SECTION S-1

WASTE MANAGEMENT PROCEDURES IN MANNED SPACE OPERATIONS

by

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In this informal presentation I shall attempt to outline past problems in waste management so as to put the present into perspective, and direct our attention to future needs.

At the time of the initial Mercury mission - a suborbital flight of 15 minutes - no concern about waste management was needed. In this and succeeding flights of lengthening duration an in-suit urine bag was worn continuously, and urination was accomplished as required without further preparation. Because of the tendency for back-up and leakage in the absence of gravity, the astronauts were all "wet-backs" by this procedure.

No procedure was required for defecation. The longest Mercury flight was ~~24~~ 34 hours, + 20 minutes, and appropriate dietary preparation preflight, using low-residue foods, made defecation unnecessary.

Urination, however, was not a simple procedure, especially when it became necessary to transfer urine from the in-suit bag to a container inside the spacecraft. On Gordon Cooper's flight - the last one in Mercury - a transfer system was used which was a veterinary syringe with associated tubing ~~lying on the side of the craft~~. The tubing was connected to the urine bag inside the suit, and urine was removed from the bag after each urination by drawing it into the syringe barrel with suction from the plunger. It then was transferred through a needle plugged into the syringe by pumping the withdrawn urine with the plunger down into storage bags under the couch. At that time separate samples were preserved of all the urine from each urination. Of course, this introduced the problem of how you can preserve intact in the urine the components for which you need to analyze the samples postflight. This urine transfer system created a lot of difficulty - so much so that the flight was known unofficially as H_2O-7 because of difficulties with urine and water transfer. ~~Everything was constantly~~ Things were frequently wet during the flight.

Gemini was next. These were to be long duration flights. After a 3-orbit check, they were to go 4, 8, and 14 days. It was thus imperative now that we take a look at defecation. The requirements were that the system be usable in the narrow confines of the two-man Gemini cabin; and obviously there was no room for either man to move much out of position. The simplest feasible thing was to design a fecal bag, which was a plastic bag with sticky surfaces around the top, and with a finger cot in the side. It was stuck to the buttocks, and a finger inserted in the cot was used to help get the feces into the bag. Wet wipes and tissues were in a pocket on the side, together with a capsule of a disinfecting agent to mix with the feces to stop further putrefaction of the feces in the bag. After defecation, the top was sealed and the package was kept for post-flight analysis. We have never dumped feces in space and have always returned the total amount for analysis.

This arrangement did work fairly well, but the man had to stretch one leg into the other man's lap; and it was not aesthetically acceptable because literally a man must defecate in his hand. No matter how clean he tried to be with the bag and the wipes, he would end up having feces all over his hands. The operation was so distasteful, that, although they did manage, the crew was always trying to put off defecation by using Lomotil. This had been included in the medical supplies only as a precaution against diarrhea.

With regard to urination in Gemini, it had been planned to take in-flight samples, which was the first time multiple samples were attempted, other than the syringe and needle transfer in Mercury. It was impossible to save and store all the urine so we couldn't take total samples. The plan was to measure total volume, then to take and preserve an aliquot for analysis, and finally to dump the remainder overboard. This was the only sensible way to go, considering the stringent weight and volume limitations.

The system itself was quite ingenious, although it was still necessary to have an in-suit urine bag during launch. The penis was connected at all times to the bag through a tube with a roll-on condom. Thus urination took place without any preparative procedures during the suited phase of the flight.

Once you were in orbit or after you could get out of the suit, you could take out the urine bag and dump it through the regular system used for taking a sample, and thereafter you could go ahead and use the in-flight system. This Gemini in-flight system was one requiring 17 or 18 operations to complete the process of urinating each time it was necessary. The system used a tritium tracer mixed with the urine flowing into the bag through a ~~flowmeter~~ valve. The user connected himself to the system through an individually fitted personal condom and connector tube.

There were always problems with leaks out along the condom connection even though the condoms were carefully fitted. Their specifically designed use as a connector has been fairly satisfactory except for another difficulty with the rubber condom getting sticky ~~or tacky~~, so that it had to be replaced about every day during the 14-day Gemini flight. Once the user was connected to the device he set a valve at the "Urinate" position and the stream of urine had tritium mixed with it as it passed into the bag.

After completing urination the fitting was disconnected; the bag collector was kneaded to mix the tritium uniformly with the urine; and the valve was turned from "Urinate" to "Sample" position. A sample bag was taken from the stored supply,(this is a small plastic bag with a rubber top much like a vaccine bottle), and the sample bag top was connected to a fitting on the valve. After it was connected, another handle near the valve was turned to thrust a trocar through the opening of the fitting and pierce the rubber top. By squeezing the large urine bag, a 75 cc sample of the urine was forced into the sample bag through the hollow trocar. The valve was turned off the "Sample" position, and the trocar was withdrawn by turning back the other handle. The sample bag was disconnected, labelled with time and source, and stowed for post-flight analysis.

Next a heater on the urine ~~vent~~ dump line was turned on, and enough time was allowed for the outside part to warm up in order to make sure it was not frozen shut at the exit. Finally the valve was turned to the "Dump" position, and vacuum from outside was allowed to empty the urine in the bag overboard. The tritium concentration in the urine was used post-flight as a measure of the total volume of urine voided.

Although this system could work fairly well, there were definite problems with acceptance by the crew. Although it could be a good system in the laboratory with very meticulous attention to how it was used, there also had to be a certainty that no leaks developed in order to have it give fairly accurate volumes. To repeat, it was not operationally acceptable to the crew, and crew cooperation is necessary to do the kinds of measurements that will be required to measure what is happening to man during long duration space flight. Procedures must be acceptable, and they must be done simply, in order to get the necessary information.

As a result of the Gemini experience, it was a strong conclusion that the engineers must design a system that would allow the man virtually to urinate as he would on the ground. The system ought to be designed to measure automatically the volume of each urination, and then take a sample, and label it. ~~and tie it for~~

storage. All the astronaut should have to do would be to detach the sample bag and stow it.

Some study contracts went out on a crash basis in the latter part of the Gemini program, and three companies had ideas on how such a system could be designed. Prototype systems were built and tested at Manned Spacecraft Center from all three companies, and activity has recessed since then.

As we came to the Apollo experience, we hoped that something had been learned in the process, and everything was expected to be right. It seemed, however, that the Apollo system was developed without much attention to experience gained in Gemini. There was a start on development of an in-flight system that has a fecal canister, and a urine system that was somewhat mechanized. The urine device provided a closure with a diaphragm that fitted around the penis. The fecal canister was pretty small. It required airflow for the weightless state, using either vacuum or pressure to induce the airflow to move the feces.

Several things happened when the system faced acceptance by use test. Two things were important. The crew rejected the system because the canister was too small and you couldn't position yourself properly on it before use. Also, the airflow was totally inadequate - there was not enough flow to move the bolus, or to operate the vacuum cleaner for collecting debris, or to move the urine. So the whole system was rejected. Prior to the 101 flight it was decided to go back again to the archaic Gemini waste management system in this third-generation spacecraft; and even now the man virtually defecates in his hand, and the urine is dumped overboard.

There are still a large number of operations to making a urine dump. On Apollo 7 the crew described some 16 different operations to urinate and dispose of the urine. There was no sampling even then - just disposal. It is remarkable that the tests in chambers on the ground have always frozen the urine dump line, but nothing of the kind happened in flight. Freezing was expected to happen with such certainty that an emergency dump line was provided to dump through the hatch, if necessary. However, to repeat, there are still too many operations, and this situation must be improved.

To summarize - we still have a serious problem with the fecal bags. Wally (~~Cunningham~~ Schirra) never had defecated in flight prior to Apollo, either in Mercury or Gemini, so we tried to do some preflight training, and found there were problems even with gravity. The crewmen were concerned about the wipes. We developed a detailed procedure, in which they laid out everything ahead of time, something like this: first, get out the bag, then take out the wet wipe, (which isn't wet), wet it, take out a bunch of tissues, lay them out, and wet them so they can be used later on to remove smears from your hands (because you wouldn't want to touch the water gun with dirty hands), and so on. In the mission log, ~~Wally~~ Walt wrote a treatise on this operation. (Editor's note: Walter Cunningham's report is given as Appendix C, Summary Report on Waste Management). The crew had some 11 bowel movements during the flight, and the operation didn't get any easier with practice, so it is not a system that is desirable for continued use. It can be used to accomplish the Apollo program but we would prefer not. Timewise, there will be not much opportunity to make revisions. However, we cannot afford to face 30, 60, and 120-day missions with this system.

There are still other problems with the Apollo waste management system, because there are other wastes that must be handled. As you know, waste water is dumped. Since there is a sufficiency of potable water, urine is dumped too. In every spacecraft flown so far there has been a cross connection between the potable water and the urine waste system through the water dump. As a precaution we have tried a chlorination system for the potable water. Test results preflight were poor, and the chlorination system could not be qualified on the basis that tests did not prove it capable of maintaining 1/2 ppm of chlorine residual after 24 hours. A regime of a 24-hour chlorination period was set up, but chlorine content was insufficient in the latter part of the period.

Then a second problem arose, in that the chlorine treatment caused marked corrosion in the water piping, which contained dissimilar metals. There was worry about having any chlorine at all present because of the corrosion. Thus there was a conflict as to whether this system should be operated to safeguard against corrosion or to safeguard health. It is always difficult to apply quantitative limits to either corrosion or health criteria, so that desirable or permissible levels of chlorine could not be specified from either viewpoint. It seems reasonable, however, that we leaned in the direction of preventing illness rather than preventing corrosion failure of the water system. So we did chlorinate ever 24 hours for the first three days, and thereafter every 48 hours, because the crew believed they could still taste chlorine in the water after 24 hours. How this could happen is still unanswered. There were organisms in the water postflight, but there are no details at the present time. This does illustrate that there are still problems with the drinking water as well as the waste water.

Another real problem was with flatus. During the latter part of the mission, the crew got out the emergency oxygen masks and used them frequently as protection against the overpowering and suffocating flatus odor. The crew were all so concerned that they kept the masks available and ready to put on with the shortest warning. This obviously is a very distasteful situation which should be remedied.

Now to go on for a look at some things in the future. It is imperative that we have adequate and accurate samples of waste, taken in flight. Simply having a fancy toilet does not answer the requirements, in AAP particularly.

There will be an opportunity for experimental studies of man's responses to flight of long duration, and many of the studies will depend upon information derived from an accurate metabolic balance. There must be a certain degree of accuracy which will be discussed later.

Although I may sound unhappy with the engineering designs of the waste management components, this is not the whole source of difficulty. We have had many problems to solve in the past that were of higher priority than waste management, because the mission couldn't otherwise have been flown. But now we are at a stage where we have to start considering what are man's requirements in order to just live - to sleep, eat, drink, urinate, defecate, etc. These simple, mundane things should now be taken care of better than they are now, or have been. This is my main message to the Workshop.