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TUNNEL COOLING FOR BYRD STATION, ANTARCTICA - PROGRESS REVIEW

BY

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U. S. NAVAL CIVIL ENGINEERING LABORATORY
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ABSTRACT

Deformation of the snow tunnels at Byrd Station, Antarctica, attributed in part to above $0^{\circ}F$ tunnel temperatures, threatens the structural integrity and useful life of the undersnow camp. Observations in February 1967 indicate that continued deformation of the snow tunnels will require major reconstruction in the near future.

Lower tunnel air temperatures in 1967 at most locations throughout the station are attributed to recent installation of doors at tunnel passageways which prevent entrance and circulation of warmer surface air.

Priority construction of a full-scale tunnel cooling system with potential capacity for lowering tunnel temperatures is recommended in view of the continued deterioration of tunnel L-7. When this is completed, NCEL will instrument and evaluate the performance of the system.

The major problems in operation and maintenance of the Byrd Station facility are of an engineering nature. As a result, the station complement should include an experienced engineer thoroughly familiar with past station operation and current procedures and requirements.

INTRODUCTION

Deformation of the snow tunnels at Byrd Station, Antarctica, threatens the structural integrity and useful life of the undersnow station. Plans for retarding this deformation require a reduction in tunnel air temperatures by improving station operation and maintenance procedures, and by the injection of cold air from a snow-plenum air-cooling system which utilizes the heat-absorption capacity of the in-situ snow.

This technical note presents observations made at Byrd Station, Antarctica, in February 1967. Information is included on snow-tunnel deformation and ventilation as well as the general camp facilities. The snow-plenum air-cooling system, to be installed to reduce air temperatures in the tunnels during the summer, is also discussed.

BACKGROUND

Byrd Station, Antarctica, is an undersnow camp designed by the U. S. Naval Facilities Engineering Command (NAVFAC) and constructed by Navy Seabees during the antarctic summers of 1960-61 and 1961-62. The station consists of a network of tunnels which contain prefabricated buildings and other facilities. The tunnels were constructed by excavating trenches in the snow and roofing them over with corrugated-steel arches. The general layout of the tunnel complex is shown in Figure 1.

Since completion of Byrd Station in 1962, plastic deformation in the snow-tunnel walls, arches and passageways has required nearly continuous maintenance for the protection of structural and mechanical facilities located in the tunnels. Areas where snow deformation has been most destructive include distortion of the tunnel roof arch, deflection of combustion-exhaust and ventilation ducts extending to the surface, and deformation of door closures at side tunnel entrances.

It is known that the rate of tunnel deformation can be reduced by lowering the temperature of the tunnel snow walls and arches. During design of the station, $0^{\circ}F$ was selected as the desired tunnel temperature, but this has not been achieved year around because of inadequate engineering knowledge of camp operating procedures and the above-zero air temperatures on the surface during the summer months.

In August 1965, NAVFAC proposed the construction of an experimental snow-plenum air-cooling system to lower air temperatures in tunnel L-7. This proposal was reviewed by NCEL,[1] and a tunnel-ventilation and heat-load study was conducted at Byrd Station[2] to obtain current information on which to base a design. The recommendation made by NCEL for construction of a large-scale air-cooling snow plenum with potential capacity to cool tunnel L-7 to 0°F was rejected in favor of a smaller plenum suitable for evaluating the air-cooling concept. Construction of the plenum was scheduled during the early austral summer of 1966-67.

OBSERVATIONS

Byrd Station, Antarctica, was visited on February 6-7, 1967, in company with Messrs. P. Brewer, J. Tyrell, R. Mattheis, H. Ingram and R. Thomas of NAVFAC.

During a detailed tour of the station, specific observations were made in each tunnel as well as summary observations of a more general nature. Comparisons were made between the present conditions and those existing when a technical progress survey was conducted in 1965.[3] Special consideration was given to tunnel L-7 and the scheduled installation of the experimental snow-plenum air-cooling system. Following this, a discussion with the Officer in Charge (OIC), Lt. E. M. Cranton, USN, who is also the station doctor, revealed problems not obvious to a short-term visitor.

Tunnels

Observations made during the tour of the station are as follows:

L-1 DFA Storage. Conditions in this tunnel were essentially unchanged from the inspection the preceding year. The exhaust fan in the arch crown was not being operated and a door had not been installed at the tunnel entrance in accordance with good fire protection procedure. The air temperature near the entrance was the same as last year, -8°F, with the temperature and wind condition on the surface being nearly the same, +5°F and 8-mph wind from the north-northeast.

L-2 Supply. There was little change in this area. The tunnel was badly cluttered with new and old supplies. The chargo chute from the surface became filled with snow and was being reopened as time permitted. The snow removed was melted electrically in an open-top 55-gallon drum, and the water dumped into the tunnel floor. This operation, which had been in progress only a few days, was producing ice crystals on the overhead arch. The temperature in the tunnel was -6°F, 7 degrees colder than the preceding year.

L-3 Maintenance. Continued collapse of the roof arch was noted. Twelve sections of arch have now been removed at the ramp entrance, four in late 1966, and eight the preceding year. The vehicle ramp from this tunnel no longer bears straightaway from the tunnel but angles to the south, with a tremdnously large bank of snow several hundred feet long and 30 or more feet high to the north. A door with heavy timber frame was installed in the passageway from L-3 to the main tunnel. This was very effective in preventing surface air from blowing through the tunnels. Air leakage around the door casing was beginning to occue due to evaporation of the snow. The air temperature in this tunnel was the same as the surface temperature, +5°F.

L-4 Fuel Storage. This tunnel shows little apparent change from the preceding year. The exhaust fan in the arch of the antechamber draws air from tunnel M-1. This resulted in a growth of ice crystals 3 inches or more in thickness on the antechamber roof. The temperature in the antechamber was -10°F, compared to +1°F the previous summer. In the rear chamber, the temperature was -15°F, compared with -12°F previously.

M-1 Main Passage, Food-Storage. The apparent change in this tunnel is small except for installation of the U. S. Army Cold Regions Research and Engineering Laboratory (CRREL) deep drill at the south end, and installation of two new exhaust fans in the roof arch over the drill. The old ramp at the south end of M-1 had been open earlier in the summer to facilitate installation of the drill. When this was completed, the opening was closed with a light plywood bulkhead, and the ramp allowed to drift closed. To make room for the drill rig, foodstuffs stored in that area were moved to the north end and stacked in a center row in the tunnel. All the original arch-crown exhaust fans have become inoperative due to distortion in the duct and burying of the surface outlet under drifted snow. The air temperature in the south half of the tunnel was -4°F, compared to +5°F the preceding year.

L-5 Quarters-Science-Administration. This tunnel surprisingly showed the greatest deformation of the roof arch during the preceding 13 months. Secondary buckling of the arch occurred about one-quarter the distance up the south side for nearly the entire tunnel length. This deformation brought the arch in contact with the eaves of the quarters building and within inches of the eaves on the science and administration building. Removal of the steel arches was planned, with trimming of the snow where required to prevent pressure on the buildings.

The sewer line on the south side of the tunnel has caused sublimation of the snow under the building foundation timbers. The ends of the steel foundation trusses are supported on 6- by 8-inch timbers laid on

the 8-inch side. At the time of the inspection, 4 inches of the timber was unsupported and the foundation was in danger of dropping at least 6 inches into the sewer-line trench.

The snow walls of the tunnel which were trimmed 2 years previous are again deforming and will require additional trimming in about 12 months. When this is done, the arch footing will be on the edge of the wall and be poorly supported. However, at this time, all arches will probably have been removed and the footing will no longer be required.

A tight-fitting door with spring closure was installed at the entrance from M-1 and was effective in preventing cross circulation between the tunnels.

Temperatures in the tunnel were unchanged from the preceding year, being +10°F near the entrance from M-1 and +2°F at the science building.

L-7 Generator-Galley-Communication. Considerable deformation has occurred in the arches and side walls of this tunnel over the past year. The arch over the generator building has flattened extensively and water was dripping from around the generator exhaust stacks. Both these conditions were undoubtedly due to the higher air temperatures in this tunnel. Over the generator building, the temperature was +18°F, and 5 feet above the floor level, it was +8°F; both temperatures are essentially the same as previous measurements. At the entrance from M-1, the air was +4°F, 6 degrees cooler than previously. Conditions of high temperature were further aggravated by an exhaust fan over the generator building which had recently become jammed due to twisting of the mount caused by arch deformation.

A door had been installed at the entrance of the tunnel from M-1 but was blocked open. Air movement through the opening was moderate.

The distance from the tunnel floor to the surface was measured at the escape hatch and found to be 44 feet.

L-8 Meteorology. Little change was found in this tunnel from the previous year; however, deformation is continuing and trimming of the snow walls will be required in the near future. The temperature was -6°F, compared to 0°F previously.

L-9 Seismic. Little change had occurred in the preceding year. Lights were installed in the vertical escape hatch, but this is seldom used as a passage to the surface since installation of more convenient steps from one of the surface structures to the ground. This shaft is still used for raising and lowering cargo but otherwise remains closed. The distance from the tunnel floor to the surface is about 30 feet at this point. The temperature was -12°F and was unchanged from the preceding year.

Snow Plenum

Excavation of the experimental snow plenum in tunnel L-7, delayed by higher priority work, is rescheduled for the summer of 1967-68 as a Seabee construction task. In early January 1967, winter-over personnel were relieved of the responsibility for plenum excavation by the Antarctic Support Activity because of a short of electric chain saws at Byrd Station.

When inspecting tunnel L-7, special attention was given to features which might affect construction and operation of the system. In discussion of the system between the OIC, cognizant NAVFAC personnel, and the NCEL representative, the following items were resolved:

1. If NCEL provided an electric chain saw, excavation of the plenum by winter-over personnel would be considered. (A saw was provided from their McMurdo camp in early February 1967.)
2. The location of the plenum would be changed from the southeast corner of tunnel L-7 to the northeast corner for easier access to the plenum entrance.
3. The floor elevation of the plenum will be the same or lower than the floor elevation of the tunnel. This will provide at least 36 feet of snow over the plenum chamber.
4. The entrance tunnel to the plenum will join L-7 at either floor elevation or ramp downward from the snow-melter chute elevation, this being left to the OIC.
5. Snow excavated from the plenum will be used to feed the snow melter or melted in a portable electric melter and wasted into the tunnel floor.
6. Plans would be made to install plenum accessories in two stages. The first stage will consist of installing all air-handling equipment complete to the junction with L-7. After proof of the plenum performance, second-stage installation of the extensive air-distribution ducts will be undertaken.
7. The large number of openings from tunnel L-7 to the surface, which cannot be sealed, preclude the possibility of pulling cold air from the tunnel walls to supplement cooling from the plenum.
8. Honeycomb-like channeling of the snow, similar to that which has occurred in the Stanford facility at Byrd Station,[4] can be expected in the plenum chamber walls.

The procurement status of the plenum mechanical components is unknown, as well as plans for procurement of water-spraying equipment for sealing the walls of the plenum access tunnel.

Comments by FY-67 Station Personnel

The oil furnace vent stacks, which carry combustion products to the surface, are giving considerable trouble. They are crooked, rusted out, leak water, and do not provide adequate draft. When the furnaces are not operating, cold air flows down the vent stack and out the draft regulator. When the furnace starts, a minute or so is required to heat the long vent stack and reverse the air flow. During this period, fumes come from the furnace out the draft regulator and into the room. This condition is particularly bad in the east end of the quarters building and the administration building, both in tunnel L-5. The arch-crown exhaust fans and the door on this tunnel from M-1 may result in a slight negative pressure in the tunnel, which would aggravate this condition.

Two generator sets are being operated continuously with a combined capacity of 280 kw. The present load is 160 to 180 kw, not counting the 100 kw required when the CRREL deep drill is operating. It was suggested by the OIC that more electric heat might be used, and thereby eliminate furnaces and their present problems. Present fuel consumption is 400 gallons per week for heating, and 2,000 to 2,400 gallons per week for power generation.

Fluorescent lights are used to some extent and more will be installed to reduce the electrical lighting load.

SUMMARY

With the continued deformation of the tunnel walls and the impending closure of large sections of steel arch on buildings below, it appears that a major tunnel reconstruction effort will be required within the near future. This will probably include the removal of all arches from L-5, L-3 and L-7, and trimming of the snow above. Reconstruction of all tunnel exhaust fans and other surface exhaust ducts is required now.

Serious consideration should be given to priority construction of the snow-plenum air-cooling system. Also, the size of the plenum and its potential capacity for cooling tunnel L-7 should be reexamined. If a snow-plenum air-cooling system is expected to preserve the usefulness of tunnel L-7, the proposed experimental plenum should be cancelled and a full-scale plenum chamber constructed with potential capacity for cooling the tunnel. Further delay results in continued deterioration of the facility.

The lower air temperatures at most locations throughout the station are attributed to installation of doors at entrances to L-3, L-5 and L-7, which prevent cross circulation of air through the camp. The door at the junction of L-3 and M-1 is of particular importance, since it prevents the entrance of large volumes of warm surface air to the snow tunnels.

The major problems in operation and long-term maintenance of the Byrd Station facility are of an engineering nature. As a result, the station complement should include an experienced engineer thoroughly familiar with past station operation and current procedures and requirements. The critical nature of the tunnel temperatures, ventilation requirements, and other engineering features do not permit random experimentation or use of improper procedures.

FUTURE PLANS

When a snow-plenum air-cooling system is constructed at Byrd Station, NCEL will instrument the system and evaluate it performance. Instruments for this purpose are currently in storage at McMurdo, Antarctica.

REFERENCES

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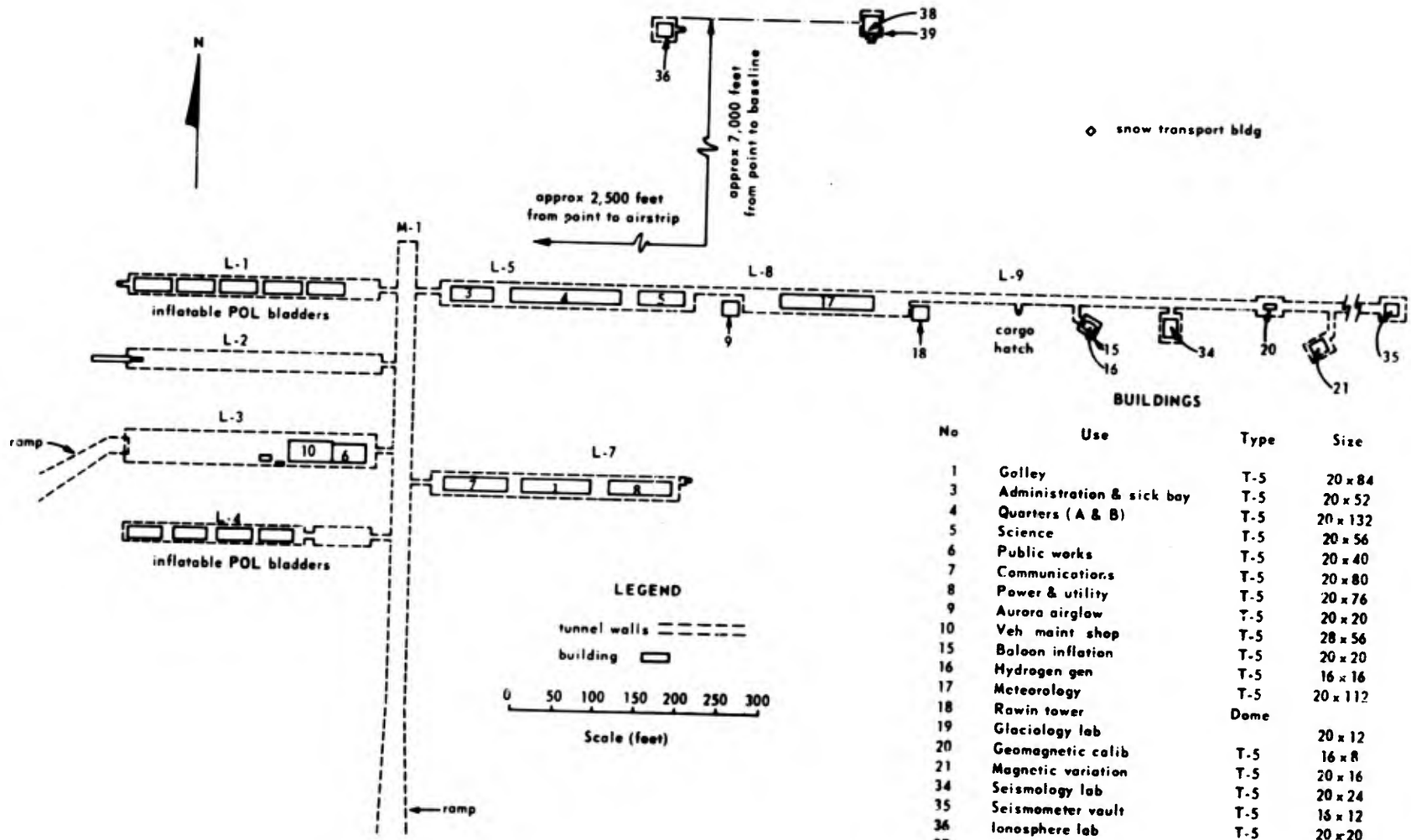
3. _____. Technical Note N-815: Technical progress survey - Byrd Station, Antarctica, by C. R. Hoffman. Port Hueneme, Calif., June 1966.

4. U. S. Army Cold Regions Research and Engineering Laboratory. Technical Report 138: Undersnow structures, Byrd Station, Antarctica, by M. Mellor and G. Hendrickson, Hanover, N. H., Feb. 1965.



BUILDINGS

No	Use	Type	Size
1	Galley	T-5	20 x 84
3	Administration & sick bay	T-5	20 x 52
4	Quarters (A & B)	T-5	20 x 132
5	Science	T-5	20 x 56
6	Public works	T-5	20 x 40
7	Communications	T-5	20 x 80
8	Power & utility	T-5	20 x 76
9	Aurora airglow	T-5	20 x 20
10	Veh maint shop	T-5	28 x 56
15	Baloon inflation	T-5	20 x 20
16	Hydrogen gen	T-5	16 x 16
17	Meteorology	T-5	20 x 112
18	Rawin tower	Dome	
19	Glaciology lab		20 x 12
20	Geomagnetic calib	T-5	16 x 8
21	Magnetic variation	T-5	20 x 16
34	Seismology lab	T-5	20 x 24
35	Seismometer vault	T-5	16 x 12
36	Ionosphere lab	T-5	20 x 20
37	VLF (whistler)		15 x 10
38	Radio noise lab	T-5	20 x 20
39	Gen noise lab	T-5	16 x 16

Figure 1. Plot plan of Byrd Station, Antarctica. Conditions as of DF65.

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	ROLE	WT	ROLE	WT	ROLE	WT
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