

Temperature Control Method in the Snow Road Construction

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Abstract. The paper substantiates the process of heat treatment before the snow compaction in snow road construction. The methods to measure the temperature of snow as a moving dispersed material have been considered in the paper.

1. Introduction

Snow roads are constructed to provide transportation network to remote settlements, and to deliver cargo and equipment in severe northern weather conditions. In permafrost areas, snow roads are used during the arctic winter season to provide an improved traffic surface and protect the underlying vegetation and permafrost. Sufficient snow cover and frost depth in the active layer are required to support construction activities.

During the construction of temporary winter roads on virgin snow with frozen ground, it is advisable to use special thermo vibrational snow grooming machines for 1 pass loosening and mixing of snow, warming the snow mass and vibration compaction. To streamline the process for snow road construction, a mobile unit has been designed to construct snow roads or runways; it performs consistently sketch of snow and grinding heat treatment, sealing and coating of snow chains notches. Each of the operations requires a set of equipment including the following devices (figure 1): rotary snow plows 1 equipped with the nozzle 2 for guiding the snowpack to the conveyor 3 and gas burner 4, then through nozzles 5 under the working body to seals 6 (vibro-compaction tool from STM-2), trailed rubber-tired roller 7 and a hard roll with a special profile.

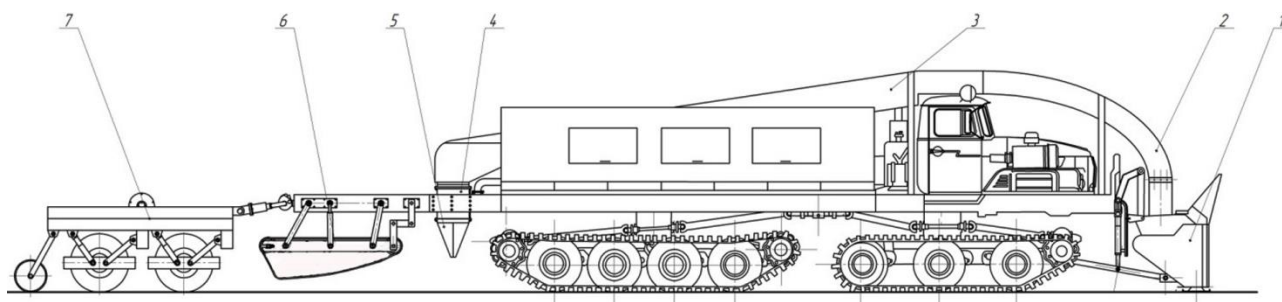


Figure 1. Tracked all-terrain vehicle Ural-5920 with a set of equipment.

According to Construction Codes 137-89 [1], snow road construction requires the snow road density profile to be over 0.65 g/cc. Density and hardness are the most important snow road characteristics. Density depends on the packing efficiency of snow crystals, that is, the degree to which a volume unit of snow is free of void space. Hardness depends on the tendency of neighbouring crystals to bond to each other by ice bridges (sintering). Both density and hardness are metamorphic, that is, they change with the time and surrounding environmental conditions. Methods used in snow road construction alter the state of natural metamorphism to accelerate the rate at which density and hardness increase. These operations will ensure the maintenance quality by maximizing snow grain contacts for optimal sintering and minimizing the labour and equipment operating hours [2–16]. Most experiences in snow road construction result in such values of density and hardness, the preliminary moistening of snow is essential [3].

In order to get a strong road profile, it is important to moisten the snow mass to 10%, when the snow roads are constructed [12]. Moisture of snow depends mainly on the temperature, so to provide the technological process, it is necessary to raise the temperature of snow to $-2 \dots -8^{\circ}\text{C}$ by introducing hot gases, microwave energy, infrared radiation and so on into the snow. The heat treatment intends to raise the temperature of snow immediately before compaction, and provides equalized moisture distribution [13]. The snow is compacted more effectively with the higher snow temperature (figure 2). Strength and durability of the road depend on the temperature.

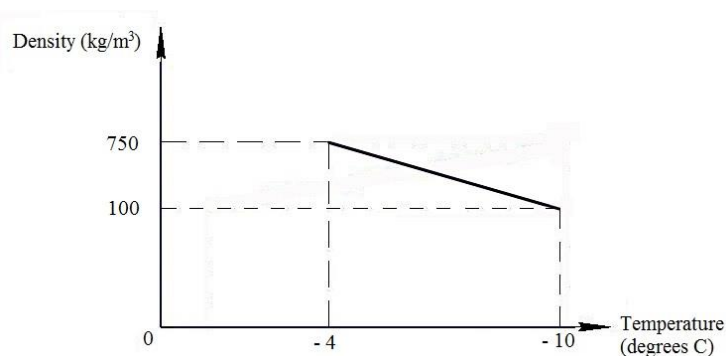


Figure 2. Dependence of the final density of the packed snow on the temperature at the constant maximum load.

The design of a mobile installation involves snow grinding and feeding to the conveyor in the thermal device. Heating of suspended particles in the thermal unit is called a dispersive method of warming, it presents a uniflow convective heat exchanger. Heat exchange occurs in free convection and the heat transfer coefficient is constant. Heat time is equal to the time of snow particles suspension [14]. Therefore, the main task is to maintain snow in the predetermined temperature range to prevent overheating. To do this in the planning phase of the experiment, it is necessary to select a measuring device to monitor the temperature of snow to set the thermal module and to prevent overheating.

2. Instruments and methods for measuring the snow temperature

The temperature control method depends on the range of measured temperatures, precision, operating speed, and the input quantity of heat capacity [15]. The contact method (when the temperature sensor directly contacts with the measured material) is applied to determine low and medium temperatures. The method is based on:

- thermal expansion of liquids, gases and solids (extension thermometers). Thermal expansion is based on the principle of changing the liquid volumes (liquid thermometers) or linear dimensions of solids (deformative thermometers);

– pressure change in closed space with the temperature changes (manometric thermometers). All types of manometric thermometers are almost identical and consist of a thermal bulb, manometric tubular springs (single or multi-turn in the form of bellows) and connecting capillary tube (figure 3);

– change in electrical resistance with the temperature changes (resistance thermometers or thermoelectric thermometers). Measurements with high accuracy are based on the temperature properties of conductors and semiconductors to change electrical resistance when the temperature changes. The higher the temperature, the higher the resistance in conductors. There is an inverse relationship for semiconductors. Quantitatively, the dependence is expressed in the temperature coefficient of electrical resistance. These thermometers consist of a sensor (thermocouples) and protective fittings (figure 4).

– thermoelectric effect (thermocouple). Thermoelectric thermometers are the most widely used devices for measuring temperature because they allow us to define a wide range of measurements, have high accuracy and high sensitivity, allow a remote transmission of readings and automatically record the measured temperature with recording instruments.

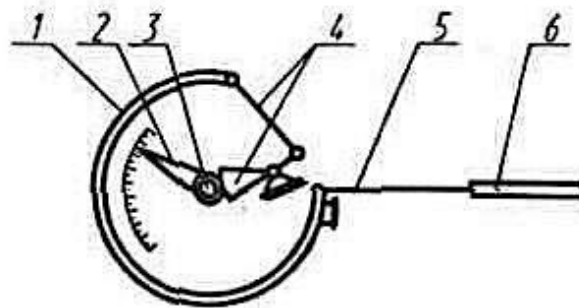


Figure 3. Manometric thermometers: 1 – springs; 2 – an indicating arrow; 3 – an axis; 4 – a gear; 5 – a transmission capillary; 6 – a thermal bulb.

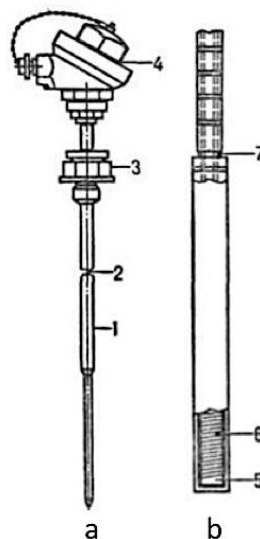


Figure 4. Resistance thermometers: a – general view; b – a sensitive element; 1 – a metal carrying case; 2 – thermocouples; 3 – a pipe connection mounting; 4 – a head for connection to the secondary device; 5 – a micaceous carcass; 6 – winding of platinum wire; 7 – leads.

There are some difficulties in applying contact methods to investigate the snow thermal characteristics:

1. Multiphase systems. A layer of snow is a complex physicochemical system. Its condition depends on the thermodynamic equilibrium of solid, liquid and gaseous components. Solid particles of different shapes and sizes are separated by a gap filled with gas and liquid [16];

2. Measurement occurs at a moving stream of particles in the cross section, at the same time speed and direction of the snow particles have a great importance.

Also, a non-contact method based on the energy of radiation of heated bodies is used to measure the temperature when direct contact with the measured product is impossible. In this case, pyrometers are used. There are three types of the devices depending on the input quantity: radiation, brightness and colour. However, application of these methods to determine the snow temperature is difficult due to low temperatures of snow and complexity of devices design.

However, there is a sensor for continuous indication of the bulk solids operational state (certificate of the authorship SU1656432). The temperature is determined by the contact method: a material stream flowing around the sensor provides virtually instantaneous heating of the thermosensitive plates located on the sensor side (figure 5).

The plates are mounted in thermocouples, which record the steam temperature. Temperature dependence empirically determines the material humidity. The obtained dependence allows us to determine the temperature range in which the moisture content is close to the scheduled one. The fourth thermocouple staked into the base is the control sensor.

The sensor 1 is a hollow case, which is made of thermally conductive material and fixedly mounted in the tray. The front wall 2 is inclined and has the edge 3. The case includes thermally conductive plates 4 with thermocouples 5 and 6 mounted inside. Thermocouples and plates are insulated from each other and from the case. All thermocouples have the output to the recording device.

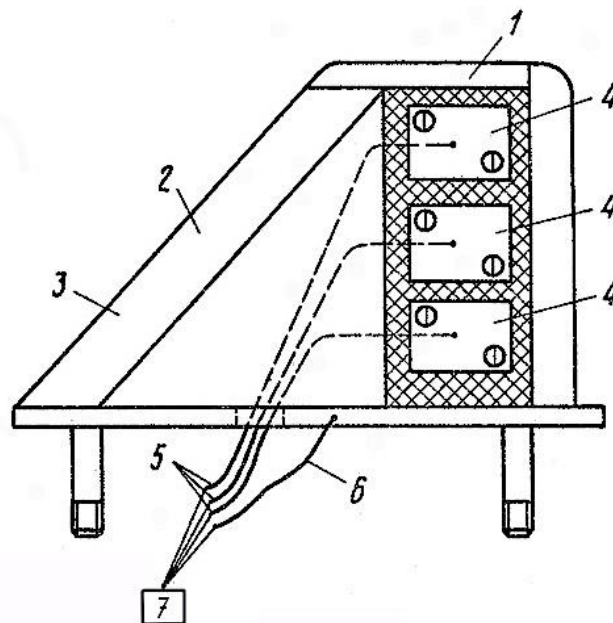


Figure 5. A sensor for continuous indication of the operational moisture state bulk materials: 1 – a sensor; 2 – a heat-conducting wall; 3 – an edge; 4 – thermally conductive plates; 5, 6 – thermocouples; 7 – a recording device.

3. Summary

The technological process of snow road construction should comply with certain thermal conditions of the snow preliminarily compaction to allow configuration and control of the operating modes of a thermal unit (burner) for heating the snow mass in a predetermined temperature range.

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