PAP 63

A CODING DEVICE FOR TELEMETERING HYDROLOGIC DATA

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See Hyd. Lab Dwg & Data File 188
for more information and
Kuemmich draft of report on Design
& Development of System.

ABSTRACT OF PAPER

The telemetering of hydrologic data in some instances requires speed, accuracy, and dependability in readings. A system has been developed for a particular problem involving rainfall. The background, development, and application of the equipment is discussed in this paper.

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Introduction

This paper describes the purpose and function of the electronic coding device developed by the Bureau of Reclamation in its Engineering Laboratories at Denver, Colorado, as a feature of the system of six radio-reporting precipitation stations on the Bureau's Central Valley Project in California. The device is the core of the system, which literally reports a picture of the watershed conditions for a 4,500-square-mile area of the Sacramento River drainage basin, transmitting instantaneously to the project's operation headquarters data on when and where potentially flood producing rain has fallen.

Development of the electronic coding device arose from the necessity of recognizing the influence which flood flows from uncontrolled tributaries below Shasta Dam--a major structure on the Central Valley Project--exert upon the scheduling of releases of water from Shasta Reservoir. The locations of the tributaries with reference to Shasta Reservoir and to the main stem of the Sacramento River are shown in the accompanying map, Figure 1.

In the headwaters of the tributaries to the Sacramento River, slopes are steep, distances are short, and travel times of flood flows are apt to be of short duration. Engineers operating the Central Valley Project must recognize the occurrence of a major flood in an uncontrolled tributary and control releases from Shasta Reservoir so that releases from the reservoir do not combine with the natural flood peaks below to create potentially dangerous floods. As the difference in the travel times is short, it was necessary to install a radio-reporting, hydrologic-data-gathering network, governing remote precipitation stations.

With this instant coverage, Bureau of Reclamation project engineers are able to forecast flood peaks on the Sacramento River as much as 12 hours in advance, and to regulate releases from Shasta Dam. The radio-reporting system is helping greatly in the present flood control functions of Shasta Dam.

While the coding device was originally developed for use in the Sacramento River drainage basin of the Central Valley Project, eventually its use will be extended to other river basins of the project.

The unique characteristics of the device also offer promise of widespread application and usefulness in related engineering and scientific fields.

Rain Gage Network

The six radio-reporting rain gages, located at strategic points in the remote mountains on each side of the Sacramento River Valley provide a warning of several hours before the run-off becomes evident in the river. They are located on Cow, Battle, and Deer Creeks on the east side of the valley and on Clear, Cottonwood, and Elder Creeks on the west, Figure 1.

Operationally, each station transmits a radio signal beamed to relay station on Bass Mountain, northeast of Shasta Dam. The information is relayed to the control room in the powerhouse. The output of the receiver in the powerhouse is applied to the vertical plates of an oscilloscope for reading. Each station may be called by transmitting a signal from the Bass Mountain station modulated by a preset audio frequency. A standby receiver in the rain gage station applies the audio frequency to a resonant reed relay and initiates a transmission for a predetermined period of time.

Components of Gaging Station

Figure 2 shows a view of the Elder Creek Station. The radio antenna is of a corner type, providing a beam approximately 60° wide and is directed toward Bass Mountain. Line of sight transmission for the 172 megacycle signal is realized at five of the stations, and a quarter watt transmitter was used. At the sixth station, Clear Creek, more power was required to deliver a usable signal. A twenty-five watt transmitter was used last season. Ten-watt transmitters are being purchased for installation this fall at all stations.

Figure 3 is a closer view and gives more detail of the outside of the station. A Weather Bureau reconnaissance-type recording gage with an Alter type windshield is shown at the left. It has been in operation for several years to collect rainfall records and to correlate the radio reporting station to a standard.

The windshield mounted on the roof was designed and tested in a wind tunnel by the University of Idaho at Moscow, Idaho. A new design was necessary on account of the size and shape of the shelter.

It was decided to heat and insulate the shelter, thereby increasing the efficiency of the batteries used for operating the equipment. Thermostatic control keeps the temperature of the shelter above 40° F. A tank of propane fuel, sufficient for operation during one season is used to fire a wall type heater.

An exchanger was designed and built in the Denver laboratories to transfer heat from the wall heater to the rain gage intake so that snow will be melted and drop into the catch bucket for measurement. The heat exchanger is a sealed vapor system and uses one of the Freon refrigerants. It absorbs heat in a copper tube coil around the heater flue and gives up the heat from a copper tube coil around the rain gage intake.

The precipitation accumulates in a catch bucket mounted on the platform of a commercial, pendulum, indicating-type scale for weighing. The capacity of the scale is 125 pounds which corresponds to about 65 inches of rainfall, based on the standard 8-inch diameter intake orifice.

Figure 4 shows the coding device mounted in place on the rear of the scales and coupled mechanically to the indicator shaft.

Coding Device

Figure 5 shows the coding device proper. Starting at the bottom right of the picture is a photocell enclosed by a fixed cylinder with a slot parallel to its axis and directed toward the light source; around the left end of the fixed cylinder is a positioned cylinder with two 3/4-inch, 180° helices; a disc which is rotated by a motor; a small "indexing" step disc coupled mechanically to the positioned cylinder through a gear train and a light source-lens combination which produces a narrow ribbon of light extending radially from the center of the rotating disc and along the slot in the fixed cylinder. A two-stage resistance-capacitance coupled preamplifier is used to match the photocell impedance to the radio transmitter.

The layout of the coder is shown in Figure 6. In one semicircle of the driven disc is a spiral slot, the extremities having a 3/4-inch difference in radial spacing. The two extremities of the spiral are adjusted so they coincide with the extremities of the 3/4-inch helices of the positioned cylinder. In the other 180° of the disc are two series of holes. The inner set of 11 holes is on a constant radius about a quarter inch greater than the maximum radial distance of the spiral. The light that passes through these holes is outside the influence of the movable cylinder. These are the calibration holes. The outer set of holes, which are slightly smaller than those in the inner row, are on a spiral. Each hole is spaced circumferentially midway between the second to eleventh holes of the inner row respectively, and may be blocked out by the small indexing step disc. The indexing step disc contains 10 equal steps on its outside diameter which match the increment in radial spacing of the spiral holes on the motor-driven disc and is synchronized with the positioned cylinder through a gear train. The axes of all components lie in the same plane.

Figure 6 also shows the path of the light beam, which is focused on the slot in the fixed cylinder. During one-half revolution of the motor-driven disc, light will fall on the photocell when a hole coincides with the fixed slot, and then for a short interval of time, producing a pulse of electric current in the photocell proportional to the size hole in the rotating disc. Eleven pulses are formed within the 180° of rotation of the disc with the first and last pulses higher in amplitude than the other nine. The larger pulses are used for synchronizing the oscilloscope. It is assumed that in this condition, the indexing holes are covered by the step disc. During the other 180° of rotation of the driven disc, the spiral intersects the light ribbon and produces a spot of light that scans the fixed slot searching for the helix on the positional cylinder, since light falls on the photocell only when the spiral on the disc and the helix on the positioned cylinder coincide. In this manner, a pulse is formed with a time lag that is dependent on the angular displacement of the movable cylinder or proportional to the value of the measured quantity. This pulse is referred to as the intelligence pip.

As the positioned cylinder is rotated beyond the range of the first helix on the cylinder, the second helix takes over, the indexing disc advances one step, and one indexing hole is uncovered. The uncovered hole allows a pulse to appear on the oscilloscope in the middle of the second space. Thus, the range of the coding device is extended. The range of a single spiral is 10 units, each index pip when present, represents 10 units.

Oscilloscope Picture

The entire trace produced in one revolution of the driven disc is shown in Figure 7. All calibration pulses and three of the indexing pulses are present in the first half of the pattern, and the intelligence pulse shows in the second half.

If the oscilloscope sweep is adjusted for two sweeps per revolution of the disc, i.e. synchronized on pulses one and eleven as noted before, the pattern shown in Figure 8 is produced. The reading from the oscilloscope pattern is roughly 37.5 inches. In order to read it closer, the trace can be expanded as shown in Figure 9. With a scale mounted on the face of the oscilloscope, a reading may be taken to the nearest five-hundredths of an inch of precipitation regardless of the amount of water accumulated. The true reading then is 37.55 inches. The difference between periodic readings gives the incremental rainfall.

Development Problems

The requirement of being able to read storm increments to 0.05 inches over a range of 65 inches eliminated several principles which were first considered. On the basis of direct deflection of a meter, for instance, an accuracy of one part in 1,300 would be necessary. Such a degree of accuracy wasn't practicable under the maximum range of expected temperature variations, long time operation, and with the required stability. A method whereby a calibration or scale would be transmitted with the measurement of the unknown and on a single channel of communication was desirable. No switching or contacts were to be used in the coding mechanism. Since the information is used in the operation of the Central Valley Project, ease and speed in reading was more important than a permanent record. A reading is taken in 70 seconds. Since the equipment in the station would be powered entirely by batteries, low current drain is a necessity. The coder requires about 15 ampere-hours in a month's operation.

The motor for driving the disc was set for 900 revolutions per minute, or 15 revolutions per second. The trace on the oscilloscope will therefore have a repetition frequency about equal to the retentivity of the eye of the operator. The fundamental frequency of the calibration pulses is about 300 per second, since 10 pulses are formed in one half of a revolution of the disc. Three hundred cycles per second is the lower limit for the audio section of the radio transmitter. To reproduce a pulse on the oscilloscope at the control station equivalent to the input pulse at the transmitter, it was assumed that the tenth harmonic of the fundamental was required. The tenth harmonic of the fundamental is 3,000 cycles per second, and the required range of 300 to 3,000 cycles per second matches the band width of a standard communications transmitter and receiver. Tests were made with a General Radio Wave analyzer on the signal and the results show that the tenth harmonic was down 40 decibels from the fundamental, and therefore contributes but slightly to the wave shape of the pulse. There should be no interchannel interference caused by the signal. A test was made by listening on a receiver tuned to an adjacent channel. No interference was noted when the modulation was properly adjusted. The speed of the motor is not critical as the oscilloscope can be synchronized over a wide range of frequencies. Accuracy of the reading is the same, regardless of motor speed. The characteristics of the motor involve a comparatively high starting torque to come up to speed quickly and remain constant during the read out time. Motor manufacturers have had difficulty in meeting the speed, torque, and power requirements for the motor.

The torque requirements for rotating the positioned cylinder have been held to approximately one-half an ounce-inch. Ball bearings are used throughout. To further reduce friction losses, the bearings were cleaned in carbon tetrochloride and lubricated with a small amount of a silicone product.

The ribbon of light was produced by use of a long filament instrument lamp and a cylindrical lens. A fairly uniform intensity of light was produced and the amplitude of the intelligence pulse remain constant, within reason, throughout its sweep.

The principal difficulty has been with the photocell. The sensitive coating on the cathode is not uniform and therefore the size of the intelligence pulse varies appreciably as the positioned cylinder is rotated. By selecting a photocell with a nearly uniform coating, and use of a dispersion film, oiled paper for instance, proper and consistent response is realized.

Operational Experiences

In the past season, there were six rain gage stations operating for 155 days each, or an aggregate of 930 station-days. A total of 73 days were lost. This corresponds to an operational efficiency of 93 percent. None of the days lost could be traced to the coder. The four difficulties in operation were with discharged standby batteries, broken antenna leads, faulty station selective circuits, and burned-out radio tubes. There was sluggish operation of the weighing mechanism in part of the stations which can be traced to the dashpot in the scales or to friction in the coding device which is somewhat critical since there is a very high ratio of turns in the rotating cylinder to the vertical motion of the platform.

Acknowledgments

The author expresses his appreciation to the following Bureau of Reclamation engineers: Mr. M. H. Blote and Mr. H. M. Posz of the Sacramento office of the Bureau for their enthusiastic support in developing the coding device; to Mr. D. B. Sturtivant and Mr. R. H. Mix of the Shasta Dam Division for overcoming the operation difficulties; to Mr. W. U. Garstka of the Hydrology Branch in Denver for his support and valuable suggestions; to Mr. D. J. Hebert, and especially Mr. R. H. Kuemmich of the Bureau's Engineering Laboratories in Denver who contributed so much to the method, construction, and fine workmanship in developing the coding device.

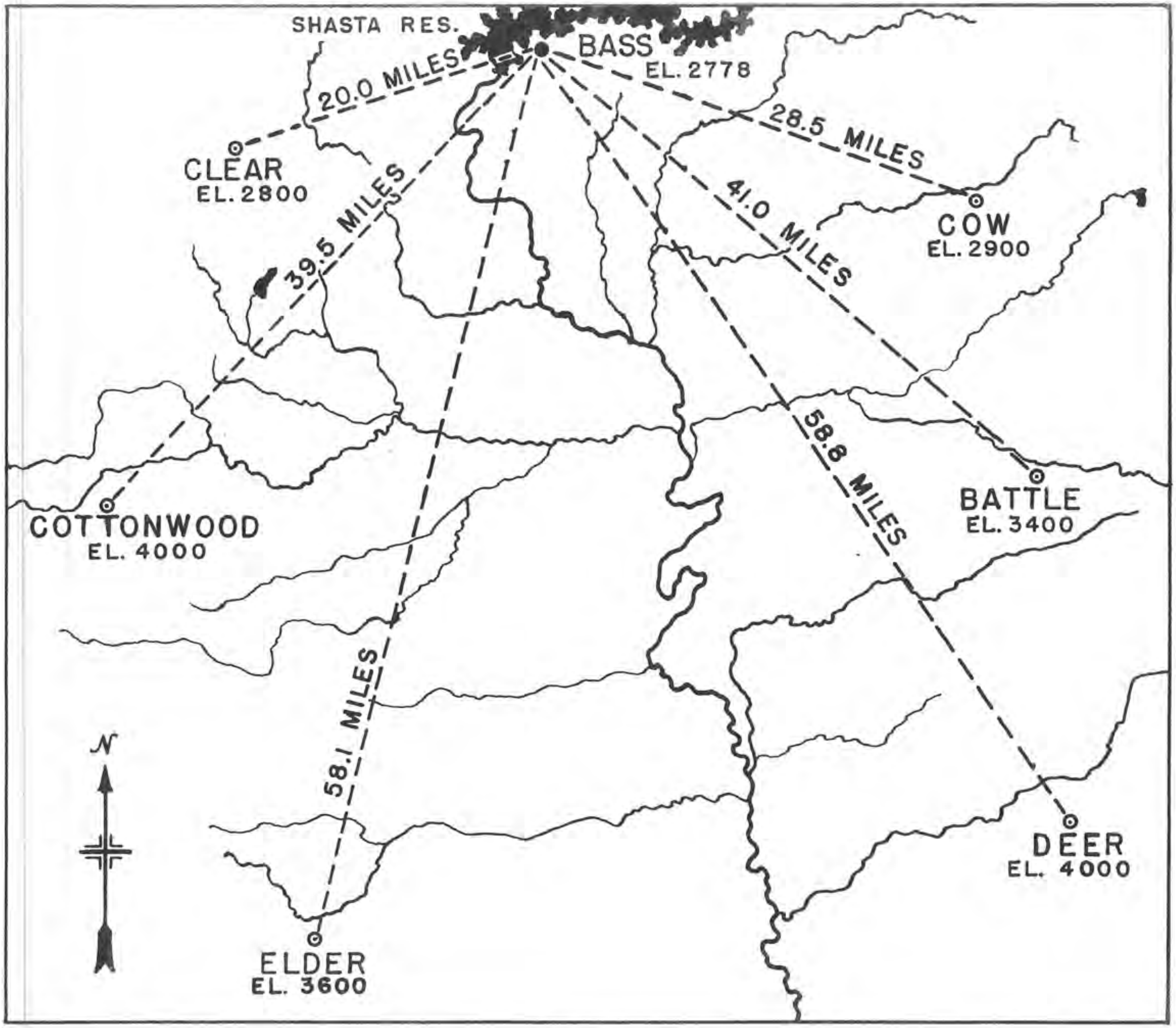

Figure 1. A map of the Sacramento River, tributaries, and rain gage

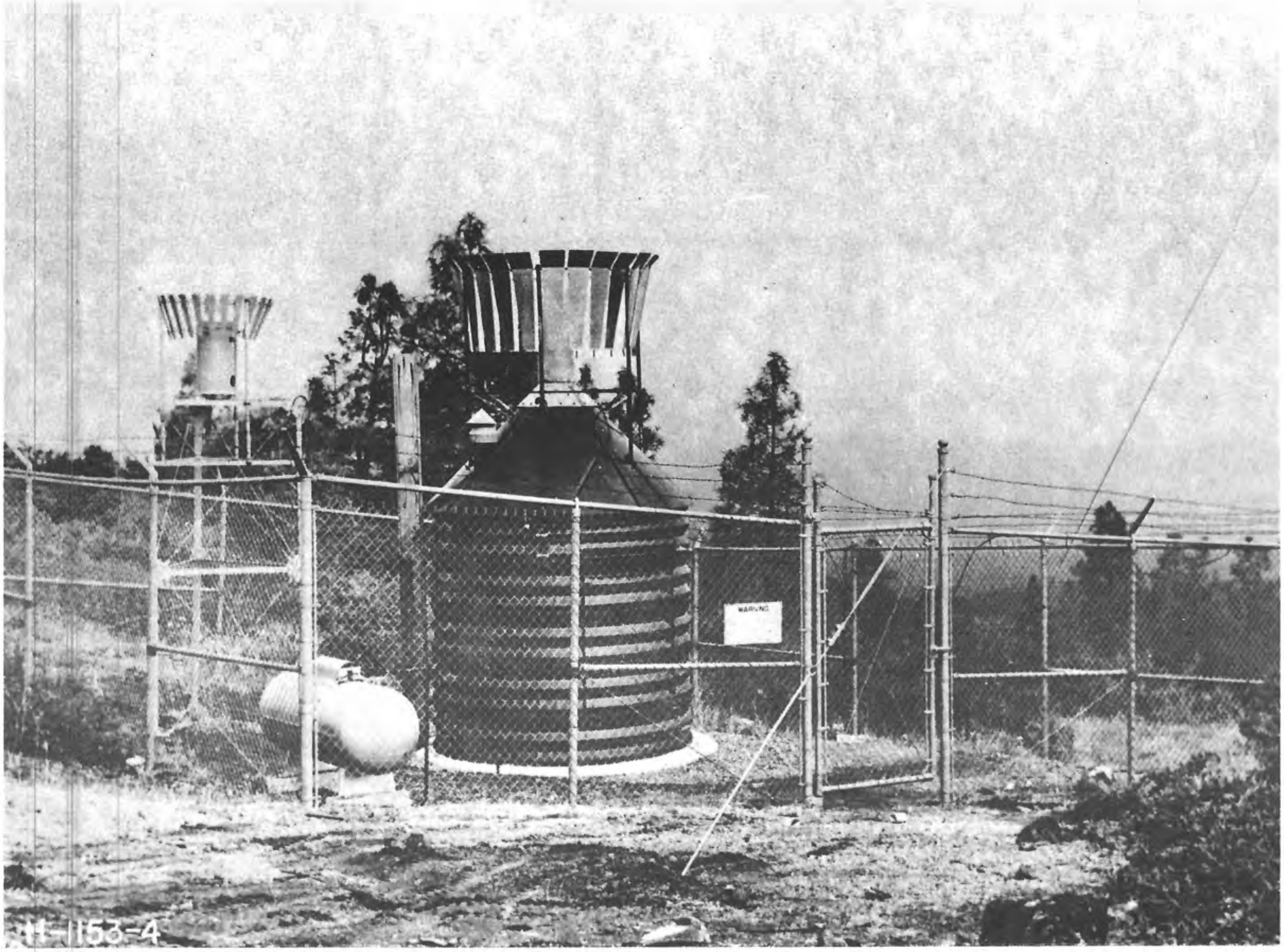

Figure 3. Closer view of rain gage station--Elder Creek.

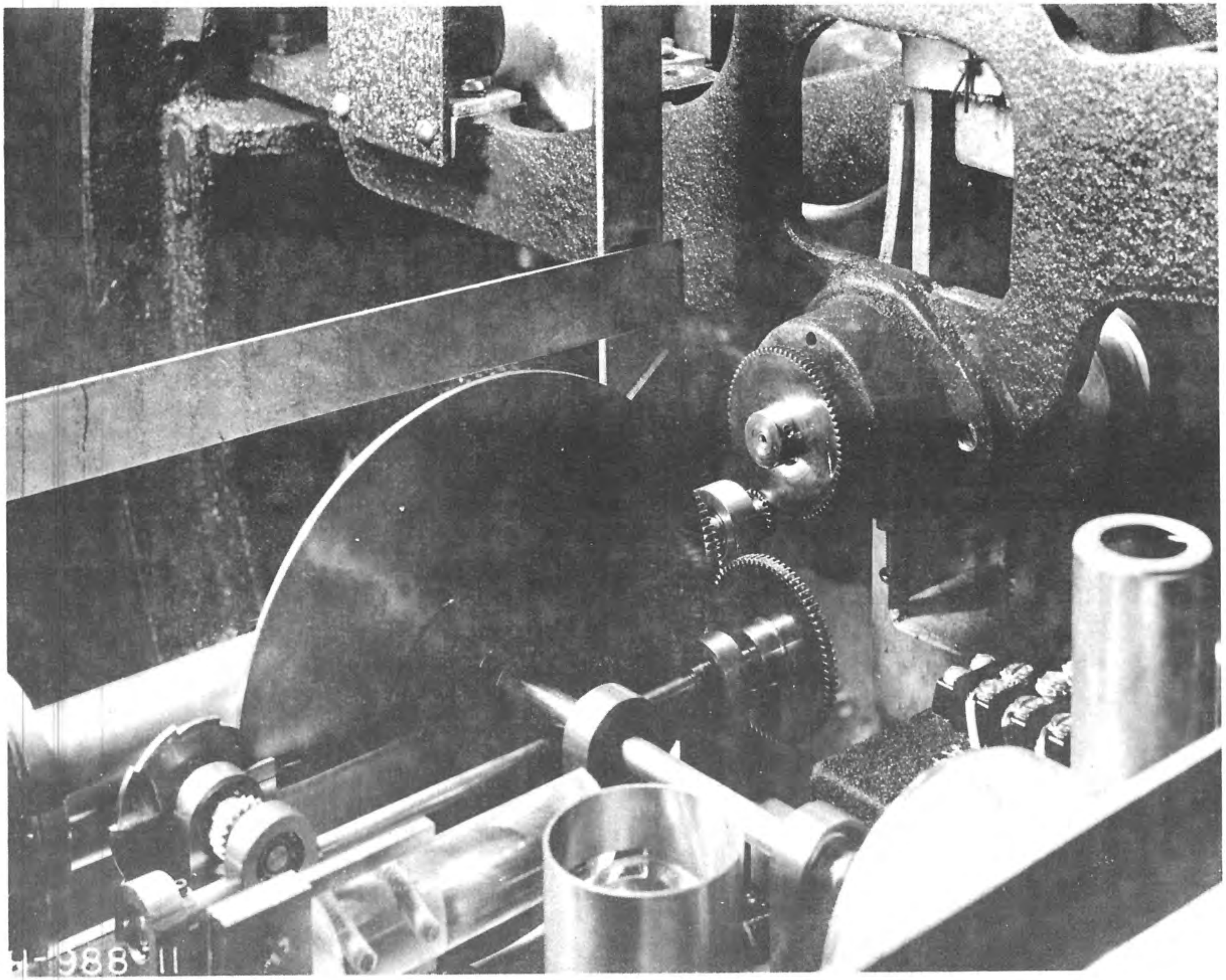

Figure 4. Coding device mounted on scales.

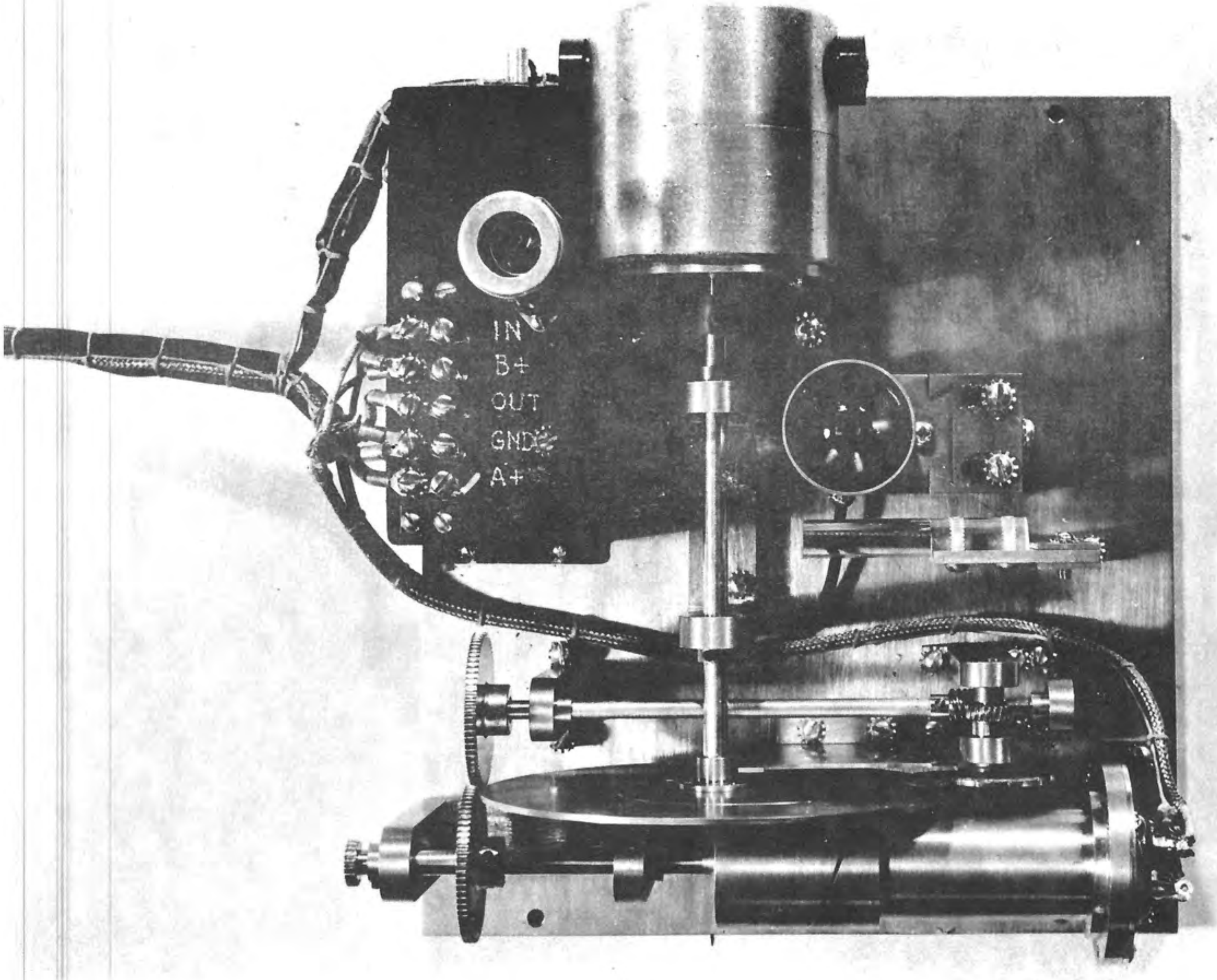

Figure 5. Coding device viewed from above.

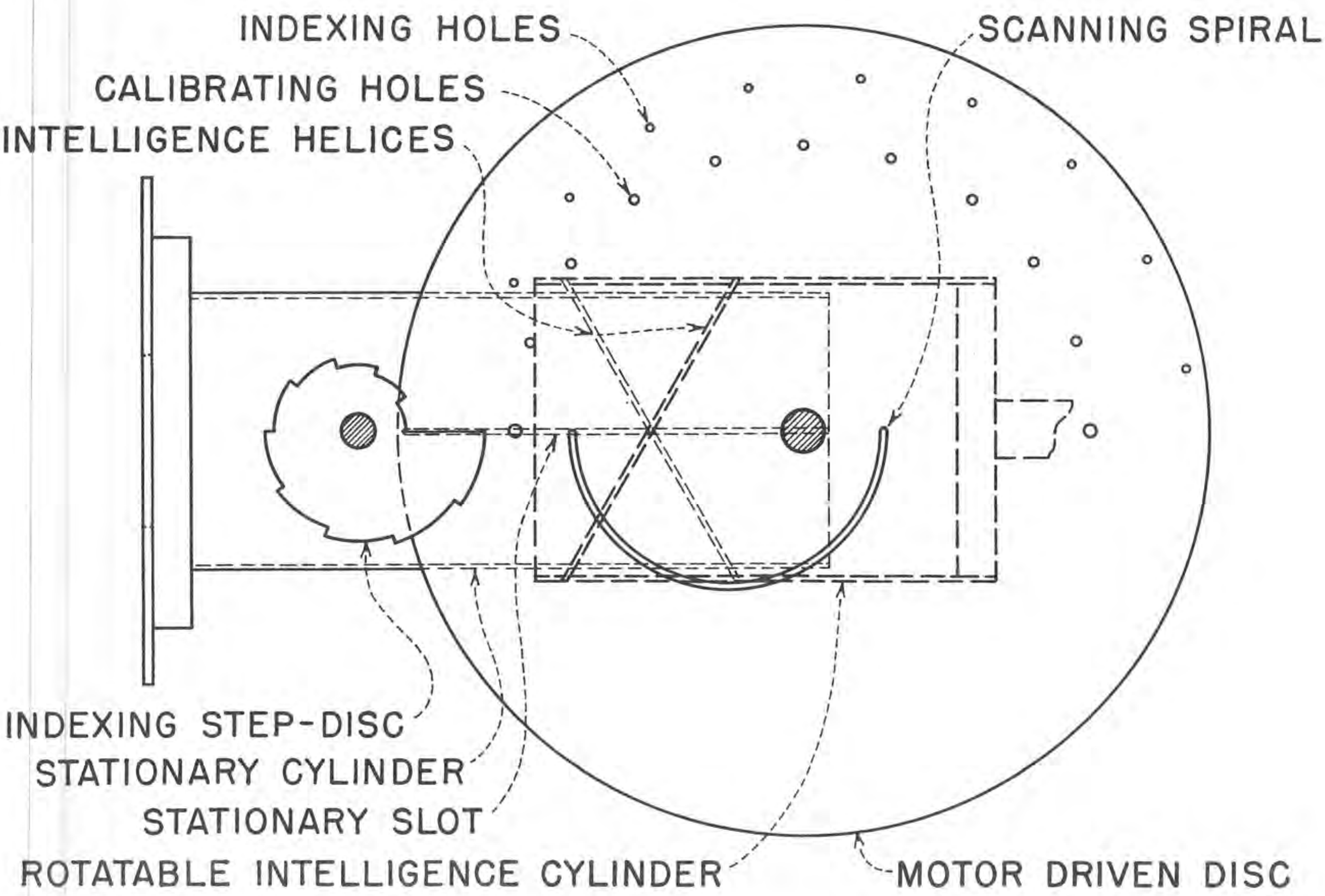

Figure 6. Details of driven disc and relationship to other components.

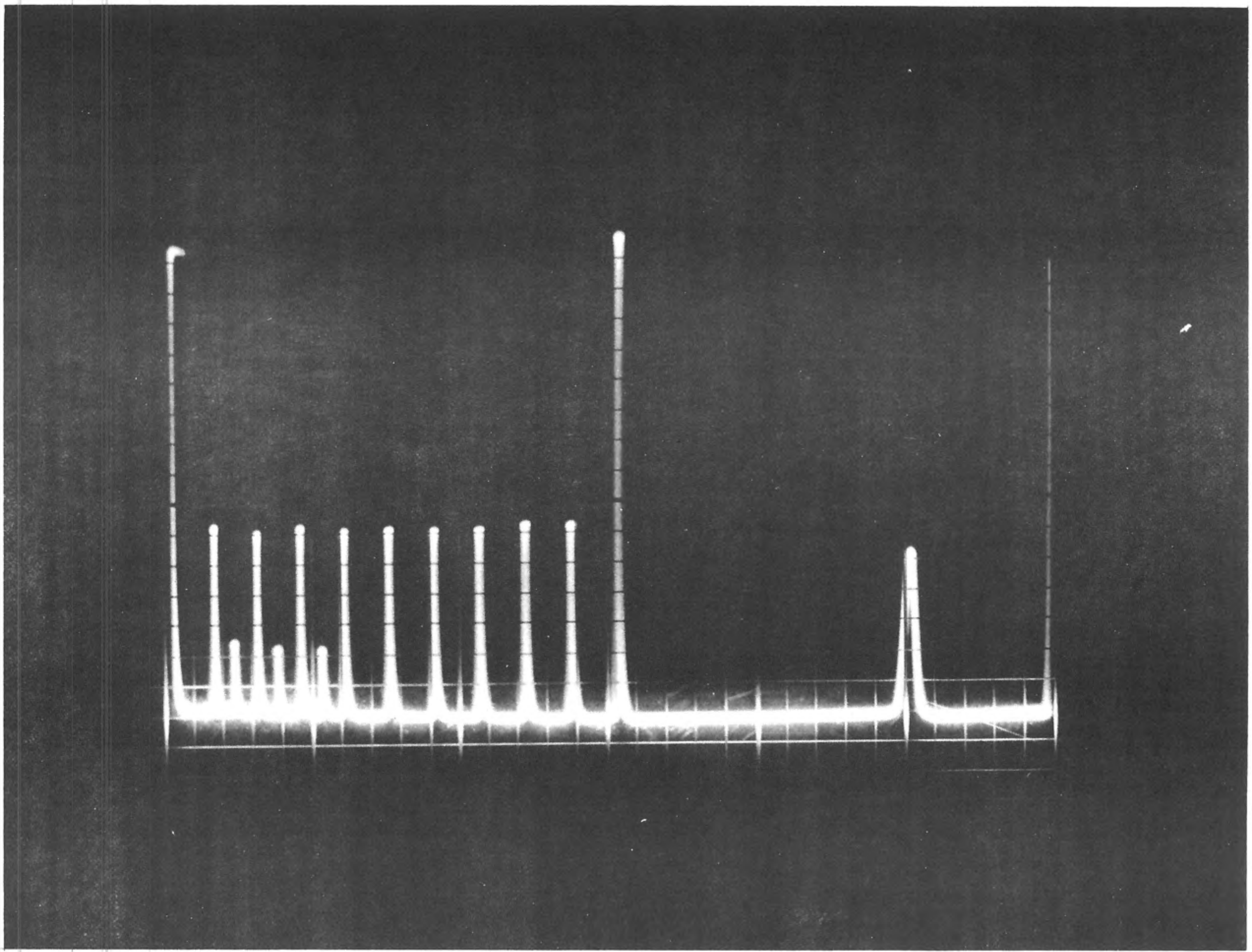

Figure 7. Oscilloscope trace for one revolution of disc.

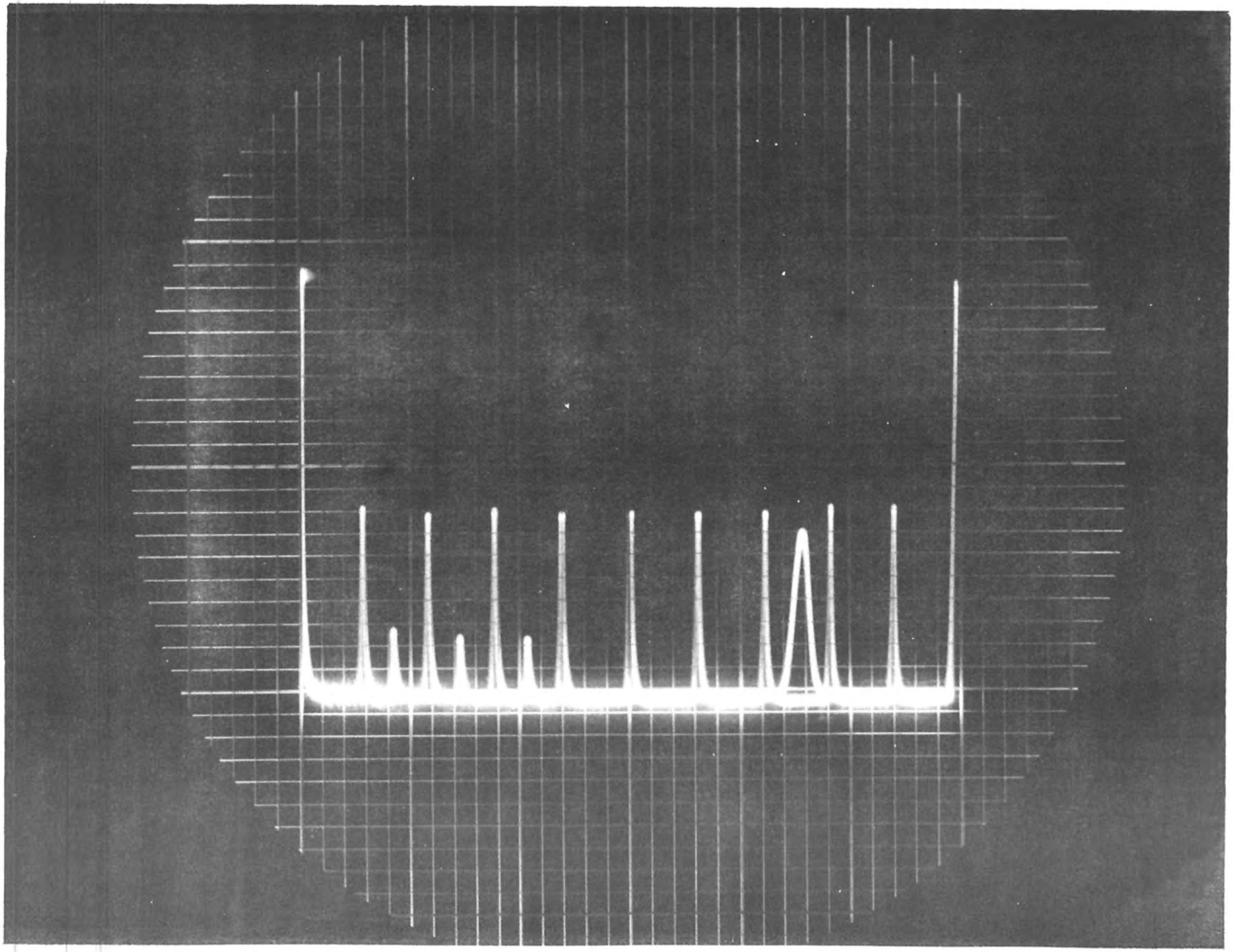

Figure 8. Oscilloscope trace for double sweep frequency and coarse reading

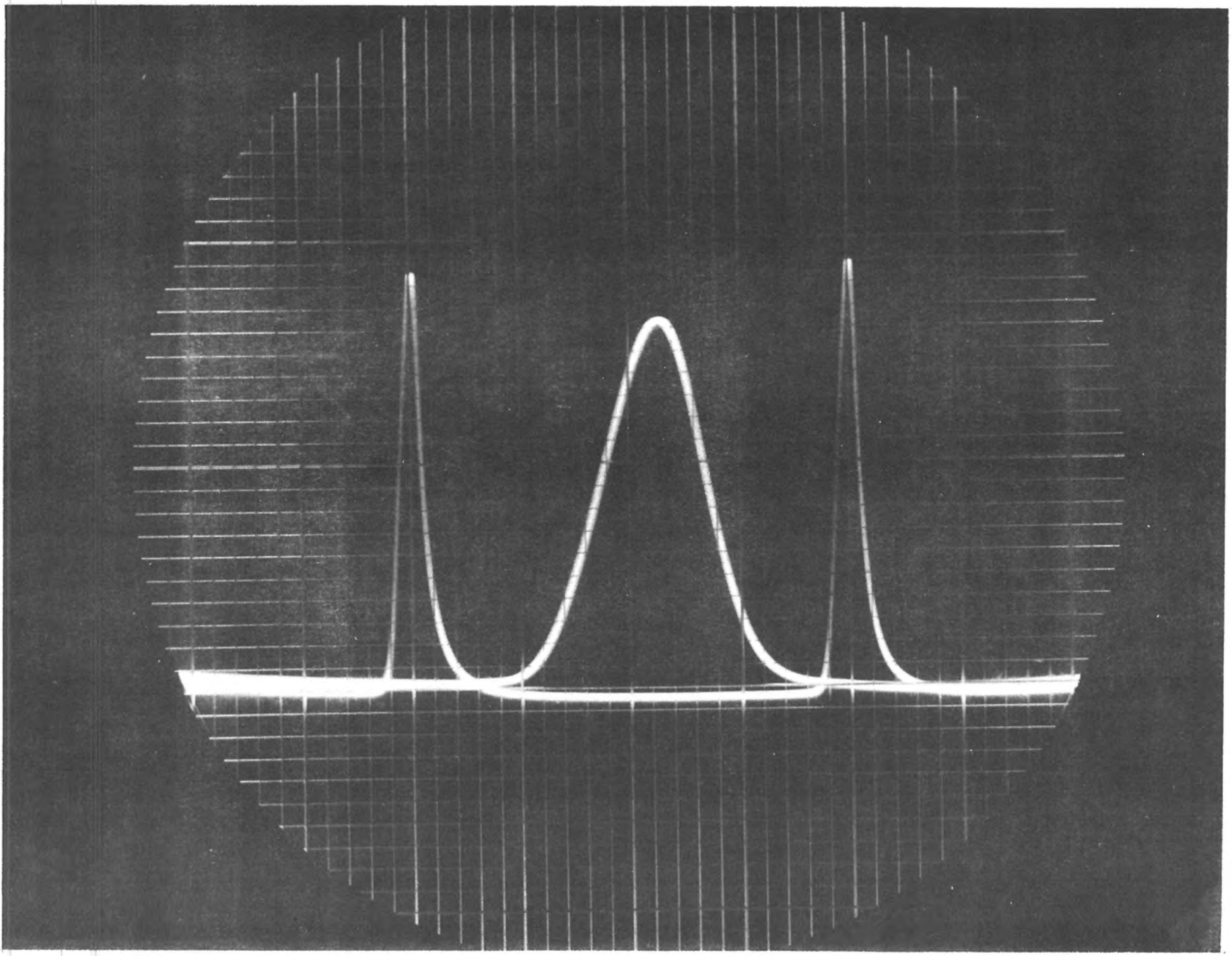

Figure 9. Expanded section of trace for fine reading.