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Temperature in underground containers for the installation of repeaters

ITU-T G-series Recommendations – Supplement 34

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NOTES

1 Supplement 34 to the G-series Recommendations was approuved in Melbourne (1988) and published in Fascicle III.5 of the *Blue Book*. This file is an extract from the *Blue Book.* While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Supplement, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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TEMPERATURE IN UNDERGROUND CONTAINERS FOR THE INSTALLATION OF REPEATERS

(Melbourne, 1988)

(see Recommendation G.950)

1 General

This Supplement consists of two parts: A and B.

Part A (source: Federal Republic of Germany) informs about the ground temperature taken from meteorological sources in most regions of the world, and shows the seasonal variations as a function of the depth (in the Federal Republic of Germany).

Part B (source: Italy) gives guidelines for the calculation of the ground temperature in the container, depending, *inter alia*, from the atmospheric temperature, the depth and the dissipation of the equipment in the container.

Both parts give additionally some general information which is useful as a guidance for planning.

2 Part A

2.1 *Definition*

In the following, climatic conditions are discussed which are relevant to small underground containers without any means for adjusting to specific temperature conditions. These containers are normally hermetically closed and need not be opened e.g., for preventive maintenance. They can be operated with or without gas pressure supervision or they may contain drying agents.

2.2 *Temperature in underground containers*

The temperature in underground containers depends on the temperature of the surrounding soil. Additionally, it is influenced by the power dissipation of the installed equipment.

The ground temperature at various depths is well known for most of the regions of the world [1]. Figure 1 shows the seasonal variation of the ground temperature as a function of the long term mean value of the ground temperature. Examples of the variation of the temperature with time for a period of 1 year is shown in Figure 2. The yearly minimum and maximum temperatures as a function of the depth are plotted in Figure 3. Figures 2 and 3 are examples only for a specific region in Germany (Federal Republic of) and for sandy soil.

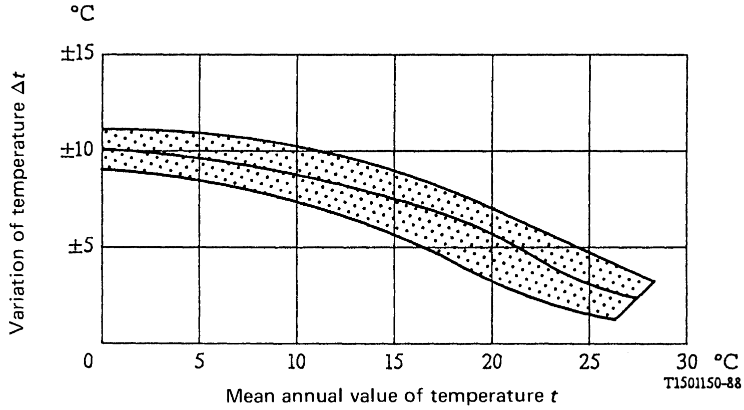


FIGURE 1

Relation between the long-term mean value of the ground temperature *t* and the annual variations to be expected at a depth of approximately 80 cm

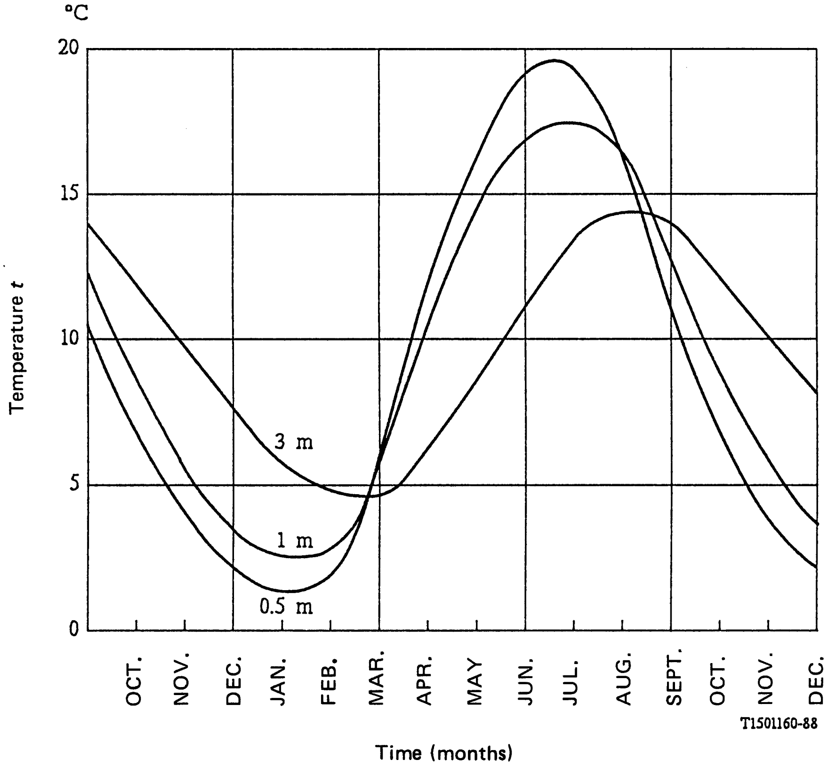
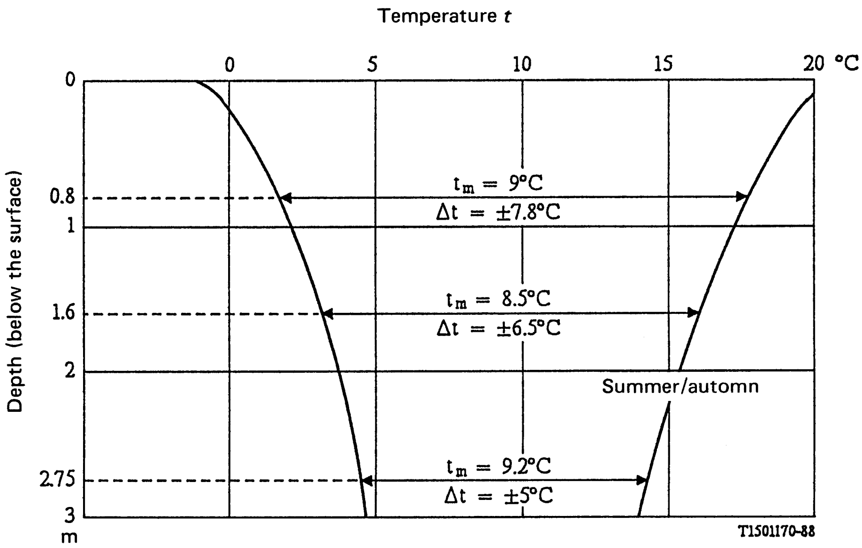


FIGURE 2

Temperature of the soil as a time function of the seasons for depths of 0.5 m, 1 m, and 3 m (long-term mean values, sandy soil in Germany (Federal Republic of))



t_m Annual mean value of the soil temperature

Δ_t Maximum annual tamperature variation in the ground referred to t_m

FIGURE 3

Annual maximum and minimum values of the soil temperature depending on the depth (long-term mean values, sandy soil in Germany (Federal Republic of))

The composition of the soil has a significant effect on the temperature and its variation with time. It should be noted that this variation occurs slowly, depending on the composition of the soil and on the depth.

The mean value of the temperature in the container is the same as that of the ground, if the possible increase caused by the heat generated by the power dissipation of the equipment is neglected. Variations of the air temperature cause variations of the temperature in the container, but with a time delay, and with an attenuation of the amplitude depending on the design of the container.

2.3 *Conclusion*

The temperature in small underground containers e.g., for the installation of remote power-fed repeaters depends on the geographical region, the composition of the soil, the depth of installation and the power dissipation of the installed equipment.

The humidity within the container is independent of external influences and can be controlled by suitable means, if necessary.

3 Part B

3.1 *Temperature in underground housing containing high dissipation equipment*

The temperature in the underground housing depends on the temperature of the surrounding soil, its composition and on the amount of power dissipated in the equipment.

3.1.1 The temperature in the soil at different depths can be directly measured at the site or can be calculated from seasonal mean temperature of the site (at ground level) taking into account thermal resistivity and diffusity of the soil.

Short term variations, like daily excursions, are rapidly damped and become negligible at a depth greater than 0.3 m so that only seasonal variation diffuses farther in the ground.

Of course such variations too are attenuated and delayed following the depth and the soil composition.

3.1.2 The heat generated by equipment dissipation in the housing is transferred via housing walls into surrounding soil thus disturbing the existing temperature field and determining a local gradient which decreases with the distance from housing walls.

In order to evaluate the maximum annual temperature in the housing it is advisable to define a mathematical model of the heat transmission and solve it for the conditions imposed by the site climate, the soil nature, the power consumption, etc.

The relevant calculation can be handled by computer making it possible to rapidly investigate the effect of the different parameters.

In critical condition, that is in soil of poor characteristics, advantage can be taken putting around the housing a backfilling material of good thermal conductivity. The effect of such an action can be previously verified by computer.

3.2 *Guidelines of the calculus*

The heat transmission from the atmosphere to the soil is described by the equation

$$T(y,t) = \mathrm{A} + \mathrm{B}\, e^{-\gamma y} \sin(wt - \gamma y) \qquad (1)$$

where

A	Mean value of the atmospheric temperature
B	Amplitude of the thermal oscillation at the ground surface
γ	Coefficient of diffusion
y	Depth

The temperature is a function of the time and depth only and the resulting field has horizontal isothermal surfaces.

The power dissipated in the housing determines a heat flux on the walls of the container and a two-dimensional thermal field in the soil.

The relevant equation is the

$$c\zeta \frac{\delta T}{\delta t} - k \left(\frac{\delta^2 T}{\delta x^2} + \frac{\delta^2 T}{\delta y^2} \right) = F(x,y,t) \qquad (2)$$

where

$F(x,y,t)$	takes into account the presence of thermal sources in the soil
C	Specific heat of the soil
ζ	Density of the soil
k	Thermal conductivity of the soil.

The problem can be further simplified neglecting the term $\frac{\delta T}{\delta t}$.

In fact the temperature in the soil is subjected to a slow variation and can be considered as steady in the short period.

Solve the equation

$$-k \left(\frac{\delta^2 T}{\delta x^2} + \frac{\delta^2 T}{\delta y^2} \right) = F(x,y) \qquad (3)$$

and introducing the "initial condition" of the (1) for the considered time, the temperature distribution in the soil can be plotted in a discrete number of points.

The centreline temperature in the housing is calculated from heat transfer relationships for natural convection on vertical walls: Nu = M. $(\bar{Gr} \cdot Pr)^N$ where NU = Nusselt number; GR = Grashof number; Pr = Prandtl number; M, N are constants to be empirically determined.

An example of calculated thermal field is given in Figure 4 where the isothermal lines substitute the local temperature values plotted by computer.

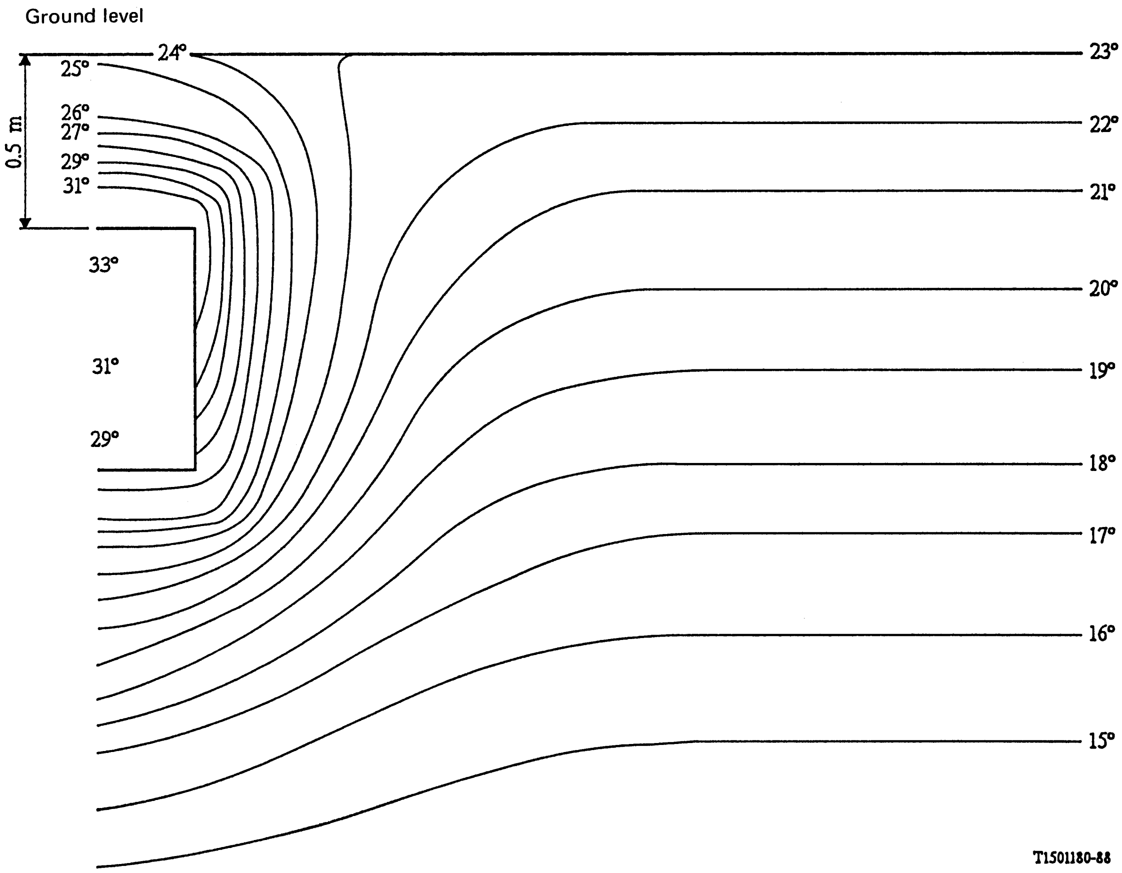


FIGURE 4

Example of calculated thermal field

3.3 *Conclusion*

The temperature in the underground housing depends on site climate, type of soil, depth, time of the year, equipment dissipation.

A mathematical analysis of the heat transmission makes it possible to evaluate the maximum temperature in the housing taking into account the effect of the parameters involved.

The use of selected backfilling material can be considered and the resulting effect evaluated.

HOUSING TYPE : CAI/24

Temperature at steady state (° C)

Housing dimensions (m) ∅ 0.85 h 0.9

Dissipated power (watt)	100
Month	8
Mean temperature of the site (° C)	12.7
Amplitude of the thermal variation (° C)	11.7
Thermal conductivity of the soil ($W\ m^{-1}\ K^{-1}$)	0.44
Density of the soil ($kg \cdot m^{-3}$)	1550
Specific heat of the soil ($J\ kg^{-1}\ K^{-1}$)	1255
Thermal conductivity of the backfilling material ($W\ m^{-1}\ K^{-1}$)	0.8
Depth of the backfilling material (m)	0.4
External radius of the backfilling material (m)	1.2

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[1] JEN-HU-CHANG: Ground Temperature, *Blue Hill Meteorological Observatory, Harward University*, Vol. I, II – Hilton 86, Massachusetts, 1958.

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