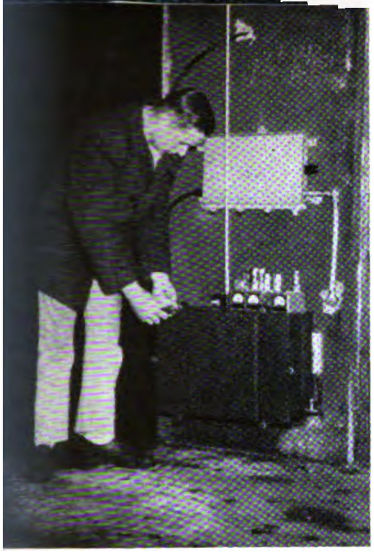
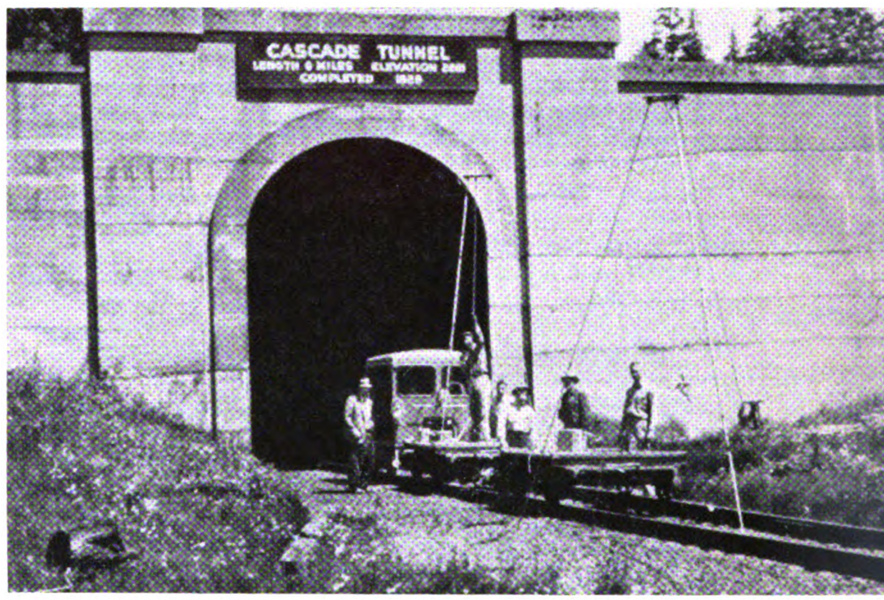


GN Radio Works in Tunnel



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ome time after the Great Northern equipped all their engines and iainline cabooses with radio and comleted a continuous line of wayside idio stations along the mainline from t. Paul, Minn. to Seattle, Wash., it was oted that locomotives and cabooses ould not use their radios end-to-end either were more than three or four ar lengths inside the Cascade Tunnel. perating officers felt this important art of the mainline should have radio ommunication.

Completed in 1929, the Cascade 'unnel is a straight single-tracked conrete-lined tunnel, 7.79 miles long with grade of 1.6% ascending from west o east. It pierces the main ridge of he Cascade Mountains in the State f Washington. The east portal is 634 t higher than the west portal. The unnel is 16 ft wide and 21 ft high. n the south wall are 21 refuge bays, ach large enough to set off a motor ar, and equipped with electric lights, telephone, and emergency oxygen nasks. In the north wall are bays conaining signal apparatus and power ubstations handling the 13,200-volt, 3-phase AC power which is fed through the tunnel from an unregulated tap on a transmission line at the east portal. As part of the tunnel radio project, one phase was regulated to supply power to the tunnel radio sets.

Until 1955 trains had moved through the tunnel, pulled by electric locomotives operating from a 25-cycle, 11,500-volt AC overhead trolley. At this time, however, the electrification was removed and today all the trains through the tunnel are pulled by diesel locomotives.

The main problem in operating diesels through the tunnel was cooling the engines, and it was solved by blowing against ascending engines with a fan. The east portal is the site of a building, housing two 800-hp motors, each driving a fan mounted in a tube which intersects the tunnel's south wall a short distance from the portal. One fan is used to cool an engine climbing the hill, while both fans are used together for 30 min to flush out the tunnel after an up-hill move takes place. Eastbound freights use multi-unit helpers through the tunnel and exhaust fumes inside become very thick. While the fan is blowing, a vertical lift door closes the east portal, forcing the air to flow to the west portal. The power for the fanhouse comes from a substation or from an emergency diesel power plant in the fanhouse. The fan equipment is controlled from Scenic depot near the west portal by means of audio tones in a communication cable.

The first radio tests were made with Stoddard field strength measuring equipment with a Bendix railroad radio for the transmitter. The tripod mounted on a push car supported the antenna at the height of a locomotive roof and a number of tests were made with the transmitter at a fixed location inside or just outside the tunnel, while field strength readings were taken as the push car with the receiving equipment was moving along the track. Reference was provided by marks measured along the tunnel from the portal.

Other tests were made by talking continuously from a locomotive or caboose and observing when the signal faded out. The range of transmission during all of these tests was very short, ranging from about 1100 ft to 1400 ft, depending on the particular antenna being tried, as well as its position in the tunnel. During some of the early tests we experimented with a six-element Yagi, suspended from the tunnel ceiling, and also with a rhombic five wavelengths on a side. These turned in the best performance records of any of the antennae tested. We then learned that no space could be occupied in the top portion of the tunnel because it was desired to have maximum clearance for high loads. Thus, our antennae were restricted to a low position close to the wall, and we eventually wound up with ⅝ wavelength fiberglass-covered whips. Some of these have been changed out and quarter-wave stainless steel whips installed with no appreciable difference in performance. The antenna location is so close to the wall that the antenna is not given much of a chance to function properly, in terms of what it could do in free space.

In casting about for a solution to the problem of the tunnel, various approaches were considered with the following criteria in mind:

The system should function with any present locomotive, caboose, rail-auto, or portable with no change whatsoever to such unit. The system must not be limited in its modes of performance, but must give such results that the tunnel would seem to vanish as far as radio was concerned. That meant the system would have to provide for end-to-end communication within the tunnel, or from a station outside the tunnel to either end of a train within, or from a station outside the east portal to a station outside the west portal, or any other combination. The system should not be extremely critical.

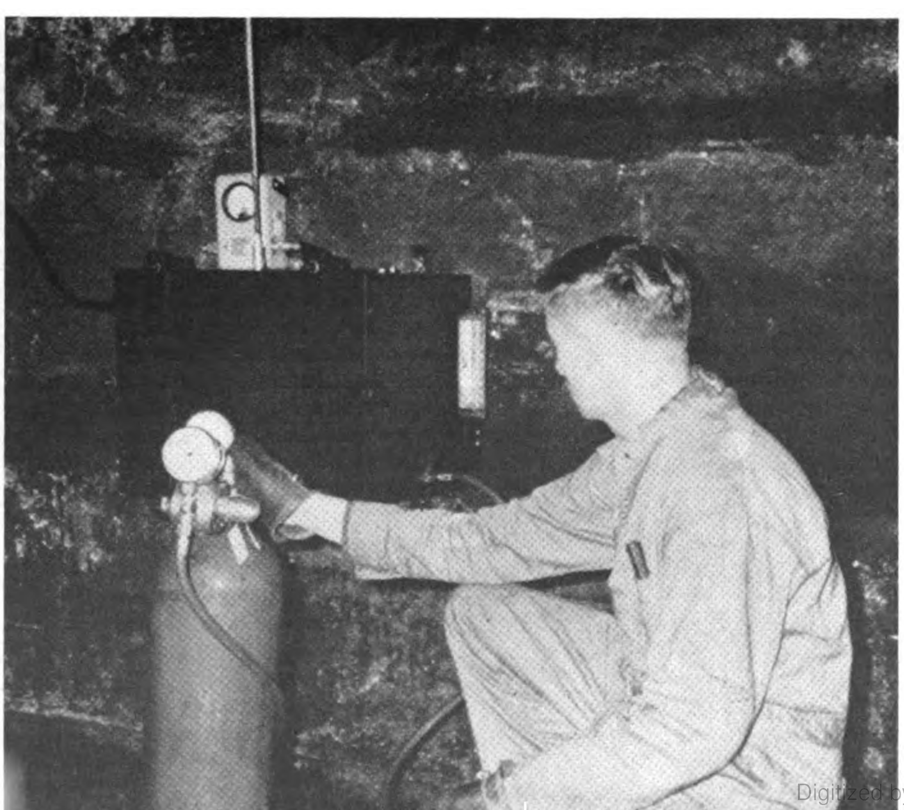
From the standpoint of future maintenance, the use of standard railroad radio units looked attractive. It was thought that one set could pick up a signal and rebroadcast it over a number of others. We put together a trial system with four stations, two inside the tunnel, and one outside each end, connected by an existing cable. The junction boxes were modified, and a few relays were connected up for control functions to see if this were a reasonable approach. We had a lot of trouble with relays galloping, and the system didn't settle down very often, but when it did, it looked promising. It appeared that with the proper design of control system using fast enough relays, this approach would be successful. and that was the direction we took.

The system in its present form consists of 33 stations. One is outside the west portal, and all the rest are inside the tunnel. The one on the east is just 2 ft inside, so it transmits to and receives from the nearest open station which is at Merritt, seven miles away.

The Merritt station, on the east side of the mountain, has solid contact via the tunnel system with the stations at Scenic and Skykomish on the west side. A train anywhere in the tunnel has contact with these same wayside stations or with other trains in the vicinity.

All the sets in the tunnel system operate on one frequency, which is the same frequency used by everything which goes through the tunnel. The stations are spaced 1300 ft apart, barely out of RF range of one another. This spacing gives the best coverage to a helper unit in the center of the train, whose range is cut down by adjacent cars to about half of the rang enjoyed by the lead engine or th caboose. This range from either en of the train into the unobstructed tunnel is about equal to the 1300 ft spa ing between stations so every oth station could be out of order withou affecting coverage to the lead unit (the caboose. The helper, howeve would experience a wider gap in h coverage, with a station out of orde and he does, in fact, experience small signal gap between stations eve with them all working. The fact th the system will function with uni out of order gives it a certain no critical feature.

Dry nitrogen is injected into radio cabinet to provide non-corrosive air.



Each station is in a metal cabin with a whip antenna on top. They a connected by an 18-pair, 22-gage pla tic cable spun on a messenger a chored to the concrete wall. This cab is fanned out on terminal strips in terminal box at each location. Fro this terminal box, a 6 ft cable with 36-pin connector connects to the radi box which contains a radio set and control unit. Each set is normally i the receiving condition. When a sig nal is received, the auxiliary squelc circuit causes a relay in the contr unit to operate. The control unit shor the auxiliary squelch line and close a master relay which puts 330 vol on the transmit pair and operates th push-to-talk relays in all the tunne sets except the one in the receivin station. Audio output from the receiving station is fed through a speci bridging transformer over a loade audio pair to the microphone input of all the other stations. Contacts o the transmit relay connect the audi line to the receiver output in the cas of a receiving station or to the microphone input in the case of a transmitting station. The relays, which set u the receiving or transmitting condition are required to be very fast to preven any interference with the normal us of the radio (see diagram).

Because the malfunction of a singl receiver could cause the other 3 transmitters to come on and stay o until damaged, it is necessary to provide protection against what might b considered an excessively long receiv time. A set of contacts, which clos whenever the radio produces auxiliar squelch voltage, starts a 240-sec timing relay. In any normal conversation an individual transmission would no last that long, so if the 240-sec relay is energized long enough to operate the receiver is judged to be in trouble and the 240-sec relay operates a latching relay which turns off power to the set, removes the short from the auxiliary squelch control line, and turns on a red pilot light outside the associated terminal box so a passing maininer can see this unit is latched off nd in trouble. In addition to this red ght outside the terminal box there are ree other lights to aid in rapid trouble ooting. A green light comes on whenver that particular radio is receiving, n amber light comes on when it is ansmitting, and a white light remains n to indicate the power is on. Voltge for the white light is picked up n the radio side of the 117-volt AC se in the radio itself, so the white ght also acts as a blown fuse indicar. A quick check may be made on e receiver by pressing the push-tolk button of a portable unit and obrving whether or not the green light mes on.

Whenever the latching relay is opered, it puts a short on an alarm pair hich puts on an alarm at the Scenic epot and indicates on a panel which roup of radios has a unit in trouble. or this purpose, the system is divided ito eight groups. This gives the radioan a clue as to how far into the tunel he has to go so he can time imself with respect to train moveents. If the trouble is close to the ther end of the tunnel, he may find it etter to drive over the mountain on the ighway. The latch-off relay and troule-indication sequence can also be tarted by another relay which senses hen the transmitter has been on in xcess of 360 seconds. The timing reys are both thermal types with intant reset.

The system has been in operation ince March 15, 1962 and has been iving good performance. It ties the ailroad together in a difficult area nd helps the dispatcher keep closer rack of his trains.

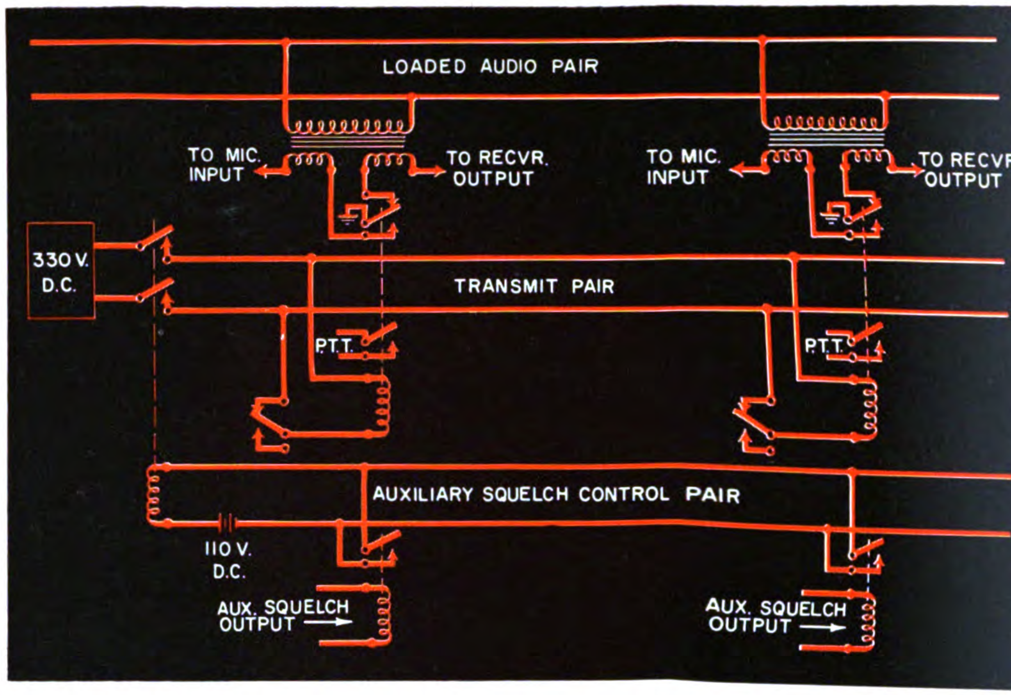
Shortly after the system went into peration, a freight train broke in two ear the center of the tunnel. The rain crew called Scenic depot immeliately on the radio system and the perator told the dispatcher on the lispatcher's telephone. He was therey able to use the information to adance a train running against the one n trouble. By calling in on the radio eriodically, the crew in the tunnel vas able to keep the dispatcher adised as to when they would be ready o start.

The section foreman on this district has a six-volt radio on his motor car, nd, when he is in the tunnel, he is ble to check frequently with the Scenc operator regarding approaching rains. In fact, he can listen to any rains if they happen to come on the ir anywhere approaching the tunnel.

During the debugging period we found failures of parts which hardly ever fail in ordinary non-tunnel operation. We thought this might be caused by the fact that the system listens to so many transmissions on both sides of the mountain and comes on to rebroadcast all of them. To cut down on these failures we intend to connect all but the two end stations to the track circuits extending from just outside the west portal to just outside the east portal. This will allow conversations to be rebroadcast from one side of the mountain to the other but will prevent the 31 stations inside from transmitting unless a train is in the circuit. An override switch will permit the Scenic operator to activate the entire system for the use of men inside the tunnel with walkie-talkies or any other situation where the track circuit is not occupied.

The atmosphere inside the tunnel is rather damp and this, together with the elements present in the diesel exhaust fumes, creates an extremely corrosive atmosphere. We were very concerned about the effect of this atmosphere on the electronic equipment and designed the system with the idea that dry nitrogen would be injected into each of the radio cabinets to provide non-corrosive atmosphere for the equipment.

The dry nitrogen approach has not been entirely satisfactory so far, as it appears the boxes have slow leaks. While we have not quite decided what to do about the atmosphere, we are doing some experimenting with dehydrating chemicals in the boxes with the theory that, if we can remove the moisture from the internal atmosphere, the corrosive effect of any other elements in the box will be much reduced. We are presently experimenting with two forms of silica gel and a chemical known as Dri-rite. These are chemicals which change color when saturated with moisture so a maintainer would know when to discard the chemical and replace it with a new container. We do not know yet if this will work out. RSC



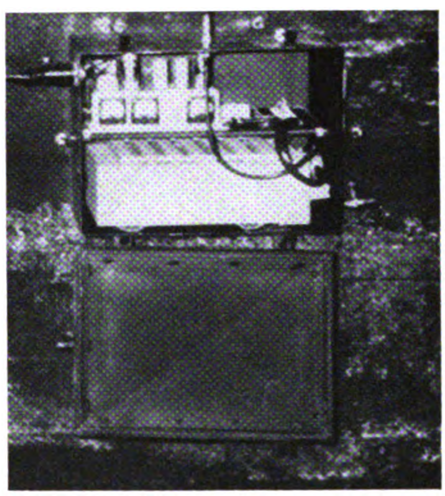


Diagram of tunnel radio station control circuits (above). Each radio set and its control unit are in a metal cabinet with a whip antenna on top (left). Multiconductor plastic cable connects to each of the tunnel radio stations. (32 inside the tunnel and 1 outside the west portal). Each radio station is normally in the receiving condition.