A. Suction pump:- To separate MR fluid and Debris there is a suction tube which is attached below the honey comb mesh plate . Once the suction tube is attached, air is released into the tube and suction mechanism is activated (as done in space toilets). MR-fluid which has been separated is moved back to the MR-fluid tank.

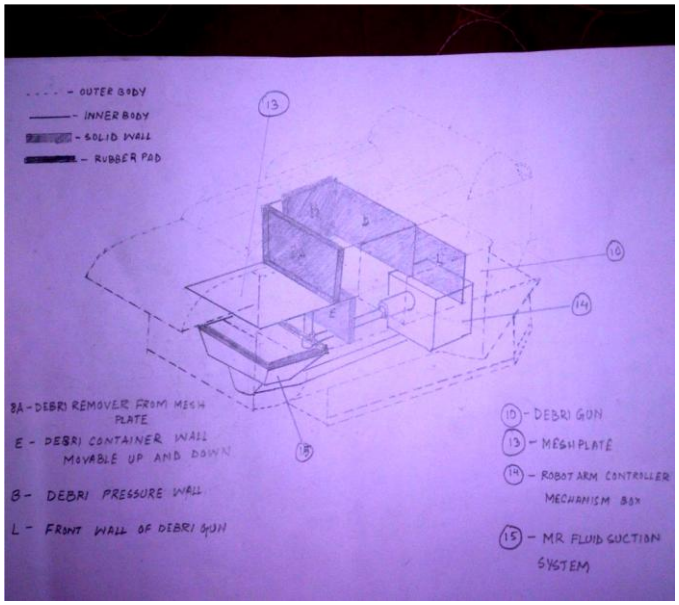

Fig 4: internal compression and ejection system

B.Sweeping Piston - The mesh plate moves up, from the suction tube. The plate is brought just beneath the surface of the sweeping piston. The sweeping piston is a slow moving piston over the honey comb mesh plate. The piston sweeps the area and all the debris are moved by the opening of the door of the compression box. The total mass of the debris is estimated by the mass flow sensor. Assuming the maximum amount of mass is of aluminium . Limited amount of mass flows into the compression box as shown-

Atomic radius of atom of a Al	= 118pm
Volume of 1 atom	= $(4/3)*л*r^3 = 6.9*10^{-30}$
Maximum volume of cube formed	= $125*10^{-6}$ m^3
Number of atoms in maximum volume	= $18.1*10^{24}$
$6.023*10^{23}$ atoms are in	= 27 grams of Al
Mass of the cube	= **811 grams**

As the mass of the debris reaches 811 grams (data got by mass flow sensor) the sweeping piston stops. The door to the compression box(8A in fig 3) gets closed by receiving the information from the on- board computer.

C.Compression box- The required amount (as discussed above) of debris is collected in this box. By maintaining the compression piston at an optimum pressure and a high temperature in the compression box of about 300º C the aluminium particles are softened. The helium gas is used to produce required pressure for compression. This type of fusing is known as thermo-compression. The aluminium particles along with other debris particles are heterogeneously fused and are further sent to the debris gun.

D.Debris gun- The fused cubical block of aluminium reaches the debris gun box. The debris gun launches the block towards the earth with a minimum trajectory. The speed given to the block is provided by the expansion of the gas behind the piston. The block is launched in the opposite direction as a result its velocity is decreased. But due to lack of enough speed for the orbit to counter balance gravitational force, it is pulled down by the gravity of earth.

Energy stored in the cube

$g = (G M_e / (Re + h)^2)$

Mass of earth (M_e) =5.97 *1024 Kg

Radius of earth (R_e) = 6400 Km

g_{750}= 7.79 m/sec^2

g_{100}=9.51 m/sec^2

Energy at 750 km= $mg_1h_1 + (mv_1^2)/2$---------- (1)

Energy at 100 km= $mg_2h_2 + (mv_2^2)/2$---------- (2)

Equating (1) & (2)

V_2= **5.08 Km/sec**

There is an increase in the speed, but this speed is not enough for the block to revolve in any other orbit, so it is pulled by the earth's gravity, following minimum trajectory.

Launching speed = 4 km/sec

To reach earth the block has to follow minimum trajectory. By approaching this speed it can have a minimum trajectory

Mass of the block	= 0.811 Kg
Impact Force required	= 0811* 4000 =3244N
Pressure created behind the piston= F/a	=3244/($25*10^{-4}$)= 12.9 bar
No. of moles	= 3.23 moles

Number of moles	= $PV/R_{He}T$ = 19.39 moles
Density of helium	= P/RT = 25859 Kg/m^3

Change in momentum along the pipe is given by-

$P_1 + p_1 (u_1)^2 = P_2 + p_2 (u_2)^2$

$u_1 = 0$; $P_2 \approx 0$

u_2	= 31.07 m/sec
Radius of the connecting pipe	= 0.5 cm
Mass flow	= pAu_2 =60.07 Kg/sec

Thus the time for which the knob is opened = 14.5 sec

VII. Materials Used

The inner and outer parts of the satellite are being insulated by MLI (multi layered insulation) material which consists of light weight reflective films assembled in many thin layers. These layers are typically made up of polyimide or polyester films (according to design could be from 5 to50 sheets) that are vapor deposited with 99.99% alumunium, on one or both sides. For sweeping piston carbon-carbon piston are to be used because of its more reliability and high resistance to structural damage caused by overheating. The internal structure of the compression system will be made up of carbon-carbon material because of its more reliability from structural deformation and high resistance to structural damage caused by overheating (this compression system consists of both the compression box and the compression piston. The helium tank will be insulated with MLI (multi layered insulation) for maintaining its temperature at 4K.

Mesh plate material would be a composite with high thermal conductivity for maintaining the working temperature of the MR fluid and must get magnetized on application of magnetic field(TBC).

VIII. Mass of MR-liquid carried

Amount of MR-liquid used once= volume* 1000[convert m^3 to liters.]
Volume = 1.5m*1.5m*0.02m [length of mesh*breath of mesh*thickness of fluid] = 0.045m^3
Amount of MR-liquid used once = 45 litters.

As on repeated use MR-liquid starts to lose its properties it can only be used 5 times hence to capture debris 100 times amount of liquid required are 900 litters.

Conclusion

The mechanism used in Astro-maid is one of it kinds, it uses themocompression-bonding to fuse debris. Astro-maid uses MR-fluid which can be used 5 times at most. It can clean 1mm-100mm size debris. OMS system is used for easy maneuverability Astro-maid uses earth's gravitation field to remove debris. Astro-maid uses impulse created by debris gun to regain its orbital velocity which was reduced to capture debris. Minimum debris mass that can be removed is 81.1 kg in one time i.e. without changing MR- fluid which gets spoiled with 5 times usage. As a result the space debris are removed from space.

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