Avalanche control, 1958-1971
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AVALANCHE CONTROL, 1958 - 1971

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JULY 1973

RADIO AND ELECTRICAL ENGINEERING DIVISION

DIVISION DE RADIOTECHNIQUE ET DE GENIE ELECTRIQUE

ABSTRACT

The history of NRC's involvement with the Avalanche Control Program at Rogers Pass, B.C., is given, as well as a brief description of some of the hardware produced for it.

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AVALANCHE CONTROL, 1958-1971

by

G. Neal

INTRODUCTION

During the 1950's the decision was taken to build the trans-Canada Highway through the Rogers Pass area of Glacier National Park in British Columbia. Fig. 1. The route chosen was to follow quite closely the right-of-way of the Canadian Pacific Railway which had been abandoned in 1916, upon completion of the 5-mile long Connaught Tunnel under Mt. MacDonald. Construction of this tunnel had been undertaken only after huge avalanches had killed many railway men working in the area since the opening of the line in 1885. It has since been determined that the combination of an average annual snowfall between 300 and 400 inches and the topography of the area produces avalanche conditions whose severity is not exceeded elsewhere in North America.

In order to permit safe passage along the new highway under these conditions a number of physical avalanche defences, recommended by experts in the Division

Figure 1.

Map of a portion of Alberta and British Columbia showing location of Glacier National Park of Building Research at NRC, were adopted. These consisted of "benches" (or terraces), mounds, and reinforced concrete snowsheds covering the highway (Plate I.) The first two were designed to dissipate, through turbulence, the energy of an occasional avalanche before it reached the highway, while the third was to be built in areas where many avalanches per season could be expected to cross the road. Owing to the high cost of these structures long lengths of the highway had to be left with no such protection.

The plan for winter operation of the Trans-Canada Highway which was finally adopted called for construction of the physical defences mentioned above and, in addition, an attempt was to be made to predict when and where avalanches were about to occur. An army gun crew could then be dispatched to fire 105-mm shells into the trigger zones to release the avalanches before they became large enough to reach the highway (Plate 2). Thus the highway would only be kept closed during the period of the "shoots" or in the rare cases when an unpredicted avalanche might block the road.

Late in 1958 this Division was approached for assistance by the Parks Branch of the Department of Indian Affairs and Northern Development who had the responsibility for maintaining the highway through Glacier National Park. At that time they requested that a radio telemetry system be produced capable of transmitting wind velocity from a remote mountain peak to a valley station. This information would enable the snow physicists to determine when the buildup of snow in the trigger zones was reaching dangerous proportions so that appropriate action could be taken.

In addition, they wished to monitor several avalanche paths where a number of avalanches usually crossed the highway during the winter season. An alarm was required at a central point, so that the road could be closed and work crews dispatched to clear away the snow. At a later date it was proposed to have traffic lights at various locations along the highway which would be automatically switched from green to red by the avalanche itself in order to allow the snow plowing operations to proceed without hindrance.

Avalanche Detector

A brief description follows of the avalanche detector developed at NRC in response to this request and a few notes on its operation.

The breaking of a closed loop of wire (Figure 2) strung across a known avalanche path near the highway initiated the operation of a low-frequency radio transmitter located safely off to one side among the trees (Plate 3). Sequential two-tone modulation was transmitted, and at a central receiving point was decoded and operated an alarm and recorder (Figure 3). Details of the circuits are given in Figures 4,5 and 6. A daily test signal was sent (triggered by a photosensor)

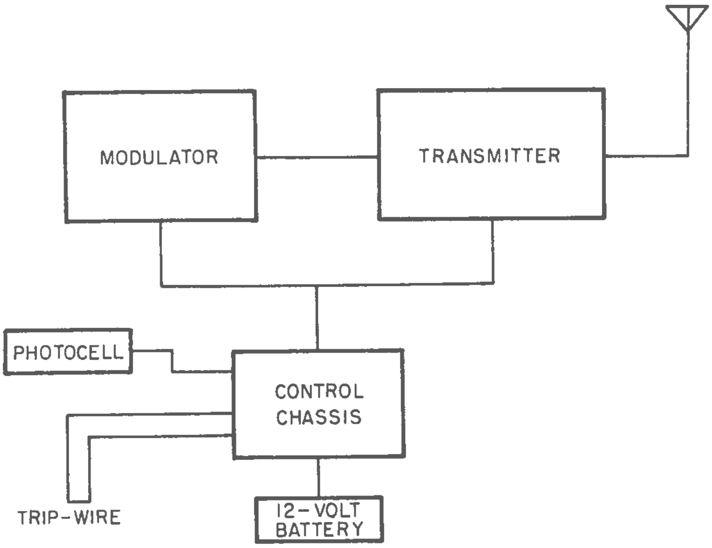


Figure 2

Block diagram of remote portion of avalanche detection and warning system

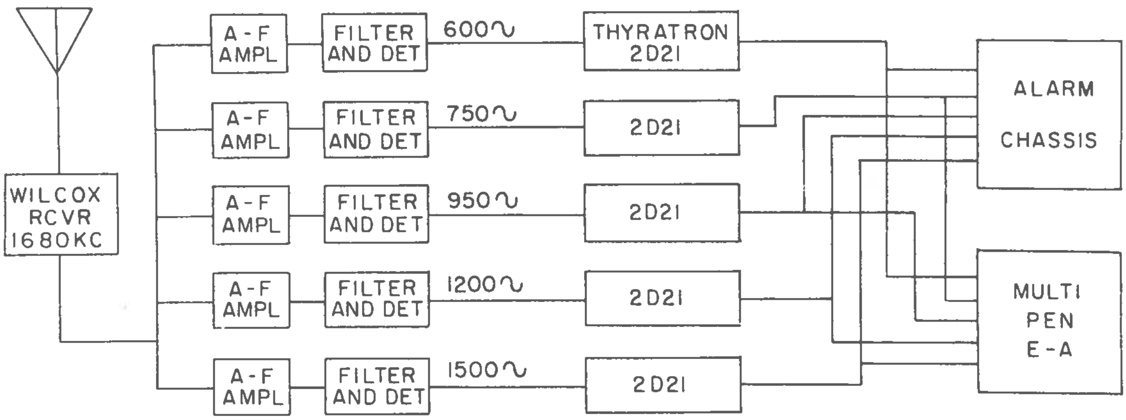


Figure 3

Block diagram of receiving end of avalanche detection and warning system

to indicate that the apparatus was ready to operate when needed. Nickel-cadmium batteries, trickle charged by lower capacity primary cells, provided the brief high current drawn by the 15-W hybrid transmitter.

The prototype path monitoring equipment was in operation for three winters between 1960 and 1963. After the opening of the highway, however, in September 1962, It was found that routine highway patrols in radio equipped cars were still necessary to give assistance to stranded motorists, and thus there was no longer a need for the avalanche detector.

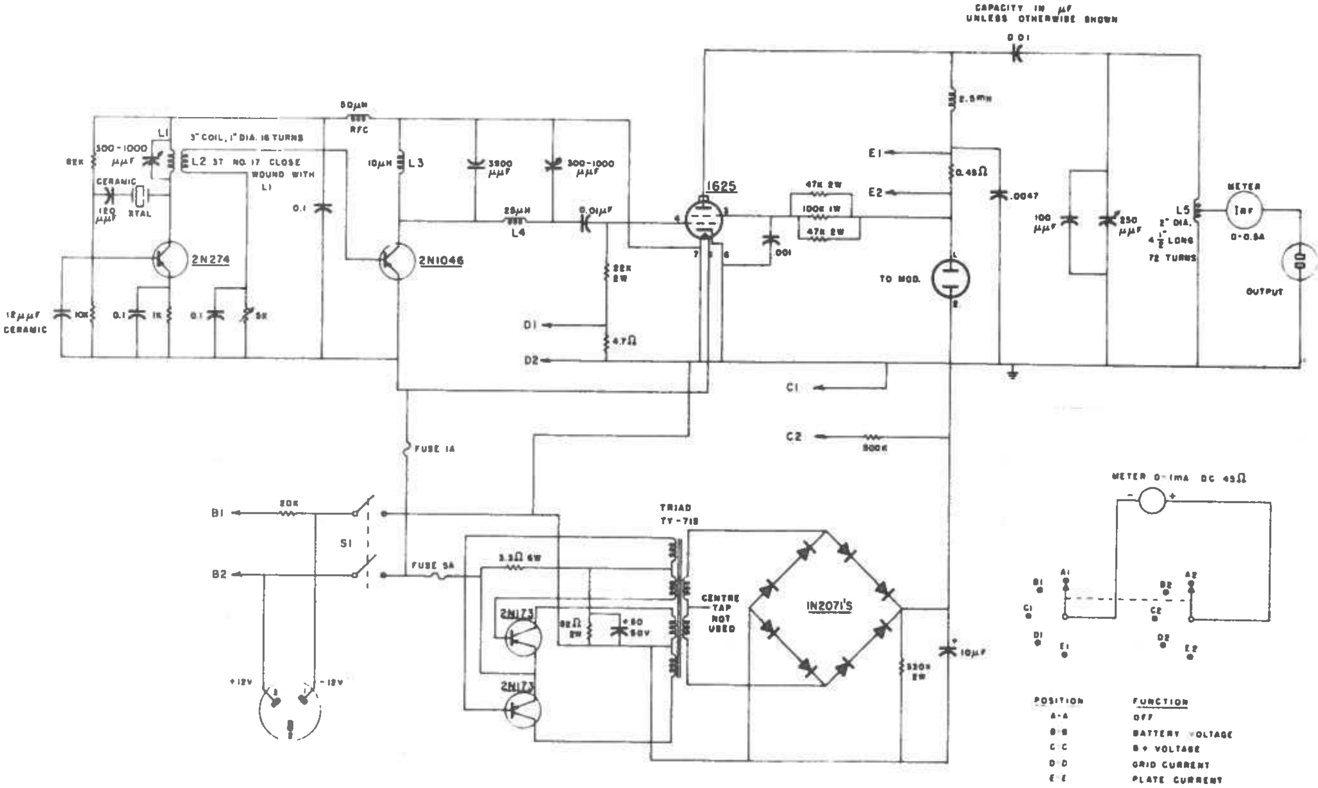


Figure 4
Hybrid transmitter circuit for avalanche detection and warning system

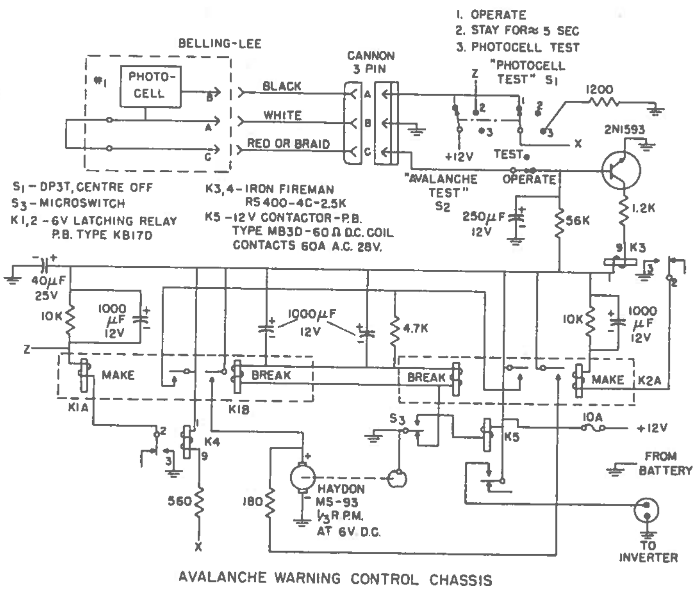


Figure 5
Control chassis for avalanche warning system

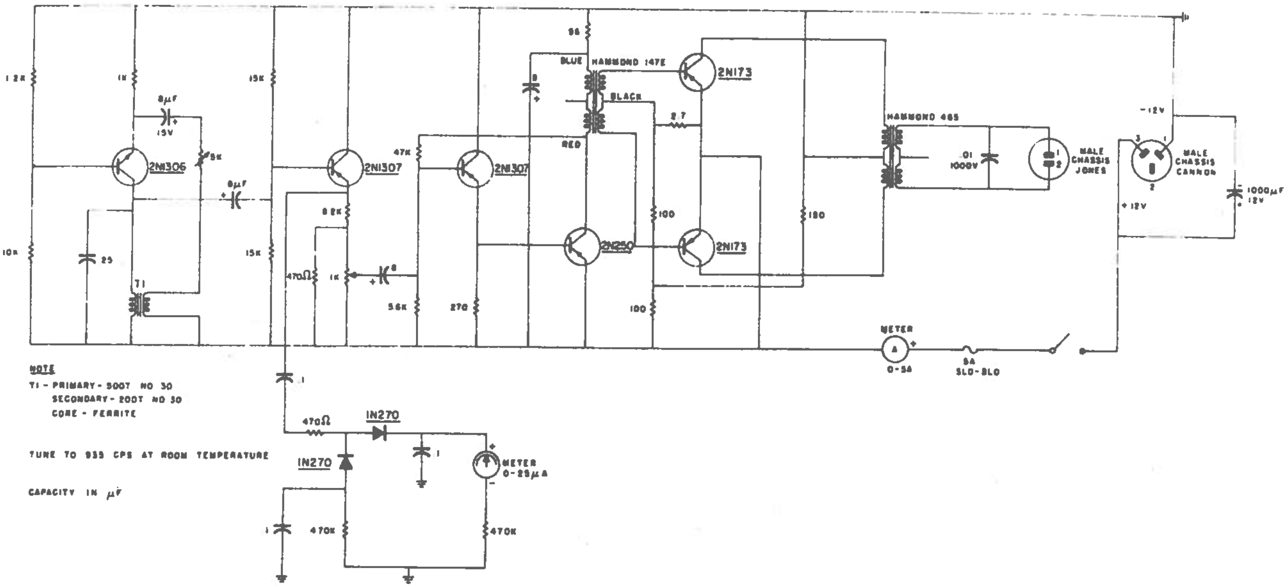


Figure 6

Modulator circuit for avalanche warning system

Warning System for Vehicle Operators

In January 1966, two Park employees were killed near Rogers Pass when their vehicles were struck by one avalanche while they were clearing away another. As a result, a request was received to produce a warning system for vehicle operators to prevent the recurrence of such a tragedy. An experienced observer was to be stationed in a safe area up to one mile from the working area and would send a radio signal at the first sign of avalanche activity. An alarm bell would then ring warning the operator to leave his slow moving vehicle and run to safety. Up to three minutes' warning could be expected under good conditions.

With these requirements in mind, some commercial GRS equipment was modified making use of the "selective calling" feature to ring a bell in the vehicle when the observer pressed a button on his hand-held tranceiver (Plate 4). It was necessary to add to the observer's unit two audio oscillators controlled by a single push button. These simultaneous tones upon passing through the mobile receiver produced an output from the "selective calling" decoder which rang the alarm bell.

Two vehicles were equipped with these alarm systems, one a front end loader and the other a "caterpillar" diesel, fitted to act as a snowplow. Because of the opposite polarity of the 24-V batteries in the two vehicles it was necessary to design and build two separate models of the bell ringing circuit.

Meteorological Telemetry System

The principal contribution of NRC to the avalanche control work in the Rogers Pass area was the progressive development of a meteorological telemetry system. Locations of the remote transmitting sites are shown on the map in Figure 7. The original requirement in 1958 was for measurement of wind velocity only, in 45^{o} steps, to be transmitted from one mountain peak to a base station in the valley. The only power source for the remote station was to be batteries which must last for the entire seven-month avalanche season. This power restriction dictated the use of transistors wherever possible in the equipment for use at the remote mountain peak location.

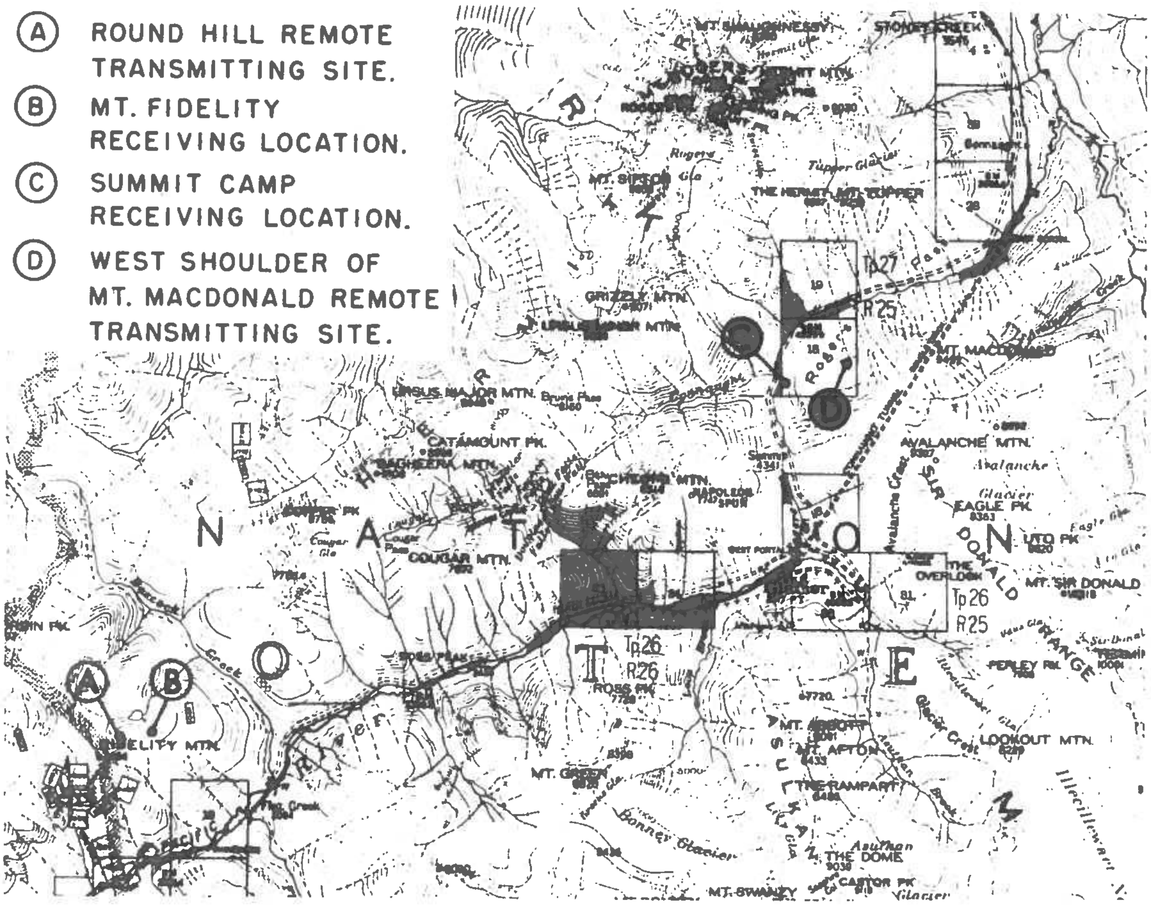


Figure 7
Map of a portion of Glacier National Park showing telemetry sites

Since the original path from peak to valley was not line-of-sight and high-frequency transistors were not generally available, a low RF of 1.65 MHz was chosen. Sequential tones (key+data) amplitude modulated the 2-W carrier to provide the instantaneous wind direction information for three seconds every five minutes. Each mile of wind passing the anemovane cups triggered a short two-tone sequential tone-burst from the transmitter. The number of these pulses recorded in any one-hour period provided the average wind speed in MPH during that time. A Wilcox vacuum-tube receiver demodulated the carrier and fed the resultant audio signal to a decoder chassis. Selective audio filters followed by thyratrons, relays, and a diode matrix drove the appropriate pens of a multi-pen E-A or standard DOT anemograph.

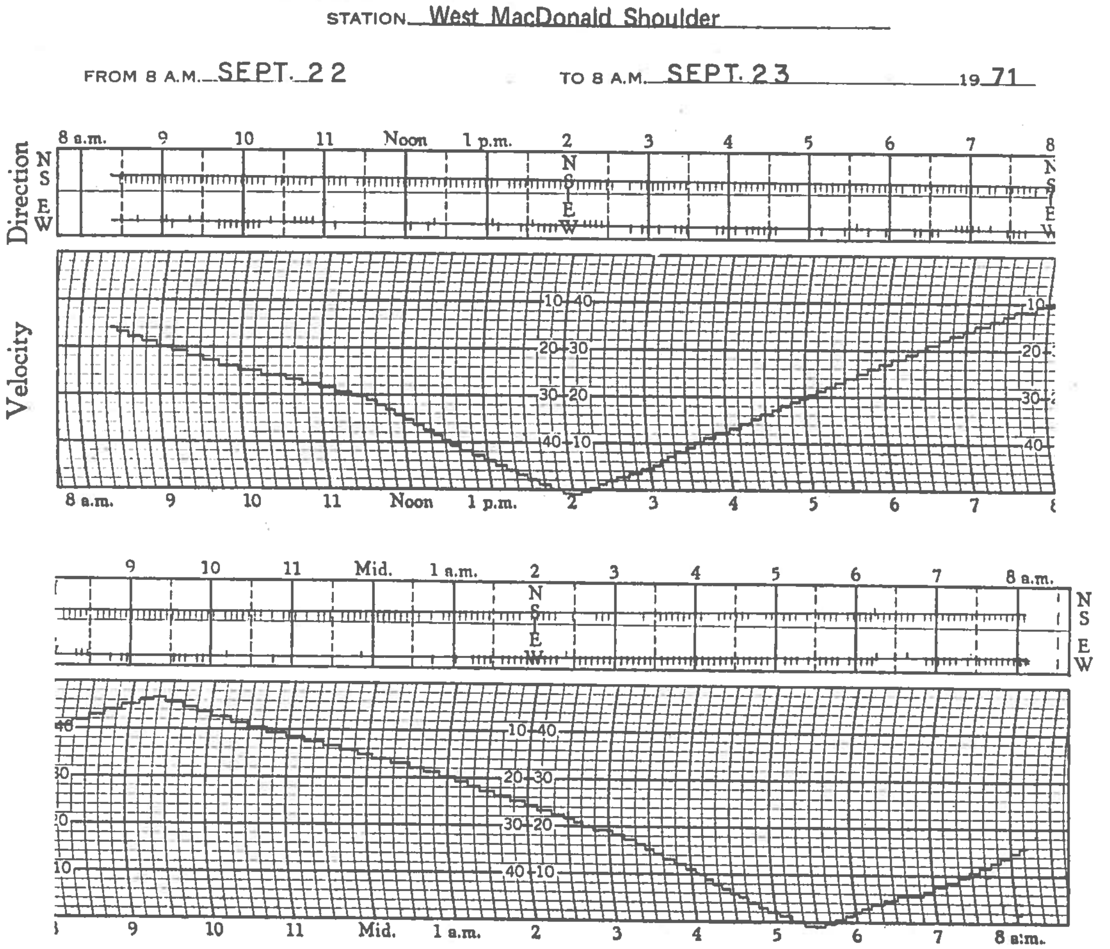


Figure 8

Sample of anemograph record

Much difficulty was experienced with icing of the anemovane when the remote telemetry equipment was situated on the South Peak of Mt. Fidelity (Plate 5). Several methods of de-icing were known at the time but any that were effective required a large amount of electric power, which, of course, was not readily available on a mountaintop.

A de-icing system was designed, built, and tested at NRC which used propane gas to heat an ethylene glycol solution. This was carried by thermo-syphon through insulated pipes to the critical rotating surfaces of the anemovane.

A unique ice sensor using the vane itself was developed which turned the catalytic burner off or on as required. The full report on this system is available in Report ERB-731.

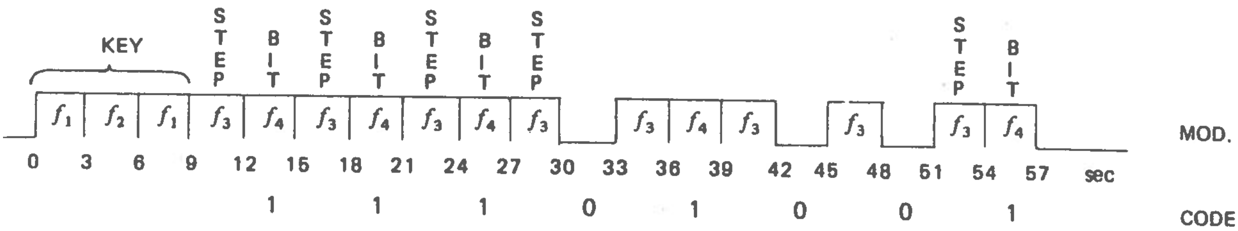
Unfortunately, just before this equipment was scheduled for field trials at Rogers Pass, it was decided for other reasons to move the station from the South Peak to another location in the same general area known as the Round Hill. The latter site had no icing problems so that no tests could be carried out under actual operating conditions. Tests carried out here at Ottawa, however, under severe icing (artificially induced) showed conclusively that the problem had been solved.

In 1960 the measurement of air temperature was provided, once an hour. An oscillator whose frequency varied with temperature (between 700 and 4100 Hz) acted as the transducer. The resultant audio tone was counted at the receiving site and displayed in binary form on a multi-pen E-A recorder.

Many problems were encountered in air temperature measurement using a frequency counting technique such as this. The unijunction frequency dividing circuits driven from a 100-kHz crystal oscillator and used to provide the accurate 1-sec gate needed for the binary counter proved balky at the higher temperature levels encountered in the receiving building. Flip-flops made up of discrete components also proved unreliable under similar conditions. It was not until the advent of integrated circuits that these problems were completely solved. Finally, false counts were produced whenever the signal became "noisy". Plans were completed to convert to a digital method of temperature and relative humidity data transmission when the project was terminated.

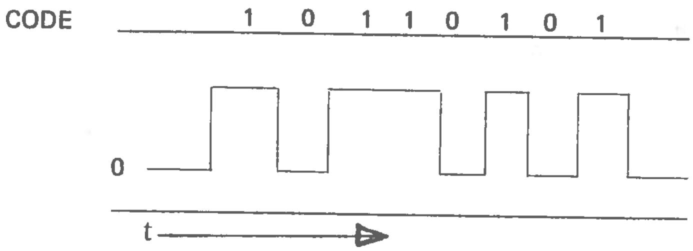
One more measurement, weight of precipitation, was requested and provided once every two hours during the winter of 1964-65. On the basis of simultaneous measurements made at other manned stations in the area, it was decided not to continue telemetering these data beyond one avalanche season since only minor differences in readings were noted between any of the locations. The sensor used was a standard Bendix Precipitation Gauge model no. 775C in which an 8-bit Gray Code analog-to-digital shaft encoder was geared to the pen driving mechanism. This gave a range of measurement between 80 and 9400 grams (0-12 inches of rain) with a resolution of about $\pm$ 25 grams ($\pm$ 0.03 inch of rain) over the whole scale. An anti-freeze solution was used to melt the snow as it fell into the gauge's collecting bucket.

A "Cyclonome" stepping motor was activated by a timer to sample in turn each of the eight outputs of the shaft encoder.



f_1 = 1200 Hz f_2 = 1500 Hz f_3 = 1800 Hz f_4 = 2400 Hz

These data were transmitted serially by the presence of a tone f_4 (binary 1) or the absence of it (binary 0). Another tone (f_3) was sent between each bit to step the ring counter at the receiver on to the next channel. A three-tone key (f_1, f_2, f_1) preceded the above sequence to reset the ring counter and set up the decoder circuits to handle the incoming data. (see above)



The binary count representing the weight of precipitation could be displayed either on 8 pens of a multi-pen recorder or a single pen recorder as shown above. The actual weight of precipitation contained by the gauge was then obtained by consulting a calibration chart.

The hourly measurement of relative humidity, begun in 1969, was the last new quantity requested. A commercial sensor provided a dc voltage output which varied between 0 and 5 volts as the relative humidity changed from 0 to 100%. This signal coupled to a VCO generated a frequency between 700 and 2000 Hz which modulated a transmitter. Data processing and display were handled in the same way as for air temperature.

The last avalanche season during which the NRC equipment was used at Rogers Pass was that of 1971-72 when the configuration shown in Fig. 9 was adopted. Details of the circuits are given in Figures 10-18.

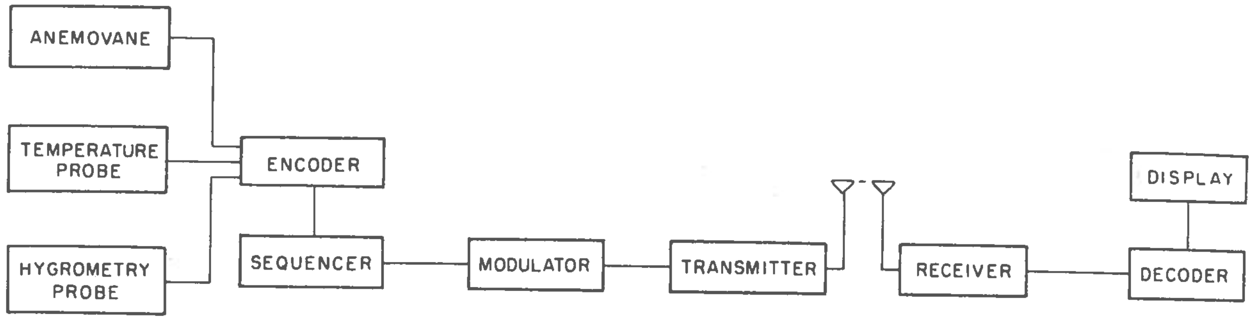


Figure 9
Block diagram of a meteorological telemetry system

Wind velocity, air temperature, and relative humidity were transmitted from the west shoulder of Mt. MacDonald and the Round Hill to both the Summit Camp and the buildings part way up Mt. Fidelity. Simultaneous tone modulation employing up to three tones was used to convey the wind velocity data on the RF carrier while the frequency counting technique described previously was used to transmit the air temperature and relative humidity measurements. A sample record is shown in Figure 19.

The original transmitter on Mt. MacDonald was a 2-W AM solid-state unit operating on 1.68 MHz capable only of transmitting to the Summit Camp, a distance of about 5,000 feet. It was replaced in 1968 by a 0.75 watt FM transmitter on 460.95 MHz working into a corner reflector having a gain of 8.7 dB. A similar antenna was used at Mt. Fidelity to receive the signals with a fiber glass whip sufficient for reception at the Summit Camp.

On the Round Hill a 1.5-W FM unit on 173.91 MHz feeding a 7.5 dB corner reflector sent data to the Summit Camp for reception by a 9.5 dB 6-element Yagi. Once again, a fiber glass whip was employed for reception on Mt. Fidelity.

Signals from a standby AM system on 219.4 MHz consisting in part of a 1.3-W transmitter and a 10.5 dB corner reflector were received at Mt. Fidelity on a whip antenna and at the Summit on a pair of 10-element stacked Yagis. Vertical polarization was used throughout with all frequencies. As well as these back-up systems for use in case of receiving equipment failures, a complete set of spare units was available for all the remote chassis in the 460-MHz and 174-MHz systems. See Plates 6, 7, and 8.

An interesting point is that the radio paths from the Round Hill to the Summit Camp and Mt. MacDonald to Mt. Fidelity were not line-of-sight. In each case a mountain peak served as a passive reflector with only a few dB change in path loss between winter and summer conditions.

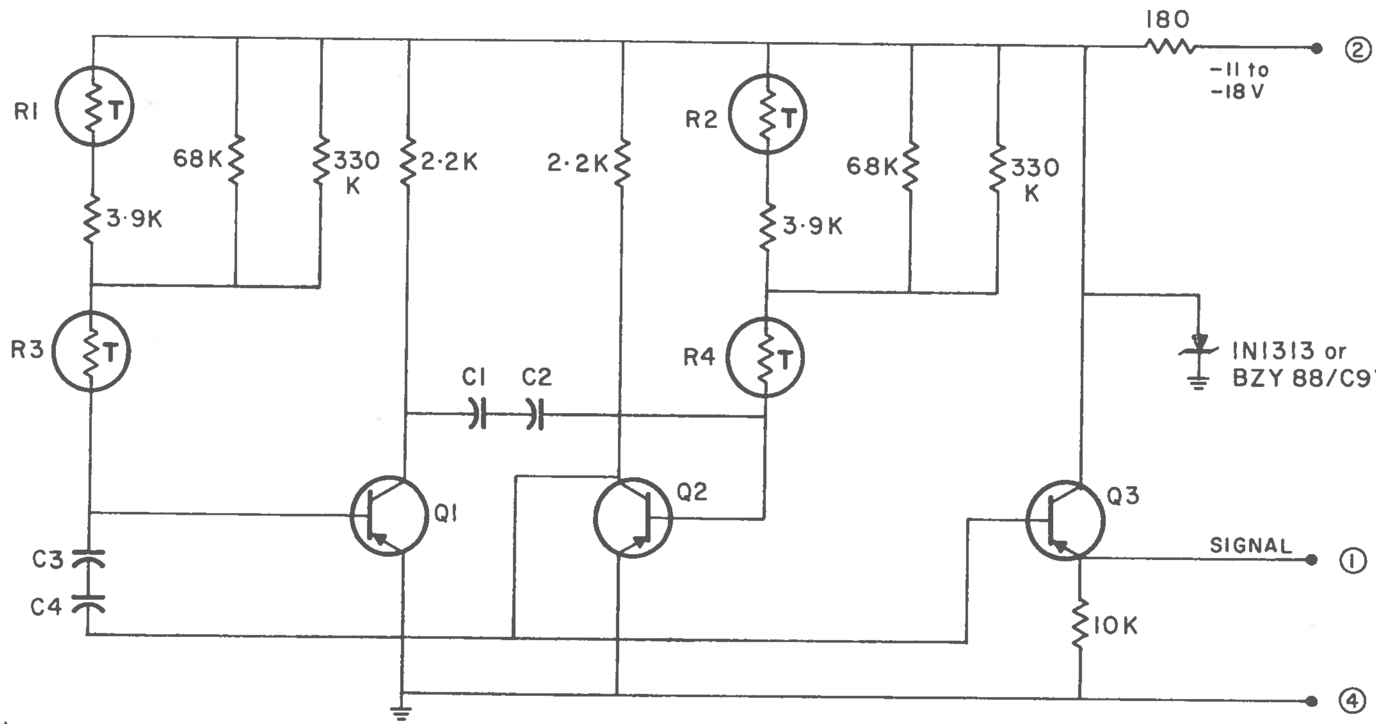
In the original 219.4-MHz transmissions from the Round Hill in 1966 a pair of stacked 10-element Yagis, complete with stacking harness, was used. A buildup of heavy wet snow and rime, common at that location in winter, resulted in a decrease in radiated signal strength of more than 15 dB compared with summer levels. The following year, however, when a corner reflector antenna with protected feed point was substituted for the Yagis, this loss was cut to 3 dB.

CONCLUSION

The equipment described in this report for several years provided data vital to the safe operation of a portion of the Trans-Canada Highway.

ACKNOWLEDGMENTS

The author wishes to express special thanks to Mr. R.A. Wright for his invaluable work over the years in the construction, environmental testing, installation, and maintenance of this equipment at Rogers Pass, B.C.



R1-R2-FENWALL RB38L1
8000Ω ± 10% AT 25°C

R3-R4-1000Ω ± 10% AT 25°C

Q1-Q2-Q3- 2N1307 (GA2684)

C1-C2-C3-C4-MALLORY MYLAR CAPS 1133
0·033μF, 100V

Figure 10

Temperature probe oscillator circuit

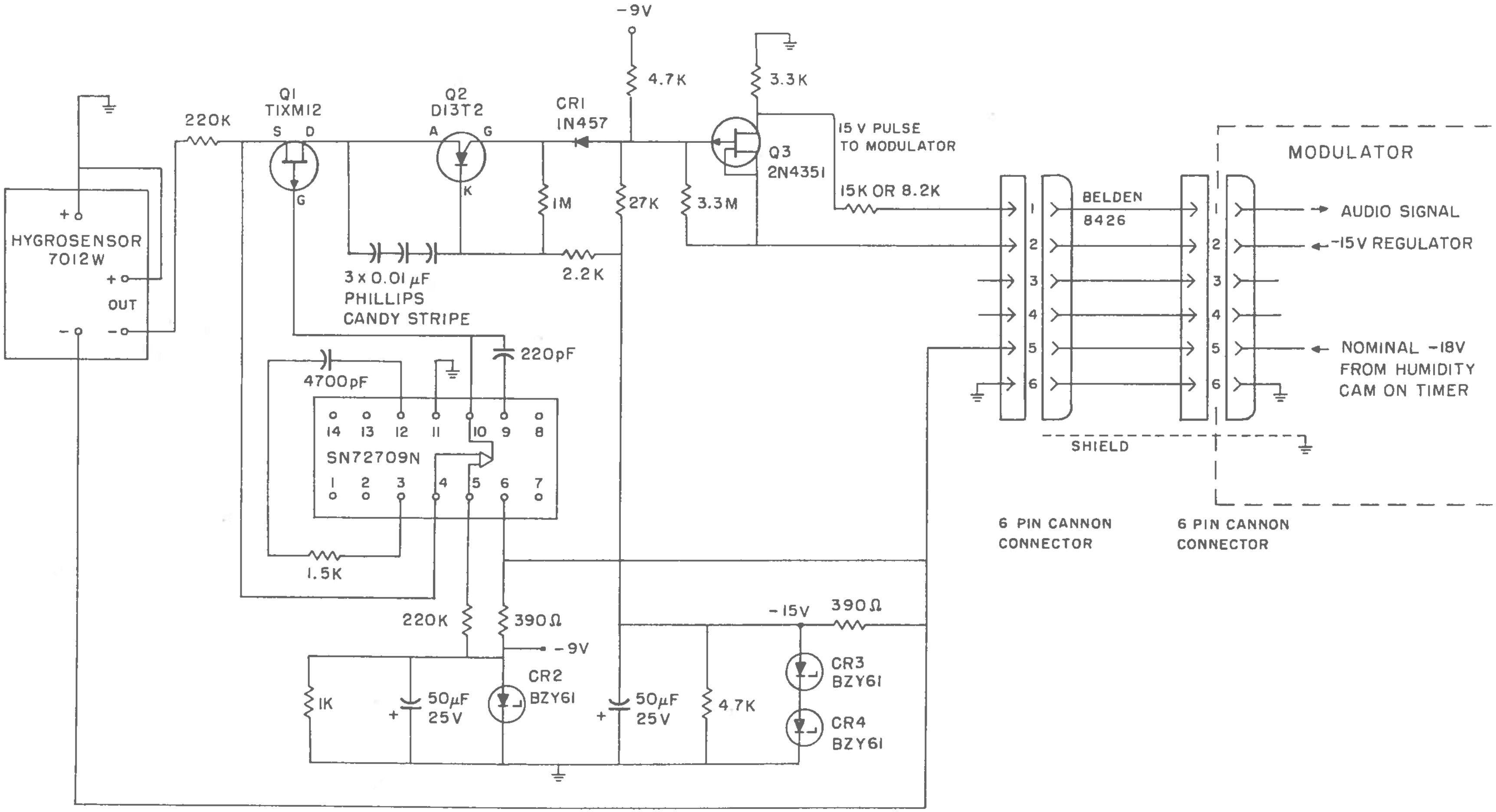


Figure 11

Humidity sensing circuit

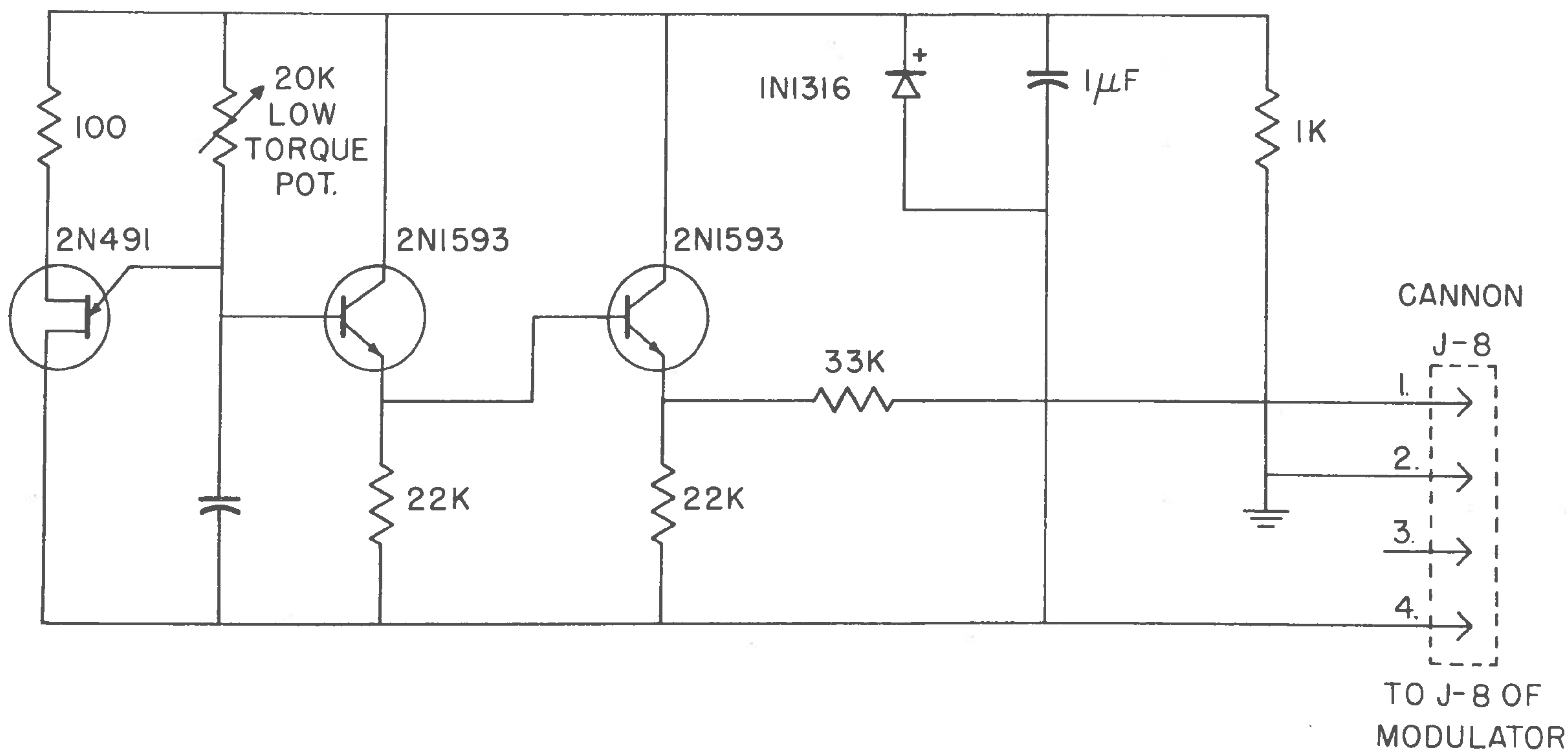


Figure 12

Precipitation oscillator circuit

ALL DIODES – IN4385
KI – SIGMA 22JNP3CC – 2500 – LS – SIL
M_1 – HAYDON K6359 – P6, $\frac{1}{3}$ RPM AT 45V D.C.

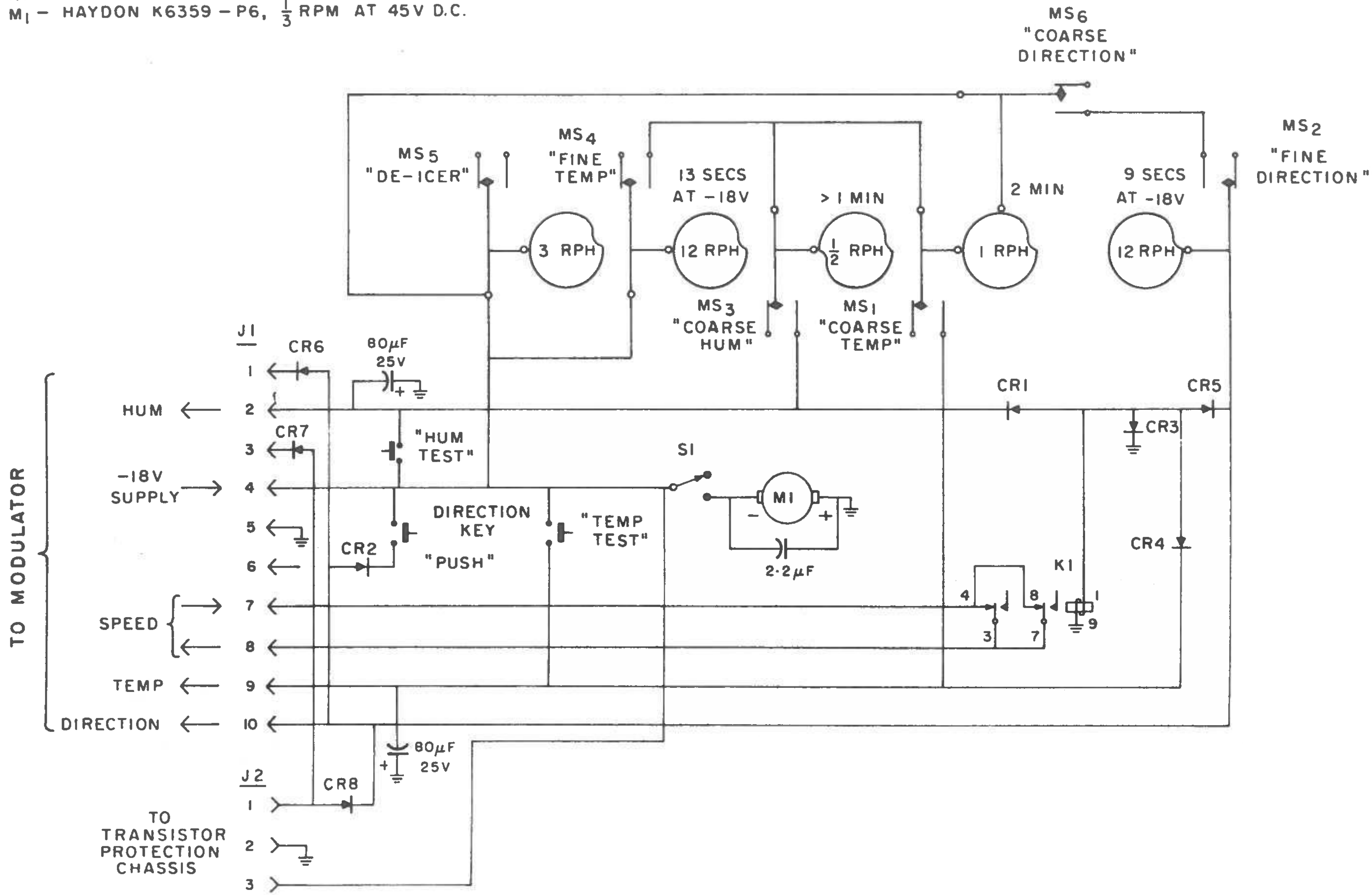


Figure 13
Telemetry sequencer

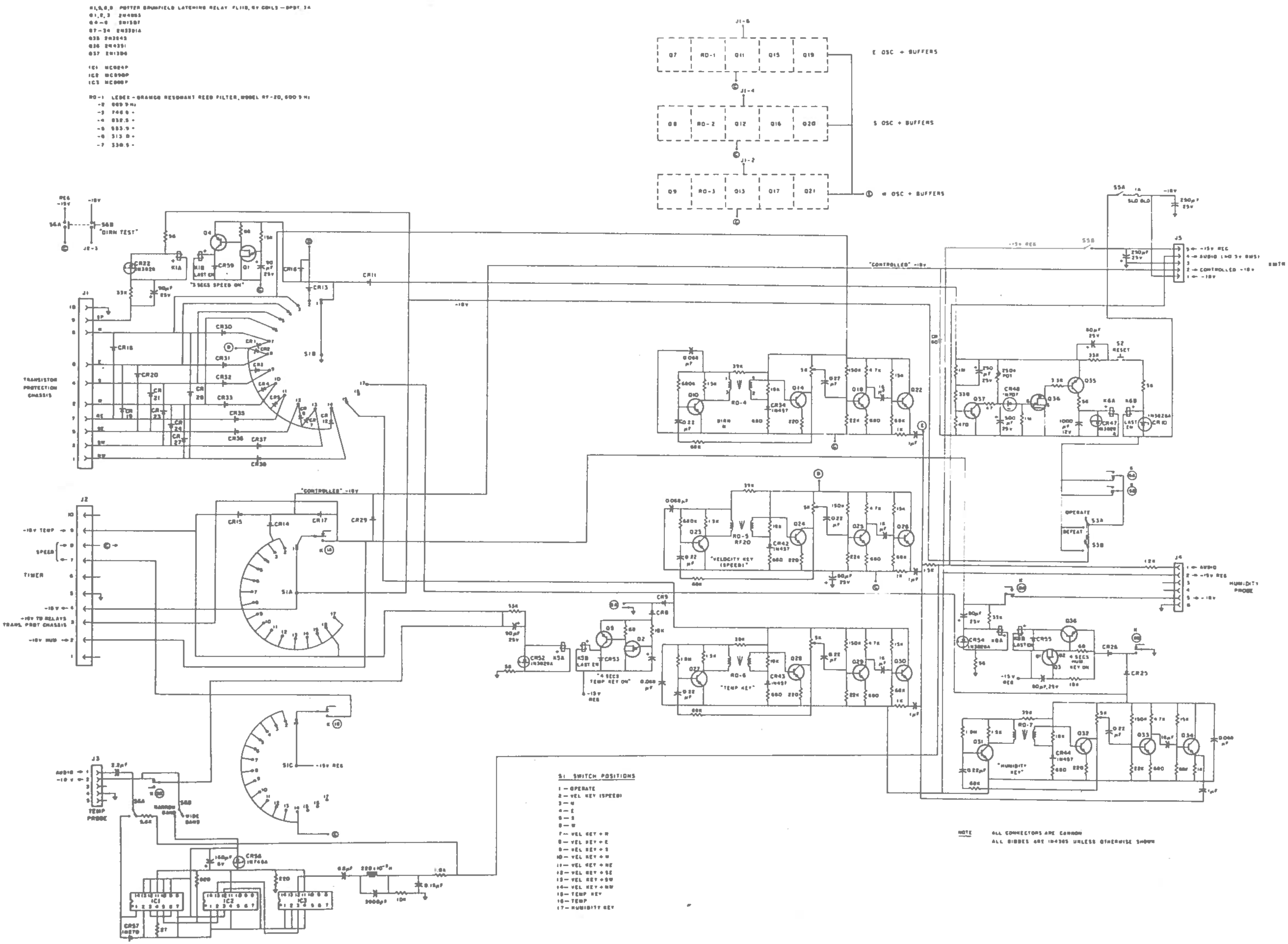


Figure 14

Simultaneous tone modulator

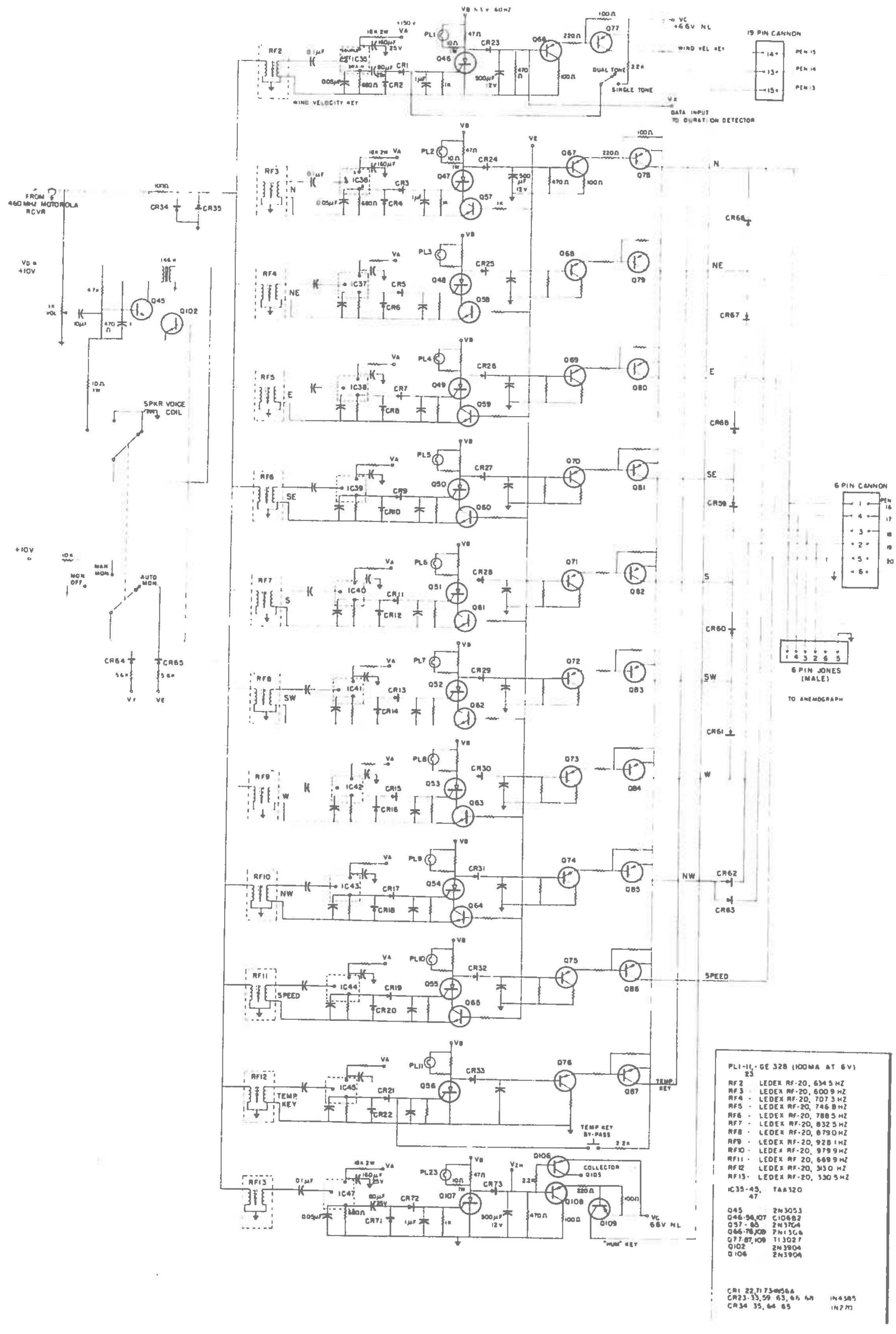


Figure 15
Wind velocity decoder and pen driver circuits

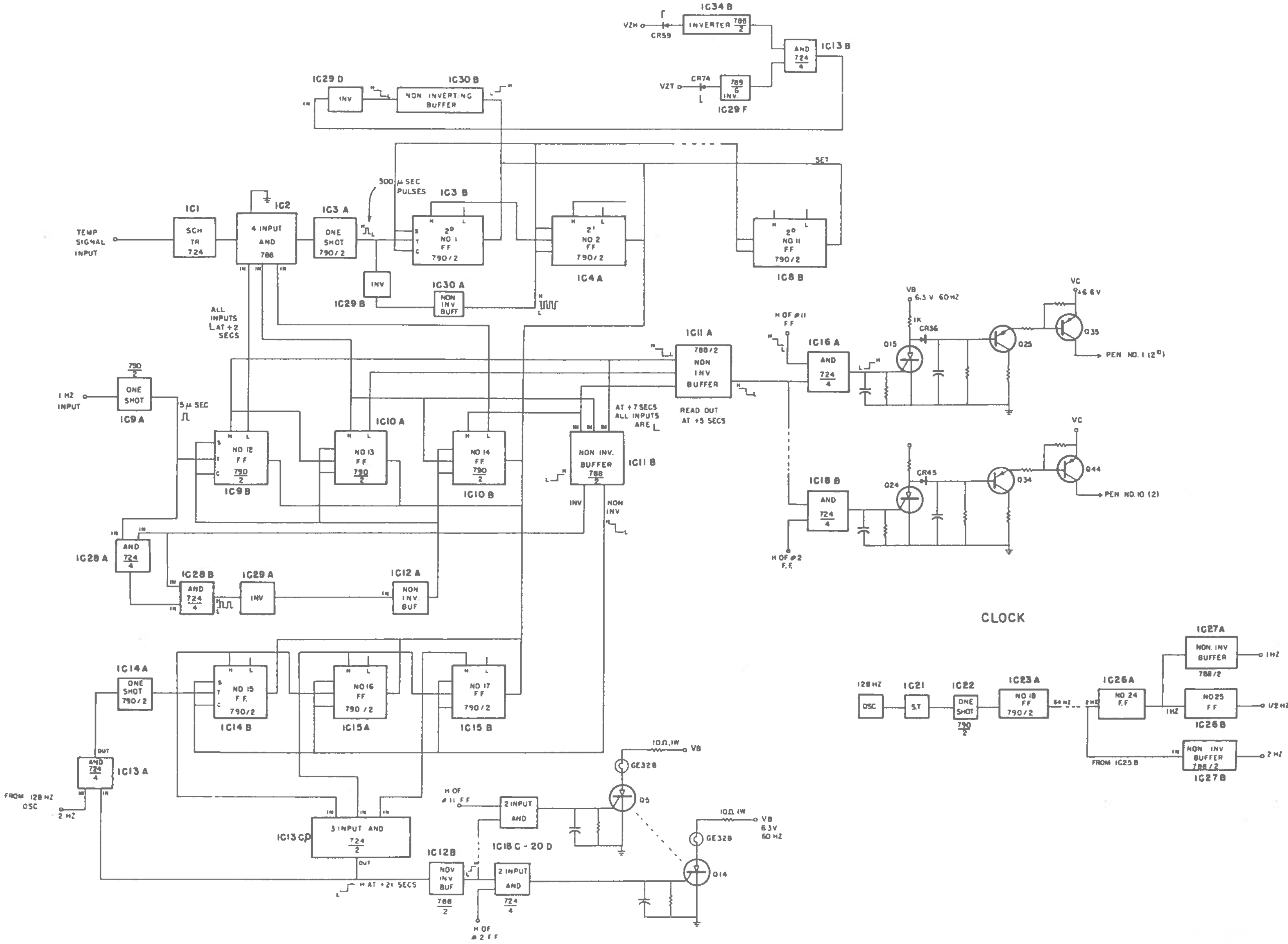
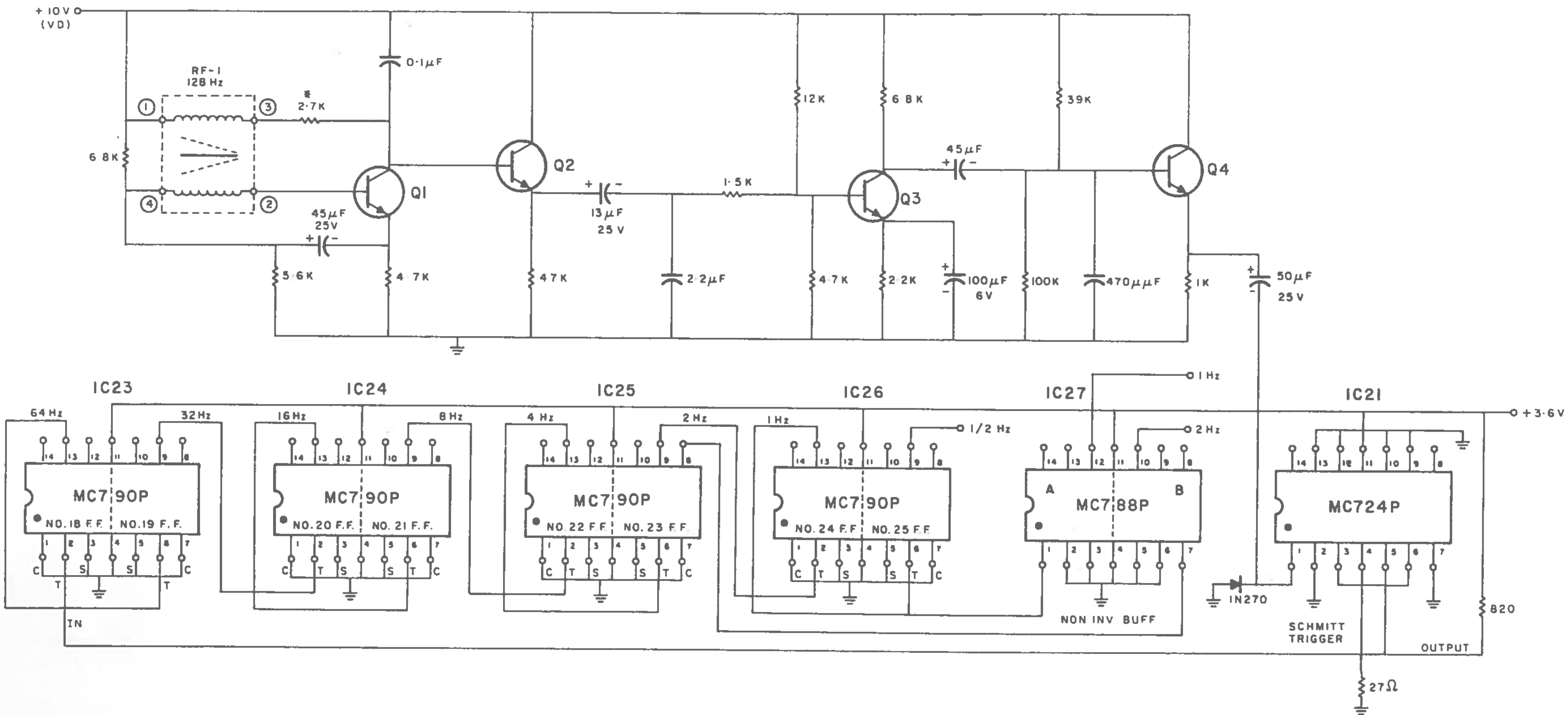


Figure 16

Block diagram of temperature decoder



Q1-Q4 - 2N3391A
RF-1 - LEDEX RF-20, 128 Hz
* ADJ. FOR 0·2 V RMS ACROSS ① & ③

Figure 17

Clock for temperature decoder

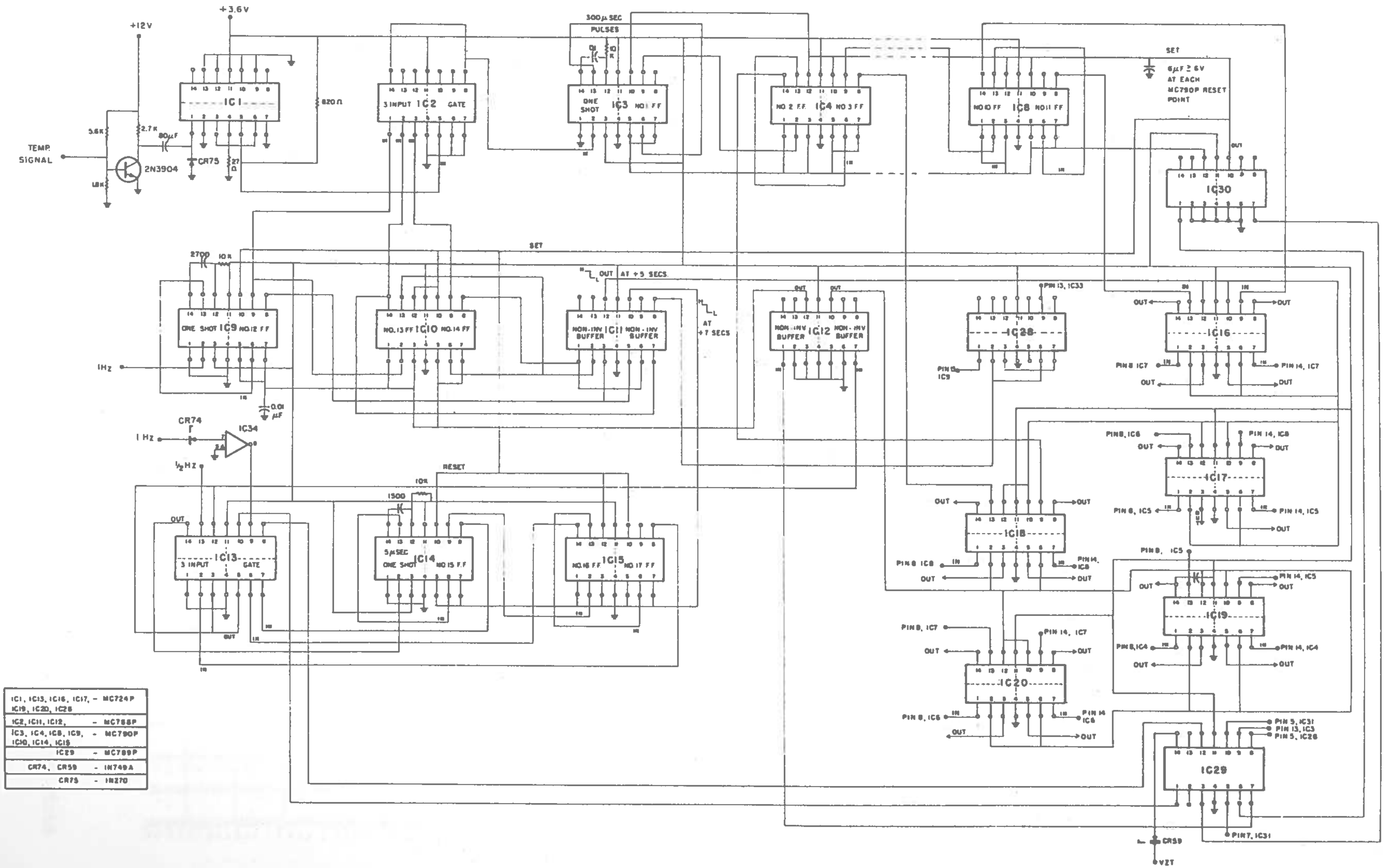


Figure 18

Temperature decoder circuit

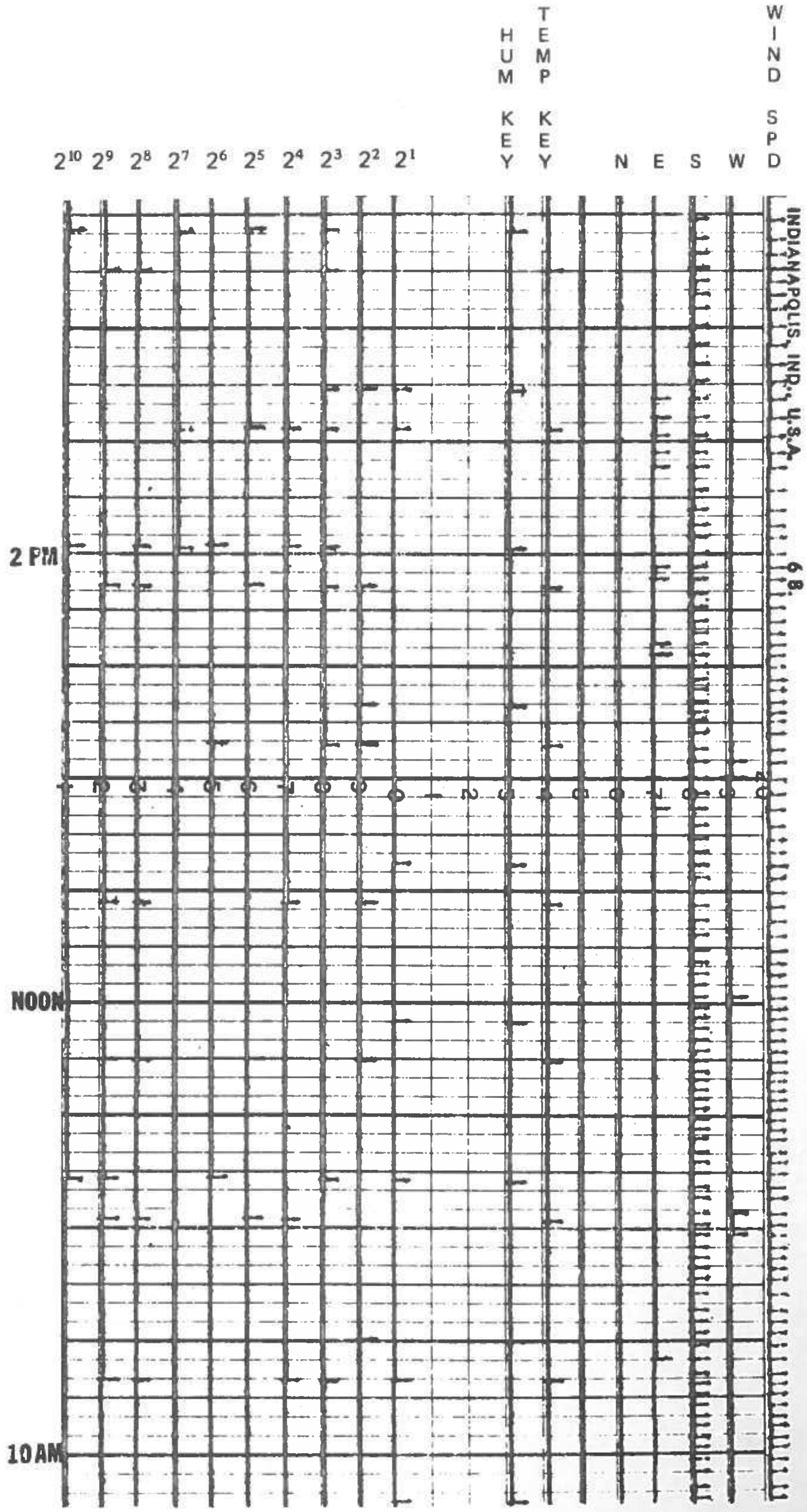


Figure 19

Sample of multi-pen record of meteorological data

Plate 1.
View of Trans-Canada highway from West shoulder of Mount MacDonald showing avalanche defences. Mounds and gun position along highway in lower left of photo.

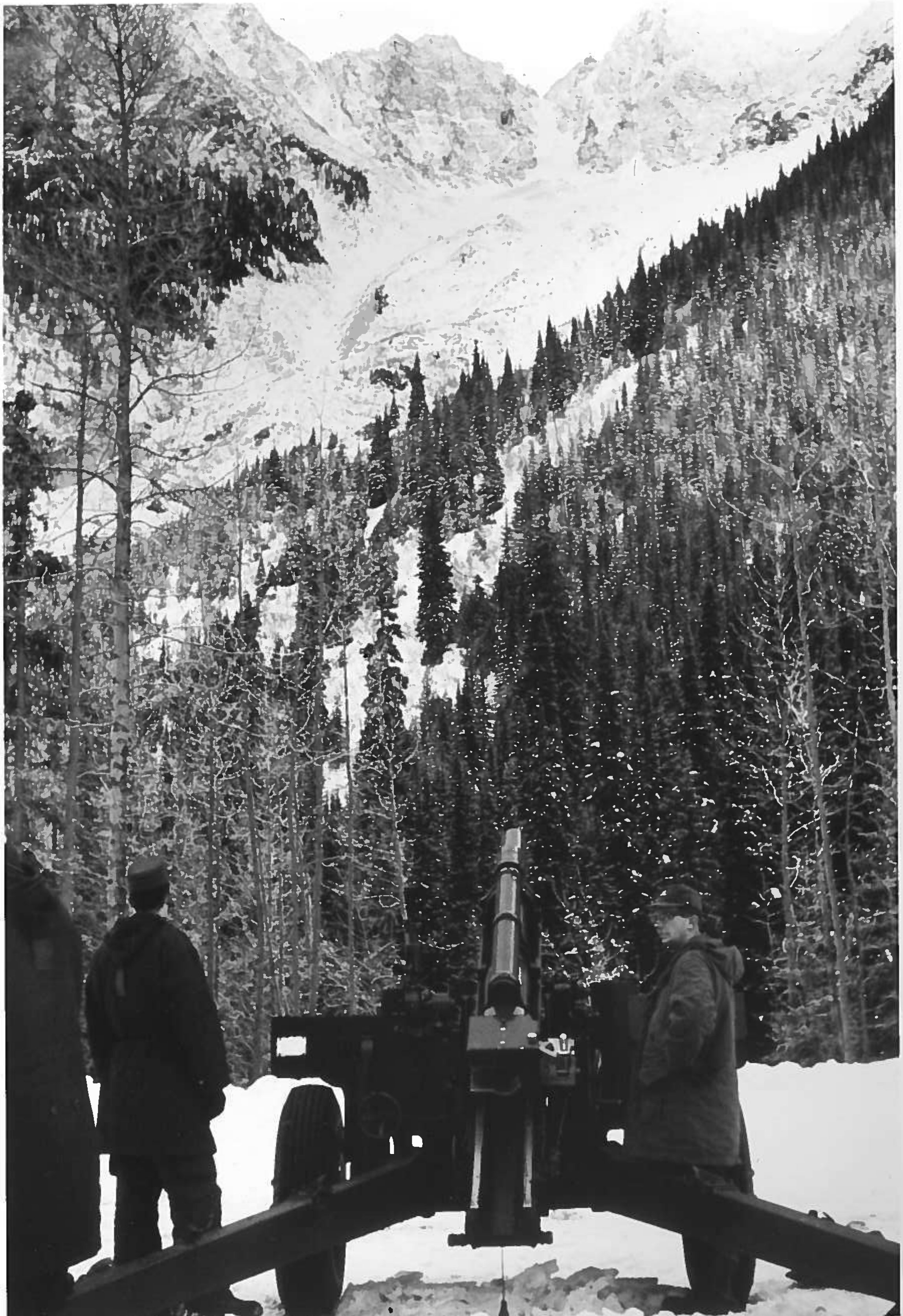
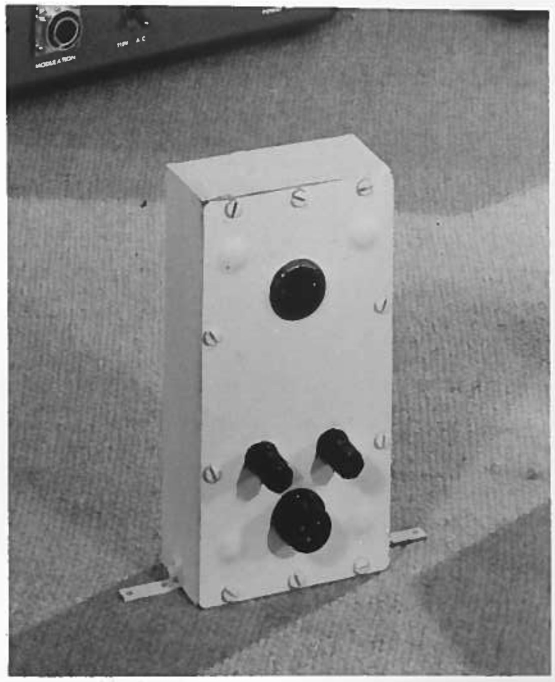


Plate 2.
105 mm. gun in position to fire a shell into an avalanche trigger zone



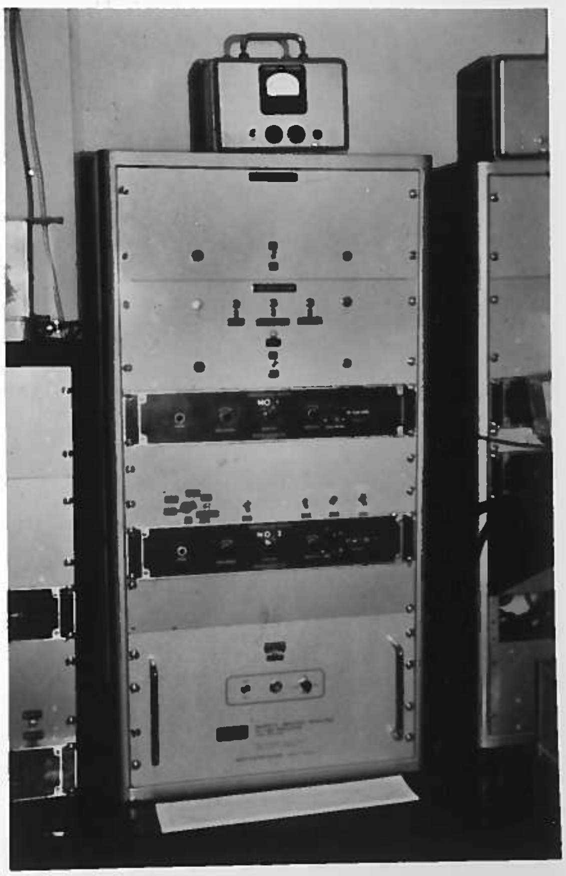


Plate 3.

Transmitting and receiving equipment for avalanche detector.

Above - transmitter

Upper right - photocell

Lower right - receiving equipment

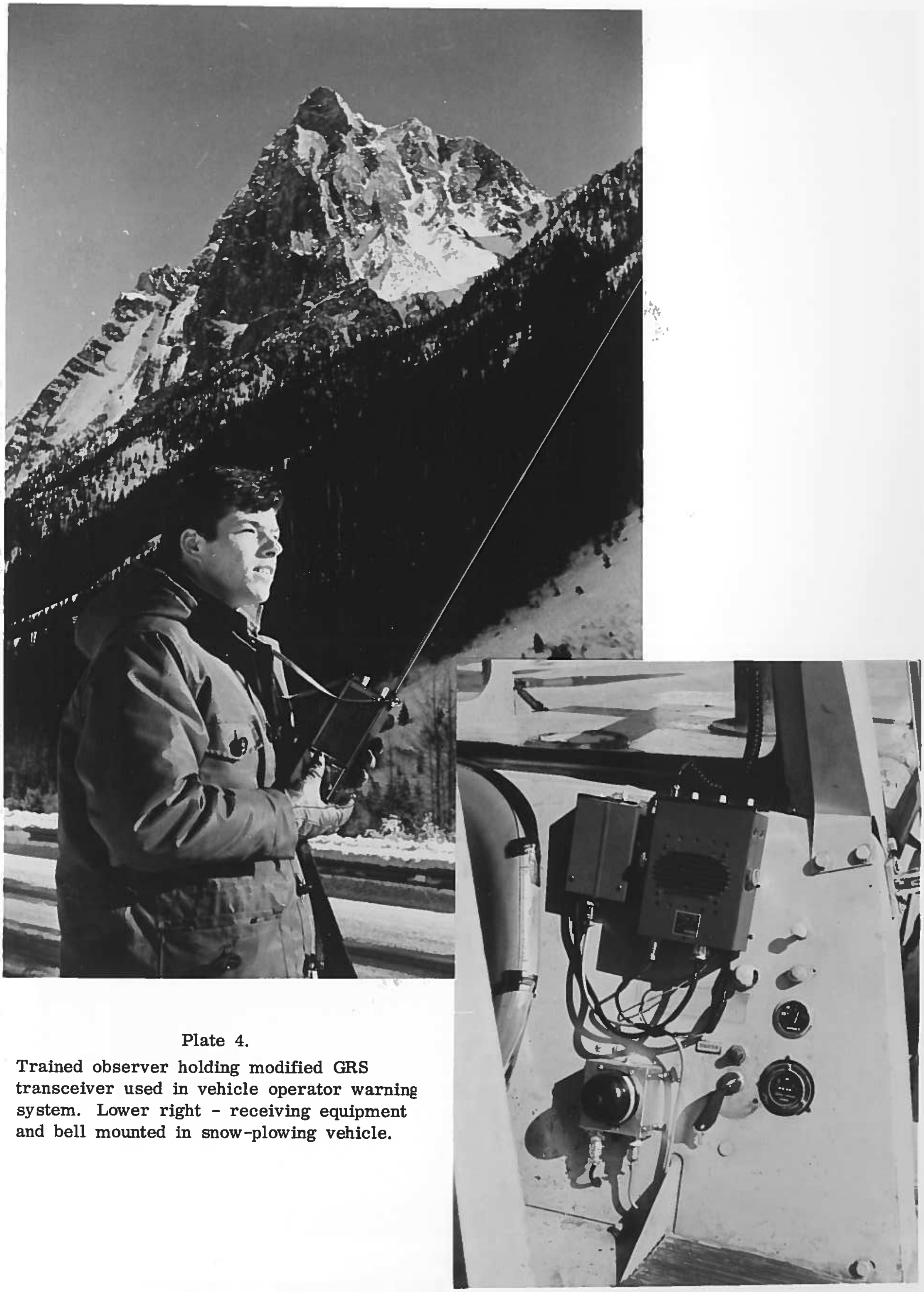


Plate 4.
Trained observer holding modified GRS transceiver used in vehicle operator warning system. Lower right - receiving equipment and bell mounted in snow-plowing vehicle.

Plate 5.

Two examples of anemovane icing conditions encountered at the South Peak of Mount Fidelity in Glacier National Park, B. C.

Plate 6.
West MacDonald Shoulder telemetry station

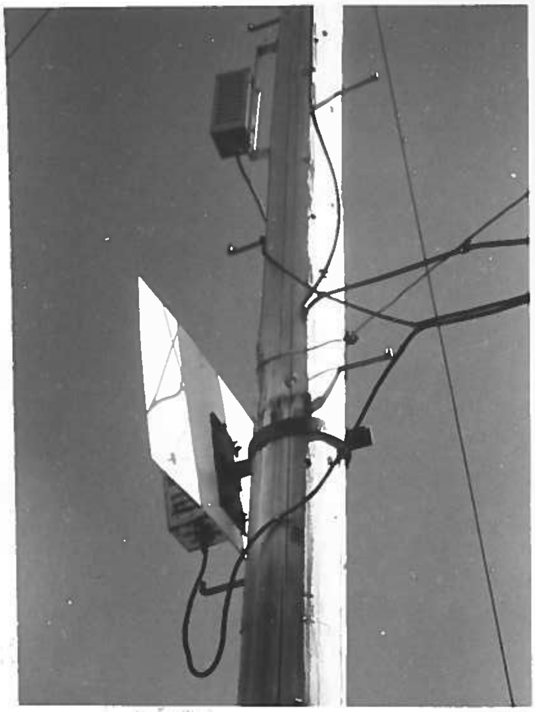


Plate 7.

Upper left - Remote telemetry transmitting equipment in operation West MacDonald Shoulder showing caustic potash battery Supply.

Upper right - Temperature and humidity probes.

Below - Remote transmitting equipment.

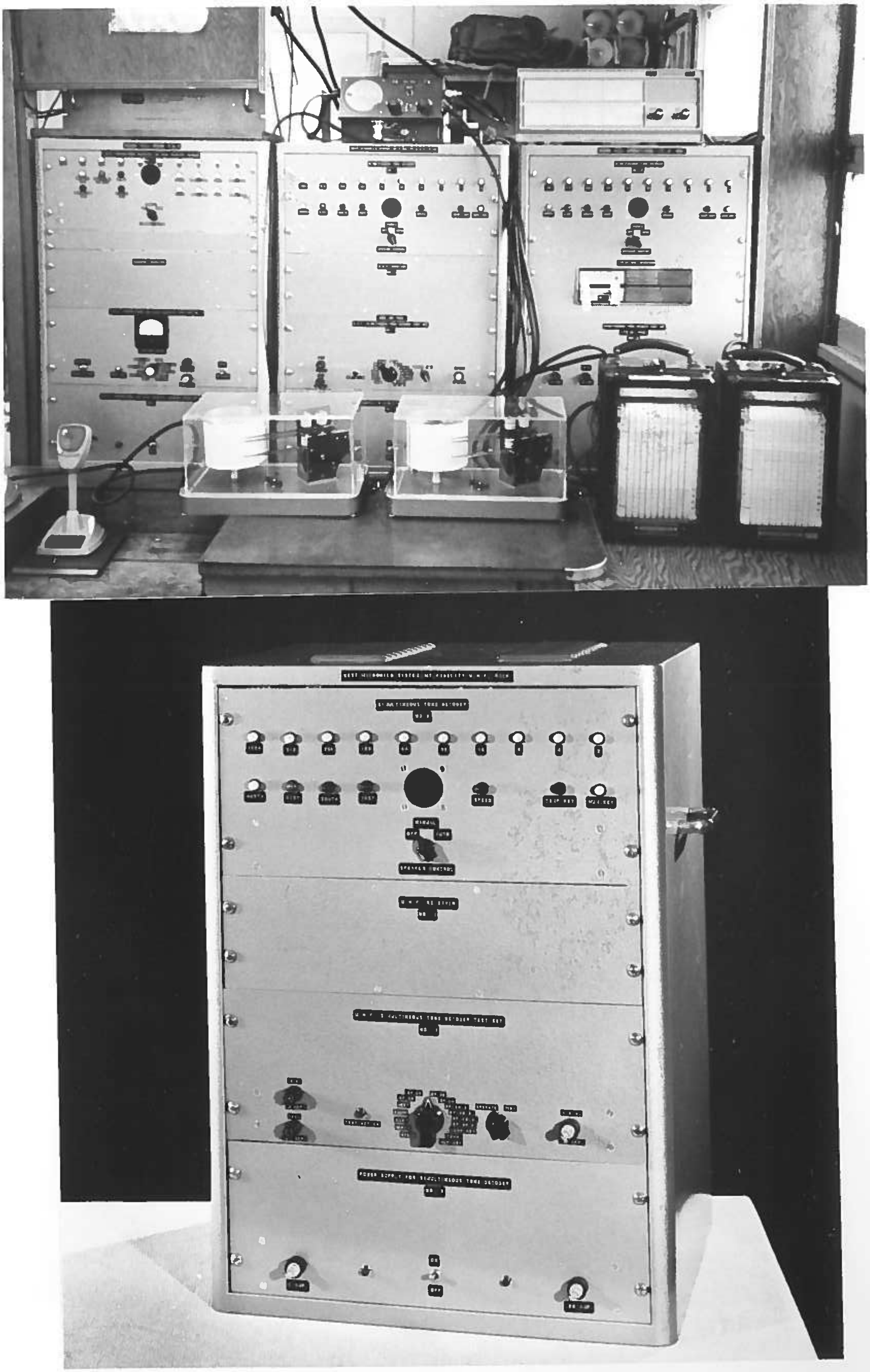


Plate 8.
Telemetry receiving equipment at Mount Fidelity

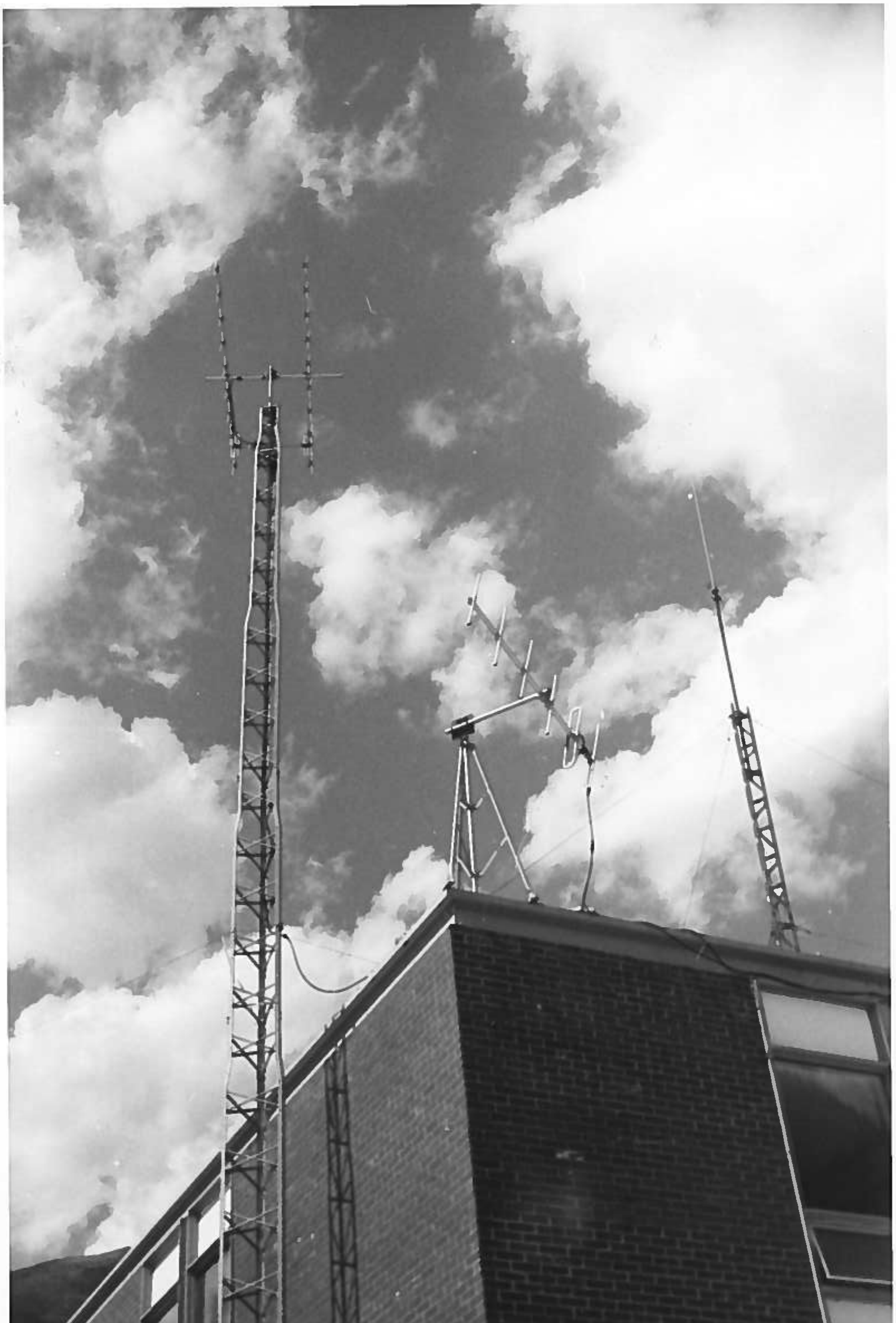


Plate 9.
Receiving antennas at Rogers Pass