Technical Note N-866

BYRD STATION SNOW TUNNELS - SIDE-CUTTING WALL TRIMMER

BY

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ABSTRACT

To prevent excessive snow-tunnel closure, equipment and techniques were developed for trimming the closure snow from the tunnel walls at Byrd Station, Antarctica. The system developed is satisfactory but time-consuming and laborious. At the present average 2-in./yr rate of closure, the walls must be trimmed at least every 3 years so that the space between the tunnel walls and the buildings does not become too restricted for the maintenance equipment.

To permit less frequent clearing of the tunnel walls and to simplify the operation, a concept was developed for a side cutter which clears the tunnel walls in advance of the maintenance equipment, thus requiring no work space between the closure snow and the buildings. Based on the present rate of closure, this device could extend the frequency of clearing up to 9 years, resulting in both a labor and monetary savings over the existing system.

INTRODUCTION

Measurements taken in the undersnow camp at Byrd Station, Antarctica, indicate that the tunnel walls are closing in due to the plastic flow of the snow. Maintenance equipment developed for removing closure snow from the tunnel walls by scoring the snow and chipping it off to the depth of the scoring cuts is workable but time-consuming and laborious. Although the rate of closure is slow, the limited space of 2 to 4 feet between the tunnel walls and the buildings becomes too restricted for access with only a small amount of closure. With the existing system of scoring the snow, the walls must be cleared every 2 or 3 years in order to have adequate work space to operate the maintenance equipment.

To permit less frequent clearing of the tunnel walls and to simplify the operation, a concept was developed for a side cutter which clears the tunnel walls in advance of the maintenance equipment, thus requiring no work space between the closure snow and the buildings. This report presents a conceptual design for the side-cutting equipment.

BACKGROUND

Byrd Station, Antarctica, was built during Deep Freeze 61 and 62 to replace the International Geophysical Year surface station of the same name. The undersnow complex was patterned after Camp, Century,[1] Greenland, with improvements suggested by construction and operation of that camp. Deep trenches were cut with snow millers. These trenches were roofed with metal arches, which were covered with snow to form tunnels. Prefabricated buildings to house the scientific and support activities were erected in the tunnels.

The difficulties experienced in maintaining proper clearances in the tunnels at Camp Century prompted an investigation of wall-tunnel closure rates at Byrd Station immediately after construction. Measurements taken by U. S. Army Cold Regions Research and Engineering Laboratory[2] show that the average closure rate was about 2 inches during the first year; subsequent observations indicated little change in this rate through Deep Freeze 66. A study is now being made to cool the tunnels, which should reduce this closure rate.[3]

Observations on the tunnel walls from the time of construction through Deep Freeze 66, a period of 5 years, showed no measurable closure to a height of 4 feet above the floor (Figure 1). Above this point, the closure increased to a maximum at a height 8 to 9 feet above the floor.

During Deep Freeze 64, studies were made by NCEL at Byrd Station to determine an approach for developing snow-tunnel wall-trimming equipment.[4] A chain saw was mounted on a wooden frame which could be placed a controlled distance from the tunnel wall. The chain saw was operated in a fixed vertical plane to score the snow to the depth to which it should be removed. A square-ended shovel was used to chip the snow from the wall to the depth of the scoring cuts. Waste snow was loaded onto banana sleds for manhauling to the main tunnel, where it was reloaded onto a large sled and towed by a tractor to the surface.

During Deep Freeze 65, studies were continued,[5] but the scoring principle was refined by mounting the chain saw on an aluminum guide frame (Figure 2) which was wide enough to permit scoring a 5-foot length of wall without moving the frame. The frame also permitted both the vertical and horizontal movement of the chain saw. After the snow was chipped from the walls, it was loaded into a snow melter (Figure 3), and the resulting water was pumped into the sewer system. This equipment was used during the winter season to trim all the walls of tunnels containing buildings.

One of the main limitations of this system is that in order to have enough clearance between the tunnel walls and a building to operate the wall-trimming equipment, the maximum allowable closure cannot exceed 7 inches. With this limitation, the walls have to be trimmed every 2 to 3 years.

Another disadvantage of the system is the large amount of labor required to chip the snow from the walls and move the snow to the melter. There is no way of catching the snow as it is being chipped, so it has to be loaded onto banana sleds and towed to the snow melter.

REQUIREMENTS FOR A NEW WALL TRIMMING DEVICE

To permit less frequent trimming of tunnel walls, with consequent saving in manpower, a wall-trimming device would be required to trim the closure snow from the wall in advance of the equipment. Clearance would then not be critical since work space would not be confined to the space between the closure snow and the building. The snow trimmed from the walls could be caught in a hopper and transferred directly to the snow-melter tank for disposal. Criteria developed for the wall-trimming system were:

1. A cutting device which will remove the closure snow in advance of the frame on which it operates
2. A guide for fixing the distance of the cutter from the wall to assure a uniform depth of cut

3. System components sized to pass through 3-foot by 6-foot-8-inch openings

4. A cutter capable of removing 12 to 18 inches of closure snow

5. A device for catching the snow removed and transferring it to a snow melter

CONCEPT OF A SIDE-CUTTING WALL TRIMMER

As an snwer to the foregoing requirements, the Naval Civil Engineering Laboratory developed the concept of a side-cutting wall trimmer (Figure 4). Essentially, the concept is of a rotating-drum cutter moving vertically on a guide frame. After each cut, the frame, which is mounted on wheels, is moved forward for the next cut. The axis of the rotating drum is perpendicular to the tunnel wall, and the drum operates ahead of the guide frame, thus clearing a path for the guide frame as it proceeds. The frame is manually moved forward after each cut with the cutting drum. The vertical movement of the cutting drum is powered by an electric motor. A shroud around the cutting drum catches the snow and drops it into a snow blower, which moves it through a 4-inch flexible hose into a snow-melter tank. The tank is mounted on rubber tires so that it can easily be moved to a gasoline-fired boiler, which supplies heat to coils in the melter tank. The guide frame and melter tank both run on a track consisting of plywood with timber guides.

Guide Frame

The guide frame for the tunnel wall trimmer consists of two upright channels mounted on a rubber-tired base. The maximum overall width of the unit is 24 inches. The uprights are hinged at the third points so that the unit can be collapsed to pass through doors when moved from one tunnel to another. The channels serve as tracks for the frame supporting the cutter and snow blower. An electric motor raises and lowers the cutter by means of a continuous chain.

Cutting Drum

The cutting drum, consisting of angle teeth for cutting snow, is 18 inches in diameter by 18 inches long. It is driven by an electric motor at one end. A sheet-metal shroud covers the drum to catch the loose snow cut from the wall. The cutting drum can cut to a depth of approximately 4 inches. The vertical movement of the cutting drum is controlled by a switch easily accessible to the operator, who stands behind the wall-trimming device to push it forward after each cut.

The drum can be positioned horizontally to cut flush with the finished wall, or up to 6 inches from the wall when cutting around obstructions. The wall trimmer can also be positioned to face the wall and make cuts with the drum. This technique can be used to make the first cut in starting to trim a tunnel wall. The wall trimmer can then be turned to move along the wall, removing the closure snow as it progresses. The snow cut from the wall drops into a small snow blower having an impeller powered by an electric motor. A 4-inch hose connected to the snow blower directs the snow into a melter tank.

Base

The wall trimmer is supported on a base with four rubber tires. The axles are 3 feet apart, and wheels on both axles are spaced 2 feet out to out. The uprights are supported on this base, and a bar at hand level is attached to the base so the operator can control forward movement.

Track

The track for the wall trimmer consists of sections of plywood, with two-by-fours nailed to the top surface to guide the wheels. These two-by-fours are located between the wheels and are beveled slightly on the outer edges to prevent binding. The track is laid in 8-foot-long sections and must be leveled as it is laid. The sections could be made in any desired quantity. Enough track could be provided for the entire length of a tunnel, or only a few sections could be used by moving sections from behind the wall trimmer and laying them in front of the trimmer as it advances through the tunnel. The sections are laid and leveled manually. They are placed 4 inches from the original wall surface to allow for a possible slight closure at the base of the wall. Boardwalks along one wall of each tunnel are level and should simplify laying the track in these locations.

Snow-Melter Tank

The waste snow is transferred to a melter tank mounted on four rubber tires which operate on the same track as the wall trimmer. The tank is 2 feet wide by 3-1/2 feet long by 3 feet deep, with a capacity of 150 gallons. Coils are installed in the bottom of the melter tank for circulating heated fluid to melt the snow. The coils are equipped with quick-disconnect couplings for connecting hoses from a gasoline-fired boiler. Another melter tank on wheels is used to receive the waste snow while snow is being melted in the first tank. The number of tanks required depends upon the rate at which the trimming is accomplished.

After the snow is melted, a submersible pump is used to pump the water into the camp sewer system for disposal.

Heating Unit

The heating unit (Figure 5) is a 150,000-Btu, gasoline- or diesel-burning, recirculating-coolant heater mounted on a sled-tank equipped with a tow bar. It is 48 inches long, 24 inches wide, 34 inches high, and weighs 475 pounds dry. The fuel tank holds about 18 gallons, which is enough for 10 hours of operation at rated output.

The unit is powered by a 1-hp, single-phase, 60-cycle, 110-volt AC motor. This motor, which drives the coolant-circulating pump, the fuel-distribution pump, the combustion air blower, and the magneto, remains in continual operation after starting. The heating operation is also automatic after starting and maintains the coolant temperature between 145°F and 180°F by cutting the burner in and out.

The heated coolant is circulated through the heater and melting tank at 7.2 gpm and a maximum pressure of 25 psi. The two pressure and return circulating hoses, between the heater and tank, are 1-inch-ID, single-ply, cotton-braid-covered, neoprene hoses, 25 feet long. They have quick disconnects at the melter-tank end. The hoses can be connected together so the coolant can be recirculated through the heater.

The combustion chamber of the heater is cylindrical, with the burner at one end. The water jacket is a 2-pass system with a thermostatic actuator that relieves the fuel pressure when the coolant reaches the upper temperature limit.

DEVELOPMENT COST

The complete development of a side-cutting wall-trimmer system would involve both design and fabrication costs. The estimated cost of designing the wall trimmer, track, and snow-melter tank is $3,000. Based on available information, the estimated cost of fabricating one wall trimmer (guide frame, drum, and base), 200 feet of track, and one snow-melter tank is $4,000. The estimated cost of an additional snow-melter tank is $1,000. The cost of one heating unit[5] is $2,000; however, the unit used with the existing wall-trimmer system could be used with the side-cutting wall trimmer. The estimated total cost of developing the system, including design and fabrication of one wall trimmer, 200 feet of track, and two snow-melter tanks is $8,000.

WALL-TRIMMING RATES

The rate at which the track for the wall trimming can be laid is dependent upon the condition of the tunnel floor, since the track must be leveled in order for the wall trimmer to make a vertical cut. Tracks in limited spaces behind buildings should be left in place. The time required to lay the track will also be affected by the stored items in the tunnel that have to be moved. These tasks must be performed only once for each time the walls are trimmed, so the less frequently the walls are trimmed, the more economical the operation.

Although no wall trimmer has been fabricated for testing, it is estimated that it could make three 4-inch cuts per minute to advance along the wall at the rate of 1 ft/min, or 60 ft/hr, for any amount of closure up to the 18-inch width of cutting drum.

The rate of melting snow, however, is dependent upon the amount of closure. Based on an increase in closure of 2 in./yr in the configuration shown in Figure 1, the additional cross-sectional area of snow each year approximates a triangle with an area of about 5/8 square foot. The gasoline-fired boiler, melting snow at the rate of 106 gallons per hour, could melt the 1-year accumulation at the rate of 60 lineal feet per hour. With a 2-year accumulation, the melter could be operated around the clock to keep up with the wall trimmer operating only during the day. With a 4-year accumulation, the trimmer could be operated only half a day, or two snow melters could be used. One man would be required to operate the wall trimmer, and one man would be required to operate each snow melter.

The estimated manhours, exclusive of melting and disposing of the snow, required to clear the 1,600 lineal feet of tunnel walls in the occupied tunnels at Byrd Station are given below. These figures are independent of the frequency of clearing.

Trimming Operation	Mandays*
Trimming walls at 60 ft/hr	3
Moving equipment including track nine times at 4 manhours each time	4
Moving supplies stored in tunnels	28
Returning supplies to storage location	28
TOTAL	63

The labor requirement for disposing of the snow is 3 mandays for 1 year of accumulation, and increases as the frequency of clearing decreases. The total manpower requirement per year, based on a frequency of clearing of 1 to 9 years, is shown in Figure 6. The calculations for the annual manpower requirement plotted in Figure 6 were made by dividing the 63 mandays required for the trimming operation by the number of

*One manday equals 9 manhours

years of accumulation and adding the 3 mandays for disposing of the snow, which is a constant annual requirement. Thus, the annual requirement for clearing the walls at a 1-year frequency is 63 plus 3, or 66 mandays; the annual requirement for clearing the walls at a 2-year frequency is 63 dividied by 2 plus 3, or 34-1/2 mandays.

If the technique is used of scoring the tunnel walls and chipping to the depth of the scoring cuts, the walls must be cleared at least every 3 years. Based on a 3-year frequency of clearing, 33 mandays per year are required;[5] based on the same frequency of clearing with the side-cutting equipment 24 mandays per year (63/3 + 3) would be required. The difference of 9 mandays represents a saving of $855 per year based on the $95-per-manday average cost of Seabee labor in Antarctica. With the side-cutting equipment, the frequency of clearing could be extended up to 9 years, thus reducing the labor requirement to 10 mandays per year (63/9 + 3). This is 23 mandays per year less than required by the scoring-and-chipping method, which represents a saving of $2,000 per year, or $18,000 of labor in 9 years. At an approximate cost of $8,000 to develop the equipment, this represents a monetary saving of $10,000.

FINDINGS

1. The present wall-trimming system requires trimming the walls at least every 3 years.

2. A side-cutter wall-trimming device has been conceived which does not require work space between the tunnel walls and buildings, thus permitting a frequency of clearing at up to 9-year intervals based on the present rate of tunnel-wall closure.

3. Less frequent clearing is estimated to represent a saving in labor of 23 mandays per year, or $2,000 per year, or $18,000 in 9 years, based on the $95-per-manday average cost of Seabee labor in Antarctica.

4. The estimated cost of designing and fabricating the proposed side-cutting wall trimmer is $8,000.

CONCLUSIONS

1. The present wall-trimming system is satisfactory, but based on a 2-in./yr average rate of closure, wall trimming in the Byrd tunnels is required at least every 3 years with this system.

2. The side-cutting wall trimmer presented in this report will increase the wall-trimming interval up to 9 years at the present rate of closure in the Byrd tunnels, resulting in both a labor and monetary savings.

RECOMMENDATION

If the requirement for wall trimming in undersnow camps becomes sufficient to warrant its development, a prototype of the side-cutting wall trimmer should be provided for Byrd Station.

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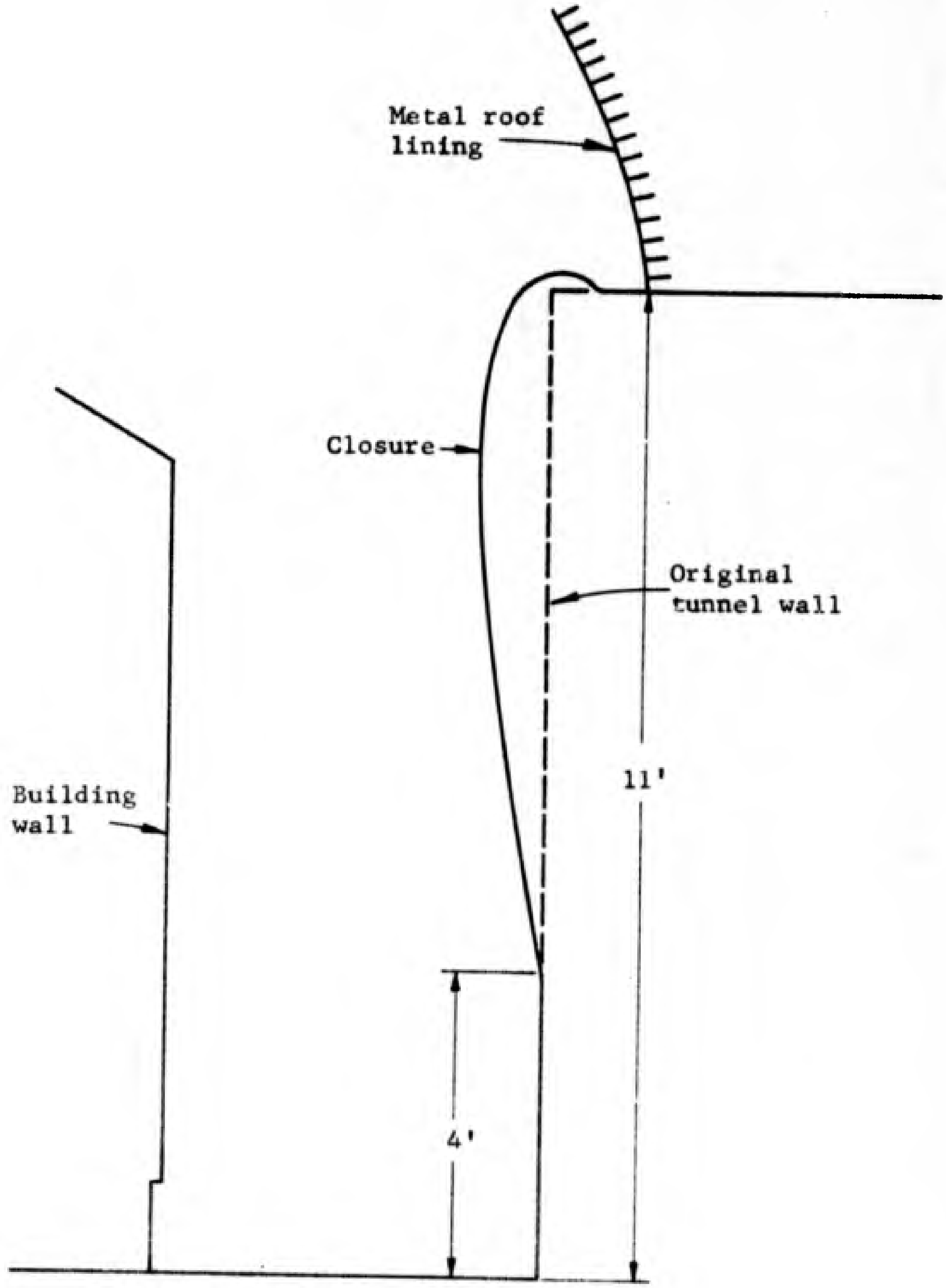

Figure 1. Typical closure in snow tunnel walls.

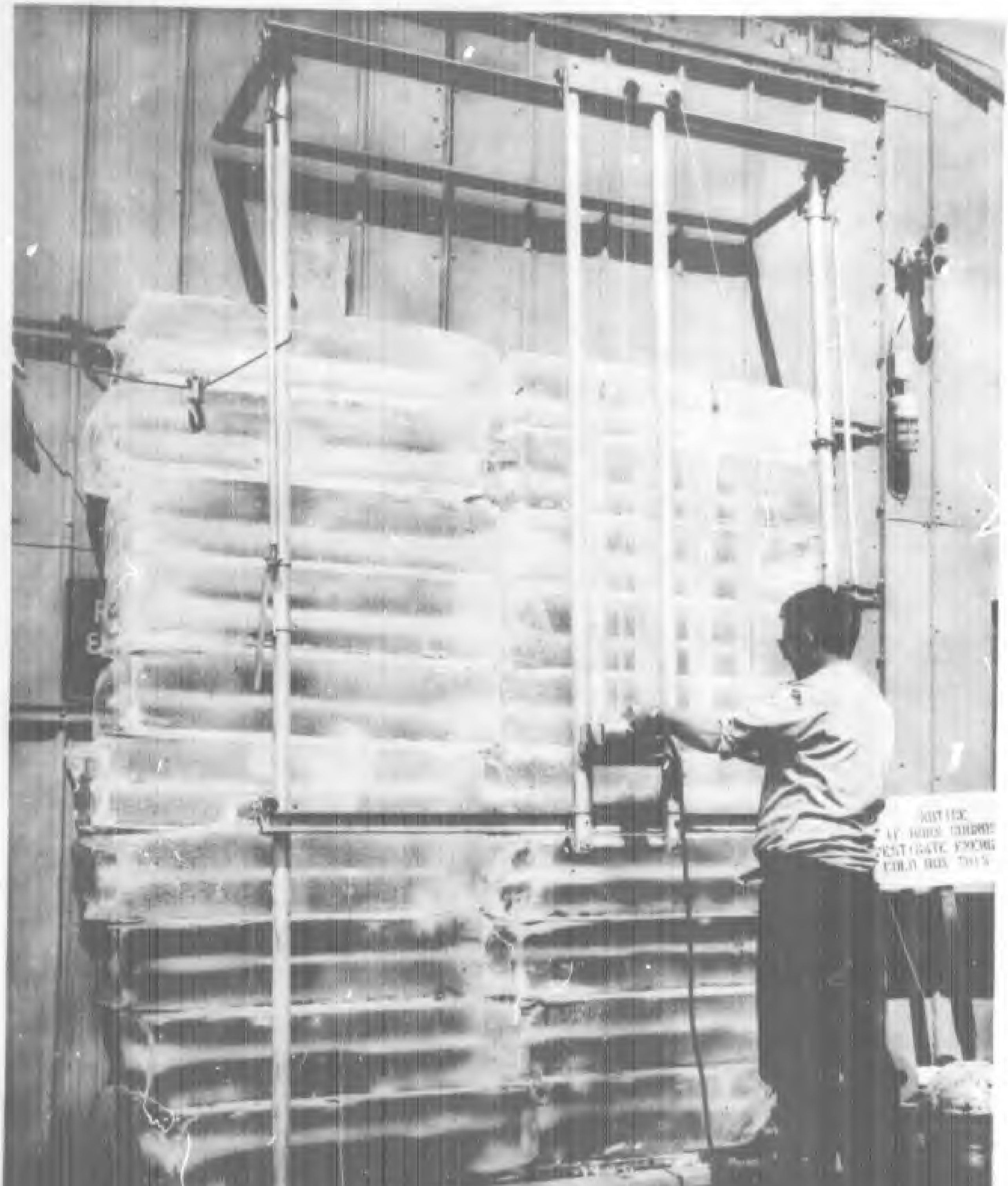

Figure 2. Aluminum guide frame for chain saw.

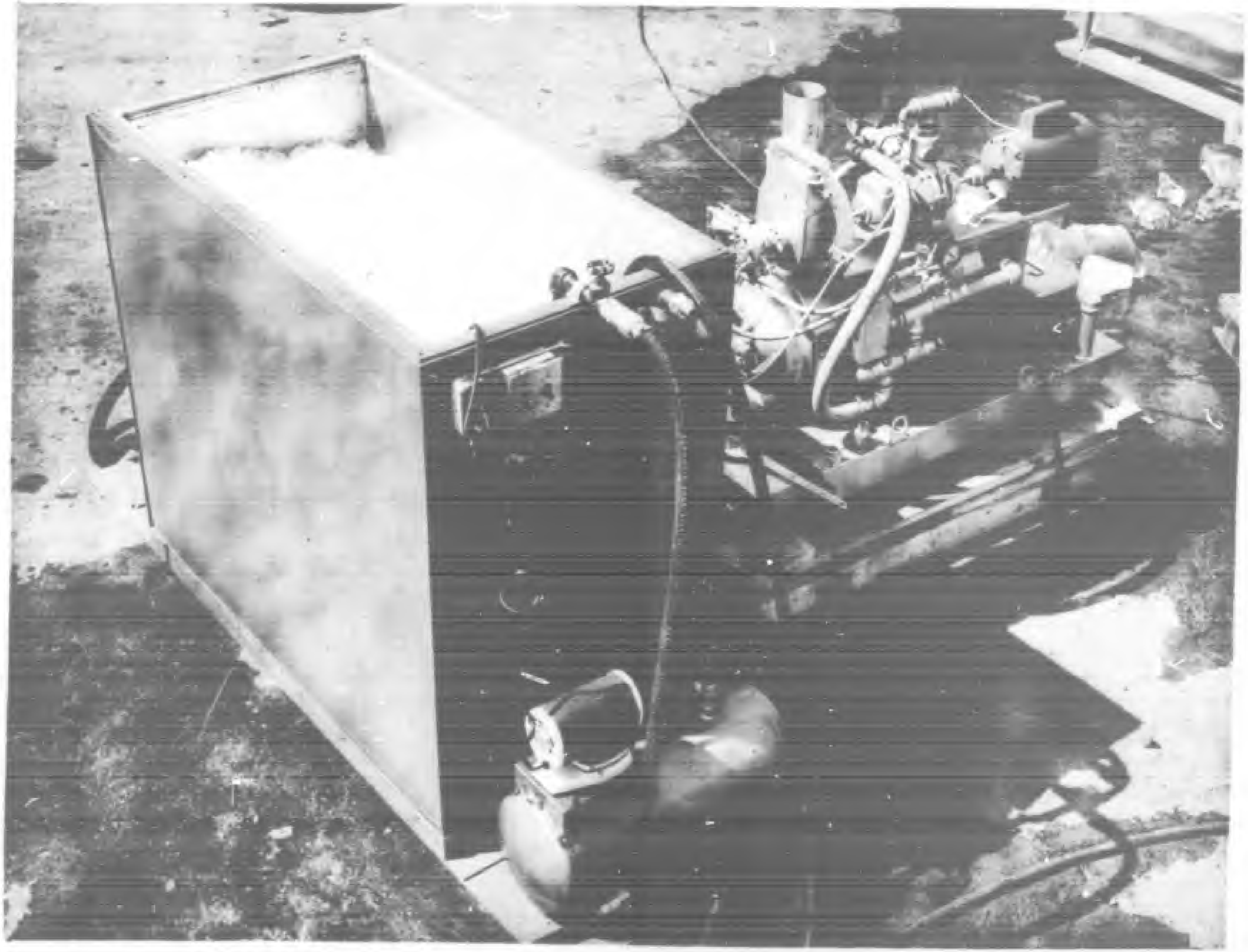

Figure 3. Snow melter used for disposal of closure snow.

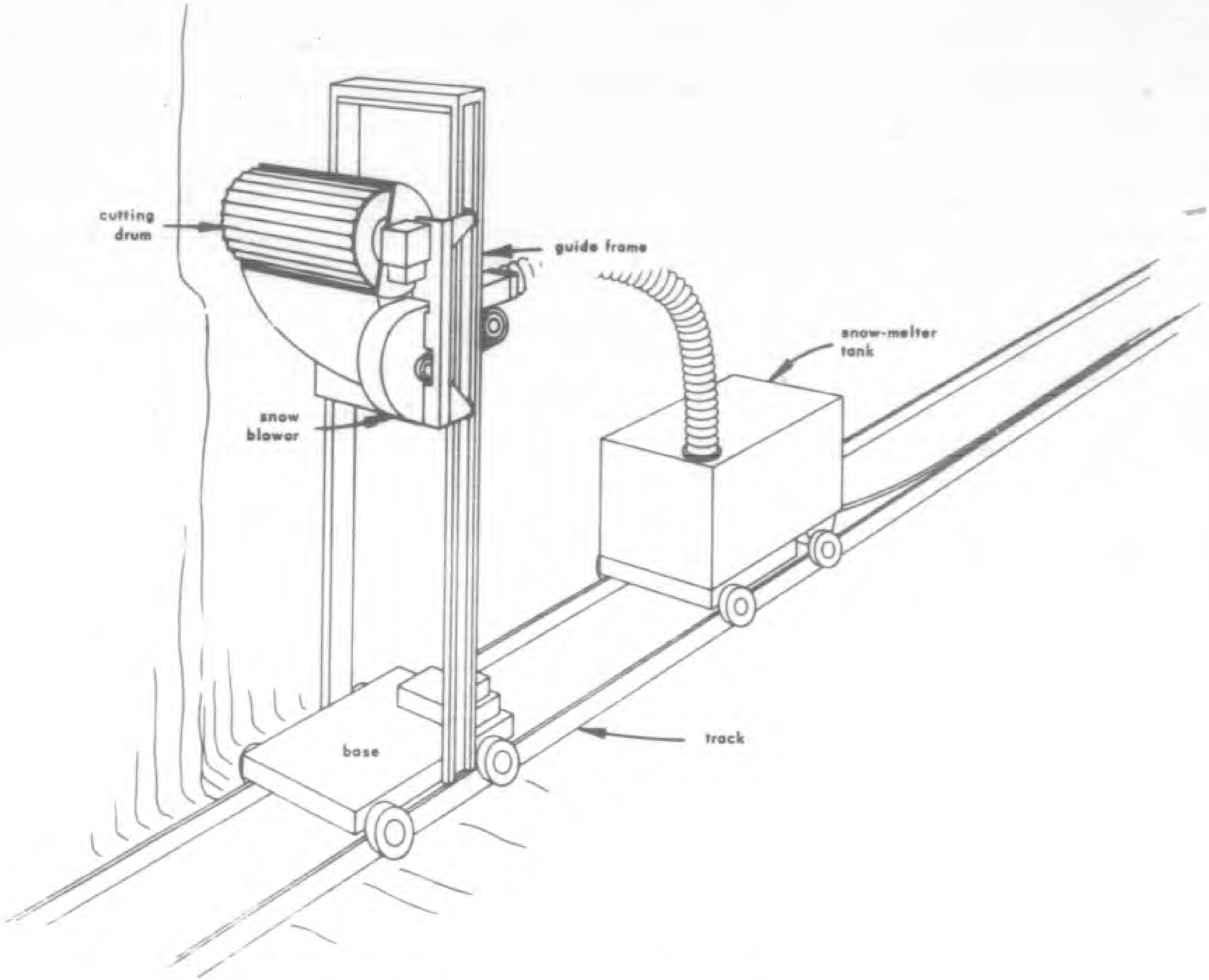

Figure 4. Side-cutting wall trimmer

Figure 5. Heating unit for snow melter.

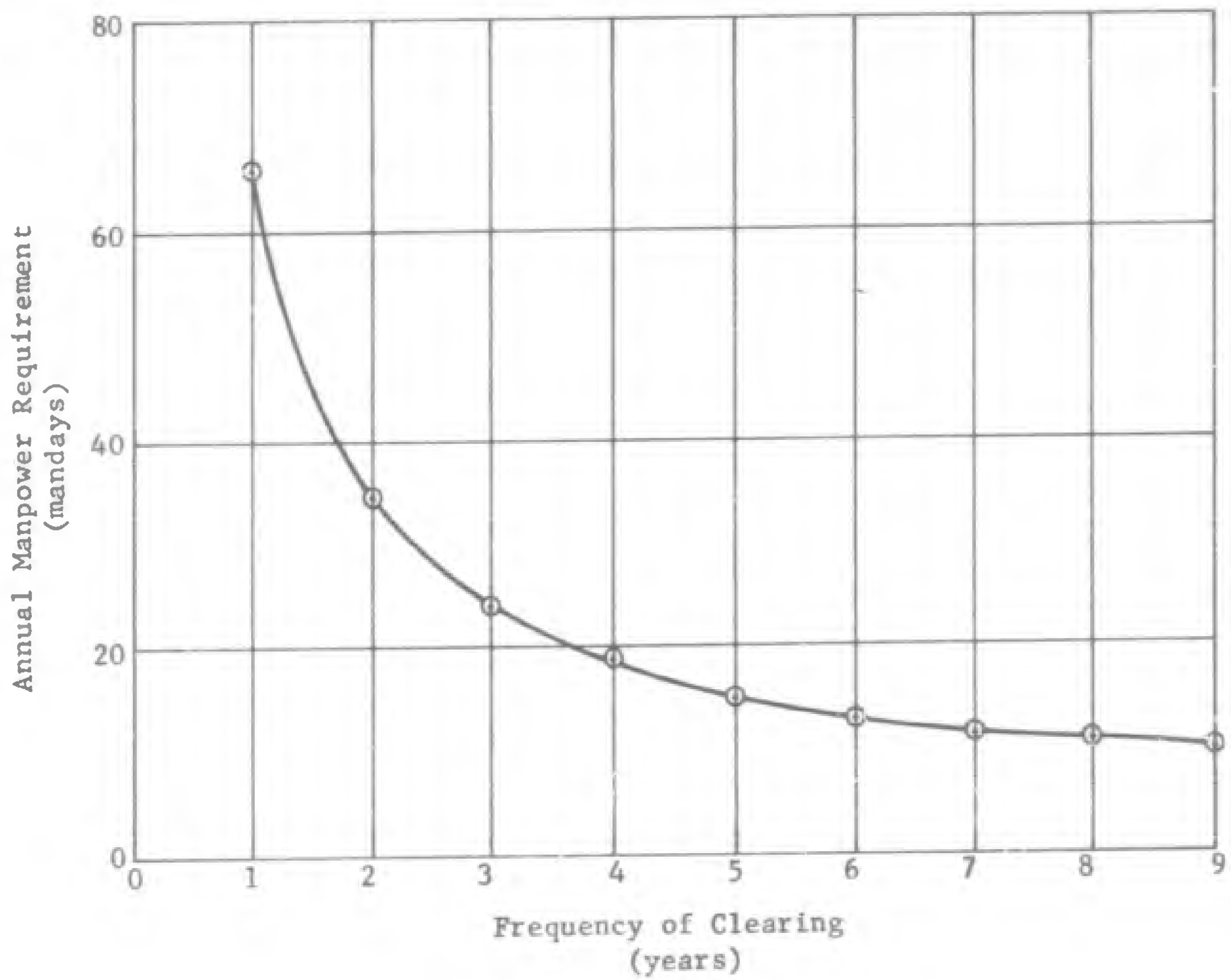

Figure 6. Annual manpower requirement for clearing 1,600 lineal feet of Byrd Station tunnel walls at various frequencies.