-market treatment of spinal bone tumors irritates the spinal cord & organs, decreasing the quality of life for 200,000 patients. Spine-Rad™ Brachytherapy Bone Cement mixes radioactive powder (Phosphorus-32 Hydroxyapatite(P-32-HA)) with an FDA-approved bone cement to be injected into the patient's spine to improve quality of life. This project is a powder dispensing device that *snaps* open a vial of the radioactive powder using a tungsten-carbide blade & *dispenses* a user-specified amount of powder into a syringe using a screw conveyor & analytical balance, so that the radioactive powder can be mixed in with the bone cement to inject into patients. The team has finished designing and has begun to manufacture a proof of concept, leading into the initial prototype.

Procedure Overview:

P-32-HA (radioactive powder) sealed glass vial to packaged syringe process:

1. Scoring & Snapping
2. P-32-HA Dispensing

- **1.1** Vial is rotated 360° by a flywheel and scored by a blade on the other side of the vial
- **1.2** Vial is held by a clamp wheel that will rotate downward to snap the vial open over a fulcrum
- **2.1** Auger filler moves P-32-HA radioactive powder to a nozzle which will be dispensed into a syringe
- **2.2** Syringe containing the powder will be weighed by the electronic scale

Key Mechanical Components:

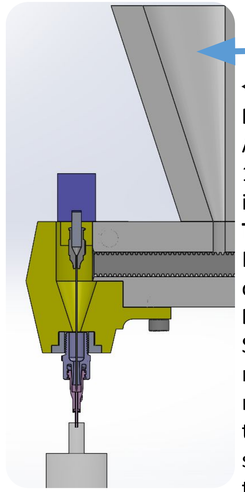

Fig. 1: Axial Cross Section of Dispensing System

◄ **Weigh/Dispense**

Purpose:
Accurately dispense 14-340 mg of powder into a 30mL syringe

Technique:
Horizontal screw conveyor and needle

Design:
Solenoid pushes 22G needle through 18G needle to dispense the powder to the syringe after it is transferred from the hopper to the nozzle tip by the screw conveyor (auger filler)

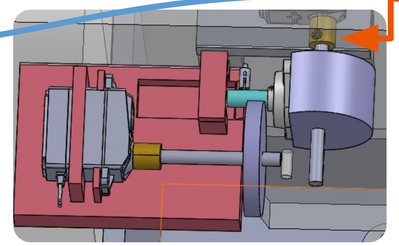

Fig. 2: Top View of Snap & Score System

▲ **Snap/Score**

Purpose:
To score a glass ampoule 360° around, and to snap it open using a downward force.

Technique:
Clamp wheel and flywheel

Design:
Flywheel rotating the ampoule while a blade scores it. Clamp wheel rotating the vial hitting a fulcrum to cause the vial to break open.

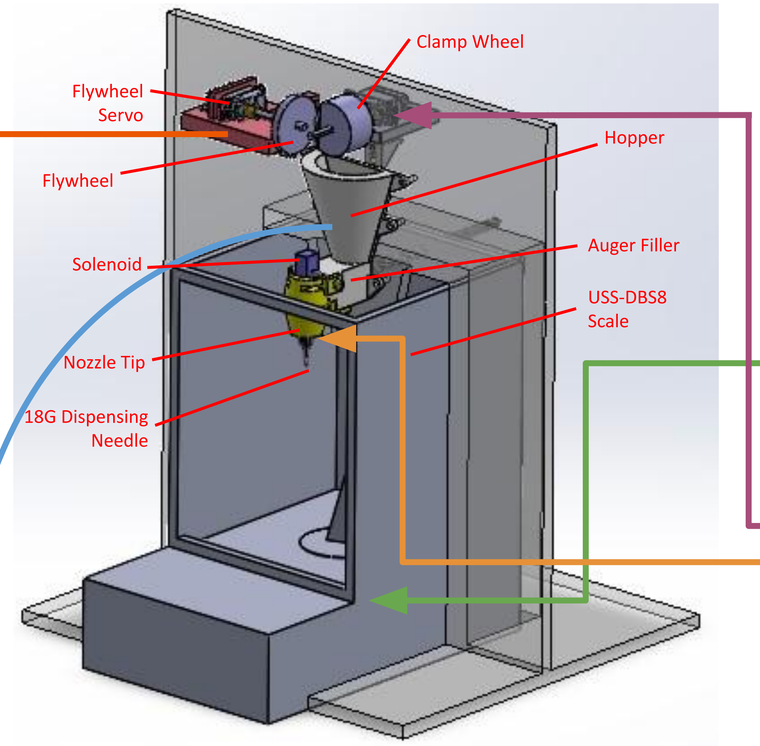

Fig. 3: System Assembly

Key Electronic Components:

Fig. 4: (a) Microcontroller (b) Auger Screw Servo (c) Pusher Solenoid (d) Clamp Wheel Servo

- **(a)** Used to control all motors & actuators, thus requiring precise response time
- **(b)** Requires 360° rotation and precise positioning to dispense P-32-HA powder
- **(c)** Requires linear motion (stroke length: 4.5mm) to prevent lumps of powder
- **(d)** Requires precise positioning and high torque in order to snap the glass vial

Weighing Component:

◄ Fig. 5: USS-DBS8 Analytical Laboratory Balance used to weigh dispensed P-32-HA radioactive powder

- Critical weighing component allows us to verify the system is dispensing the correct amount of P-32-HA
- Specified range of mass to dispense: 14-340mg ± 5%
- USS-DBS8 Load Capacity: 200g, 0.1mg readout
- RS232 communication to microcontroller allows for real-time adjustment of powder flow-rate to ensure accurate amount of mass to be dispensed

Powder Flow Mechanics:

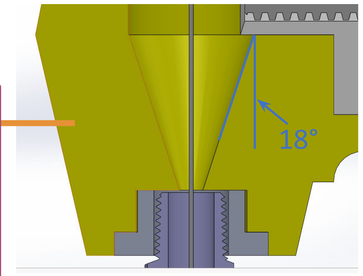

Fig. 6: Hopper/Nozzle CAD

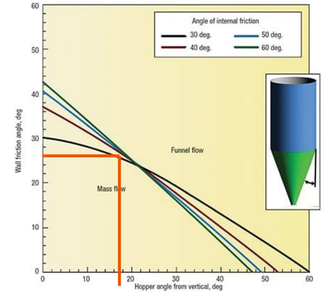

Fig. 7: Hopper Design Chart

- P-32-HA has free-flowing mechanics which affects dispensing system design
- Based on wall and internal friction angles, hopper angle for P-32-HA is 18°[1]

[1] Whyte, Daniel, et al. "Understanding morphology, bulk properties, and binding of silk particles for 3D printing." Powders, vol. 1, no. 2, 18 June 2022, pp. 111–128, https://doi.org/10.3390/powders1020009.

Conclusion:

- **(1) Proof of Concept:** Electrical & mechanical component functionality
- **(2) Project Timeline & Future Improvements:** Part of the concept generation for the snap/score solution was done prior to MAE151A in Winter 2024; the team will create an improved prototype which will improve system geometry & integration, as well as refine the electronic components used
- **(3) Societal & Environmental Impact:** Being able to implement this design will improve 200K patients' lives, however, a major environmental roadblock of disposing the glass vial fragments and radiation waste remains