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A REVIEW OF SPACECRAFT WASTE-MANAGEMENT SYSTEMS

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Houston, Texas

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ABSTRACT

Manned space flight has created the requirement for unique waste-management systems. This document reviews the design requirements, development, and use of the waste-management systems for Project Mercury and for the Gemini Program. A review of the use of these systems during actual missions is included.

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A REVIEW OF SPACECRAFT WASTE-MANAGEMENT SYSTEMS

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SUMMARY

Manned space flight has created the requirement for unique waste-management systems. This document delineates the methods and the devices developed for Mercury and Gemini spacecraft waste-management systems.

INTRODUCTION

Prior to the first suborbital and orbital space flights, only marine shipping and specialized and experimental aircraft had waste-management system constraints similar to those of spacecraft. However, the limited flight durations of experimental aircraft (for example, the X-15) placed only nominal requirements on the waste-management systems.

The extended flights of Project Mercury and of the Gemini Program introduced unique spacecraft waste-management requirements. Fundamentally, these requirements consisted of the development of efficient methods for collecting feces, urine, and vomitus under severe limitations of weight and space.

MERCURY SYSTEMS

Urination

During the first manned Mercury missions, spacecraft waste-management system requirements were nominal, primarily because of the limited duration of the flights. For subsequent Mercury flights of somewhat longer duration, a simplified waste-management system, which consisted of an in-suit urination bag, was the only requirement. However, on the extended flight of Mercury-Atlas 9 (MA-9), a more complex waste-management system was required. The system (fig. 1) consisted of two units: (1) the urination bag affixed to a quick disconnect and (2) a storage bag, a syringe-type pump, a hose assembly, and a quick disconnect.

When this system was to be used, the two units were mated at the quick disconnects. The syringe-type pump, manually operated by the crewman, provided the differential pressure required to transfer the urine from the in-suit bag to the storage unit. After use, the quick disconnects were unmated, and the second unit was stored in a container. During the flight, however, two difficulties were encountered. The effort required to operate the pump was excessive, and the line from the space suit to the pump developed leakage.

Defecation and Vomitus

To minimize the need for a defecation bag, which was not provided during any of the Mercury missions, the crewman was fed a low residue diet for 3 days prior to scheduled launch. If a delay occurred in the prelaunch phase of a particular mission, the low residue diet was continued until launch. An emesis container (fig. 2) for the storage of vomitus was provided for the crewman on each of the Mercury missions.

GEMINI SYSTEMS

Urination

The extended orbital space flights introduced during the Gemini Program generated more extensive spacecraft waste-management system requirements.

On Gemini missions III and IV (Gemini missions I and II were unmanned), the urination system consisted of two units: an in-suit unit for use prior to launch and a unit for the inflight disposal of urine. The in-suit unit (fig. 3), which was worn throughout the preflight and early postlaunch period, consisted of an in-suit urine bag (a modification of the bag used on Mercury flights) and an external catheter. When stable orbital velocity had been achieved, the in-suit unit was removed. The unit for the inflight disposal of urine (fig. 4) consisted of a receiver-line assembly (fig. 5) which had an inflatable cuff to collect the voided urine, an extendable urine-bellows assembly (fig. 6) capable of storing 800 cc of urine, a water-management panel, and a urine overboard-dump system.

The urine-bellows assembly induced the negative differential pressure required to transfer voided urine from the receiver-line assembly into the bellows for storage. To provide the negative pressure required during operation, the bellows had to be extended manually at a rate proportional to the crewman's rate of urination. After urination was completed, the voided urine in the urine-bellows assembly was vented overboard by means of the overboard-dump system. During the flight, however, the crewman had difficulty in manipulating the bellows (that is, synchronizing the bellows-extension rate and the urine rate), and the assistance of the other crewman was required. Back pressure frequently occurred, which resulted in fluid backup from the receiver. In addition, air leakage occurred in the system around the penis.

The operational difficulties encountered by the crewmen on the previously discussed flights resulted in the redesign of the waste-management system. The new system was designed to specified mechanical requirements and afforded maximum ease of operation. The redesigned spacecraft waste-management system (fig. 7) was used satisfactorily on Gemini missions V to XII.

With the redesigned system, as with the previously discussed systems, the in-suit bag was used during the preflight phase. During the flight, the voided urine was collected by means of a roll-on cuff receiver (fig. 8). A one-way check valve, housed within the roll-on cuff receiver, closed immediately if fluid backup occurred. A manually controlled valve allowed urine to flow from the roll-on cuff receiver into an 800-cc collection bag. After urination was completed, the manually controlled valve was closed, and the urine flowed from the collection bag into the overboard-dump system through a flexible hose.

On Gemini missions VII and IX, a chemical urine-volume measuring subsystem (CUVMS) was added to the existing spacecraft waste-management system to collect samples for experiments which were designed to assess the effects of space flight on metabolism (fig. 9). Feces samples were also collected for analysis.

Figure 10 depicts the selector-valve handle used to control the direction of urine flow. To urinate, the crewman turned the selector-valve handle clockwise from the bypass (dump) position to the urinate position. This procedure automatically depressed the tritium metering piston which injected 0.3 milliliter of tritium (a radioactive tracer) into the collection/mixing bag, while an undetermined volume of urine flowed into the bag. After manually mixing the urine and tritium in the collection/mixing bag, the crewman turned the selector-valve handle clockwise to the sample position which forced an aliquot of approximately 75 milliliters of the urine/tritium mixture from the collection/mixing bag into an attached urine-sample bag (fig. 11). The urine-sample bag was then removed. Finally, after mating the CUVMS to the overboard-dump system, the crewman returned the selector-valve handle to the bypass position and directed the remainder of the urine in the collection/mixing bag into the overboard-dump system. The valve which controlled the overboard-dump system was actuated, which promptly vented the urine overboard. The CUVMS was then disconnected from the overboard-dump system and stowed. After the flight, the volume of each urination could be extrapolated from the radioactivity level of the individual urine samples.

Defecation and Vomitus

A defecation system was required for the extended flights of the Gemini Program, although (as during Mercury preflight preparations) Gemini crewmen were fed a low residue diet to minimize the total volume of defecation accumulated.

The defecation system consisted of a flexible plastic bag (fig. 12), the open end of which had a sticky surface used to seal the bag to the buttocks. A germicidal agent (a mixture of sodium orthophenyphenol and sodium chloraphenyphenol dissolved in propylene glycol and stained with amaplast blue LXP) and tissues were provided in a pocket on the bag. After use, the bag was sealed and stored in a waste container. Although use of the defecation bag required considerable dexterity and time, the system was considered to be adequate. Two emesis containers were provided for each crewman on all Gemini missions to store vomitus, if necessary.

CONCLUDING REMARKS

The invaluable operational experiences obtained from the spacecraft waste-management systems used during Mercury and Gemini missions contributed significantly to the ongoing development of increasingly effective spacecraft waste-management systems.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, December 6, 1968
914-50-95-69-72

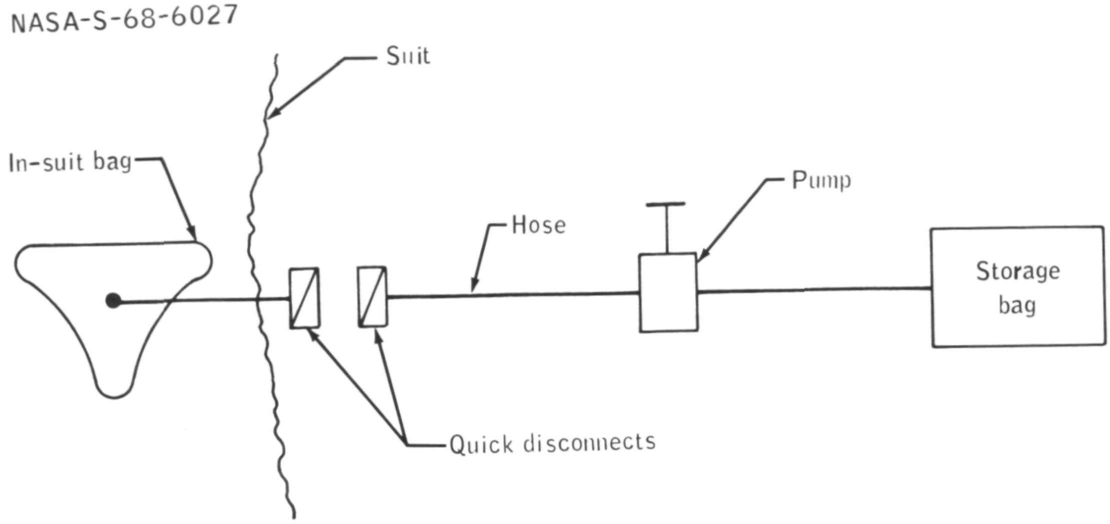

Figure 1. - Mercury-Atlas 9 (MA-9) urination system.

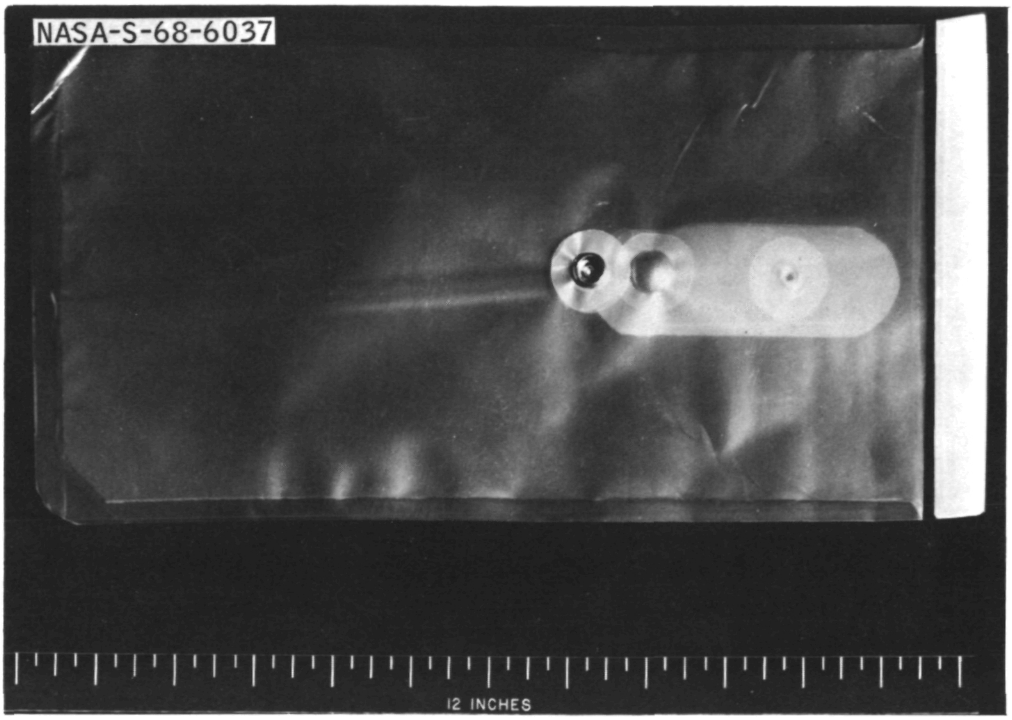

Figure 2. - Emesis container.

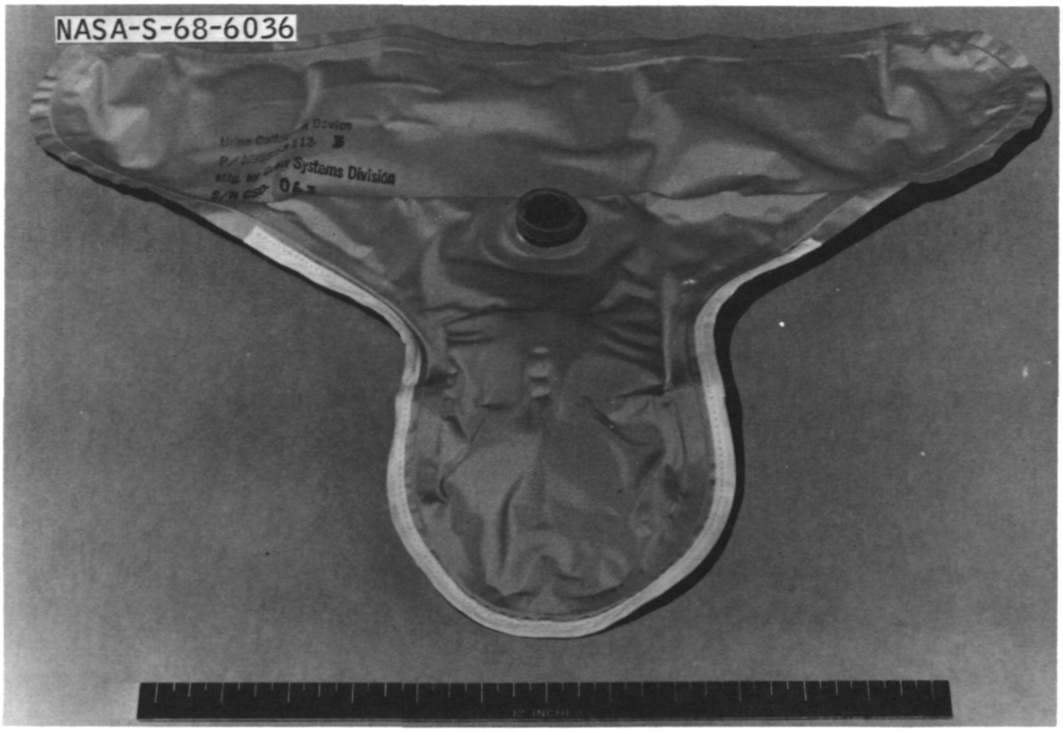

Figure 3. - In-suit urine-collection device.

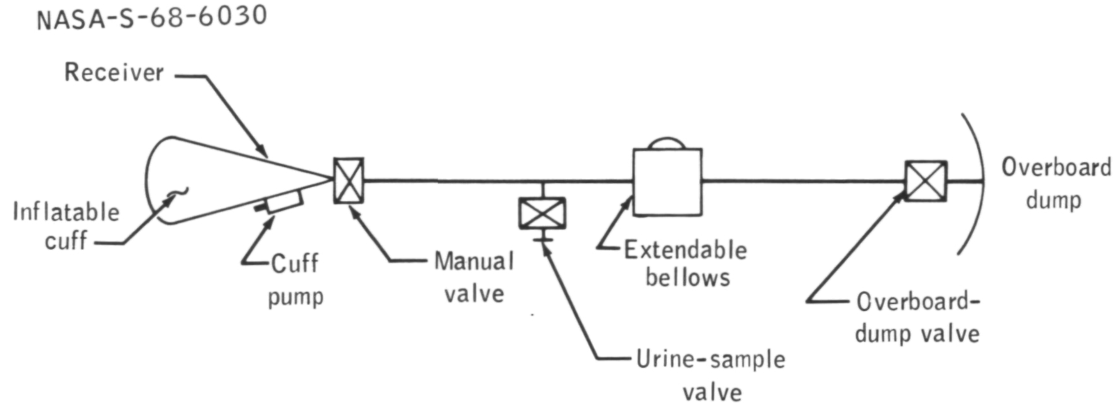

Figure 4. - System for inflight disposal of urine for Gemini missions III and IV.

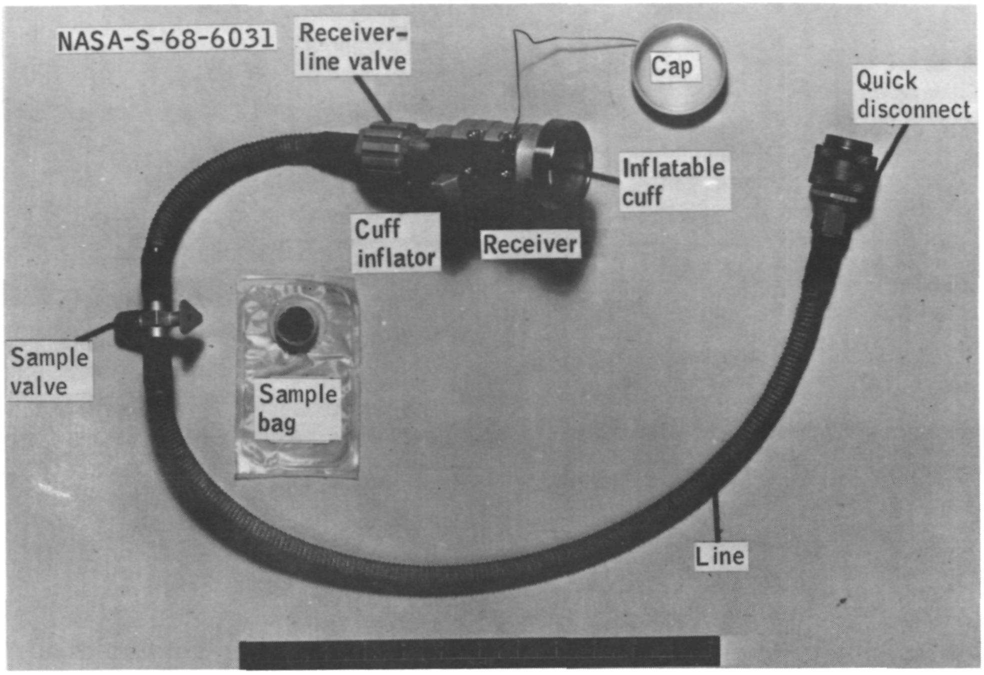

Figure 5. - Receiver-line assembly.

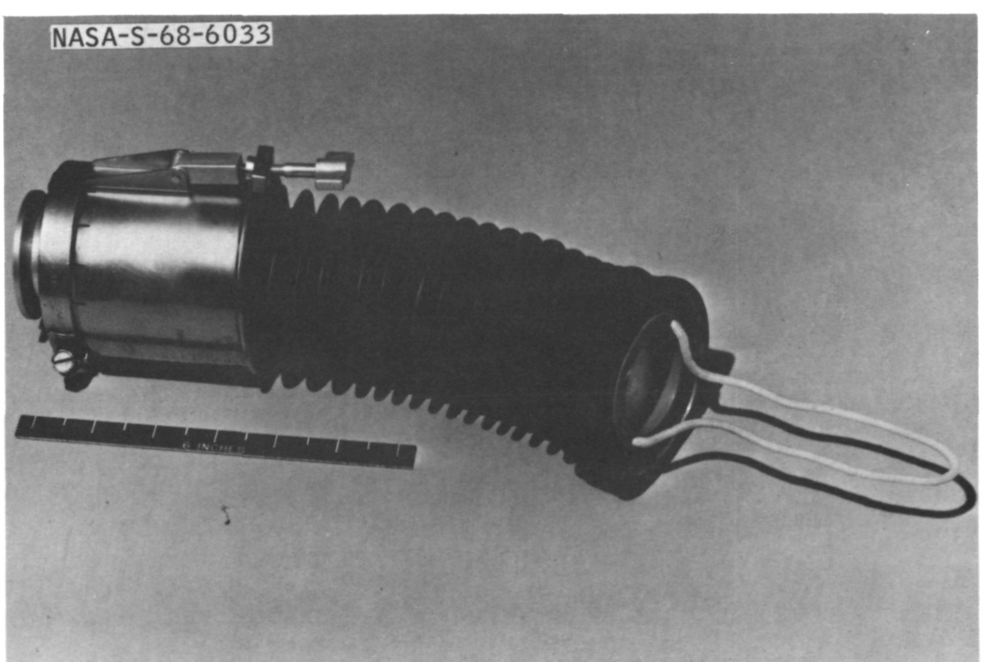

Figure 6. - Extendable urine-bellows assembly.

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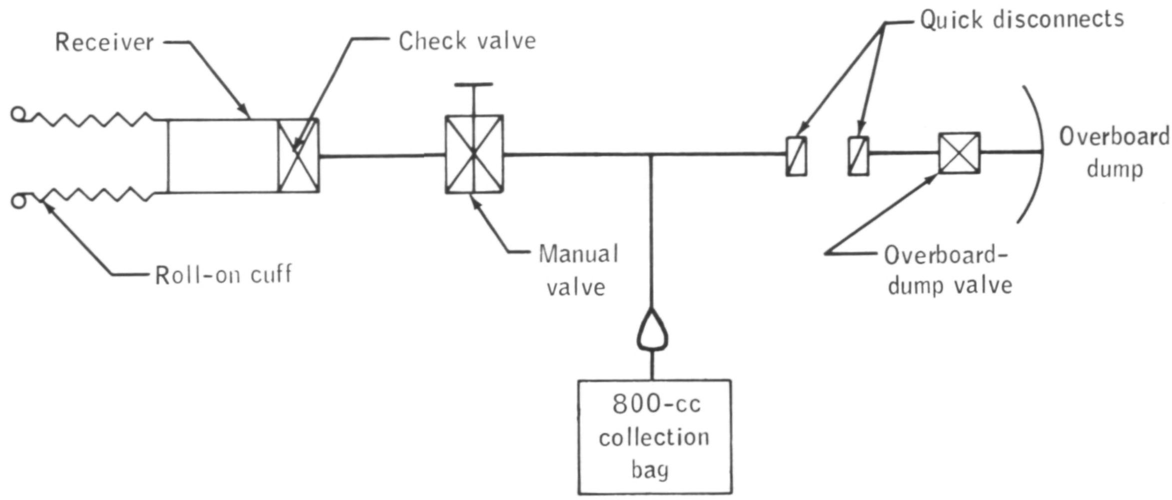

Figure 7. - Redesigned waste-management system for the Gemini spacecraft.

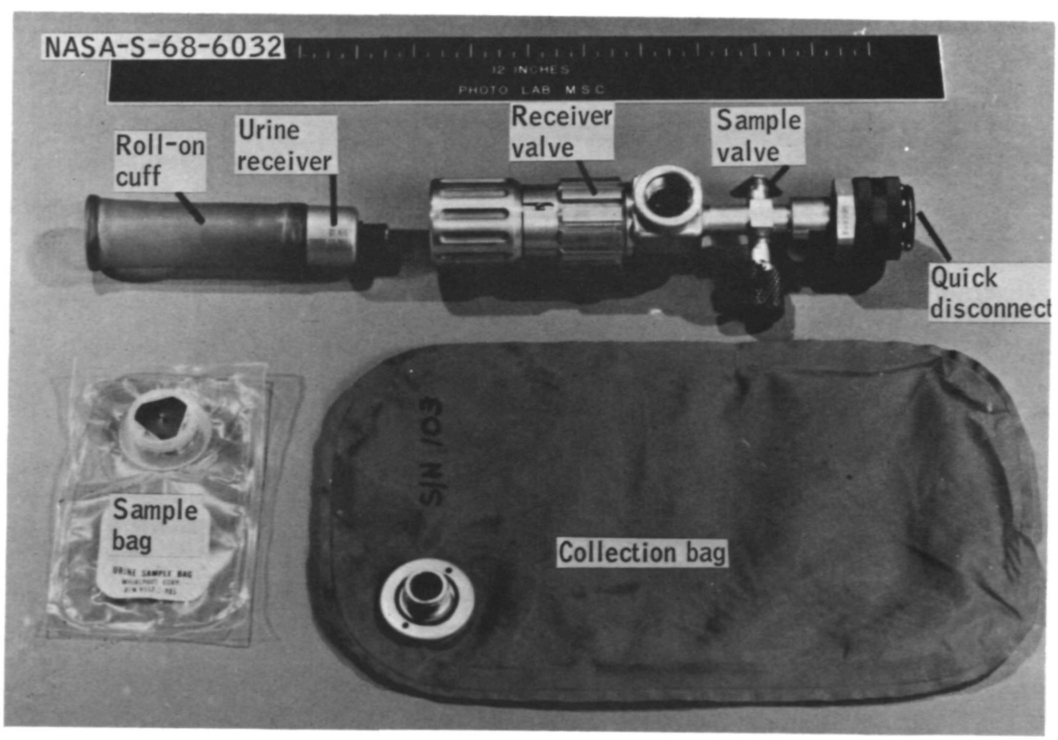

Figure 8. - Roll-on cuff receiver, urine-system assembly.

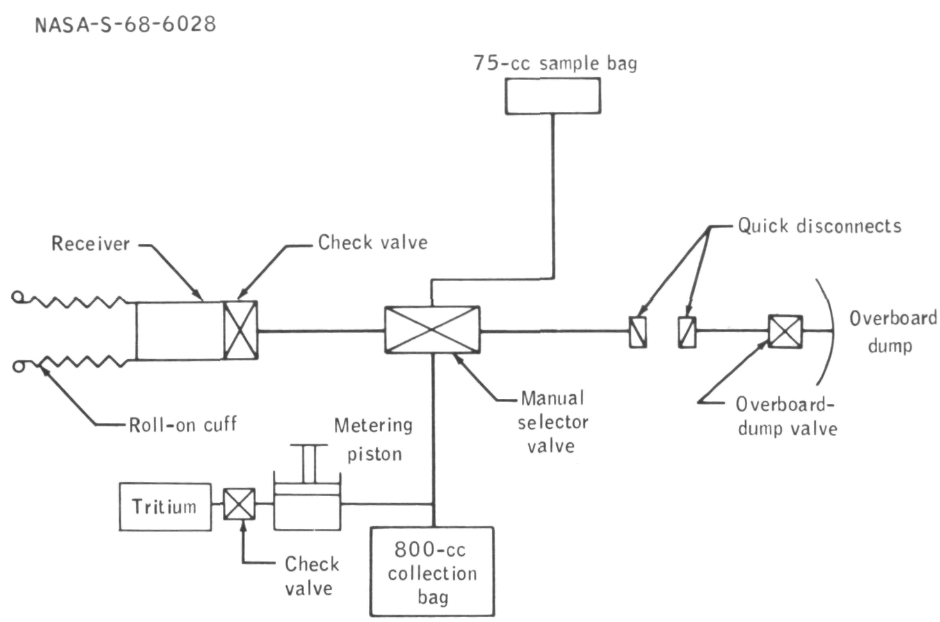

Figure 9. - Urination system with chemical urine-volume measuring subsystem (CUVMS) attachment for Gemini missions VII and IX.

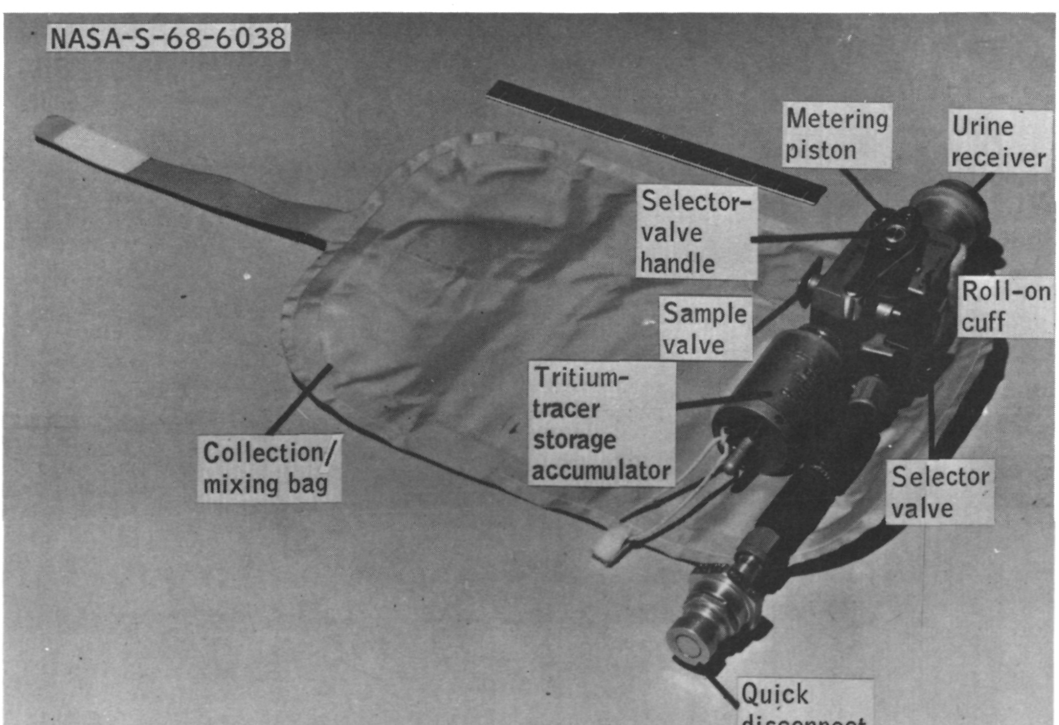

Figure 10. - Chemical urine-volume measuring subsystem (CUVMS).

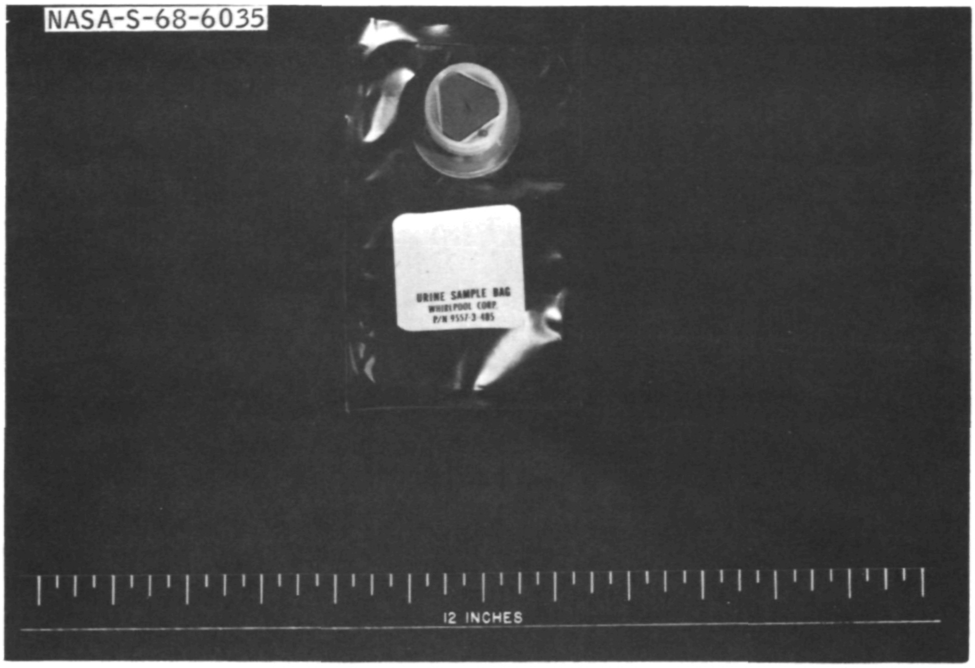

Figure 11. - Urine-sample bag.

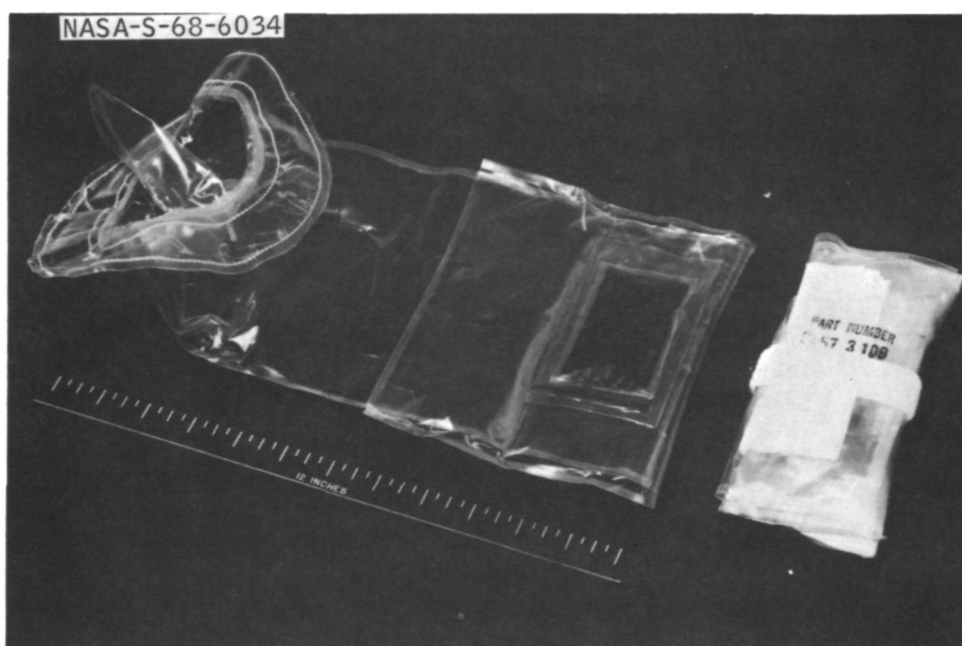

Figure 12. - Defecation-collection device.

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