26 June 1985

Dear Henry

A disclosure of sorts that was submitted to the NASA patent attorney is enclosed. If you see something you don't understand or like, call me before you fly off the handle (otherwise someone might accuse you of behaving like Thornton).

We need to move on this—

H. T.

U.S. Government
MEMORANDUM

Lyndon B. Johnson Space Center NASA

REFER TO: CB-85-218	DATE June 25, 1985	INITIATOR CB/WEThornton:ms:6/25/85:3721	ENCL 1

TO: AL3/E. K. Fein

CC CB/J. W. Young

FROM: CB/W. E. Thornton

SIGNATURE W. Thornton
W. E. Thornton

SUBJ: Waste Collection Devices Disclosure

This took me a weekend and is the best I can do under the circumstances. I cannot write about it and build it at the same time; and, as you may know, there is a crash program to get something that works.

Apropos our conversation, the fecal portion of this is very much a joint invention of myself and Mr. Henry Whitmore. If it seems appropriate, the urine apparatus could be separated from the fecal. I developed a series of initial concepts including the critical flow urinal, bags for feces, etc., during and after flight of SL-3 and went through them on a give-and-take session with Henry by phone and further chewed them over with him when he came through on vacation. We worked separately on them until he returned from vacation, and we continued to refine them. Finally on June 13, we had about 2 hours on the phone when we agreed this approach was most likely to proceed and at that time jointly went through all aspects of the problem, devising practical solutions to them. I do not know of anyone else I could have done this with, and it is a result of more than 20 years of technical collaboration* and Henry's genius for practical working mechanisms to turn thought into practice. In any event, he was not under contract nor being remunerated in any way; hence, this should be a joint application. He will undoubtedly contribute additional ideas as this is translated into practice, and any future rights will depend on the situation.

At the same time, some of the ideas have emergency application to patch up existing designs, and I, of course shared them with the WCS committee. In some cases, the major contractors have been directed to explore them, e.g., the positive pressure jet. For this and other reasons, we should document who had what and when.

My notebook and notes have some of the record and, in particular, my N.B. 1985-II has the fecal collector transcribed immediately after our June 13 conversation. I will put the enclosed into whatever format is required when time allows, but it seems pertinent to document a few ideas, for the contractors that have controlled this for 10 years have made megabucks and won't welcome any change that they don't control.

N.B. Last week Tom Grubbs, an engineer working on the committee, came up with another urinal design based on critical flow which may be even better, but only testing will prove the value of any concept or design.

*I have no financial interest in his efforts, and indeed our development efforts have often cost both of us, e.g., the prototype treadmill, tonometer, etc.

Disclosure of Improvements for Waste Collection Systems for Space Flight

Problem: While there may never be a completely satisfactory method for collection of urine and fecal wastes in weightlessness, systems to date have had a series of recurring problems which render them unsatisfactory, including: backup of urine, retention of urine on subjects, retention of urine on collectors, questions of clean up and hygiene of the collectors, separation of fecal bolus, interference of waste with defecation, fecal contamination, difficulty with hygiene, difficulty with maintenance of hardware, turnaround time and expense, and others.
The number of proposed approaches, both theoretical and experimental, has been too great to describe here but such efforts will be described if pertinent in proposed solutions.

Overview: Urine and fecal collection might be treated separately, but there are also areas of commonality, as will be seen.

Urine Handling: There is no transport of liquid (as by gravity and water on earth) and air streams are substituted for such transport. An associated problem is removal of urine from surfaces.

Several situations are of concern in urine handling, including: Collection (body/machine interface), which should include removal of residual urine from the body, transport of urine both in the air and along conduits in a form of droplets to globules and removal of urine from collector and other surfaces.

From a theoretical viewpoint, these may be viewed as three cases:

1. Transport of fluid by an airstream - The practical considerations are that particles with appreciable velocity as in a splash from a stream, must be entrapped and that transport is rapid enough to prevent coalescence and cessation of air flow or "back up." (Fig. 1-A)

2. The second situation is movement of fluid attached to an extended surface such as the wall of a conduit. (Fig. 1-B)

3. Finally, there is need to strip fluid from a variety of surfaces and transport it by air, e.g., removal of residual urine from the body. (Fig. 1-C)

Theoretical treatments which cover these situations ~~which~~ to varying degrees are available. In general, at the velocities here, the force on fluids is proportional to some power of velocity, typically the square, e.g., $F \propto V^2$ where V = velocity and F = force; hence, the effects can change drastically with relatively small changes in velocity. In addition, in the case of fluids attached to solid surfaces there are critical velocities below which no action occurs, e.g., below a "Weber number" of 3 no separation occurs.

The quantity of concern in air pumping is usually volume $\cdot$ time^{-1}, e.g., ft.^{3} min^{-1} and this is held constant in so far as possible. Velocity then becomes a function of the area of the orifice or conduit through which the volume passes; hence, effects of air at a given flow are proportional to the reciprocal of area squared and to (See Fig. 2) the square of flow rate. Although not rigorously demonstrated in weightlessness, simple demonstrations on SL-3 are in qualitative accord with this elemental theory; hence, the following improvements are made from this flight experience taken in conjunction with theory.

The existing collector is a flattened cone whose entrance is large and connected at its exit to a small conduit with a modest velocity, capable of transport of most urine streams. The flow profile of such a device is shown in Fig. 3. The practical effect is that unless the urinary stream is rapid and well directed, globules can form and when they finally reach the conduit may "choke" air flow, causing even more backup. Other problems are that globules may adhere to the person and/or collector walls. It is also inevitable that drops and globules are spread on the collector walls and only those close to the exit, in the region of adequate velocities, are removed. The rest must be wiped manually. This same type of collector system, sometimes with devices to direct the incoming air, is used with females but the same problems are, if anything, more severe. In an apparent attempt to increase flow and reduce splash, a cover with a circular opening has been tried for males, but this frequently compounds the problem with urine backflowing under this cover which causes an increased clean up problem. The hygienic aspects of this entire problem should be obvious for a common collector is used for the entire crew. One other unsuccessful modification has been the addition of a second tube with increased air flow with a small inlet near the collector inlet. This will supposedly remove adherent urine from the male but in weightlessness does not unless actual contact is made and then incompletely.

As a first step to solution of these problems, the following is offered. The collector must maintain an air velocity which exceeds the critical flow requirements such as Weber number and maximum urine flow at all times. To do this for a given flow, the collector area is maintained below the minimum cross section required to maintain adequate air velocity. Custom fitting is not acceptable but the sizing may be controlled in a general way and most importantly the role of anatomy is accounted for. Such a "critical velocity" collector is shown schematically for males in Fig. 4 and females in Fig. 5. The crucial point is that areas and flow velocities are maintained below and above their critical values respectively. Some accommodation may be necessary for uncircumcised males. To prevent uncontrolled wall contact and stagnation, snubbers are provided to control male position in this collector. These collectors would be inexpensive molded units which would allow individual use. Current units are complex metal fabricated items costing thousands of dollars. Further, the proposed devices would have simple press fits into the collector tube to avoid the complexity and cost of current fittings and ease of interchange.

If additional aid is needed in removing residual urine from either male or female, transient directed jets of positive pressure air (relative to ambient) may be used to achieve separation (Fig. 6) or alternatively directed ultrasound (Fig. 7) can be employed to overcome adhesion forces which are much greater than those required for transport.

<u>Fecal Collection & Storage</u>: While we take for granted the collection and disposition of fecal wastes on earth, in the absence of gravity and large amounts of water, it becomes a problem of surprising complexity. The attempts and failures to date are too extensive to describe; rather, a listing of the major problems and a method of solution is given.
Problems include man/machine interface, fecal collection, transport & stowage (or processing), hygiene (including odor and gases) individual cleaning, and

maintenance. Rather than treat these separately, the proposed solutions to the various problems will be presented as features of the apparatus.

The basic apparatus is shown in Figs. 8 and 9 and its major features include a closed collection chamber, for illustration shown as a cylinder, with a piston which may be progressively moved from a stowed position, past a means of putting a new sheet of material on the face of the piston, past an inlet orifice which may be opened for use and through the length of the container sweeping all material in the container before it until compressed material from previous operations covered by the sheet material are encountered. At this point appreciable force is applied and held, compressing all waste material and spreading fecal material throughout waste paper and into permeable portions of the piston face sheets. For usage the piston is withdrawn into its initial position, a slide port under the seat is opened, and the air pump is started which applies negative pressure to a manifold surrounding a portion of the chamber and positive pressure to a second manifold in the seat. Defecation is carried out in the usual fashion except that urine will be collected and handled separately and the subject may be restrained to the seat by conventional means such as thigh bars, etc., or by elastic shoulder straps (not previously used). After defecation toilet paper or impregnated wipes may be used for cleaning and deposition in the collection chamber. At the end of this operation, the air is stopped, the port closed and the piston cycle to the storage end is initiated.

A number of features which are felt to be novel and which solve various problems are described in detail.

Fecal Separation and Waste Containment: In the absence of gravity relatively small adhesive forces can cause fecal material to adhere to the subject. This problem becomes worse with increasing fluid content (Fig. 10). Other very real problems in separation are mechanical interference from other fecal material (Fig. 11) or the entrainment tube used in the current Shuttle and from partially closed buttocks. These problems are addressed as follows. The seat itself will be contoured to spread the buttocks insofar as possible and the area beneath the seat will be opened sufficiently to avoid interference from misalignment and will be clear of obstructions such as the tube. The volume below the opening will be positively swept clean to avoid interference. It is recognized that all conditions of feces and defecations cannot be covered by machine operation just as on earth. Conversely, the following devices will aid in removal. Firstly, there will always be a positive flow of air into the chamber by virtue of the negative pressure transmitted to the chamber through the small orifices in the chamber beneath the negative pressure manifold which is maintained by the pump whose output is filtered and returned to the cabin. This will preclude escape of material or odors into the cabin. A second pumped loop provides positive pressure air to a manifold with directed nozzles which produce high velocity discrete jets onto fecal material. In addition, these jets may be programmed to produce sharp bursts of pressure and/or pressure from single directions to produce torques on a bolus for severance.

Unique to the design is facing of the piston with a replaceable sheet which not only prevents fecal contamination of the piston face but also ensures that no fecal or other material can return to the use area. Further, the sheet may be impregnated with a variety of materials such as antiseptics to prevent or control microbiological action or adhesives to aid compaction, etc. Placing this sheet will require considerable mechanical coordination which includes transport of the sheet from storage, registration, preflight preparation of the sheet for easy separation, registration of the sheet on the piston face, and clean separation of the sheet from piston onto the compacted waste mass. These features might include those shown in Fig. 12. The long sheet may be composed of an impermeable hydrophobic backing on the piston face side, with attached layers of absorbent paper treated as required. It will have reinforcing strips on each edge which contain means for accurate registration of a pre-perforated area corresponding to the piston face. If required the face will contain means for sheet retention such as small points or small orifices to conduct either positive or negative pressures to develop forces to retain or remove the facing as required. Operation of this facing function is as follows. Prior to piston travel through the sheet plane, a fresh area will be automatically drawn into exact position by mechanical means and secured. The piston will advance through the selected area of the sheet and carry the removed portion which completely covers its face. Any feces, waste paper or other material will be carried to the face of the previously compacted mass where it will be compacted into a mass with the fecal material acting as adhesive which will be spread more or less thinly between the sheets and into any other permeable material such as waste paper. Should further retention of this mass to the ends and walls of the container be required, automatic means for inserting transverse mechanical elements into the mass as the piston is withdrawn will be employed.

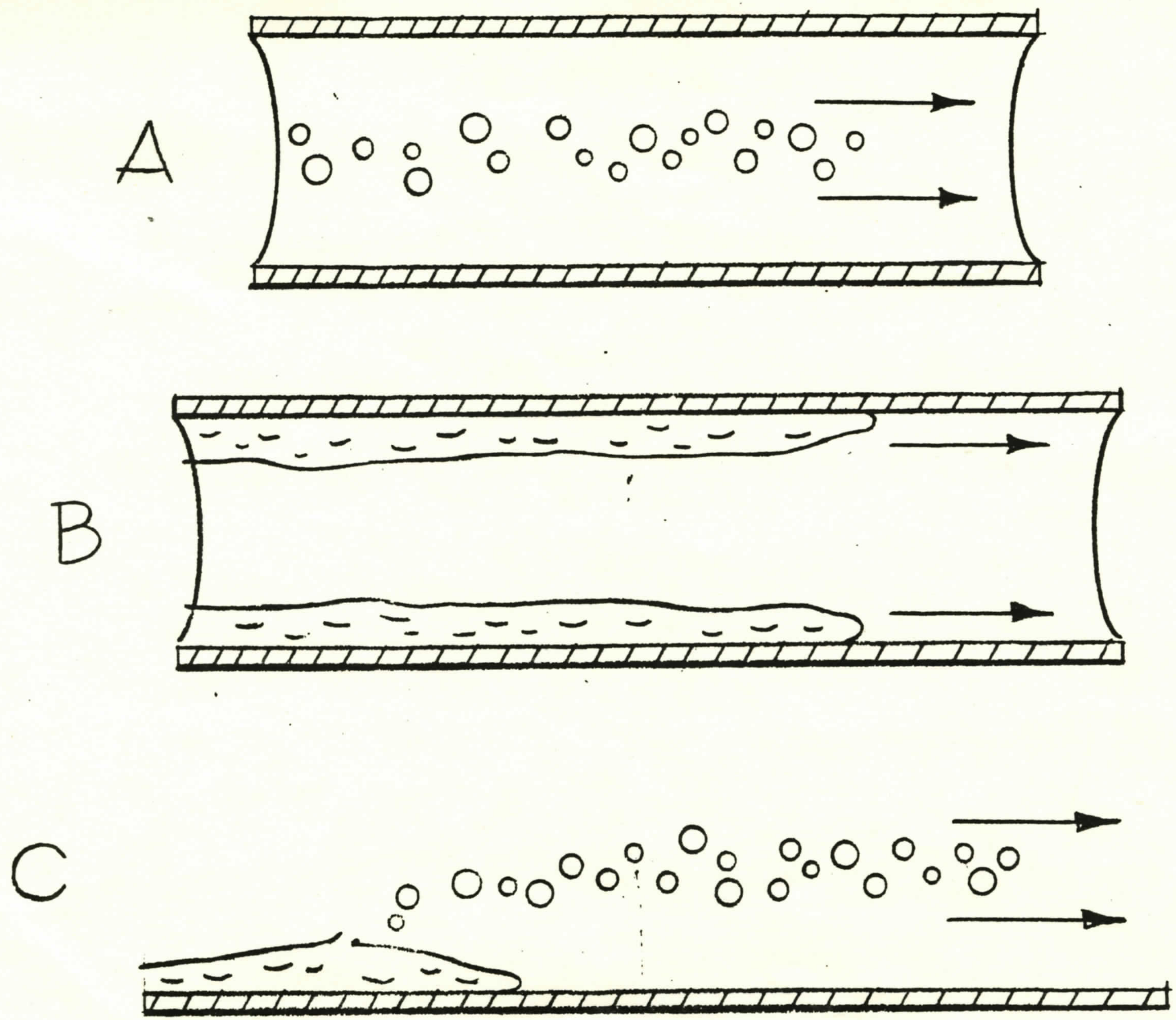
Piston

Positively Controlled Stowage: The continued pressure of the piston will ensure the location of all wastes in a desired area. Although the cylinder can be built for exposure of the interior to vacuum, this is not felt to be necessary and only a small controlled negative pressure is planned to remove any evolved gases, etc., if indeed this is required. Should full vacuum be considered necessary, the design can accommodate it.

Other features: Means for automatic removal of material from the negative pressure orifices will be provided to eliminate any problem with pumps, lines, etc.

The design by its nature will tolerate a wide variety of materials unlike current designs. It lends itself to scaling up or down as required for a variety of missions including future designs and to simple servicing and maintenance, e.g., the stowage section and sheet dispenser could be replaced in situ and immediately reflown. Unlike the existing pressure vessel designs with a single small access port, virtually unlimited access may be easily obtained. Further, the design will be modular in nature such that it can be maintained in situ. Although the various operations will be automatic, there will be manual overrides for any contingency such as loss of piston drive. The design is inherently fail safe and taking the worst case--a piston jam, it will then revert to the same mode as normal operation of the present Shuttle.

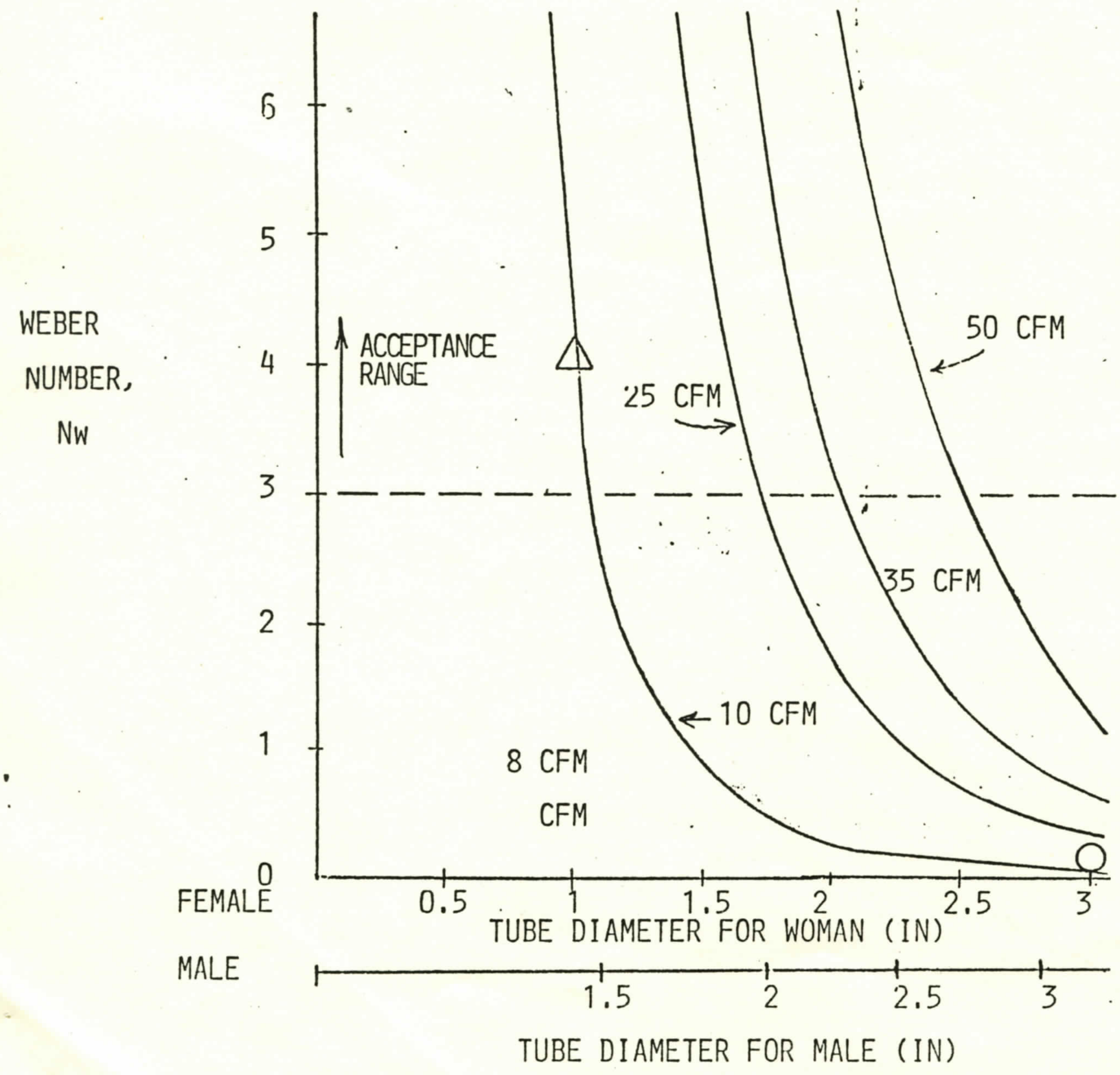
Figures


A
B
C

LIQUID SEPARATION FROM WALL SENSITIVITY TO AIR FLOW AND TUBE DIAMETER

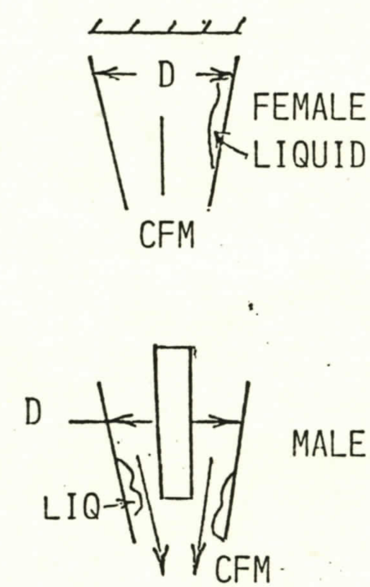
Fig-2

$$N_W = \frac{\rho_L V^2_{AIR} \delta}{\sigma} = \frac{C \rho_L \dot{V}^2 \delta}{D^4 \sigma}$$



$\dot{V}$ - VOLUMETRIC FLOW

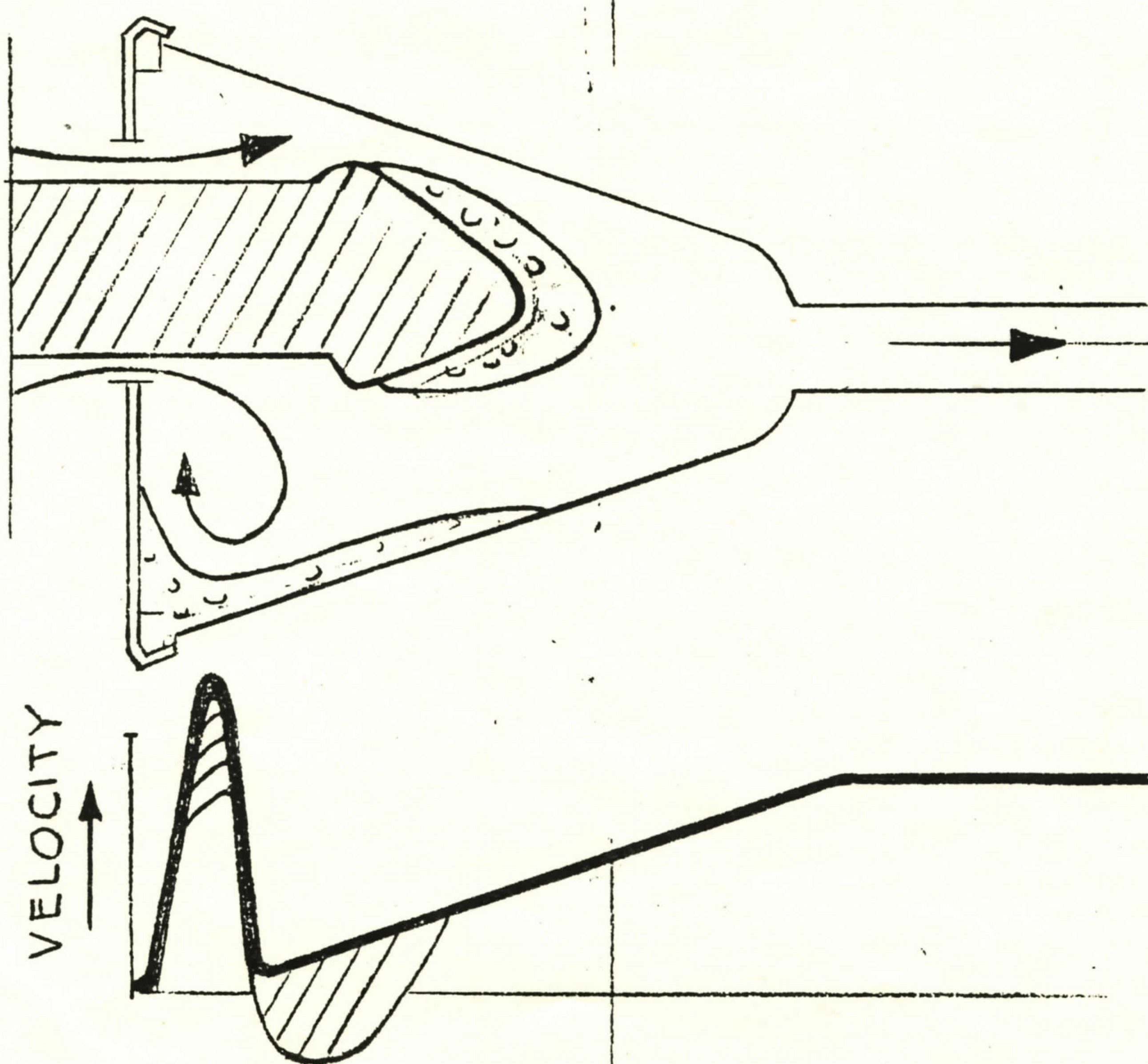
D - CHARACTERISTIC DIAMETER



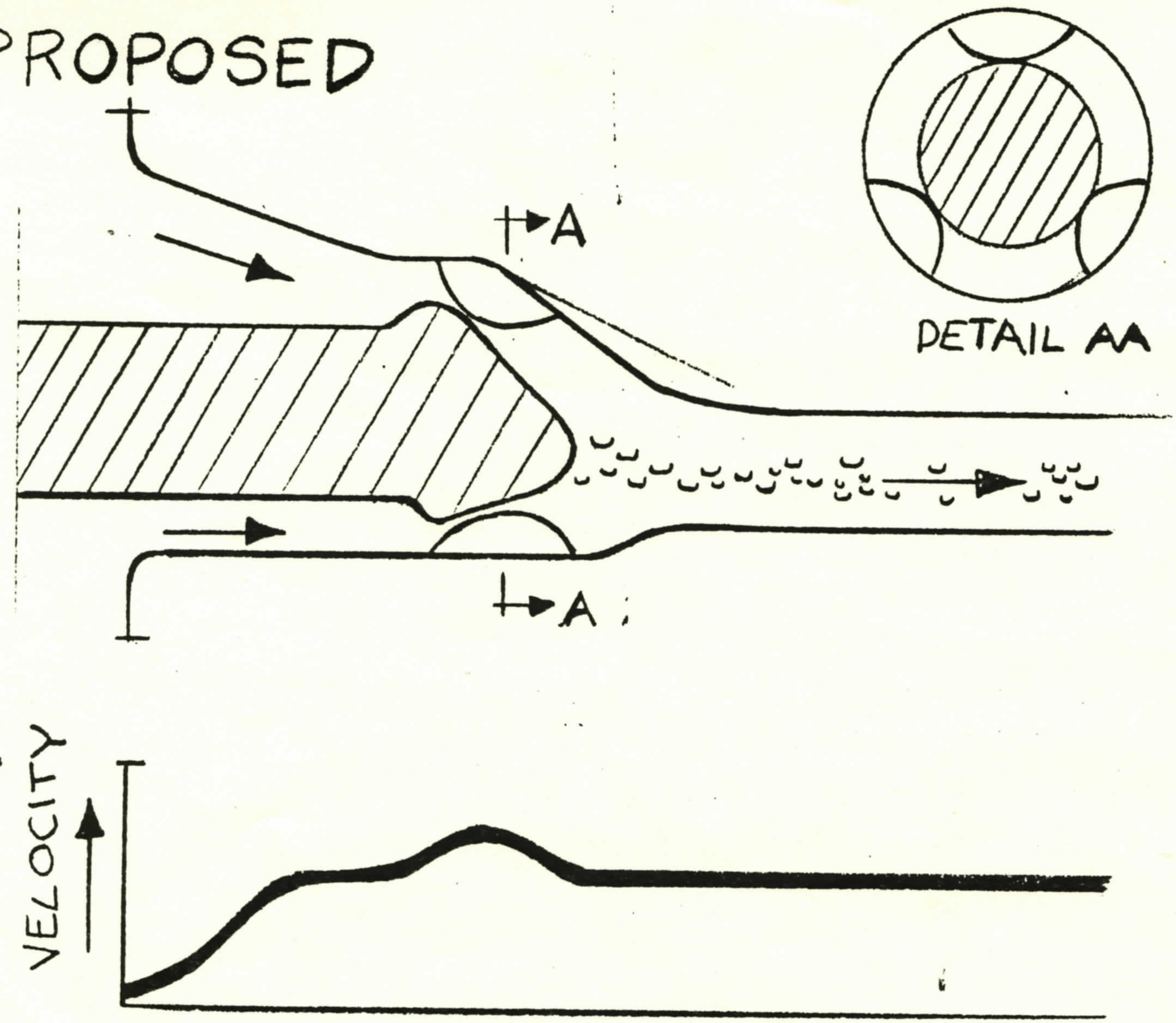
△ - PIPE WALL

○ - COLLECTOR WALL

PRESENT



PROPOSED



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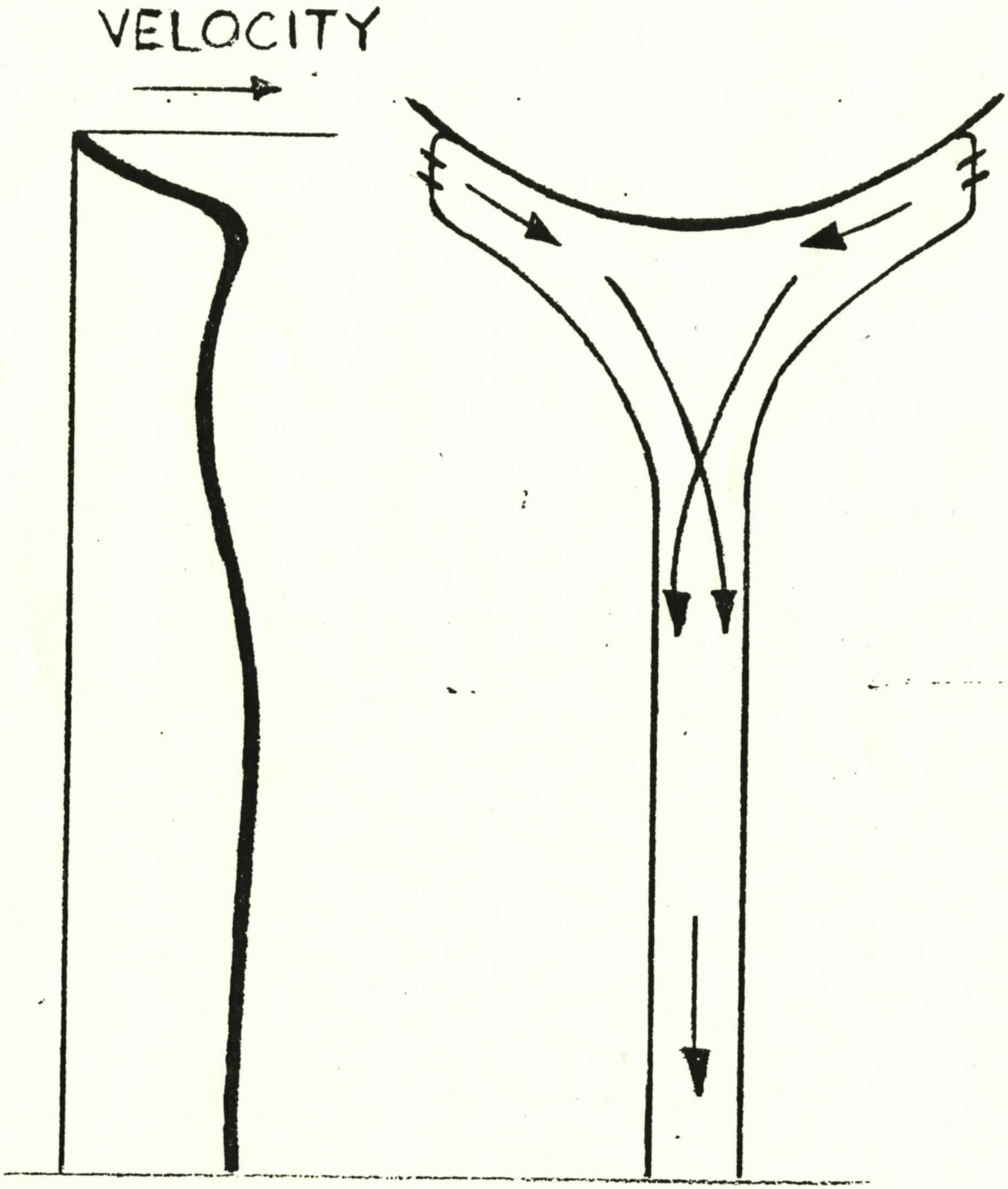
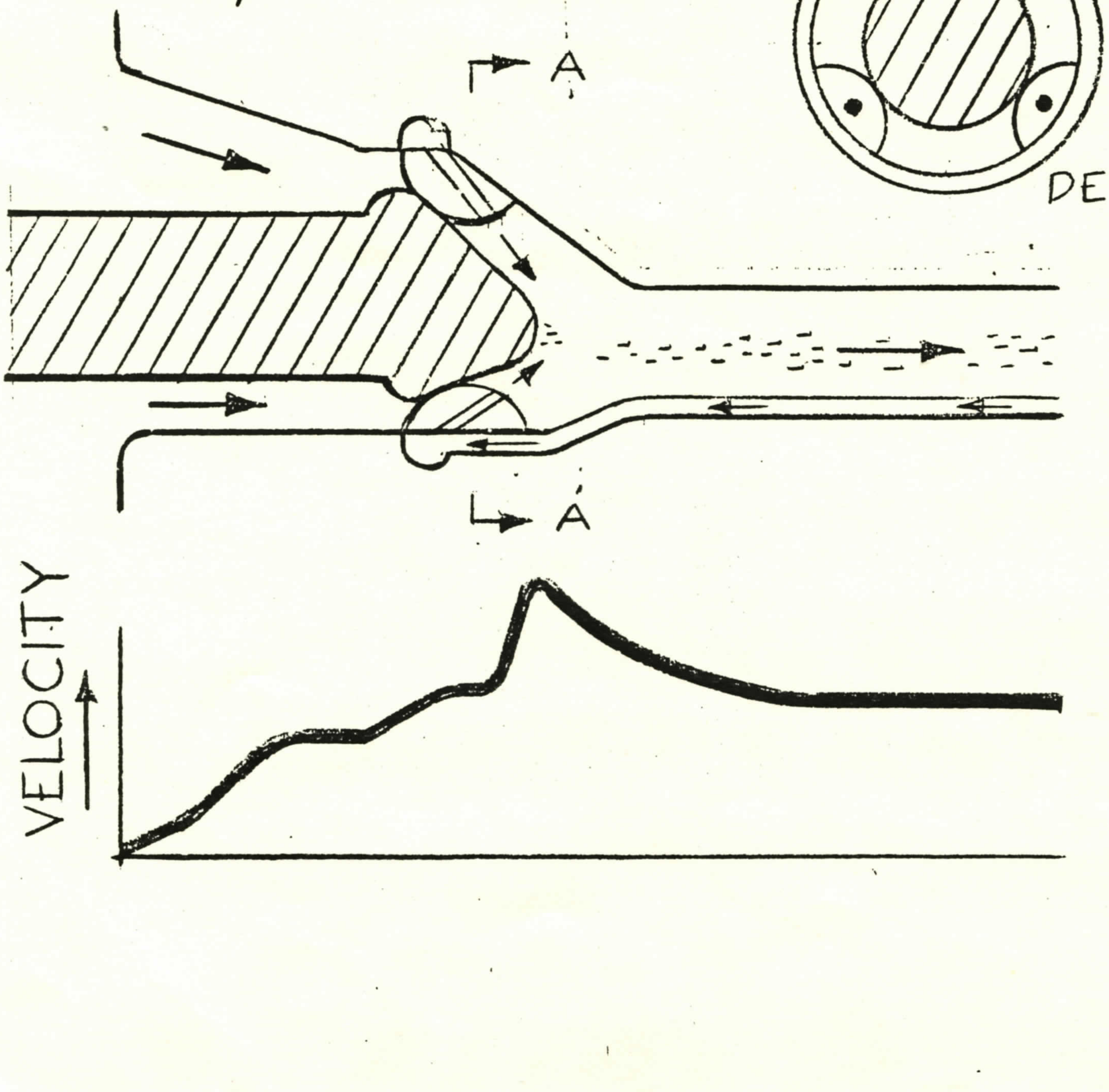
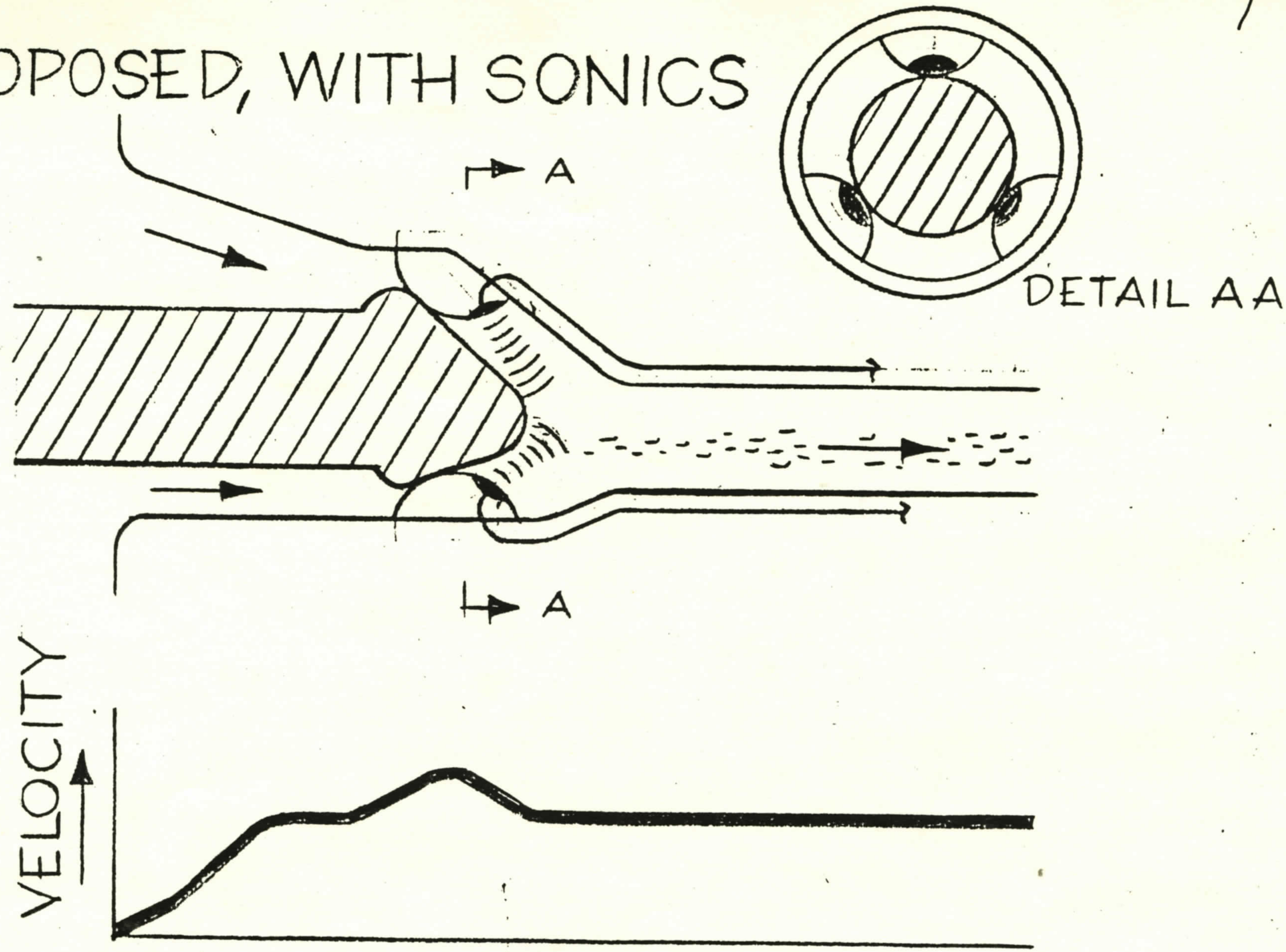


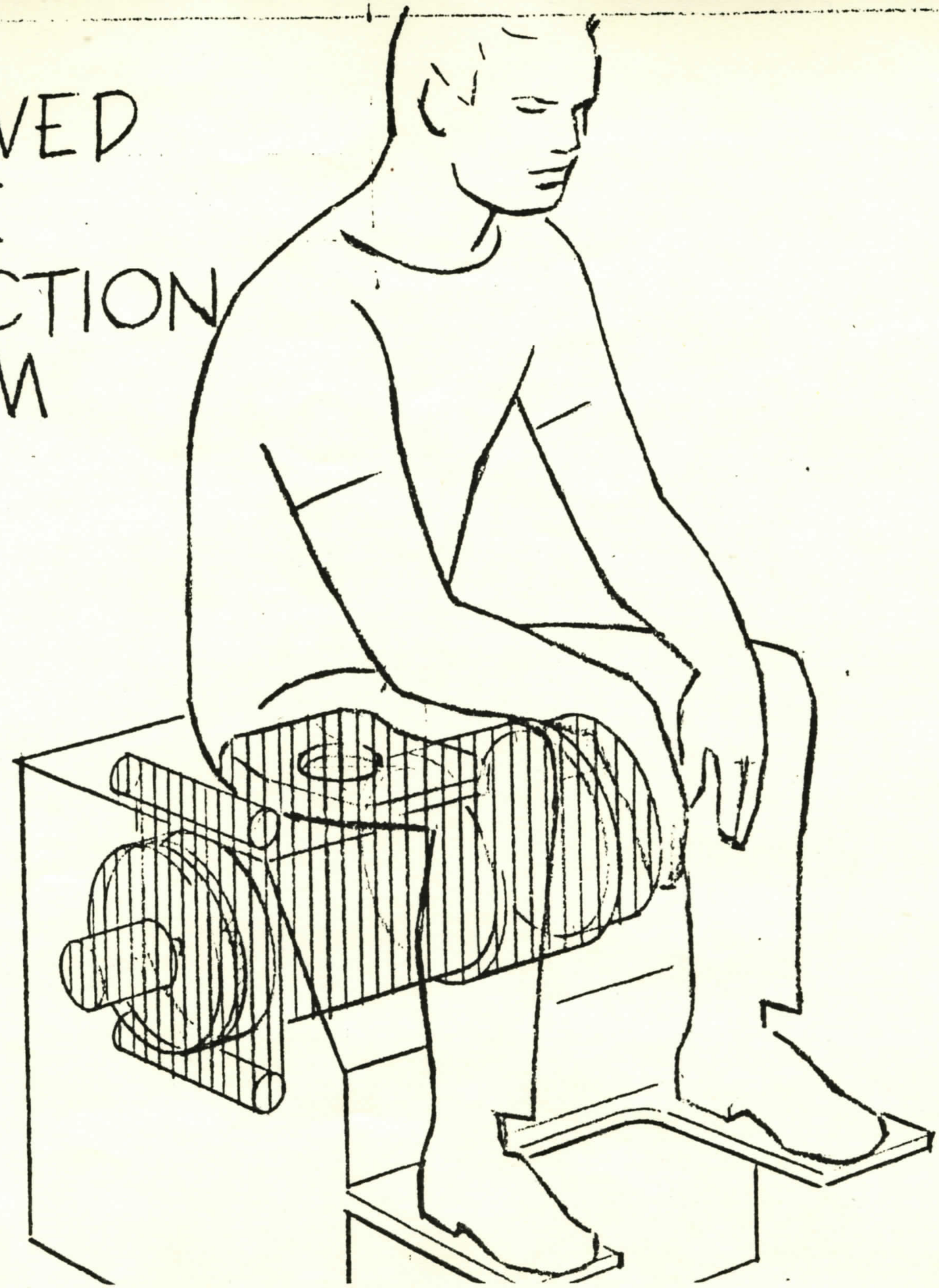
PROPOSED, WITH JET



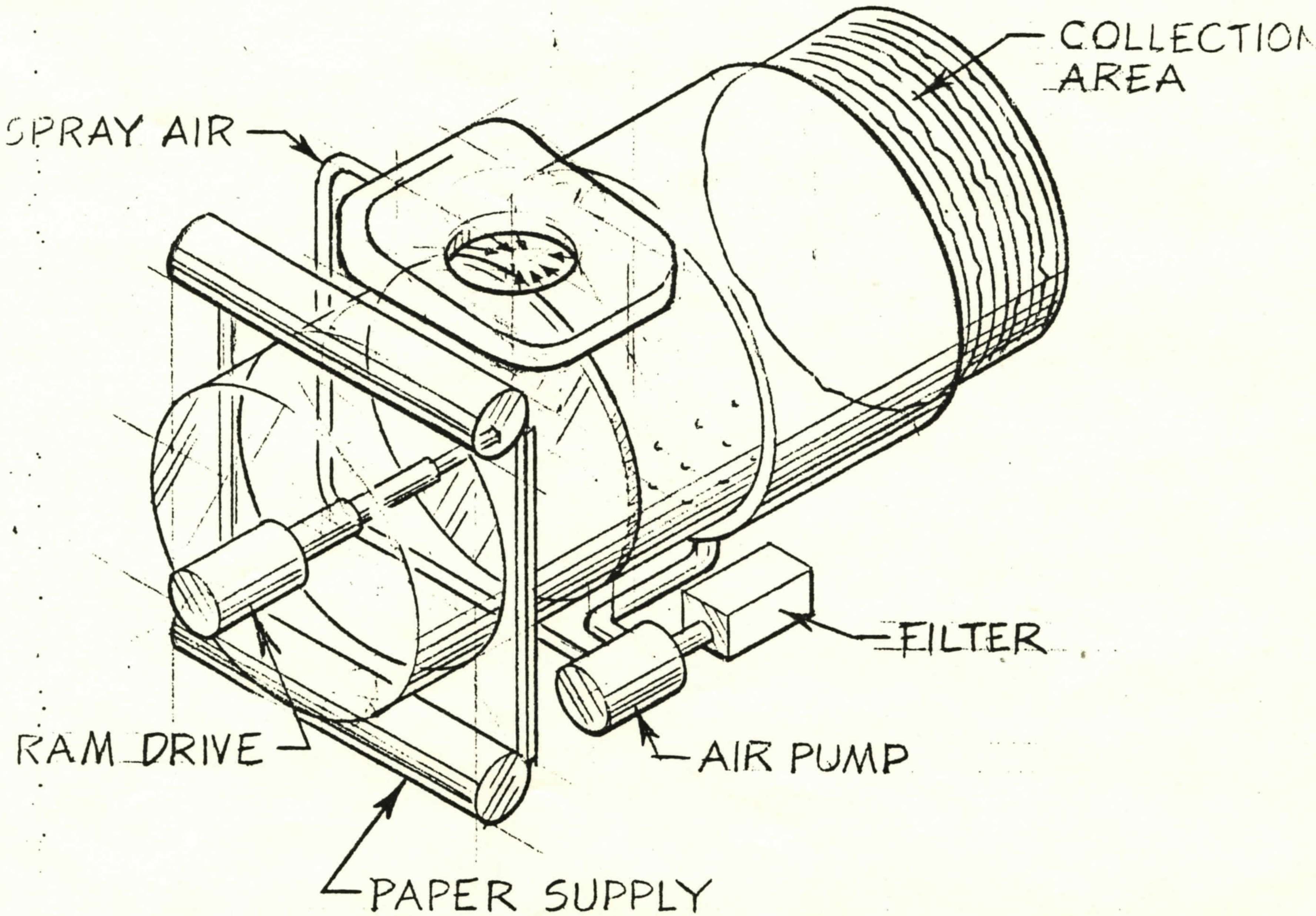
PROPOSED, WITH SONICS



IMPROVED WASTE COLLECTION SYSTEM

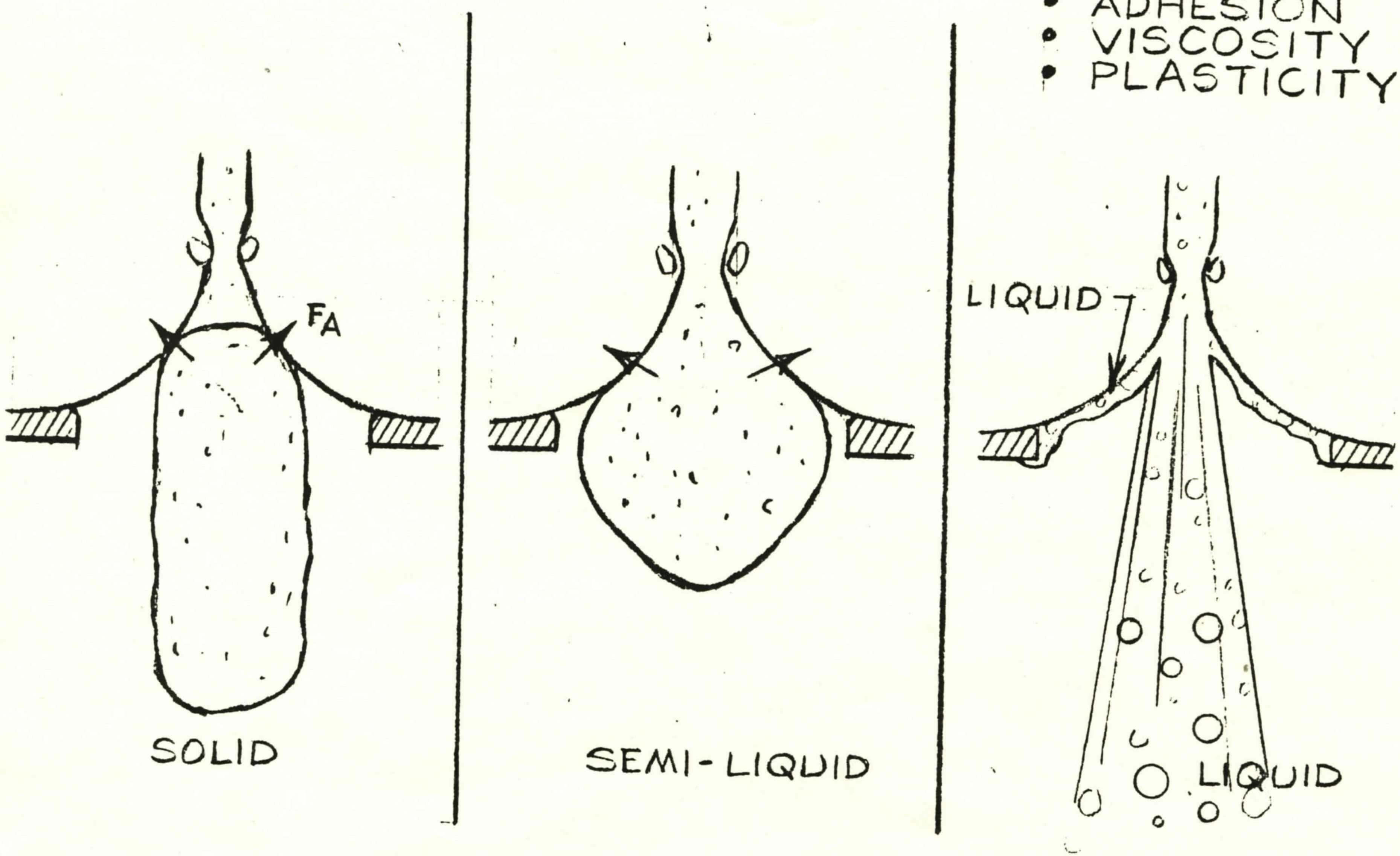


IMPROVED WCS

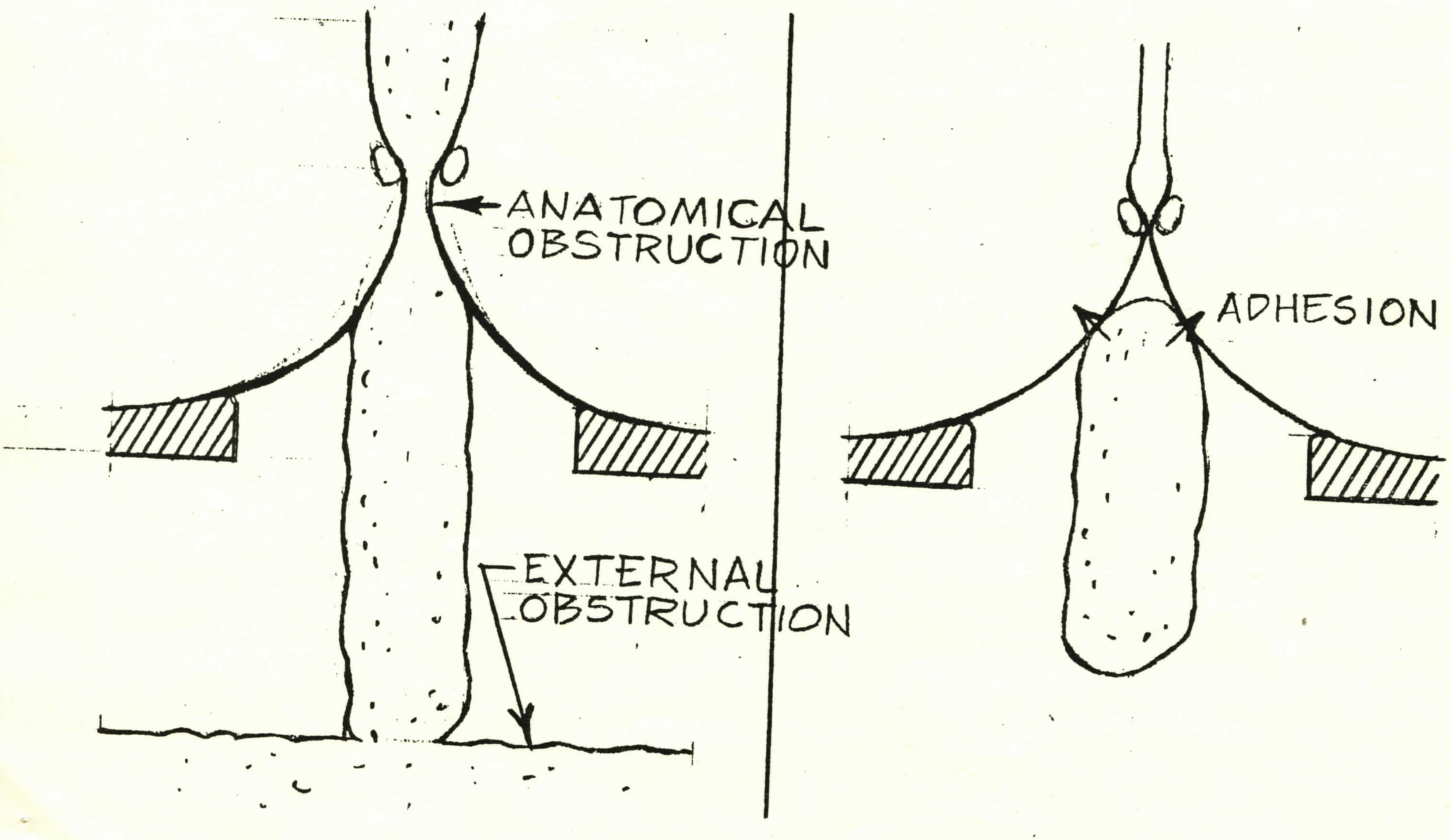


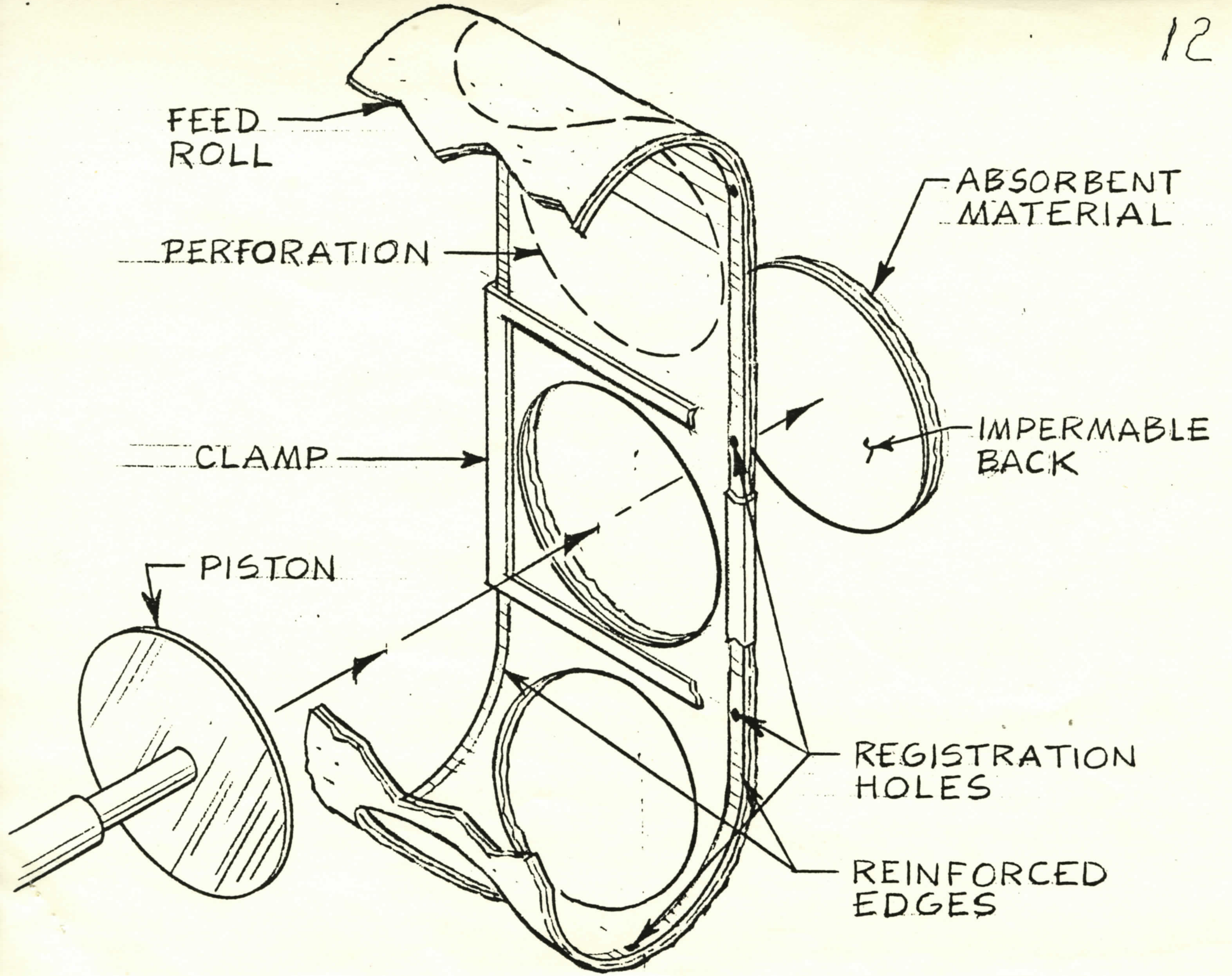
NORMAL VARIATION

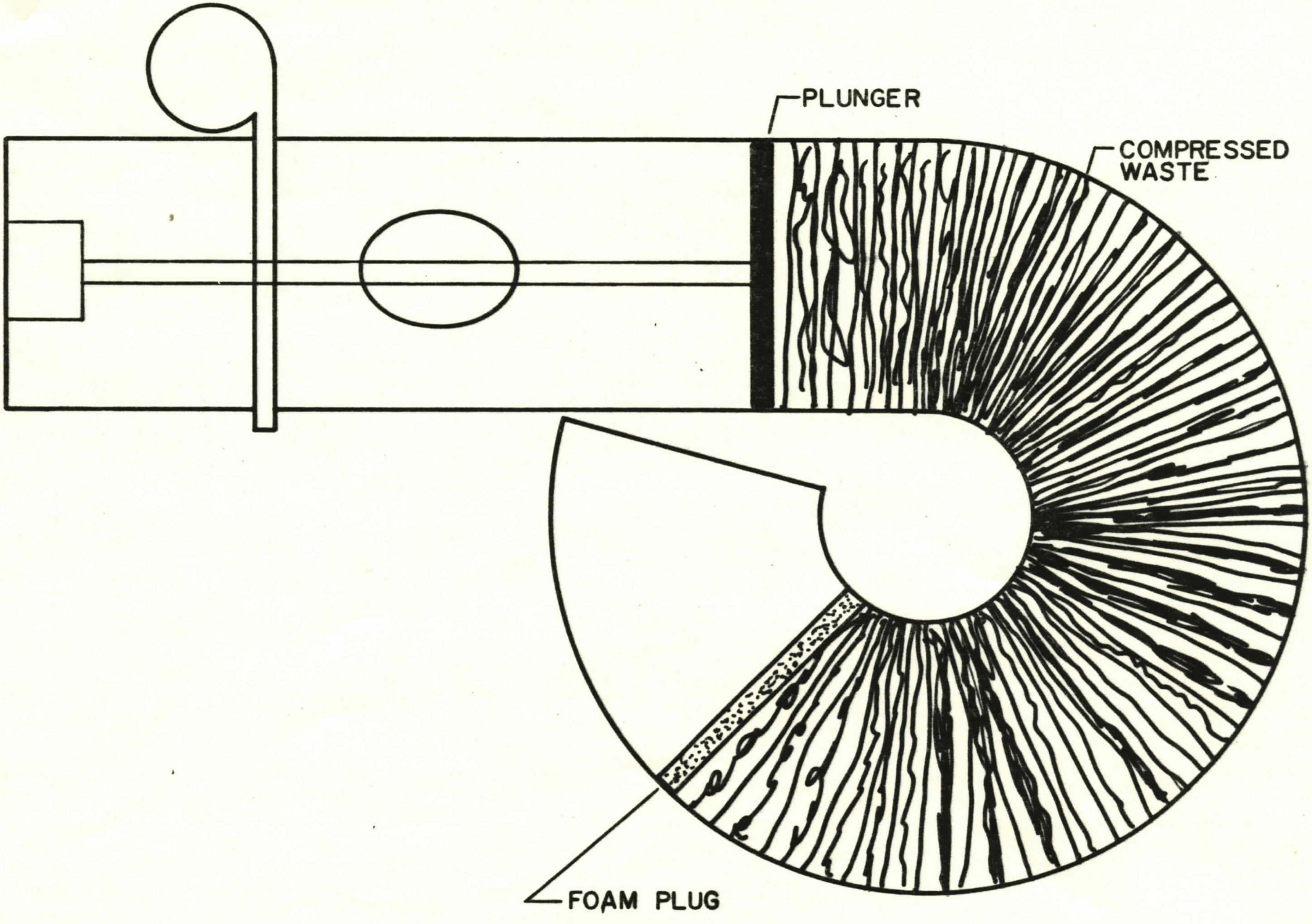
FORCES
- ADHESION
- VISCOSITY
- PLASTICITY



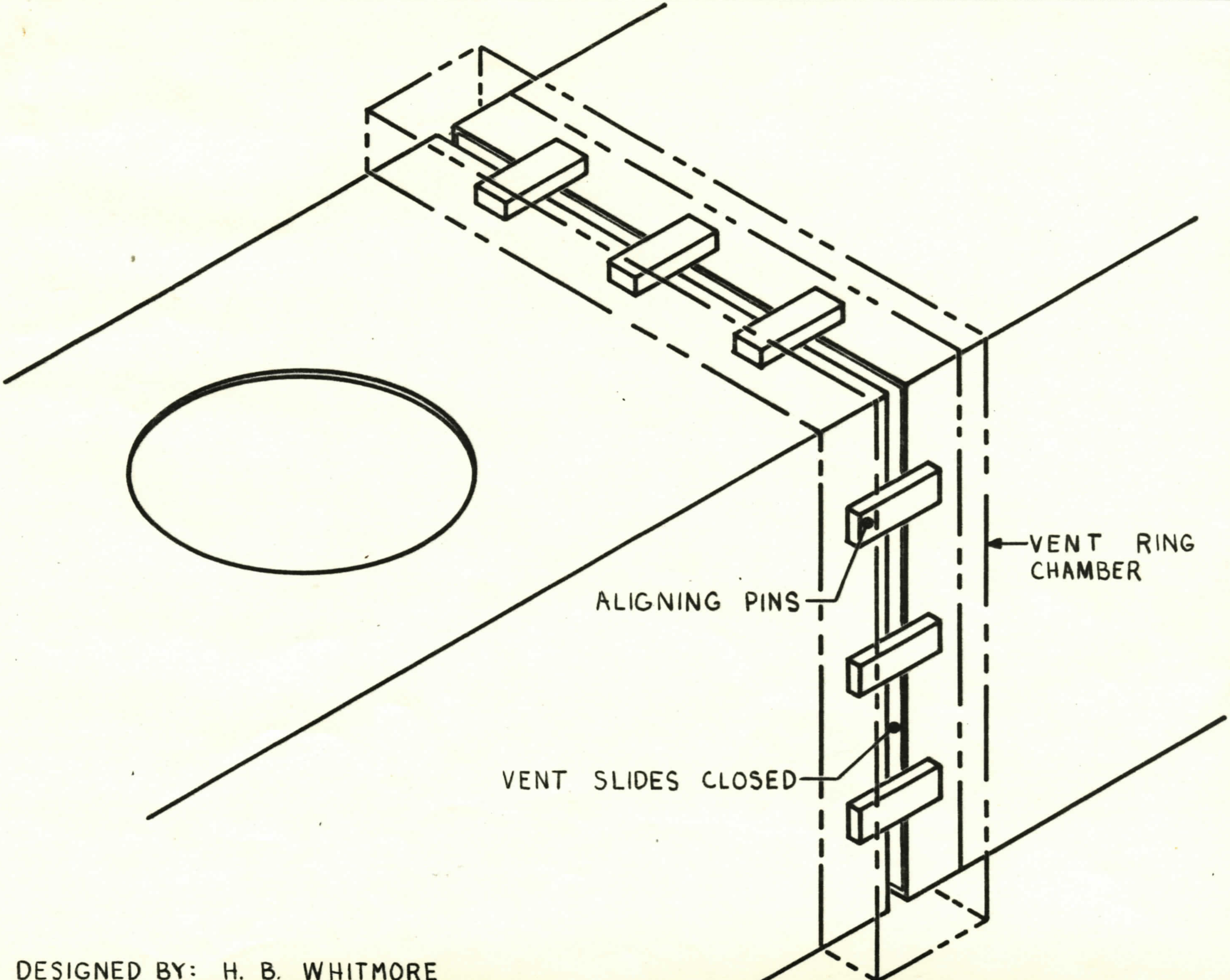
SEPARATION PROBLEMS - FLIGHT




FEED ROLL
PERFORATION
CLAMP
PISTON
ABSORBENT MATERIAL
IMPERMABLE BACK
REGISTRATION HOLES
REINFORCED EDGES



DESIGNED BY: H. B. WHITMORE



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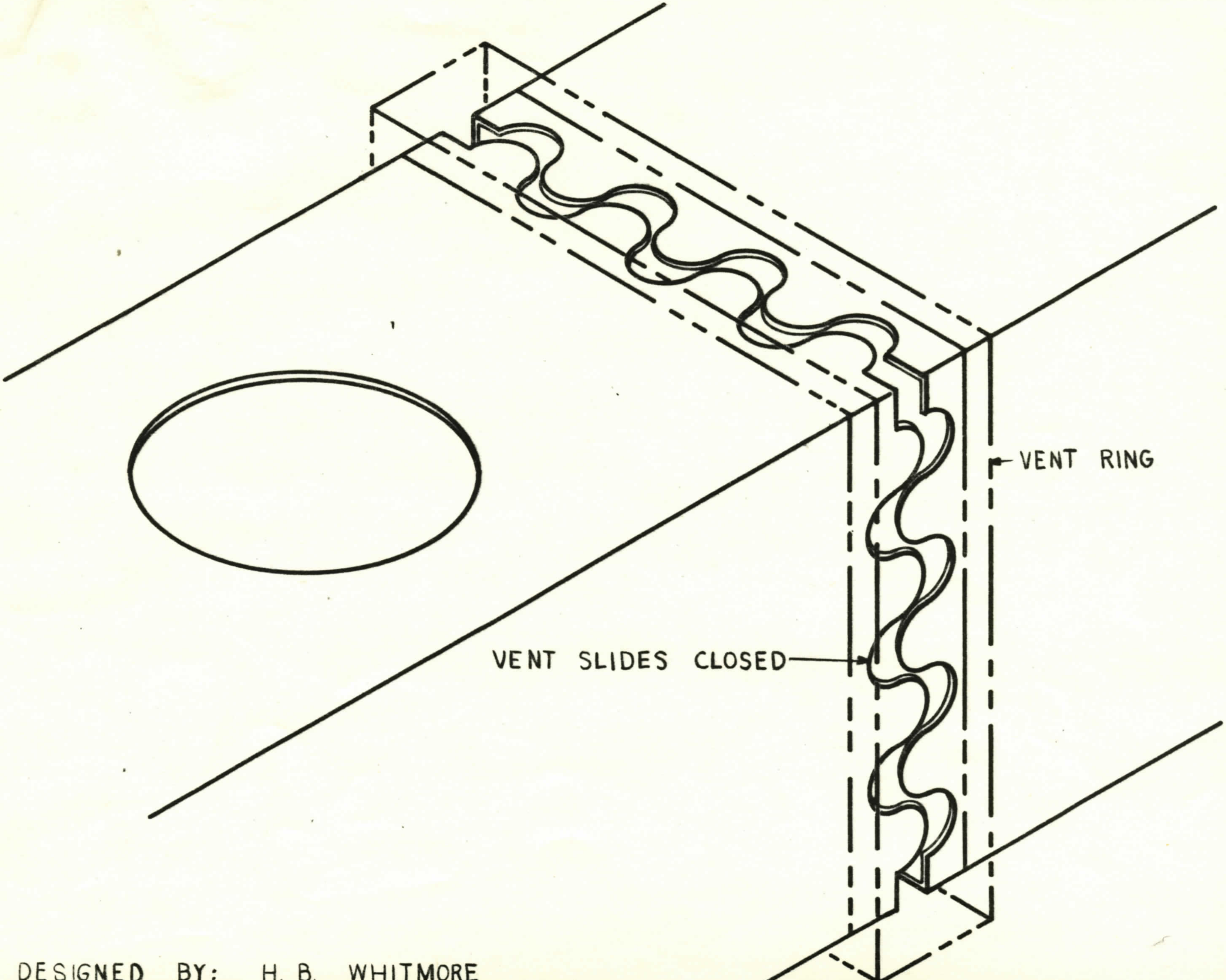

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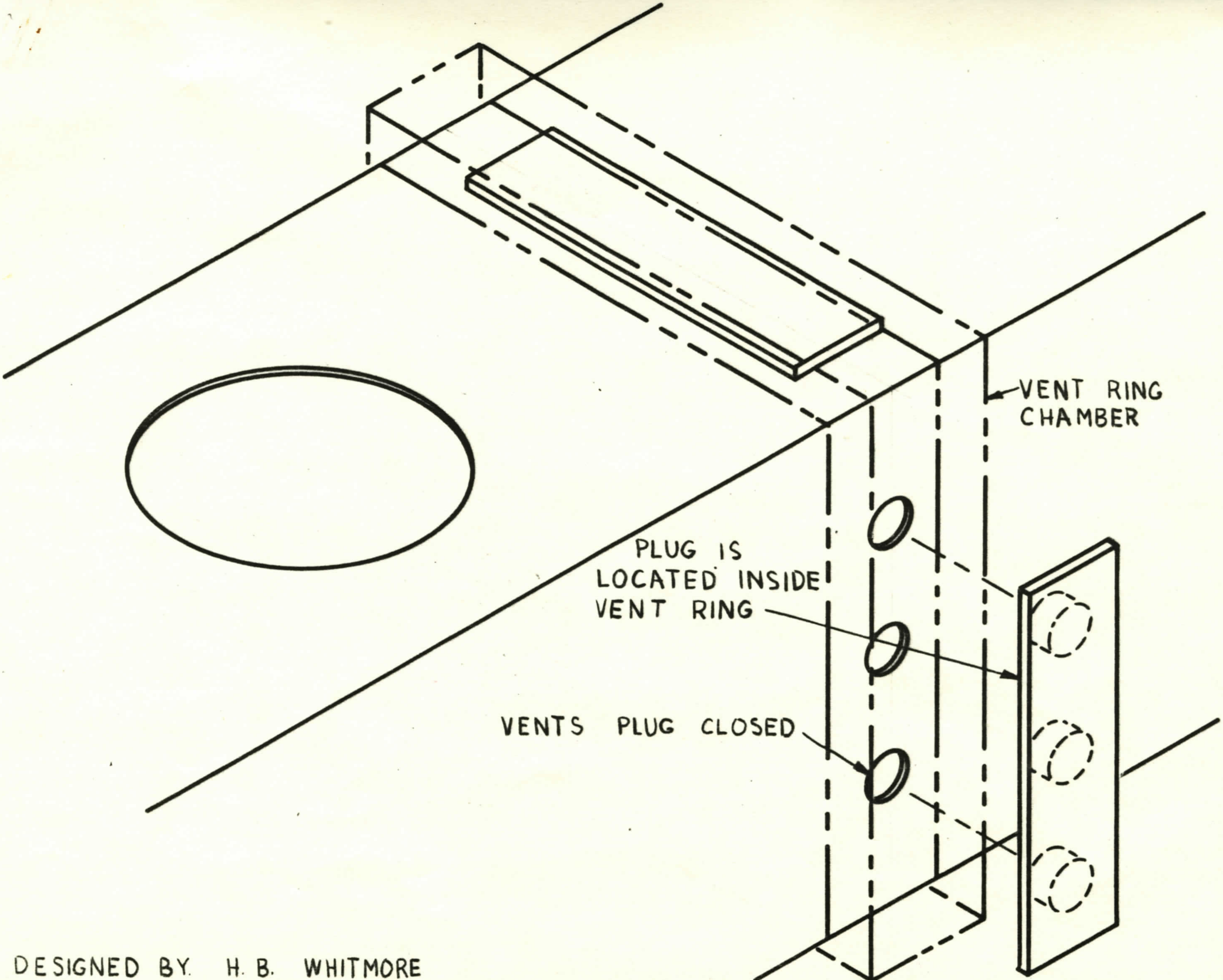

DESIGNED BY H. B. WHITMORE