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DEVELOPMENT, FABRICATION, AND TESTING OF A MAGNETICALLY CONNECTED PLASTIC VACUUM PROBE SURFACE SAMPLER

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16. Abstract

A plastic vacuum probe surface sampler was designed, fabricated and tested under the subject contract. This sampler utilizes permanent magnets and soft metal pole pieces to connect the cone/filter assembly to the sampling head and vacuum supply. The cone/filter assembly is packaged in a plastic container and presterilized so that the need for any human contact during the sampling procedure is completely eliminated.

Microbiological tests have demonstrated that the sampling efficiency is not affected by the magnetic coupling apparatus and that the probe appears to function as efficiently as the conventional plastic and Sandia vacuum probes.

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DEVELOPMENT, FABRICATION, AND TESTING

OF A MAGNETICALLY CONNECTED

PLASTIC VACUUM PROBE SURFACE SAMPLER

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INTRODUCTION

The Becton, Dickinson Research Center of Raleigh, North Carolina entered into a contract with NASA on April 13, 1970 for the purpose of designing, fabricating and testing a magnetically connected vacuum probe surface sampler. The major advantage of such a probe was the potential for total aseptic operation during the sampling and assay procedures.

The development program has been concerned with the selection of materials, selection of optimum coupling and decoupling method, methods of fabrication, and microbiological testing of completed units. Late in the contract, it was decided to redesign the machined prototype units so that the design would lend itself to potential molding. Therefore, the final delivered units represent a magnetically coupled vacuum probe surface sampler which can be molded if and when the desired quantities warrant.

TECHNICAL APPROACH

The initial efforts on this contract included a review of the original Sandia vacuum probe surface sampler[1*] and the sampler previously developed by BDRC under NAS1-9398[2]. The details of these previous designs were considered in order to retain identical dynamic airflow characteristics and microbiological sampling efficiencies for the magnetic sampler.

Design Criteria

In accordance with the contract workscope, the following criteria were considered in arriving at the final design:

1. Forces available from magnetic holding devices must be sufficient to effect sealing of the head/cone assembly.

* Superscripts refer to references cited in the Appendix.

2. Holding mechanism must be designed so that a convenient decoupling means can be employed.

3. Possible effect of magnetic holding components upon microbiological sampling efficiency.

4. Method of removal of filter and overall assay of filter and cone.

5. Packaging and sterilization of filter/cone assembly.

Design Concepts

Several means to accomplish the design objectives were considered in arriving at the final design.

1. Metal ring around periphery of cone assembly with attachment via permanent magnets in head. Release to be accomplished by friction from an assembly to be designed to accept cone, or by an electromagnet in such an assembly.

2. Electromagnet built into head assembly to be powered by a battery housed in the probe handle. Cone to be molded from a magnetic material such as Devcon, or cone to house metal ring as in (1) above. On-off switch in handle to control pickup and release of cone. (Figures 1 and 2 illustrate these methods).

Final Design

All of the design concepts outlined in (1) and (2) above were thoroughly evaluated. It was concluded that the concept of an electromagnetic holding coil with power supplied by a battery in the handle was impractical. Anticipated difficulties in obtaining reasonable battery life and holding forces precluded further consideration of this approach. The idea of a separate holding device for detaching the cone from the head assembly was also rejected due to the fact that such an assembly complicates the overall sampling procedure, in addition to increasing the manufacturing cost.

The final design was selected after consideration of all aspects of the sampling procedure. The following decisions were made:

1. The holding mechanism would consist of permanent magnets in head and soft iron discs in cone.

2. Detaching would be accomplished by a thumb operated fork mechanism on the handle.

3. The cone and filter would be returned to the original shipping container for assay. Figure 3 illustrates the final design concept.

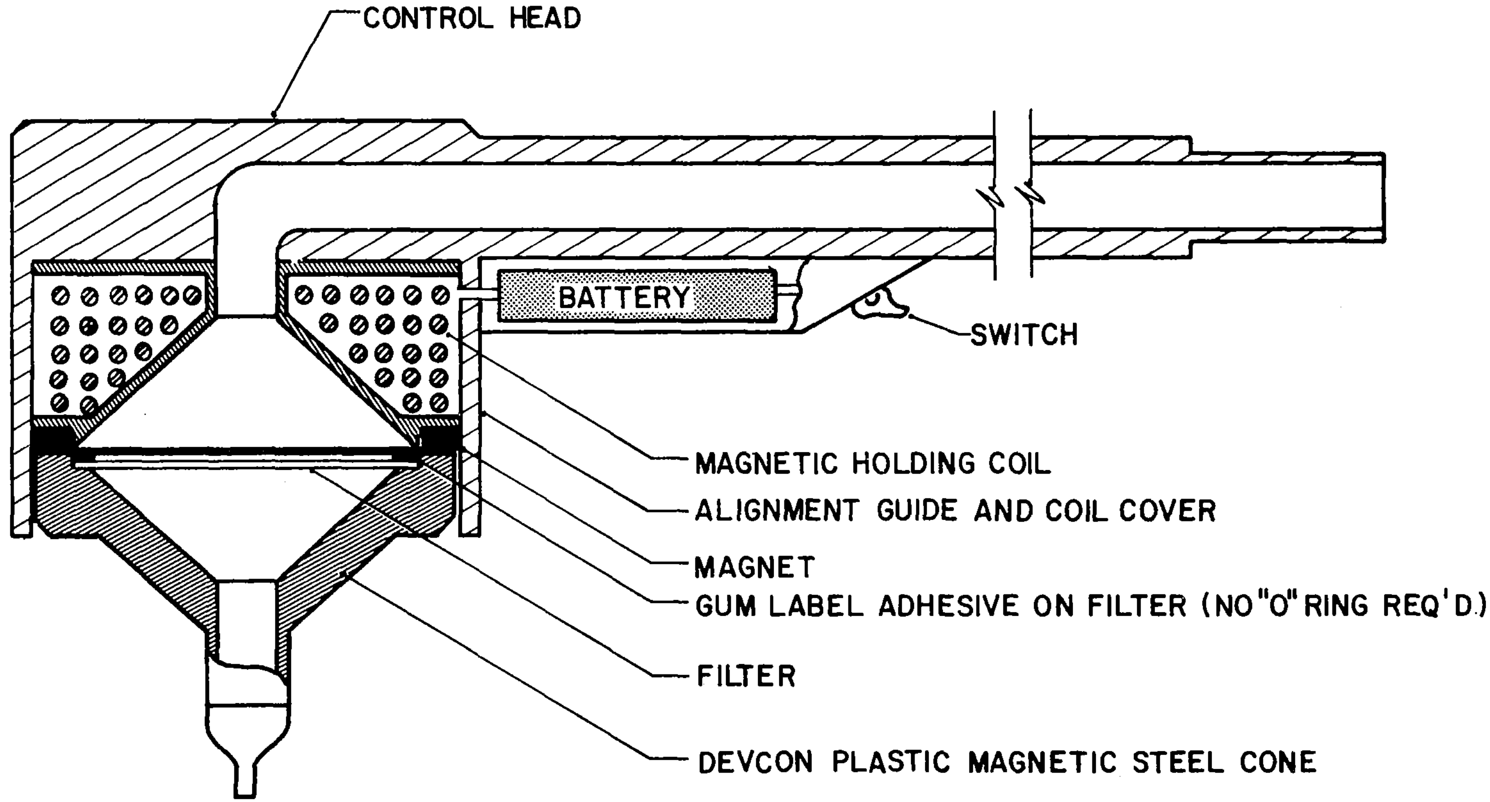


FIGURE 1: DESIGN CONCEPT - ELECTROMAGNETIC HOLDING ATTACHMENT

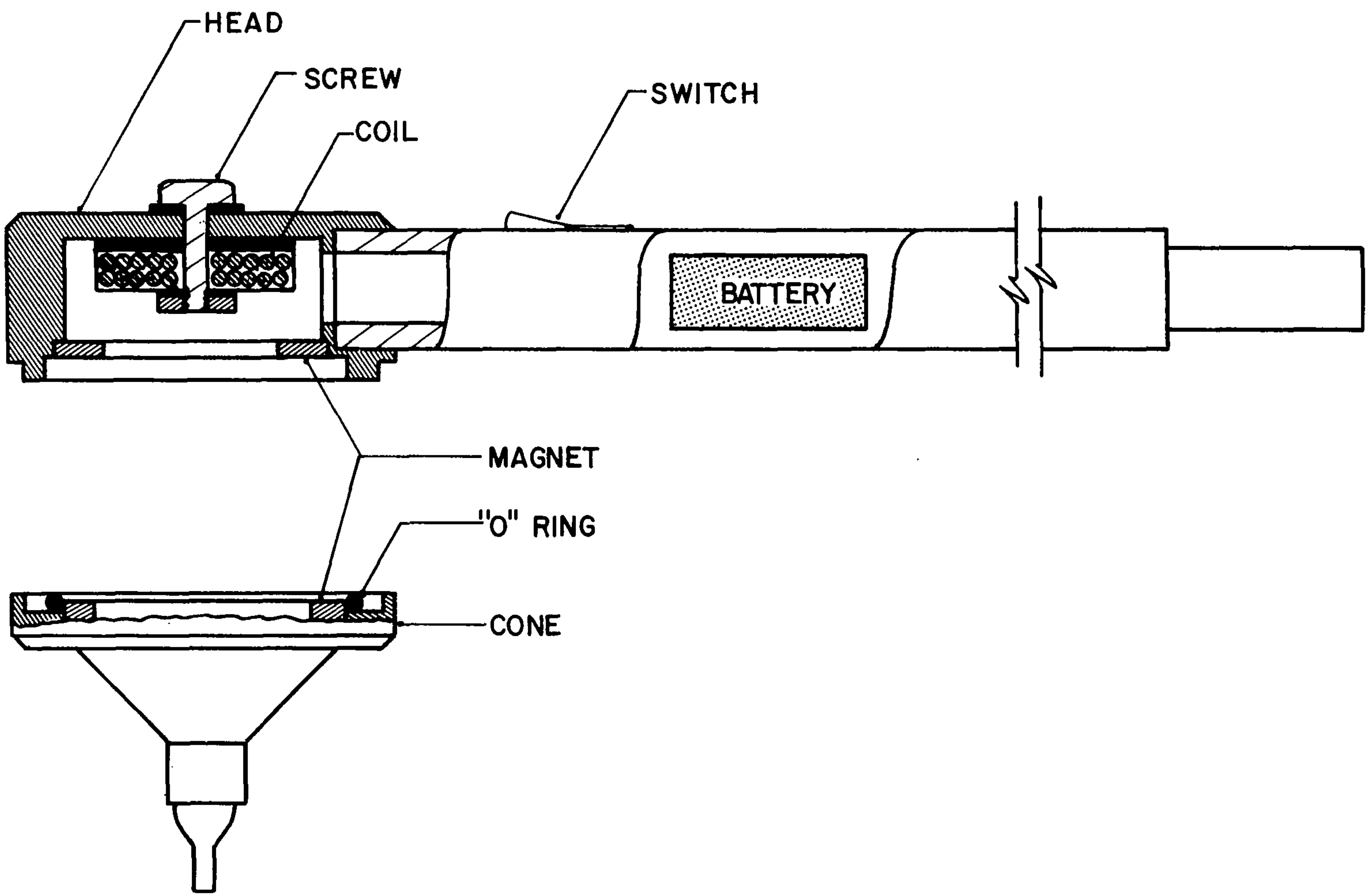


FIGURE 2: DESIGN CONCEPT - ELECTROMAGNETIC HOLDING ATTACHMENT

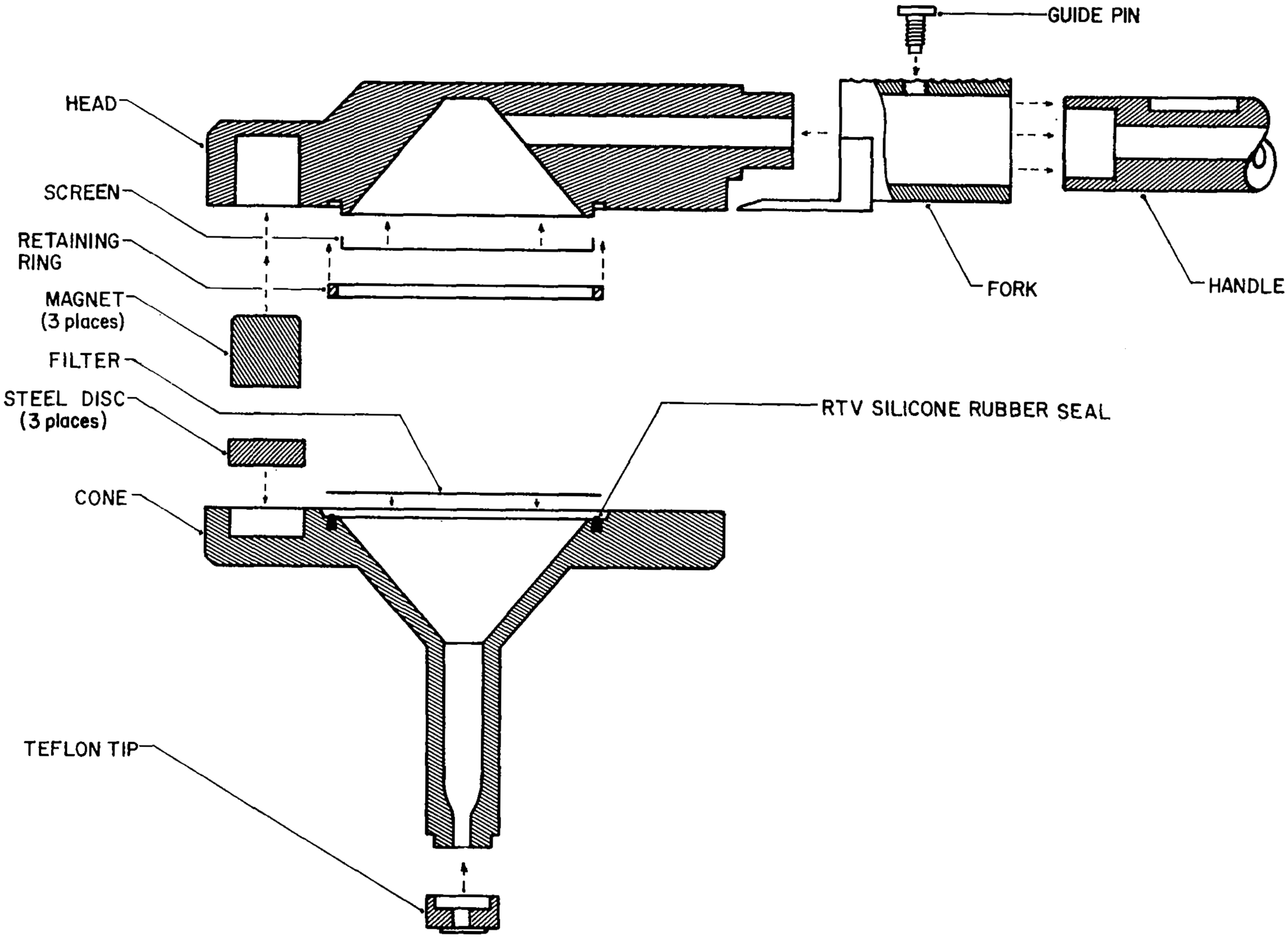


FIGURE 3: PROTOTYPE # 1 - MAGNETIC VACUUM PROBE

In order to obtain a quantitative idea of the holding forces which could be obtained from a given magnet size, a prototype holding mechanism was constructed. This mechanism consisted of a plexiglass holder 5 1/2" in diameter by 1/2" thick which held four magnets 1/2" diameter by 1/2" thick. A similar piece was fitted with four matching soft steel pieces 3/8" thick. This assembly was attached to a Chatillon Force gauge. The test assembly is diagrammatically illustrated in Figure 4.

The holding strength of the prototype assembly was tested by slowly pulling the pole piece holder from the magnet holder. The same test was repeated using a .003 inch gap between the magnets and the pole pieces. Results of both tests are shown in Table I.

TABLE I

MAGNETIC HOLDING STRENGTH

Pull Number	Force No Gap	Force .003 Gap
1	2800 grams	1000 grams
2	2550	900
3	2500	900
4	2300	900
5	2300	900
6	2400	900
7	2300	900
8	2400	900
9	2300	900
10	2300	900
Average	2435	910

It was concluded from the above tests that the force obtainable from four DMH-10 magnets was sufficient to seal cone assembly and that any air gap must be kept very small to avoid excessive loss of holding strength.

The magnetic field strength of the DMH-10 magnet was measured using the Bell Model 640 Gaussmeter and the T-6030 Transverse Probe. The measured field strength in a .030 inch air gap was 3 kilogauss.

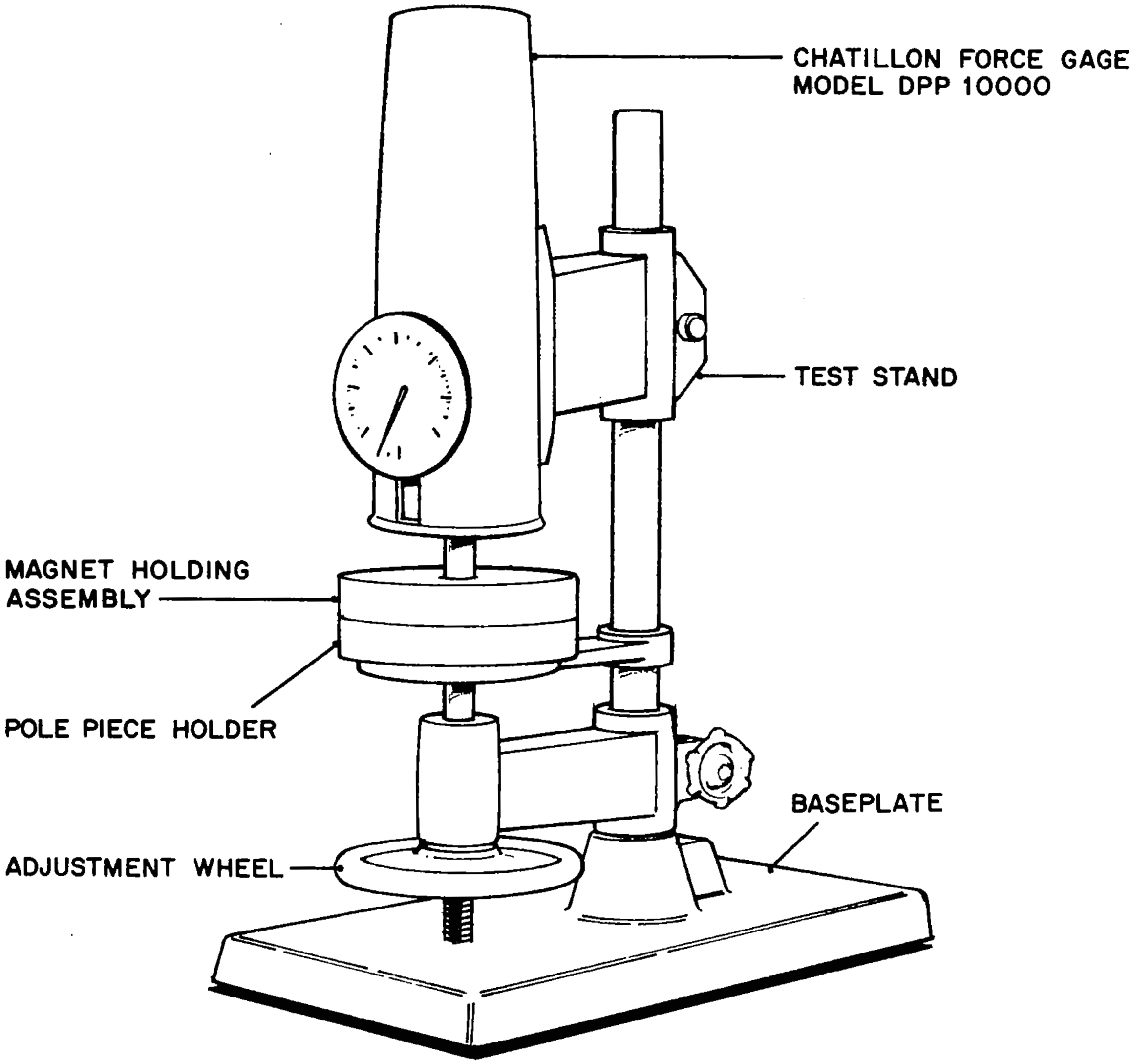


FIGURE 4: TEST APPARATUS FOR DETERMINATION OF HOLDING FORCES

Container

In order to obtain total aseptic operation of the cone and filter, it was mandatory that this assembly be supplied to the user presterilized in a low cost container. It was also desirable that the container be used as a receptacle for the cone and filter after the sampling procedure. The container selected was a 24 oz. polypropylene food container, 4 3/8" diameter and 3" deep.

This container was modified by placing a supporting tube in the center and a retaining ring in the cap. The tubing was perforated to allow free exchange of media when the container is used for culturing. Figure 5 shows the container and associated parts.

Re-Design of Probe for Moldability

The original prototype unit was completed and submitted to NASA in July, 1970. Figure 6 shows the unit as originally submitted. After review of this unit, the following changes in design were recommended:

1. Re-design of decoupling mechanism to ease decoupling effort.
2. Re-design of head/cone assembly to allow packaging of filter with cone.
3. Re-design of container to allow culturing of cone and filter.

Further review by NASA indicated that substantial advantage might be gained by modifying the design so that the unit would lend itself to molding. Therefore, the head and cone assemblies were re-designed by BDRC as shown in Figure 7. The changes which were made are obvious from comparison of Figure 6 and 7.

It is important to note that the present design, while it lends itself to molding, is not intended to be the final moldable version. Certain changes will undoubtedly suggest themselves when the mold is fabricated. In fact, certain choices will need to be made by the mold designer. Therefore, the prototypes delivered to NASA are dimensionally as close to the molded configuration as the structural characteristics of the material will permit. Furthermore, the submitted engineering drawings identify all critical tolerances and dimensions. The ultimate molder should submit actual mold fabrication drawings which will specify exact dimensional characteristics.

Air Flow Characteristics

The internal dimensions of the probe are essentially the same as the plastic vacuum probe designed by BDRC under NAS1-9398 and the earlier Sandia vacuum probe. Several previous publications provide a detailed analysis of the airflow characteristics of both vacuum probe surface samplers.[1,2,3,4]

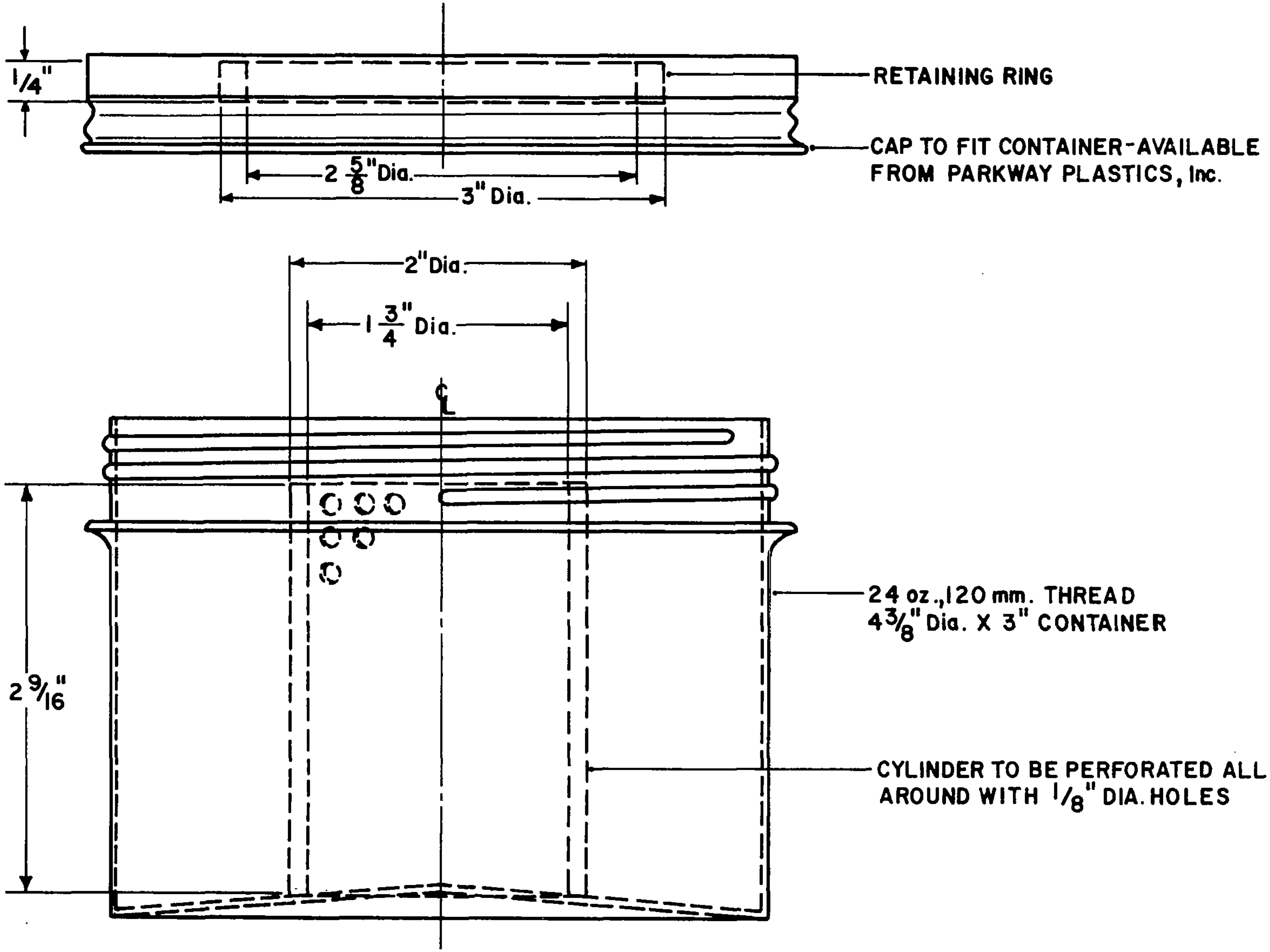


FIGURE 5: CONTAINER FOR CONE AND FILTER

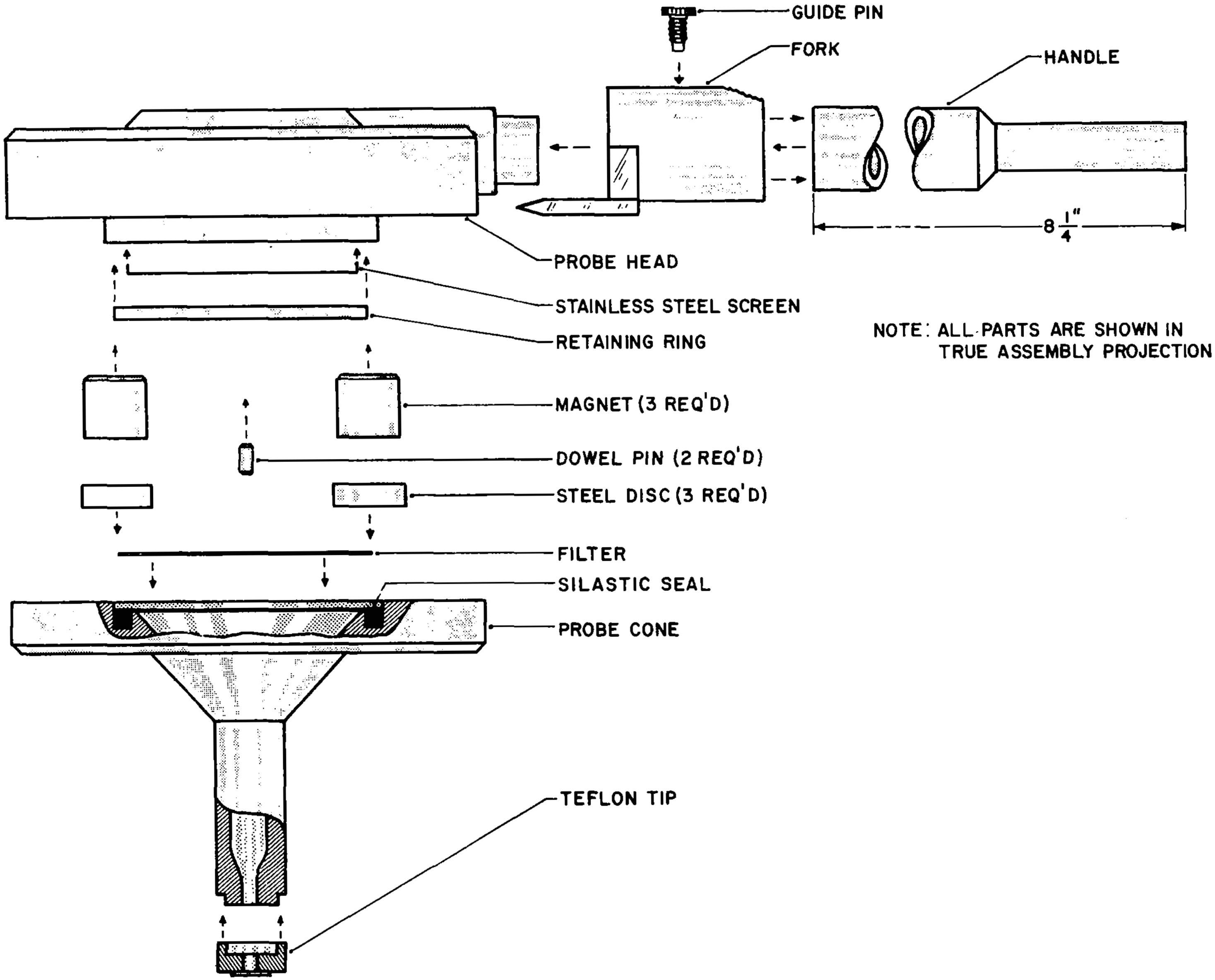


FIGURE 6: ORIGINAL DESIGN

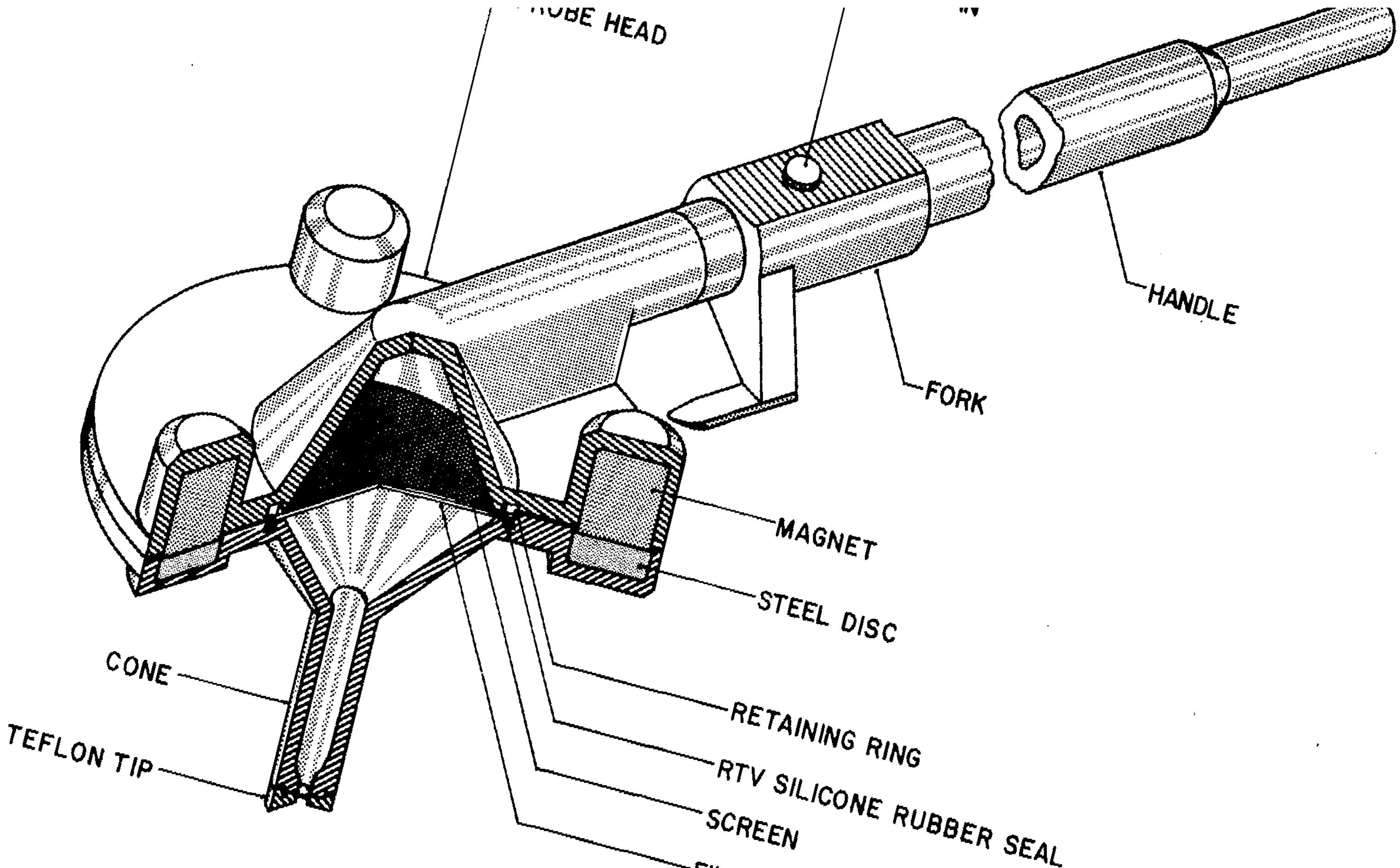


FIGURE 7: MODIFIED DESIGN FOR POTENTIAL MOLDABILITY

Final Design Review

The re-designed, moldable version of the probe was reviewed by NASA personnel in January, 1971. Several recommendations resulted from this review:

1. Investigate cost of molded teflon tips to be used on final unit or to be offered as an optional item to future users.
2. Consideration of culturing procedure using cone container with entire cone/filter assembly immersed in media.
3. Investigate possible use of a fixed "O" ring seal rather than a poured silastic ring.
4. Use of a keyway to orient tip with cone.

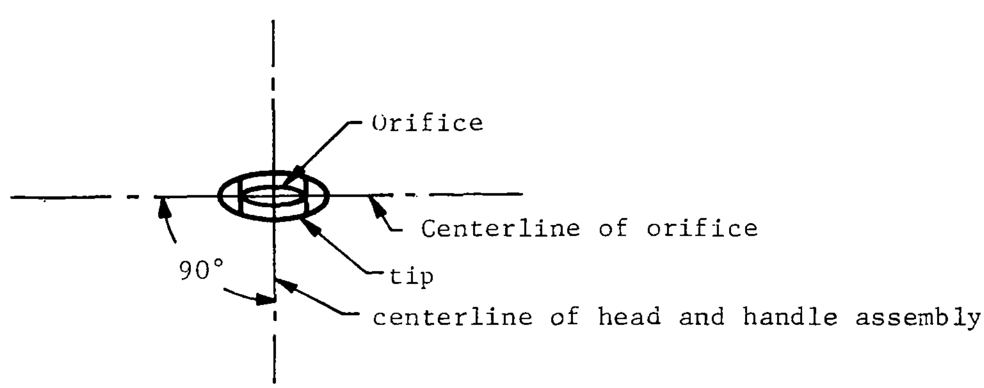
A quotation was obtained for the fabrication of a mold and supplying of teflon tips for the probe. The estimated cost for a single cavity mold was $870.00 and the cost for the teflon tips was $.29 each in quantities of 500 pieces.

A soft silastic Parker "O" ring was obtained and was incorporated into the final design. Tests showed that the seal was adequate with this "O" ring. The costly process of pouring the silastic "O" ring was thereby eliminated.

The problem described in point 4 above is that the centerline of the critical orifice of the tip is sometimes inadvertently oriented at an angle other than 90° to the head and handle assembly centerline. Figure 8 illustrates the correct orientation.

FIGURE 8

ORIENTATION OF HANDLE WITH TIP



After review of the prototype design by B-D mechanical engineering personnel, it was concluded that the tip with critical orifice will be cemented to the cone on the prototype delivered units to prevent misalignment. To further aid in aligning the cone to the head assembly, a red alignment marker has been included on the delivered items. Reasonable care in the use of the probe should eliminate any difficulty with tip/cone/head alignment. If a keyway or other orienting mechanism is deemed necessary in future molded units, it can be incorporated at no increase in cost via slight modification of the drawings.

Sterilization Method

The sterilization procedure selected for the container and cone/filter assembly was a chemical process using formaldehyde gas. The mechanism for formaldehyde gas production was paper impregnated with paraformaldehyde and used as an insert within a polyethylene bag housing the container and cone/filter assembly. Sterilizing formaldehyde gas was evolved from the paper inside the package using a temperature-time exposure cycle of 45°C for 25 hours. The top of the container was left loose during this period. After exposure the top was tightened without rupture of the polyethylene bag. Tests indicated that this method produced satisfactory sterilization of the assembly.

Microbiological Tests

The magnetic vacuum probe was trial tested to determine recovery of mesophilic organisms on the probe filter membrane after sampling floor tile squares. Tile floor squares were sampled (six squares each day) for a period of four consecutive days.

Table II shows organism recovery using the magnetic vacuum probe. The average recovery per tile each day appeared similar to that obtained previously with the plastic and Sandia vacuum probes using similar test procedures. Comparative test data from previous studies are shown in tables III and IV.[2] The overall average organism recovery using the magnetic probe was higher than for the other probes tested.

TABLE II

NORMALLY OCCURRING MESOPHILIC ORGANISMS RECOVERED FROM FLOOR TILE USING THE MAGNETIC VACUUM PROBE(a)

Test Day	Mesophilic Organism Recovery at Indicated Test Tile (b)						Average Recovery Per Tile
	1	2	3	4	5	6	
1	9,260	3,000	5,860	2,670	12,900	3,400	6,182
2	2,600	1,200	5,260	660	26,100	2,120	6,323
3	103,000	2,780	3,390	9,900	7,340	37,000	27,235
4	2,120	1,650	8,800	18,100	16,300	5,500	8,745

(a) Vacuum source; 1 CFM Gast vacuum pump; average vacuum pull recorded during testing was 9-11 inches of mercury.

(b) Tile squares located in laboratory room at normal traffic walk. Each tile square (9" square) was sampled horizontally and vertically for time period of 3 minutes.

TABLE III

MICROORGANISM RECOVERY FROM NORMAL ROOM CONTAMINATION
OF FLOOR TILE SQUARES USING VACUUM PROBES

Testing Unit	Vacuum Force Range Inches of Mercury Tile No.					Microorganisms Recovered Per Tile Square Tile No.					Average Organism Recovery Per Tile Square
	1	2	3	4	5	1	2	3	4	5	
Plastic Probe Teflon tip	9-10	10-11	10-11	9-12	11-12	2200	400	2800	1200	6000	2520
Plastic Probe Teflon tip	9-10	10-12	11-12	11-12	11-12	3400	1600	22600	3800	700	6420
Plastic Probe Polystyrene tip	10-14	10-14	10-14	12-13	11-14	500	600	500	1100	700	680
Plastic Probe Polystyrene tip	12-15	12-14	11-14	11-15	10-14	7800	900	6200	5200	3700	4760
Sandia Probe Teflon tip	10-12	10-12	11-12	12-13	12-13	600	3300	15600	2600	10600	6540

TABLE IV

MICROORGANISM RECOVERY FROM NORMAL ROOM CONTAMINATION OF FLOOR TILE SQUARES USING DILUTION ASSAY

Testing Unit	Microorgansim per Tile Square Tile No.					Average Recovery per Tile
	1	2	3	4	5	
Plastic Probe Gelman Filter	1900	500	900	1000	2000	1260
Sandia Probe Gelman Filter	1400	1200	600	600	1100	980
Plastic Probe Millipore Filter	600	1800	700	200	400	740
Sandia Probe Millipore Filter	1200	800	1000	1900	1400	1260

UNPACKING AND OPERATING INSTRUCTIONS

It is desirable that steps 1-3 be performed in a laminar flow hood or other clean environment. If this is not possible, the operator should take precautions to insure that the cone and filter are not contaminated. Figure 9 illustrates the required steps in this procedure.

1. Slit polyethylene bag and remove container.
2. With container in upright position, unscrew cap. Check to insure that filter is properly positioned. If not, position filter with sterile forceps.
3. Note red alignment marker on cone. Also note red alignment marker on head assembly. With these marks aligned slide the head over the cone/filter assembly until magnets engage. Lift assembly from container.
4. Attach vacuum supply to handle. Probe is now ready for use.
5. To disengage cone from head, slide the fork mechanism forward with the thumb until the stop is reached. Rotate the fork mechanism slightly to the left with the thumb. Cone will detach. (Note: Cone may be returned to its original container if desired or may be detached into any convenient holder).

CONCLUSIONS

The design and fabrication of the magnetically coupled vacuum probe surface sampler has satisfactorily demonstrated the feasibility of producing a sampler which can be used in a totally aseptic manner. It has been further shown that the magnetic components have no demonstratable effect upon the sampling efficiency of the probe.

The final design has also been made such that a moldable version of this unit can be produced if the demand for such probes should warrant.

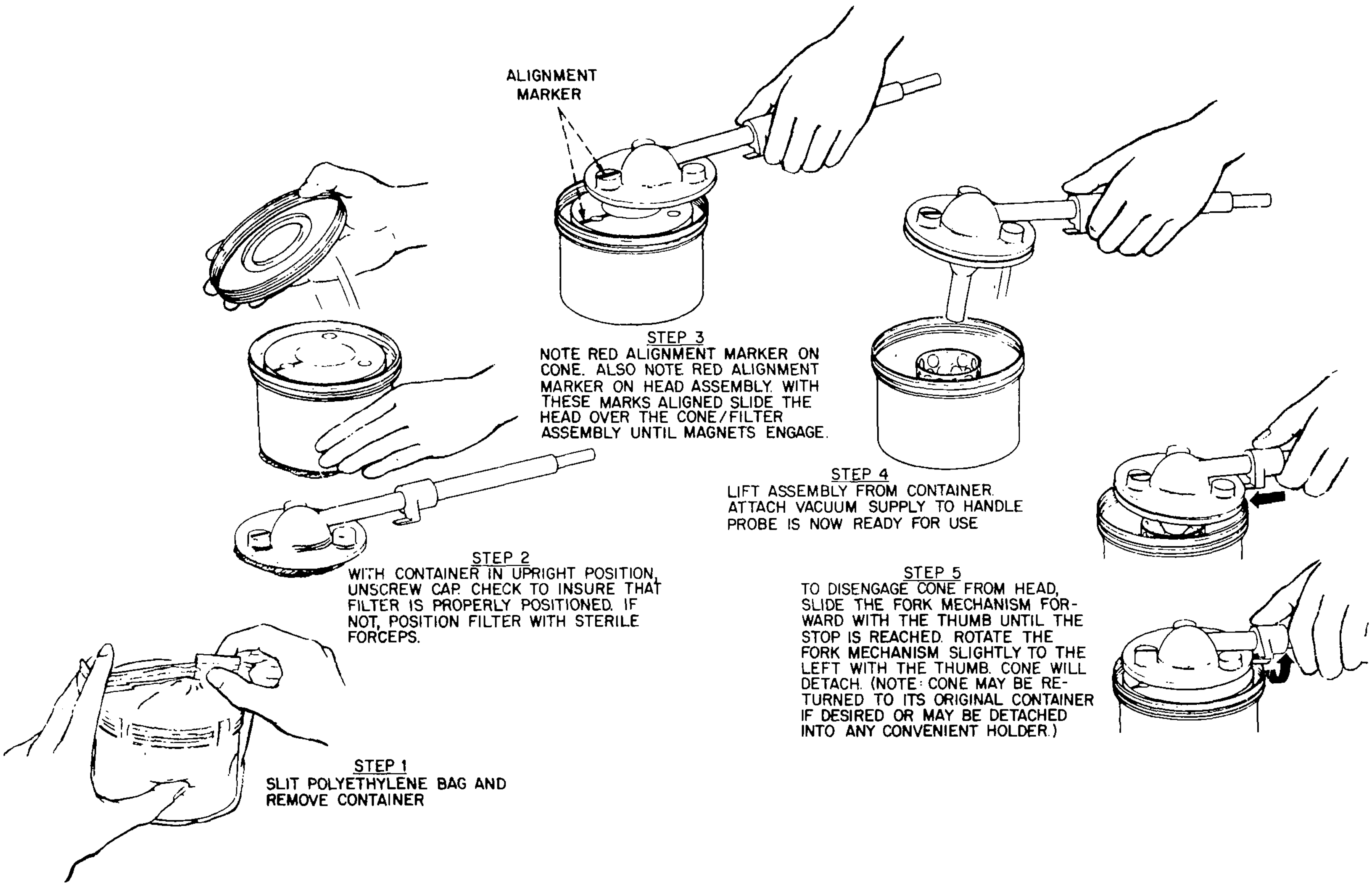


FIGURE 9: UNPACKING AND ASSEMBLY OF PROBE/HEAD

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