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WATER SUPPLY AND SEWAGE DISPOSAL
IN PERMAFROST AREAS OF NORTHERN CANADA

BY ANALYZED
H. B. DICKENS

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WATER SUPPLY AND SEWAGE DISPOSAL IN PERMAFROST AREAS OF NORTHERN CANADA

BY H. B. DICKENS*

[MS. received 10 September 1958.]

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Introduction

Although the principles of water supply and sewage disposal in the north of Canada are the same as those for more temperate regions, the physical features of the installations often vary with the influence of low temperature and permafrost. These not only create technical problems of design but, when coupled with the relative isolation of most northern sites, they also introduce serious economic considerations. Operating costs as well as initial construction costs are higher, making facilities of the kind normally provided too expensive for many people.

Water supplies

Sources. Permafrost increases the problem of locating suitable water supplies by restricting the movement and the use of ground water as a source. Ground water may exist above (suprapermafrost water), within (intrapermafrost water) or below (subpermafrost water), the permafrost layer. Suprapermafrost water is not usually available throughout the year in regions where the seasonal frost extends to the top of the permafrost. In more southerly areas, where some thawed ground remains above the permafrost all year round, sources of suprapermafrost water may be found. Such supplies, however, are generally limited in quantity and of doubtful quality, since they are rarely more than 20 ft. (6 m.) deep and receive their water from the contamination zone of the subsoil. Intrapermafrost water rarely provides a suitable supply, and is likely to vary greatly in quality and safety.

Although subpermafrost water appears to offer the most promising means of continuous water supply, these sources are difficult to locate and costly to develop, particularly in areas where the permafrost is relatively deep. In many cases they contain large amounts of organic matter and objectionable quantities of iron and manganese.

* National Research Council, Canada, Division of Building Research.

Wells have been drilled successfully through permafrost but they pose special problems and are costly. Operation of wells in permafrost also presents difficulties. It is often necessary to provide controlled continuous pumping or to supply auxiliary heat in some form in order to prevent freezing. Too much pumping of wells in permafrost can in itself create freezing difficulties by depleting the total quantity of water in the well to such an extent that encroachment of the surrounding permafrost begins to occur.

Year round supplies of surface water are sufficiently scarce in permafrost regions for their availability and extent to govern the location of communities and determine the future development of a region. This statement may come as a surprise to some who have flown over these vast northern areas in summer and seen the myriads of ponds and lakes that dot the landscape. These small ponds and lakes are generally the result of retarded drainage due to the impermeable nature of the permafrost below; they are usually so shallow that they become completely frozen in winter. Bodies of water must be more than 8 to 10 ft. (2 to 3 m.) deep in such areas before they can be expected to provide some water in liquid form throughout the year. Ice cover rarely exceeds 8 ft. but it has considerable effect on the storage quantity of water in a lake. In addition, the mineral and organic content of the lake tends to concentrate in the unfrozen water below the ice, and may make it unsuitable for domestic use. A thorough study of lake depths, temperatures and related geological features is of vital importance before a water source is selected.

There are comparatively few rivers large enough to maintain an appreciable flow throughout the year, and utilization of water from rivers in the permafrost region is complicated not only by such bodies freezing solid in some places, but also by the formation of frazil and anchor ice at water intakes. Clogging of intakes with ice can be minimized by ensuring a deep pool of water over the intake and maintaining low intake velocities. Auxiliary heating facilities; using steam or electricity, may be provided to maintain the small temperature rise necessary to prevent icing of the intake structure. Care must be taken to protect the intake structure from damage due to movement of heavy ice masses during spring break-up.

Rainfall is so small throughout much of the Arctic that it is impractical to rely upon cisterns as a source of water supply.

The principal source of water supply used by the natives is melted snow and ice. Ice is cut from fresh water lakes or rivers in the fall when it is about 10 to 12 in. (25 to 30 cm.) thick and stored in a permafrost cellar or stacked on the ground. Special melting tanks equipped with steam coils have been provided in some of the larger buildings, but in the majority of homes ice is melted in a container in the building. High costs of fuel and the labour make such a method impractical for obtaining large quantities of water such as are required to serve a community. It would require the melting of 30 to 35 cu.ft. (0.8 to 1 cu.m.) of snow to provide 15 gallons (67.5 l.) of water per person per day, a figure generally considered a minimum for adequate drinking, cooking, bathing and laundering purposes. It is not surprising that the northerner

occasionally develops an immunity to bathing and, in some areas, keeps his use of water down to only two gallons per day.

During the summer months water for household use is usually obtained from fresh-water lakes or rivers, sources which may introduce health hazards by subjecting the water to undesirable handling and possible contamination. It is such practices, coupled with the general lack of water treatment and sewage disposal facilities, that have produced the most critical sanitary problems of the north.

Treatment. Low temperatures and permafrost do not in themselves reduce the occurrence of diseases associated with filthy conditions or faulty waste disposal methods. The quality of the water may change materially with the seasons but some degree of water treatment is generally required. In water sources subject to run-off, such as the large rivers of the Yukon and Northwest Territories, turbidity becomes a major problem at certain periods of the year. The Slave and Hay Rivers which run into Great Slave Lake carry with them considerable silt from break-up in early May until late summer, and the Hay River in particular carries sufficient organic matter to colour the water brown or greenish. Filtration is considered necessary during both spring and summer and chlorination is always necessary.

Many small shallow lakes develop an unpleasant taste and smell caused by concentration of organic and mineral content as the water depth decreases. In Lake Isabelle, which provides the water for Churchill, copper sulphate has to be used periodically during the summer months to control algae, and activated carbon to control taste and smell.

A major consideration in the treatment of northern water supplies is their low temperature. It is not uncommon to find both ground and surface sources at temperatures only slightly above 32° F. (0° C.) during the winter, although ground water from deep wells below the permafrost may be warmer.

Aeration, filtration, sedimentation, mixing of chemicals and chemical action all take place at a slower rate at low temperatures because of changes in the physical, chemical and biological properties of the water. This generally means that the time of mixing and aeration and similar operations must be increased, capacities of sedimentation chambers must be made larger and chemicals added in greater quantities. For instance, difficulties are experienced with gaseous chlorine apparatus due to the formation of chlorine hydrate crystals at temperatures below 50° F. (10° C.).

These factors suggest that it may be desirable to raise the temperature of the raw water prior to treatment. The question is really one of balancing cost of auxiliary heat against increased cost of treating low-temperature water. The possible savings in operating costs that may be effected by the right combination of conditions during treatment also suggest that experiments should be carried out on chemical dosage, flocculation and settling over a wider range of conditions to determine the most economical method of obtaining satisfactory treatment.

In small water systems, where seasonal turbidities are the only problem, diatomaceous-earth filters offer a useful alternative to orthodox coagulation

and filtration processes. Their initial cost is said to be much less and their operation simplified.¹ One northern community, the old Aklavik, has used these filters successfully for its summer water system.

Simple but rugged equipment is important because of the isolation of many communities and the difficulty of obtaining replacement parts. "Gadgetry" should be avoided.

All equipment and processes must be properly housed, insulated, and protected against low temperatures. Serious condensation problems can occur in buildings housing treatment facilities due to the tendency towards high humidities through evaporation from the several water surfaces in the plant. These problems must be controlled by proper attention to insulation and vapour barrier details in both design and construction of the facilities, and by provision of adequate ventilation during operation. Waterworks buildings must be built so as not to thaw the permafrost and must be protected against frost action in the active layer. These impose considerations not only of design but also of cost.

Distribution. The most common methods of delivery of water are by sledge and barrel or by tank truck. Such methods afford many opportunities for contamination of supply, and water obtained in this way may still be quite costly.

Some communities, such as the old Aklavik, have installed a pipe distribution system for summer use only, by laying pipes directly on the surface of the ground. During the winter months such a system must be dismantled and drained. Here again, there exists a real danger of contamination, particularly where the pipes are not picked up and stored in winter but are simply disconnected and left lying on the ground until the following summer.

Where permanent distribution by pipes is provided, the pipes cannot be laid below frost level because of the presence of permafrost, and sufficient heat must be available to prevent freezing of the water during distribution. If the heat naturally present in the water is inadequate to replace the heat losses from the system under normal conditions of operation, then freezing must be prevented by incorporating one or both of the following modifications: (i) by supplying heat to the water, or, (ii) by maintaining continuous water circulation.

If heat is supplied to the water, it may be added either at the source, or in the distribution system.

Water can be heated at the source either by steam, or hot water boilers, or electric heaters. Wherever possible, waste heat from other facilities, such as heating or power plant energy sources, should be used.

Heating of the water in the distribution system may be accomplished by enclosing the water line with other heat sources in a conduit or "utilidor"^{2,3} (see photographs p. 421). Utilidors are enclosures of concrete, wood or metal, often insulated. They may be built to carry several services including steam, water, sewer, telephone and power lines or only one or two. The heat source may be steam or hot water central heating lines, where these are to form part of the community installation (as in the case in Inuvik) or a special steam tracer line may be placed alongside the water main. Utilidors range in size

from those large enough to walk through, and thus allow maintenance from inside, to those of only sufficient size to carry the utility lines. Access to the smaller ones is provided through a removable top. Well-designed utilidors greatly simplify the continuous distribution of water in low-temperature areas, but at a high cost; in addition to their high initial cost, there are operational hazards. With both water and sewer lines placed in the same duct there is the danger that leakage of sewage may contaminate the water supply. To reduce this possibility, the water line should always be kept above the sewer line and adequate drainage of the utilidor provided. Drainage constitutes a major problem with underground utilidors, since they must be made watertight to resist seepage of ground water. One method of handling this difficulty is to drain all such water to sumps at low points in the utilidor and to empty these sumps periodically by pumping to the sewer.

Preservation of the permafrost and prevention of frost heaving in the active layer must be given careful consideration. With utilidors containing central heating lines, the problem of thawing of the permafrost is greater due to their increased heat load. In areas of gravel or coarse sand, where little ice exists, few if any difficulties are experienced, since thawing of these materials does not usually produce any significant change in their properties. However, in fine-grained soils or organic material with high ice content, considerable settlement is likely to occur on thawing, resulting in differential movement of the utilidor and creating problems of alignment and groundwater seepage. In such conditions, an accepted method of construction is to support the utilidor on piling, steamed into the permafrost. Use of the pile method of construction permits the utilidor to be located completely above grade, leaving an air space between the bottom of the structure and the ground surface, thus reducing heat transfer to the frozen soil. In some cases, utilidors are placed directly on the ground, after first removing unstable material to some depth and backfilling to the level of the utilidor with soil not susceptible to frost action. In another method the permafrost is left undisturbed and a gravel mat at least 2 ft. (0.6 m.) thick is placed on the ground surface with the utilidor laid directly upon it. Local conditions will of course govern the choice of construction method but, in general, unless the active zone and the underlying permafrost are in well-drained non-frost-active material for a considerable depth, the above-grade system of construction is probably the most satisfactory.

Although heating of water at the source has been suggested as a means of avoiding freezing in northern water systems, the problem can rarely be overcome economically by this means alone. The water begins to lose heat as soon as it leaves the water plant and it is simply a matter of time before its temperature is lowered to 32° F. (0° C.). To make this system practicable, methods of continuous water circulation have been developed in which the unused portion of the supply is returned to the treatment plant for further heating and recirculation. These systems are of two main types—a dual main system consisting of a two-pipe service with high-pressure supply line and low-pressure return line laid side by side, and a single main service in which one pipe serves as

both distribution and return main, and is laid to form a closed loop beginning and ending at the circulation pumps.

A comparison of costs at the time the Fairbanks system was designed in 1953 showed that a single main system to serve this town would be \$900,000 less than a dual main system. A similar comparison for Uranium City in 1957 estimated the cost of the distribution portion of a single main system to be \$107,000 cheaper than that of a dual main system.

A preheated recirculating water distribution system arranged to make the most efficient use of all the available heat affords the most economical solution to water distribution in many instances, but such a system is also not without its problems of design and operation.

Service connexions. Service connexions to individual premises are usually the most frost-susceptible part of a water system. With a dual main system it is relatively simple to provide circulation of water through each service connexion. A drilled plate is inserted at the junction of the supply and return piping within the building to restrict the amount of water circulated and to ensure sufficient pressure differential between the supply and return mains.

In the single main systems circulation through the service connexion is protected by use of a "thermal tap".² The method is based on the principle used for maintaining circulation in single-pipe hot water heating systems. A further method depends on the use of the velocity head in the supply main, aided by special orifices, to maintain flow in the service connexions.

Alternatively, a very small pump in the supply line to each building can be used to keep water in the service connexion circulating. Where recirculation back to the main is not feasible the service connexion may be protected by means of a heated utilidor enclosing the service connexion from the main to the building, or an electric resistance heating unit attached to the service pipe. A continuous flow may be obtained by wasting water through open house taps, or by a device installed on a water tap to permit controlled continuous leakage to the sewer.

Considerations of design. In laying out a distribution system, there are a number of considerations that should be kept in mind to achieve maximum economy and minimum operating trouble.

Dead ends should be avoided and the system arranged so that the largest users are located at points furthest from the treatment plant. The cost of insulating water lines must be balanced against the increased cost of heating if the lines are left uninsulated. Consideration should be given to the use of cheap local insulating materials such as peat and moss. Studies carried out on the Yellowknife water system in which moss was used around the pipes as insulation, suggest that it is of little value when used below grade unless it can be kept dry.⁴ Wet moss is not a good thermal insulator; when present at the surface, it protects the permafrost through the mechanism of evaporation, but, when placed around pipes, this process cannot take place and its insulating value is therefore reduced.

Fuel is expensive and only just sufficient heat should be added to the water to prevent freezing. Owing to the complex nature of heat losses from a

circulating water system, the temperature to which the supply water must be heated to achieve this condition is difficult to determine except by trial when the system is in operation. It should be noted, however, that the temperature of the return water when it reaches the treatment plant provides only a relative indication of the freezing hazards in the system, since it is quite possible for this return water to be several degrees above 32° F. (0° C.) and yet some part of the water supply still be in danger of freezing. In the Yellowknife system, for example, it has been found that the return water has to be kept at about 41° F. (5° C.) to prevent freezing in some remote part of the system during the coldest periods.

The temperature of the source water is also an important factor in the overall economy of any system, since an increase of a few degrees at the source can effect a considerable saving in the heating bill. For this reason, advantage should be taken of the thermal anticlines that exist in lakes during the cooling cycle. Because the density of the water is at its maximum at 39.2° F. (4° C.) very little convection takes place as the water cools below this temperature and it is therefore possible to obtain water close to 39° F. near the bottom of the lake for some time after the water at the surface has cooled several degrees below this. The advantage of obtaining warmer water is sufficiently great to justify some expenditure for this purpose, as is the case in the newly designed water system at Whitehorse. Here, wells have been drilled to supplement water obtained from the river, the temperature of this well water being several degrees above that of the river water.

Finally, whichever system of water distribution is selected, the question arises whether to place the pipes above or below grade. The condition of the soil in the area and the difficulties that may arise from frost action in the active layer or from melting of the permafrost are probably the most important factors in this decision. If these conditions do not prohibit placing the services below grade, then the question of construction cost plus heat loss becomes important. If the system is placed in the ground it may be located in permafrost or in the seasonally frozen layer. If it is placed in the seasonally frozen layer it will experience lower temperatures during the winter than it would in permafrost. If placed in permafrost it will remain below freezing point throughout the year. An important factor is of course the work required to excavate for buried lines.

Soviet engineers are reported to prefer laying water supply pipes in the ground to depths of 10 ft. (3 m.) at which depth temperature fluctuations are insignificant and the temperature remains only a few degrees below freezing. A layer of gravel and sand is placed around the pipes and the pipes surrounded for a distance of two diameters by loose earth. The moisture retained in this soil is intended to retard frost penetration. Sand and gravel are then placed around this loose earth and covered from above by a layer of dried peat approximately 8 in. (20 cm.) thick. Although not stated, it would seem that such practice would be more suited to sporadic permafrost areas than to continuous, because of the difficulty and high cost of excavating to those depths where the permafrost is close to the ground surface.

Sewage

Individual systems. In most communities, the primitive pail system, or modifications of it, is the common method of sewage collection, the wastes being dumped on the tundra or into nearby water courses. The dumping may be done by the householder or occasionally, in larger communities, by a contractor. Final disposal of sewage by this means is not always controlled and may lead to the creation of offensive and insanitary conditions over the entire disposal area, as well as to the pollution of local water supplies.

The chemical toilet offers some advantage over the simple pail receptacle, providing the chemicals are added when required, but these units are not used extensively due probably to the cost of the chemicals.

Septic tanks have been used with only limited success. Some tanks have relied on auxiliary heating to prevent freezing and to maintain temperatures at which satisfactory bacterial action will take place. Others have depended solely on insulation. The most satisfactory have been those placed in a heated building. Studies on septic tanks carried out at the Arctic Health Research Center in Anchorage, Alaska⁵ suggest that such tanks can operate satisfactorily in sub-arctic areas over a winter period without the use of heat simply by utilizing undisturbed snow cover as insulation. The disposal of the effluent from a septic tank still presents a problem, however, since disease-causing bacteria are not destroyed in the tank.

Community systems. Very few water-carried community sewage collection systems have been installed in permafrost areas. This is due in part to the lack of water, but an important contributory factor is the problem and expense of combating low temperature, frost action, and permafrost.

Community systems have been in use at Flin Flon since 1932, at Fairbanks since 1939 and at Yellowknife since 1949.

The system at Flin Flon utilizes wood stave pipe, a large part of which is located with less than 3 ft. (1 m.) of cover, due to rock formation in the area and is placed in wooden boxes containing heated water-mains, the entire assembly insulated with wood shavings. Freezing difficulties with this system are generally related to flow obstruction arising from frost heaving and differential settling which produces low spots in the lines, or to low flow where only small quantities of water are used in the building serviced.

At Fairbanks also wood stave pipes were used with many of the lines having only 3 ft. of cover and an unusual number of dead ends in the system. Shortly after being put into operation, this system began to experience difficulty due to misalignment because of melting of the permafrost, and clogging from freezing brought about by insufficient flow and lack of soil cover. In 1949 work on the rebuilding of this system was started. The Arctic Health Research Center has studied the use of automatic flushing wells to maintain sewers in operative condition using ground water at only 33° F. (-5.5° C.). The addition of such water to the sewers at the rate of 500 gallons (2250 l.) per hour, from 100-gallon flush tanks, has greatly reduced the freezing problem and

it has even been possible by this means to thaw a sewer partially filled with ice.

At Yellowknife, the collection system consists of a corrugated steel pipe laid in the ground with a minimum cover of $7\frac{1}{2}$ ft. (2.3 m.) and located 2 ft. (0.7 m.) below and 6 ft. (2 m.) horizontally, from the water-mains. Moss was placed around the pipes during construction as insulation, but no auxiliary heat was added to the sewer during operation. Underdrains were placed below the sewers to carry off ground water and to improve the insulating properties of the moss.

Experience with these various systems has shown that collecting-sewers, like water-lines, can be kept operative only if they are protected from freezing and from differential movement due to frost action in the active layer, or to melting of the permafrost.

Enclosing the sewer in a heated conduit or utilidor is probably the most positive way of ensuring trouble-free operation, but such installations are expensive to construct. The importance of economy in community sanitary installations suggests a preference for systems in which the pipes can be placed directly in the ground.

When water systems are installed without heated utilidors they require heating and circulation of the water to function properly. Sewers are somewhat less vulnerable as the sewage contains warm waste water from heated buildings. This additional heat may be sufficient to allow the sewer to function satisfactorily without insulation or auxiliary heat, particularly if the sewer pipes can be laid at depths where the soil temperatures are only a few degrees below freezing, and do not fluctuate very much throughout the year. Rock outcrops, frost-active soil and permanently frozen ground with high ice contents must be given careful consideration in design.

Where ground conditions are such that buried pipes can be considered, various precautions may be taken to preserve heat and protect against freezing. The sewer lines should be located where advantage can be taken of solar radiation and of the insulating effects of snow cover and vegetation. They should not be placed under the travelled section of roads where little insulating cover is available and where they are subject to damage from compaction of soil above them.

There are instances where the thermal properties of the pipe itself are significant. One example is a short run of outfall sewage line subject to intermittent discharge of sewage by siphon from a heated building, where the quantity of heat required to warm the pipe, as represented by specific heat and density of the material, is an important factor. Analysis in this case showed that differences between the thermal characteristics of thin-walled aluminum and thick-walled cast iron pipe were important.

It has been noted that sewers have frozen even when the adjacent ground temperatures were themselves above freezing, due to the tendency of very cold air to flow downward through the sewer vent and displace warm air in the sewer. The plumes of frost that form on house vents provide visual evidence of a secondary aspect of this problem (the blocking of house vents by frost)

and one which can itself create difficulties. Some method of control of air flow within the vent stack may be required to limit the heat exchange that can occur by this means.

Treatment. The effectiveness and safety of most methods of sewage disposal are greatly impaired by low temperature and the presence of permafrost. The processes of assimilation and decomposition of wastes that occur in soils in temperate regions do not appear to take place at all in permanently frozen ground, and only very slowly in the shallow top layers of seasonally thawed ground. Thus the normal methods of sewage disposal in the soil, including the use of leaching pits, septic tank disposal fields, and the pit privy, cannot be readily practised in northern regions. Since a large percentage of the present population must rely on individual household disposal, this limitation is a serious one.

Yellowknife is the only community in the Northwest Territories that provides much in the way of treatment of its sewage wastes; most communities discharge their raw sewage with little or no treatment directly into nearby water courses or tidal waters. The problem of stream pollution is complicated by the low temperatures of surface water which tend to slow biochemical reactions and reduce bacterial die-away rates so that less reliance can be placed on natural self-purification of effluents in the receiving waters. As the population increases, the discharge of raw sewage into natural water courses will become a more significant health matter and the need for treatment facilities more pronounced.

Experience with the design and operation of both primary and secondary sewage treatment processes in regions of low temperature has been summarized by Thomas⁶ and by Clark;⁷ but many questions remain unanswered.

Two recent developments in treatment of sewage hold particular promise for northern use. The first is the process of sewage lagooning.⁸ This method of treatment consists of discharging raw sewage into large shallow lagoons, or oxidation ponds, where aerobic conditions are maintained and natural decomposition takes place. Sewage lagoons provide for biological or secondary treatment of sewage and, if properly constructed, they will provide a high degree of treatment approaching that in most of the more expensive treatment plants.

Lagoons appear to work satisfactorily in cold climates. In winter months the effectiveness of the lagoon is reduced, but even during this period a biochemical oxygen demand reduction of 65 per cent has been obtained, as compared with 85 to 95 per cent in summer. The lagoon depth should not exceed 3 to 5 ft. (1 to 2 m.) to ensure aerobic conditions and eliminate smells. In cold climates, depths greater than this must be provided to allow for ice cover, and it may be desirable in such areas to provide some form of control that will permit the lagoon to operate at shallower depths during the summer.

The main advantages of lagoons are that both initial and operating costs are less than for conventional plants and the effluent is normally in a stable condition.

The principal disadvantage associated with this method is the large area of land required for construction of the lagoon. One acre (4047 sq.m.) for

one hundred persons is normally recommended, based on experience in areas with an evaporation loss of 18 in. (46 cm.) per year and percolation rates through the soil of $\frac{1}{8}$ in. to $\frac{1}{4}$ in. (0.3 to 0.6 cm.) per day. In areas in which evaporation and percolation are likely to be less, larger lagoon areas may be required.

An important consideration with lagoons in permafrost regions would appear to be the danger of using areas where the soil has a high ice content and where melting of the permafrost can cause settlement. Under these conditions, the dykes may wash out and allow seepage of sewage wastes into the surrounding area.

A second recent development is one in which the sewage is collected and subjected to aerobic digestion in a tank located in a building. This system is essentially a biological oxidation process, using a modified activated sludge treatment, and is reported to be capable of providing a degree of treatment which compares favourably with that obtained in a conventional plant. The essential parts of the system, in addition to the tank, are a compressor to aerate the sewage and a circulating pump to flush the toilet mechanism. A grinder type toilet is used to prepare the sewage solids for more effective treatment by aeration. The grinder can be operated electrically or by the pressure of water during flushing. An important advantage of this method is the possibility of operating the unit as a closed system handling toilet wastes only, and without any discharge of effluent to the outside. Treated effluent from the tanks serves as the flushing medium, being simply recirculated through the toilet bowl and back to the tank by a small circulating pump. Other household wastes from bathroom and kitchen can be connected to the treatment tank, if desired, but this means operating the system as an open unit and raises the problem of discharging sewage containing human waste to a suitable disposal area. With the closed system, the only material requiring disposal from the tank is the sludge that may accumulate after prolonged periods of operation. Initial studies suggest that this accumulation of sludge is small. Advantages offered by this system are a potentially high degree of treatment, and savings in water resulting from the use of the effluent for toilet flushing. Initial and operating costs are at present not low but are comparatively so, when considered in relation to the degree of treatment that may be achieved. Further studies appear necessary with respect to the effect of tank size, aeration rate and population load, before rational design can be attempted. Research of this nature is now under way in Canada under the auspices of the Central Mortgage and Housing Corporation, the country's national housing agency.

Summary

Although low temperature and permafrost complicate the provision of sanitary facilities they have not altogether prevented the construction of workable sewage and water systems, but they have seriously increased their cost. Experience with existing installations has demonstrated that the sanitary engineering practices of more temperate regions must be modified

to suit the special climate and soil conditions of the north. In providing adequate economic sanitary control in these fast developing northern regions, the engineer is faced with one of his most challenging tasks.

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Utilidor laid on ground surface

Utilidor raised above ground surface

Water supply and sewage disposal in northern Canada
(Facing p. 421)

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