Design Of A Powder Dispenser For A Heterogeneous Acidic Radioactive Zirconium Molybdate(Zr-Mo)Gel Powder

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1

Abstract

In BRIT at Vashi, Navi Mumbai, the radioactive gel powder called Zirconium Molybdate (Zr-Mo) gel powder is filled in the glass column (GC)using a fixed volume dispenser. As the demand for this powder increased, users preferred denomination as per their requirement thus converting the demand into user specific. At production management level, need of converting the process specific dispenser into user specific one generated specification of the desired dispenser which will have advantage over the existing machines. With the objective of designing a machine which will be able to dispense powder in small volumes (between 0.2 to 0.6 gm/sec.) to control the powder discharge so that production team will be able to deliver the powder as desired by the user, a general approach to the design of the powder dispenser was followed. This paper highlights the design process of the powder dispenser for dispensing the radioactive gel powder while facing the constraints related to the radioactivity and unknown powder characteristics.

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Keywords—Zr-Mo powder, screw feeder based powder dispenser, hopper, flow rate, bulk density.

1. Introduction

BRIT offers a nuclear medicine product called Geltech generator to the nuclear medicine fraternity in India This generator carries the radioisotope Mo-99 in the form of Zirconium Molybdate gel powder. Radioisotope Mo-99 decays to Tc-99m (half life= 6hours). Tc-99m emits gamma radiation and it is this property in addition to other favourable ones made it the work horse of nuclear medicine industry. The Mo-99 in powder form continuously generates Tc-99m which is separated by using saline at nuclear medicine center. This powder is stored in a sealed glass tube called GC. The process of conversion of the Mo-99 liquid form to gel powder form happens after going through the several steps of processing in the lead shielded cells called as shielded tong box (STB). In the final stage of this process, the produced gel powder is transferred to the GC using the powder dispenser. In 2006, when the facility for production of Geltech generator was commissioned, depending upon the customer requirement, two volumetric powder dispensers (dispensing 5g and 6g of powder per stroke) were deployed. As the Geltech generator demand increased, new customers expected the production team to introduce new denominations of the generator which was related to the volume of the powder inside the GC. Using the existing facility of dispensing, it was difficult to satisfy customer demand, thus giving the production team a new task of designing a versatile dispenser which can dispense powder in rate less than a gram per second. Using the conventional method of designing, a powder dispenser was designed by overcoming the hurdles of unknown properties of the powder, hazards of radioactivity; ergonomic considerations in the design of machines in handling of the radioactive material etc. The proposed paper discusses the design and development of the powder dispenser while facing constraints.

2. Objective

Mo-99 in liquid form is converted into powder from by reacting with Zirconium Oxychloride solution. The conversion of the liquid radioactive material to solid is has to undergo chemical reaction, filtration and drying process in the special facility called as STB. STB is a sealed and lead shielded facility with negative pressure inside. The powder produced is transferred to the GC using the volumetric powder dispenser which is then sealed hermetically before transferring into the lead shielding of the product called Geltech generator. Process of transferring the powder to the GC is done by using the machine called as powder dispenser. Two different volumetric dispensers were deployed which can dispense approximately 5g and 6g powder per stroke. Powder dispensers can be seen in the photograph (fig. 3). Due to fix denomination of the radioactive content of the Geltech generator, the mass of the powder per column was constant

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in initial years. As the market shar+ of the Geltech generator increased, the expectations of the customers in the form of activity per generator also increased. To satisfy the customer's demand, fix volume dispensers proved to be main hurdle. Additionally there was a problem of loss of precious powder through the interface between the moving parts of the powder dispenser. This loss proved to be one of the limiting factors as well in addition to the excessive spread of contamination inside the STB. With varying bulk density, the equal distribution of the powder proved to be a cumbersome job as the number of customers increased. To overcome these difficulties, it was decided to develop a powder dispenser which will dispense powder in smaller volumes which can be easily be correlated with the mass of the dispenser is dispensing per unit time.

3. Materials and Method

With the objective of designing a versatile powder dispenser, design started with a classical approach by noting the constraints to satisfy like

1. Limitation of space available for installation; 200mm x 400mm x 600mm
2. varying bulk density of the gel powder
3. Avoid loss of precious radioactive gel powder
4. Material of construction (MOC) shall suit the corrosive atmosphere and radiation stable so that service life of the machine can be at least 5years
5. easy to operate and maintain, remotely from behind the lead shield
6. Final rate of delivery shall vary between 0.2 to 0.6 gm/sec.
7. weight of any sub-assembly of the machine shall not be more than 5kg
8. machine shall be able to deliver or transfer the powder fully to the destination i.e. glass column means dispensing efficiency shall be more than 98%
9. shall operate using existing power supply like compressed air, electricity, or manually operated to reduce operational cost
10. shall have arrangement for manual overriding

***3.A. Mechanism selection*:** After noting the constraints to satisfy, design start with studying the proved machines and mechanism. This step involved market and literature survey. Study lead to selection of the probable mechanisms and machines which can be miniaturized (to satisfy the space availability constraint) like

1. Augur Feeder
2. Vibratory feeder
3. Screw feeder
4. volumetric feeder

Additionally some of the designs using the hopper (fig. 5 and 6) as principle component have been studies like

1. Rotating hopper valve mechanism
2. hopper with belt drive
3. guarded hoppers for granular substances
4. continuous rotary feeding device

While most of these proved machines have been found to be complicated not only from the point of view of design but also will prove to be least maintenance friendly. Some of the machines available in the market were studied and their characteristics were noted.

3.A.a. Characteristics of the Augur dispenser(fig. 1)

1. Big industrial size feeders are available in the market. Thus can not be adopted directly.
2. Equipped with a hopper and the vertical screw for controlling the flow of the fluid
3. Can work efficiently with consistent fluids
4. Can dispense fluid with desired accuracy and repeatability

Not suitable for the powder to be handled as the powder particle size is inconsistent.


Auger dispenser


Auger dispenser with a belt conveyor

Fig.1

3.A.b. Characteristics of the Vibratory feeder dispenser (fig.2):

1. Available in the market in smaller sizes
2. Poor accuracy of dispensing. Always work in tandem with automatic weighing system.
3. Size increases with no of supporting components.

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4. Used mainly as controlled feeder to the main process and not as main components
5. Used where accuracy of dispensing is not an issue
6. Vibration is a main concern
7. Best with consistent powders
8. Not suitable for powder to be dispensed.

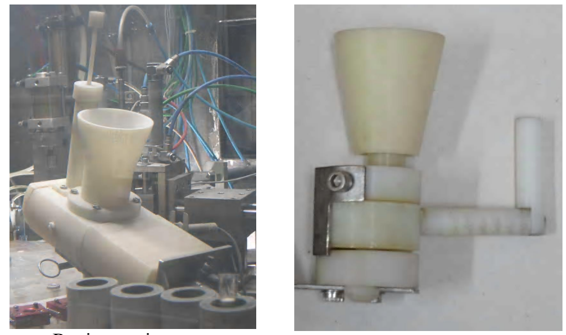
Fig. 2 Vibratory feeder

3.A.c. Volumetric dispensers (fig.3):
Characteristics:

1. Limited use where slow dispensing process is not a problem
2. Can be used for very accurate dispensing of the powder where powder is homogeneous
3. Typically design is fixed and speed remains same.
4. Simple in design, maintenance, operation
5. Typically used on laboratory scale for research and development
6. used in TCGP facility in two different designs typically rotary type and reciprocating plunger type.

3.A.d. Characteristics of the <u>screw feeder dispenser</u> <u>(fig.4)</u>:

1. Available in industry in big sizes
2. Commonly used for transportation of coal etc
3. For consistent powders, accuracy and repeatability of dispensing is excellent
4. Can work for any type of powder
5. Basic structure is suitable for present process
6. Screw controls the rate of dispensing thus accuracy of dispensing can be high.
7. Can be designed in small size to accommodate in the existing set-up.



Reciprocating type Rotary type

Fig. 3

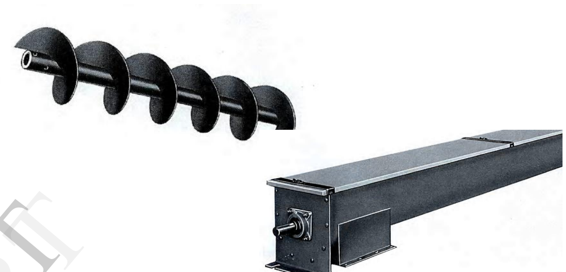


Fig. 4 Screw feeder

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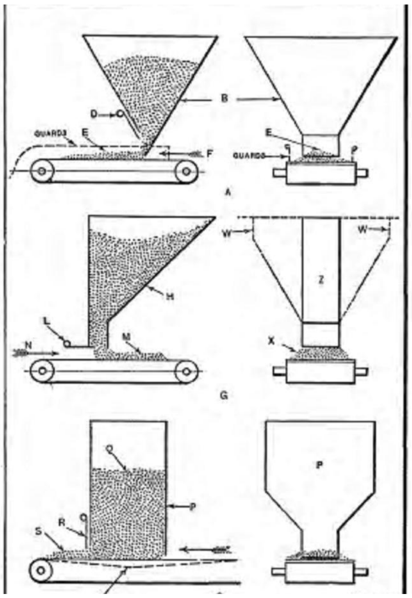
3.A.e. Additional Mechanisms studied (fig. 5 and 6):

Additional mechanism found to be superior in concept and excellent for process and continuous production systems. But the similar machines like guarded hopper, hopper valve mechanisms have been tried at the conceptualisaton stage before the volumetric feeders, same was avoided. Also the cost of designing and developing the powder dispensers based on these mechanisms would have been more as compared to the purpose to be served.

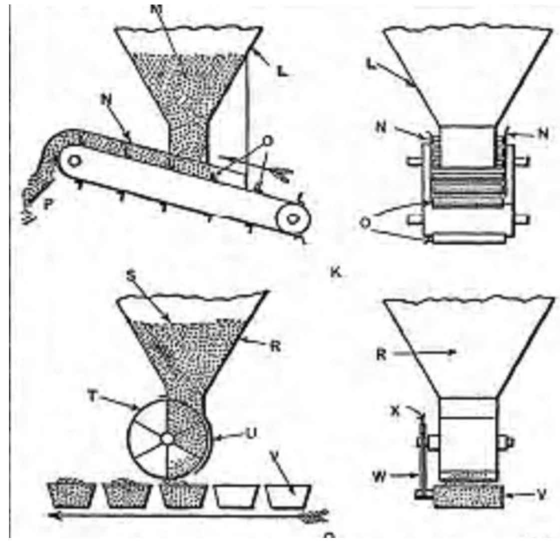
3.A. f. Summary of the available machines in the market:

After studying the characteristics of the available machines in the market, it was found that the screw feeder based powder dispenser will suit the requirement of the desired powder dispenser. Some of the reasons responsible for selection of screw feeder based powder dispenser are:

- Miniaturization of the screw feeder for coal transport is possible



hoppers used for granular material



Rotating hopper valve mechanism

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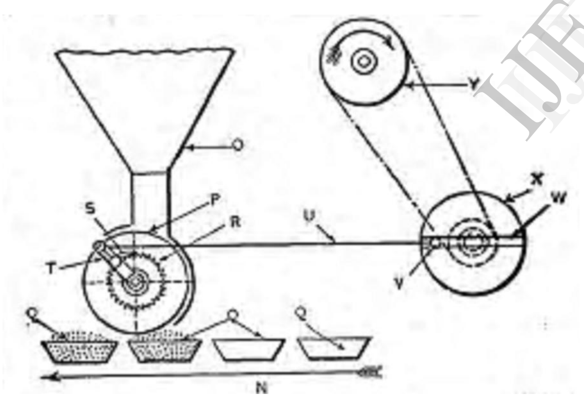

Guarded hoppers for granular substance

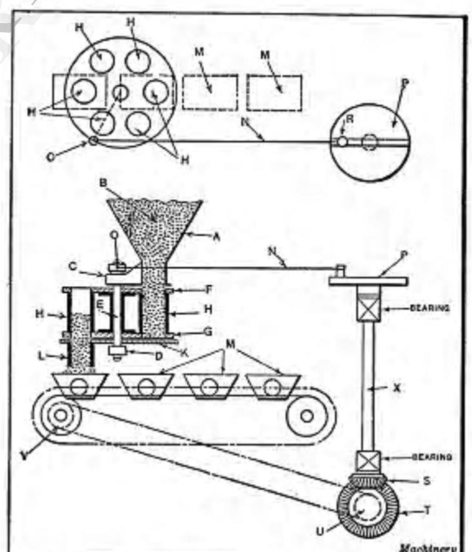

Fig. 5

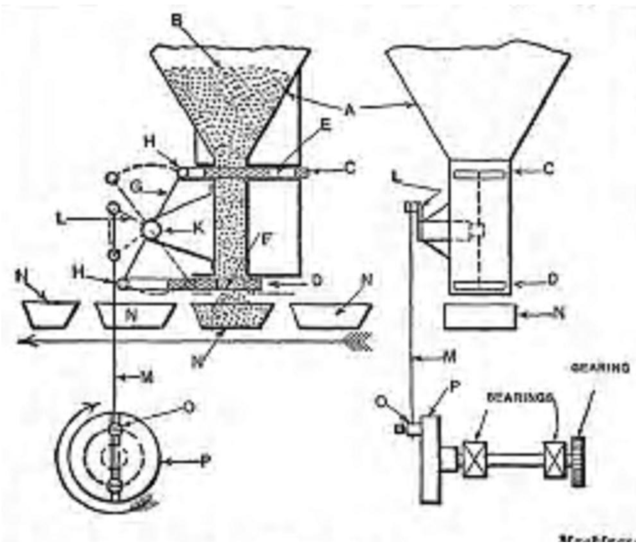

Fig.6 Hopper valves arrangement for handling granular substances

- By properly designing the screw, rate of delivery can be controlled between 0.2 to 0.6 gm/sec.
- Weight of any sub-assembly of the machine can be controlled within 5kg.
- Using practical knowledge, machine can be designed for ease of assembling and dismantle, setting etc. By selecting proper fit between the screw and the barrel, machine can deliver or transfer the powder fully to the glass tube with efficiency of more than 98%
- Design of the machine can have arrangement for manual overriding for recovery of the powder in case of motor failure.

3.B. Designing the powder dispenser

Typically the powder dispenser is having following principle components:

1. Hopper- for storage and transfer of the powder to the screw for dispensing.
2. Screw feeder – to regulate the flow of the powder from the hopper to the glass tube

Powder properties plays biggest role is design of the dispenser. Since the powder Zr-Mo is unique, it's properties were unknown. It was the first hurdle in designing the powder dispenser. It was therefore decided to know the following properties of the powder.

1. Particle size distribution
2. Particle shape
3. Composition of the particles
4. Moisture
5. Temperature
6. Powder particle size:
7. Bulk density: few observations- on an average untapped bulk density of the powder is found to vary between 1 to 1.2 gm/cc.
8. Powder shear
9. Angle of repose

3.B.a. Study of the powder:

Since the powder is radioactive in nature, the regulations related to handling of the same do not permit to handle the same in unapproved facility. Therefore, powder can not be tested in the approved laboratory using the standard testing machines. In order to over come this constraint, it was decided to test the most desired properties of the powder which will help in designing the hopper and the screw feeder based dispenser. For this following properties were finalized for study:

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1. Angle of repose : for hopper angle and dispenser design
2. shear: for screw feeder design and motor rating by studying the internal angle of friction and the friction between the material of the hopper and the powder,
3. particle size : for screw pitch , hopper outlet diameter
4. friction angle : for motor rating
5. Bulk density: basic property of the powder

Accordingly, following instruments were developed

1. Volumetric beaker: to study the untapped bulk density of the powder (fig. 7)
2. Horizontal hinged platform with vertical screw for adjusting the platform angle: to study the hopper angle when the hopper material is stainless steel or the ultra high molecular weight polyethylene (UHMWPE) (fig. 13)
3. Shear test equipment: for knowing the co-efficient of friction between the powder particles and between the powder and the MOC of the hopper. (fig. 8)
4. Graduated X-Y scale: to confirm the angle of repose (fig. 11 and 12)

Table -1 shows the effect of the particle properties on the design of the powder dispenser components.

Basic Bulk Solids Properties that Influence Handling and Processing Equipment Design and Functioning

Property	Influences on Equipment Design and Functioning
Bulk unconfined yield strength	Hangups such as arching and ratholing, segregation potential, density variation, feeder accuracy, blender efficiency, feeder sizing, fluidizability.
Bulk density or bulk weight per unit volume	Hangups such as arching and ratholing, segregation potential, limiting flow rates from hoppers, feeder and conveyor power, equipment structural design, feeder accuracy.
Air flow resistance or permeability	Deaeration time in equipment, limiting flow rates from hoppers, fluidizability, air required to increase powder flow rates, air required to break bridges and ratholes.
Wall surface friction angle or kinematic slide angle on a flat plate	Flow patterns in bins, chute angles, hopper angles, maximum conveyor belt slope, screw conveyor and feeder effectiveness.
Wall surface adhesion on static slide angle on a flat plate	Chute plugging, chute design parameters, screw feeder and conveyor efficiency, belt conveyor, cleaning problems, blender efficiency, pneumatic conveyor pipe buildup.
Bulk modulus of elasticity	Hangups such as arching and ratholing, bin geometry, feeder design parameters, feeder accuracy.
Particle size range and distribution	Segregation potential. May influence all the other bulk properties.
Particle density or specific gravity	Rate of air injection to effect flow or destroy hangups.

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Fig. 7. Metering beaker to know the volume of the untapped Zr-Mo powder produced

Fig. 8. Instrument for knowing the coefficient of friction between the powder particles and between the powder and the hopper material.

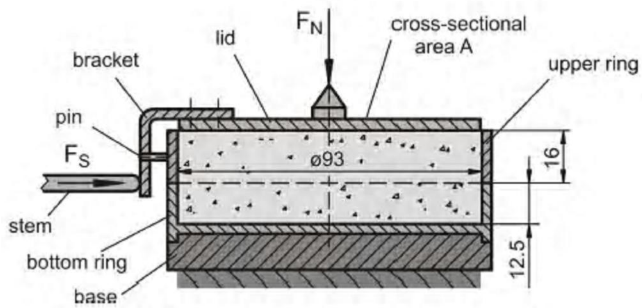


Fig. 8 Shear Cell of the Jenike Shear Tester

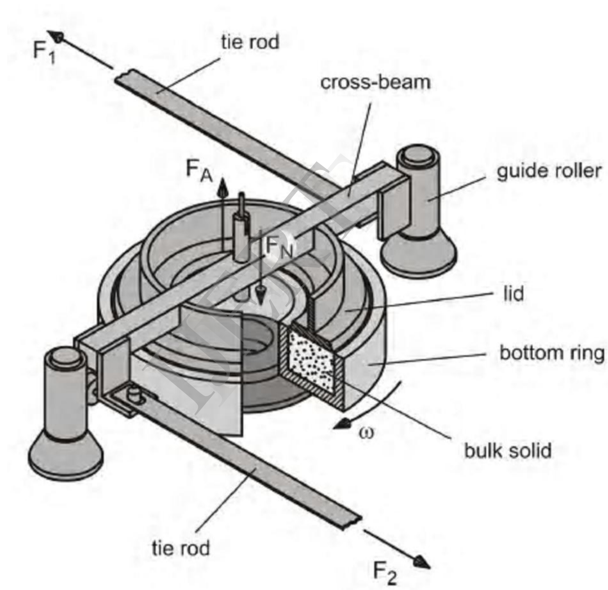


Fig. 9 Schulze Ring Shear tester

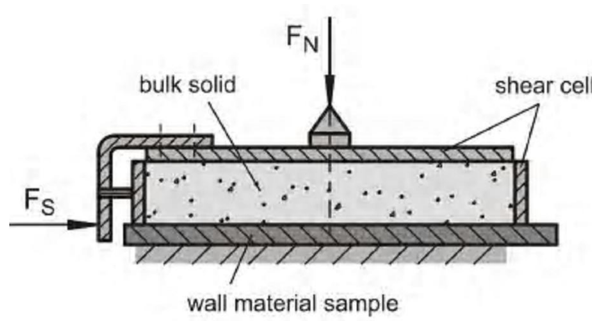
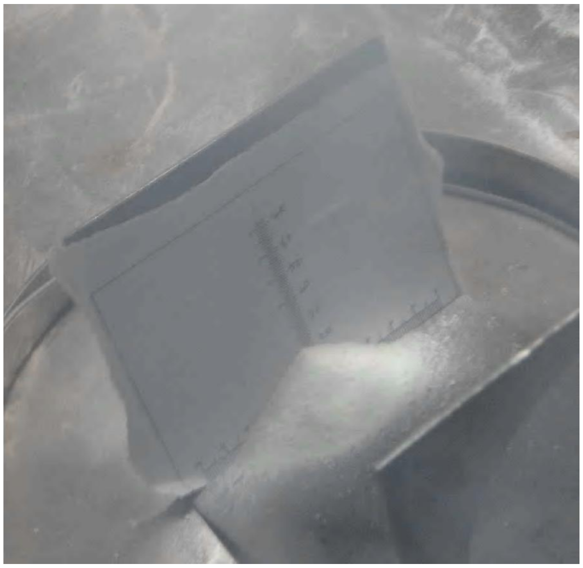


Fig. 10 Measurement Wall Friction using Jenike shear tester

Figure 9 and 10 shows the schematic of the standard powder testing machines for studying the shear stress and the friction test.



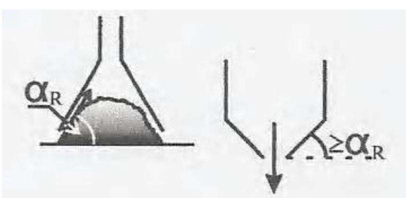


Fig. 11 Angle of repose of the powder

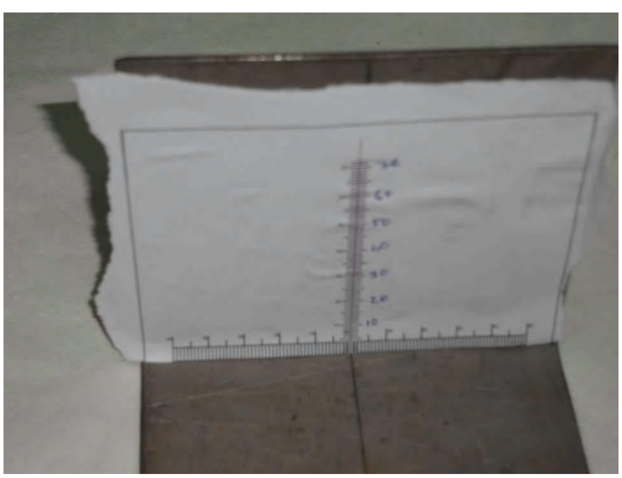
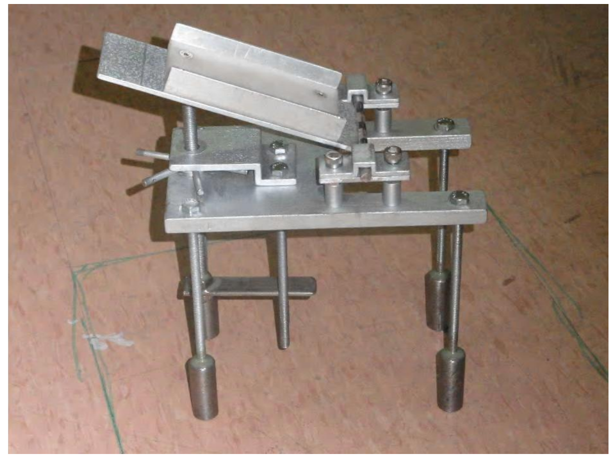


Fig. 12 Instrument for knowing the angle of repose



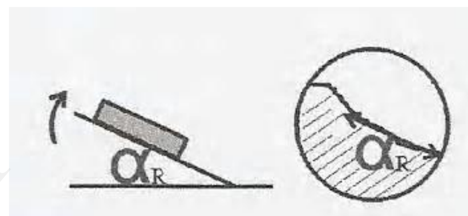


Fig. 13 Instrument for knowing the frictional angle

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Fig. 14 Maintenance door with transparent barrier of the STB used for studying the powder properties

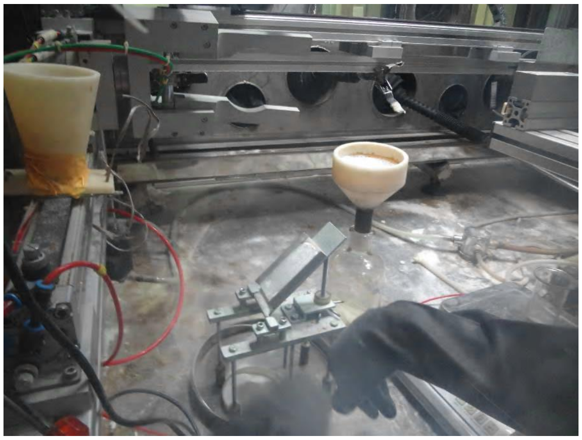

Fig. 15 Study of frictional angle between the powder and the UHMWPE hopper

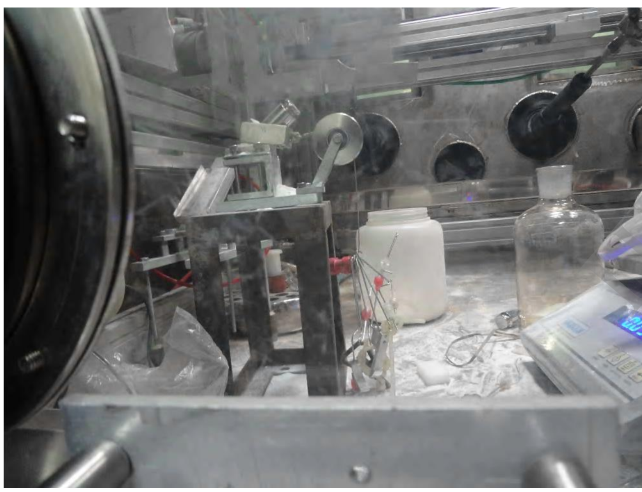

Fig. 16 Shear test Instrument in operation

3.B.b Experimentation to find out the properties of Zr-Mo powder

In the whole process of testing the powder, use of the powder sample produced during the actual processing using standard production conditions has been done. Tests on the powder were performed inside the STB, following the safety norms. ~10 tests were carried out generating the result required for designing the machines using the existing test set-up. Earlier, as the requirement of the new powder dispenser started gaining demand, the production staff was instructed to gather information on the powder properties like the bulk density. Since the equipment for

Table -2
Study of the bulk density of the Zr-Mo powder obtained in processing

Sr. no.	Volume	Weight , gm	Bulk density , g/CC
1	50	59.7	1.194
2	75	81.7	1.09
3	60	61	1.06
4	60	65	1.1
5	70	81	1.15
6	62	70.7	1.14
7	60	73	1.21
8	50	56	1.12
9	60	74.7	1.245
10	80	104.7	1.3
11	65	70.7	1.08
12	50	69.7	1.39
13	60	81.7	1.28
14	75	82.7	1.1
15	80	86	1.075
16	50	66	1.3
17	70	88.7	1.26
18	60	71	1.18
19	65	81	1.25
20	60	78	1.3
21	80	97	1.21
22	50	64	1.28
23	50	61	1.21
24	65	78	1.2
25	50	67	1.34
26	100	116	1.16
27	40	55	1.375
28	70	83	1.18
29	65	77	1.18

tapping the powder in the beaker could not be used due to various reasons, the bulk density obtained is untapped bulk

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density. A graduated volumetric beaker (fig. 7) was designed and fabricated specially and an electronic balance was placed inside the production cell. Data gathered by the production team is tabulated in table-2. On analysis of the data gathered from the 29 batches of production of the ZrMo powder, the average untapped bulk density obtained was 1.18g/CC.

Further, the available surplus decayed Zr-Mo powder was used for carrying out the tests to know the angle of repose, frictional coefficient between the hopper material (AISI304 and UHMWPE) and internal coefficient of friction of the powder using the developed gadgets. Result obtained by performing experiments is as explained in the following section.

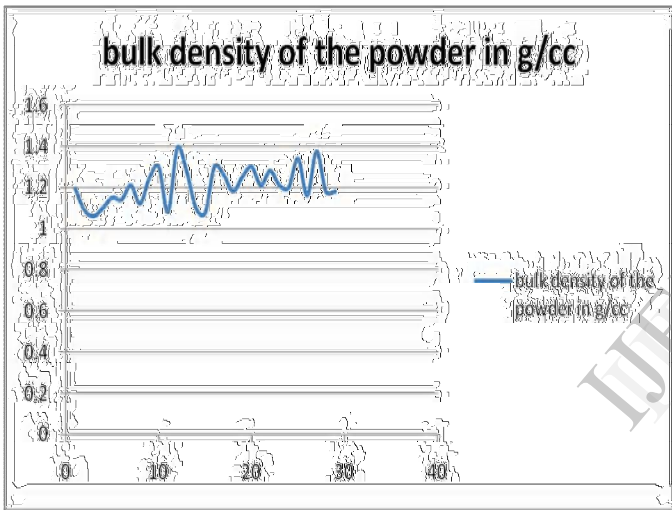

Fig. 17 Bulk density (Y-axis) of Zr-Mo powder Average bulk density = 1.18g/CC

1. Friction between stainless steel and powder: In order to find out the resistance of the stainless steel (hopper) for gravity flow of the powder, shear test equipment has been used. After performing around 10 experiments, the angle of friction is found to vary between 26º and 27º and so the frictional co-efficient vary between 0.494 to 0.510. The average µps shall be 0.502. This property will be used for selecting the screw feeder motor.

2 Friction between UHMWPE and powder: Similar to the friction between the stainless steel and the Zr-Mo powder, study on UHMWPE has been conducted. It has been found that the angle of friction in this case is ~35º. Therefore, the average frictional co-efficient is µps = 0.7.

3. Internal coefficient of friction i.e. frictional coefficient within the power particle is found to be μ_i= 0.949. By using the shear testing machine, shear stress and normal stress were found out and using the graphical method (see fig. 18, 19 and 20) the internal coefficient of friction has been calculated.

4 Angle of Repose

For mass flow of the powder through the hopper top the screw feeder, by using the instrument for knowing the same, it is found that the angle of repose for Zr-Mo powder vary between 34º-36º. The same would be used as minimum value for determining the hopper angle.

To conclude, it can be said that minimum properties required for designing the powder dispensers have been roughly obtained. Using these properties, dimensions of the dispenser components as mentioned below will be decided:

1. Hopper: hopper angle, minimum and maximum diameter and height, material of construction
2. Screw: pitch, screw diameter, length, shaft diameter
3. driving mechanism: motor type and rating , speed

3.B.c. Designing the powder dispenser

Designing the screw feeder based powder dispenser mainly involves

1. The feeder design and
2. The hopper design

III.B.c.1 The feeder design:

Since the feeder is basically the screw feeder, design of the feeder involves

* Deciding the material of construction of the screw,
* Deciding the entry and exit diameters
* deciding the screw dimensions like diameter, pitch, length, core diameter etc
* Deciding the motor rating for the screw feeder like speed, torque, wattage etc

a. Material of construction of the screw feeder:

Since the powder to be dispensed is corrosive one and it has a medical use, easily available materials like austenitic stainless steel and aluminium with special surface treatment were considered for screw feeder construction. Above mentioned materials are excellent

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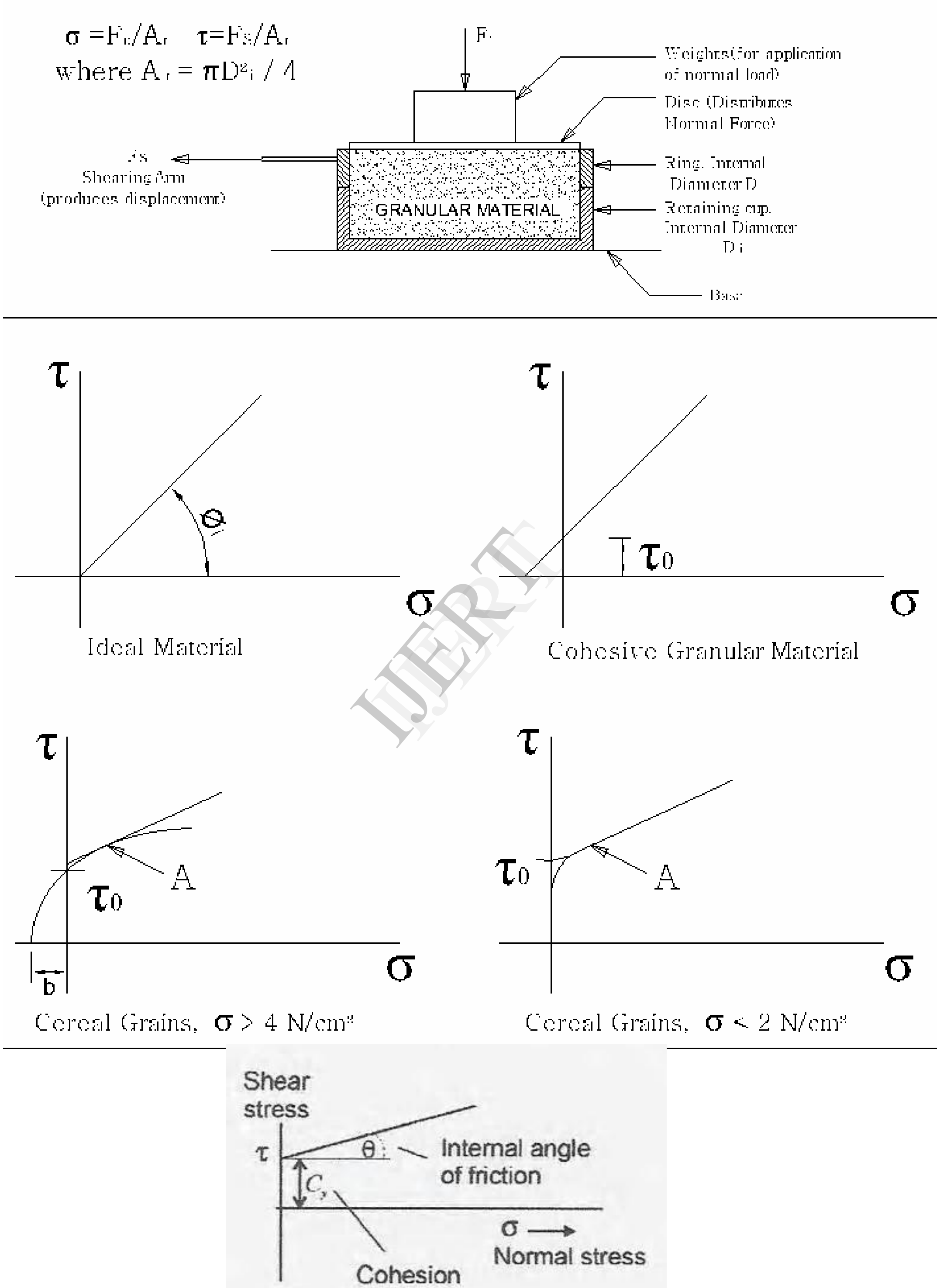

Fig. 18 Theory of internal angle of friction

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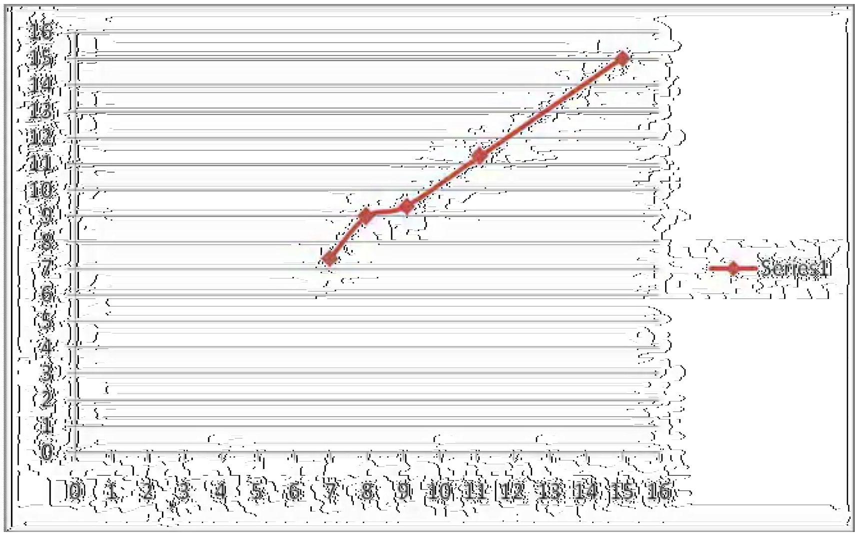
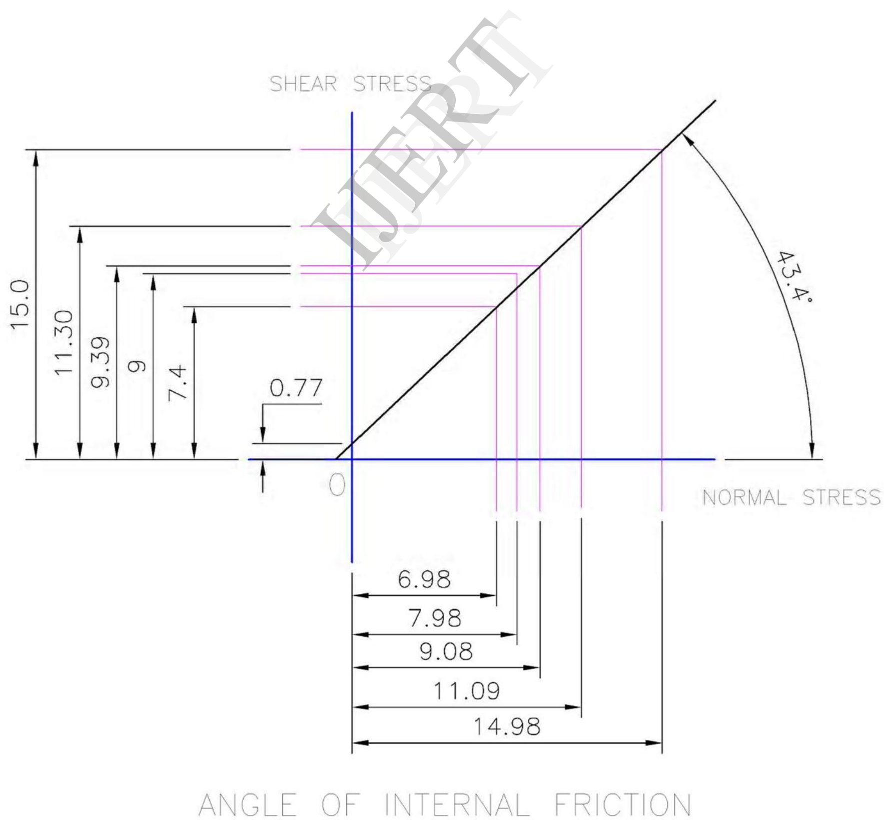


Fig. 19 INTERNAL ANGLE OF FRICTION, ϕ_i



ϕ_i= 43.4° , Therefore, μ_i= 0.949

Fig. 20

against corrosion. But due to lack of sulfur in the composition of the above mentioned stainless steels, it lacks desired machinability required to machine the screw. In case of aluminium, desired torsional stress put limitation of it's use. After rigorous hunt for the suitable material from the market, it was found that AISI303 is most suitable and easily available corrosion resistant and machinable material as compared to above mentioned ones.

b. **Screw pitch(fig. 21)**: Since the average diameter of the powder is 3mm, 5mm pitch was considered as most appropriate to carry the powder along. By considering the thickness of the screw flight ~1.5mm, the pitch of the fabricated screw has been fixed as 6.4mm.

c. Screw diameter(fig. 21): Similar to the pitch of the screw, the screw major diameter was selected on the basis of the average particle size i.e. 3mm diameter maximum. By using pitch and the screw core diameter, the screw diameter has been finalized as 17mm i.e. two times the pitch and 5mm core diameter.

d. **Length of the screw feeder (fig 21 and 22)**

Length of the screw feeder is based on the angle of repose of the powder of interest. During investigation, it was found that the angle of repose varies between 34º - 36º. By considering following dimensions like 34º angle, the screw diameter of 17mm, pitch of 6.5mm and full screw threads, the length of the screw feeder has been finalized as 51mm.

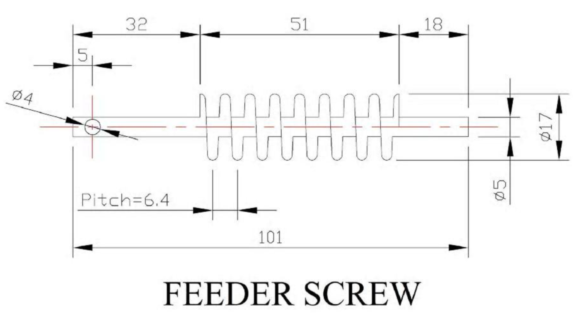


Fig. 21

e. **The entry and exit diameters of the powder dispenser (fig. 22):**

Entry diameter is 13mm and exit diameter is 9mm. Both the diameters were taken same as that of the existing volumetric feeder as it was designed depending upon the GC dimensions and the experiment on the powder flow through the hopper.

3.B.c.2 Designing the hopper

Hopper has following principle dimensions mainly the hopper side wall slope, maximum volume, exit diameter of the hopper, maximum diameter of the hopper etc.

For the free flowing solids like grains, the angle of repose of the material (slope of the crater) is greater than

$$\alpha > 45^{\circ} + \varphi/2$$

Where φ is internal friction of the material (in this case it is 43.4º)

Therefore, α shall be 66.7º. Even-though angle of repose does not give correct value of the hopper, the hopper side wall slope has been taken as 40º based on the result of the angle of repose and internal angle of friction.

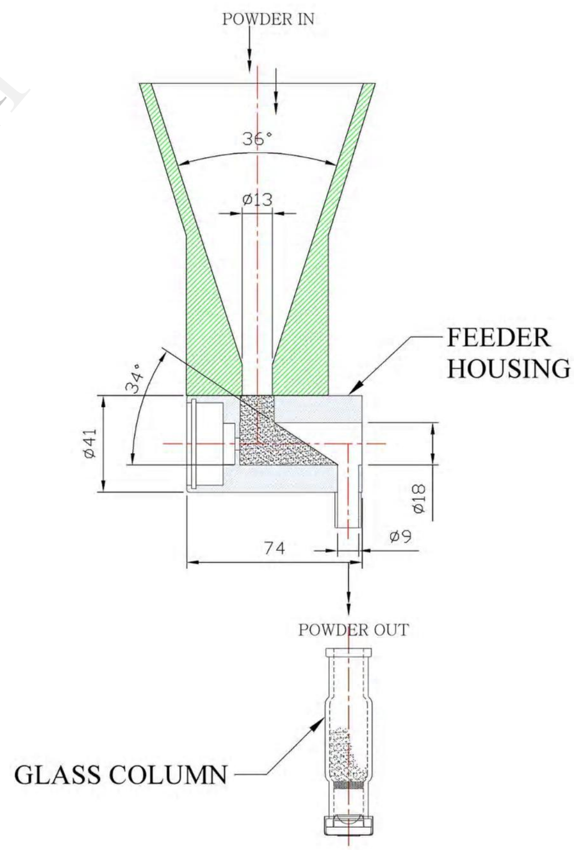


Fig. 22 Sectional view of the typical arrangement of the hopper, the powder , the spout of the dispenser and the GC.

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3.B.c.3 Selection of the motor for screw feeder: Selection of the motor for screw rotation has been done by calculating the torque required to rotate at 60RPM. To move the powder by the screw, passed by the hopper, towards the dispensing spout, the motor will experience the toque induced by the resistance of the powder to the screw rotation and to the translational motion and by the shaft end bearings. Both the resisting forces will induce torsional stress on the screw shaft. Initially shaft diameter has been taken as 5mm.

$T_m = T_{fsc} + T_{fcy} + T_b$

Tm – motor torque

Tfsc = torque due to friction between the powder and the screw surface

Tfcy – torque due to frictional resistance to translational movement of the powder at the surface of the screw casing

Tb – bearing torque

Considering all the factors, coefficient of friction between the stainless steel and the Zr-Mo powder, it has been found that required torque is less than 0.001N-m. For the powder dispenser under consideration, for 60RPM, most suitable DC motor available in the market was having rating 24VDC and 2A current. Core diameter of the screw found to be satisfying the design criteria.

3.B.c.4 Fabrication of the machine, installation, commissioning and testing:

Using above mentioned dimensions, engineering drawing for fabrication of the variable dispensing capacity screw feeder based powder dispenser (VDC SF based PD) was made. Machine was fabricated and tested to know the flow rate. During testing it was found that the machine hopper fails to transfer powder to the screw feeder due to formation of rat hole which happens basically due to moisture content and powder particle size. To avoid this failure, the hopper was redesigned to use a stirrer to break the powder mass. For this a small 12VDC, 30RPL motor was selected and a long pitch screw was designed. Figure 23 show the schematic of the designed machine and figure 24 shows the photograph of the fabricated and installed machine. Using this machine, tests on the flow rate of the powder was carried to reveal the behavior of the machine flow rate with respect to bulk density of the powder and plotting the same for standardization.

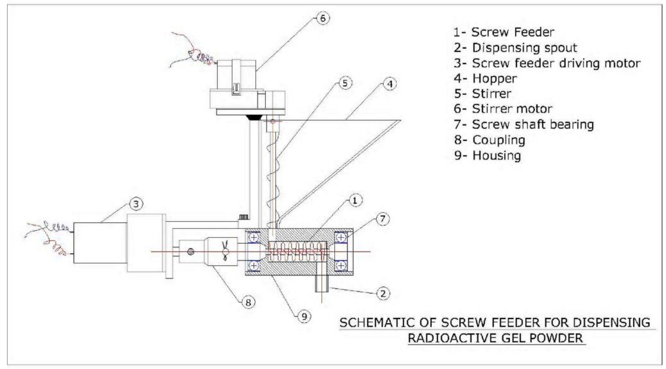

Fig. 23

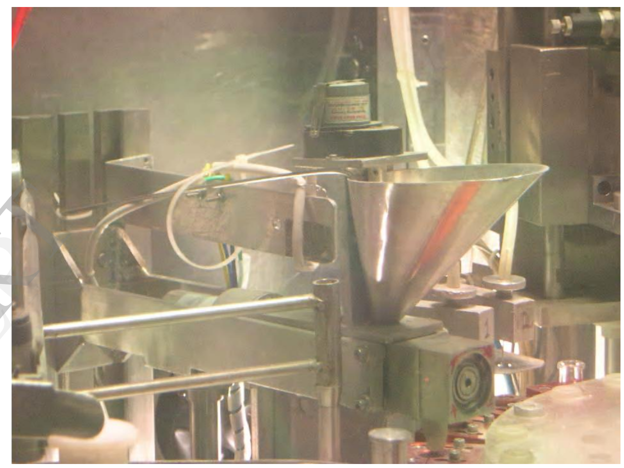

Fig. 24 Fabricated VDC SF based powder dispenser

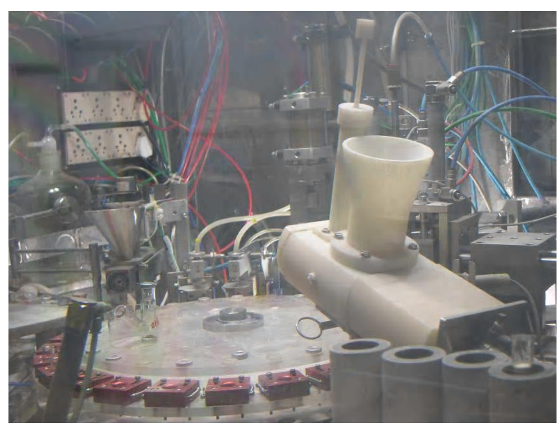

Fig. 25 Volumetric dispenser opposite to VDC SF based powder dispenser

During installation of the machine, for controlling the motor rotation, a timer has been used (installed in the

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control panel). Timer controls the mass flow of Zr-Mo powder to be delivered to the GC. The VDC SF based PD has been so designed and fabricated that it required minimum modifications in the existing facility. The machine was lifted and placed to the desired location in the existing system and synchronized. Designed and developed machine perfectly matched the limitations imposed at the beginning of the concept stage.

3.B.d. Study of the developed powder dispenser:

Powder dispenser, before installing into the STB for actual use, was tested for flow rate with respect to the bulk density of the powder. It was required to characterize the machine. Study obtained useful data regarding the behavior of machine with respect to the powder bulk density and gave useful plot to help the operator of the machine in operation. It was found that the bulk density controls the flow rate of the dispenser. Study on the flow rate was carried out by using the available samples of the Zr-Mo powder (see table-3). From the plot, it can be concluded that the flow rate vary between 0.2g/s to 0.22g/s. The average dispensing rate exhibited of the dispenser is 0.21 g/sec. This rate is as per the objective of the design. But since the powder is heterogeneous, as the particle size varies, flow rate also varies. Rotation of the screw feeder is controlled using a timer. From the graph (fig. 26 and 27) of bulk density against the flow rate, the operator selects the characteristic flow rate of the dispenser against the calculated bulk density of the produced Zr-Mo powder.

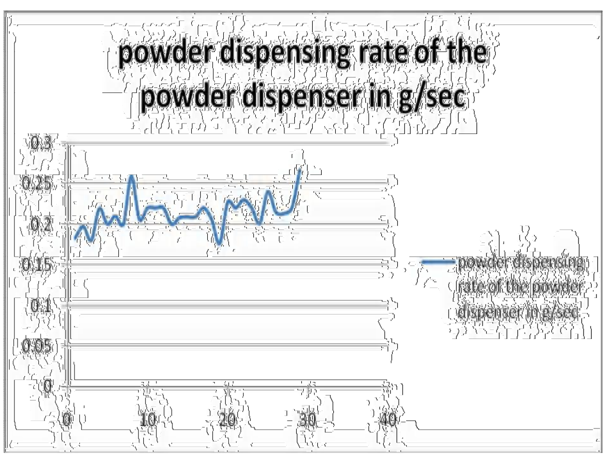

Fig. 26 Graph showing the flow rate exhibited by the VDC SF based powder dispenser

Operator then calculates the time to be set in the timer for continuing the dispenser rotating to deliver the mass of the powder correlated to the activity to be loaded. By this the operation of dispensing of the Zr-Mo powder as desired by the customer become easy.

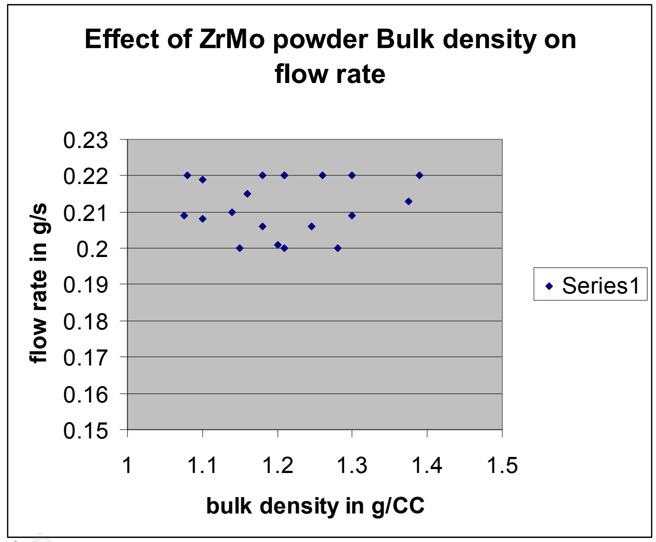

Fig. 27 Variation of the flow rate of the powder dispenser with bulk density

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III.C. Results

In order to design a versatile powder dispenser which can dispense the powder in small volumes which in turn can be correlated with the powder's bulk density, a classical approach of design was adopted. Design was totally under the influence of the constraints imposed by the existing facility. This approach involved

1. Market survey, where in study of at least 8 successful concepts was done. Based on the desired characteristics most appropriate one i.e. the screw feeder based powder dispenser was selected.

2. Designing of the screw feeder based powder dispenser and fabricating the desired powder dispenser- in this case, while designing the dispenser, knowledge of powder properties was required. Since the powder is unique in nature, published data base failed to give any direct information about the same. Since the powder of interest is having special characteristics, the design of the dispenser was not possible without knowing the minimum desired properties of the Zr-Mo powder like bulk density, angle of repose, shear strength, coefficient of friction etc. In order to overcome these constrain and since the Zr-Mo powder is radioactive in nature, powder was tested by developing required testing machines. Machines for testing the powder were designed based on the design and purpose of the standard machines available in the market.

Table 3
Flow rate of the screw feeder based powder dispenser for different bulk densities of the ZrMo powder

Bulk density of the Zr-Mo powder, g/CC	Powder dispenser flow rate; g/s
1.1	0.219
1.15	0.2
1.14	0.21
1.21	0.2
1.245	0.206
1.3	0.22
1.08	0.22
1.39	0.22
1.28	0.2
1.1	0.208
1.075	0.209
1.3	0.209
1.26	0.22
1.18	0.206
1.21	0.22
1.21	0.22
1.2	0.201
1.16	0.215
1.375	0.213
1.18	0.22

Since the objective of the knowing of the powder properties was general in nature, design and fabrication of the same was general purpose only meeting bare minimum requirement. Tests on the available Zr-Mo powder were conducted inside the approved STB. Tests unfold the powder properties like angle of repose, bulk density, internal angle of friction, co-efficient of friction between the powder and the hopper material like stainless steel, UHMWPE, powder shear stress etc. Using these properties and the general design principles, machine was designed. Designed machine was fabricated and tested. Testing of the machines was done to know the behavior of the machine i.e. the flow rate with respect to the powder bulk density. Machine finally has been commissioned and is in use. Most of the constraints in developing the desired powder dispenser have been satisfied.

3.D. Discussion

For designing the powder dispenser, market survey step found to be useful to eliminate the unsuitable mechanisms required for designing the desired powder dispenser. Past experience of designing the powder dispensers also helped in eliminating the unsuitable mechanisms. The screw feeder based powder dispenser needed unknown properties of the Zr-Mo powder to get unfolded to design it. Accordingly, due to limitations related to handling of the radioactive powder, the gadgets were designed to know the least desired properties. Four gadgets were designed and powder properties were found out. Based on the test results, the principle components like hopper, screw dimensions like pitch, diameter, motor rating etc were finalized. The designed machine fabricated for testing the results. The machine found to be functioning as desired i.e. dispensing rate of 0.2g/s. also, the machine which was supposed to be with full delivery proved to be delivering more than 99% powder to the destination (<1% fines). Machine has been so designed that it need not be fixed to the parent assembly line for production of the GC filled with Zr-Mo powder. It can easily be lifted and place at desired location.

As a step to improve the dispenser and since the powder is free flowing, there is need to remove the extra motor used for disturbing the powder bed. It will be done by studying the flow characteristic of the dispenser for different hopper angles while passing the Zr-Mo powder having different bulk density. Based on the result, most appropriate will be selected. In case of failure of the motor driving the screw when the hopper is holding the Zr-Mo powder, machine will have to be designed for retrieving the same.

3.E. Summary and Conclusions

A versatile, variable dispensing capacity screw feeder based powder dispenser has been designed and successfully deployed at the Geltech generator facility of the BRIT at Vashi complex. It has given the delivery rate of 0.21g/s which will help in controlling the mass of the powder dispensed in the glass column or tube by controlling it using the timer. As desired, the machine has been designed for maintainability and operation. By following the constraints imposed by the existing facility, the developed machine is ergonomically superior.

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IJERT

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