BYGGFORSK
NBI: A515.161

# WATER CISTERN CONSTRUCTION for SMALL HOUSES

ALASKA BUILDING RESEARCH SERIES HCM-01557

**Introduction**

This publication is one of nine that has been translated from Norwegian. They are taken from a series of publications produced by the Norwegian Building Research Institute (NBI) series, "Byggdetaljer," which literally translated means "building details." It is hoped that Alaskan builders will be able to glean useful ideas from these publications. The translations were done by Dr. Nils Johanson and Richard D. Seifert of the University of Alaska Fairbanks with the cooperation and permission of NBI, Oslo, Norway. The financial support for the translations and printing came through the Alaska Department of Community and Regional Affairs, from USDOE Grant DE-FG06-80CS6908. The publications use the original index code of the Norwegian "Byggdetaljer" series so that specific translations can be directly cited. All questions on these translations should be directed to Richard D. Seifert, Cooperative Extension Service, P.O. Box 756180, University of Alaska Fairbanks, Fairbanks, Alaska 99775-6180. Phone: 907-474-7201

## 0 GENERAL

01 This bulletin describes construction of a cistern for collecting and storing rainwater for household use. The design for a collection system and the construction and maintenance of such a cistern are described.

02 In many places along the coast, collecting rainwater is the only realistic method for obtaining useful drinking water. Usually, it is collected from the roof and diverted to a cistern (water tank) (Figure 02).

03 The rainwater, which is collected and stored under appropriate conditions, will be sanitary and safe as drinking water. The water can be purified, and the taste, color, and appearance can easily be improved.

04 Air pollution from industrial emissions has caused some rainwater to be relatively acidic and to contain soot and similar particles. However, evidence shows that there is no reason to warn against the use of rainwater.

05 Plant debris, soot, and dirt from the collection surface, will be flushed into the cistern. This will gradually reduce the quality of the water. A filter can be used to collect some of these contaminants. If the filter is installed in front of the cistern it must be large enough to accommodate all the water that will flow through it. If the filter is placed on the outlet side of the cistern, only the water that is used will be filtered. A filter will last longer if water for washing, irrigation, and so on is diverted and bypasses the filter. The simplest design is to place a filter in front of the drinking water outlet. If a filter is used, be sure that it has a sufficient capacity. If the filter clogs and this goes undetected, large amounts of water can be lost. Install an overflow to drain the water away if the

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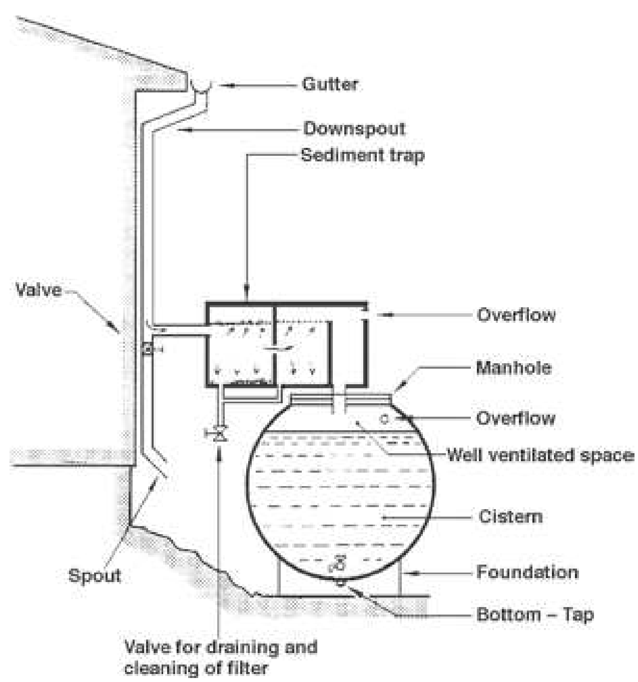


Figure 02
Examples of cistern installation for a summer house.

filter is clogged. The overflow should empty where it will be noticed.

**06** Before choosing a cistern design, select a location where sufficient water can be collected. It is important to realize ahead of time that a cistern will require regular maintenance in order to provide water of good quality.

## 1 COLLECTION SYSTEM

### 11 Collection surfaces

The collection surfaces must not contain impurities that can be carried into the cistern. If a roof surface is used for water collection, it should not contain tar or lubricants. Asbestos cement plate can also be unhealthy. If questionable materials are used, ask the manufacturers if they will affect water quality. Sod roofs are not suitable as a collection surface. Roof covering materials that are normally useful as collection surfaces include tile, concrete, or slate shingles, aluminum, and corrosion-proofed steel. Plastic materials can also be used as a coating material or as a separate cover. If rock surfaces are used for collection, they must be protected against traffic and soiling. The area must be fenced in. If water can seep in from uncontrolled areas, it must be drained away.

**111** Birds are the most common source of pollution on roofs. They can, however be prevented from landing by putting wires low over the roof surface (Figure 111).

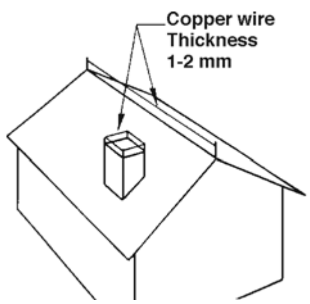


Figure 111
Bird wire to protect from birds landing on the roof.

**112** Leaves, conifer needles, and pollen will, together with soot and dust, create a constant problem for the cistern user. Trees that are close to the house can be advantageously removed. After long, dry spells and during the flowering periods of plants and trees, let the first rain shower bypass the cistern until the collection surface has been flushed clean.

## 12 COLLECTION SYSTEM

**121** Gutters and downspouts must be dimensioned and constructed so that a permanent water collection system is achieved. Collection plumbing must be corrosion resistant. Gutters can be made from many materials, such as plastic, zinc, copper, and steel. Most manufacturers have gutters of different sizes, shapes, and materials. To ensure good results with tight joints, use components made by the same manufacturer. If these guidelines are carefully followed, installation of a water collection system is usually easy, even for do-it-yourselfers.

**122** A 100mm (4 in) roof gutter, correctly installed, will usually have sufficient collection capacity for a house with a floor area of $150m^2$ (1,500 sq ft). A large enough gutter allows for easy removal of plant debris. Steeply sloping roofs can cause water to gush over the edge of the gutter during heavy rainstorms. This should be considered when dimensioning the gutter. The roof gutter should have a 1% slope towards the downspout. (Figure 122).

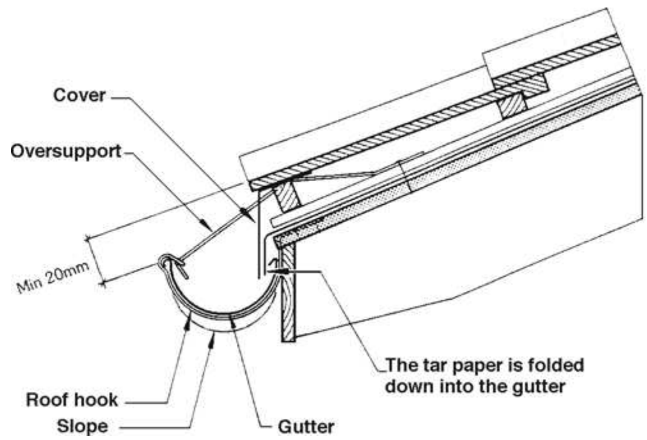


Figure 122
Installation of gutter

**123** Downspouts from the gutter to the filter or intake box should be selected after evaluating the manufacturers specifications. Downspouts must be large enough for leaves to flow into the silt separator. From the filter installation, use a soft pipe of polyethylene or ABS plastic. This pipe can be as small as 32mm (1.5 in) in diameter.

## 2 CISTERNS

### 21 Sizing and selection of cistern

To determine the most economical cistern size, first evaluate the annual house demand for water and determine the annual precipitation and distribution of precipitation throughout the year. In parts of the country where most of the precipitation falls during the fall, it may be necessary to have the cistern volume equal to the entire annual usage. If the precipitation is evenly distributed throughout the year, a cistern volume of one-third of the annual need is reasonable.

211 The demand for water varies from person to person. Twenty gallons per person per day is generally used as an average number if there is no flush toilet in the house. If a flush toilet is used or if a garden is watered, daily use can be as much as 70 gallons a day per person . As a rule, it is impossible to cover a large demand for water with a cistern. So called "cabin toilets," which flush to a closed tank, use about 1.5L (0.5 gallons) / flush. Normal toilets use about 9L /flush (3 gal). It is normal to calculate about 5 flushes/person/day. For year-round occupancy the necessary cistern volume is 20 – 30 $m^3$ (5,000 to 7,000 gal) where 1$m^3$ is 1000 L. For cabins and seasonally occupied buildings, the necessary volume generally ranges from 500 to 3,000 gal.

212 Cistern volume should be determined by the local average annual precipitation and the available collection surfaces.

Two inches of precipitation yields one gallon of water per square foot of collection surface. The collection surface is measured horizontally. For a roof, it is the floor area of the house plus the area of eave overhang. A good rule of thumb is to subtract about 10% of the calculated water volume to allow for loss by flushing, overflow, and so on.

213 The shape of the cistern should allow for easy placement and maintenance. Divide the cistern into several separate compartments so that water flow will enhance bacteriological self–cleaning. For systems designed for year-round use, it is necessary to have a minimum of two separate tanks so that cleaning and maintenance can be done without having to empty the cistern. All cisterns must have a manhole lid in order to clean the entire internal surface.

214 The construction material for the cistern must be water tight. In addition, the inside surface must not give off substances that make the water unsuitable for drinking. Traditionally, poured concrete systems have been the rule, but lately prefabricated systems made of plastic or glass fiber–reinforced polyester are popular. These systems are especially the well–suited for summer houses, cabins, and seasonal-use buildings.

215 Poured concrete cisterns are generally used for buildings which have year-round occupancy. The shape is totally arbitrary and, with careful design, the cistern will blend into the overall landscaping. The year-round cistern must be protected against freezing to avoid leaks and to assure a continual water supply throughout the winter. If the concrete cistern is buried, groundwater must not penetrate the cistern. On frost susceptible soils, cracks in the cistern may occur, increasing the danger of groundwater infiltration. See recommendations for placing of poured cisterns (Figure 22).

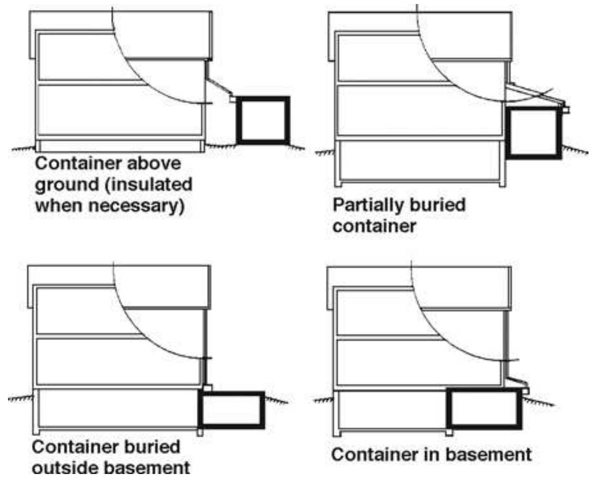


Figure 22
Examples of placement of systems.

216 Prefabricated tanks of plastic are an appropriate cistern solution. Plastic materials are usually maintenance–free and tight enough that they can be buried. There are several cistern types on the market. They vary in shape and hold up to 1000 gal of water. Some manufacturers deliver larger tanks by special order. To obtain good storage capability and to avoid emptying when cleaning, it is necessary to put the tanks in series or to have several separate tanks. The price of prefabricated cisterns will generally decrease with size on a relative cost-per-gallon basis, the larger the cistern, the cheaper the per gallon cost. (This also is true for special orders up to 20 or 30 $m^3$.)

217 Vinyl cloth or polyethylene can also be used as a liner material in cisterns. The storage tank can be buried or stand above ground (Figure 25).

**22 Placement**

Placement of cisterns depends on local site conditions. The tank should be protected against heat, mechanical loads, and so on. When installations will be used year-round, winter freeze protection for both the foundation and the water supply system must be considered. Figure 22 shows some placement possibilities.

221 In the case of seasonal use or installations where there is no electricity, the tanks should be placed so that gravity feed can be used to deliver the water. This can be accomplished by placing the cistern in sloping terrain, in the attic, or on a support under the eaves. The water can be pumped by hand from the cistern to a day tank in the attic or to another place higher than the outlet pump (Figure 221).

The cistern can be placed underneath the building in the basement or buried outside for some freeze protection.

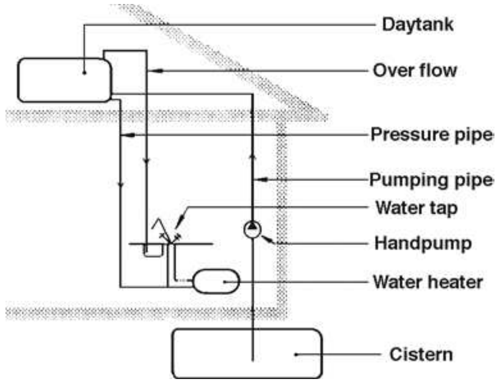


Figure 221
Schematic drawing for a gravity–fed pressure system with a cistern pump and a day tank.

222 If the cistern is buried as shown in Figure 222, the fill material must be packed in tightly around the tank, especially the lower quarter of the tank. Fill material, such as sand or gravel with a diameter of less than 0.5 in can be used. Mechanically crushed rock must not be used. Nor should fill material that contains frost–susceptible material such as clay be used. If the cistern is subjected to uplift pressure due to a high groundwater table, it must be secured. Avoid placing the cistern where there will be mechanical loads, such as vehicle traffic, on the tank.

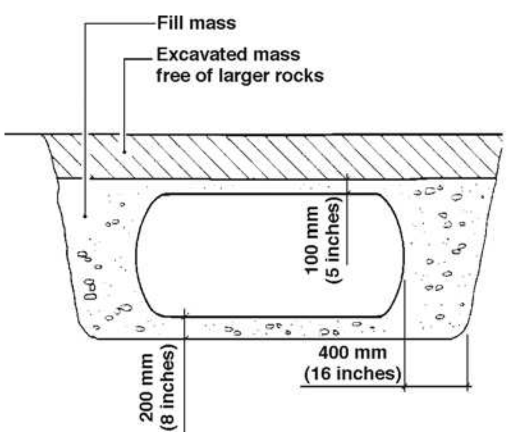


Figure 222
Schematic drawing for placement and backfill of buried cistern.

## 23 Cisterns cast in place

231 The container should be constructed at one end of the house for ease in collecting water from downspouts on either side of the roof. There must be a lid for each chamber with an opening of .7m x .7m (2 ft x 2 ft). The lids must be lockable.

The bottom of the container must have a gradient of 1 to 50 to a drain so that the container can be totally emptied of water. The container must be buried at a frost-free depth, and in many locations, the walls and roof must be insulated (see point 3). The container must never be placed where the water from a sewer line can infiltrate the system.

232 A tank with crawl space over the concrete deck is shown in figure 232. The roof water is directed from the downspouts over the tank's inclined roof to the intake box. Between the container and the wooden walls of the house, there must be a water–tight barrier made of roof tar paper with the joints glued together (Figure 232). Ensure good drainage under and around the container so that contaminated or polluted water cannot penetrate. The terrain must always slope away from the container to ensure drainage.

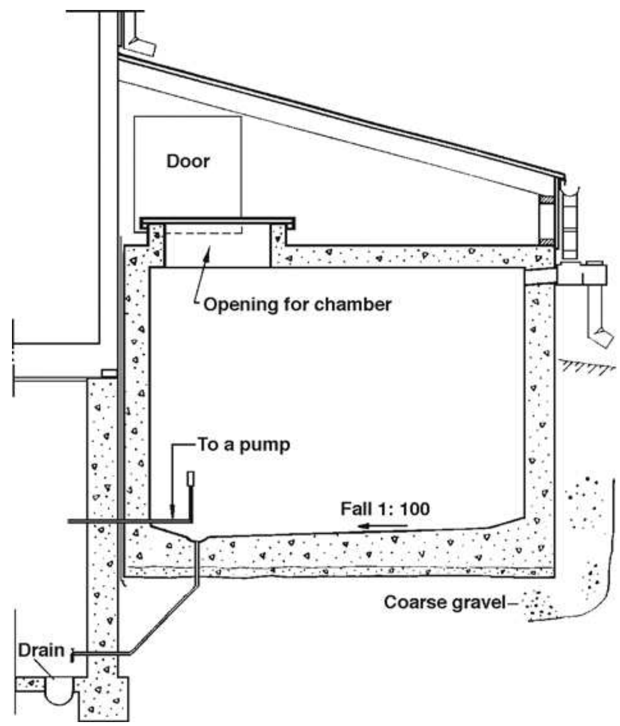


Figure 232
Cistern built partly above ground.

233 The concrete should be C-20 1:2.5:2.5 (cement/sand/gravel). Use clean aggregate with a maximum diameter of 25mm (1 in). The floor is poured, compacted, and leveled after the initial set. Smooth it with wood and steel trowels. When the forms are removed, after about a week, cover the interior and exterior walls with a mixture of cement and fine sand. (The walls can also be polished and smoothed with steel trowels instead of being covered with a layer of cement mortar. This will ease the cleaning process.)

There are additives that can be added to the mortar to reduce water penetration.

**24 Masonry cisterns**
Cisterns can be made of masonry, such as lightweight concrete. Special blocks are used that have room for mortar and reinforcement (Figure 24).

The inside of the cistern is covered with a good cement mortar and the surface is coated with a water–sealing layer. The watersealing layer can also be added directly to the mortar.

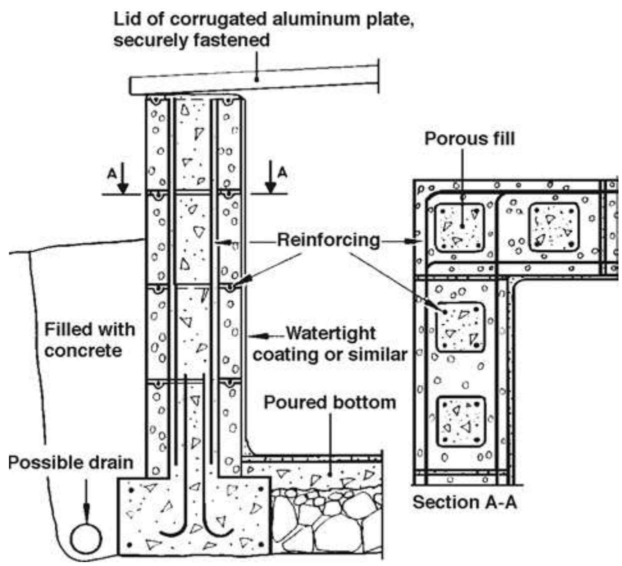


Figure 24
Cistern made of lightweight concrete

**25 Cisterns of fabric or foil**
A cistern can also be made like a pool, with a plastic liner as the impermeable layer. Manufacturers of swimming pools sell premade vinyl cloth. Fill the excavation with sand that is carefully compacted, or mount the pool on a special frame that is placed above ground (Figure 25).

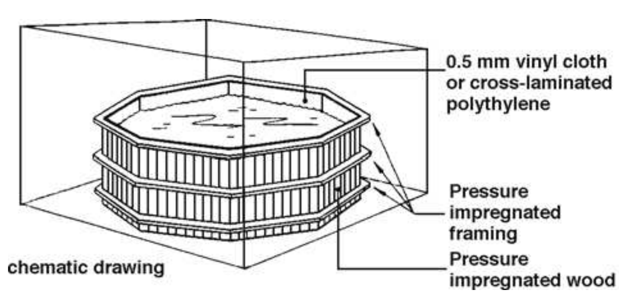


Figure 25
Cistern pool of vinyl cloth.
The cistern must be built-in, or provided with a solid lid.

**26 Prefabricated cistern**
Most cisterns are now made of plastic. Different plastic materials are available; the most common is fiberglass-reinforced polyester (GAP) and polyethylene (PE) (Figure 26a). Larger cisterns are made in the form of cylinders, preferably of fiberglass-reinforced polyester, a material that is both strong and light weight. Smaller cisterns of polyethylene are made in a variety of shapes and dimensions that make them easier to place (Figure 26b).

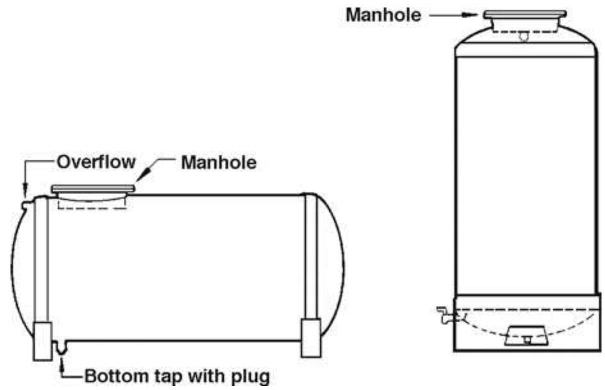


Figure 26 a
Examples of GAP cisterns

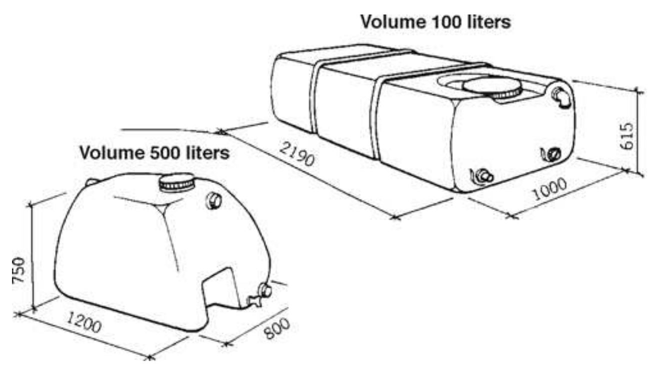


Figure 26b
Examples of polyester cisterns (daytanks)

**3 FROST PROTECTION**
Even in coastal areas wintertime temperatures can cause a cistern system to freeze. To avoid problems, a system designed for year-round use must be insulated against freezing.

**31 Placement**

**311** If the cistern is placed on the ground with the top surface exposed to open air, the walls and top must have extra insulation. If the bottom of the cistern is deeper than about 4 or 5 ft it can remain uninsulated. To avoid cold bridges and to maintain higher ground temperatures, insulation should be placed as shown in (Figure 311).

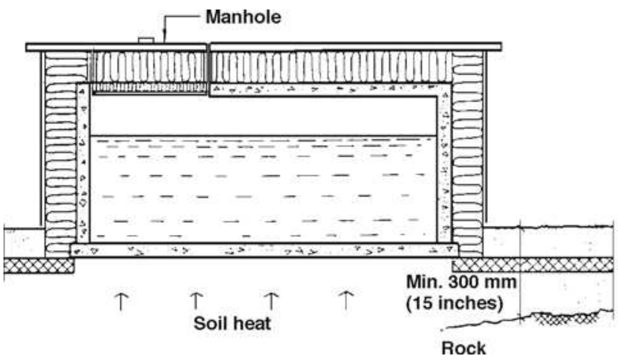


Figure 311
Frost protection using the soil geothermal heat (in nonpermafrost areas only).

**312** If the cistern is placed on solid rock, significant warming by the soil is not likely and the bottom must usually be insulated (Figure 312a). If the cistern cover is more than 8 to 10 square meters (80 - 100 sq ft) it may be advantageous to insulate as shown in figure 311. Boards of extruded polystyrene are recommended for this application because they resist moisture and normal loads. As small a surface area as possible is recommended. Cylindrical cisterns should be insulated with batt insulation (Figure 312b).

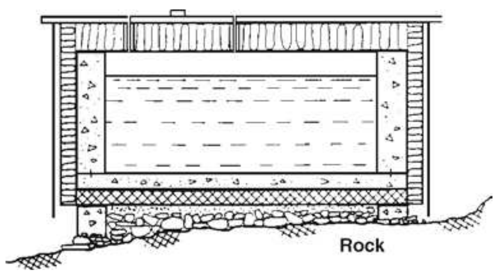


Figure 312a
Frost protection of cistern on rock.

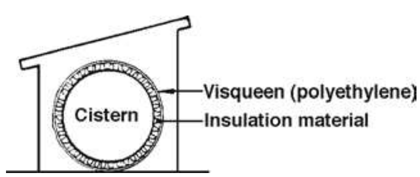


Figure 312b
Frost protection of prefabricated cisterns above ground.

**313** If the cistern is excavated down to a frost free depth, frost problems are avoided. However, this in itself leads to several other problems, such as difficulties in cleaning, and may not be practical. A better solution would be to insulate the ground above the cistern as shown in figure 313. The necessary depth of soil cover will depend on the thickness and the extent of the insulation.

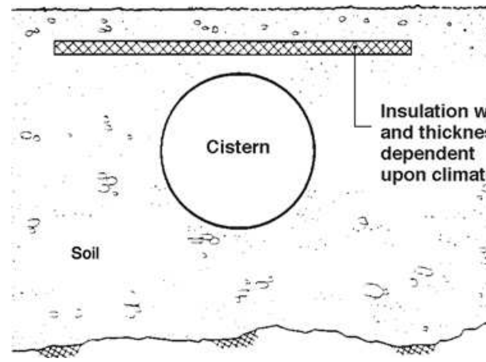


Figure 313
Frost protection of cistern buried in soil.

**314** In maritime coastal climates there are often large variations in temperature during the winter. With a large, insulated, year-around cistern, the stored heat in the water will often be sufficient to prevent freezing during a short cold period. If the cold period is prolonged, freezing will usually start at the coldest surfaces. By placing the intake a bit above the bottom of the cistern, longer frost-free operation can be maintained. The intake pipe should be insulated and heated with a heat tape. The heat tape can be threaded inside the pipe or wrapped around it. If thermostatically controlled, 2 to 4 watts per meter might be sufficient. If the heat tape itself can be frozen, then freezing can take place, and the heat tape can be used as a thaw cable. This type of heat tape can be operated manually and should have a capacity of 25 watts per meter. See Figure 314. In a well–insulated installation thawing will take about 30 minutes. The electricity must be shut off after thawing to avoid overheating.

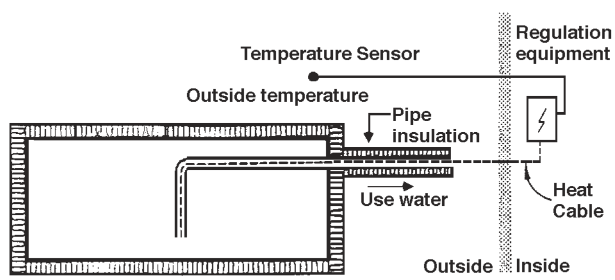


Figure 314
Placement and frost protection of intake pipe in the cistern with temperature sensor in the outside air.

**315** Heating with a thermostatically controlled heat tape will afford good protection against freezing. The tape is placed in loops on the tank bottom and intake and wired to an automatic thermostat that will turn on at the appropriate temperature (Figure 314 and 315). A well–insulated cistern will need heat tape with a capacity of about 10 watts per square meter of surface. There are two main types of heat tape.

Traditional cables have a fixed resistance per length. If the electricity is used directly, the cable can be used in a fixed length. If a change in length is desired, use a transformer. There are also self–regulating cables that can be cut to the desired length without changing the heating capacity. A transformer is unnecessary. The heating increases with a decrease in temperature in such cables. The temperature sensor is placed inside the cistern and the tape will operate whenever the temperature is below freezing (Figure 315).

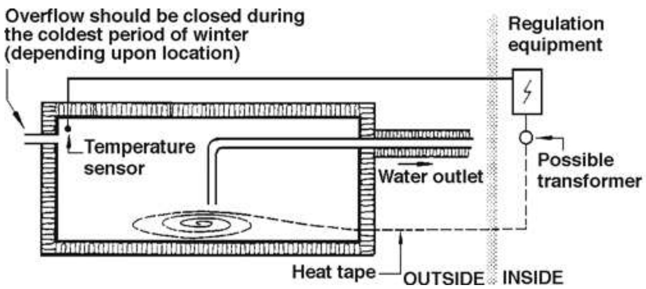


Figure 315
Frost protection of cistern with heat tape.
The temperature sensor is placed inside the cistern.

**316** Sediment traps, filters, and plumbing must be secured against freezing. Cold temperatures and snow on the roof, combined with solar heat and snow melt during the day, can lead to a frozen filter system. Figure 316 shows the filter insulated together with the cistern. If this causes problems, the filter can be insulated separately and heated with heat tapes. Problems can also be solved by allowing roof water to bypass the filter outside the cistern in the winter season. If the filter and cistern temperatures are above freezing, a positive heat flow in the downspout will occur and prevent freezing.

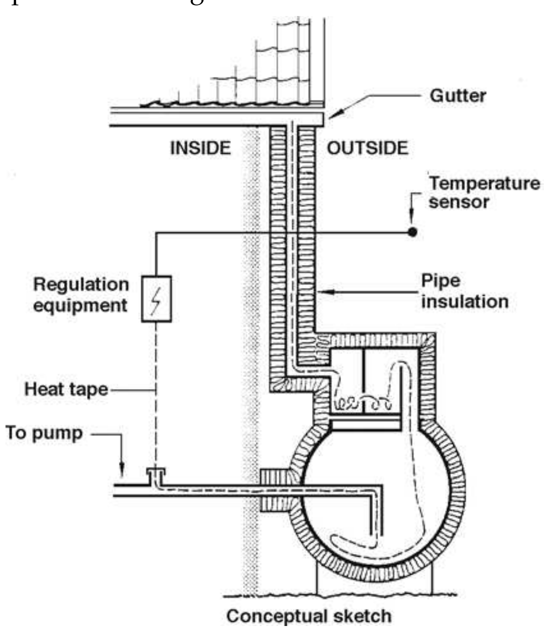


Figure 316
Frost protection of filter and cistern with heat tape.

A heat tape placed within the downspout will simplify thawing if the pipe freezes. Pipes that are in the shade or in drafts should be of a material that can resist freezing.

## 4 MAINTENANCE AND OPERATION

### 41 Cleaning

Regular cleaning of the cistern is necessary to maintain pure, potable water. Microbiological activity in the sediments causes a slime-like substance to grow on the inside of the cistern. The growth increases with temperature and the coating will, if not removed regularly, impart taste to the water. Cleaning is usually done once a year. Use a stiff brush, water, and baking soda. Finally, wash the area with ample amounts of clean water. Careful cleaning of the collection area (the roof and downspouts) along with a good intake filter and cold storage, can lengthen the time between the cleaning. Summer cisterns must always be cleaned by emptying and decommissioning at the end of the season. The cistern openings should be plugged after cleaning for winter storage.

**411** Gutters and pipes normally require no maintenance but must be cleaned, usually in both the spring and the fall. Cleaning should be part of the maintenance routine whenever the filter is checked.

**412** When decommissioning summer cisterns, the downspout must be vented to the ground in the normal way. Excess water spray can cause the building to rot.

**413** If several collection tanks are used, they should be used in sequence so bacteriologically clean water can be stored.

**414** Winter operation of cistern installations does create problems. Components that cannot withstand freezing must be frost protected or dismantled. Filter systems which are to be used during the winter must be placed in a frost free environment.

## 5 REFERENCES

**51** Bulletin is developed by Oddvar Stensrod and edited by Johan H. Gosbak. The editing was completed September 1978.

Translated into English by Nils Johansen and Richard D. Seifert, University of Alaska Fairbanks, May 1989

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8/91/RS/1400 Reprinted May 2008