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Compost Toilets: A Guide for Owner-Builders

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Compost Toilets

**A Guide
for
Owner-builders**

National Center for Appropriate Technology

P.O. Box 3838

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INTRODUCTION

Why use a compost toilet? The reasons most often mentioned are water conservation and elimination of water pollution. The flush toilet, long considered the symbol of modern sanitation and progress, wastes approximately 40 percent of all water piped into the home. In recent years, the demand has escalated, leaving that resource increasingly scarce in some regions. The waterless, or compost toilet can save from 25-60 gallons of water per person per day.¹

A second consideration is waste recycling. The decision was made, years ago, that water would serve as a sewage disposal medium; that choice is becoming a heavy social burden. American taxpayers spend billions of dollars each year on sewage treatment facilities. As water use increases, treatment plants get bigger and yet the technology is hard-pressed to keep up with the volume and types of wastes in our disposal water. On-site waste treatment and recycling through compost toilets could partially alleviate the strain on these facilities.

Of course, composting toilets fill only a small gap in regional waste disposal needs. After all, such systems must necessarily be accompanied by back-up systems to handle other waste water (i.e., tub, shower, sinks). What's more, the cost of these alternative toilets is still high, and beyond the reach of far too many people.

Nonetheless, there is sufficient need to develop suitable designs and encourage the use of waterless toilets in areas where they are appropriate. One way to make the technology cost-effective is to design and build your own system.

In each individual case, the relative value of using a compost toilet must be determined. This value varies with environmental conditions and personal lifestyles. For example, in a rural setting where septic tanks and leach fields are not feasible, the composting toilet can be extremely valuable. But using a compost toilet in a New York City apartment may not be practical. Using such a toilet is not a simple exercise. Where we are used to convenience, this alternative entails work.

When is the compost toilet the most efficient option for human waste treatment? Efficiency entails more than saving water and recycling wastes; it involves public health as well. Most societies choose a water sewage treatment system for more reasons than convenience. The potential for disease borne and bred in human wastes is great. Compost toilets are imperative and must be part of the efficiency rating for this alternative technology.

A compost toilet, as this guide points out, can be a safe and efficient, sanitary human waste treatment system. The main question facing owner/builders is whether they are prepared to take the time to manage the system efficiently.

We assume that our reader has already examined his or her need for a compost toilet and determined the purposes for its use. Our primary aim is to identify the important construction, installation, and maintenance considerations relative to compost toilets. Our goal is to put the reader in a better position to manage the decisions and subsequent tasks of compost toilet use.

The theme of Section I is process: the composting process; the breakdown of human wastes through natural decomposition; and effective management of the process in order for decomposition to occur. The difference between an outdoor composting pile and a compost toilet is clarified and, most importantly, the health implications of compost toilet usage are examined.

In Section II, basic compost toilet designs are reviewed. Here the prospective owner/builder is introduced to problems that may arise in the construction, installation and/or maintenance of compost toilets.

Section III cites the valuable experience of other users. Last year, the National Center for Appropriate Technology conducted a survey of compost toilet owner/builders. The results of that survey, presented in Section III, indicate what other people are doing in the field of owner-built compost toilets.

The authors do not intend this Guide to be the definitive work on compost toilets. It is written to promote information development and exchange. Alternative human waste disposal systems are an emerging technology in which more research is needed. Modifications and improvements in design, as well as reductions in cost, could spur greater public use. The authors hope this Guide will instigate communication and feedback among researchers in this field, and help get individual owner/builders started on the right track.

CREDITS:

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I. OVERVIEW OF THE COMPOSTING PROCESS

A. Introduction:

In this section a brief but concise overview of the composting process is provided, with special considerations relative to compost toilets. The biological process involved in composting organic wastes is reviewed and the differences between a "compost toilet" and a "compost pile" are clarified. Finally, the health implications of compost toilet usage are examined.

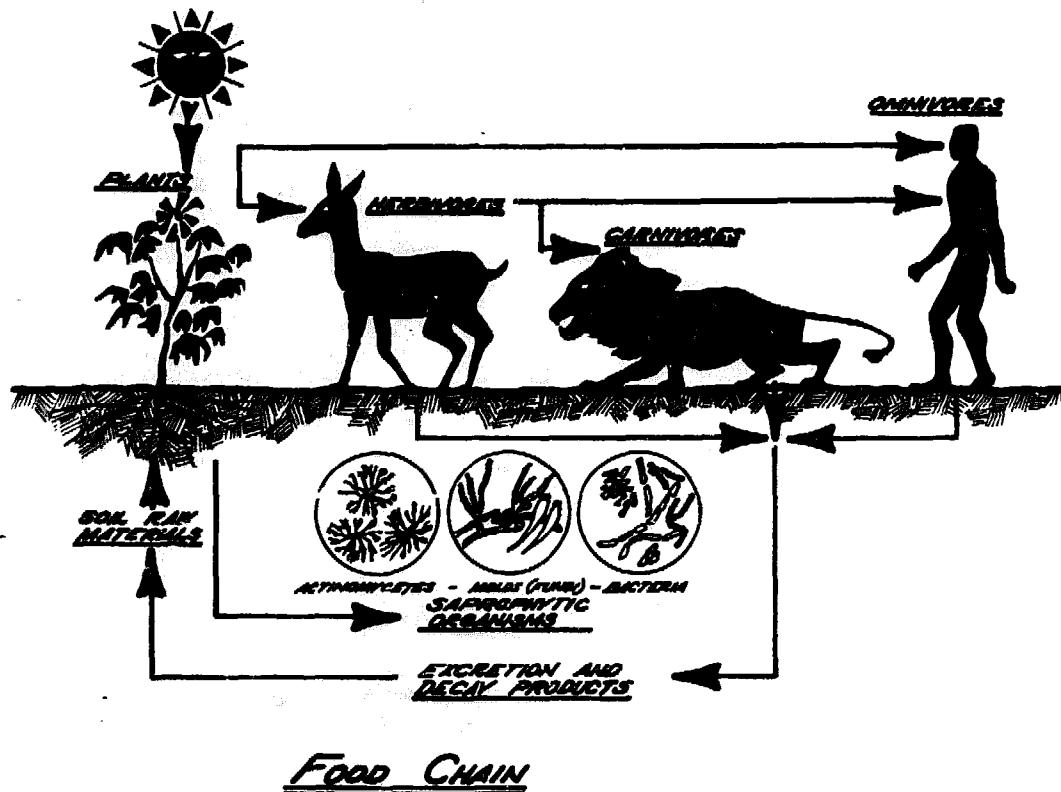
A compost toilet owner, builder, or user must be critically aware of many important factors. Because of the potential health problems associated with human excrement, special precautions must be taken in all stages of compost toilet use. The user must understand the degree of maintenance required for a compost toilet to function properly. The user must take time to learn health-safety precautions and how human wastes are transformed into a manageable end product through biological decomposition. A compost toilet may be a safe, environmentally sound alternative to the flush toilet but only if constructed and maintained correctly.

B. Composting: A Biological Process

Generally, "compost" is a mixture that consists largely of organic matter. The organic matter undergoes a chemical and physical change--natural decomposition through biological action. The result is a reduction in the volume of matter and an end product that has been used by some as a soil conditioner. (However, NCAT cannot recommend this use unless the end product has been proven safe without additional heat sterilization.)

A look at the food chain, one of the elementary principles of biology, helps to illustrate the composting process.

Figure 1.1



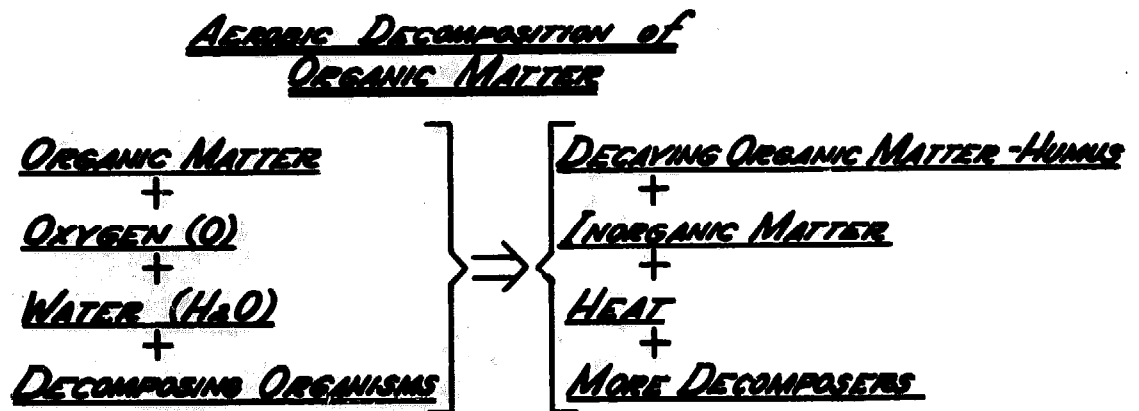
Every living thing is reduced to its organic and inorganic constituents by decomposing organisms (also called saprophytic organisms). These organisms include a variety of fungi, bacteria and protozoa. To live, saprophytic or decomposing organisms must utilize carbon from other sources (namely organic material). They cannot take energy from the sun and use it as green plants do through photosynthesis. More simply put, the decomposing organisms eat and live off organic matter. Some types of organisms such as actinomycetes, have complex nutrient needs, and in addition to carbonaceous compounds (i.e. straw, dry leaves) they are able to decompose (or eat) a variety of other substances found in compost toilets and piles.

Two types of decomposition can occur: Anaerobic and Aerobic.

Anaerobic decomposition occurs without the presence of oxygen, like the decomposition that occurs in swamps, septic tanks, cesspools, or the bottom of a garbage can when it hasn't been emptied for a while. The foul-smelling odor is a result of the production of chemical by-products which are produced, along with organic acids, ammonia, and methane by anaerobic bacteria. No heat is liberated in the anaerobic decomposition process.

Aerobic decomposition utilizes oxygen in the decaying process and no odor is generated. Composting is aerobic decomposition. The simplified equation in Figure 2 depicts how organic matter is decomposed into its organic and inorganic constituents by decomposing organisms.

Figure 1.2



C. Compost Toilet vs. Compost Pile

There are several critical differences between a compost pile and a compost toilet that tend to be overlooked due to the similarities in their names.

The basic difference is that the compost toilet uses a high volume of human wastes and the compost pile uses none. The potential disease factors associated with human excrement make it necessary to use a toilet design which minimizes the handling of waste.

The presence of human wastes in the process places important constraints on the use of the end product from a compost toilet. A compost pile is basically a waste recycling system; it is usually built with the express purpose of recycling organic wastes. Periodic turning of the collected waste is part of regular maintenance to achieve proper aeration and insure that all areas of the pile are heated. The pile is maintained in this manner to insure that the end product can be used safely as a fertilizer or soil conditioner.

A compost toilet, on the other hand, is basically a waste treatment system. Its main purposes are to save water and reduce the volume of human wastes with on-site treatment. Little research has been done addressing the pathogen content of the end product from a compost toilet. While certain individuals generally regard the end product as a safe soil conditioner for residential lawns and ornamental plants, the safety of this practice has not been proven. Likewise, its use as a fertilizer for food-producing gardens is questionable as the potential for disease transmission remains unclear.

However, while there are major differences between a compost toilet and pile that require special precautions, there are also similarities between them. It is a good idea for individuals to experiment with the process of building outdoor compost piles or using indoor composting bins to acquaint themselves with the composting process. Start off by using plant materials and animal manures only. Meat, dead animals, or human excrement should never be used in a compost pile because of the danger of introducing harmful organisms. Once the process becomes familiar and an odorless, biologically balanced pile has been built that results in a humus/soil-like end product, the basics required to build and maintain a compost toilet should be understood enough to consider trying a composting toilet.

D. Composting Considerations for Compost Toilets

Through the experience gained in building an outdoor compost pile, you will learn the importance of layering the wet, green, nitrogenous materials with the dry, brown carbonaceous materials to provide a balanced diet for the decomposing organisms. Air and water are also necessary, as well as soil or old compost (to inoculate the pile with the decomposers). These ingredients are the basic necessities for the composting processes, whether it be outside or inside, or on a large or small scale. Carefully attend to balancing these biologic requirements to keep your indoor composting toilet in good working order.

1. Household Sewage Description

Before building a compost toilet, it is a good idea to identify personal household waste categories. Household waste can be divided into three major categories:

TABLE 1: HOUSEHOLD WASTE CATEGORIES

	<u>Definition</u>	<u>Examples</u>
Black Waste²	Any material normally disposed of through the toilet	Urine, feces, toilet paper, tampons
Grey Waste²	Other household wastes normally disposed of through plumbing fixtures	Laundry water, bath and/or shower water, sink water, garbage-disposal water
Solid Waste	All other household wastes not normally transported by water	Cans, glass, waste paper, plastic, etc.

It is important to remember that a compost toilet will only handle black waste and organic solid waste such as fruit peelings, egg shells, coffee grounds, etc. Therefore, other means must be available for dealing with grey waste⁵ and non-organic solid waste.⁶

2. Carbon/Nitrogen Ratio

For optimum composting, food for decomposers must be in balanced proportions for rapid reproduction. One way to maintain the right nutritional balance is to monitor the ratio of carbon to nitrogen in the organic matter to be decomposed. Carbon is utilized as a source of energy by the decomposing organisms, while nitrogen is used in building the protein necessary in cell structure.⁷

About 20-25 times more carbon is needed than nitrogen.⁸ If there is an excess of nitrogen, the carbon will be used up before the composting is finished and the extra nitrogen will be wasted. Odor is a key clue here as the loss of waste nitrogen can be detected by the odor of ammonia escaping from the pile. When carbon is too plentiful, all the available nitrogen will be utilized before the organic matter is thoroughly digested. The material can still be broken down, but the process is much slower. Besides providing a source of energy and balancing the diet for decomposing organisms, the addition of carbonaceous material prevents compaction by increasing the air spaces in the mass.

With specific regard to maintaining the C/N ratio in a compost toilet, a few facts should be considered. First, the nitrogen content of black waste is high, mainly because of the high nitrogen content of the urine. Secondly, feces and fresh kitchen wastes, also thrown into a compost toilet, are relatively high in nitrogen. Therefore, it is important to add sufficient amounts of carbonaceous material to insure that proper composting is accomplished.

For example, a 180 pound adult male's daily excrement output is about one (1) quart of urine and approximately one-half ($\frac{1}{2}$) pound of feces.¹⁴ Also, a household will accumulate a daily amount of organic wastes (i.e., leftover vegetables, fresh fruit peels). Remembering that the optimum C/N ratio for proper composting is 30:1, a significant amount of carbonaceous material is needed to balance the nitrogen content. Dried leaves, dried grass clippings, hay, and straw are good carbonaceous supplements to the highly nitrogenous content of human wastes.

It's good to remember that, to a certain extent, the carbon content of organic materials is a function of moisture: drier wastes - higher carbon; more wet - lower carbon, more nitrogen. For example, fresh cut, green grass clippings will have a higher nitrogen content than dried clippings. Remember, a variety of wastes and layering these wastes are key to the right C/N ratio. Use what is available; soon you will have a sense of what kinds of waste combinations work best in your toilet.

Table 2 shows the C/N ratios for some common organic materials. Relative to a compost toilet's ecosystem, materials with less than a 30:1 ratio should be considered nitrogenous, whereas over 30:1 should be considered carbonaceous.

TABLE 2: C/N RATIOS FOR ORGANIC MATERIALS⁷

Example 1:

Urine is approximately 14% C
 17% N
 69% Other (Potassium,
 Phosphorous, etc.)

C/N = 0.8:1

For every 0.8 parts carbon,
 there is one (1) part nitrogen

Example 2:

Feces is approximately 48% C
 6% N
 46% Other (Potassium,
 Phosphorous, etc.)

C/N = 6:1

For every 6 parts carbon,
 there is one part nitrogen

Urine	0.8 : 1	Raw Garbage (eggshells, peels)	25 : 1
Blood	3 : 1	Dried Grass Clippings	19 : 1
Feces	6-10 : 1	Wheat Straw	128 : 1
Green Grass Clippings	12 : 1	Rotted Sawdust	208 : 1
Tobacco	13 : 1	Wood Chips	800 : 1
Farmyard Manure	14 : 1		
Seaweed	19 : 1		

3. Aeration

Another key requirement for effective composting is air. It is imperative that the entire pile (or toilet chamber) receives sufficient quantities of air to support the decomposing organisms. If optimum aeration is not maintained, the composting process will turn anaerobic and slow down. Odor will develop from the toilet throne if there is poor aeration or poor ventilation.

Outdoor compost piles are usually aerated by manual or mechanical turning. Likewise, indoor compost toilets require some means of keeping the pile from going anaerobic. As mentioned before, adding carbonaceous organic matter is one way of providing sufficient air while eliminating compaction.

Some toilet designs include a mechanical turning device for pile aeration, other designs use air-fed sloping floor inclines to aerate the organic contents slowly as the material slides to the front of the chamber. The potential for disease transmission with toilet contents requires that manual handling be minimized and preferably eliminated. Those designs requiring frequent manual handling are not recommended.

4. Moisture

There is a delicate balance between air and moisture in the composting process. Too much air results in a too dry pile, while too much water results in poor aeration. Excessive moisture will result in liquid pooling at the bottom of the (toilet) container. It will also cool the pile as the accumulated liquid takes away the generated heat, and encourages anaerobic conditions. Black waste has a high water content, therefore, it is necessary to consistently add dry carbonaceous material to reduce wetness to a moist, slightly damp-dry condition. Adding the dry material on a regular basis after the addition of black waste is an effective method for moisture retention. Likewise, the elimination of urine in the toilet will solve large water content problems.^{10,11}

A too dry compost pile, on the other hand, will cause decomposition to slow down and, in the case of the smaller commercial compost toilets with heating elements, the pile will harden.

After obtaining experience with building compost piles using only plant material, you will be able to judge optimum moisture content. Maximum moisture content for wastes is 55-65 percent.⁸ If moisture drops below 45-50 percent, dryness will become a limiting factor in the decomposition process. Generally, compost should look damp when turned.

5. Decomposing Organisms

The purpose of a compost pile is to simulate, as closely as possible, the same ecology that exists in the top layers of soil. It is here that organic material is decomposed by saprophytic organisms for use in the food chain.

Fungi are very useful organisms in a compost pile (or toilet chamber) and are generally found in the cooler outer layers of the pile, along with the actinomycetes (which closely resemble fungi in appearance).⁷ Colonies of actinomycetes give soil and properly-prepared compost the smell characteristic of freshly turned earth.¹² These organisms also produce antibiotics, the most familiar of which is streptomycin produced by the genus Streptomyces. The antibiotics produced from these organisms will appear later in the discussion of preventing growth of human pathogens in compost toilets.

Actinomycetes will grow in the cool outer layers of the compost pile and, together with fungi, appear as greyish-white threads covering the pile.⁷ Cellulose and lignin (carbon compounds which are particularly resistant to decomposition), are decomposed by actinomycetes and fungi in the latter stages of the composting process.

Bacteria are the other soil organisms that are important in composting, and, because of their numbers, they do most of the decomposing. Speed and effectiveness of the decomposition process depends on the type of bacteria involved. Decomposition occurs most rapidly at high temperatures which support a certain group of organisms. Therefore, bacteria are grouped according to the temperatures at which they are found.

Mesophilic bacteria are found predominantly at the beginning of decomposition with an optimum temperature range of 77-104°F.¹³ Thermophilic bacteria (heat-loving) begin to thrive and soon proliferate at temperatures between 122-131°F.

Insulating qualities of a certain size pile (one cubic yard or larger) trap the heat generated by these organisms. The center of the pile is then able to retain heat and support thermophilic bacteria which results in more rapid decomposition.

Many other types of organisms which live off of the saprophytic organisms are found in soil and compost piles. Most visible are the many types of insects. Most of the insects present in a compost pile are a natural development of the food chain and should be encouraged by careful maintenance of the compost environment. Other insects such as flies can be a nuisance and, more seriously, in the case of the house fly, carriers of pathogenic organisms. Spiders are useful in controlling unwanted fly populations and are also essential parts of the food chain.

E. Health Implications of Compost Toilet Usage

Historically, it was a major triumph in public health to be able to use human waste treatment to prevent many infectious diseases. Primarily, waste treatment involved preventing human wastes from contaminating the soil and drinking water supplies. Thus, the flush toilet was developed.⁵ The use of compost toilets as an alternative to the flush toilet has raised serious health considerations. Many unanswered questions remain regarding the management of compost toilets and the effects of their use on public health and safety. These questions are the major reason for the reluctance of local health departments to allow the installation of such alternative toilets.

While states are now re-examining their building and health codes to allow for greater use of compost toilets, such systems are still considered experimental.^{14 15} In order to convince local health authorities of the feasibility of using a compost toilet to treat wastes, and more importantly, to protect the health of the owners and their neighbors, it is imperative that the owner-builder understand and address accordingly the health implications of compost toilet usage.

1. The Potential Problem

The goal in using a compost toilet is to insure that disease transmission does not occur during use, maintenance or handling of the final product. Sanitary management of feces is critical to maintaining a healthy population. Feces contain undigested food substances, chemical by-products of the pollutants we are subjected to or ingest voluntarily, and a variety of bacteria, viruses, protozoa and parasites that occur naturally or as a result of infection.¹⁷ Healthy individuals also harbor many pathogens in their gastrointestinal tracts. Examples of fecal-borne diseases are listed below in Table Three.

TABLE 3: EXAMPLES OF FECAL-BORNE DISEASES^{7 17}

<u>Agent</u>	<u>Disease</u>
Bacteria	Bacillary Dysentery Typhoid Fever Cholera
Protozoa	Amoebic Dysentery Flagellate Diarrhea
Parasites	Ascariasis Trichuriasis Giardiasis
Viruses	Infectious Hepatitis

Urine is relatively harmless compared to feces. However, it is not toxicant or pathogen-free. If an individual has been exposed to a toxic chemical (such as arsenic), the chemical is primarily eliminated in the urine.¹⁹ Also, infections of the kidney, bladder, or other parts of the urinary tract will contaminate urine excrement.¹⁸ Finally, urine is contaminated when exposed to skin as it leaves the body.^{20 21} Therefore, it is mandatory that urine also be treated before disposal.

The transmission of disease is dependent upon the existence of all of the following factors:^{9 22}

1. Agent of the disease (cold virus)
2. Source of the infection (another human)
3. Mode of escape from the source (sneeze)
4. Mode of transmission from the source to the host (air-borne droplets)
5. Mode of entry into the host (person breathes in contaminated droplets)
6. Susceptible host (contaminated person's resistance is low)

Absence of one of the above factors will prevent transmission of the disease. On dealing with feces and urine, the most practical method of disease prevention is eliminating the mode of transmission from the source to the host, that is, isolation and sanitary disposal of the wastes to prevent contamination of soil, food, water, etc.⁹

2. Preventing Disease Transmission in Compost Toilets

Theoretically, a compost toilet should be designed to isolate and render harmless the pathogens that are associated with excreta. Isolation occurs by enclosing the wastes in a container and preventing disease-transmitting vermin or insects from entering. Ideally, the toilet should eliminate the necessity of handling contaminated material.

The theory behind pathogen reduction in a compost toilet centers around three factors: heat, bacterial interaction, and time.^{7 17} Heat is a direct consequence of the composting process. The heat of metabolism at the center of a compost pile is generated by the organisms engaged in the decomposition process. Temperatures in the center of the pile can reach over 131°F, which exceeds the thermal death points of many pathogens (Table 4). However, slant-bottom type commercial compost toilets have no provisions for waste pasteurization. They never get hotter than 90°F, and seldom over 70°F.

TABLE 4: THERMAL DEATH POINTS OF SOME COMMON PATHOGENS AND PARASITES⁷

<u>Organism</u>	<u>Thermal Death Points</u>
<u>Salmonella typhosa</u>	No growth beyond 115°F; death within 30 minutes at 131°F to 140°F.
<u>Salmonella spp.</u>	Death within one hour at 133°F; death within 15 to 20 minutes at 140°F.
<u>Shigella spp.</u>	Death within one hour at 131°F.
<u>Escherichia coli</u>	Most die within one hour at 131°F and within 15 to 20 minutes at 140°F.
<u>Endamoeba histolytica</u>	Thermal death point is 154°F
<u>Taenia saginata</u>	Death within five minutes at 160°F.
<u>Trichinella spiralis larvae</u>	Infectivity reduces as a result of one hour exposure at 122°F; thermal death point is 144°F to 162°F.
<u>Necator americanus</u>	Death within 50 minutes at 113°F
<u>Brucella abortus</u> (or suis)	Death within three minutes at 142°F
<u>Micrococcus pyogenes</u> (var. aureus)	Death within 10 minutes at 122°F.
<u>Streptococcus pyogenes</u>	Death within 10 minutes at 129°F.
<u>Mycobacterium tuberculosis</u> (var. hominis)	Death within 15 to 20 minutes at 151°F or momentary heating at 153°F
<u>Mycobacterium diptheriae</u>	Death within 45 minutes at 131°F.

In much of the literature on compost toilets, it is stated that it is the generation of this pasteurizing heat that theoretically insures the sanitary aspects of a compost toilet. However, as is emphasized by Cooper and Golueke,¹⁷ it cannot be assured that every pathogen in the pile will be subjected to high temperatures or that the exposure time will be sufficient to kill 100 percent of the pathogens. The pile must be of sufficient size to insure heat insulation, and the moisture and nutrient (C/N) balance must be maintained. However, it is virtually impossible to assure that all of the pile will be subjected to these temperatures and pasteurized, even with frequent turning. Therefore, it becomes important to consider bacterial interaction and time when discussing the safety of the toilet's end product.

Bacterial interaction includes: competition between the organisms involved in decomposition and the less well-adapted pathogens; and antibiosis, the process by which many of the fungi and actinomycetes involved in composting produce substances that kill many pathogens. One year is the minimum figure for retention of human waste in a well-maintained compost toilet to insure sufficient reduction of pathogens.¹⁷ Time is really the most important factor, as it compensates for bacterial interaction. The longer the pathogens remain in an alien environment, the more likely that their numbers will be reduced because of a lack of suitable nutrients and a suitable environment necessary for propagation.

Disease transmission by insects is another important consideration in building a compost toilet. No matter how insect-proof you attempt to make your toilet, there is always one entrance for them - the toilet seat hole. The major insect agent in the transmission of the disease is the house fly. The house fly lays its eggs in and feeds on excrement and, in doing so, picks up pathogenic organisms on its body and legs and by digesting infested material.⁹ Various other flies may also live on excrement. All must be controlled to prevent personal and public health problems. Flies are attracted to light and odors. Dark areas or dark surfaces are utilized to repel flies. Sufficient additions of cellulose material after use diminish or eliminate odors. Chemical control should be carefully considered and only as a last resort. Do not use pesticide strips with 0,0-dimethyl-2, 2-dichlorovinyl phosphate (DDVP) as some commercial compost toilet manufacturers suggest.²³ This chemical is a suspected carcinogen, and other controls are available which are far less toxic.^{3,19} Borax is a good example. An extremely small amount (approximately two tablespoons) can be sprinkled on the pile as a fly control measure. However, borax is toxic to plants and will inhibit growth if the concentration is too high.

The effective destruction of pathogenic bacteria may be possible in compost toilets that are constructed and maintained properly.⁷ Pathogens are the major concern if the end product is to be recycled. Equally important, however, is the question of a virus destruction which has not been addressed adequately. This subject also is important when deciding what to do with the end product of a compost toilet. One study involved the inoculation of 21 different models of composting toilets with Poliovirus.¹⁸ After four weeks, the survival rate had dropped to zero in all of the toilets tested. However, the test was performed under controlled conditions and was designed to test toilets used infrequently in vacation homes. More research is needed to test virus survival in the year-round use of compost toilets. Dr. Poorbough in California has started some research in this area on behalf of EPA.³⁷

F. Summary and Recommendations

This section is intended as a guide for people contemplating using and/or building a compost toilet.

1. Familiarize yourself with compost toilets through available literature. The bibliography found in Appendix B contains annotations of publications concerning compost toilets or related topics. The references used in writing this section also are highly recommended reading. You cannot read too much on the subject if you are to make an informed decision. Goodbye to the Flush Toilet is one of the best complete sources of information.⁵ Remember that in addition to the whole compost toilet idea, there are also associated topics (e.g., composting, greywater) that you'll need to read about to understand.

2. Consider whether or not a compost toilet is feasible for your particular needs and living situation. Familiarize yourself with the concept. Health departments and building inspectors are hesitant to approve compost toilets and very few states or local counties have plumbing codes which permit them. You will have to thoroughly justify your needs. Justification will entail convincing authorities that you understand and can solve all potential problems involved in compost toilet usage. Remember, too, that a system will be required to dispose of or treat (on site) all household greywater. This includes urine, if you decide on a system with a urine diverter. The size of the toilet holding tank may present a problem. The holding tanks of the

slant-bottom type toilets, drum privies and vault privies (see Section 11 on design) all have to be designed to fit into basements or into additions on existing buildings. Be sure to give retrofit serious consideration before you make a final decision on a particular type of unit.

Your wastes will not be flushed away and will be with you until they are composted or otherwise used. The number of people using the toilet also will be a limiting factor - the more people, the larger the required size of the holding tank. Smaller holding tanks require more frequent emptyings, especially if there are large numbers of users. Consideration also must be given to the disposition of the end product. There are sanitary requirements for burying such material which should be followed to insure personal and public health.⁹

It is inevitable that at some point, you will have to handle feces. It is strongly recommended that you use elbow-length rubber gloves and a shovel designed for handling waste material. When you have finished, be sure to clean and disinfect both gloves and shovel for added protection. Additionally, hands should be thoroughly washed after you have finished cleaning your equipment. Special precautions have to be utilized with composted human wastes at all stages of the process. While you and your immediate family may be relatively "healthy", you may have a guest-user who is a disease or virus carrier. It is imperative that users of compost toilets thoroughly understand the health implications involved.

While climatic conditions can be overcome, it is important to realize that cold indoor temperatures may affect your toilet's efficiency. Liquids aren't evaporated as readily, the biological decomposition process slows down, and the pile builds up more rapidly. Temperature extremes or other design problems may necessitate the use of fans, solar collectors, heavy insulation or other modifications.

3. Experiment with the composting process. To acquaint yourself with the biology and successful management of the decomposition process, try building an outdoor compost pile using kitchen scraps, leaves, hay, etc., as defined in the book Composting.⁸ Experience in maintaining a compost pile will enable you to identify potential problems, and their solutions in your compost toilet.

4. If you are thinking of building, carefully select and evaluate the model you wish to copy. Read more literature, and write to commercial compost toilet representatives. They will all have their usual sales pitches, but some useful information can be obtained. The best sources of information are others who have built their own toilets. The following section on Owner-Builder Systems is a good starting point for this kind of information. Be sure to ask about failures as well as successes. Each individual has probably modified a particular design to suit his/her needs while solving specific problems. Maybe their modifications will work for you.

5. Build and monitor your design. Make sure your toilet design meets basic sanitary requirements. Attach permanent usage instructions in a conspicuous place near your toilet. All guests should be made aware of these requirements, e.g. no plastic, no cigarette butts or lighted matches. Measure temperatures, odor generation, insect populations, appearance of pile, potential

liquid build-up and end-product appearance, and record them over a period of twelve months or until your toilet stabilizes. This will give you information upon which to base any needed modifications, and will enable you to determine if, in fact, your toilet is composting properly.

II. OVERVIEW OF COMPOST TOILET DESIGN

A. Introduction

When beginning a construction project, it's always wise to survey the field and find out what already has been done. Whether it's a greenhouse, a home, or a compost toilet, there's a good chance that someone has already built the design you're hoping to construct, or at least something similar.

In Section II, the general design considerations for compost toilets are reviewed. The authors have established a set of criteria to judge the suitability of compost toilets, given the applicable use, maintenance, and health requirements. Secondly, four basic compost toilet designs are examined briefly to orient the prospective owner-builder. Also described are the leading research organizations and individuals in the field of compost toilet construction. Fourth, detailed information on determining the proper size toilet (for your use), choosing and evaluating building materials and estimating costs is presented. The fifth part identifies specific design problems that must be addressed when building a compost toilet. Based on their experience and research, the authors include solutions they formulated for these problems.

B. General Design Considerations

A composting toilet can be built into an existing house, as a separate room, or as a detached privy, or designed into a new house. It can be installed in a basement or crawl space, conceivably even on a lower floor if the loaded weight can be supported. Long commode chutes (i.e., a second floor commode emptying into a basement installation) are not recommended since updrafts are likely to occur.

The toilet is traditionally in the same room with the shower/bath for convenient plumbing hookups. Water for handwashing should be available near a waterless toilet, so the traditional tie is not completely severed. However, it may be desirable to locate the privy and a small basin in a separate room from the shower. Such a division may eliminate the need for a second bathroom, and isolates the toilet in case of fan breakdown or other possible problems.

Liquid build-up has been shown to be a problem in most owner-built units; therefore, be prepared to design a control of some sort. Also, the storage or decomposition chamber must be waterproof to prevent contamination of surface and groundwater supplies. Ventilation systems must be screened to minimize fly problems.

Air entering the toilet should be 66°F or warmer, so consider inducing air from 1) above a stove or furnace; 2) inside the house; 3) through a glazed, south-facing solar "blackwall." It may be helpful to place the toilet on the south side of a house to take advantage of various solar heating, venting, and insect control techniques.

1. Design Criteria

There are a number of factors to consider in designing a compost toilet for a particular site and use. The following checklist is a designer's guide to a well-built system and can be applied to all compost toilets.

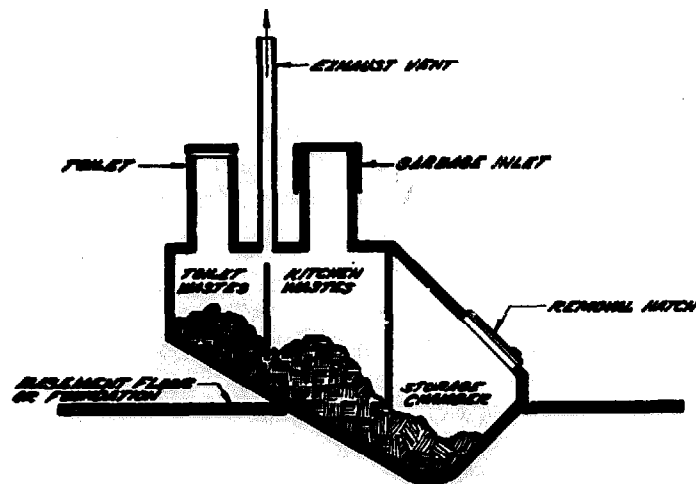
1. Flying insects must be controlled.
2. The container must be vermin-proof, moisture-proof, airtight, and child-proof.
3. The unit must control liquid buildup.
4. Convenient emptying and handling of the waste material is imperative.
5. Mass must be sufficiently aerated, preferably with a constant warm air flow of over 66°F.
6. Room should have no foul odors.
7. Commode and room must be conducive to clean and sanitary conditions.
8. Toilet capacity must be well matched to the household supply. The unit must accommodate all the wastes of the household as well as the wastes of occasional visitors.
9. The unit must be practical, inexpensive, and built from locally available materials.
10. Graphics clearly explaining the use and maintenance of the toilet should be displayed in the room.

C. Basic Designs Reviewed

1. Slant-Bottom Design

The best known commercial compost toilet is the Clivus Multrum; this is the design that is most often emulated in owner-built models. The principle behind the Clivus is that a large, sloping collection chamber receives urine, feces and other toilet waste through the toilet opening, and kitchen wastes through a garbage chute (Figure 2.1).

FIGURE 2.1: SLANT-BOTTOM COMPOST TOILET DESIGN



The chamber theoretically receives a constant supply of air through an intake portal. Sometimes, air also is diffused through an air duct to permeate the pile. An initial bed of soil and cellulose materials, e.g. straw, peat moss, grass clippings, is necessary to provide an absorption medium for urine, as well as to supply organisms necessary to decomposition.

The decomposition gases and evaporated liquids are vented out the exhaust stack. It takes the system at least one year to stabilize, and liquid build-up is a prevalent problem. The chamber should be emptied every 2-4 years.

This design raises a question regarding two chutes (toilet and kitchen). For the sake of convenience (kitchen chute), the composting process is somewhat hindered. Wastes added in the kitchen chute may be disproportionate to the wastes added at the toilet. Materials may not be layered efficiently to allow proper aeration and effective breakdown. With one chute a more efficient layering process is attained.

Another potential drawback to the slant-bottom type design is the huge tank. Unit size may necessitate major retrofitting of one's basement or home (i.e., the addition of a special room). Also, the size of the unit directly affects the composting process. Note the maintenance of a large tank. If the accumulating mass is not of sufficient size to retain the generated heat (given the overall size of the chamber), the decomposition process will be slowed down and liquid may not evaporate. Likewise, greater maintenance is required. A smaller unit, on the other hand, will gain its mass and retain its heat more readily, thereby breaking down wastes more rapidly, but it will require more frequent emptying.

A major advantage of a slant bottom unit is that it utilizes gravity to simplify handling. Raw material enters at the upper end while the older composting matter creeps toward the emptying door. Air induced through the pile reduces turning requirements.

As you have read, there are strengths and weaknesses to the slant-bottom design. Every owner-builder should thoroughly understand the potential problems before construction.

2. Drum Privy Design

Homesteaders around the country have experimented with container type privies, often using 55 gallon drums as waste containers. Advantages are that waste material can "age" in one filled drum without being contaminated by more fresh matter, drums or other available containers find a recyclable use, and the interior of the privy box does not need to be completely waterproofed. There is a wide spectrum of design possibilities, but there are limitations as well. This individual container method does not make efficient use of space in the privy chamber as there must be room for drum handling, and in storage there is lost space between the round drums as well.

Tom Riley, P.E., an NCAT engineer, stated his objections to 55-gallon drum usage:

"55-gallon drums are basically large tin cans that are intended for use in transports of liquids. They're intended neither for rough handling nor for prolonged storage of corrosive materials.

"In long-term storage of corrosive materials the most common failure is pinholing or rusting-out of small leaks. These will start to show up at the end of the second year of storage of water-based materials. These often occur either around the bottom seam where the metal has been stressed or at the air/water interface around the sides or top. Once the first one has occurred, several more will not be far behind, so the drum should be considered to have ended its useful life when the first one occurs.

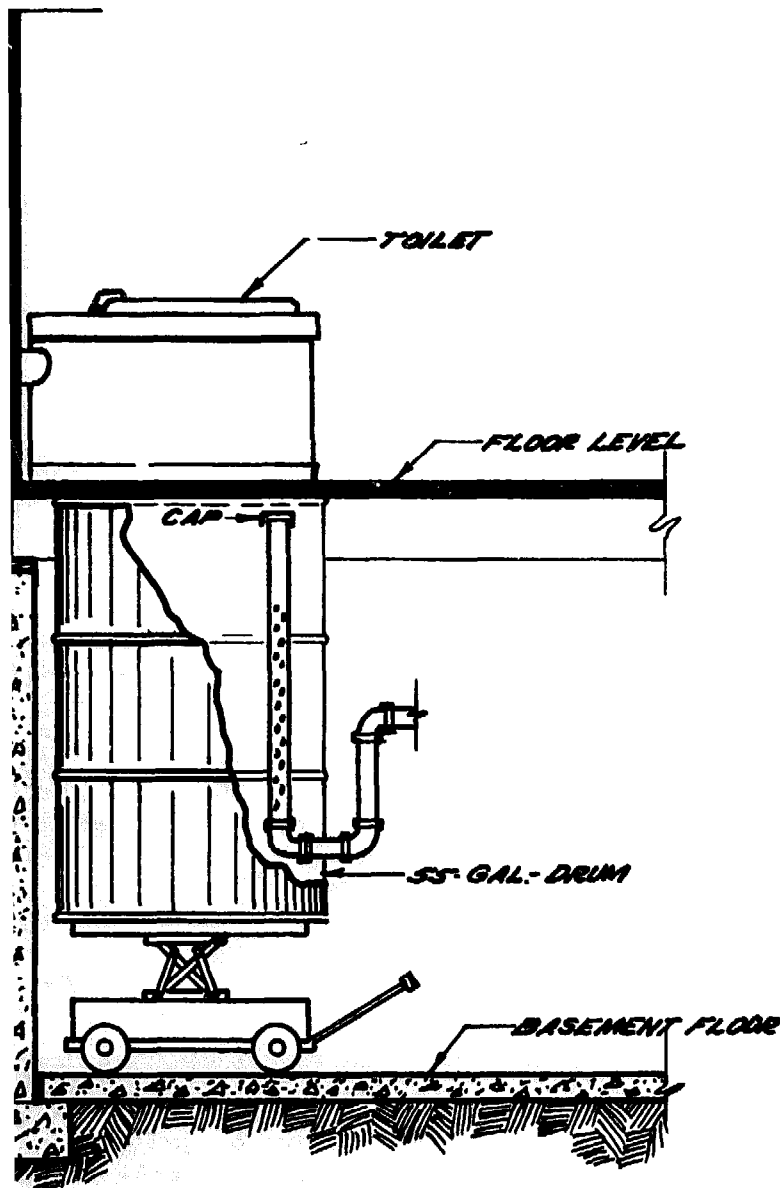


FIGURE 2.2: DRUM PRIVY

are often coated with various materials on the inside to prevent rusting. The interior coating of a drum, however, is difficult to do. There is a deep seam around the bottom and top, which is usually filled, as the coatings tend to shrink as they dry, causing the interior to crack. And, as air circulation is limited, it is difficult to get the seams to dry properly. This will add several years to the life of the drum, but should not be dependable beyond that. The drums can be "hot dipped" in a complete heavy plastic liners can be installed, but this will add so much to the cost of the drum that they are no longer a viable container.

"A second consideration is the mechanical handling, a 55-gallon drum full of water weighs approximately 480 pounds. A full drum is then very difficult to handle by hand, and if mechanical aids are used, the drums are easily damaged. The drums can often be damaged simply by letting them fall over on their side. Once a drum has been bent or beat up, the seals for the lid and bung holes should not be considered dependable, and once rust has started, the metal of the drum is severely weakened and mechanical damage becomes all the more likely.

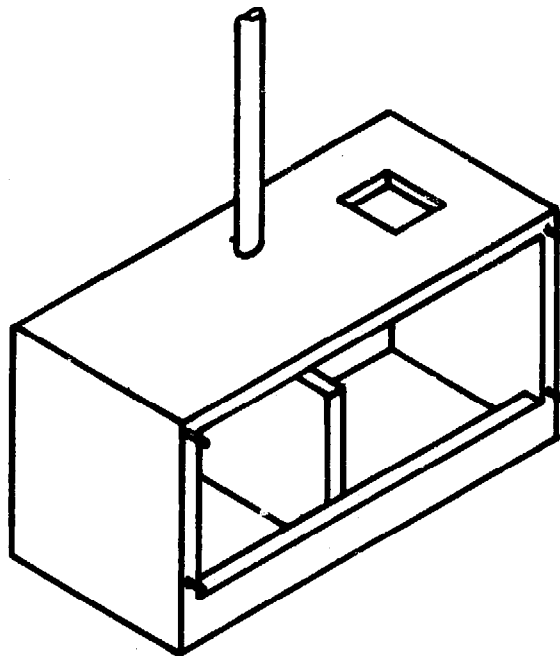
"The drums also are not intended for high pressure; in fact they are rated at 8 pounds per square inch. If a sealed drum is heated and cooled during the thermal cycling process several times, leaks from the canning at the top and bottom of the drum are highly likely."²⁷

With due regard for Riley's position, drum privies may provide sanitary toilet facilities, and experimentation has been done with the technology. An excellent report of drum privies has been published by the California Office of Appropriate Technology. Prospective builders interested in this design should obtain and read the paper entitled, "Final Report Phase I of Rural Waste Water Disposal Alternatives" (write OAT, P.O. Box 1677, Sacramento California 95808).

3. Vault Privies

A vault privy is a double chambered box and generally consists of two vaults. The seats are moved after one is filled or the material from one vault is moved to the other for composting. The unit is similar to an outhouse except that the waste storage chamber is designed for accessibility to facilitate turning. It is recommended that the end product is allowed to stabilize for 6-12 months before handling.

FIGURE 2.3: DOUBLE CHAMBERED BOX OR VAULT PRIVY



The double (or multi) chambered box privy is the simplest system; one chamber is filled for usually six months, then the pile (or in some designs, the commode) is moved and the other chamber used. Pile should be turned once or twice a month. Such regular pitchfork turning allows for effective composting. However, sanitary precautions must be taken to insure that a health hazard isn't created. Use of rubber gloves, sterilizing equipment, and hand washing is recommended. Additionally, it is questionable as to how many owner-builders will be willing to turn the pile on a regular basis.

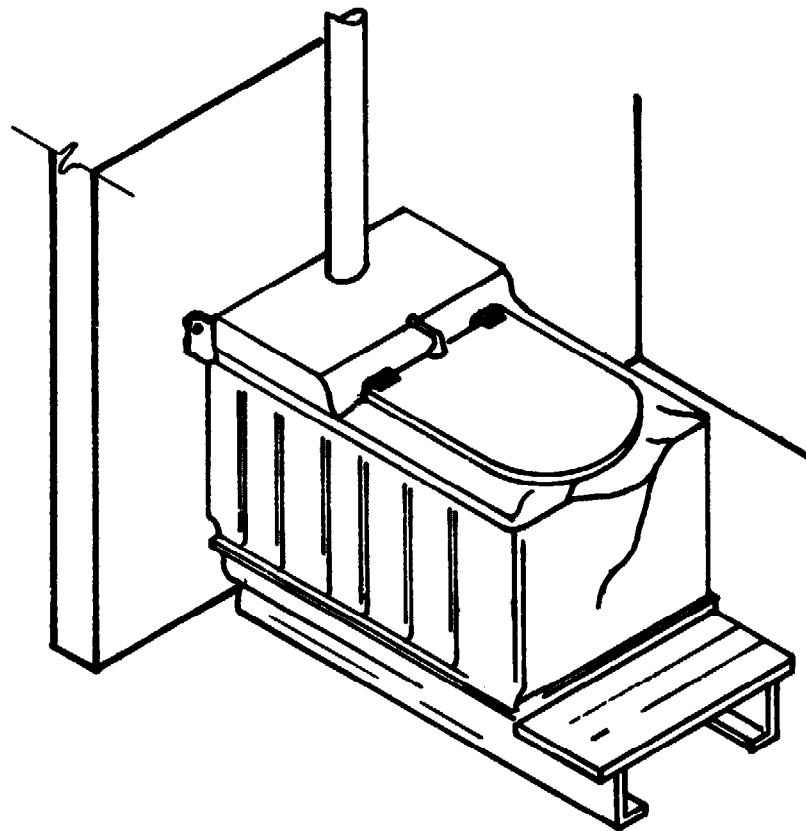
Also, without urine separation or drainage, there will be a liquid buildup. The Farallones Institute has tried to solve these problems by collecting urine separately, recommending use of 100 pounds of dry material (straw, peatmoss, sawdust) during each month, and advising people as to the turning procedure. According to Farallones researchers, separately collected urine can be siphoned off and used in a diluted form on an outdoor compost pile, as well as on house and ornamental plants. However, the safety of using the liquid for such purposes has not been proven.

This system provides an excellent educational opportunity for observing the decomposition process and allows one to invite potential converts in to watch the turning process. It also provides them with an opportunity to witness malfunctions or problems (if any) which makes the educational experience realistic. (See California OAT report for more details).

4. Appliance-Type Designs

Small appliance-type composting toilets use induced heat to raise pile temperature for speedier decomposition. Such above-floor units can be easily installed in most existing bathrooms. Disadvantages: their electricity consumption is about the same as a refrigerator; they can serve only one to three people full time; they are susceptible to caking and hardening of the mass near the heater; explosive fruitfly populations are prevalent; and, (in some types) there is liquid pooling. They have a more delicate balance point than the larger units and need more sophisticated care. There is practical application of the units in specific situations, as well as solutions to most of the problems; but, the average family (or individual) generally requires a unit that needs less maintenance. Also, the appliance-type design is least likely to be constructed/duplicated by an owner-builder. These small electric compost toilets are intended only for use in seasonal buildings where they receive very controlled and intermittent use. They are not recommended for year-round homes.

FIGURE 2.4: APPLIANCE-TYPE DESIGN



5. Design Research

Since so little information exists on owner-built compost toilet designs any experience in using an owner-built design can be considered research. This section highlights the efforts of a few individuals and groups who are noted for their work in compost toilet research.

The Clivus Multrum compost toilet is the subject of a number of research papers concerning the stack gases emitted and the analysis of the bacterial and chemical composition of the end product.^{28, 29, 30} However, each of the studies only involved a limited number of toilets (2-9 units). In the papers concerning chemical and bacterial analysis, seven of the toilets were installations in Sweden.^{28, 29} Since Sweden is the birthplace of the original Clivus Multrum, it is probably true that the toilet owners there were quite familiar with the use and maintenance of such a toilet, and therefore, the positive results may be misleading.³ While the results are informative, they cannot be relied on as being the final proof of compost toilet safety.

The Farallones Institute in California has researched compost toilets and greywater recycling.^{3, 14} Their work in compost toilets primarily involves research with vault-privy and drum privy designs utilizing a pasteurizing unit.³¹ Compost toilets and greywater systems can be observed there.³²

The California Office of Appropriate Technology Phase I Report of Rural Waste Water Disposal Alternatives stated research needs for dry toilets and greywater systems for that state.⁶ Phase II will proceed with funding from EPA to develop design guidelines, a user-education program and a health and

building officials approval program for non-conventional toilets, and health risk evaluation data.^{16 33} The project will analyze 36 dry toilets and 12 greywater systems. Completion of the Phase II in about one year will result in a publication from EPA. (Contact Steve Hathaway, Project Officer, Systems Engineering and Evaluations Branch, Wastewater Research Division, EPA, Cincinnati, Ohio, 45268, for information.) The final Work Plan for Phase II can be obtained from the Office of Appropriate Technology, 1530 10th Street, Sacramento, California, 95814.³³

The State of Oregon allows experimental use of compost toilets. The Department of Environmental Quality's On-Site Systems Program asked permit holders to fill out questionnaires concerning the use of their toilets.³⁴ The descriptive survey generally identified the problems with compost toilets. Most owners installed slant-bottom type toilets, and almost all experienced problems with explosive fly population during ecosystem stabilization. Many owners also experienced problems with liquid buildup. One owner installed a drum privy and reported few problems. This system proved to be the most efficient in terms of cost and maintenance of all systems surveyed. The Oregon study indicated that commercially available models have the same general problems as do owner-built units. For more information on this survey write to the Department of Environmental Quality, State of Oregon, P.O. Box 1760, Portland, Oregon, 97207.

The San Diemas Equipment Development Center performs research for the Forest Service. Their work includes compost toilet design for back-country usage.³⁵ The compost toilets that are being used are commercial models. Research with these units concerns the reduction of mass. Core samples, volatile solids and decomposed mass versus fresh feces will be tested in California and Appalachia Forest Service areas, and the results will be published around the fall, 1979.

In Maine, Alexander "Zandy" Clark has been involved with compost toilets for several years and has some unique and ingenious ideas in their design, particularly for use on "the rocky and romantic Maine coast."¹⁰ Maine, because of its high water table, has recognized the use of compost toilets in its plumbing code. The major problems with compost toilets identified in Clark's research are excessive liquid buildup from too much urine and too little evaporation.^{10 36} Clark's solution is a urinal, made from a cut-out bleach bottle and hose, and attached to the front of the inside of the compost toilet (see Sit-Down John in Section III). This requires everyone to sit while urinating. The urine is then treated separately. After being in the commercial compost toilet business, Clark strongly recommends that any serious owner-builder seek "intelligent, unbiased consultation" in choosing a design.³⁶ For more information on the urine diverter, write to Clark (and read about his system in Section III). Clark has recently revised his compost toilet booklet, Cheap Tricks for North Country Compost Toilets, Wastewater Recycling and Methane Digesters. (1979).

D. Construction Parameters

1. Sizing

Proper sizing of unit eliminates overloading the system and insures more efficient operation. One way to determine a size estimate for an owner-built system is to compare and average the sizes of commercial models. A more

technical method involves estimating the volume of wastes that the toilet must be able to handle. Consider this approximate sizing process:

DAILY TOILET USAGE*

½ pound of feces per person

1 quart of urine per person

Plus: One scoop "dry flush" mix (peat moss, sawdust, straw) for each use; kitchen garbage, toilet paper, sanitary napkins, etc.

Note: For five people, the 2½ pounds of feces per day will eventually reduce to .75 pounds dry.

The mass in the unit will not reach this dry weight and volume at the same time since there is continuous input of fresh material. At the end of the year, 30 percent of the feces averages wet, and half of the urine solids will have drained off. If the unit is to be used without emptying for 1½-2 years, there must be two cubic yards or more of usable volume.

Farallones uses larger quantities of sawdust/straw than is suggested here, the main purpose being to raise the ratio of carbon to nitrogen. Use of larger quantities of sawdust/straw also serves to absorb excessive liquid. If less nitrogen-rich urine enters and evaporates in the chamber, there will be a reduction in the nitrogen content, making it possible to cut down the amount of added carbonous material.

*Note: Many of these base figures are from "Technical Bulletin #1, Composting Privy," The Farallones Institute, 15290 Coleman Valley Road, Occidental, California, 95465.

2. Building Materials

Cinderblock, cast concrete, treated plywood, fiberglass, and ferro-cement have all been used by innovators in construction of composting toilets. A wood-frame ferro-cement structure also is a suitable building material for several reasons: 1) the box can be well insulated for a winter climate by using 6-inch studs and R-19 fiberglass (to help the pile hold heat); 2) ferro-cement has a certain amount of elasticity making the interior somewhat crack-resistant; 3) the medium is easily shaped to a minimum 6 inch radius of curvature on lower edges to prevent freeze damage to the box; ferro-cement on wood frame medium allows for great design freedom and innovation. All sorts of shapes, sizes, and effects are easily achieved.

However, the construction of a wood-frame unit can present problems. Beware of heavy, rough-cut lumber, as the resulting box can be too huge and heavy to move into place. Often there is not enough space to assemble the stud walls and position the box, and cement blocks might then be more practical since they are raised into place one at a time. If the unit is to be partially buried, consider investing in pressure-treated framing and plywood.

Working with rough-cut lumber is generally half the cost of planed, yet it can take twice the time and be frustrating. Be sure when using rough-cut 2x6's and 2x4's that the lumber is not green, as it may shrink and cause cracking of the cement interior. Be sure the lumber is of even widths. Unless you are experienced with rough lumber, and/or have an open and accessible work area, it is advisable to use planed 2x6's. Remember that it will be inconvenient to go inside the unit after it is in service if the cement cracks. Do it right the first time...choose appropriate materials and build on a foundation that will support the weight of the filled container.

3. Cost

Cost of commercially made composting toilets sized for full-time family use ranges between \$850 and \$2500 for the unit and installation. The site-built system (similar to the one outlined in Appendix A) costs approximately \$450 for materials plus \$500 for labor. By building yourself or having a knowledgeable contractor build for you, cost figures are cut roughly in half. Furthermore, the money is recirculated closer to home. Presently, commercial units have high initial factory and advertising costs; prices should decrease whenever demand rises to a supportive level.

There is a second cost to consider: the additional expense of installing some sort of treatment system for shower, sink and washwater. This "greywater" also contains pathogenic organisms and needs treatment. Cost of an effective greywater recycling or disposal system will usually run between \$400 and \$1000. However, one advantage of using a compost toilet is that it allows for the use of a reduced size greywater disposal system.

E. Design Problems and Solutions

1. Criterion: Flying insects must be controlled.

Infestation by germ-carrying flies has been a major problem of composting toilets. One way the insects enter the composting chamber is in the larvae stage on wet grass clippings or in wet straw that is added to the toilet mass. Flies are not harmful in the toilet. However, they do cause trouble when they leave the compost. Attracted by the light above the seat, the flies carry bacteria into the room.

All interior surfaces of the toilet should be black. The chute and underside of the commode lid should be black, as this coloring limits reflection of light. Since most flying insects are drawn to light, the next step is to attract them into a small container from which they cannot escape. A "solar" Bye-Bye Fly Trap can be mounted high on the side or on the top of the unit; daylight shines in through glass and reflects on the white painted surfaces of the trap's small box (see construction details of fly trap in Appendix A). The flies, attracted by the reflected light, easily enter through a funneled opening. Inside the air tight chamber, flies are killed by chemical pest strip or can be captured on flypaper. Fruit flies are least apt to enter the Bye-Bye Fly Trap; house flies can be 99 percent controlled. The trap (for large volume, owner-built units -- see drawings for construction and details) is easily serviced and is removable so the pile can be observed and raked through the 7½" square opening. If sufficient direct or indirect sunlight is not available, a "nightlight" or 15-watt bulb can be secured on the glass. As manufacturers and owner-builders further develop and employ this national "bug to the light" technique, composting toilets will be safer.

As mentioned previously, borax applied directly to the pile has been used as an effective chemical against fly larvae. However, the chemical is toxic to plants and could render the composted end product useless or even harmful to soil. It should be used sparingly. The addition of lime and woodash (with no clinkers or sparks, which increase the fire hazard) will control flies and produce no negative effects. An excellent and easily read article on fly control and the fly's life-cycle is the USDA's publication on "The House Fly and How to Suppress It."²⁶

One homesteader in West Virginia painted the inside of his Mullbank (a small appliance type) toilet with a special flat black paint (he used heat-resistant charcoal-grill paint which adheres well to the polystyrene, once the surface is sanded). Using a drill and a saber saw, he cut a 2½-inch diameter hole in the upper right side of the back of his unit. He sanded the surface and, using Eastman 910 adhesive, cemented on a 3 inch jar lid with a corresponding hole cut from its center. After the glue dried, a 5 inch long olive jar, containing ¼ of a pest strip, was screwed onto its lid now on the side of the Mullbank. Fruitflies have to date been the only pests, and have been kept in check by this simple jar trap.

Manufacturers of commercial toilets recommend various insecticides or customarily suggest placing a chemical pest strip inside the unit. We are not sure about possible damage to the compost or to helpful organisms from such a control technique. Some insecticides used in pest strips are suspected carcinogens. Nonetheless, control is more regulated and effective with pest strips since most of the poison no longer goes directly up and out the vent stack, and risk of contaminating the pile with the poison is almost eliminated.

General Notes: It is still vital that all incoming and outgoing airvents are screened, and that kitchen garbage is well covered until placed in the toilet. Handle pest strips with rubber gloves. Spiders can prevent flies from entering a bug trap by spinning webs across the trap opening, so be sure to clean old webs from trap entrances. Spiders are, however, an efficient fly control and their presence should be encouraged.

2. Criterion: Unit should be free from liquid buildup problems

Without auxiliary heat, composting toilets cannot evaporate the total urine input. Excess liquid pools at the bottom of the unit, a common occurrence with Clivus Multrum, Toa Throne, Farallones Box Privy, and others. Manufacturers often claim their units will evaporate liquid if incoming air temperatures remain above 66°F and sufficient dry material is added. In practice, this temperature condition can be hard to achieve.

What is the advantage of a "closed" or "contained" system over an "open" one which will drain? It is easier to install, and may be applicable to more situations since there is no effluent. In working situations, we have seen too few closed systems performing satisfactorily. An open system can eliminate liquid buildup worries.

A drain is placed at the lowest point of the toilet's chamber floor. Use a bell-type basement drain, a rooftop drain, or a shower drain and treat with epoxy or resin. The drain must be accessible for cleaning. Cover with gravel contained by a 1-inch high circle of galvanized and epoxied diamond mesh. Cap with straw.

Liquid, instead of pooling at the bottom of the unit, will automatically drain through a 2 or 3-inch line into:

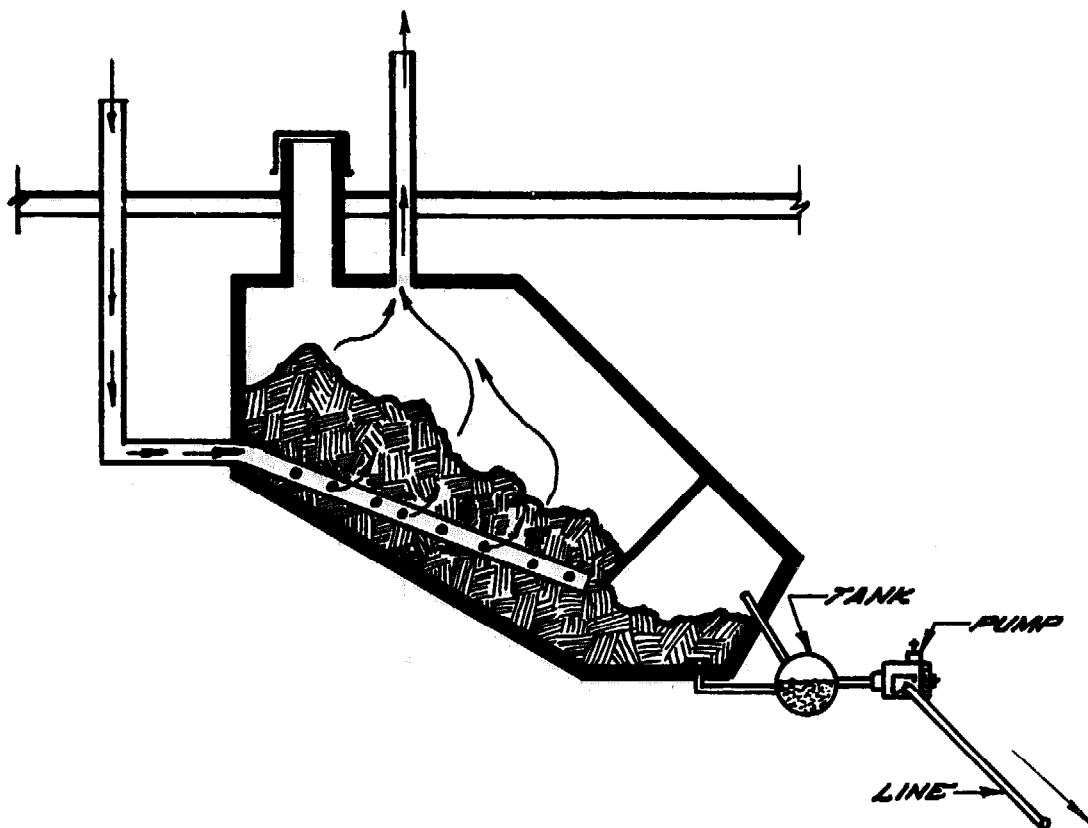
A. A health department-approved, reduced-size septic tank and leach field. With water saving hardware (e.g., 2 gallons per minute aerated shower-heads, saver sink aerators), a 500 or 750-gallon tank coupled with half the standard leach field should do the job and (might) meet approval. Effluent from the toilet and urinal with five users amounts to no more than 300 gallons a year (80 gallons per person, less evaporation). Also, it is

quite possible that the nitrogen-rich toilet effluent will aid in breakdown of greywater (a subject worthy of research).

B. a treated, buried, 55-gallon drum (serving as a mini septic tank) connected to a minimum 10-foot length of leach line set in a standard gravel trench. This method takes toilet and urinal effluent only, and may be well suited to a free-standing privy when leach field area is available.

C. a 20-55 gallon holding tank. Use shower drain; vent holding tank back into the toilet with a straight 2 inch pipe. The tank can be equipped with a marine hand operator bilge pump, or if desired, an electric sump pump (can be automatic with ball-cock). Tank should have a float or window gauge, and an access panel so that any solids building up could eventually be removed. A butterfly valve in the line could send effluent recirculating over dry edges of the pile for another chance at absorption and evaporation, or into a leach field, or to the serious recycler's hose and bailing bucket (dilute with water and use as a non-edible plant and shrub fertilizer Remember, the safety of such use has not been proven).

FIGURE 2.5: SUGGESTED DRAIN SYSTEM



D. a greywater recycling filter system (see other sources for specific information).

Some experimenters have used diverters to separate urine by placing a screened funnel or auxiliary container inside the front of the commode. Our trials resulted in toilet paper clog-ups. The bases for urine separation are: liquid pooling and cooling problems are lessened, and less nitrogen is put to the pile. To lessen maintenance, it is probably easiest to build in a drain and install a separate urinal rather than the diverter. The pile can be kept damp, not wet, and concern for urine buildup will be reduced.

A practical urinal can be made from a Hollywood Accessories brand or similar plastic or metal mechanic's funnel, and built so that it closes on a wooden mount. A half-cup of water can be poured in after use to limit odor. Plumb into existing greywater system, toilet drain system or holding tank. The urinal also eliminates splashes and drips on the seat from the male users.

3. Criteria: Convenient emptying and minimal handling of the waste material are imperative.

Slant-bottom designs use gravity to move the pile; older material is emptied from the bottom, away from the raw material that enters from above. More efficient composting will take place with some sort of hand or mechanical stirring, so we suggest this monthly procedure.

Wear elbow length rubber gloves. Poke pile with a stick or hoe from commode opening, topple and mix the "cone". Add additional "dry flush" or straw to give pile a looser consistency. Mixing should also be performed through the fly trap/access port, but only expose one opening at a time so odor does not draw into room. Clean gloves and hands immediately afterwards with disinfectant soap and water, or with alcohol. The stick can then be buried, placed in a plastic bag for disposal, or stored inside emptying hatch for future use. This mixing operation should take about 15 minutes.

A properly sized, slant-bottom unit should need emptying after the first 1½-2 years, and regularly every 3 months thereafter. Current National Sanitation Foundation standards require afterburial of the end product for varying lengths of time corresponding to the length of time the substance was in the container. Plan on afterburial for 1-2 years under at least 6 inches of topsoil. The Farallones Institute uses screened, wooden composting bins for their continued composting, and they find further significant reductions in volume. Plans for construction of such bins are sold by the Institute.

4. Criteria: Mass must be sufficiently aerated, preferably with a constant warm air flow of over 66°F. Room should have no foul odors. Additionally, potential fire problems must be considered and corrected.

Compost piles are usually aerated by a person with a pitchfork. Compost toilet designers attempt to eliminate this person's job with designs that continually induce air under and through the pile. There are three basics to such a ventilation system: 1) a source of warm incoming air, 2) a means of inducing the air, and 3) a means of exhausting the air.

An effective way for inducing warm air in the wintertime would be to install the unit in a plenum crawl space, where the periphery rather than the floor of the house is insulated and warm air is blown down from the ceiling

into the crawl space. There air is forced into the rooms through open floor registers, achieving central heating without duct work. Draw from the toilet's small fan would pull a portion of the warm air. However, this is an untested idea.

Since we do not usually have the opportunity to design into such an integrated system, the best approach for most installations is to pipe air directly into the unit from a warm high place in the house. Use four- or six-inch PVC pipe and insulate as it passes through any unheated areas. Bends of 45° rather than 90° are best to decrease resistance. It may be desirable to draw summertime air directly from the outside: remember that the screening takes away half an opening's space; design intakes and exhausts to make use of the size of the pipe.

Air is most commonly ducted through slant-bottom units by using inverted "Y" shaped or slit-open PVC thickwall pipes. Be sure pipes are strong enough to hold up under the weight. Perforated pipes are not recommended because the holes may clog. The use of pipes helps keep the pile from compacting, but can complicate pile turning and efficient operation of the bottom of the pile. Remember that pipes should not inhibit downward flow of the pile, and they should run parallel to the slope.

The most efficient aeration system to date may be one recently built by Max Kroshel at the Farallones Institute, working under a grant from the Department of Energy's Small Grants in Appropriate Technology program. His air system is similar to the Toa Throne in that air passes through the bottom of the pile by means of "stairsteps" that incline downward. Max's unit draws air from the main chamber down through the steps on warm days and across the top of the pile on cold days and nights. The stairsteps increase chances for aerobic composting to take place in the entire pile, and set similar conditions for any manual or mechanical raking and turning. The steps are inclined downward so that no material enters the open chamber underneath and are spaced several inches apart so that a sort of tumbling action takes place as the pile slides.

Air is exhausted most reliably through use of a small, continually operated, long-life fan mounted in a six-inch vent stack. If natural draft must be used, carefully research options. A San Diemas Equipment Development Center (SDEDC) study shows a 16 inch wind turbine placed over the roof vent to be slightly less efficient than use of a two-foot extension over the vent. Max Kroshel's stairstep privy uses natural draft drawn out of the unit by means of a thermosiphoning solar chimney, which opens and shuts automatically with use of bi-metal dampers. Natural draft becomes complicated because of change in day/night, summer/winter temperatures, and wind factors. Careful planning, with consideration for venturi effect is necessary in vent design. Refer to the SDEDC study for further information.

Another potential problem of composting toilets is the possibility of fire. Inside the toilet chamber (instead of water we Westerners have become accustomed to) there is some dry toilet paper and air flow, so a cigarette, hot wood ashes, etc. could start a damaging fire. Users should be made aware of this danger.

With a good design there is almost no possibility of methane buildup and subsequent fire, as airflow keeps any gases from collecting. However, if poor design causes air flow to be inhibited, gas will accumulate and create a fire hazard. Heating elements positioned too close to dry toilet paper or flammable components also will cause fire. Faulty design rather than mis-use is the chief cause of fire.

Toilets can be equipped with thermostatically controlled extinguishers, sprinkler systems, or heat alarms. Such equipment should not be necessary in home installations where users become accustomed to the systems.

III. SELECTED OWNER-BUILT SYSTEMS

A. INTRODUCTION

Once you are sold on the idea of owning a compost toilet, you must decide whether to build or buy the system you prefer. There are advantages to either choice. If you build, you will spend less money, be able to use local materials, and take pride in having built your own system. What's more, you can tailor your toilet system to meet the specific needs of your family. On the other hand, buying a "ready-made" system is practical for different reasons. Primarily, you don't have to invest the considerable time and energy involved in toilet construction. Building and installing can be difficult and frustrating. Usually, those persons who opt to buy recognize this time commitment, and prefer to spend the additional money for a commercial system.

In this section, the authors describe units which can be owner-built and installed. A couple of the units are commercially produced, prefabricated models for home installation. Other designs are personalized copies of commercially built compost toilets. At the end of each review is a summary of apparent good and bad points for each of the designs. We will leave it to the reader to determine which is best for his or her needs.

Should the reader be interested in a particular model, it is recommended that the designer of the unit be contacted, extensive reading be done on the subject, and visits be made to sites where the unit is in use, if at all possible. It is also advisable to investigate local plumbing, health and building codes to insure that construction, installation and use are permissible.

We have provided this survey of owner-built models to indicate what people are doing in human waste management. System costs ranged from "for free" (using recyclable materials, free for the time and labor expended in collection) to about \$1600. Most of the units were designed for year-round homes, but the number of persons each type of toilet can accommodate varied with each design. Maintenance and start-up requirements, frequency in handling raw materials, and uses of end products will be discussed for each model.

It is recommended that the reader contact the designer/builder regarding retrofit requirements, greywater and other types of backup systems. A report on greywater systems is forthcoming from NCAT.

We sent out questionnaires as we received leads on owner-built units. However, very few responses were received by our deadline date. It should be noted that most of the responses received were from the east coast and most of these were from the New England or upper mid-Atlantic states. (This is not to say that there is nothing being done in other geographical regions, only that responses were primarily from the northeast.) We hope to update this handbook within the next year; by that time there should be more owner-builders to supply input with improved information.

An outdoor toilet (the Bin Composter) which requires regular maintenance and works in conjunction with an outhouse, has been included. This design

is for those who live in an area where outhouses are acceptable and electricity isn't feasible, but who would like to use the end product relatively soon, rather than sealing up the privy and letting it decompose over an extensive period of time. This type of system was initially designed for use at backcountry campsites. This system possibly could be applied in principle to home usage, especially if there are large numbers of people in the family to use it.

Two written descriptions (no diagrams or drawings submitted) of original design, owner-built models were received. One strongly resembles the Clivus Multrum. Most of the models cited in this report are owner-built, but are copies of commercially available systems.

The other unit, which was completely owner-built and designed, is for use in a year-round home and is made completely from recycled materials (plywood, plastic and any other scrap materials that could be had for the hauling). The unit can accommodate up to six adults, year-round. It is relatively maintenance free (yearly cleaning out; knocking down the pile once every three months). If flies pose a problem, flypaper strips are hung and layers of peat moss are added after turning. This particular system also includes a built-in drainage system (similar to the urine diverter designed by Zandy Clark), which cuts down on maintenance problems. The owner-builder does not use straw in his compost toilet because, when combined with urine, it attracts flies. The owner is very satisfied with the prototype. (For more information on this system, write to: Shabazz, P.O. Box 294, Beacon, NY, 12508).

One commercial unit, the Bio-Recycler, is described in this section. It has been included because it takes the concept of composting toilets and carries it farther than any of the other units described. The Bio-Recycler aerates organic material, effectively disposes of urine runoff, has no insect or odor problems and uses earthworms. These features will be discussed in greater detail in the section on the Bio-Recycler.

We did not cover the smaller electrical units because our primary focus was on units which can be built by the typical homeowner with typical handyman skills. The reader should keep in mind that discussion of a particular type of toilet does not mean endorsement by NCAT.

As a final note, those persons involved with composting toilets are to be commended for their efforts in human waste management. We hope that this handbook will prove helpful to those who wish to put an end to the five gallon flush.

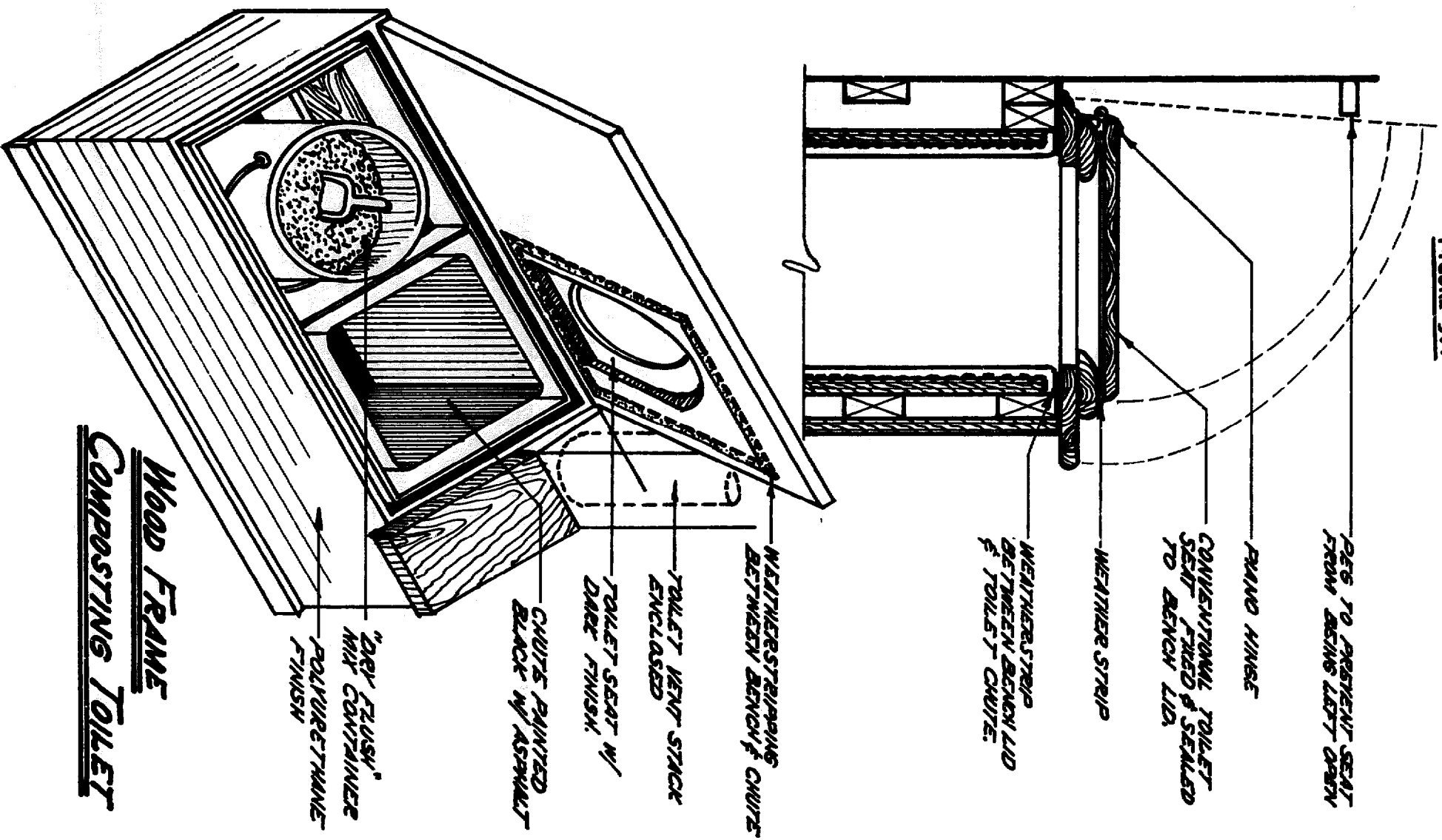
B. WOOD-FRAME COMPOSTING TOILET

Information: Jon Averill
Box 40, Brooks Route
Hinton, WV 25951

The wood-frame composting toilet has a slant-bottom wood frame supporting a ferro-cement shell (see drawings) and installation costs are estimated at about \$500 for materials plus \$500 for labor.

Four full-time users plus occasional visitors can be accommodated by this unit which can be installed in a basement or attached to a house. The wood-frame composting toilet also can be a free standing unit. Maintenance requirements for urine control involve maintaining air temperatures at 66°F or warmer and adding sufficient dry materials. A drain to suitable disposal field is highly recommended.

FIGURE 3.1



Control of insect problems is attained with a "Bye-Bye Fly Trap" (99 percent effective for house flies) which keeps fruit flies in check. Screens on incoming and outgoing air vents are also recommended, as well as painting the outside of the toilet black to limit light reflection.

Handling of raw materials requires approximately 15 minutes monthly. It is recommended to wear elbow length rubber gloves and to sterilize gloves and hands after mixing compost.

This system is reasonably priced, but the unit and its air system are somewhat complicated to build. This toilet is designed with a Clivus-type sloped bottom, as this slant-bottom is most effective for allowing aged materials to creep forward out of the way of newer materials with minimal poking at the pile. This is important for those persons who need to use compost toilets (because of terrain, lack of water, high water table, etc.), but who are not necessarily pleased with the idea of working with composted materials, except as a finished product. In Appendix A, Averill details his construction procedure for the wood-frame composting toilet, including the fly-trap mechanism.

C. SIT-DOWN JOHN

Information: Zandy Clark
Star Route #3
Bath, Maine 04530

This model is similar to other Clivus-type slant bottom units with the exception of the urine diverter feature. The Sit-Down John is a wood and concrete angle box.

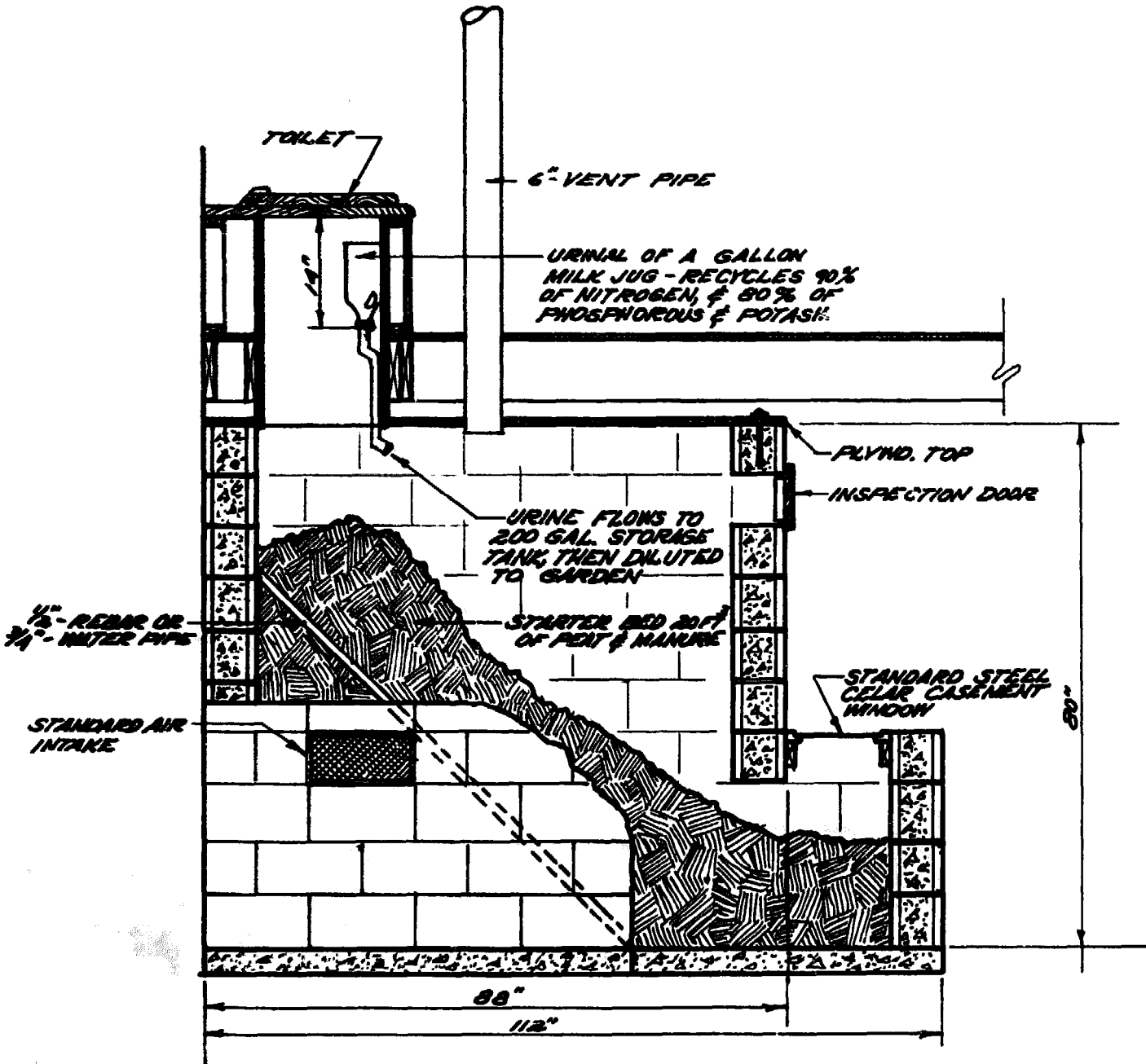
Urine diversion allows the chamber to be unheated, or even frozen, in winter, reducing the house heat load and complexity of design. The chamber can be very small, since little cellulose material needs to be added. Also, the whole system can be cheaper and can serve an unlimited number of people without overloading. Urine diversion recycles nitrogen better than aerobic composting, because it remains liquid and does not evaporate as ammonia.

Installation costs for this toilet range from approximately \$270 for materials only, to an estimated \$850 with labor. Lag bolts, faucet (emergency draining), cinder blocks for walls, standard steel cellar window casing, standard vent fitting, brackets, 3/4" galvanized water pipe or 1" pipe, wood resin for caulking, B.F. Goodrich caulk, PL-200 Rubber Sealant, adhesive or silicone caulk are included in the materials necessary for construction.

The Unit accommodates ten or more persons. The number of people a unit can accommodate depends largely upon good aeration, maintaining air intake temperature of 65°F and diverting urine from the pile. It is recommended that four to five people use the unit if urine is not diverted. Emptying one or two buckets of compost yearly, cleaning dust from intakes (which is mosquito netting), and adding peat moss or grass clippings to the toilet twice a year are required maintenance.

Start-up requirements for this system are the same as for others, including cover grid with hay or damp newspaper, addition of manure, etc.; to get started (20 cubic feet to start), three bales of wet peat moss will work. The end product can be used on lawns, ornamental plants and shrubs, or added to new toilet compost.

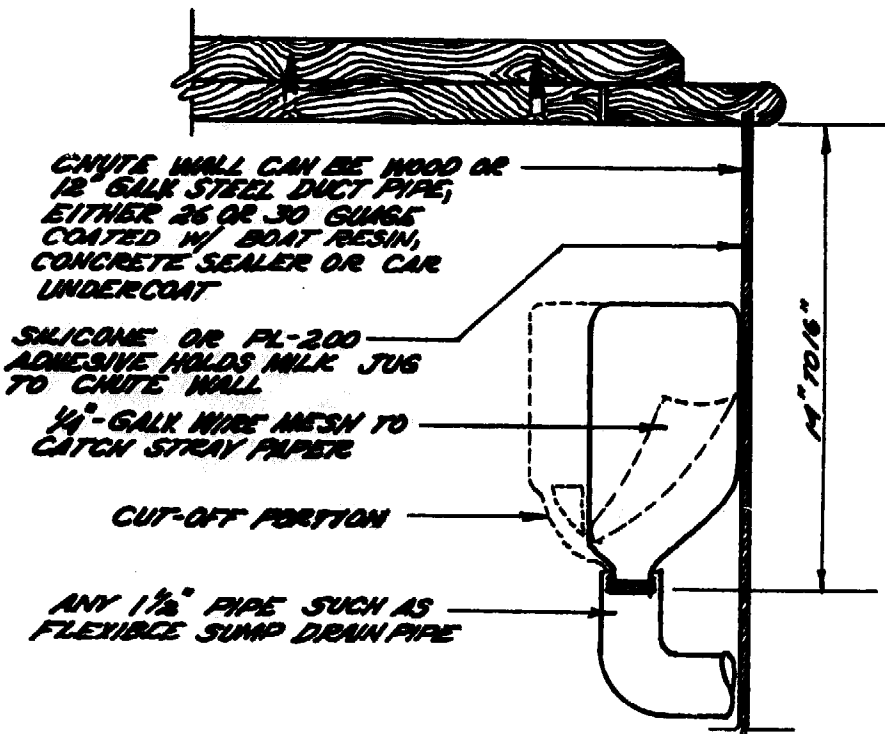
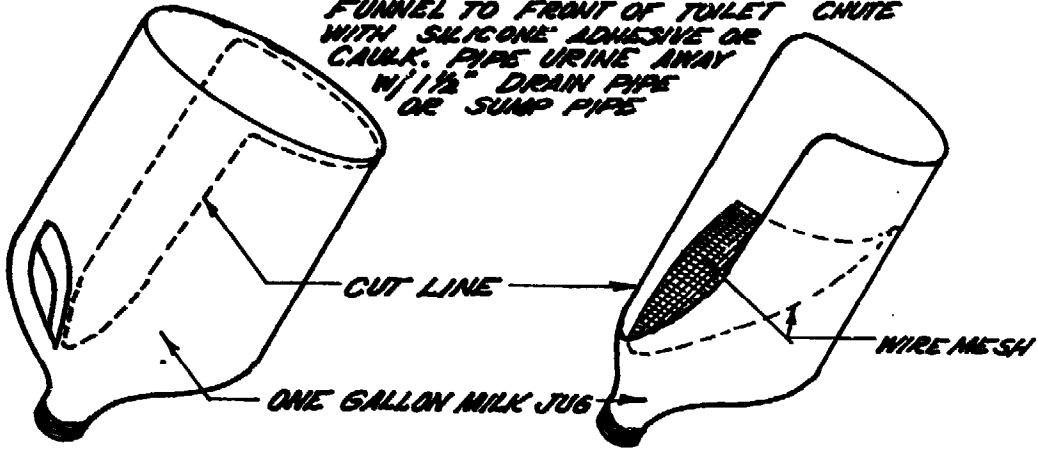
FIGURE 3.2



The Sitdown John

FIGURE 3.3

**NOTE: CUT MILK JUG ON
DOTTED LINE & THROW HANDLE
PORTION AWAY ATTACH THE REMAINING
FUNNEL TO FRONT OF TOILET CHUTE
WITH SILICONE ADHESIVE OR
CAULK. PIPE URINE AWAY
W/ 1 1/2" DRAIN PIPE
OR SUMP PIPE**



for SIT DOWN JOHN

Clark founded the Alternative Waste Treatment Association and published the Compost Toilet News until recently. It is recommended to contact Zandy for materials and systems specifications. He is well informed on compost toilets and is most willing to share his knowledge with others.

It is worth reiterating that the urine diverter keeps the pile drier, allowing operation in colder buildings and use by more people. Use of urine diverters requires that men be seated, which may be distasteful to some men. Women, however, will appreciate the dry seat.

The amount of beverages consumed by the users is critical. For example, alcoholic and caffeinated beverages make for more urine. If this moisture can't evaporate, the pile becomes too wet, cools and turns anaerobic. Again, urine separation makes heavy drinkers less bothersome. Zandy's convinced that compost toilets without urine diverters or some type of drain mechanism are severely limited.

D. THE MAINE TANK

Information: Peggy Hughes
Maine Compost
Deer Isle, ME 04627
(207) 348-6687

The Maine Tank (poured-in-place concrete tank) is smaller than any prefabricated unit on the market and costs less than \$900, excluding labor. Materials cost under \$500 (1978), which can be reduced by recycling some materials such as sheet metal, existing chimneys for venting, etc.

The unit accommodates three people with continuous use and can be installed in a one or two-story home. The backup system consists of leaching chambers (a concrete box without a bottom or ends, about 13' X 5' X 2') and costs about \$200.

Treat the tank of this system as you would a garden compost heap; sprinkle with hardwood sawdust or fine shavings (peat moss, grass clippings, chopped hay) after each use.

After some months, the insect population will stabilize and spiders will take care of fly larvae. If flies are a problem use sparingly an organic pesticide (hargate, pyrenone or nicotine) inside the tank; you do not want to kill the composting organisms. Use sawdust after garbage deposits, especially in summer time; it helps to control the insect eggs that come in the house on fresh fruits and vegetables.

Raw materials must be raked down and poked once a month during the first year and less frequently after that.

All construction must be fireproof. Engineering plans are available for \$10 (complete instructions). These plans are designed for people with some building experience. It is assumed that the builder knows how to cut through floors and walls and that the builder will read a good book on water-proof concrete before beginning.

This composting toilet is one of the few that permits the toilet to be placed in an existing second-story bathroom. Of course, this design requires additional lengths of plumbing, but for those who have hang-ups about compost toilets being confused with outhouses, this is probably the answer.

FIGURE 3.4

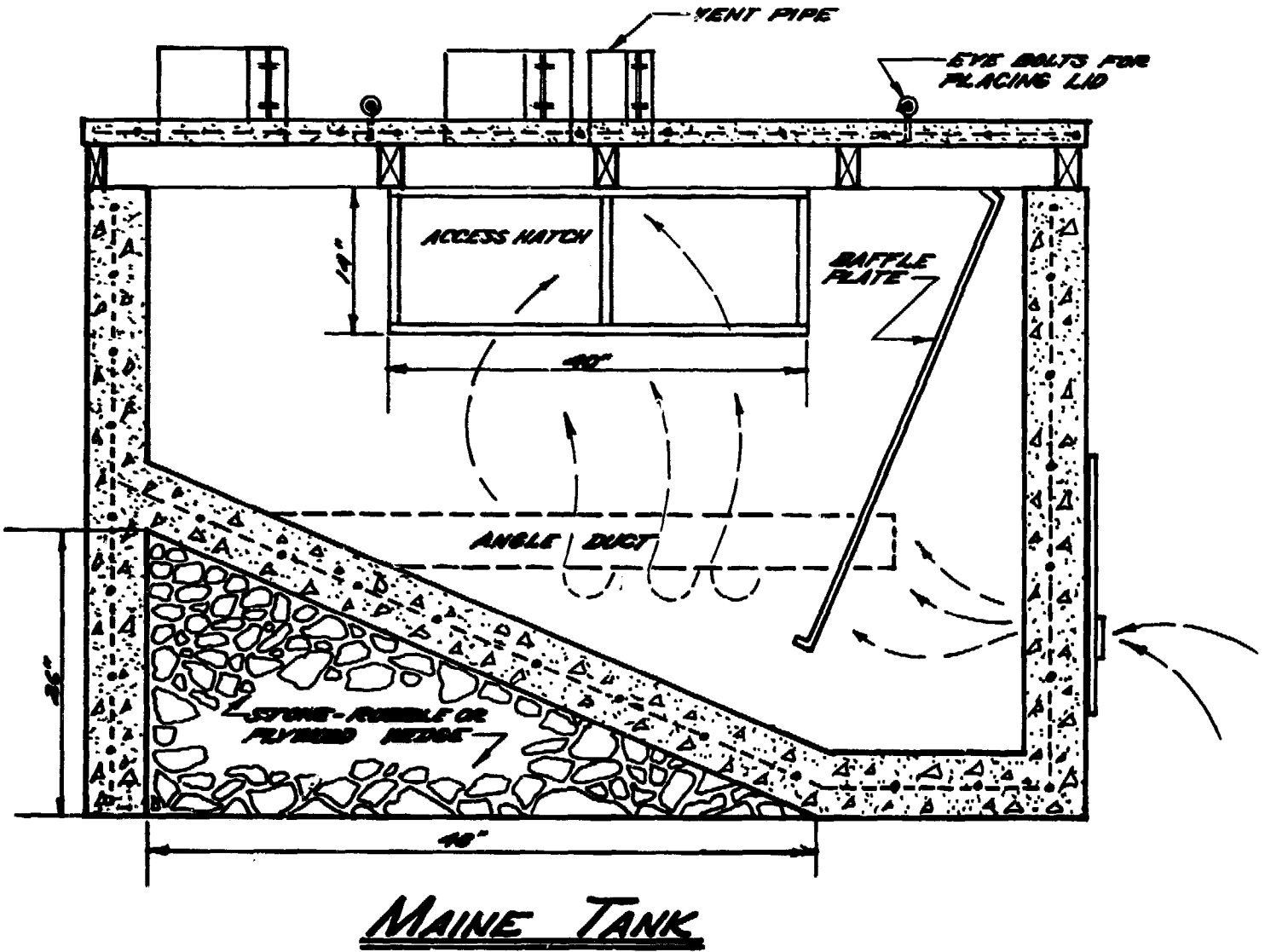
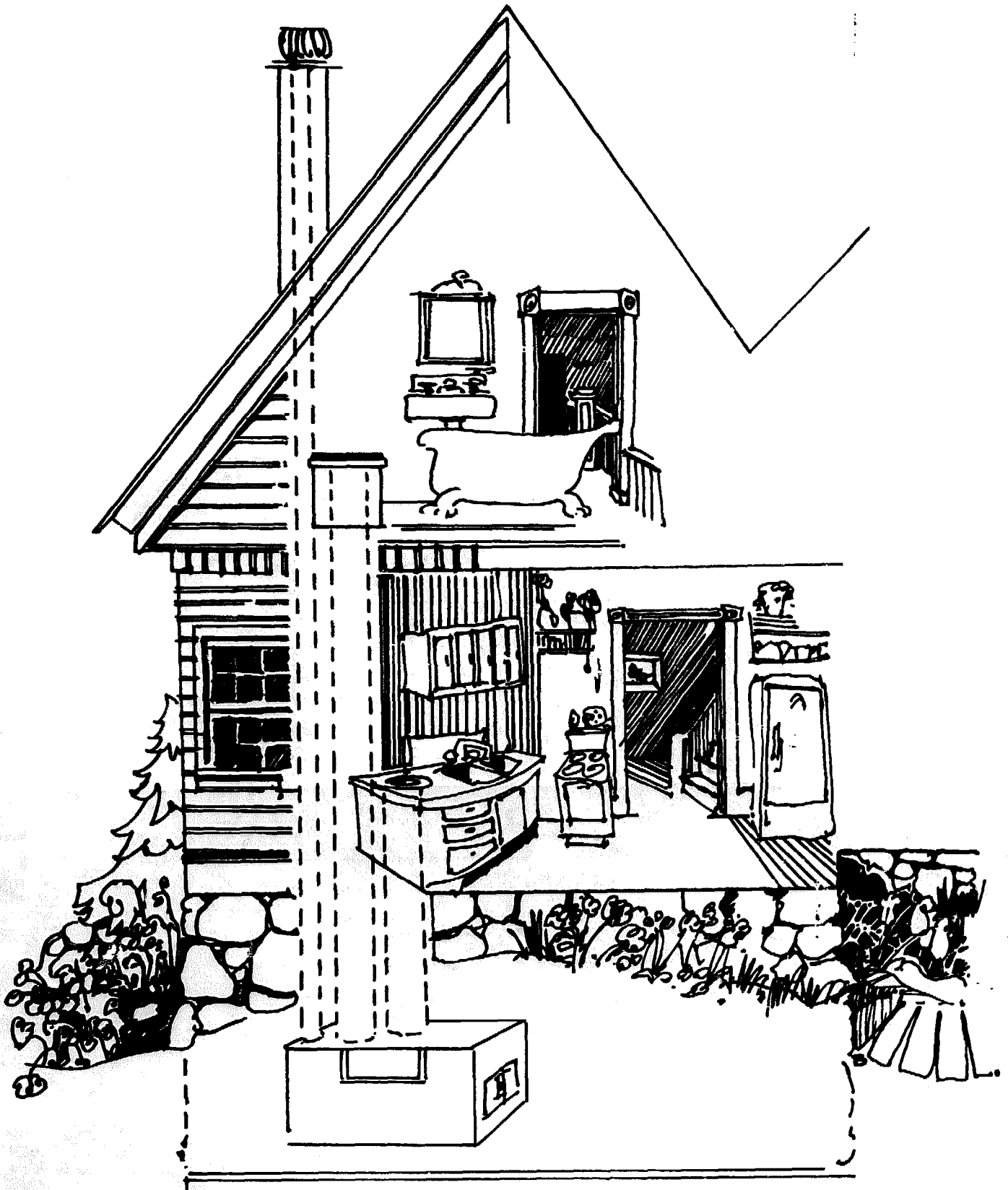


FIGURE 3.5: Second Floor Application of Maine Tank



Peggy Hughes' information packet on the Maine Tank is detailed and explicit. As with other composting toilet systems, deviation from recommended practices usually creates problems. The Maine Tank, when used properly, is relatively maintenance free and is one of the few models which is fireproofed.

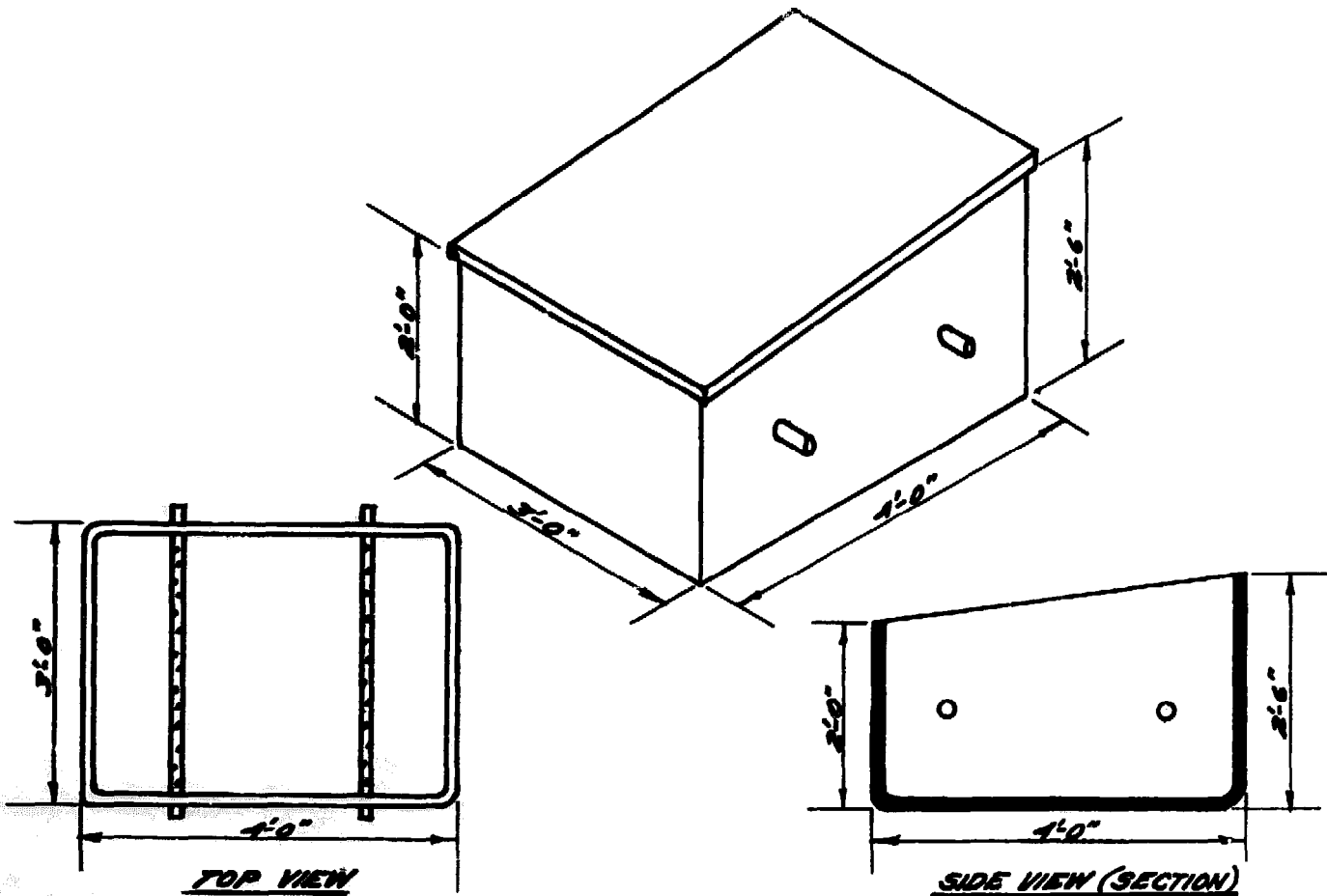
E. BATCH COMPOSTER

Information: Appalachian Mountain Club
Corham, NH 03581
Attn: Edward L. Spencer
(603) 466-2721

The batch composteur is designed to treat small volumes of waste quickly. It works with, but is separate from, an outhouse, and waste must be transferred from one to the other (see below). Total cost for installation, including transportation to site without outhouse is \$155; with outhouse and transportation, \$1000 to \$1200. Necessary materials include fiberglass sandwiched in a wooden frame (top), $\frac{1}{2}$ " exterior grade plywood (sides and bottom not fiberglassed), perforated aeration tubes of PVC, hooks and eyes. The unit weighs about 75 pounds.

FIGURE 3.6:

BATCH UNIT DESIGN



This unit can accommodate 60 overnight visitors per site or 200 visitors per season (300 gallons of treated waste), and should be installed at campsites. Compost using a bark bulking agent is required for maintenance. The unit needs regular but not continuous attention and requires a manager (someone to get to the site to maintain the compost process. Feces from the outhouse drop into the collection chamber where they are mixed with the bulking agent at 10 gallon or 90 pound intervals. Temperature of 140°F for 36 hours should be maintained and compost must be allowed to rest for seven more days. Handling is required.

Insect problems can be controlled by covering all inlet vents and pipes with fine mesh screening and keeping the toilet seat closed with a tight seal. If insect problems persist, spray diluted pyrethrin (organic pesticide) on the compost pile. Flies usually indicate that the pile is too wet. Allow a dry crust to form on the surface of the pile to further discourage odors and flies.

Material must be transferred from the outhouse to the bin composter whenever approximately 10 gallons of waste have accumulated. Add 40 pounds of drying materials and food scraps. Two turnings, at seven day intervals, are required. Remove composted materials and let them dry so they can be reused as a bulking agent. Material can be stored.

Start-up requirements involve adding a two-to-three-inch layer of drying material such as bark to the collection container and sliding it under the privy. This layer will absorb liquid and reduce odors. It requires high cellulose content materials.

The end product can be reused for composting fresh wastes or turned onto the forest floor.

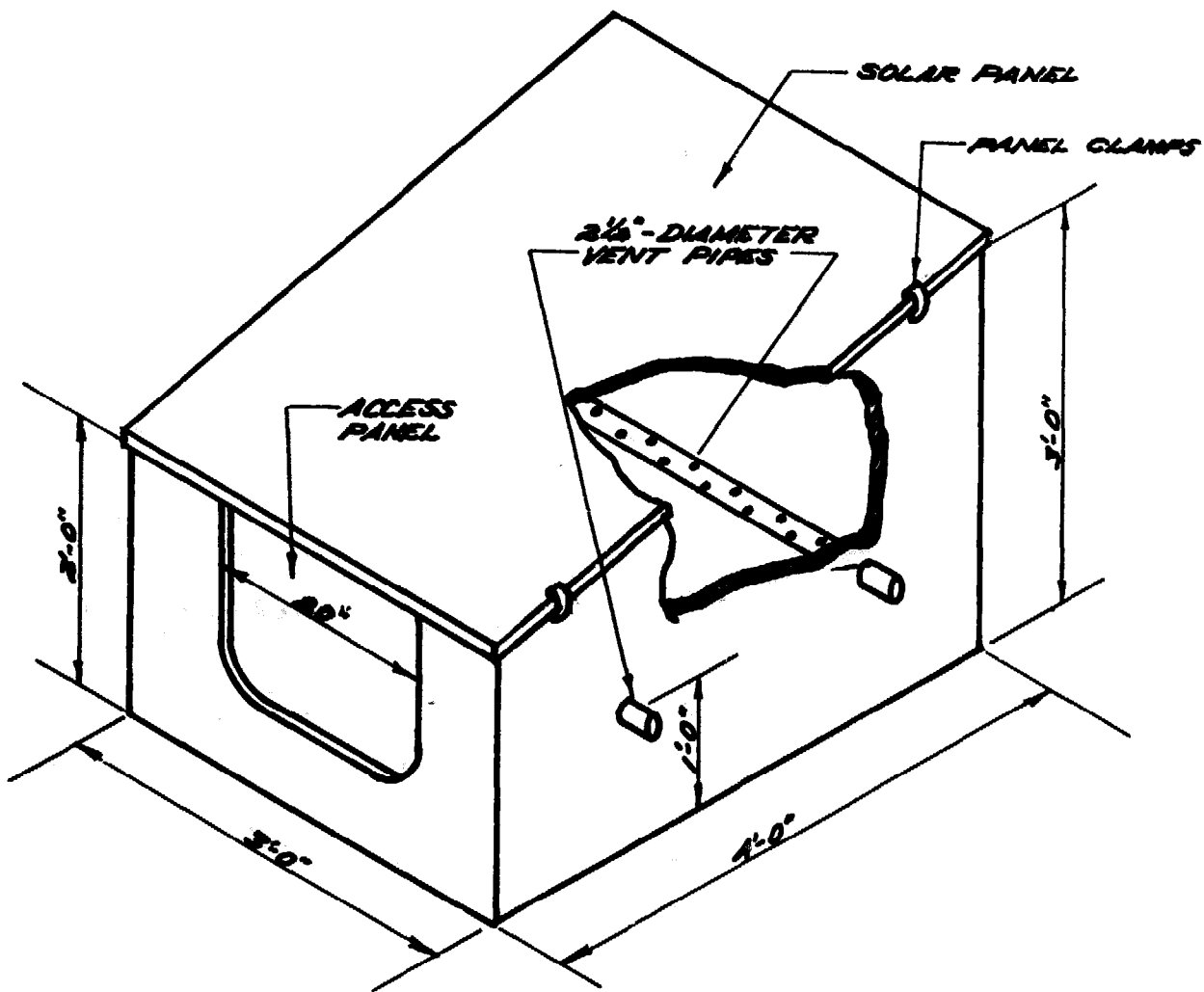
F. BIN COMPOSTER

Information: Northeastern Forest
Experiment Station
Forestry Sciences Lab.
Concord Post Road
P.O. Box 640
Durham, NH 03824
(603) 868-5576
Attn: Ray Leonard

The bin composter is a fiberglass, leak-proof box to be used at back-country shelter sites in conjunction with privies. The total cost for installation is \$85 to \$100. Necessary materials for construction include Fiberglass, exterior grade plywood, stock softwood/hardwood, nails, polyester resin, hooks and eyes, fiberglass mat, and two perforated PVC tubes. No retrofitting is required.

This free-standing unit can accommodate five or more persons/night. Aerobic and thermophilic processes are aided by using hardwood debarker waste for maintenance to eliminate odor, absorb moisture and provide nutrients to the decomposing micro-organisms. No insect problems have been indicated. It uses a solar panel which helps to reduce liquid build-up through evaporation.

FIGURE 3.7



BIN COMPOSTER

Materials collected in the privy container must be dumped into the composter bin when full, which depends upon frequency of privy usage-- approximately 20-plus days.

Start-up criteria include close proximity or access to a privy, and the money and materials to construct the composter bin. The end product can be scattered on the forest floor or used to recondition the soil in worn areas (campsites and along trails).

This composter bin has a ten-year lifetime and this type of system appears to be just what the doctor ordered for backcountry campsites. It could probably be used at remote summer homes if regular maintenance were provided. Maintenance is the major drawback; however, if sanitary precautions (e.g. rubber gloves) are taken, this shouldn't pose too much of a problem.

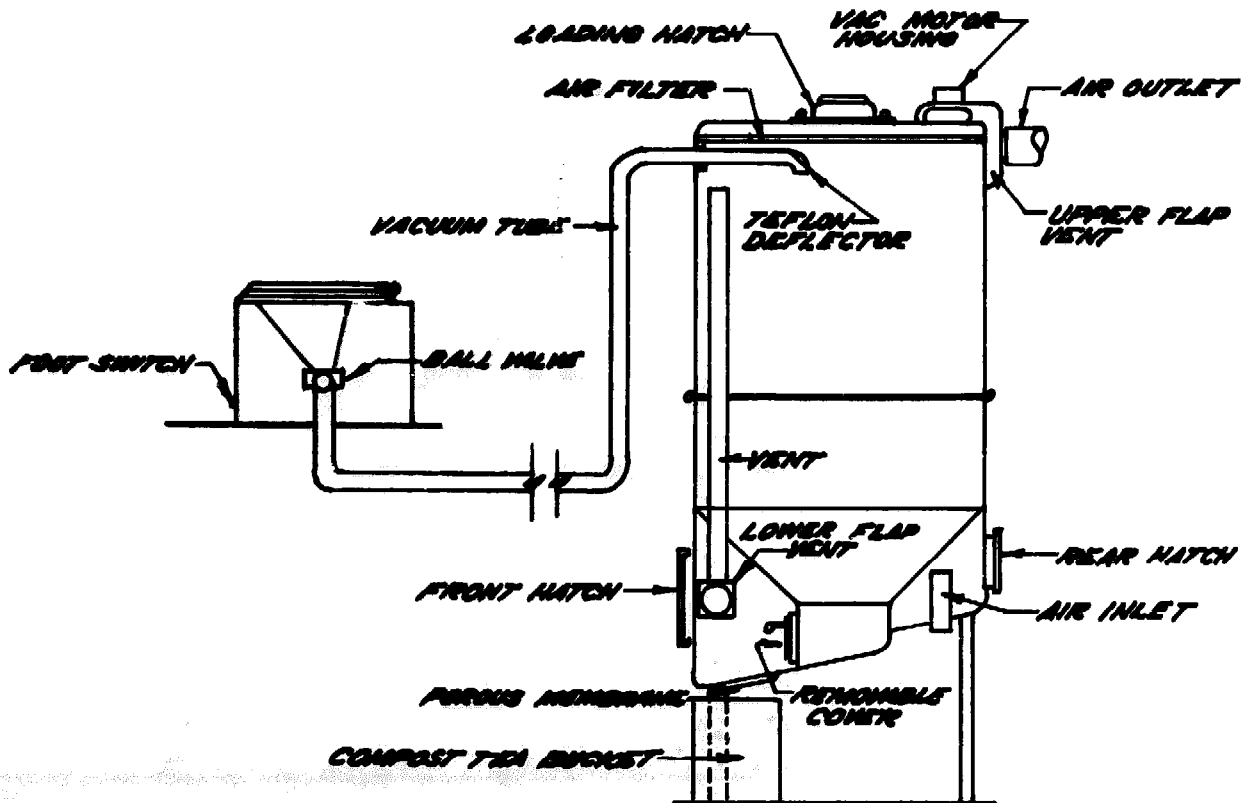
G. BIO RECYCLER

Information: Bio-Recycler
5308 Emerald Drive
Sykesville, MD 21784
(301) 795-2607
Attn: Jeremy Criss

The Bio-Recycler effectively blends modern and appropriate technologies. Jeremy Criss has put at least twenty years of experience into perfecting this composting toilet. The size and shape of the composting container make major retrofitting unnecessary. The composting container takes up about the same amount of space as a large hot water heater or furnace (three foot diameter by 6'6" height). The only retrofitting is to replace the regular flush toilet with the Bio-Recycler unit. The unit is vented through the wall rather than through the roof and is screened to prevent flying insects from entering the container.

Total cost for installation is approximately \$1600. Materials list and materials can be obtained from the Bio-Recycler supplier. The unit uses 110 volt electricity. Power is needed only when the toilet's vacuum pump is in use. The unit requires no fan, heating coils or elements. It is not recommended for recreational use or part-time occupancy homes or public facilities, as it requires maintenance, and drying-out cannot be permitted.

BIO-RECYCLER



The feces are broken up and aerated during the first few seconds, as the unit uses a high velocity vacuum delivery system that transports excrement from the toilet to the composting container. Each time the toilet is used, about four ounces of water is used to rinse down the sides and keep the actual toilet clean and free of contaminating materials which attract flies. The addition of four ounces of water also serves to effectively reduce fire hazards. However, warnings against adding cigarettes and hot ashes should be posted.

Kitchen garbage is added through the loading hatch directly into the composting container. As materials break down, they drop into the lower container (which takes several people several years to fill. According to Criss, the system has no problems with odors, flying insects or urine build-up. And the compost container houses redworms (Eisenia foetida) in the lower chamber.

The redworms eat the aerated feces which has been mixed with kitchen waste and broken down to the point where the heat of decomposition doesn't kill them. These worms function the same in the composting container as they do outdoors or in compost bins. The resulting compost is rich in worms, castings and capsules, which can be removed as needed and used in the garden. Laboratory testing is recommended as the worms may have concentrations of heavy metals in their bodies or in their castings and these metal concentrations may have toxic effects on the human body.

Urine flows through the upper and lower chambers and drains into a 'compost tea' bucket. This liquid is a combination of urine, water and any liquid runoff from the aerated feces and kitchen waste. The compost tea is odorless and almost black in color. It is recommended that the potential buyer check with the local health department to find out how the compost tea should be collected, stored and ultimately used (or disposed). Usually it is collected in a 5 gallon plastic bucket. It can also be used as an indoor plant and outdoor ornamental plant fertilizer and/or applied to outdoor compost piles. The compost tea also is beneficial in septic tanks because of the nutrients it supplies to the anaerobic process.

The Bio-Recycler effectively eliminates odors by keeping the vacuum tube to the composting chamber closed except during use. In addition to the tube which is only open during use, the Bio-Recycler is vented to the outside through the wall. This vent is screened to keep out flying insects.

The composting container is equipped with an observation window. Through it, flying insects can be seen and the height of the container contents can be checked. No insects fly in the vicinity of the container. The vacuum aeration system provides enough air to sustain them in their environment.

Mr. Criss is considering offering the Bio-Recycler in kit form. Orders would include some pre-formed parts and the unit would require some assembly. No price has been affixed to the kit at this time. However, it will afford the kit purchaser a considerable savings when compared to the pre-assembled Bio-Recycler.

APPENDIX A

The following report was written by Jon Averill of Hinton, West Virginia. Under contract with The National Center for Appropriate Technology, Averill constructed a wood-frame composting toilet for a low-income family in West Virginia. This report is a summary of his construction details, including an options chart and materials check list.

A. SUMMARY: WOOD FRAME COMPOSTING TOILET

General description:

This unit is designed to be built on site with commonly available materials. It has a Clivus-type sloped bottom, and is constructed of wood and ferro-cement for several reasons:

1. box can be well insulated
2. ferro-cement has a degree of elasticity to resist cracking
3. medium allows a great deal of design freedom

Retrofit requirements:

Unit is large: it requires 4x6x8 ft. of space for installation, and considerably more room for the construction process.

Number of persons unit can accomodate:

Recommended for four people full time.

Type of structure in which the toilet is to be installed:

Designed primarily for basement or attachment to house; basic technique can be used in a free-standing privy. Unit is not practically constructed in a crawl space.

Backup or greywater system:

Unit uses a drain and separate urinal; so far we recommend backup system be a reduced-size septic tank and leach field, and toilet effluent be also fed into the system.

Maintenance requirements:

Daily additions of kitchen garbage and "dry flush" material (peat moss, aged sawdust, chopped straw, forest soil). Monthly 15 minute poking of the pile with a stick (see pg. 12). Monthly service of the fly trap (2 min.). After 2 years, emptying every three months.

Insect problems and control methods:

Entire inside of unit is black. Insects fly into an attached window box and are poisoned with chemical no-pest strip.

Frequency in handling raw materials and end products:

Poke raw matter once a month with a stick. Empty end products once every three months (approx. 10 gal.) after 2 year start-up.

Start-up requirements:

Use six inches of non-sterile peat moss, forest soil, etc. across entire bottom of container. Cover drain with gravel and straw.

Use of end product:

After burial under 6" of soil until considered safe (1 year); use on non-food crops.

Disadvantages of this wood-frame unit:

The cost is high; the air system complicated to build. Wood in contact with the ground can be problematic. This design can be improved upon; it is in no way considered the final word in wood-frame toilet designs. It should be viewed as a stepping stone toward more efficient design.

Cost for toilet installation:

\$400 to \$500 depending upon materials used; add to this the cost of greywater-blackwater treatment system.

B. CONSTRUCTION PROCEDURE:

Foundation:

2716 pounds weight of compost
1500 pounds weight of toilet
4216 pounds total weight of loaded unit

Unit should be built on existing basement slab; 18 inches of gravel; or a poured 5'x9' footing, 6 inches thick around perimeter and 4 inches in center. Use $4\frac{1}{2}$ gallons water per sack of portland cement, and 2 parts sand, 3 parts gravel ($1\frac{1}{2}$ inches aggregate).

18.75 cubic ft. concrete = .7 cubic yd.

Mix sand and cement first, add water and then gravel (in this way cement gains 11% more tensile strength). Use polyethylene under slab and wire reinforcement sandwiched within.

Frame:

Build stud sections. Use temporary diagonals on sides and nail bottom sections to the sides. Put top on only after unit is in place (lap plywood appropriately). Caulk all seams.

Interior: Have pipes (air ducts) cut to fit and slide them in place after cement has cured (keep wet) for two days. Seal the pipes as they exit from the box with silicone caulking and black asphalt. Prepare baffles outside and insert them last.

Most other construction details can be gathered from the blueprints. Basic carpentry and masonry skills are required. Refer to the listed criteria to know what conditions must be achieved (i.e., air-tight, moisture-proof box). Use material list as a guide for construction sequence.

C. NOTE TO DESIGNERS AND BUILDERS:

At the time of publication our first unit is awaiting cement work. Many hours of planning have gone into the design of this unit, but we ourselves haven't completed round one yet, due to lack of resources and time.

We are soon to begin building another unit and plan to use the wood frame composting toilet plans only as a guide. Do not take these plans as gospel -- use your heads, and find ways to simplify and improve upon the design, without sacrificing the necessary water tight shell etc. Consider these possibilities:

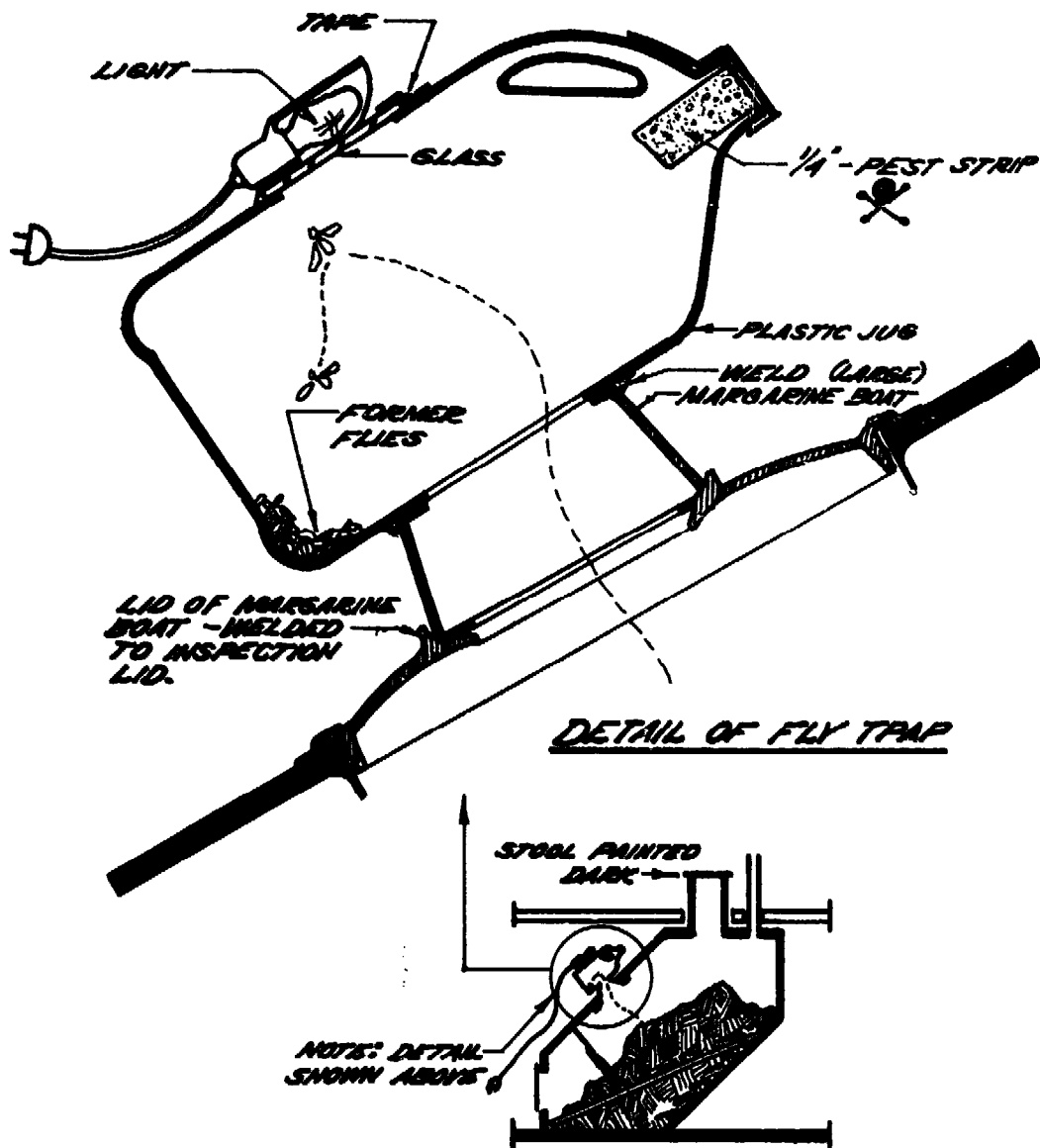
1. Eliminate bottom stud sections; build sidewall onto slab, nail wire through rigid insulation and onto slab. Build an air staircase with downward sloping steps; slope slab for liquid drainage. Build staircase with 1" galvanized pipe or heavy rebar wrapped with diamond mesh and coated cement - (similar to Max Kroshell's new unit at Farallones).
2. Use cement block and an air staircase technique -- fill block with concrete and insulate on the outside of slab and block so all the concrete acts as heat storage. (Paul Galimore in North Carolina is designing one.)
3. Expand wood frame design to accommodate 2 - 4 comodes; partition between the chambers. Make half of the chambers inactive half of the time; follow a rotation procedure similar to Farallones vault privy.

<u>OPTIONS</u>	exterior	aeration	approximate total cost
Trial unit	<ul style="list-style-type: none"> a) 1-inch treated plywood bottom b) black fiberboard sheathing on walls and top c) 6 - mil polyethylene d) aluminum newspaper print plates, caulked between sheet laps. e) asphalt coating 	<ul style="list-style-type: none"> a) three 3-inch PVC thickwall pipes cut out in bottom; run through wall at upper end of chamber and down to the baffle b) air induced to these tubes through 4-inch pipe to kitchen ceiling c) summertime outside air intake opt. d) 4-inch ventstack with Italian made plastic barrel fan e) insulated attic area with black roof (ventpipes pass through) f) 16-inch wind turbine on roof 	\$300
45 Recommended construction	a-e) ½-inch stained or creosoted plywood nailed over polyethylene; caulk seams	d) best to use a 6-inch ventpipe with a constant operating, long life, moisture resistant 11-15 weight fan, strapped inside a removable section	\$500
Other options	<ul style="list-style-type: none"> b-e) tar paper, chicken wire, stucco (applied in place) a-b) 1-inch boards (heavy) 	<ul style="list-style-type: none"> a) air stairstep technique b) natural thermosiphoning (create draft from hot air rising) 	\$400
What to avoid	<p>We tried coating fiberboard with a commercial fiberglass-cement mix; we thought this would strengthen the board and make it seamless, vermin proof. Coating peeled off in sheets. Inventor had success using white glue for bonding; we were in hot sun... further experiments could bring better results but...?</p>	<ul style="list-style-type: none"> a) thinwall pipes; perforated draintile pipes; any pipes placed in such a way as to impede flow of the pile b) direct cold air input c) installation without a fan where electricity is available 	

<u>OPTIONS</u>	site preparation	frame	interior
Trial unit	<ul style="list-style-type: none"> a) prepare level-surfaced pit where unit is to be placed b) fill with 1-inch gravel c) slide unit in place d) partially bury with drain tile on top and side 	<ul style="list-style-type: none"> a) rough 2x6's on 16-inch centers creosoted b) R-19 fiberglass 	<ul style="list-style-type: none"> a) fibered paper (lumber wrapping free from lumberyard) b) 1/2-inch extended diamond mesh attached with galv, roof nails c) coat with masonry cement, sand concrete mix d) Thoroseal Block Sealer e) black roof coating
Recommended construction	<ul style="list-style-type: none"> a) excavate and level site b) pour reinforced-slab footing 5'x9', 6 inches thick around perimeter and 4 inches thick in center a-d) use existing basement slab 	<ul style="list-style-type: none"> a) planed 2x6's on 16-inch centers creosoted b) R-19 fiberglass 	same as trial unit
Other options	<p>1 1/2-foot gravel bed</p> <p>for a free standing unit use block or pressure treated foundation on appropriate footing, or pole foundation</p>	<ul style="list-style-type: none"> a) planed or rough 2x4's on 16-inch centers, creosoted b) flame retardant foam or sheet insulation 	a) tar paper
What to avoid	direct contact of wood to the ground unless it is pressure treated and seams tightly sealed	<p>green lumber in frame: shrinkage could crack the cement, moisture in sealed walls could start rot</p> <p>cellulose hard to install and settles, it is not appropriate for small framed compartments</p>	do not apply cement mix if it is likely to freeze during the first two days

Sample Materials List: Wood Framed Composting Toilet

<u>material</u>	<u>quantity</u>	<u>cost</u>	<u>purpose</u>
portland cement	4 bags	\$14	footing
medium grade sand	½ ton	\$10	footing and interior
1½ inch aggregate	½ ton	\$ 5	footing
6 mil polyethylene	25 sq. yd.	\$ 8	footing, exterior
reinforcement wire	5'x9'	\$10	footing
2x6's, 8' length (planed)	10	\$25	frame
2x6's, 12' length (planed)	14	\$52	frame
2x4's, 8' length	5	\$ 8	frame
16-penny nails	7 pounds	\$ 4	frame
R-19 Fiberglass insulation	125' (run)	\$25	frame
creosote	2 gal	\$ 8	frame, exterior
½" plywood	8 sheets	\$80	exterior, chute, baffle
galvanized siding nails	5 pounds	\$ 6	exterior
caulking compound	3 tubes	\$ 5	exterior
Fibered paper	150 sq. ft.	\$ 0	interior
½" extended diamond mesh (gal.)			
2x8' sheets	10	\$50	interior
galvanized roofing nails	5 pounds	\$ 6	interior
staples (staple gun type, ½")	1 package	\$ 1	interior
masonry cement	1½ sacks	\$ 5	interior
Thoro Seal Block Sealer	30 pounds	\$ 9	interior
black asphalt roof coating	1 gallon	\$ 4	interior
1" boards, 6" wide, 12" lengths	2	\$ 3	interior
drain	1	\$ 6	interior
drainline, 3" PVC, elbows	10"	\$10	line to leach field
3" PVC thickwall	24'	\$30	interior air ducts
4" PVC "T"s	3	\$ 4	air connection box
4" to 3" PVC reducers	3	\$ 3	air connection box
20' 4" PVC thinwall	20'	\$15	air intake
4" PVC 45° "L"s	4	\$ 6	air intake
6" PVC couplings	2	\$ 3	fan assembly
11-15 watt long life fan	1	\$20	fan assembly
cord, suspension wire	1	\$ 2	fan assembly
6" PVC	15'	\$15	vent stack
8" stack cover, cap	3'	\$ 5	vent stack
silicone caulk	1 tube	\$ 2	interior air ducts
screen	3 sq. ft.	\$ 1	air intake and exhaust
1" board 9½" width, 8' length	1	\$ 2	fly-trap
glass	5½"x10½"	\$ 1	fly-trap
glue, putty, caulk, nails		\$ 1	fly-trap
hinges	2 sets	\$ 8	fly-trap, door
metal brackets, screws	4	\$ 3	baffles
urinal	approx.	\$10	
commode	approx.	\$20	



BYE-BYE FLY TRAP

Infestation by germ-carrying flies has been a major problem of composting toilets. Flies are not harmful in the toilet, but they cause trouble when they leave the compost and enter the room, attracted by the light above the seat.

So: We painted the underside of a Toa-Throne seat and the commode liner black as to limit reflection of light, then added this fly trap. Results: the flies are not all dead, but they are under control. Fruit flies are the least apt to be attracted to the Bye Bye Fly Trap; house flies almost always enter and die. Will have more information later (i.e. types and quantities of flies, effects of different wattage or color of lights). Also we plan traps for other

commercial models such as Clivus, Humus, and Mullbank. You should be able to easily adapt these plans to fit a homemade waterless toilet. We are interested in your experiments, and we welcome modifications on our plans.

How to Build the Bye Bye Fly Trap (for under \$2)

Materials: *one plastic gallon milk jug with somewhat flat sides
*one margarine or similar plastic boat (a non-crackable plastic with a 7" diameter, 4-5" deep, and a tight-fitting lid)
*small piece of glass, approximately 4" x 5"
*caulking
*masking tape
*no-pest strip
*12" nylon fish line
*nightlight, or refrigerator light (15 watt bulb), socket

Tools: soldering gun, sharp knife, scrap strips of plastic for welding rods

How to: With a Toa-Throne, cut the handle section out of the inspection opening lid. This is hard plastic but it can be cut (so can your hand be careful). Then take the lid to the plastic food container, place it, top down, on the top of the toilet lid. Slowly melt a strip of plastic (1/8 inch wide) to join both lids. You can achieve an airtight "weld." Be sure to melt all three surfaces evenly so that they will bond together into one piece of plastic.

Cut out the center of the food container lid, approx. 5" diameter. Cut out the bottom of the food container with a hole slightly smaller (3-3½"). Now "weld" the food container bottom to the side of the milk jug (careful: milking walls are thin and melt through easily). Make airtight.

Cut a hole in the milk jug through the bottom of the food container. Make it the same size.

Cut a hole in the jug on the opposite side, the same size or slightly smaller. Edge the hole with caulking compound. Put the small piece of clear glass on the caulk. Neatly wrap masking tape around the jug in two places to tightly hold the glass to the jug.

Mount the light in such a way that it will not burn the jug or tape, but only touches the glass. (Taped or suspended over the glass.)

Quarter a no pest strip. Put a small hole in it, thread with the nylon line. Secure it in the mouth of the jug by running the line through the top of jug as pictured, and tie to handle. Replace every month with a fresh no-pest quarter. Make sure the jug lid, like everything else, is airtight.

Put the inspection lid section in place, then attach trap section, snapping it into the inverted container lid. To empty trap, shake flies from jug. Flies may be too chemically contaminated to put in toilet. Flies entering the trap will die in about 30 seconds. The strip will not radiate enough poison into the chamber of the toilet to damage the compost.

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