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Technology and Machinery for Construction of Winter Roads

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Abstract
Exploration of Russian North and Siberia is related with further increase in the use of automobile transport and operation of service vehicles. Increase in freight and passenger transportation, their costs, conditions of organization of transportation and provision of traffic safety depend significantly on development and state of road network. Creation and maintenance of expanded transportation network is impossible without utilization of road building machinery specialized for these conditions (Dyunin A. K., 1983). Construction of permanent roads usually falls behind exploration and development of oil and gas facilities, and quite often their construction is unpractical die to low intensity of their operation and seasonal nature of the activities. Winter period in these regions continues for more than seven months per year and is accompanied with prolonged influence of low temperatures. Temporary winter roads with their deep history gained good reputations for solution of the problem of traffic provision for oil and gas facilities, fishery and forestry (Adam K.M., 1977). Solution of the problem of construction of road networks and establishment of mechanized complexes for their development is an important and urgent issue for the Northern and Siberian regions of Russia. The main concept of the work is development of efficient traffic systems for exploration and development of districts with low ambient temperatures. Presumably, mechanization of construction of temporary roads of compacted snow/ice leads to increase in quality of road surface and decrease in production costs and construction period; improvements of quality of temporary road surface reduces the expenditures for transportation in the Northern and Siberian regions of Russia due to increase in traffic capacity and road operation lifetime.

Key words: efficient traffic systems, mechanization of construction of temporary roads, construction of winter roads, snow compaction, snow moisturizing, machinery for construction of snow and ice roads, technologies of construction of temporary snow roads.

1. Introduction

Russian North and Siberia are the regions with severe natural and climatic conditions which stipulate increased costs of products and provision of inhabitants. North regions include totally or partially six republics, three krais, ten oblasts and eight autonomous okrugs. The Concept of state support of economic and social development of north regions approved by Decree of Government of Russian Federation dated March 7, 2000 No. 198 states that here the reserves of mineral resources are concentrated: 93 % of Russian natural gas, 75 % of oil, 50 % of timber, 100 % of diamonds, cobalt, platinoids, 90 % of copper and nickel, 2/3 of gold. The North provides nearly 60 % of foreign currency earnings.

Production of oil and gas, exploration of mineral resources, increase in freight traffic in these regions intensify the use of automobile transport and service vehicles, which in its turn requires for efficient traffic infrastructure.

The conditions and development extent of the traffic network significantly influence on capacity of freight and passenger traffic, its organization, self cost and traffic safety (Vasilyev A. P., 2004).

Poor traffic network in the North and limited period of river navigation complicate freight transportation in these regions. Construction of permanent roads lags behind the exploration and development of oil and gas deposits, sometimes their construction and maintenance is not economically feasible due to low intensity of operation and seasonal pattern of the operations.

Scarce roads, moorland, and intensive flooding of soils in the periods of positive temperatures of ambient air exclude nearly completely delivery of goods to the facilities far from navigable waterways. Due to these reasons nearly overall scope of transportations is carried out in winter periods by means of temporary (one-season) winter snow roads (Abels H., 1982). In this regard temporary winter roads are the approbated variant of transport provision of the facilities of oil and gas industry, fishery and forestry (Sattarov T. Kh., 1987).

Up till now the erection of snow roads is performed by means of nearly primitive technologies and maladapted tools (Mishin V. A., 1988). This leads to low efficiency and low quality of the construction.

The bed and covering of such roads are made of snow, ice and frozen soil (Zolotar I. A., 1981). Application of such materials in winter period decreases the costs of road building due to negative temperatures as favorable factor for production of road bed.
Low efficiency of the applied methods of construction of temporary winter roads for service vehicles, heavy trucks and road caravans required for investigation into conversion of snow cover into monolith body and development of highly efficient technologies and tools for their erection (Racine C.H., 1977).
In early 1970-s the efforts of such institutes as TsNIIME (Khimki, Zhdanov GPI (Gorky, now known as Nizhny Novgorod State Technical University (NGTU)), NIAI VVS, SevNIIP (Arkhangelsk), Gersevanov NIIOSP (Moscow), Krasnoyarsk Affiliate of VNIIstroidormash and others provided development and testing of experimental snow compacting machines (Sarttarov T. Kh., 1981).
Starting from 1983 the team of Tyumen Industrial Institute (from 1994 known as Tyumen State Oil and Gas University) in cooperation with Severtruborpovodstroi Company and DSU-22 Enterprise (Nadym, Tyumen Oblast) carries out development of efficient technologies of construction of snow and ice roads, designs of machinery for their erection and maintenance.
The work discusses the research results of the author with co-workers being performed during more than twenty years in Tyumen State Oil and Gas University. Designs of temporary winter (snow and ice) roads are proposed, the bed and cover of which are composed of wetted, compacted and frozen snow. In order to prevent sediment accumulation the upper level of snow and ice roads is lifted above snow cover as well as the specialized cross section profile of the road bed is provided.
The roads of such design, having the same advantages as conventional winter roads, upon duly construction have solid and flat surface, admit multiple safe traffic of automobiles and service vehicles at required velocities. They provide necessary traffic capacity and can be readily repaired after destruction by passing transport, they protect soil against destruction by machinery. In addition, their advantages include possibility of rapid erection with complete automation of works, minimum demand for supply of construction materials and increased operation lifetime in spring period.
The author developed scientific backgrounds of development of mechanized complexes for construction of temporary winter roads in the regions of North and Siberia. On the basis of the studies the scientifically supported technologies are proposed, single machines and mechanized machinery complexes have been designed and implemented for erection of snow and ice roads. Pilot and commercial roads are erected near Nadym and Vorkuta.

2. Experimental

2.1. Approach

Snow is a construction material in erection of snow and ice roads (Addison P.A 1975). Machinery used for erection of the winter roads interacts with snow. In order to determine the process variables and operation modes it is necessary to study physico-mechanical properties of snow, its structure; to determine the coefficient of its thermal conductance; to reveal the patterns of snow destruction during shear; to specify the influence of properties of snow bulk on snow removal (filling onto road cover); to study compaction, factors influencing on compacting efficiency (influence of loads, moisture, impact of time, temperature etc.).
Erection of snow and ice roads is a complicated process stipulated by interaction of operating parts of construction machinery with the snow medium (Balovnev V. I., 1981). The key technological procedures of this process are snow filling onto the road bed, wetting and compacting.
The influence of dimensions of working elements and properties of snow on snow compaction is not studied sufficiently, hence, at the design stage of machine or road it is impossible to determine technological parameters of compacting unit and compacted snow (maximum load, load time) and to achieve the required quality of road.
In order to obtain high quality of road surface it is required to know, how many passes and what load should be used to obtain necessary density of snow of preset moisture, as well as the travelling velocity of snow compacting machine.
Numerous and various works are carried out upon construction of winter roads, various machinery and equipment are involved: cross-country vehicles, snow ploughs and snow blowers, road graders, machinery for wetting, grading and compacting of snow, equipment for freezing, snow dragging machines, snow mixers, pneumatic rollers, vibrating compactors, ice breaking and crushing machines, water tank trucks, sand spreading machines (Kushnir S. Ya., 2007). All aforementioned machines should be produced in the variants (modifications) for efficient operation in Russian North regions (Karnaukhov N. N., 2006).
An alternative way to improve efficiency of the machinery under severe conditions of operation is to adapt the machines to actual conditions: construction commencement, road natural and climatic conditions, etc..
Taking into consideration that all machines interact directly with environment, it is required to study their impact on environmental situation of construction site.
Analysis of the existing technological flowcharts of snow roads and relevant machinery resulted in development of genuine efficient technology and machinery for mechanization of road building based on filling (Karnaukhov N. N., 1994). Development of innovative machinery designs required for scientific background of computation procedures of their parameters, which would optimize the creation of snow and ice cover, and with this aim the described below studies were performed.
All aforementioned generates backgrounds of the theory of interaction of working units of snow compacting, wetting, and briquetting machines with environment (Egorov A. L., 2004).
The main trend of the subsequent studies is optimization of mechanized machinery with regard to parameters of climatic and regional conditions in order to decrease power consumptions.

2.2. Challenges to be solved by the studies.

It is necessary to continue development of oil and gas deposits of Russian Federation located mainly in the North and Siberia.

However, these regions have no transport network for prescheduled transportation of commodities and personnel to operation sites.
Construction of temporary winter roads facilitates solution of traffic problem in North and Siberia. In comparison with permanent roads the temporary ones have certain advantages:
- no expenditures for expensive high quality construction materials, which could be delivered to the considered regions only in winter due to low bearing capacity of soils in summer periods;
- snow and ice as construction materials are abundant in the considered regions; the time period with negative temperatures of ambient air is more than six months;
- preparatory operations of erection of winter roads are sufficiently cheaper than those of permanent roads;
- no necessity to maintain the quality of road surface in short summer period.

Wide experience in erection of temporary snow and ice roads proves their efficiency. However, at present there is no substantiated approach to development of machinery providing required level of mechanization of construction works, quality and long operation lifetime of road surfaces, optimization of expenditures for power and other resources for erection and maintenance of the obtained road network.
The existing technological and other requirements to road building materials and technologies, providing erection of efficient traffic system, do not consider for natural and climatic conditions of winter road sites, conditions of the use of snow and ice as construction materials for such works (Huebner C., 2000).
The theory of soil compaction does not reveal completely the processes and conditions of snow compaction. The snow properties vary in time, which does not always permit achievement of the required quality of road surface of snow and ice (Balovnev N. I., 1983).
In addition, there are no machinery designs with adjustable parameters with regard to specific tasks of road (site) erection.
There are no theoretical backgrounds for arrangement of machinery fleet aimed at erection of winter roads and modernization of existing machinery for solution of specific engineering tasks.
The aforementioned challenges make it necessary to develop procedures for designing of innovative machinery and methods of modification of snow properties for optimization of expenditures involved in erection of snow and ice roads.

2.3. Main working hypothesis.
In the studies the following main working hypothesis was formulated: development of scientifically substantiated mechanized complexes for purposeful formation of properties of compacted snow/ice leads to decrease in production cost and time periods of construction, improvement of quality of winter road surface and decrease in transportation costs in the North and Siberia by means of increase in traffic capacity and road operation lifetime.

2.4. Aim of the work.
The work is aimed at development of scientifically substantiated mechanized complexes for erection of winter snow and ice roads in the North and Siberia, facilitating to increase their operation lifetime, to improve their quality and to increase traffic capacity.
Therefore, the following issues were considered:
- development of concept of machinery designing for erection of winter roads;
- development of procedure for designing of mechanized complexes aiming at reduction of power consumption upon erection of winter road;
- development of testing procedures, development of laboratory and field facilities for snow compacting and wetting;
- determination of regularities in modification of snow density as a function of its properties, pattern and time of loading impacts;
- determination of design parameters of working units of wetting and compacting machines;
- establishment of conditions of cost minimization upon erection of winter roads;
- implementation of the research results into the practice of erection of winter roads and estimation of their economic efficiency.

3. Results
3.1. Technology of erection of snow and ice roads.
The major practical value of the work is the developed procedure for designing of mechanized complexes for erection of snow and ice road based on filling (Merdanov Sh. M. et al., DOI: 10.17513/spno.2013.5.111-10427) and machinery designs for erection of temporary winter roads (Fig. 1).

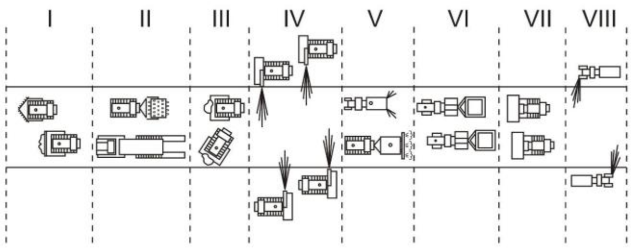

Fig. 1. Mechanized complex for erection of snow and ice road.

The mechanized complex makes it possible to perform the following operations: I-brush clearing and cutting; II-preliminary compacting of wet sites and shallow moorlands along road and snow catching areas using cross-country vehicles with low specific pressure of undercarriage system; III-freezing of road bed with removal of snow precipitations into collecting snow barriers on snow catching areas using snow ploughs and bulldozers, or mechanized soil punching aiming at acceleration of basement freezing; IV-wetting (using sprinkling machines or specialized thermal wetting machines and units) and grading of collected snow along the base of road bed; V-layer-by-layer buildup of road bed with snow from snow catching areas up to the level above the ambient snow cover; VI-wetting of road bed; VII-layer-by-layer compacting of snow by towed pneumatic rollers or drags with preliminary loosening and mixing of the compacted snow by means of ribbed rollers, formation of snow and ice cover, arrangement of anti-skid grooves; VIII-buildup or recovery of road bed, if required, provision of traffic conditions.

The procedures in technological flowchart can be different depending on the construction site (Merdanov Sh. M. et al., DOI: 10.17513/spno.2013.6.113-1063).

Implementation of the research results in test and commercial road sites confirmed decrease in operation costs of freight transportation, increase in road operation lifetime and decrease in environmental harm to the regions with operation of the proposed machinery and technology of erection of temporary winter roads.

3.2. Machinery design for erection of snow and ice roads.

During erection of winter roads high scope of construction activities is performed and, hence, various machinery and equipment are applied. Being involved in construction with the use of specialized machines, the authors gained valuable experience on their improvement and modification, as well as on development of machinery with completely innovative working auxiliaries. In particular, the machines of conventional design, applied for snow moving and compacting in erection of winter roads, are generally supplemented with equipment for snow thermal treatment.

3.2.1 Development of equipment for thermal treatment of snow before its compacting.

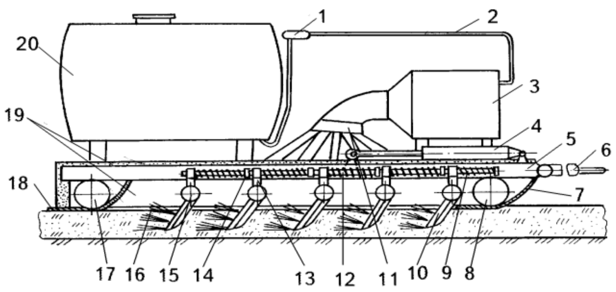

Fig. 2. Towed unit for snow compaction.

Heating machine for wetting of snow bulk (Fig. 2), developed by the author (Author's certificate No. 1622497), differs from previous wetting machines by the existence of additional thermal insulating shell. The machine consists of the frame 5 with the trailer 6, supported by the front 7 and the rear ski 18 via the supporting tubes 8 and 17 and the side sleds 16. The frame is closed with the shell 19. In the front and the rear portions the shell is provided by the skis 7 and 18, respectively, covered with thermal insulation from inside. The shell and the frame are integrated into a single system. On the top of the frame with the shell there are installed the fuel tank 20, the fuel pipeline 2 and the fuel pump 1, the thermal power system 3 with the collector-distributor of hot gases 11 and the hydraulic cylinder 4 for moving of the thermal blades 10 into working or travelling position. On the sidewalls of the thermal insulating shell 19 the latches of thick wall thermal pipes 15 are installed pivotally, on which the thermal blades 10 are fixed. From the opposite to the blades side the guiding rods 13 are welded to each thermal pipe 15, these rods slide along the guide 12 and are fixed on it with the bolts 14 on one side, and with the springs 9 on the other side in order to prevent damage of the blades upon collision with unexpected obstacles.

The thermal blade is composed of sharp cutting edge in the front and lower part, steam collecting chamber in the middle part and hold-down wall with nozzles in the rear part. The thermal blades are fixed on the pipes with constant pitch and located in staggered order. The pipes with blades are installed pivotally on the sidewalls of thermal insulating shell.

The machine works as follows. At the start of cycle the thermal blades are moved from the travelling position to the working position by the hydraulic cylinder 4. Impacts of the blades against possible obstacles during operation of the machine are damped out by means of the springs 9.

Hot gases from the generator 3 are fed by the collector-distributor 11 via gas pipelines and internal cavities of the pipes holding the thermal blades in the cavity of steam receivers of the thermal blades, from where the gas jets via nozzles are fed into the grooves, made by the blades, and further into snow bulk. The groove shape provides high pressure and velocity of hot gases upon inlet into snow bulk, thus providing deep vertical penetration and snow melting. Hot gases, escaping upwards from lower layers of the treated snow bulk, are collected in the chamber of thermal insulating shell and continue their action on the surface of snow bulk. The latter just after heating is graded and slightly compacted by the rear ski of the machine. Final compaction of the melted snow is performed by rollers.

The heating snow-wetting machine makes it possible to increase significantly economical efficiency of snow melting due to decrease in heat losses into ambient air.

3.2.2 Development of equipment for thermal treatment of snow upon its compacting.

Thermal equipment of snow compacting machines is intended for wetting of snow bulk directly during compaction. Thawing and compacting can be performed either across the total width of the road bed or in parts in accordance with the planned dimensions of track and inter-track lanes of the road with reinforced tracks. In the latter case thawing and compacting are performed with dosing of hot gases across the road width.

The simplest compacting machine with thermal wetting of snow is thermal drag developed by the author (Fig. 3), thawing snow with hot gases after fuel combustion.

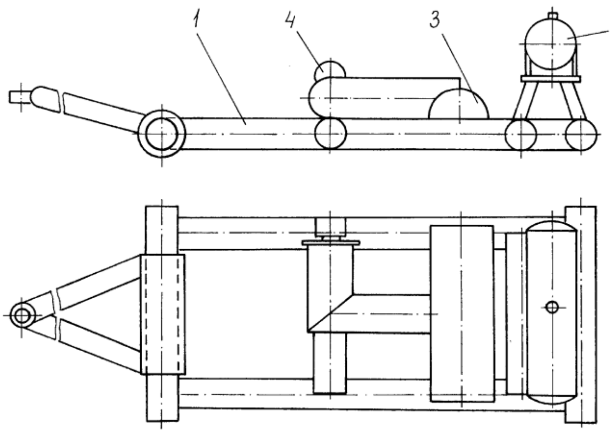

Fig. 3. Thermal drag layout.

The thermal drag is composed of the frame 1, welded of pipes, with the installed tank 2, the combustion chamber 3, the fan unit 4 driven by trailer and thermal box. Both fuel oil and diesel oil can be used. Thawing of snow layer with the thickness of 0.05 m and the density of 0.4 t/m^3 is sufficient for wetting of filled layer with the thickness of 0.1-0.15 m. The thermal drags are simple, reliable and highly productive, though rather inefficient.

3.2.3 Development of towed equipment for snow compaction.
Aiming at combination of advantages of compacting and rolling of snow the design of compacting machine was proposed, where compacting wedges on the wheel continuously and alternatively go down onto snow bulk like stairs of infinite stairway (Fig. 4). Compaction degree of snow layer depends on weight of the drum 1 and can be additionally adjusted by the hydraulic cylinders 7 and 10, by means of rotation of the frame 8 relatively to the basic machine 11 about the axis 9.

Operation of the proposed by the author compacting machine is as follows. By means of the hydraulic cylinders 7 and 10 the drum 1 goes down to operating position up to the support on pneumatic wheel. Position of the pneumatic wheels with regard to the frame is adjusted by the rod 4. While the trailer moves, the pneumatic wheels 6 by chain gearing via the sprocket 5 rotate the compacting drum 1 and the actuator 2, which maintains horizontal position of the working surfaces of the compactors 3 at random position of the drum 1. The compactors 3 are engaged into the working position alternatively, capturing a segment of snow bulk and compacting it at a certain angle to vertical to the depth determined by the initial density of snow cover.

The machine compacts the snow layer of heavy thickness providing high productivity and compaction of high quality.

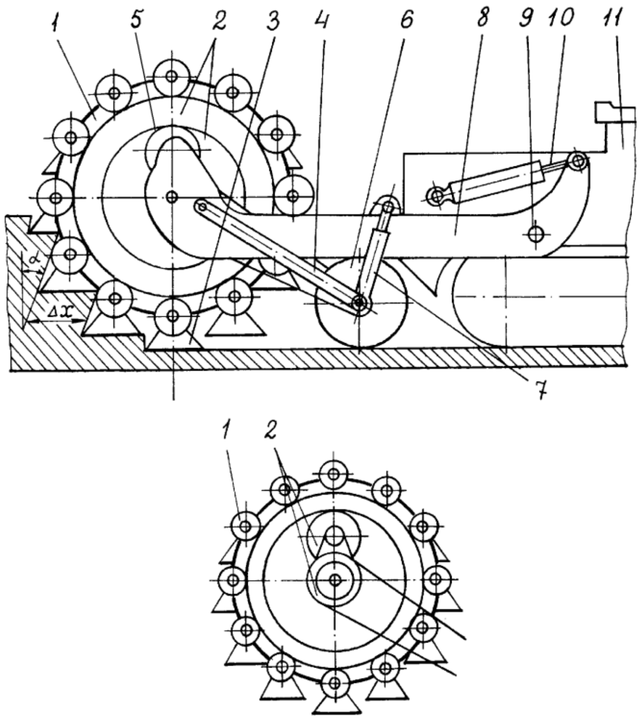

Fig. 4. Snow compacting unit.

The unit according to Patent 2156845 (2000) is intended for snow compaction (Fig. 4). The required result is achieved as follows: the snow compacting unit is composed of two section in the form of frames with installed on them skis, connecting pivot which facilitates independent motion of the sections with regard to each other in vertical plane, the length and the weight of the ski of the section two are higher than those of the section one. Relatively independent motion of the sections makes it possible to increase specific pressure of the ski of the section two in comparison with that of the section one up to optimum value, because the second ski compacts snow bulk of road bed after preliminary compaction of the first ski, and the higher length of the ski of the section two makes it possible to increase the time of its action on the compacted surface at preset travelling velocity of the unit.

The unit according to Patent 29732 (2003), Sh. M. Merdanov et al., is intended for wetting of snow bulk (Fig. 5). It is composed of the heating apparatus 1 for wetting of snow bulk, the basic trailer 2 and the unit for snow compaction 3. The heating apparatus for wetting of snow bulk is comprised of horizontal cutter mounted on the frame 10, supported by the pneumatic wheels 11 via the hydraulic cylinders 12 and by the trailer 2 via the hydraulic cylinders 13. In addition, the boiler 14 with the heating conduit 15 and the fuel pump 16 are mounted on the unit. The fuel pipeline 17 and two tanks for fuel 18 are characterized in that the working part is fabricated as a cutter with horizontal axis of rotation, and the cutting elements of the working part are tapered and mounted in staggered order along its generatrix, herewith, the working part is driven by at least one hydraulic engine.

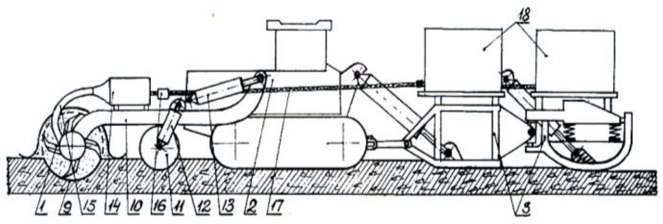

Fig. 5. Facility for wetting of snow bulk.

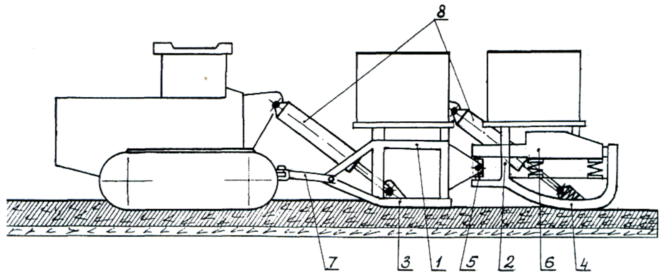

Fig. 6. Facility for compaction of snow bulk.

The unit according to Patent 29733 (2003), Sh. M. Merdanov et al., is intended for snow compaction (Fig. 6). The facility for snow compaction is comprised of the first 1 and the second 2 sections in the form of frames with the mounted on them skis 3 and 4, fastening the of the pivotal unit 5, providing possibility of independent motions of the mentioned sections with regard to each other in vertical plane. The vibrator 6 is installed on the second section, which increases the compaction efficiency. The towed unit 7 is pivotally fixed on the first section with the aim of connection of the compacting unit with the trailer. It is characterized in that the proposed facility is additionally equipped with the hydraulic cylinders 8, facilitating adjustment of the pressure of the first and the second sections by pressure redistribution.

3.2.4 Equipment for fabrication of snow briquettes and ice blocks.

Snow and ice briquettes and blocks are applied for erection of reinforced track roads, ice bridges, road fences, snow-retaining shields and other facilities. Dimensions of the briquettes and blocks can vary depending of their purpose from 0.05 to 1.5 m (A. F. Shakmakov, 2007).

Figure 7 illustrates a facility for fabrication of snow blocks. The facility is comprised of the inlet chambers 1, the packer-compactor 2 in the form of infinite band with the uniformly positioned self-adapted ribs 3, the wetting device 4 for snow bulk, pressing chamber formed by the conveyers 5 and 6 and two side shields. The conveyers 5 and 6 are actuated by propulsion of pressed stuff by means of packer-compactor. The pressing density of blocks is adjusted by decelerating of the drum 7. The ribs 8 are installed on the belt of the conveyer 6, their pitch equals to the length of the pressed blocks plus 150 mm (technological gap). The presser-compactor is actuated by the trailer power shaft.

This facility works as follows. Loose dry snow enters into the inlet chamber 1, where it is wetted with steam or water, then is captured by the ribs 3 of the packer-compactor and, while travelling by the conveyer, step-by-step compacted in the pressing chamber under the action of forces applied to the ribs of the packer-compactor. When a new rib 8 of the conveyer enters into the pressing chamber, a ready snow block is pushed out of the pressing chamber.

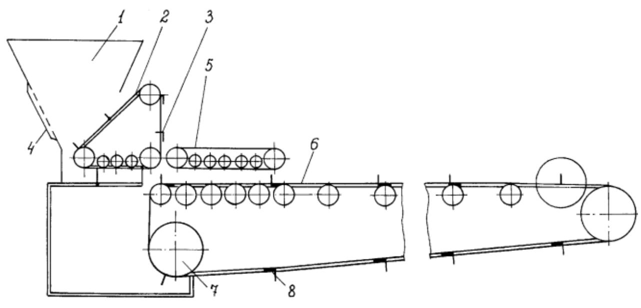

Fig. 7. Facility for fabrication of snow blocks for ice roads.

The snow cleaning machine (Patent 2207427, Sh. M. Merdanov et al.) is composed of the basic chassis 1 (Fig. 8), where the collecting mechanism 2 is installed, the conveyer 3 and the hopper 4 with the feed port, above which there is the grid 5. Under the grid there is the hollow shaft 6 with the holes 7; the vanes 8, the ripper tips 9 and the blades 10 are installed on it. The length of the hollow shaft 6 corresponds to the length of feed port of the hopper 4. The shaft is rotate by the drive 11. The air duct 12 is mounted movably on the free end of the shaft. Four pressing chambers 13 are located in the bottom part of the hopper 4.

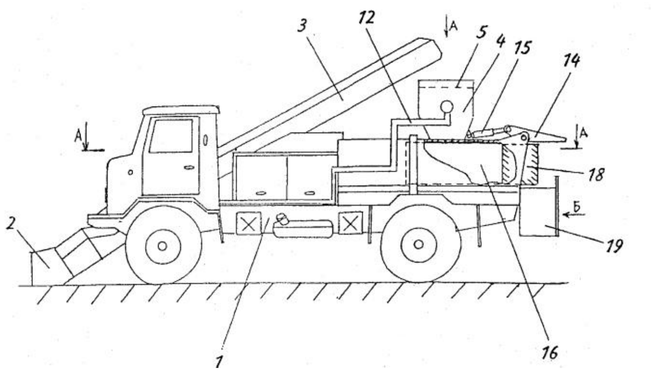

Fig. 8. Snow cleaning machine (Patent RU 2207427)

The pressing chambers 13 have the end walls 14 equipped with actuator for opening: the hydraulic cylinder 15. The chambers 13 are equipped with pressing mechanisms composed of the plungers 16 connected with their actuators in the form of the telescopic cylinders 17, which act also as the mechanism of discharging of snow blocks 18. In order to discharge a snow block aside, the ramp 19 is installed in the rear part, which facilitates discharge of snow blocks to the left or to the right. In addition, the plunger pair is equipped with the rubber seal 20 (Fig. 9).

The machine operates as follows. Snow bulk captured by the collecting mechanism 2 is transferred by the conveyer 3 and

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fed to the hopper feed port 4, herewith, the grid 5 in the hopper feed port 4 eliminates penetration of oversized material (stones, ice lumps) into the pressing chamber 13. Then the snow in the hopper 4 is distributed over its total width by the vanes 8 and is additionally loosened by the ripper tips 9 and the blades 10 with simultaneous wetting by hot air or exhaust gases via the air duct 12 into the hollow shaft 6 via the holes 7, impacting on the snow bulk, heating and wetting it (Fig. 9). The order of snow feeding into this or that pressing chamber 13 is determined by alternative motion of the plungers 16 (Fig. 9).

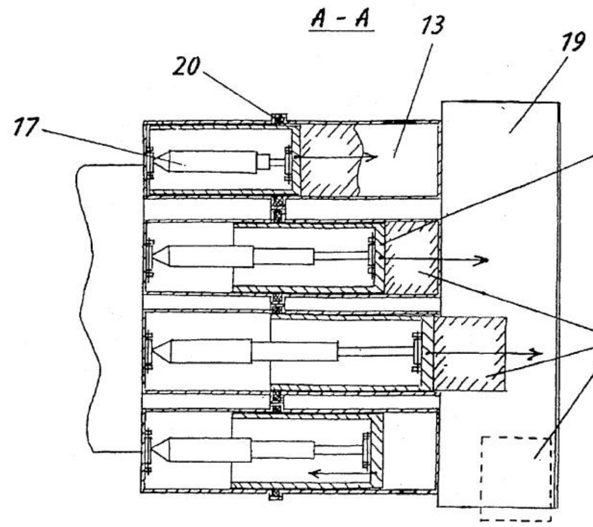

Fig. 9. Hopper of snow cleaning machine (Patent 2207427)

Alternative snow feeding to one or another pressing chamber provides continues process. When one of the plungers 16 moves to the wall 14, it transfers a portion of snow and presses it at the stroke end, whereas the plunger top edge closes the hole via which snow is transferred from the hopper 4 to the pressing chamber 13.

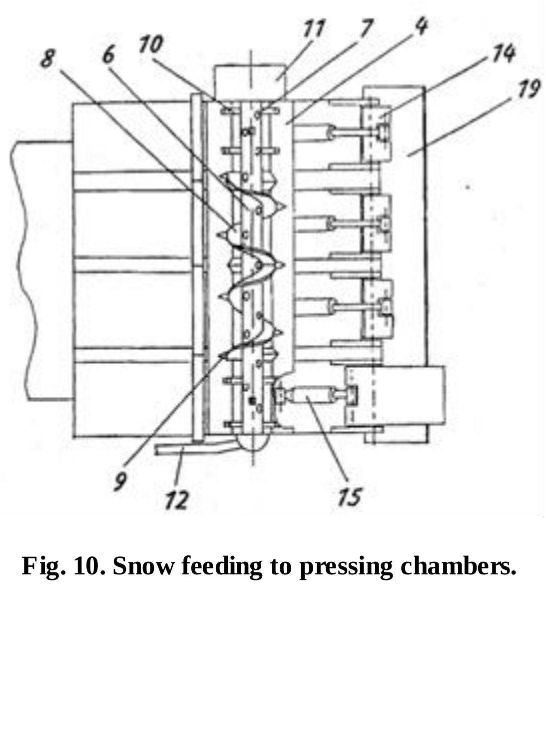

Fig. 10. Snow feeding to pressing chambers.

After achievement of certain load on snow the end wall 14 (Fig. 10) is opened by the cylinder 15, and the telescopic cylinder 17 pushes snow briquette 18 outside, and then the telescopic cylinder 17 is reversed and the plunger 16 moves to initial position. While the first plunger is moved into the initial position, the second plunger pushes the snow briquette 18 outside, the third plunger presses snow, and the fourth plunger is in the initial position, facilitating filling of snow into the pressing chamber. When the snow briquette is pushed outside by the plunger, it falls onto the ramp 19 and then by the tramp slips aside, the end wall 14 closes. Such operation pattern of the plungers makes it possible to provide continuous discharge of the snow briquettes 18. The fourth plunger starts its motion only when the first plunger reaches the initial position.

The snow loading machine and snow compacting unit (SPM RU 28133 U1, Sh. M. Merdanov et al.) operates as follows.

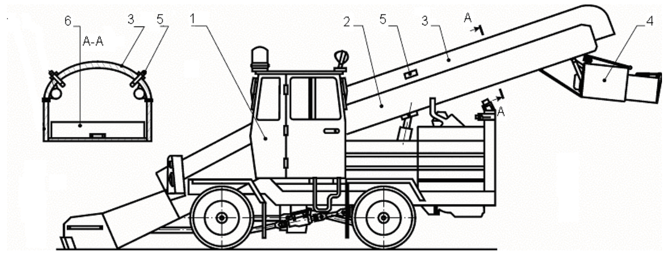

Fig. 11. Snow loading machine and snow compacting unit.

The casing 3 is mounted onto the beam 2 of the basic machine 1 (Fig. 11). The casing is made of material with low heat conductance or of metal with thermal insulating coating. the heating device 4 is installed inside the casing. The sealing 5 with the actuating cylinder 6 is mounted pivotally on the beam end.

During operation the snow loading machine contacts with snow barrier by its working unit and destroys the barrier by penetration force, its value depends on the friction coefficient of driving wheels of the snow loading machine. The feeder blades separate snow from the barrier, move it by the shovel surface and feed to the conveyer. Then snow is conveyed to the first operating chamber formed by the surface of the chain conveyer, the beam sidewalls and the casing. Here snow is heated by the heating device. During passing by the conveyer snow bulk is wetted, the wetting rate can be adjusted by heat, and if snow thaws, then the generated water flows down the conveyer and wets the snow below.

The heating device of the snow loading machine is intended for wetting of snow bulk before compaction, it is composed of burners installed in the casing 3, fuel and air ducts, as well as exhaust gas supply to the chamber where snow thaws.

Then snow is transferred to the second working chamber, into compactor. The compactor is indented for direct snow compaction and fabrication of compacted snow blocks, briquettes.

4. Recommendations

1. An important social and economical challenge has been met – increase in efficiency of erection of snow and ice roads by filling in the Russian North and Siberia.
2. The concept of formation of mechanized complexes for erection of temporary winter snow and ice roads has been developed.
3. As a consequence of the performed studies the scientifically substantiated engineering solutions have been obtained for designing and application of machinery for erection of winter roads.
4. Classification of snow and ice roads has been proposed, which facilitates formulation of approaches to development of mechanized complexes.
5. On the basis of analytical and experimental studies the use of snow and ice as construction material for winter roads has been substantiated. The mechanism of snow compaction has been studied and on its basis the optimum value of its wetting has been determined (14…28 %), which provides compaction with the lowest consumption of mechanical energy.
6. Main factors influencing on the obtained snow density upon its compaction have been detected. They are as follows: compacting load, initial snow density, snow temperature, modification rate of compacting load. A mathematical model has been developed considering their influence on final cover density of snow and ice road.
7. Recommendations are given on formation of machinery complexes for various conditions of construction accounting for optimization of technological variables of snow compaction as a function of its physico-chemical properties.
8. Efficient technological variables of snow compaction have been determined, including its physico-mechanical properties at which the highest density of snow and ice road cover is achieved. It is experimentally established that with increase in the temperature of compacted snow its final density increases. The most intensive density growth is observed in the temperature range of-2…-10°C. It is established that with decrease in the modification rate of compacting load the efficiency of cover increases. It has been determined that in the snow moisture range from 6 % to 14 % the final density of compacted snow as a function of its moisture is nearly linear, then the density increases progressively.
9. A procedure of selection of velocity modes of snow compacting machines has been developed, which has been implemented upon erection of pilot and commercial road sites. The economic benefit of erection of 1 km of snow and ice road per year is 6.2 mio rubles.
10. On the basis of experimental researches the influence of applied load on variation of final snow density upon its briquetting in closed space has been established. Various versions of towed equipment for road building machine: foe snow compaction, for snow build-up and for fabrication of snow briquettes and ice blocks.
11. Possibilities of application of serial road building machine to the local conditions of erection of snow and ice roads have been discussed. The equipment for snow thermal treatment upon its filling and compaction has been developed. The described in this works solutions have been claimed as authors certificates and patents, fabricated and tested in the field, theoretical backgrounds for their calculation have been developed. Software for automated calculation of variables of snow and ice roads and technological parameters of machinery has been developed.
12. Unique procedures of experimental researches have been developed, as well as laboratory facilities and commercial samples of working units increasing the efficiency of study of interaction between working units and processed medium.

5. Discussion

5.1. Results of theoretical and experimental studies.

The analysis of the available information on stressed-strained state of snow cover and comparison of these data with the studied problems made it possible to suggest a hypothesis that the use of mathematical methods of planning of multifactor experiment would permit increase in informational capacity of the studies of snow compaction.

The experimental results demonstrated that with temperature increase the final density of compacted snow increases. The most intensive density increase is observed at the temperatures above minus 10°C. It is also established that with decrease in the rate of load modification the compaction efficiency increases. Herewith, at the rate of load modification above 3 kPa/s the final density of snow does not in fact increase. During the data processing it has been established that up to the snow moisture of W = 14 % the final density of the compacted snow as a function of its moisture is nearly linear. Then, at moisture above 14 % the density increases progressively.

On the basis of the performed studies it is possible to conclude that the proposed equations with sufficient accuracy determine the value of the final snow density after compaction, which confirms the hypothesis about regularity describing snow compaction under load and the hypothesis about main factors influencing on the efficiency of snow compaction.

5.2. Results of engineering development.

The performed analysis of the existing machinery designs as well as the results of testing resulted in setting of new challenges aimed at development of compacting, wetting and combined machines.

The following designs are proposed:

- thermal treatment of snow before compaction;
- thermal treatment of snow upon compaction;
- preparation of basement of winter roads;
- towed equipment for snow compaction;

- modernized machinery for snow compaction;
- fabrication of snow briquettes and ice blocks.

Aiming at designing of innovative machinery, the influence of engineering dimensions of working units and initial snow properties on snow compaction was studied, which facilitated determination of engineering parameters of machinery: maximum load, loading time and rate of load modification.

6. Conclusions

Therefore, the performed and described here investigations are obviously urgent and important for Russian economy. On the basis of these investigations on doctoral thesis and two candidate theses were presented, two more doctoral theses are scheduled for presentation. This is a promising work, it is supported by various grants.

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