SOME NEW OR EXPERIMENTAL EQUIPMENT FOR USE ON SNOW AND ICE

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ABSTRACT

The six instruments discussed in this paper have been newly developed, or modified from existing snow or ice equipment, by personnel at USA CRREL. The original concept and/or modifications of the equipment came as a result of field operation requirements or from a need to accurately measure certain physical characteristics of snow. Complete descriptions and detailed explanations of the use of three of these instruments are given in USA CRREL Special or Technical Reports. Comprehensive reports on some of the other equipment may be prepared later. A brief description and summary of the purpose of each instrument is presented in this paper. The individuals conducting the work are named and the specific reports from which additional information can be obtained are also given. Most of the discussion which follows was taken from these reports or from direct communication with the individuals named.

Other unique equipment, such as the thermal ice coring drill and the snow shock tube, are currently under research and development at USA CRREL. However, limitation on the length of this report does not permit detailed discussion of these instruments.

1. Nuclear Technique to Measure Snow Density

A nondestructive technique for direct determination of snow density profiles was investigated. This involved lowering a neutron probe in a vertical bore hole and having the density profile recorded directly on a chart recorder.

When the fast neutron source is placed in the snow the emitted neutrons interact with the surrounding medium. They collide with the nuclei of hydrogen and oxygen in a billiard-ball fashion; their direction is changed and they lose energy. With energy losses, the speed diminishes until it approaches that characteristic of the particles at the ambient temperature. Finally, the slow neutron is absorbed by the nuclei present in the snow. In dense snow the neutrons are slowed down before they get very far from the source; in less dense snow the cloud of slow neutrons around a source extends further from the source. Equilibrium is reached in less than a microsecond after the source is placed in the snow.

This technique was tested in Greenland during May 1963. Two modes of processing and recording nuclear pulses were used to determine snow and ice density profiles from the soil-moisture depth probe. In the scaler mode, the probe is lowered to a selected depth and the counts are made with the probe stationary for the duration of the count period. Repeating this procedure at different depths allows construction of a depth-count rate curve. The second mode utilized the rate meter recorder in combination with the nuclear probe. The rate meter converts random pulses from the probe into an average count rate for presentation on an external chart recorder. A continuous profile of count rate versus depth results from simultaneous travel of the probe in the hole and the recorder chart.

Although no direct correlation between snow density and nuclear count rate at the site was possible, a general fit to a regression curve from data obtained by other investigators was found. Curves were constructed for statistical deviations in snow density at different probability levels for the nuclear scaler and rate meter data based on an assumed correlation curve. These curves demonstrated that the technique has possibilities of producing the statistical accuracy required for determining snow density profiles. Such profiles would be a valuable tool to those interested in snow stratigraphy, water equivalent of the snow-pack, depth-density variations, etc.

The hardware (Fig. 1) used in this technique to measure snow density includes: (1) Nuclear Chicago Model P-19, Subsurface Soil Moisture Probe. This probe has a fast neutron source; a detector tube with a sensitive length of 5.5 inches and transistorized preamplifiers; a

1.5 inch OD probe and a 0.5 inch OD x 50 ft. length connecting cable with graduated increments, (2) Nuclear Chicago Model 1620B, Analytical Count Rate Meter designed to convert random pulses received from an external pulse type radiation detector into an average count rate, (3) Nuclear Chicago Model 2800, Portable Scaler which electronically counts and indicates the number of pulses received from an external pulse type radiation detector, (4) Esterline-Angus Model AW-D, to 1.0 de milliameter chart recorder, and (5) Transmitting Selsyn assembly with a measuring wheel 1 foot in circumference mounted horizontally in a wooden frame. The load of the probe and cable is taken by a pulley wheel above a measuring wheel. A pressure wheel holds the vertical probe cable against the measuring wheel to provide friction for its angular rotation when the probe cable moves up or down in the hole. This angular rotation is then duplicated by a receiving synchronized Selsyn in the recorder. Further detailed information is available in USA CRREL Special Report 74 by Robert D. Leighty.

2. Snow Disaggregator

For a number of years engineers and scientists involved in snow mechanics have been interested in measuring all the mechanical variables of the substance. One of the most difficult variables to measure is the tensile strength. We will define this as the strength of the bond between the crystals in the snow pack. This measurement is of importance to investigators who are considering bearing capacity, trafficability, slope, stability, and other problems assoicated with large snow masses. This device is designed to disaggregate a snow sample into small particles and indicate by numerical readout the work done during this process.

The snow disaggregator is portable and requires no electrical power, although it can be operated with an electric drill. The disaggregator wheel is about eight inches in diameter and has a large number of small spikes attached to its outer rim (Fig. 2). As the snow sample is automatically forced into the rotating spiked wheel the specimen is disaggregated one crystal at a time. The force on the spikes causes a proportional phase lag between the outer rim and the primary drive shaft. This lag causes translation of the ball carriage of a ball disc mechanical integrator. Its displacement from disc center is proportional to the applied torque. The disc is coupled to the primary drive shaft. Both the integrator output shaft and the drive shaft are coupled to numerical counters. The drive shaft counter not only permits judging shaft speed but, more important, enables the investigator to determine the integrator counts due to mechanism friction. The latter is done by making a "dry run" prior to the test to determine the ratio of integrator counts to shaft counts at no load. The final integrator count is reduced by the value of this ratio applied to the shaft count, as a correction. With the present torque springs the work constant for the integrator is 1.58 inches-lbs per unit count.

Mr. Roscoe Perham designed this instrument; the drawings and construction of the equipment were done by other members of the Technical Services Division, USA CRREL.

3. Ice Chipper

The ice chipper (Fig. 3) is a machine used in construction of runways on sea ice packs. It is designed to make the runways smooth by removing hummocks and pressure ridges. The chipper is a self-contained unit consisting of a gasoline engine drive arrangement, including disconnect clutch and reduction gear box, an ice cutting auger and a suitable sub-base and auger support. The unit is mounted on a fork lift attachment on a tractor. Manipulation of the ice chipper while operating is by means of the normal loader controls of the tractor. The unit makes a minimum eight-inch cut before penetration is limited by any part of the auger drive or supports.

The auger assembly has a diameter of 29-3/8 inch at the tooth tip, has seven changes in pitch and a 3/8 inch by 9 inch double flight ribbon (Fig.3). The unit is driven by a Waukesha Model 14 GZ engine through a Cotta Model SR 972 transmission reduction gear box and clutch assembly. The rpm of the auger is between 400 and 450.

The major requirement for the tractor is that it be a track-laying front end-loader, meet weight requirements for air dropping and have a minimum forward speed as low as 0.2 mph. With some modifications the Caterpillar Model 933 Traxcavator meets all of the requirements.

A chipper drum was first used which rotated upward at the front to gain maximum operation control and to reduce the force necessary to remove the ice. The chipping teeth or bits are common to mining machines and were so mounted that replacement presented no problems. Tests on this drum revealed that the ice chips did not move to the side sufficiently, so it was decided to replace the drum with an auger to permit the chips to be carried to the right. Tests on the equipment were very successful. The bit holders are mounted on the inside of the auger and the deflector hoods were modified to open up on the right to improve the movement of the chips on the discharge side.

In a rough area of sea ice at Barrow, Alaska, two 500 x 30 ft. strips were laid out and two types of augers were tested. An auger with a single pitch, 24 inches removed a 14 ft. high pressure ridge and rough ice at the rate of 37 tons per hour and on a straight run averaged 96 tons/hr. An auger with changes in pitch averaged approximately the same tonnage on the rough ice, but averaged up to 199 tons/hr. on the straight run. This auger also moved the chips to the side much better than the single-pitch auger. A rotary snow blower was used to remove the snow and ice chips that remained on the roadway leaving an ice surface ideal for road or runway.

Additional information on this equipment is available in USA CRREL Special Report 73 by Guenther E. Frankenstein.

4. Soniscope

The soniscope (Fig. 4) is a set of instruments to measure the velocity of the sound wave and the effect on a signal amplitude as it progresses through a snow or ice sample. The transmitting equipment is capable of producing energy waves of known amplitude from approximately 100 cps to 20 Kcps. The insturmentation consists of a transmitter and receiver, and the electronics to produce and receive the signals. The output is displayed on a cathode ray tube.

The information collected is the time of travel through the material and a qualitative measure of the amplitude of the received signal. By varying the frequency and measuring the attenuation, engineering constants of the sample can be obtained. The values received from these tests are necessary to calculate constants such as: the elastic constant, Poisson's Ratio and attenuation of energy with distance.

This instrument was extensively used by Dr. Hans Roethlisberger to measure movements of the Greenland ice sheet. By locating a number of receivers back in the wall of the tunnel that was excavated at the edge of the ice cap and accurately locating the transmitter at predetermined locations on the floor of the excavation, a transmitted signal could determine, by triangulation, the position of the receivers with respect to the transmitter. Measurements of the first year established zero onditions. By taking the same measurements in subsequent years, detailed information was obtained of the internal movements of the ice sheet.

Continued testing, evaluation and modification of this instrument is being conducted by members of the Experimental Engineering and Technical Services Divisions, USA CRREL.

5. Modified Rammsonde

The original Rammsonde hardness instrument was found to be unsatisfactory for use in processed, age-hardened snow of density over 0.5 g/cm3.

This original Rammsonde cone penetrometer consists of a hollow aluminum tube, 2 cm in diameter, with a conical head having a 60° ram cone proved unsatisfactory because the entire ram assembly would rebound if the snow was too hard. Excessive vibrations were observed, penetration often was erratic and occasionally no penetration occurred after 100 blows were made with a 3-kg drop hammer. It was also noted that the depth markings on the standard ram shaft were difficult to read. Several simple modifications in the design of the instrument, therefore, were suggested so that its useful range could be extended and its operation simplified.

The principal recommendation was to provide two shafts in the kit; one with a conical head with a 30° point and another with a 60° point. The 30° point permits smoother penetration in hard snow and afterward is more easily retractable (Fig. 5). A steel shaft was tested in place of the aluminum one, but it provided no advantage and added unnecessary weight to the instrument. However, it may be desirable to provide the cone with a hardened tip. Five centimeter wide bands of contrasting colours anodized on the shaft facilitate reading. The depth markings are stamped at 120° intervals around the shaft to allow readings from any position. Although the 1-kg weight may be useful in soft snow it is not needed in high density snow. Only the 3 kg drop hammer is required in hard snow and variations in the input energy are made by adjusting the drop height.

A test was conducted to evaluate the effects of the 30° cone with respect to the time interval between hammer drops. The results indicate that more energy is required for penetration when the delay between hammer blows is increased. Using a 0-sec time delay as a standard, the 30° cone head showed that 16.4% more energy is required with a 1-sec delay and 19.0% more energy is required with a 5-sec delay. There appears to be an area of disaggregated snow below the point of the ram cone and constant ramming keeps this area disturbed. Slight time delays produce interlocking and possibly some bonding of these particles, resulting in a harder snow and thus requiring more energy for penetration.

Additional information on this equipment is available in USA CRREL Technical Report 153 by Landon Niedringhaus.

6. Snow Permeameter

This instrument while rather crude mechanically provides, through the coefficient of permeability, information on the distribution of solids in a permeable material. It was designed and has been used exclusively for testing the permeability of snow. Snow samples of 500 cc or less, in the form of a cylinder 5.81 cm in diameter and 18.9 cm or less in length can be tested.

The apparatus (Fig. 6) consists of a cylinder of the sample diameter in which the sample is sealed. Air is forced through the snow at constant velocity by a sealed piston traveling at various speeds controlled by a variable speed electric drive. The volume of air per unit of time passing through the snow is measured by noting the length of piston travel on a graduated scale attached to the piston. The time period should not exceed 30 seconds. Pressure developed in the void between the piston and the bottom of the snow sample is measured by a micromanometer. The manometer is equipped with an optical readout on a meniscus so that the readings are accurate to ± 0.0002 in. Water or an alcohol can be used in the manometer depending on the temperature. Alcohol density is sufficiently temperature sensitive to require correction under ordinary conditions, where 2°C or more variation in temperature occur.

The practical range of the instrument is limited to wind drift snow or depth hoar of 0.25 g/cm^3 density where the coefficient of permeability ranges from approximately 150 to 400 cm/sec. Material of lower density is usually too fragile to handle. Permeability of 1 cm/sec is found in snow of about 0.6 to 0.8 g/cm^3 density depending on its metamorphic history and initial granular nature. In most snow problems this magnitude of air permeability is considered zero. Reports on data acquired by this machine are in progress.

The current micromanometer in use is a commercial produce of Flow Corporation. The permeameter in use by USA CRREL is the original model of a product now sold by Soil Test Inc. of Chicago.

Mr. Robert Waterhouse is conducting the investigations on and with this instrument and provided the above summary.

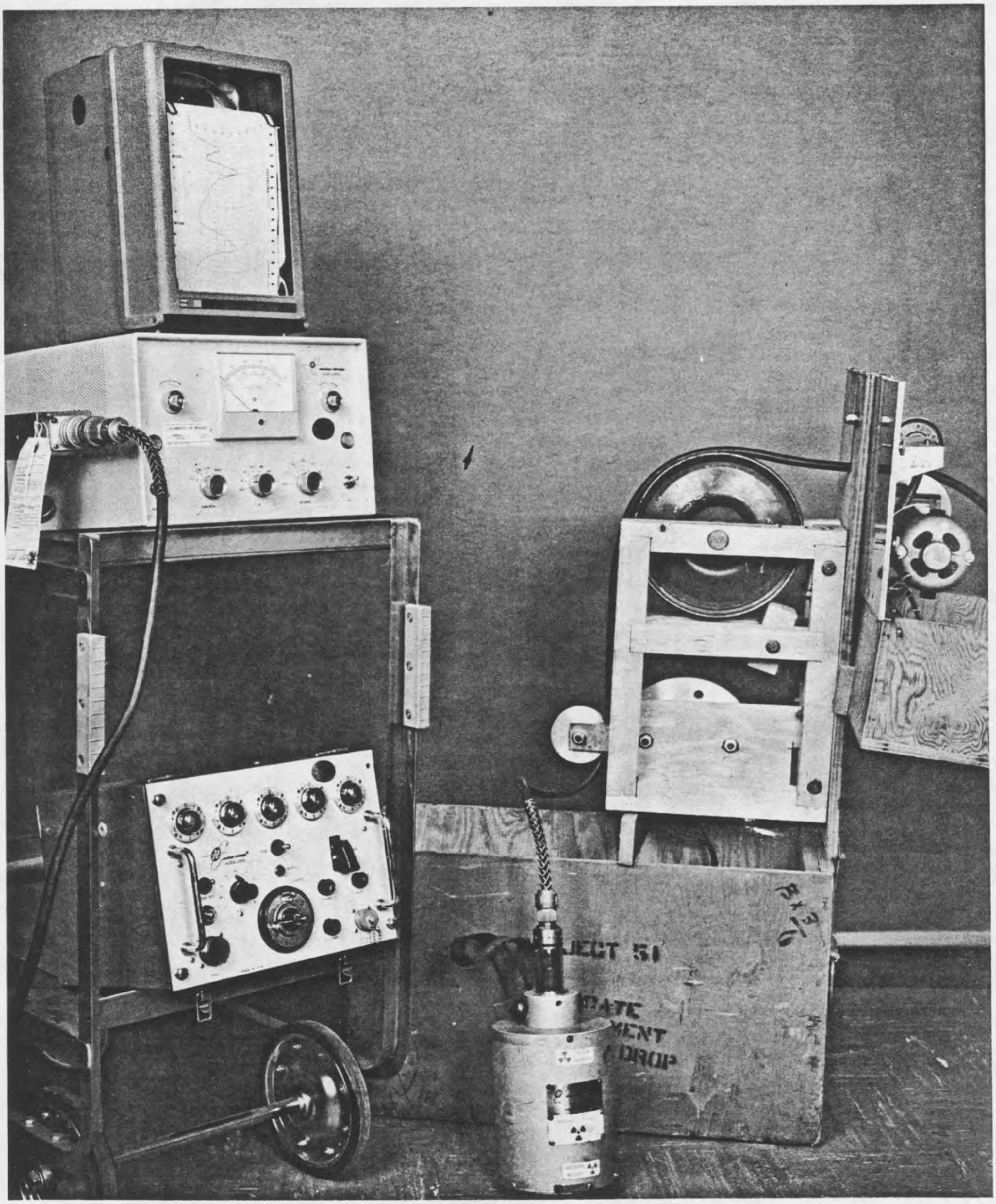

Fig. 1 Equipment used in Nuclear Technique to measure Snow Density

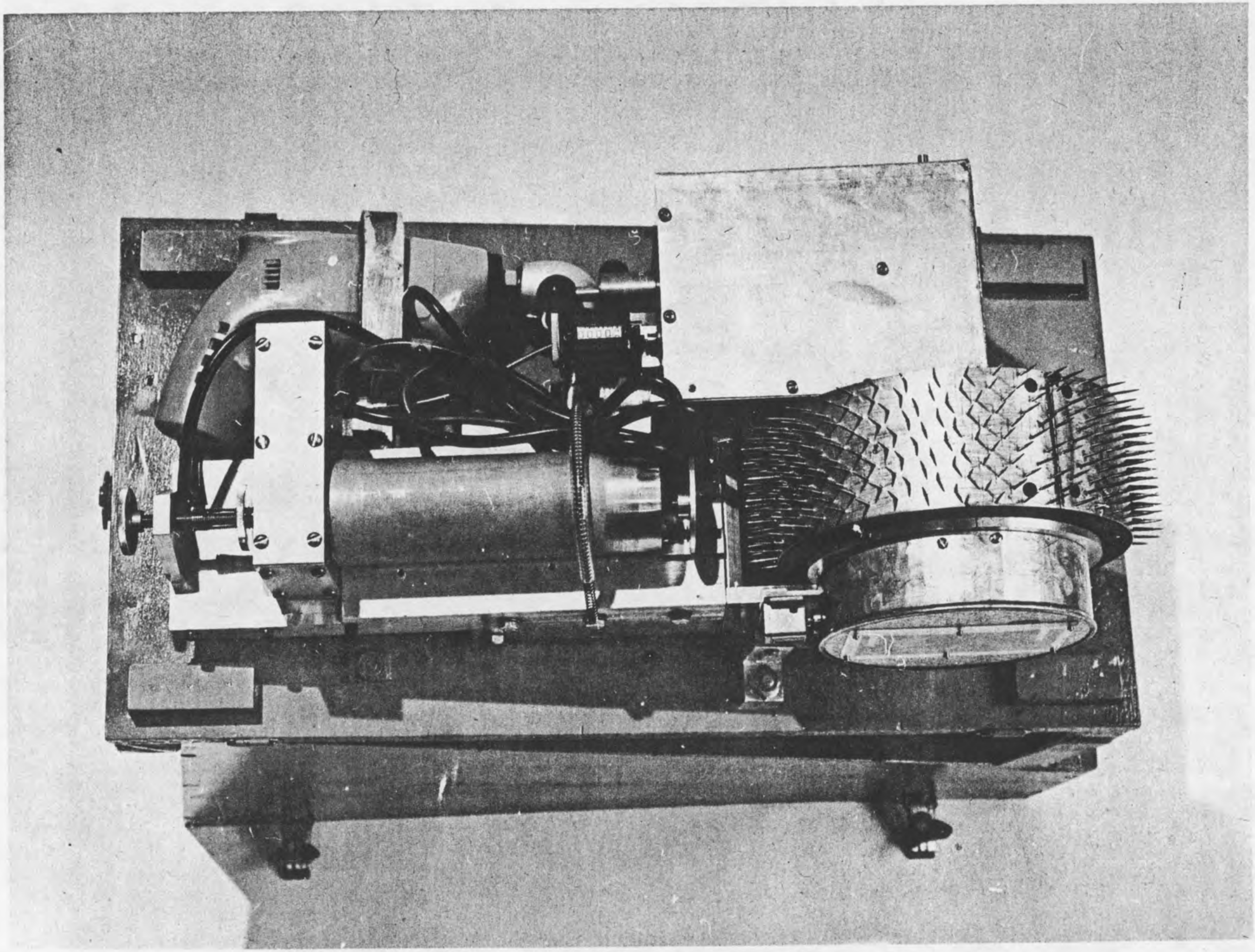

Fig. 2 Snow Disaggregator used to Disaggregate Snow Samples into Small Particles

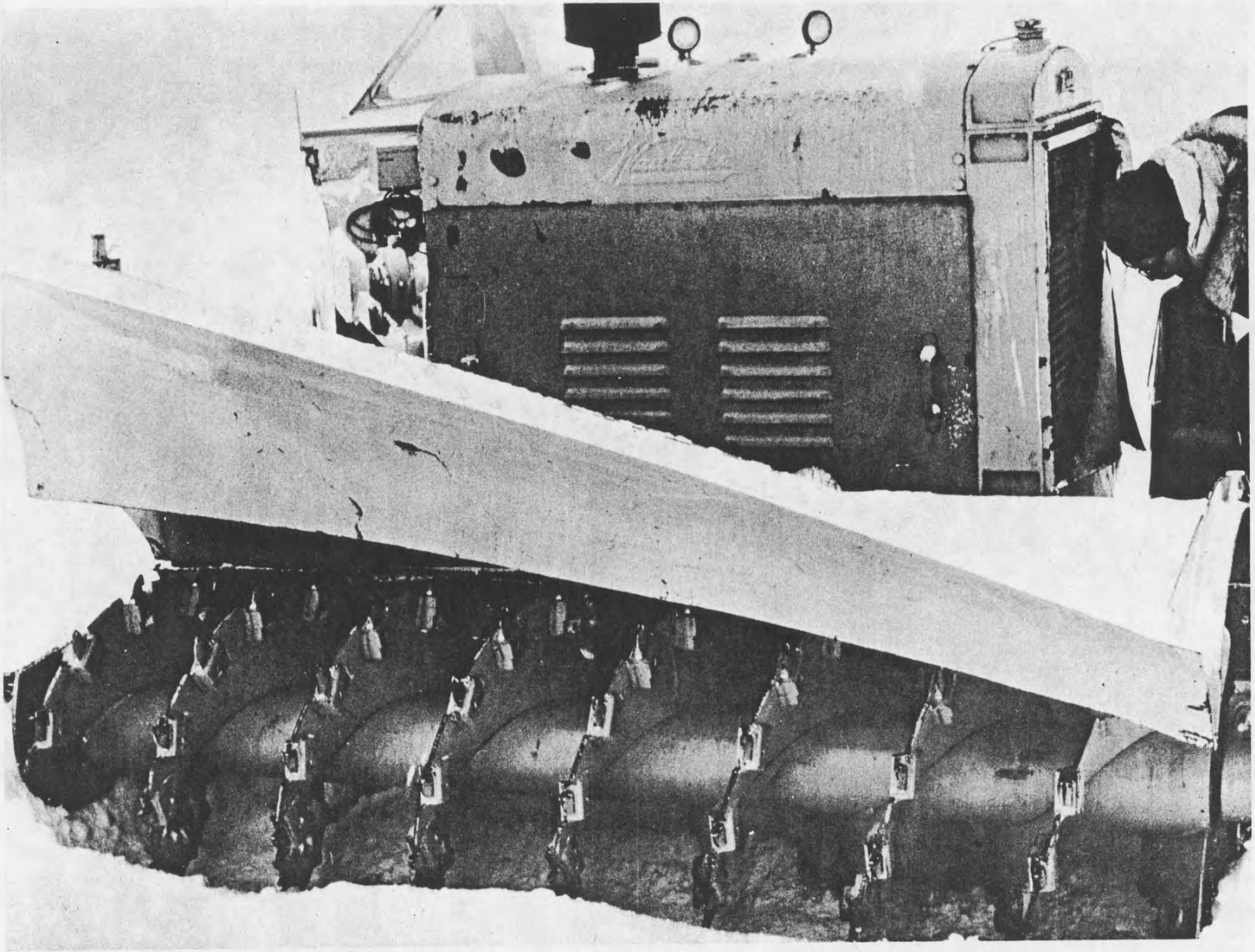

Fig. 3 Ice Chipper for use in Construction of Runways on Sea Ice Packs

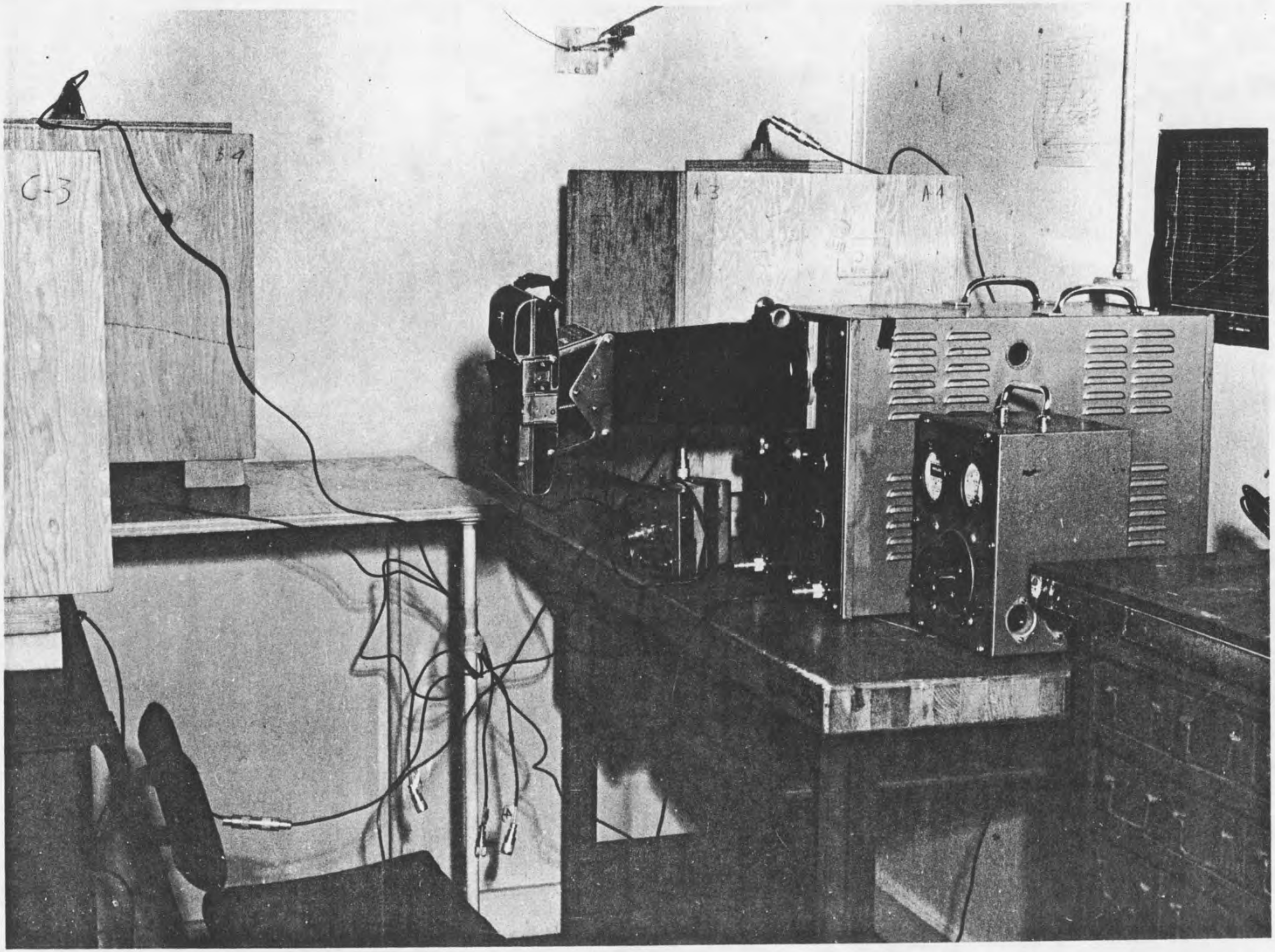

Fig. 4 Soniscope for Measuring Velocity of Sound Wave through Snow or Ice Sample

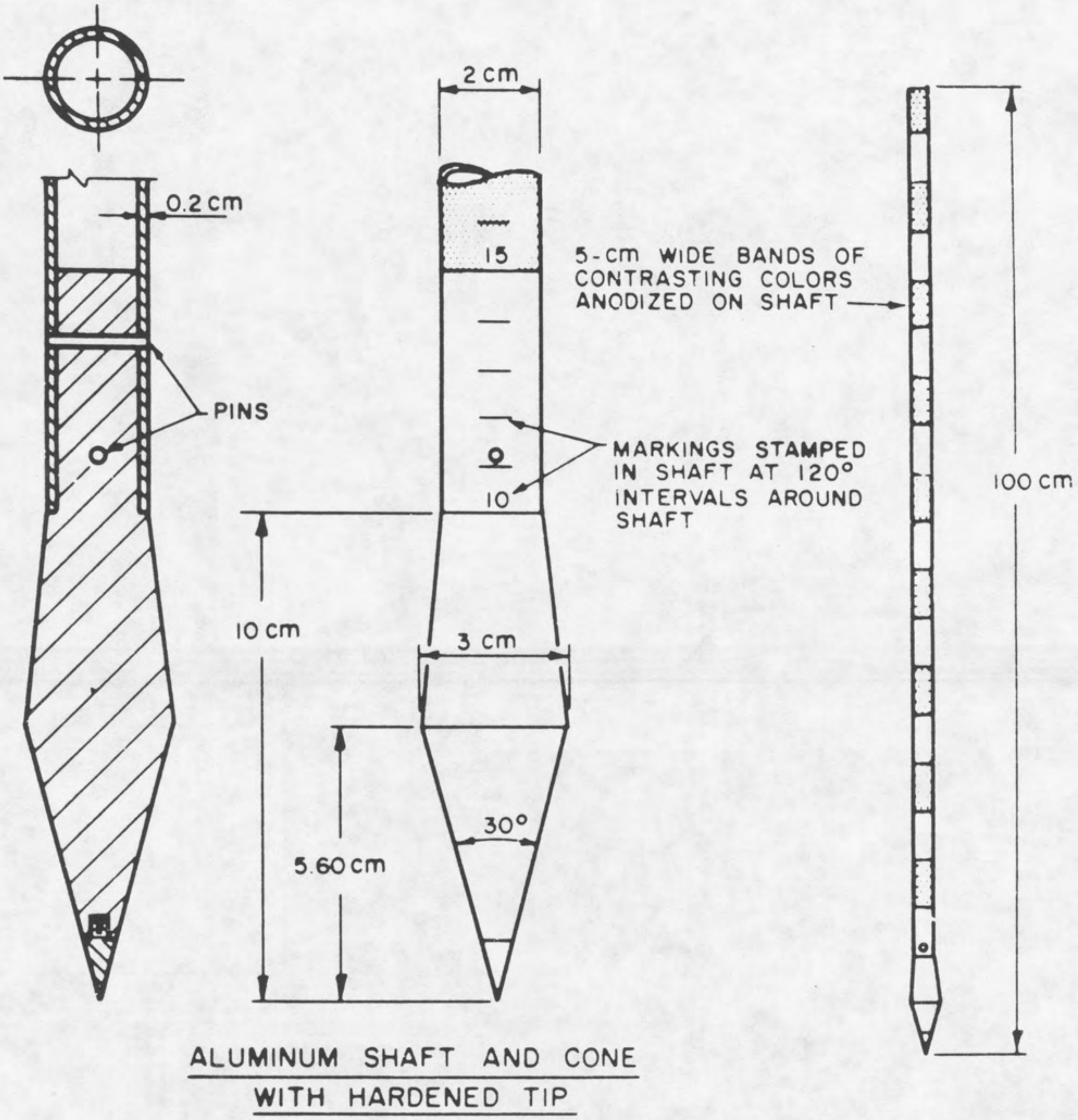

Fig. 5 Modified Rammsonde for Measurement of Hardness of Age-Hardened Snow of Density over 0.5 g/mc^3

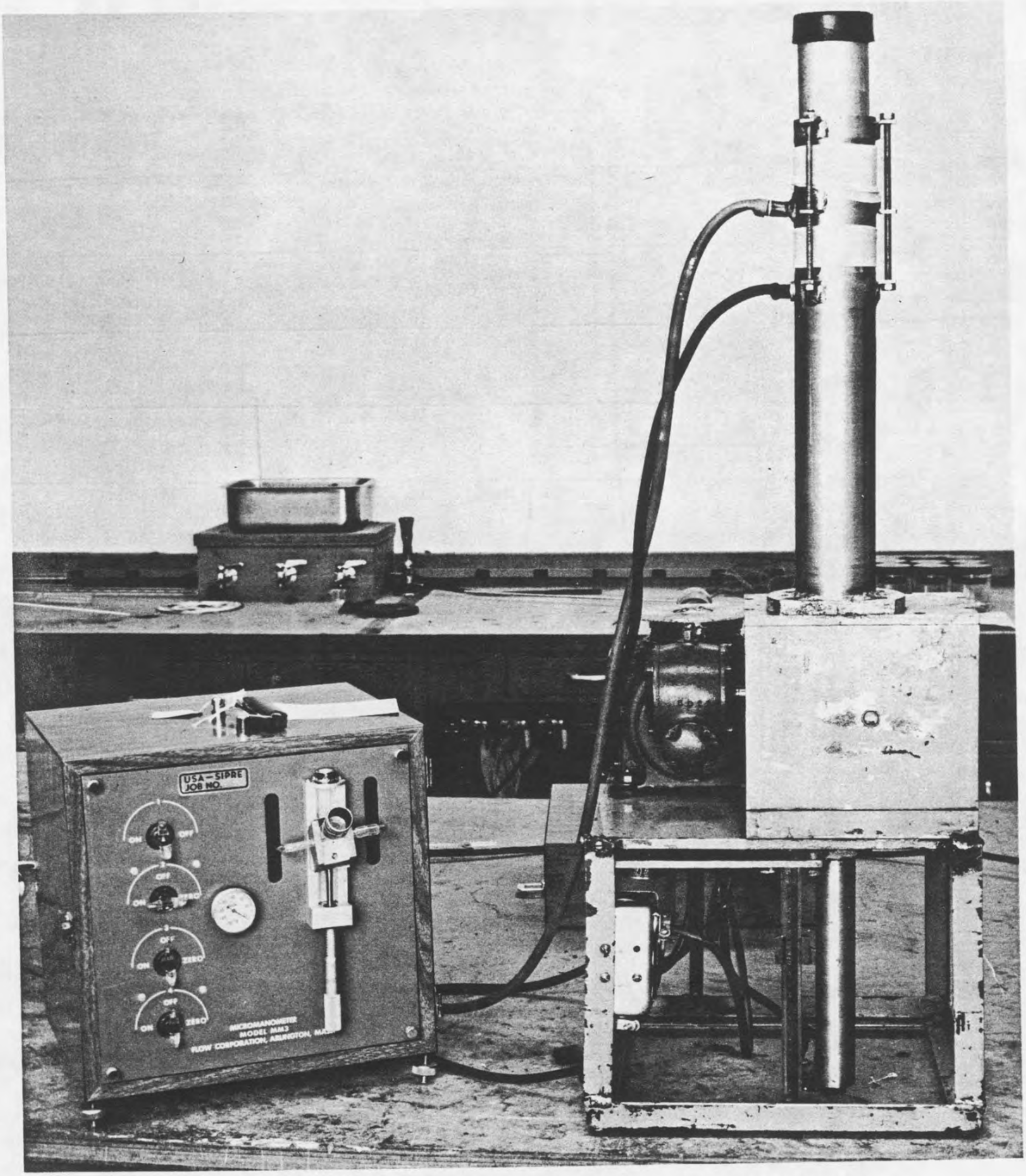

Fig. 6 Snow Permeameter used for Testing Permeability of Snow