Department of Mines and Resources
Surveys and Engineering Branch

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Dominion Observatory

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SEISMIC RESEARCH PROGRAM
ROCK BURST PROBLEM
LAKE SHORE MINES

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Report No. 14
February, 1944 - June, 1945

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Ernest A. Hodgson
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OTTAWA

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Part A. Underground Program and Discussion of Results

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Ernest A. Hodgson

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In this latter phase, he was assisted up to the end of November, 1944, by Mrs. Ethel Grace. Her work was very satisfactory, but she found it necessary to resign at that time. Her duties were taken over by Miss Mary Hallick, who has proved most capable and devoted to the project. The writer wishes to record his appreciation of the continued, efficient support he has had from these, his assistants.

I. Recording Program: As of January 31, 1944, the recording program on the east side of the mine from the 4450'-level to the 4825'-level was well established as described in Report No. 12. From time to time since, geophones have deteriorated and had to be changed. In

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I. Recording Program: As of January 31, 1944, the recording program on the east side of the mine from the 4450'-level to the 4825'-level was well established as described in Report No. 12. From time to time since, geophones have deteriorated and had to be changed. In some cases, where a hole had been partly closed by slips along fault planes, the defective geophone has had to be abandoned. When this occurred, the hole was re-drilled and put back into the program as soon as possible. A tabulation of the holes made available for this work, together with details as to their location, date of drilling, depth, drilling logs, etc., is given in Appendix IV.

Interruptions also occurred occasionally when lines were damaged in mining operations. In general, such breaks in continuity were of short duration. Somewhat longer lapses resulted from extensive timbering or mining operations, involving drifts in which cable lines were strung. The most important of these was in 4802E where considerable re-timbering was done in December, 1944, and during the first two or three months in 1945. Another important interruption held up the holes in 4701E (except H40 and H55) during the latter part of April and early part of June, 1945. Some reduction in coverage also resulted from the necessity of bringing recorders to the surface for repairs. One fairly long break occurred during October and November, when Recorder 4AB was on surface for about six weeks for use in developing the high-speed chronograph.

In every case, all available recorder channels were used every day. When the usual holes were not in operation, others were put on the recording program for the time being. When there was a shortage of recorders, the holes in good order were serviced each day in the listening program.

A graphical exposition of the recording maintained is given in Appendix V. It is to be noted that all possible coverage was made during the entire period dealt with in this Report. The notes given in that appendix indicate in each case why and when certain holes were omitted for various periods or were abandoned due to closure or mining operations.

To the end of June, 1945, a total of about 2700 records have been made, since the recording began on

July 1, 1942. Each of these is at least as long (45') as those shown in Figs. 19 and 20. Many were considerably longer. These have all been carefully studied and had their data digested daily into the tabulations and graphs as described in Report No. 12. Each has been bound into an individual, annotated cover, as described in Report No. 10, and filed in special boxes provided.

With the inception of the Intensive Seismic Program to be described later, it was found necessary to modify to some extent the routine described in Appendix VI, Report No. 12. The only part of the routine there described which has been omitted was the study of coincidences. This was discontinued as of Jan. 31, 1945.

II. Listening Program: Experience gained prior to the period covered by this report showed that listening is best carried on during the early-morning, off-shift hours. Every hole available, whether in the recording program or not, was included in the listening program every day except Sundays up to the end of February, 1945, when some omissions were necessary as will be explained.

Hodgson spent more than half his time at Kirkland Lake, and, while there, went underground each day at 3 a.m., remaining until the day shift went on duty (8 a. m. during the winter months and 7 a.m. in the summer). He carried out the listening program, as a rule, while in town. This gave Hallick an opportunity to catch up on the many jobs of line and instrument repairs underground, which were always cropping up.

When Hodgson was not present, Hallick took over the listening, going underground each day at 5:30 a.m. He had to keep the program running, attending to the line and instrument adjustments, calibration, etc. Then, on surface, he had to assist with and supervise the analysis of the records: reduction and plotting of data, etc.

With the inception of the special program early in 1945 (to which reference will shortly be made), it was impossible for him to service every hole in the listening program every day, but he gave yeoman service in an attempt to cover them and did remarkably well. The procedure adopted was to listen briefly to the holes available and limit the actual counts to the holes found to be active. In this way no effective loss of coverage occurred.

Whoever did the listening entered the counts together with full notes on forms, one for the regular program and, later, a second one for the special program. The form used in the regular listening was that shown in Appendix III of Report No. 12, which explains the procedure as it existed on Jan. 31, 1944.

In November, 1944, some difficulty was experienced in making clear just what degree of seismicity the operator felt should be assigned to each hole each day. The count alone was not a sufficient index, since the "normal" count on some holes was much higher than on others. Hodgson and Hallick pooled their experience and tried out several tentative drafts of a scheme for describing the seismicity. These were tested for some weeks by both operators, each independently assigning a "seismicity factor" to his listening at each hole. These numbers were later compared and discussed each day. After several amended drafts had been tried out, a so-called "Tentative Draft of the Seismicity Factor on a Scale of Ten" was drawn up on November 29, 1944. This is given in full in Appendix III. It has been found to work out satisfactorily in practice and has been followed by both operators ever since.

The factor, as now employed, gives considerable satisfaction to each of the operators as a reasonable statement of his estimate of the seismicity of each hole each day. It is seldom that Hodgson and Hallick differ by even one point in listening to a group of ~~nearly~~ 30 to 38 holes in a morning.

Now it is to be noted here, that, since the factor has been adopted, say Dec. 1, 1944, there has not been a single case where the number assigned was more than 6 and it is seldom that it is as much as 5. In other words, since Dec. 1, 1944, there has been no pronounced activity at any hole in the program. This is due largely to the fact that there have been few bursts in the section serviced, those which have occurred have been small, and nearly all have been set off by the blasting. The list of bursts, given in Appendix VI bears out this statement.

On one occasion, April 14, 1945 (See Fig. 19) two, small strain bursts developed and occurred during listening hours. The counts rose in the early hours of the listening program but by the time the shift came on they had again become normal.

The activity at certain holes has changed greatly over the course of weeks or months. In February, 1944, H40 in 4701E3 was very active, but it is not nearly so active now. H55 in 4704XC was very active when drilled. It was lost finally by closure due to slippage along diagonally-crossing fault planes. H107 was drilled parallel and close beside it to the same depth, but the ground there has become quiet. H62 is (see its log in Appendix IV) drilled in good solid ground but, as of June, 1945, it has shown a very high "normal" count and has been the site of a number of small strain bursts. (The bursts of April 14, 1945 were probably close to H62).

Holes having high normal counts hold them for long periods; then, eventually, the pressure (or slippage) moves elsewhere. Abnormally high counts on any hole are seldom maintained for long. Clearly, the seismic activity changes its locus very markedly in Lake Shore Mines. A hole meriting a high seismicity factor on any given day becomes normal again within a very short time — at most a day or two.

The listening data are entered in the log-book on surface and are plotted on the graphs each day. The blasting data (stopes blasted together with the number of holes and sticks of powder used) are plotted daily. The correlation between heavy blasting and high counts is remarkably poor except when a sill is taken out, at which time the count on the nearby hole goes up markedly.

Note that a heavy blast just prior to the recording shown in Fig. 19 did not result in high microseismic activity during the P.M. recording, but that the activity became greater next day. On the other hand, a smaller blast, just prior to the recording shown in Fig. 20 increased the count for a short time but it soon fell to normal again.

III. Rockbursts Experienced: In Appendix VI a list is given of the 34 rockbursts which occurred in Lake Shore Mines (during the period covered by this report), which were located and reported on by the engineering staff. An analysis shows that only three of these occurred in time and place that might have resulted in their having been predicted. In each of these three cases the burst occurred some hours after listening and recording had stopped.

Two of the bursts were quite small as evidenced by the reports given, the third displaced about 100 tons and was classed by the engineers as a "light crush burst". There was some measure of prediction for this burst, definitely from one hole and generally from the holes in section 6, which were reported by the operator (F.J. H.) as showing signs of strong seismic activity. It occurred more than four hours after the listening and recording had stopped.

As stated in the concluding paragraph of Appendix VI, we must conclude that the rockburst activity has been too low, on account of the reduced mining schedule under wartime conditions, to afford the necessary experience in the block of ground under survey.

However, these bursts which were located and surveyed are not the only ones occurring in Lake Shore Mines. There are many more, running into several hundred over the seventeen months covered by this report, which are too small or too far in the wall to throw down loose, or which occur in unused workings. These have been shown by the records to occur frequently with blasting, and sometimes also in off-shift periods, as was the case on April 14, as mentioned in Section II and illustrated in Fig. 19.

When the work was in progress in the west pillar, high seismic activity such as that shown in Fig. 19 was fairly common on the records. Oftentimes it was much more pronounced. There has been very little activity at any time during listening or recording during the past year and a half. A comparison of Fig. 19 and Fig. 20 will serve to show how easily-recognizable are even moderately-high seismic records. Yet, in spite of the thorough coverage and the highly sensitive equipment, very little such activity has been found during listening hours for the period covered by this report.

There is this point to be noted, however, that when the high seismic sensitivity does appear there is no doubt as to its identity. When records such as those in the A.M. recording in Fig. 19 are obtained, they are easily recognized. They have not been missed through inadvertence, as is shown by the coverage records in Appendix V and by the daily listening reports on file (about 1,000 to date). They just haven't occurred. The program has not been at fault and it cannot be expected that this period of quiescence will continue. For this reason, the writer feels that every effort must be made to maintain complete coverage, so long as the program continues. It is discouraging to watch and wait all these months for activity which fails to materialize. It would be calamitous to miss it because of a lapse in the rigour of the investigation.

IV. Instrument Development: This subject is dealt with, as such, by Mr. Gibbs in Part B, of this report, but a discussion of the application of the equipment to the underground program belongs properly here.

In Sections I-III of Part B are discussed three recorder improvements, under the headings: Method for Flattening Paper; Method for Adjusting Styli; Additional

Magnet Support. The value of these in service has to be experienced to be fully appreciated. By their aid, it is possible to put the styli in complete adjustment (not possible otherwise) and to maintain them so with very little effort. Comparison of the records made since the improvements were introduced with those made previously is sufficient to show the increased sensitivity and all-round intercomparability of the recorders which has been effected.

In Section IV, Part B, Gibbs discusses the clock switches which permit recording from two geophones, alternatively every half hour, on each recording channel. The only drawback to these switches has been that, every time the power is off, they get out of step and a trip to the level where each is located is made necessary. Recently, a simple but serviceable relay device was made by Gibbs and installed at each switch. These relays are connected by wire lines to the central doghouse on 4700. When a clock switch is out of step, the operator turns on the current, closing the relay, and stopping the switch, just as it changes. Then later, at the next time that same change should occur, the current is cut off and the switch carries on in step with the program. Thus, during the time spent in listening on 4700, it is possible to determine whether a switch is out of step and by how much, and to set it again without leaving the doghouse or appreciably interrupting the listening program.

The description of the high-speed chronograph (Section V of Part B) raises the question as to studies made with it. None has been made to date. The chronograph was taken underground first on Nov. 15, 1944, but experience showed that the recording styli were too delicate in adjustment for effective work. They had been made, perforce, after a pattern designed to use the only piece of monel capillary tubing then available. It was some time before a source of further supply could be located and still longer before tubing could be obtained. When it finally arrived, Gibbs was busy getting the switches built for the special program, so that the chronograph was not completed until the middle of April, 1945. It was taken underground on April 18 and tests showed that the newly-designed styli were quite satisfactory; but Hodgson had to leave for Ottawa on April 21, so no experimenting was possible. In his absence, Hallick has all he can do to attend to the routine work. On the next trip to Kirkland Lake (May 24 to June 16), the new program required everyone's full time to get it into efficient operation. For this reason, to date, no experimenting has been done with this instrument. It is hoped that considerable experimentation will be possible during Hodgson's next trip beginning about the middle of July.

V. Obert Experiments: Dr. Obert and his associates, working at the U.S. Bureau of Mines, undertook some experiments designed to show that microseismims may be generated by pressure alone (without fracturing) and that the rate of incidence of these microseismims goes up markedly, prior to rock failure. The data on these experiments were opened for Hodgson's inspection at a conference arranged by Obert at Ishpeming, Michigan, Oct. 27-29, 1944. They are referred to in a brief report made by Hodgson to Mr. Blomfield, which is reproduced in this volume as Appendix I. A lengthy report by Hodgson was prepared and submitted to officials of the Department and of the Mine. A small stock of this issue is still available and a copy may be obtained on request by anyone receiving Report No. 14, by applying to the writer at the Dominion Observatory, Ottawa. A report has since been published by Obert and Duvall in the series Reports of Investigations, issued by the U.S. Department of Mines (No. 3803, March, 1945, "The Microseismic Method of Predicting Rock Failure in Underground Mining, Part II, Laboratory Experiments".)

Briefly, small samples of solid rock were chosen and cut into symmetrical blocks about 4" x 2" x 2" having plane-parallel faces, top and bottom. Holes were drilled in the blocks to accommodate regular Obert geophones. They were placed in a special hydraulic press, designed to hold high pressures with negligible loss, without keeping the pump running. The pressure was raised level by level, in steps, usually, of 2,000 lbs/sq.in., to the point of failure of the specimen, a count being made, for five minutes at each level, of the number of microseismims heard by means of the geophone installed in the hole in the block and feeding through an amplifier and headphones. It was definitely shown that:

(1) Microseismims are generated by pressure even when there is no apparent failure of the rock.

(2) The number of microseismims per minute rises markedly at about 80 per cent of the bursting strength and continues to increase up to the point of failure.

It cannot be too strongly stressed that there is here a definite proof of the basic principle on which the microseismic method rests. It is a method which has great possibilities and is the only one so far suggested by any research worker which offers so much promise in the rockburst prediction field.

At the same time, while the basic principle is thus established, the technique of applying the method in a mine remains to be worked out. Obert and his associates have applied it with marked success in some relatively simple problems associated with comparatively shallow mining. It should be possible to evolve a technique which can be applied even in a mine so badly fractured as is Lake Shore.

In the meantime, it was felt that, while this experience was being gained, the accounts published in September, 1943, after the very encouraging results in the west pillar, as outlined in Report No. 11, should be supplemented by a statement of the somewhat stalemate results, so to speak, of 1944. Accordingly, the writer prepared a short paper which was published in the May issue (1945) of the Canadian Mining and Metallurgical Bulletin. This paper is reproduced in full as Appendix II of this report.

VI. <u>The Intensive Seismic Program</u>: In the paper referred to at the close of Section V above, mention is made of other proposed applications of the microseismic method which were about to be tried. The high-speed chronograph is one of these but the experiment on which most hope is built is the so-called Intensive Seismic Program.

It was felt that the chief cause of failure to predict in the regular east-side program, aside from the paucity of seismic activity, lies in the fact that the geophones in service are too widely scattered. Furthermore, there is not much chance of knowing whether or not they are in a sensitive piece of ground (i.e. one not cut off by open fault planes from adjacent ground). Accordingly, the multiple-geophone method proposed in item 2, page 6, of Appendix I was undertaken.

Instead of switching the geophones every fifteen minutes as there suggested, it was decided to arrange for ~~five minute~~ short samples ~~and to~~ by having each geophone record for one-eleventh of an hour. This ~~would~~ permits any set of 18 holes, selected as the best on the basis of experience, to be chosen from a total of 34 holes drilled at close intervals (30') in a piece of ground known to be under heavy pressure. The details of the plan and the method adopted to make the records available for ready intercomparison are given in full in Appendix VII. The equipment designed for use is described by Gibbs in Sections VI-VIII inclusive of Part B.

Succinctly, the new program is a special effort to obtain definite answers to three very pertinent questions, namely:

1. Is there a crudescence of subaudible snapping as rock pressures become acute?
2. If so, do they appear soon enough to provide a useful warning of a burst?
3. Further, if they occur, how close to such stressed ground must a geophone be placed to record the warning activity?

The method has been in service now for three full months.

The daily photographs make available for ready examination 85 daily records in full, together with complete instrumental listening and blasting data and explanatory notes. The following points may be stressed:

1. In all only one record shows any evidence of continued high seismic activity (See Fig. 19) and this originated in a level above the program, as was evidenced by strain bursts which occurred while the operator was on duty. (There was one other record (Pl. 3) where a small, rather distant, but never-located burst registered for about a minute but with no continued high seismicity before or after.)

2. There is a marked difference between the sensitivity of hole-geophone combinations, which is strikingly evidenced by the response to pumps and drills at approximately the same distance from all holes. The hole-geophone having the high response depends on the source of the interference, showing that the ground is broken into blocks, the good response depending on source and geophone lying in the same block, or in blocks intimately associated.

3. When activity is a little over normal at the west end of the program, it is sometimes a little under normal at the east end and vice-versa. This is further evidence that there are two blocks of ground with quite different seismic conditions, separated no doubt by a fault plane or by a series of planes.

4. Referring to our three definite questions stated earlier in this section, we get the following answers from the records to date on the new program:

    (a) There is a definite crudescence of prior snapping before a burst.

    (b) The length of time prior to the burst when it appears depends on:

        (i) The magnitude of the impending

burst.

(ii) The distance from the centre of pressure to the hole.

(iii) The sensitivity of pick-up of the hole-geophone combination.

(iv) Evidently, on the actual rate at which the pressure builds up.

(c) A good geophone in a hole in a piece of rock intimately connected to the source picks up microseismims of quite faint type for considerably over 100' — perhaps 200' or so. But some good geophones in poor holes pick up activity at considerably less than 100'. There is a marked difference in only 30'. Distance is by no means the only factor. Block faulting must be recognized and allowed for in selecting holes and placing geophones.

We conclude from the experience gained thus far in the new program that, while the low seismic activity has somewhat hampered the investigation, we are gaining experience at a quite unprecedented rate from this lay-out. The ground cannot (in the light of experience) remain quiescent indefinitely. The program will be watched with special care to permit no instrumental deficiencies from interfering with regular complete daily coverage.

VII. Conclusions and Recommendations:

1. Microseismims are generated by high pressure alone even when no fractures are produced.

2. Natural mine noises, falling rock, cracking breasts, etc. do not generate snaps at a sufficiently high rate to confuse records of high microseismic activity; if there are many at one time as in a rock run, they may be readily

identified in listening and, by their form, on the records.

3. Microseismims are generated in greatly increased rate of incidence as the pressure rises above about 80 per cent of the bursting strength of the rock and so afford a basis of prediction.

4. When a high rate of microseismims is generated (i.e., when pressures are high) there are, at the same time, snaps of a considerable range of amplitude among them; the number picked up by a geophone depends on:

   (a) The magnitude of the impending burst.

   (b) The distance from source to geophone.

   (c) The sensitivity of the hole-geophone to the source of the microseismims.

5. Lake Shore Mine is block faulted to an extent which almost completely divorces it from those mines where the arching theory may be used as a basis for explaining rockburst phenomena.

6. Holes cannot be laid out in a geometrical pattern (as in the regular program) with any hope of covering a section of the mine. The only feasible methods are to use many geophones (of necessity in a small section of ground) or to experiment to locate the block boundaries and get geophones at proper intervals in all the blocks likely to develop bursting stress. (This is not as formidable as at first appears for there seem to be large blocks or groups of blocks very intimately related as well as others very definitely separated by faults.)

7. The intensive seismic program has already yielded much information on the major problems of hole location and prediction and seems destined to

afford experience at a rate hitherto impossible, especially as and when the section of ground under survey becomes seismically active.

It is therefore recommended that:

1. The intensive program be prosecuted with special care to avoid any lapses in continuity. (It would add to the value of this program if a few 30' holes could be drilled to replace the short 6' holes now in service.)

2. The regular program and all listening be maintained also with all diligence but as secondary (when necessary) to the intensive program.

3. The high-speed chronograph be used to determine block boundaries.

4. Other experiments be made to determine which of the holes now in service are in quite non-sensitive ground (not intimately connected to any probable source of microseismims) and to replace them with others in locations proved to be sensitive.

Dominion Observatory,
Ottawa, Canada,
July 9, 1945.

E. A. H.

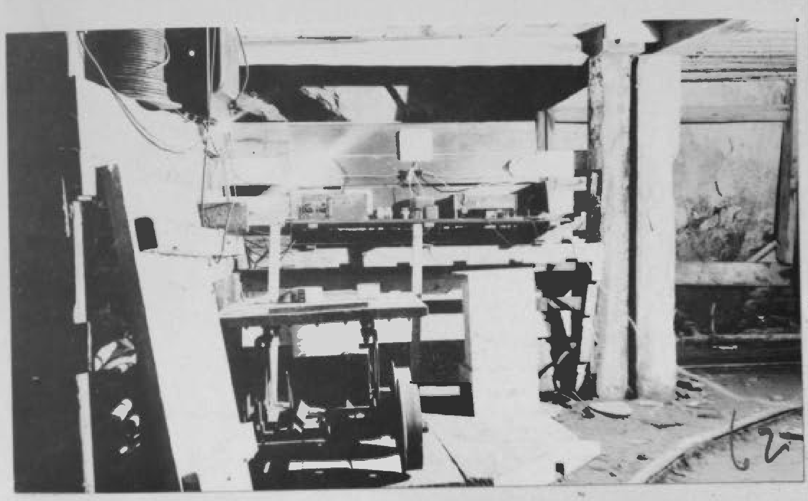
Fig. 1
Listening on Recorder 3AB
4700'-Level

Fig. 3
Listening Equipment
4400'-Level

Fig. 2
Recorder 3AB Set-up
and
Special Service Truck

Fig. 4
Clock Switch - Top View

Fig. 5
Clock Switch - Side View



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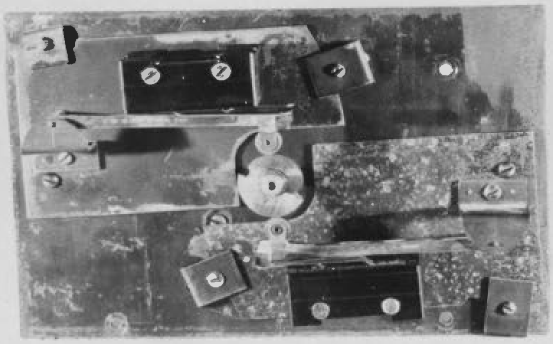

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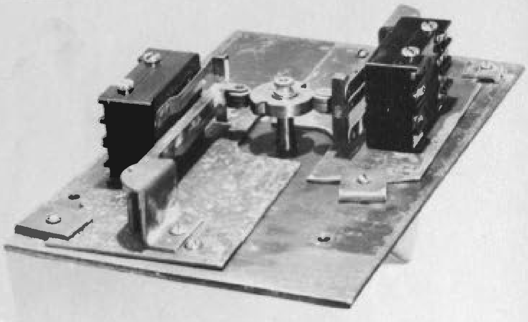


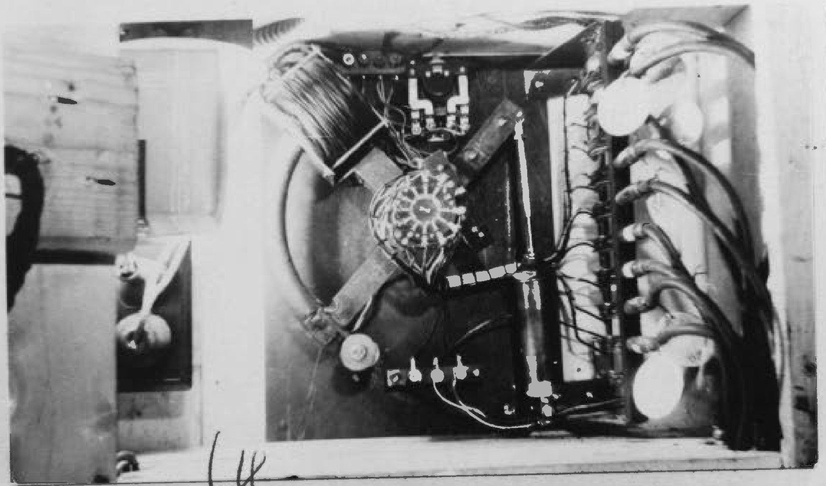
Fig. 6
Magnetic Stepping Switch

Fig. 7
Diagram of
Magnetic Stepping Switch

Fig. 8
Housing of
Magnetic Stepping
Switch

Fig. 9
Motor Switch

Fig. 10
Master Contactor



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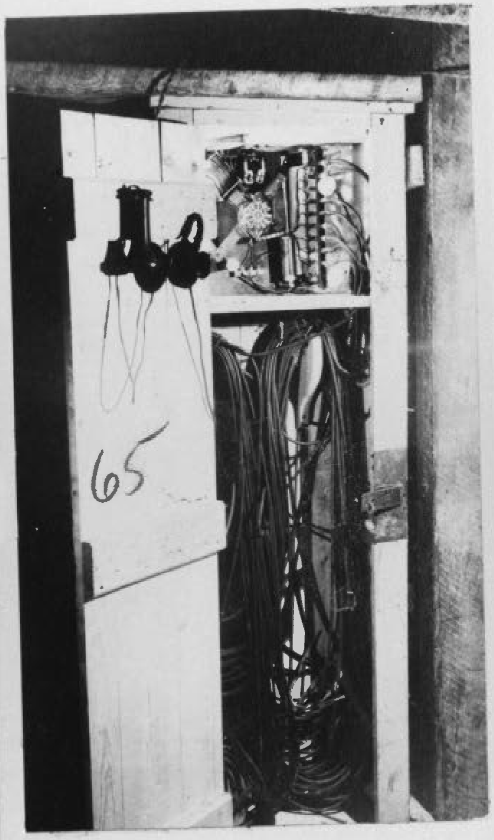

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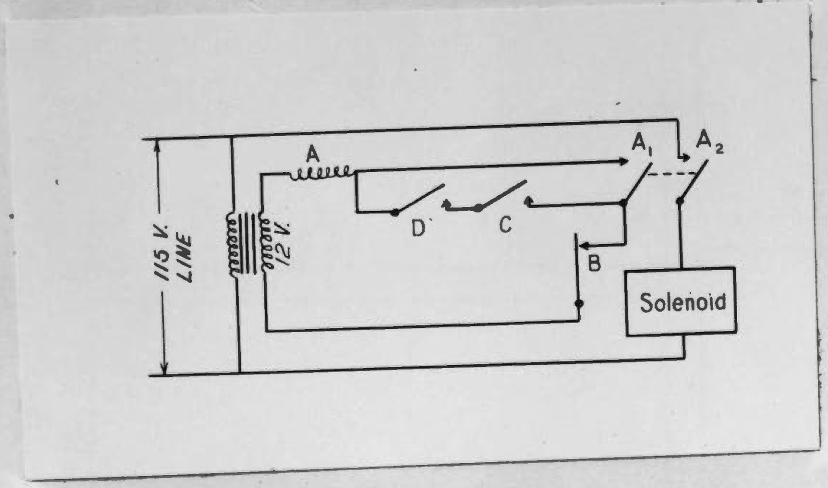

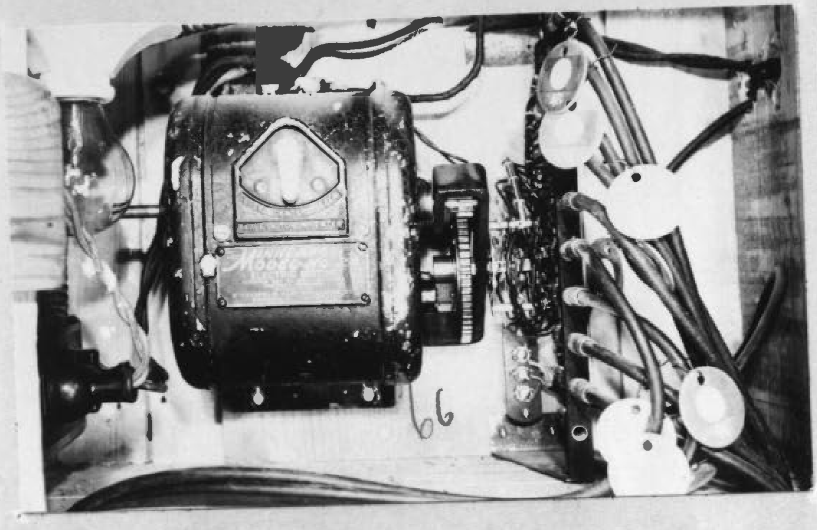

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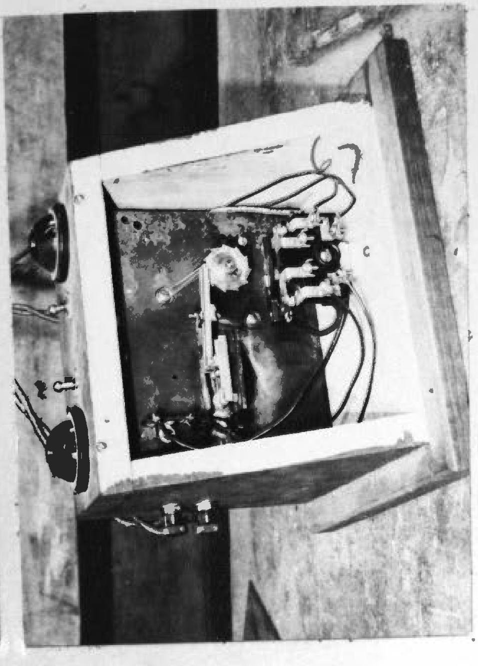

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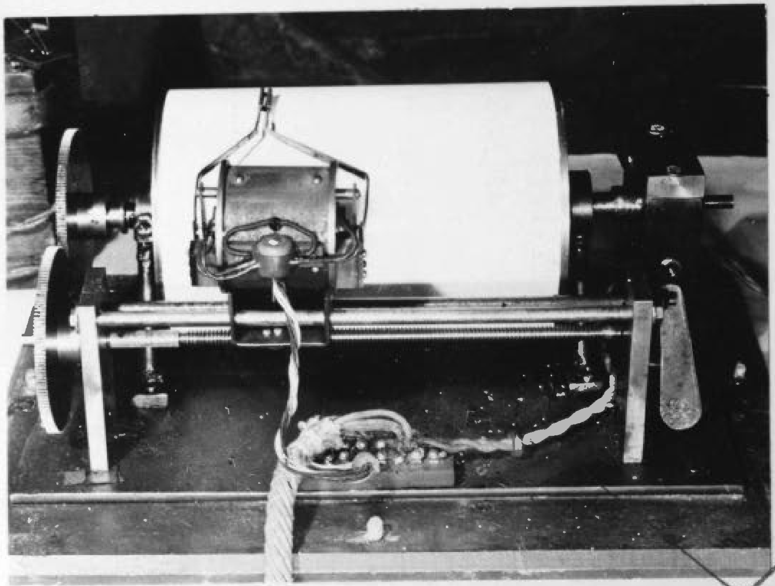
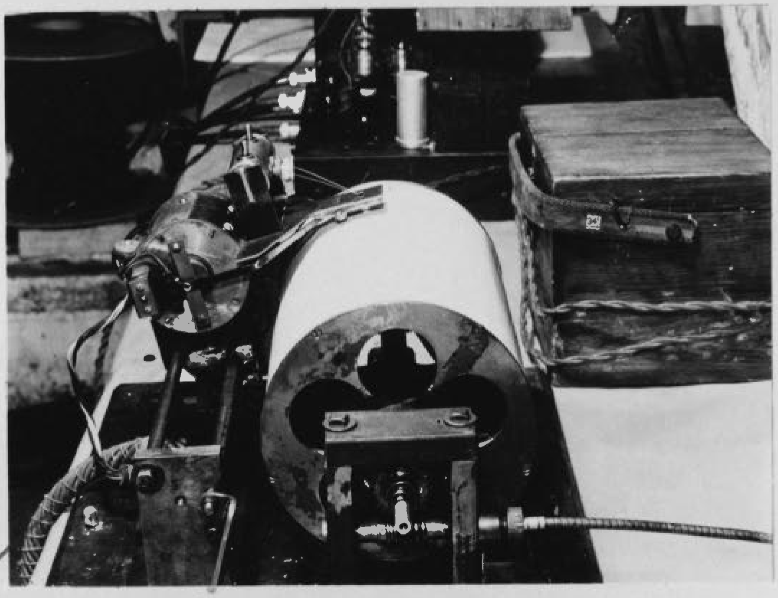
Fig. 11
High Speed Chronograph
Recording Drum
Front View

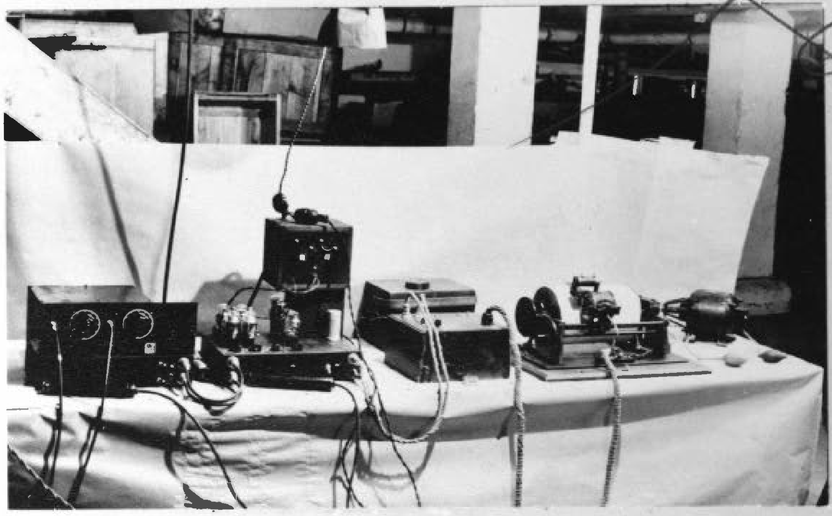
Fig. 13
High Speed Chronograph
Drum Viewed from the
Right

Fig. 12
High Speed Chronograph
Complete Assembly with
Recorder 4AB

Fig. 14
High Speed Chronograph
Details of Recording
Styli







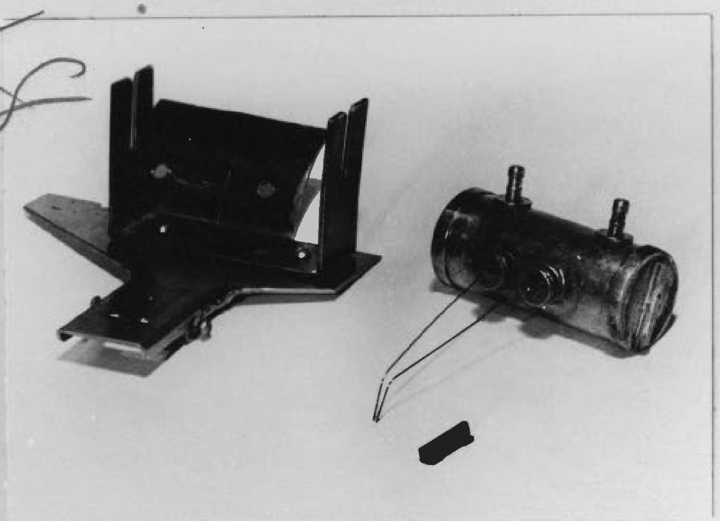
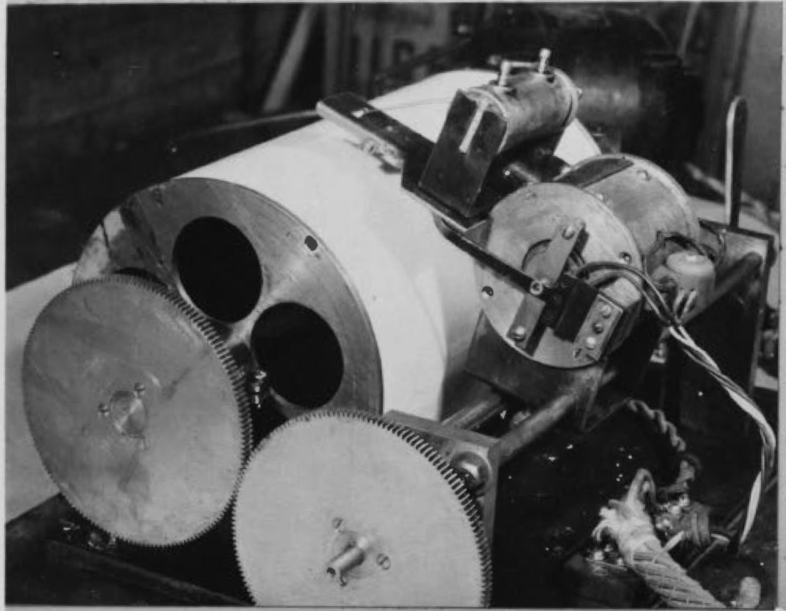


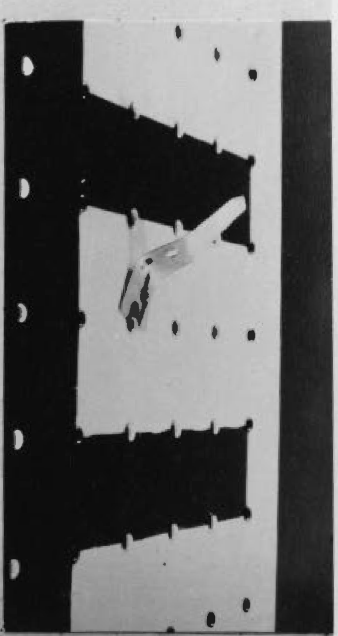
Fig. 15
High Speed Chronograph
Drum Viewed from the
Left

Fig. 17
Detail
of
Record Board
with
Depth Gauge

Fig. 16
Copying Camera
with
Stand and Record Board

Fig. 18
Record Board Illumination
Lower Half of Lamp Standard





70

69

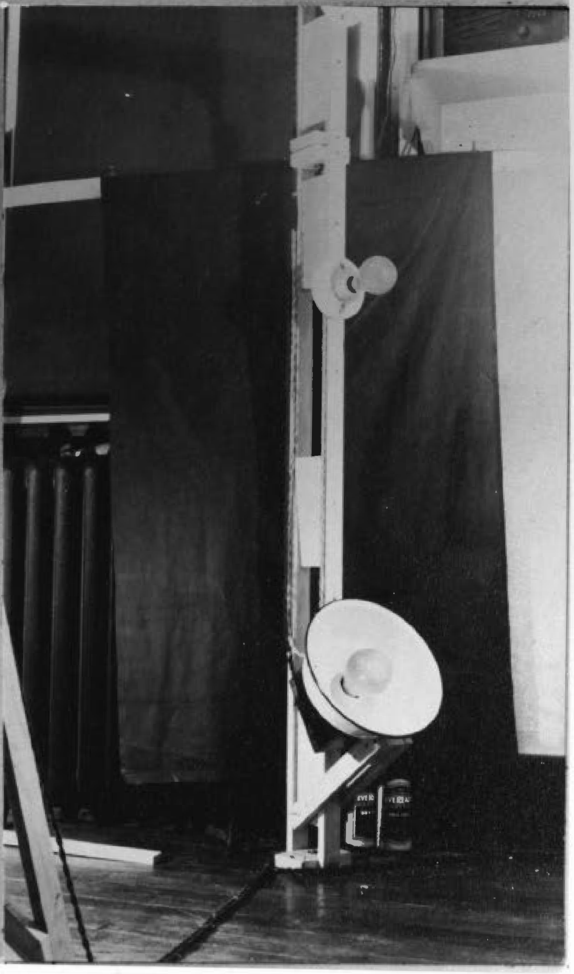


Fig. 19

Plate 15, April 13-14, 1945

*

1. Interference in the first, upper (P.M.) half of this plate is due to the crusher and skip. The former, working more-or-less continuously, affects different hole-geophone record sections to different degrees. The skip shows short periods of interference at intervals of about $0^{\prime\prime}.8$ on the plate (about 2^{m} 45^{s}). Such interference is usual during the P.M. recording. The actual seismic activity is low in this case, although the record began within half an hour after an unusually large blast (100 sticks, in 30 holes, in stope 4802E3-1, as shown to the right of strip 42009).
2. The lower (A.M.) recording is free from interference. The seismic activity is considerably greater, although it is recorded about twelve hours after full mining activity had ceased.
3. Two strain bursts occurred, the first just to the left of the stamped number 42014, and the other just to the left of 42016. Both were heard and felt by Hodgson on 4700, but occurred above that level, probably between 4502E4 and 4402E4 (estimated on basis of records from holes in the main program; the bursts were not located by the miners).
4. The disturbance at the left-hand end of the piece numbered 42015 was an attempt by the operator to determine the point of greatest activity by manually tripping the switches at intervals of about 20 sec. Evidently this is too short a sample.
5. Identifying the source of the sections on this plate from the diagram in Appendix VII, note how markedly the activity accompanying the bursts is confined to the west end of the lay-out.

Location: Sections 28 to 43; Drifts 4702E and 4602E
On 4702E: 17 percussion drill holes, Nos. 70 - 86 inclusive
On 4602E: 17 percussion drill holes, Nos. 90-106 inclusive

Holes were drilled about ten feet deep, breast high, horizontal
Even-numbered holes are in the hanging (south) wall in each drift
Odd-numbered holes are in the foot (north) wall in each drift

Holes 70 and 90 are each 50 ft. east of the main crosscut and succeeding even-numbered holes on each level are at intervals of 30 ft. in the hanging wall, to Holes 86 and 106 respectively

Holes 71 and 91 are each 65 ft. east of the main crosscut and succeeding odd-numbered holes on each level are at intervals of 30 ft. in the foot wall, to Holes 85 and 105 respectively

An eleven-contact switch, operated at eleven equally-spaced intervals each hour, is installed in drift 4702E3 and feeds the output of geophones in each of nine selected holes to Recorder 3A

An eleven-contact switch, operated at eleven equally-spaced intervals each hour, is installed in drift 4602E3 and feeds the output of geophones in each of nine selected holes to Recorder 3B

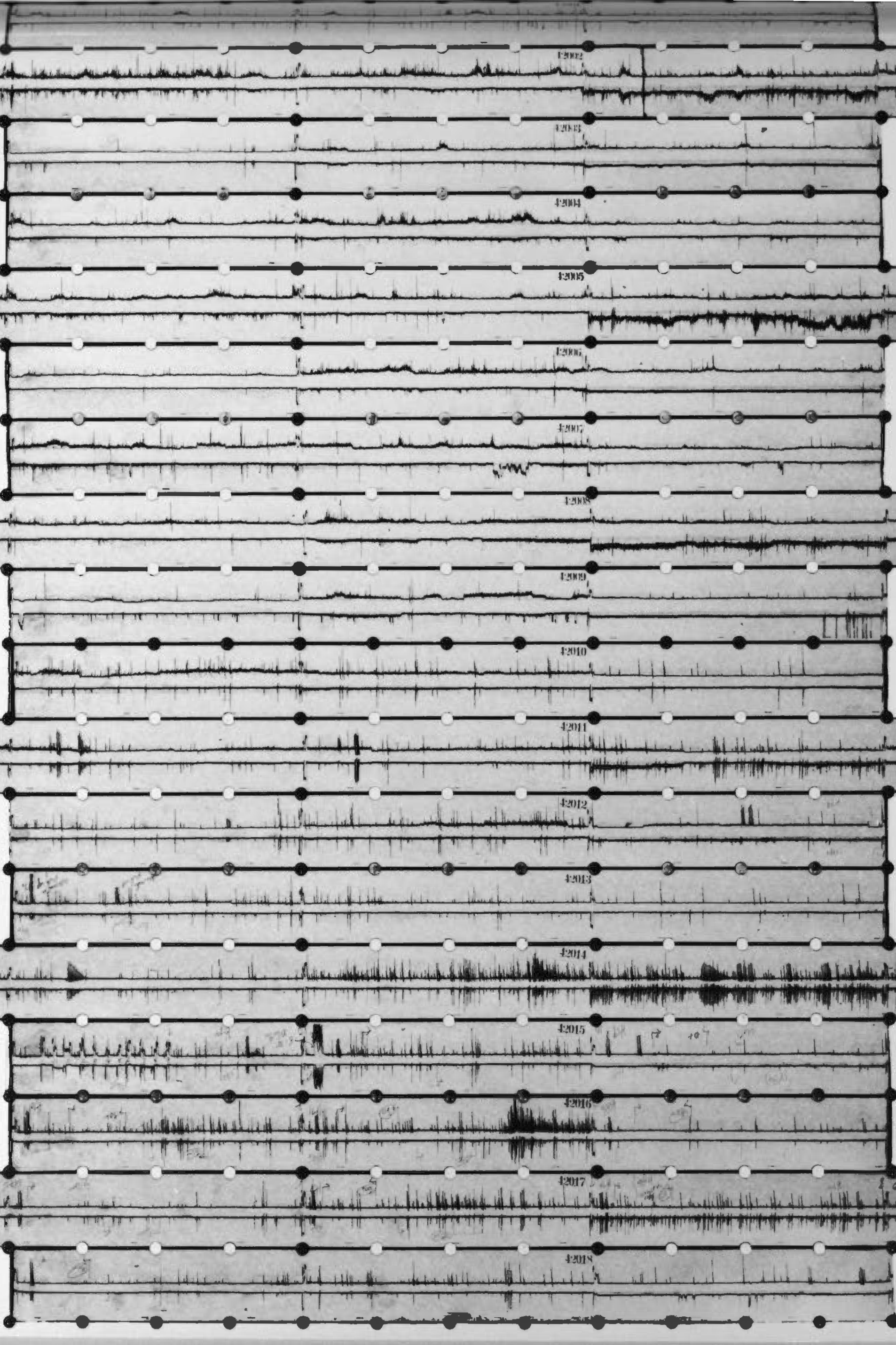
Of the nine holes used on each level, the hole-geophone combination found by experience to be the most informative is switched-on three periods per hour as a check

The check geophone on each level records during the second, sixth and tenth intervals in each hour, the sets being operated six hours daily in offshift time: 3:30 to 6:30 afternoon and morning

The nine selected holes on either level may be designated by X, A, B, C, D, E, F, G, H, where X indicates the check-geophone location and the others range always from west to east

This photograph shows six groups of three sections, each recorded in order from top down: [illegible]-4:30· 4:30-5:30; 5:30-6:30, all P.M. on the first date, and three similar A.M. hours for the second date

The switch on each level operates to record in the order AXB· CFXDG; DXE. The record is cut into sections, three per hour, as indicated by the grouping of the letters above



	x70 o 51	x71 o 48	x86 o 53	
x83 o 50	x82 o 44	x71 o 48	x72 o 49	x73 o 47.
	x74 o 55	x71 o 48	x79 o 43	

	x90 o 62	x96 o 56	x101 o 65	
x97 o 57	x95 o 67	x96 o 56	x91 o 58	x92 o 64
	x93 o 60	x96 o 56	x94 o 59	

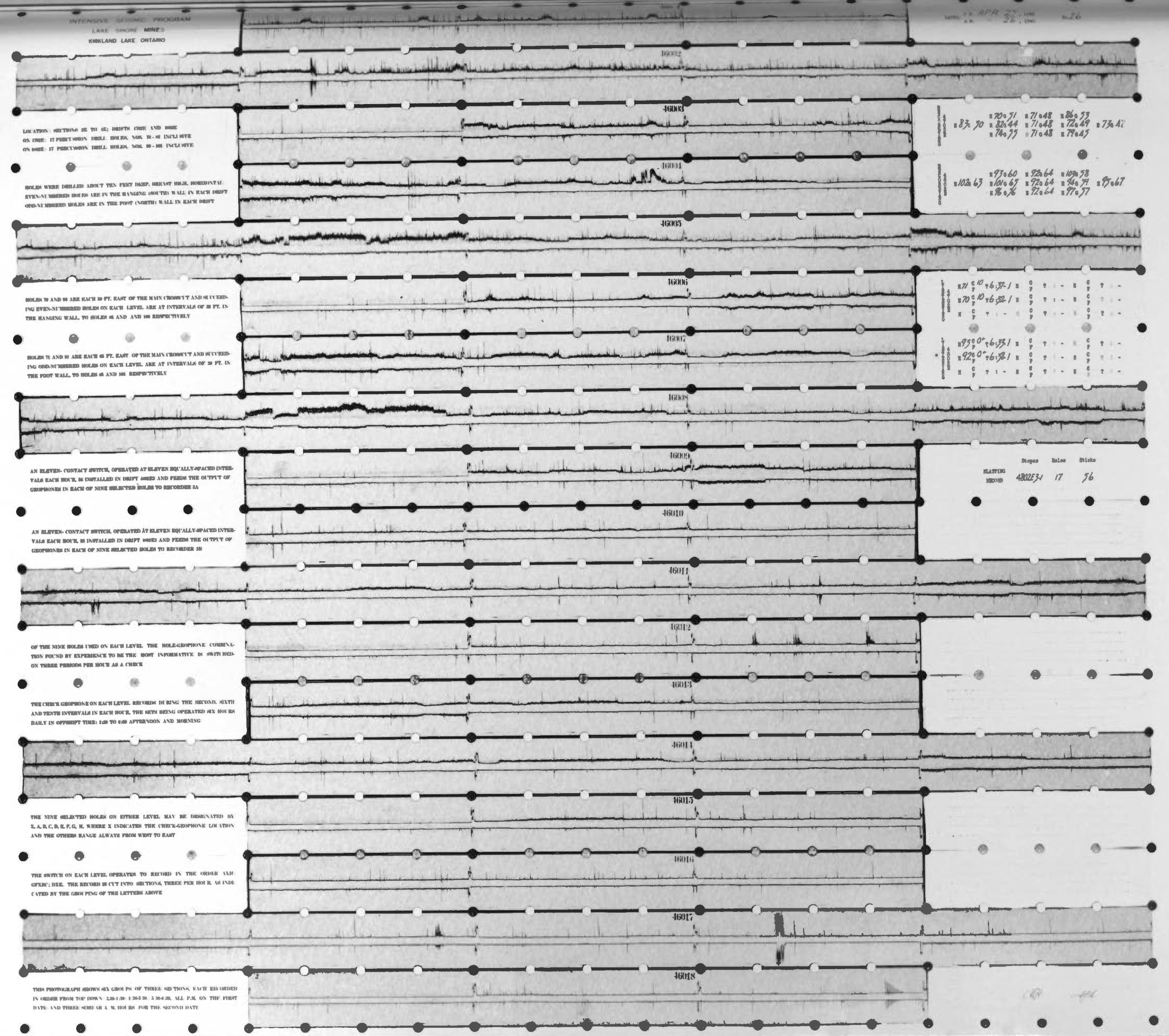
x86 40° 5:44-1	x79 0° 5:26-1	x72 60 6:05-1
x83 20° 5:48-1	x74 30° 6:16-1	x71 80 5:38-1
x82 10° 5:54-1	x75 30° 6:11-1	x70 60° 5:33-1

x101 10 5:46-1	x95 20° 5:56-1	x92 40° 6:13-1
x97 10 5:50-1	x94 0° 5:28-1	x91 80° 6:07-1
x96 30° 5:40-1	x93	6:18-1	x90 60° 5:35-1

	Stopes	Holes	Sticks
BLASTING RECORD	4802E31	30	100

Notes
H71- 5:22-1 (60+) LG. CO. CC.
- 5:59-1 (60+) LG. CO. CC.

H96- 5:24-1 (20-) DG. OO. FD.
- 6:01-1 (30+) GGD. OOO. DSF.



INTENSIVE SEISMIC PROGRAM
LAKE SHORE MINES
KIRKLAND LAKE ONTARIO

DATE APR 25, 1946
26, 1946
No. 26

LOCATION: SECTIONS 38 TO 42; DRIFTS [illegible] AND [illegible] ON [illegible]: 17 PERCUSSION DRILL HOLES, NOS. [illegible] INCLUSIVE ON [illegible]: 17 PERCUSSION DRILL HOLES, NOS. [illegible] - 106 INCLUSIVE

HOLES WERE DRILLED ABOUT TEN FEET DEEP, BREAST HIGH, HORIZONTAL EVEN-NUMBERED HOLES ARE IN THE HANGING (SOUTH) WALL IN EACH DRIFT ODD-NUMBERED HOLES ARE IN THE FOOT (NORTH) WALL IN EACH DRIFT

HOLES 70 AND 90 ARE EACH 30 FT. EAST OF THE MAIN CROSSCUT AND SUCCEEDING EVEN-NUMBERED HOLES ON EACH LEVEL ARE AT INTERVALS OF 30 FT. IN THE HANGING WALL, TO HOLES [illegible] AND AND 106 RESPECTIVELY

HOLES 71 AND 91 ARE EACH [illegible] FT. EAST OF THE MAIN CROSSCUT AND SUCCEEDING ODD-NUMBERED HOLES ON EACH LEVEL ARE AT INTERVALS OF 30 FT. IN THE FOOT WALL, TO HOLES [illegible] AND 105 RESPECTIVELY

AN ELEVEN- CONTACT SWITCH, OPERATED AT ELEVEN EQUALLY-SPACED INTERVALS EACH HOUR, IS INSTALLED IN DRIFT [illegible] AND FEEDS THE OUTPUT OF GEOPHONES IN EACH OF NINE SELECTED HOLES TO RECORDER 3A

AN ELEVEN- CONTACT SWITCH, OPERATED AT ELEVEN EQUALLY-SPACED INTERVALS EACH HOUR, IS INSTALLED IN DRIFT [illegible] AND FEEDS THE OUTPUT OF GEOPHONES IN EACH OF NINE SELECTED HOLES TO RECORDER 3B

OF THE NINE HOLES USED ON EACH LEVEL THE HOLE-GEOPHONE COMBINATION FOUND BY EXPERIENCE TO BE THE MOST INFORMATIVE IS SWITCHED ON THREE PERIODS PER HOUR AS A CHECK

THE CHECK GEOPHONE ON EACH LEVEL RECORDS DURING THE SECOND, SIXTH AND TENTH INTERVALS IN EACH HOUR, THE SETS BEING OPERATED SIX HOURS DAILY IN OFFSHIFT TIME: 3:30 TO 6:30 AFTERNOON AND MORNING

THE NINE SELECTED HOLES ON EITHER LEVEL MAY BE DESIGNATED BY X, A, B, C, D, E, F, G, H, WHERE X INDICATES THE CHECK-GEOPHONE LOCATION AND THE OTHERS RANGE ALWAYS FROM WEST TO EAST

THE SWITCH ON EACH LEVEL OPERATES TO RECORD IN THE ORDER AXH GFXEC; DXE. THE RECORD IS CUT INTO SECTIONS, THREE PER HOUR, AS INDICATED BY THE GROUPING OF THE LETTERS ABOVE

THIS PHOTOGRAPH SHOWS SIX GROUPS OF THREE SECTIONS, EACH RECORDED IN ORDER FROM TOP DOWN: 3.30-4.30; 4.30-5.30; 5.30-6.30, ALL P.M. ON THE FIRST DATE AND THREE SIMILAR A. M. HOURS FOR THE SECOND DATE

[illegible]	83 70	70 51 82 44 74 55	71 48 71 48 71 48	86 53 72 49 79 45	73 41
[illegible]	102 63	93 60 101 65 96 56	92 64 92 64 92 64	109 58 94 59 97 57	95 67

[illegible]	71 C P 10 6:57-1	C P	C P
	70 C P 10 6:52-1	C P	C P
	C P	C P	C P
[illegible]	95 C P 0 6:55 1	C P	C P
	92 C P 0 6:58 1	C P	C P
	C P	C P	C P

	Stopes	Holes	Sticks
BLASTING RECORD	4802E3-1	17	56

SEISMIC RESEARCH PROGRAM
ROCK BURST PROBLEM
LAKE SHORE MINES

•

Report No. 14, Part B
Instrument Development

• • •

Zack E. Gibbs

◆

SEISMIC RESEARCH PROGRAM
ROCK BURST PROBLEM
LAKE SHORE MINES

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Report No. 14. February, 1944 - June, 1945
Part B. Instrument Development

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Zack E. Gibbs

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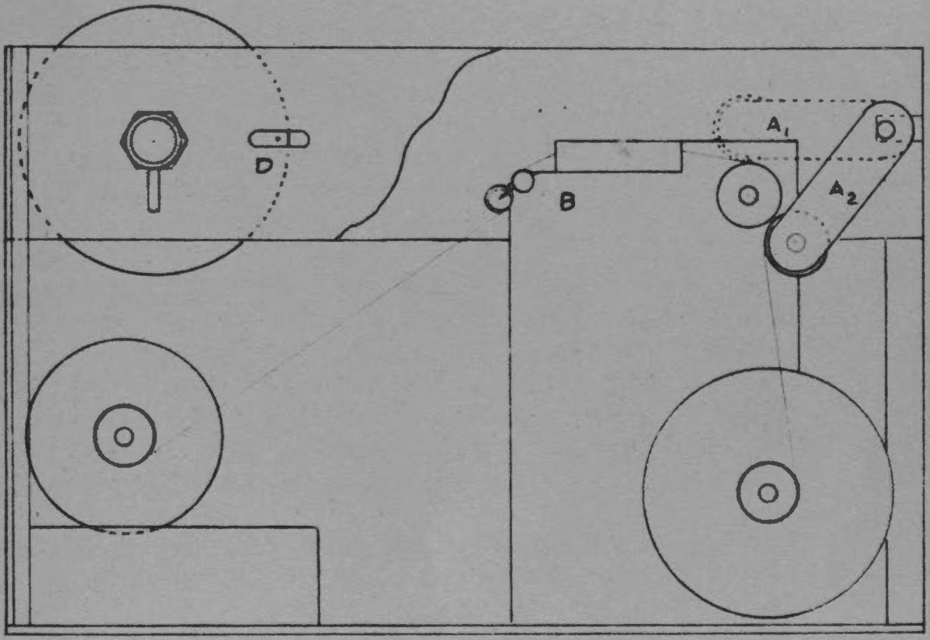
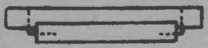
The following account may be considered a continuation of that given in Part B of Report No. 11 of this series. It covers the instrument development work of the program since the closing date of that report (March 31, 1943).

I. Method for Flattening Paper: Two modifications have been made in the recorders in order to overcome unevenness of the paper as it crosses the platen. First, the mounting of the idle pressure roller was reversed so that it now comes up from beneath the drive roll to make contact on its under side. (See Fig. 21)
In this way the paper is held in close contact with the drive roller for more than half of its circumference, insuring a much more positive paper drive. Second, a quarter-inch idle roller was attached to the spacer bar at the upper left hand corner of the motor-support plates. Short, bent steel pins support this roller about 1/16 inch from the spacer rod. (See Fig. 21) The paper is threaded under this roller and over the rod. Varying the position of the roller by rotating the rod allows more or less tension to be applied to the paper. The tension is practically independent of the amount of paper on the supply roll. The tension is adjusted until the paper lies smoothly on the platen. The original brake on the supply roll is slackened until it barely touches its disk.

II. Method for Adjusting Styli: In order to adjust the recording styli accurately, a slow-motion device was needed. A quarter-inch slot about three-quarters of an inch long was cut in the centre of the bakelite side-plate opposite the edge of the field magnet. A 1/8-inch





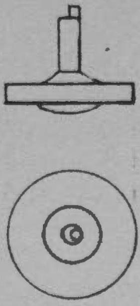


Fig. 21

OBERT RECORDER MODIFICATIONS

A_1	Original position of Idle Roller
A_2	Improved position of Idle Roller
B	Location of Tension Roller
C	Detail of Tension Roller
D	Stylus Adjusting Slot
E	Stylus Adjusting Cam

Drawn by J E Gibbs
June 23 1945
Scale 1:3

hole then was drilled into the rear face of the magnet, central to the slot when the stylus was approximately adjusted. A small removable cam was made to fit into the hole and to bear on the sides of the slot. Turning this cam raises or lowers the stylus point. The cam is made with an insulating handle and is withdrawn after adjustment is completed. (See Fig. 21)

III. Additional Magnet Support: The weight of the permanent magnet fields of the recorders tends to warp the bakelite side-plates, tilting the axes of the styli inward at the top. As a result, when the styli points are adjusted for minimum pressure to allow recording of small offsets, the points often rise off of the record at large amplitudes.

A strap of 1/4 x 1-inch steel was attached to the bakelite side-plates and positioned beneath the field magnets. In this strap, directly beneath the inner plates of the field magnets, holes were drilled and tapped for 1/4 - 28 screws. Two capstan-headed screws were then made with conical bakelite insulators inserted in their ends to bear against the magnets without short-circuiting them. By adjusting these screws, the inner sides of the magnets are raised until the axes of the styli are perpendicular to the platen and the styli make contact to the extremities of the record tape.

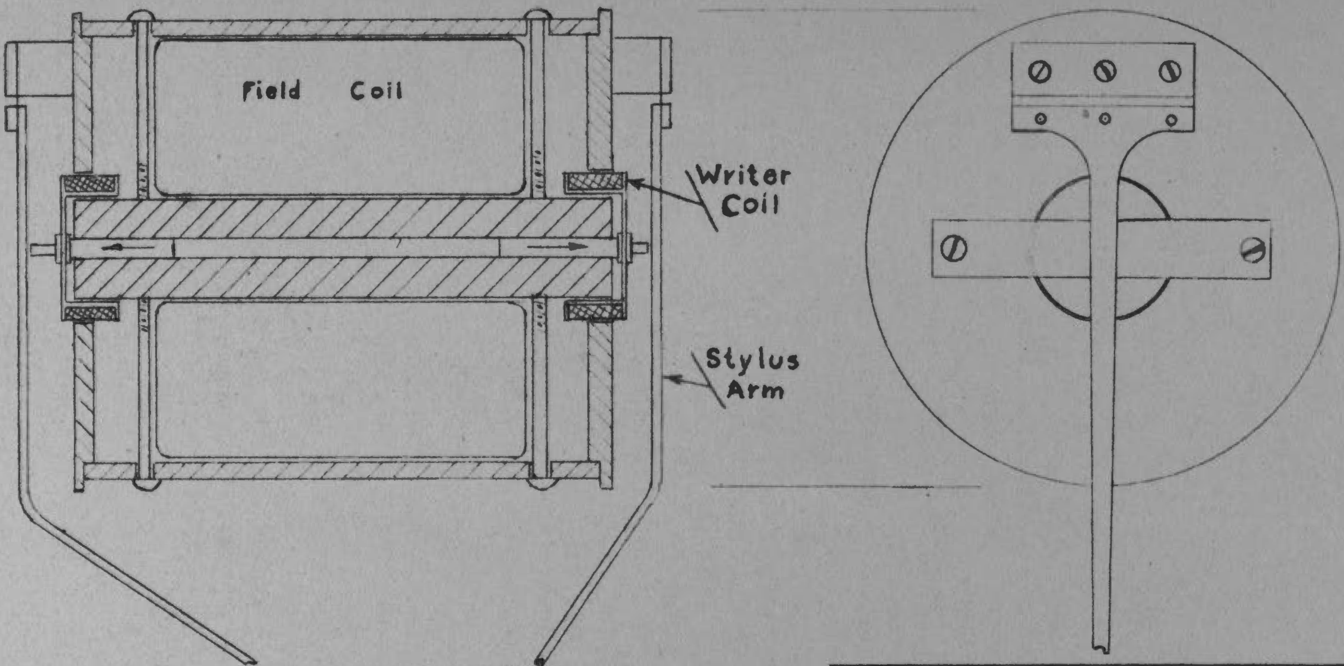
IV. Clock Switches: In the early period of geophone recording it seemed advisable to increase the space coverage of individual amplifiers at a sacrifice of time coverage. A number of switching devices were developed to change geophones automatically during periods of recording. One of the more satisfactory of these was built around a Telechron clock movement. A pair of Microswitches in tandem were arranged to be operated by a cam mounted on the minute-hand shaft of the clock. (See Figs. 4+5) Alternate pairs of contacts were closed on alternate half hours. This system proved so successful that an additional pair of Microswitches was added to each driving clock, allowing two pairs of geophones to record alternately on one dual-channel amplifier. For protection, each "Clock Switch" was mounted in an old

Square D switch box, which was fastened to the mine timbers in a position central to the connected geophones. (See Fig. 2, Report No. 12.) Electric power from the lighting mains was wired to each switch to run the clock and to supply a fifty-watt lamp for light and heat.

V. High-Speed Chronograph: In order to measure accurately the very small differences of time between arrivals of snaps at two separated geophones, a high-speed chronograph was constructed. This recording instrument was originally to have been operated directly from the power-amplifier of the Obert apparatus. With the idea of being able to select either the slow Obert recorder or the high-speed chronograph, a switching unit was provided, the case of which was also used to house the rectifier providing the magnetizing current for the chronograph recording head. The switch arrangement enables the operator to change from one recorder to the other with the least possible lost time.

The design of this chronograph has departed rather radically from conventional designs for such instruments. This was partly due to wartime shortages of brass and aluminum, but perhaps more to the fact that much of the fabrication was carried out in the mine's steel-plate shop, which is more accustomed to designing for strength than for precision. Awkward as it may seem to attempt to build a precision instrument under this handicap, the fact remains that the result, while not attractive in appearance, has proven to be very serviceable and extremely rugged.

The chronograph drum is made of a piece of six-inch iron pipe with end plates of quarter-inch steel welded to a 3/4-inch steel shaft. After assembly, the drum was turned on centres and balanced with internal weights. Bearings from an automobile generator were installed at each end of the shaft. On the left end of this shaft was mounted a four and one-half inch gear, which meshes with an identical gear to drive the ten-pitch longitudinal lead screw. This lead screw traverses the recording head. On the right end is attached a friction clutch and a 25-tooth, worm gear. Power is supplied by a quarter-horse-



DETAIL of RECORDER HEAD

Drawn by J. E. Gibbs
Date June 27, 1945
Scale approx. 2:3

Fig. 22

power induction motor through a flexible shaft to a single-pitch worm which meshes with the gear. The motor revolves about 1425 rpm., which makes the drum turn slightly less than one revolution per second. The spring of the flexible shaft, together with the inertia of the drum, resulted in occasional violent oscillations of the latter which broke several drive shafts. The installation of a pre-set friction clutch effectively damped out these oscillations.

The recording head houses a 900-ohm field coil to energize the two series air gaps, in which are immersed two regular Obert writer coils. Direct current for this field is provided by a 117Z6 rectifier and filter, housed in the switching box. The writer coils are so polarized that incoming signals cause each to move outward against the stylus arms, their axial pins bearing about one inch from the fulcrum of each arm. At the outer end of each stylus arm is attached a small copper clip which carries two 0.004-inch parallel nichrome wires separated 0.020 inch. Between these parallel wires, about 1/16 inch above the drum, pass the 0.018-ID monel metal capillary tubes which carry the recording ink to the revolving paper. Any motion imparted to the styli arms by the writer coils is transmitted to the capillary tubes with a minimum of lost motion, yet the writing points are free to rise and fall with any slight change in paper height.

The capillary tubes are supplied with ink from a double compartment reservoir which allows a different colored ink to be used in each of the two styli, thus making for greater ease in identifying the lines. The tubes are attached to the front side of the reservoir with removable joints which allow them to be taken off for cleaning and adjustment. They are connected to syphon tubes inside the reservoir, Ink flow is started by compressing the air above the ink in the reservoir with a rubber bulb applied to the filler hole. A special mounting for the reservoir enables it to be removed for filling or cleaning. This mounting is attached to the top of a shield-plate which protects the styli from harm and at the same time carries stops to limit the stylus motion to approximately 3/32 inch. (See Fig. 14)

The recording head is carried on two, parallel, 3/8-inch steel rods. One of these is eccentrically mounted and may be rotated through 180° about its axis to lift the styli from the paper and at the same time release the driving half-nut from the lead screw.

Upon testing the completed chronograph, it was found that the slope of the offsets on the record was so gradual that interpretation was both difficult and inaccurate. Certain electrical changes were made to steepen these offsets. After some experimenting, a circuit was incorporated in the recorder which substituted type-884, grid-controlled rectifiers for the regular 6F6's in the output. Additional, individual, bias controls were provided to enable these tubes to be adjusted to the most sensitive conditions consistent with reliable operation. The 884's and their associated apparatus were housed in a separate box and were connected into the original circuit through cables and plugs inserted in the sockets of the 6F6 tubes.

VI. Motor Switch: The Intensive Seismic Program recently undertaken made necessary a more elaborate switching system than that described in section IV. Here, maximum space coverage was desired even at a considerable loss of time coverage. Essentially a sampling system was required. To meet this need, a multiple-geophone-switching arrangement was built around a commercial motor valve control unit manufactured by the Minneapolis-Honeywell Corporation. (See Fig. 9) Originally this control was designed to operate a steam valve in response to signals from a thermostat. Its power-output shaft turned 180° for "heat on" and another 180° for "heat off". Slight changes in the control wiring made the unit turn through successive half revolutions for each repeated control signal. The only limitation involved is that the signal must be of shorter duration than the operating cycle to prevent re-cycling, and long enough to insure the locking-in of the motor-control relay. Satisfactory values were found to be one-half second minimum and four seconds maximum.

A Yaxley, Type 1321-L, two-circuit eleven-position wafer-switch was geared to the output shaft of the motor unit with a 6:1 gear ratio. This switch actually has twelve positions 30° apart but one position has no contact and is fitted as a stop. The stop was removed, allowing the switch to turn completely around. To avoid having one blank position each revolution of the switch, a cam was installed on the switch shaft, which closes a single-circuit contact causing the motor to re-cycle automatically each time the contact arm falls on the blank space. This effectively gives an eleven-position switch with decided marking advantage to be described later. A few changes were necessary in the circuit of the motor before it gave trouble-free operation.

The contacts of the Yaxley wafer-switch were connected directly to the blades of a set of ten Northern Electric Co. telephone jacks, according to a pre-arranged operating schedule. Plugs attached to individual geophone cables give extreme flexibility to the arrangement of the program.

VII. Magnetic Stepping Switch: The motor switch had not been installed before the need arose for another switch to perform the same function. No more motor units were available, so a different system was devised.

Fundamentally, the simplest way to position a wafer-type switch of the type used is by means of a ratchet and pawl, driven by an electromagnet. The torque necessary to turn a Yaxley, Type 1321-L, switch was measured and a suitable magnetic drive was designed. A solenoid was arranged to act upon a curved soft-iron armature fastened to a lever bar. At the centre of this bar, a pawl engages a twelve-toothed ratchet. At the opposite end of the lever was attached the plunger of a dash pot to restrain the violent motion of the armature and so prevent overshooting of the switch contacts. (See Fig. 6)

Three sets of auxiliary contacts were arranged on the drive mechanism in order to commutate the device properly. Double contacts on an associated relay serve both to switch power into the solenoid and at the same time to hold the relay circuit closed until the switch-cycle is complete. The wafer-switch is identical with the one previously described. Two of the three auxiliary contacts are arranged to re-cycle the switch at the appropriate time. The relay coil receives its operating impulse from a master contactor, located at the recording location, simultaneous with the operating impulse to the motor-switch. (See Fig. 7)

Closing of the master timer contacts energizes the relay coil (A) pulling in contacts (A_1) and (A_2). Current flows through (A_2) operating the solenoid and advancing the wafer-switch one position. Contact (A_1) meanwhile allows holding current to flow through contact (B) (normally closed) to keep the relay pulled in until the switching cycle is complete, regardless of the length of the instituting signal impulse. When contact (B) is opened at the end of the armature travel, the relay drops out, de-energizing the solenoid, and the armature returns to its initial position ready for another operation. Every time the armature returns by gravity to its initial position against its lower limit stop it closes contact (D). Nothing happens ordinarily when this contact is closed, but when the re-cycling contact (C) is closed at the skip position of the wafer-switch, the relay is closed again as soon as the armature returns to rest against its stop, exactly as though a signal had been applied by the master contactor. The wafer-switch thus skips its blank position once each revolution.

VIII. Master Contactor: In order to operate the two stepping switches in synchronism and on schedule, a master contactor was built around a Telechron clock movement. The minute-hand shaft was fitted with an eleven-point cam on which ride two cam followers. (See Fig. 10) These have insulated contact points mounted between them and are adjustable with respect to one another and to the cam. By varying the position of the cam followers, the length of contact is controlled. This time is normally adjusted to 2.5 seconds ± .5 second, to be within the limit set by the operation of the motor-switch. Erratic operation of this device was traced to lost motion in its gear train which occasionally allowed the cam to jump ahead when the first cam follower fell so that the second fell also and no contact was made.

A double-pole relay operated by this cam contact serves to institute the signal to the two stepping switches and at the same time to isolate them one from the other.

The records from the amplifiers show slight offsets at the switch-operating times. These may be due to electrostatic pickup by the connecting cables during the open-circuit time. At the skip position of each switch, the cables are left open-circuited for one complete operating cycle in addition to the usual short interval. The consequent longer offset serves very well to identify the number-one contact point on each revolution of the switch.

The stepping switches, together with their master contactor, have increased the coverage of one amplifier nine times. With the same equipment arranged for straight rotational operation, it would be possible to cover eleven times the original area.

IX. <u>Improved Geophone Crystal Mounting</u>: About the first of the year Dr. Obert sent a design for a new type of geophone crystal mount which he was trying. This new design departed from the original in two important respects. First, the Brush, Rochelle-salt crystal was restrained at both ends instead of being mounted springboard fashion as before. And second, small rubber pads were inserted between the clamps and the crystal, doing away with the cement which had formerly been used there.

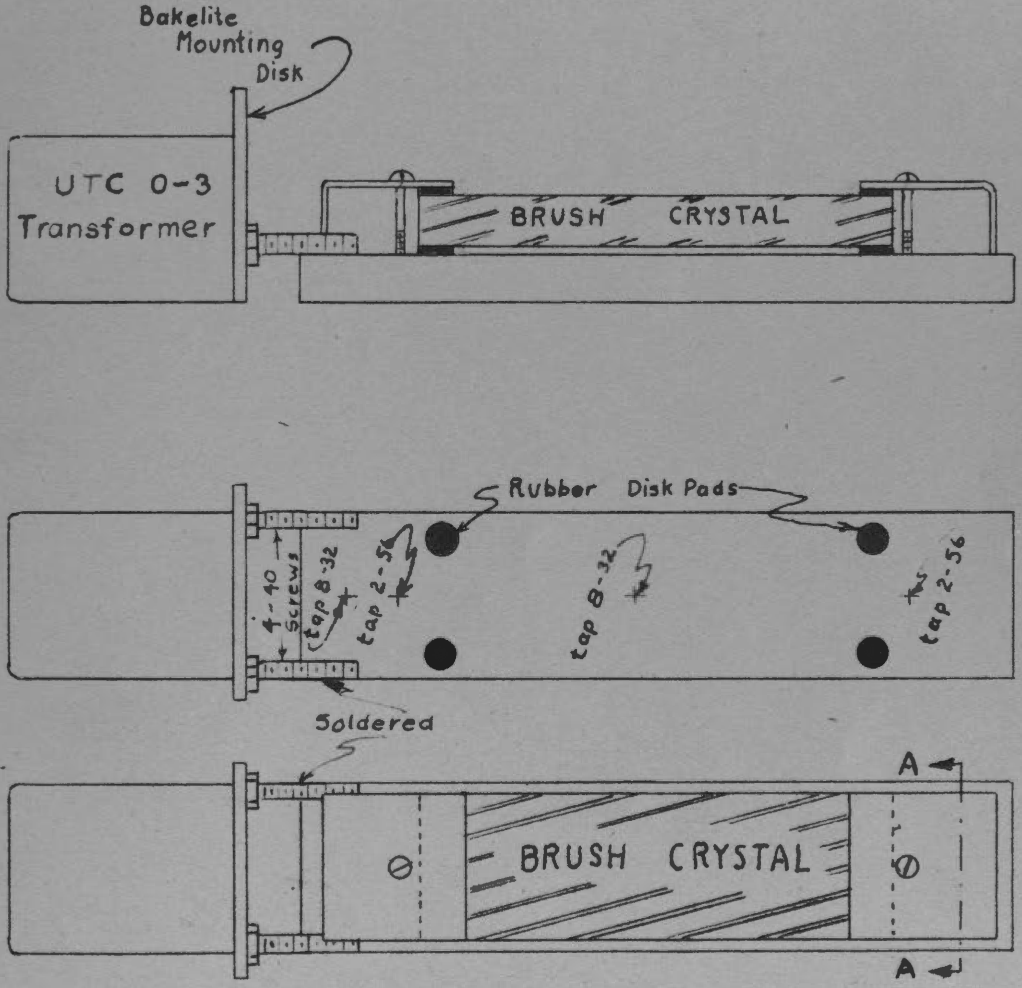
From a mechanical standpoint, the new design presents several improvements. It is far easier to machine and to assemble. There is no need for the use of a milling machine to make the mounting. The double-end mount is much more rugged and there is consequently much less chance of damage to the crystal from accidental shock. The rubber pads distribute the clamping pressure over a considerable area, thus avoiding crystal fracture during assembly due to too great concentration of clamping pressure. The elimination of cement between the crystal and its clamp has done away with one potential source of crystal failure. The solvent of the cement softened the moisture proofing of the crystal to such an extent that it has been felt that the protective coating was often destroyed at the clamp, allowing the crystal to absorb moisture and fail.

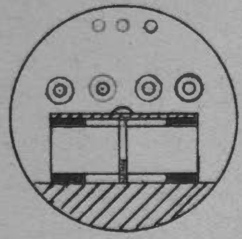
Three of these new type mountings have been in service for several months. It is impossible to tell them from the old type insofar as their response is concerned. It was thought that the fact that the crystal resonant frequency was doubled (about 2000 cps.) might affect the sensitivity but no change has been reported.

Since this new design offers appreciable advantage over the older type it will be incorporated in all new geophones put into service and all old ones brought up for repair will have their mounts replaced.

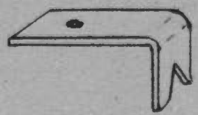
Lake Shore Mines,
Kirkland Lake,
June 29, 1945.

Z. E. G.





Section A-A



Clamp

Fig. 23

CRYSTAL MOUNT for TYPE FOUR GEOPHONE

Designed by L.A. Obert
Drawnby JB Gibbs June 28 '45
Built January 25, 1945
Scale Full

Number Four Obert Power Unit Terminal Strip for Log. Amplifier, Driver, and Demodulator, April 9, 1945

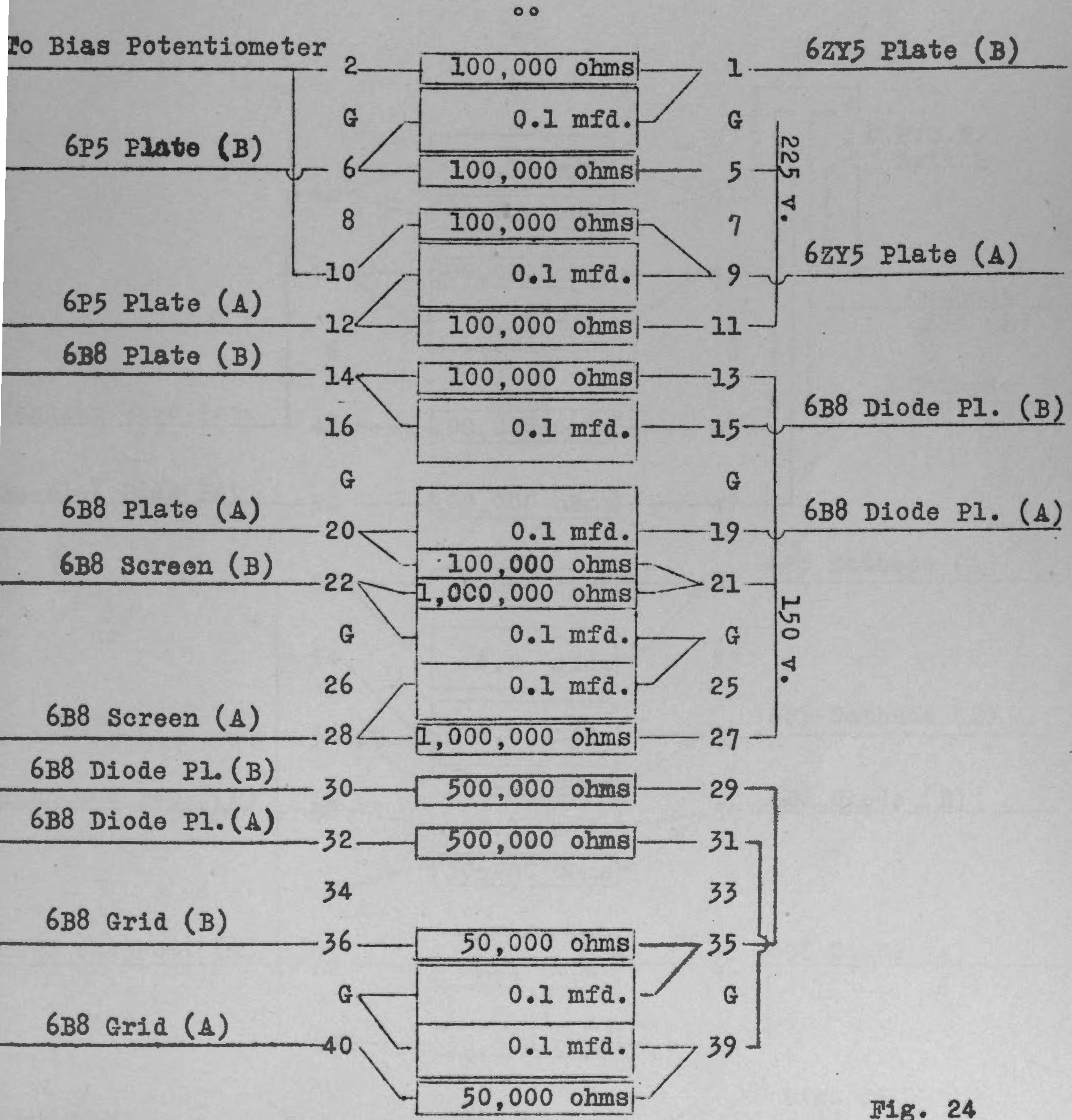


Fig. 24

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Number Four Obert Power Unit
Centre Resistor Bank
April 10, 1945

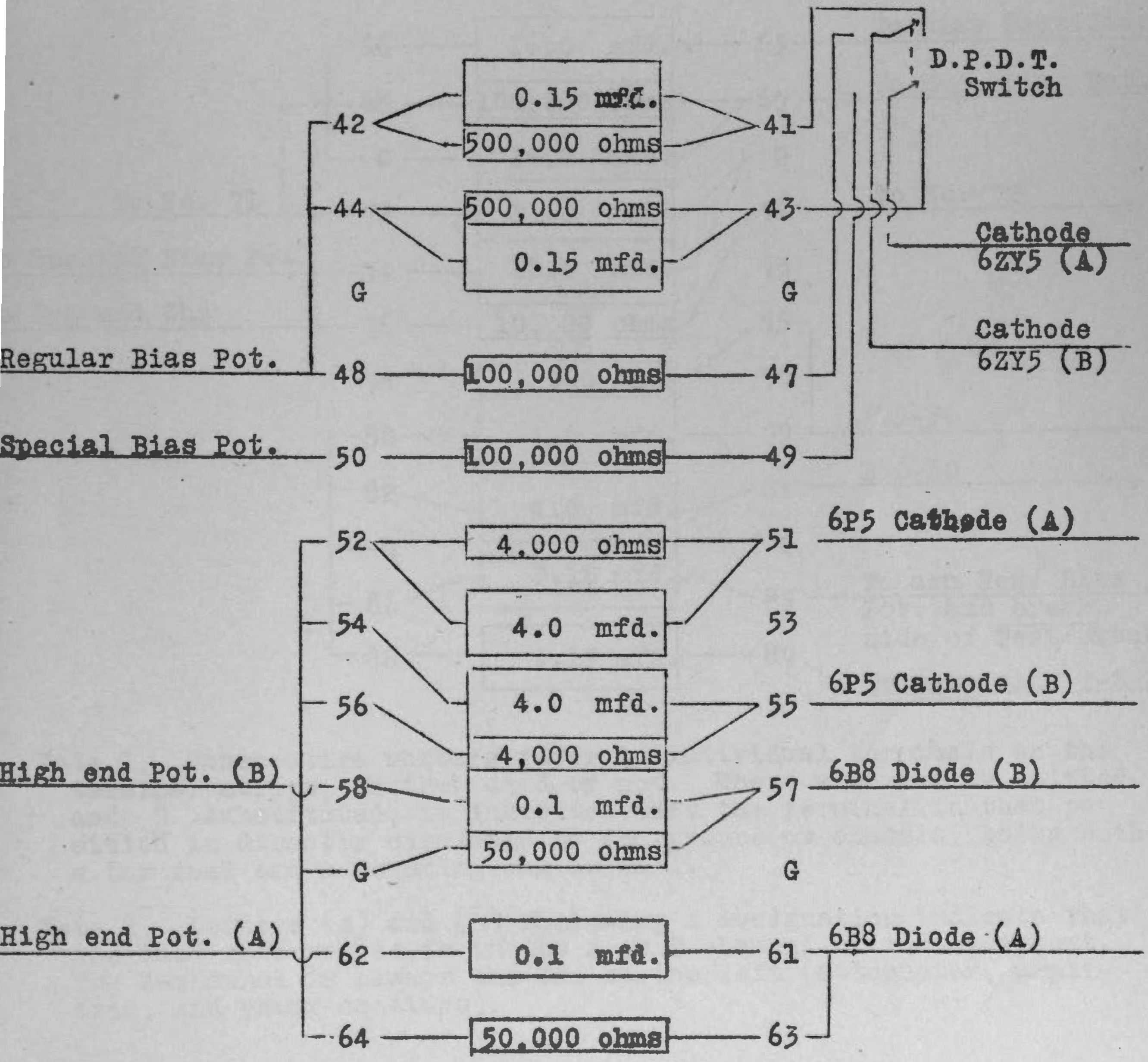
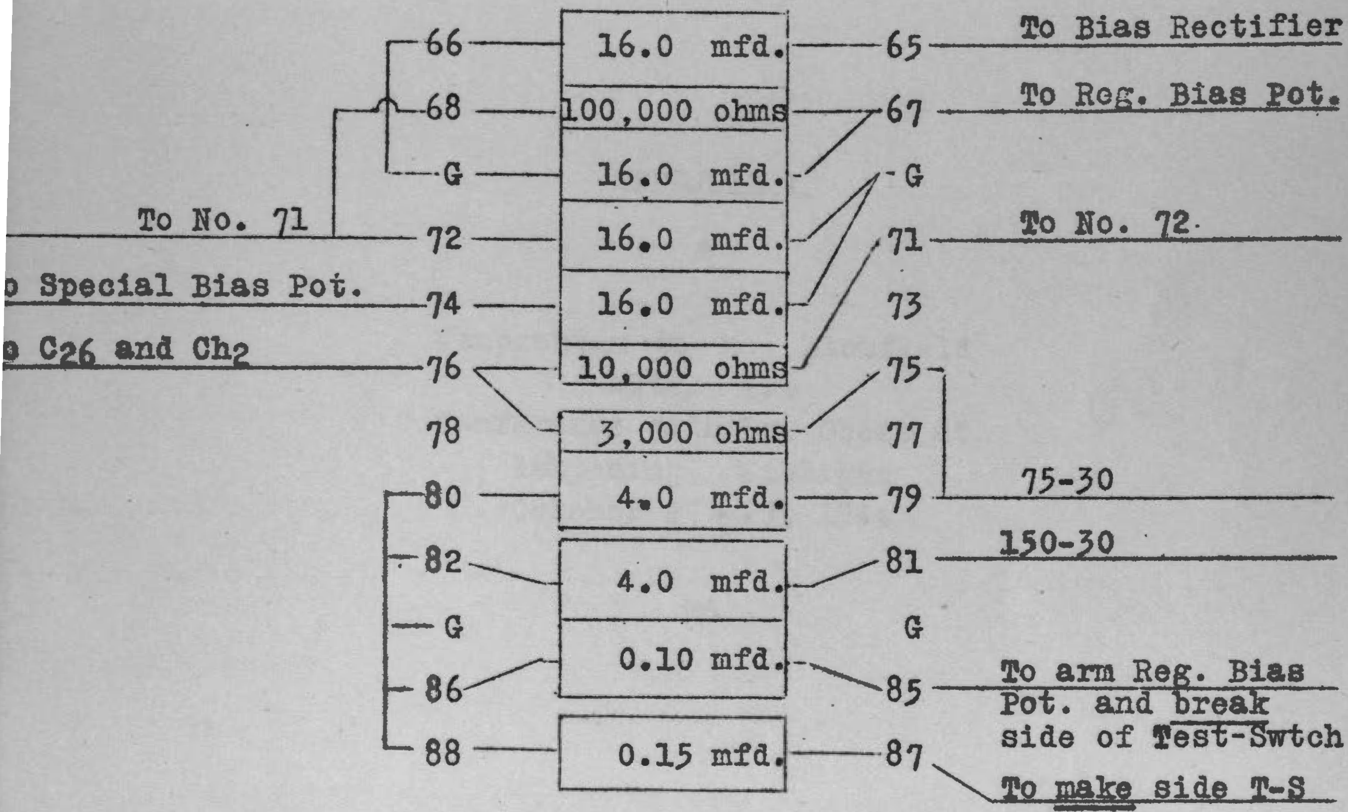


Fig. 25

Number Four Obert Power Unit
Bias Filter Terminal Bank
April 10, 1945



Note 1, Consecutive numbers refer to individual terminals on the terminal strips, whether used or not. Where a number is omitted and G substituted, it indicates that the terminal in that position is directly connected to the ground or chassis, being both a terminal and a mounting lug as well.

Note 2, Letters (A) and (B) following a designation indicate that the tube referred to is in the A or B channel of the equipment. The A-channel is always the one to the left (attenuator, amplifier, and power sections).

Fig. 26

APPENDIX I

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Memorandum to Mr. Blomfield
after the
Conference with Dr. Obert at
Ishpeming, Michigan
October 27 - 29, 1944.

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Status Microseismic Research
at
Lake Shore Mines

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Ernest A. Hodgson

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Rockburst research was undertaken, at the request of Lake Shore Mines, early in 1939. After several other methods had been tried and some experience gained, the microseismic method was begun in May, 1942. On January 29, 1943, a severe burst occurred in the exact location under study. The records definitely showed prediction, as outlined in Report No. 11. Another heavy burst on March 31, 1943, was not predicted because the instruments had not yet been rehabilitated after the January shock. The investigation was then moved to the east side.

In the new lay-out, which was in full swing on and after December 1, 1943, a new type of failure was encountered, named "slip bursts". These occur generally at blasting time and the build up of pressure is deep in the wall. So far, no prediction has been made, partly because the bursts usually occur just as the sets turn on and partly because the lay-out of holes has, so far, not succeeded in getting a geophone within recording distance of the centre of pressure. On two occasions since January 1, 1944, critical pressures have been detected, as evidenced by microseismims, and the men have been taken out. In neither case did it burst.

Another reason why there has been no prediction of the bursts at blasting time is that they are generally small and the critical pressures probably build up as blasting progresses. Some high counts have been heard (with earphones) but they were too small to record since the centre was too far from the geophone. With the new high-speed chronograph in use, it should be possible to discover the source, get a geophone within recording distance, and probably determine critical conditions as they build up.

There has been some doubt expressed as to whether or not microseismims are generated by high pressure; and, if so, if they increase in number sufficiently early to afford prediction. The recent report on the Obert tests definitely shows that they are so caused; and that, in the case of hard, brittle rock, they give ample prediction. This is in accord with the Lake Shore experience in January, 1943.

With all the above in mind the writer wishes to state that:

(1) The microseismic method is the only one ever suggested by any research worker which offers so much promise in the rockburst prediction field.

(2) It is already established as a regular program for application to the relatively simple problems of shallow mining. The principles remain unaltered for more complicated cases.

(3) Microseismims are generated by pressure alone.

(4) Microseismims give ample warning at about 80 per cent of the bursting pressure.

(5) The high-speed chronograph offers considerable promise of help in locating geophones in the present east-side locale.

(6) A further approach to the problem in Lake Shore Mines could be made by a concentration of geophones switching at 15 min. intervals on a single recorder and servicing a restricted area known to be dangerous.

(7) When the pressures are low microseismims do not register. When they are high they do. Mine pressures shift around from day to day. When the counts are high the pressure is critical. When they are low it is not. It is now possible to state when a place is safe (from bursts) and when it is critical. BUT PRESSURES MAY SHIFT BEFORE BURSTS TAKE PLACE; just as in the Obert experiments the rock would be intact after the high microseismim count if the pressure were reduced. Nevertheless, it was close to bursting when the count was high. What to do about these cases is a psychological and administrative

problem which, it seems to the writer, is the most difficult aspect of the whole program. There must be an agreement on procedure in this matter among all concerned if this work is to go on efficiently.

(8) The set-up in the east side affords considerable protection as it is now being run. Every exception to the rule of full-time, efficient service affords a chance to miss the prediction of a burst. For this reason the research staff has tried to let no interruptions occur. This is very important.

(9) Most of the cost involved in developing the method has already been met. The equipment, laboratory facilities, etc. are paid for. The personnel has been trained and has had very considerable experience in this work. The present, day-to-day cost of running the program might be considered as met by the protection it now affords the workers.

(10) There is an excellent chance that the method can be developed and/or modified to meet the routine needs of a mine, even one as complicated in structure as is Lake Shore.

The writer would thus recommend that:

(a) The research program now in operation on the 4575', 4700', and 4825'-levels on the east side be maintained, taking the greatest care to permit no interruption to all possible recording and listening.

(b) The high-speed chronograph be used to determine the velocities over various paths in the above section under study and to learn the location of zones of activity (heard but not recorded) so that a new hole (or holes) may be drilled in such positions that the activity may be recorded. It will then be possible to learn to what extent there is a promonitory build-up of microseismims prior to a burst even in the "slip" type.

(c) The recording and listening on the 4450'-level be (reluctantly) abandoned and the portable set, 3AB, used to study conditions in some limited section of ground which the Underground Superintendent and his associates consider dangerous for the time being. The geophones should be placed as close to the suspect ground as possible and a recording and listening program should be carried through regularly.

November 9, 1944. E. A. H.

APPENDIX II

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Paper Submitted to the
Canadian Mining and Metallurgical Bulletin
May, 1945
(Transactions: Vol. 28, pp. 267-269)

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Rock Burst Research at Lake Shore Mines

Ernest A. Hodgson

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When excavations are made, at depth, in hard, brittle rock structures, as in certain mines in India, in South Africa and in Ontario, the pressure due to overburden, together perhaps with inherent geologic strain, tends to become concentrated in the walls of some of these openings and the rock bursts, often closing the adjacent drifts and stopes and presenting a serious menace to the miners. Where the rock is much fractured and faulted, the danger is greater, since the pressures tend to shift without warning from point to point, sometimes within a few hours.

Attempts have been repeatedly made to find some physical property of the rock which will change with pressure, which can be measured for rock in place in the mine, and which will give an indication of the state of strain, thus warning of an approach to bursting conditions. Some of the properties tested have been: the speed of propagation of elastic waves in the suspect rock, variations in temperature due to pressure changes, rate of closure of openings or shifts along fault planes, strain gauge measures, and others. Each of these has proved unsatisfactory for the purpose. The most promising method so far proposed has been the study of the very faint, subaudible snaps (microseismims), which are produced in rocks under pressure.

Such a study has been in progress at Lake Shore Mines since May, 1942. Instruments designed to pick up, amplify and record the microseismims were perfected and a program of observing, using the microseismic method, has been carried through with persistent diligence and at considerable expense.

In 1943, experience with the method in a pillar section on the west side of Lake Shore Mines gave much promise of predicting bursts. A very heavy burst on January 29 of that year occurred in the exact section of the mine covered by the instruments, and the records indicated a measure of prediction. In response to repeated requests for information, a number of reports were given out, among others a radio talk by the writer over CJKL (Kirkland Lake), which was reported in full in The Northern News, and an illustrated paper, published in the Bulletin of the Canadian

Institute of Mining and Metallurgy.

Unfortunately, the research since that time, carried out in another part of the mine where conditions are somewhat different, has not been as successful as had been expected. A full year of recording and observing has failed to predict the many bursts which have occurred in the very block of ground serviced by the instruments. The writer and his associates feel that the disappointing results should receive the same publicity as the earlier, more hopeful ones. There are extenuating circumstances which will be outlined below, and also some interesting experiments which tend to confirm a belief in the principles on which the method is based. The work in the present locale has taught much about the nature of the subaudible snaps and the behaviour of rocks under pressure. More than 2,000 daily, recorder-offshift seismograms, and reports from nearly 3,000 man-hours of listening have been reduced to graphs and tabulation and have been studied in relation to the mining progress and the bursts from day to day. But the fact remains: As developed to date, the method cannot be relied upon to give any dependable warning of rockburst danger in Lake Shore Mines.

Now, as to the extenuating circumstances of the program of the past twelve months. The section of the mine now under survey is very much fractured and has numerous fault planes along which slippage is taking place from time to time. As a result, a further type of burst has been defined--the "slip burst". The stresses tending to induce slippage along a fault are opposed by friction. The amount of energy stored up in the rock by this opposing of forces does not become nearly as great as in the case of pillars under pressure. When a heavy burst occurred in the pillar, the energy release was so great that the tremors were recorded on the seismographs at Ottawa. When a slip occurs on one of these faults, the energy release is never enough to record at that distance, but they are, nevertheless, a menace. The point at which the block of ground was held up and where, presumably, the microseismims would develop may be hundreds of feet from the point where the fault crosses an opening, at which point (or points) the shock may throw down loose and perhaps injure men. Microseismims are definitely attenuated by distance, so that a geophone must be within a hundred feet or less of the source in order to permit recording. They can be heard at greater distances than they can be recorded--much greater distances than had been thought as has been proved by the experience of the past year. But the location of the source cannot be determined by the technique so far employed.

Another circumstance which has prevented success in the prediction of bursts is that, in this block of ground, nearly all the bursts have occurred at blasting time. The blasts seem to trigger the burst by letting down just enough added pressure to set off the slip. No one has been injured by these bursts, largely because they have occurred with the blasting, when the men were out of the workings. But, as the recording and listening can be done only in offshift times and as pressures can, and do, shift rapidly, the observations made from 3 to 7 a.m. each day do not give warning of the bursts which occur around 3 p.m. It is impossible to determine whether warning would have been given if it had been possible to carry out such observations.

The experiments to which reference has been made above and which tend to strengthen a belief in the potentialities of the method were performed in the U.S. Bureau of Mines under the direction of Dr. L. A. Obert. They will be reported by that organization, but it may not be out of place to state briefly the results. All data were made available to the writer through the courtesy of Dr. Obert and his associates. There is much encouragement to be derived from the results.

Selected, homogeneous specimens of rock were cut into small blocks having top and bottom surfaces plane and parallel. These were subjected to pressure in definite increments in a specially-designed press and the microseismims were counted for a fixed period, during which the specimen was held at the given pressure level. Beyond doubt, the microseismims are produced by pressure and increase in number as the pressure level is raised. The count rises in a most pronounced and definite manner as the pressure is raised above about 80 percent of the bursting value. This is especially true in the case of hard, brittle rocks.

The difficulty may be raised that the rocks in Lake Shore are far from homogeneous. This is true, but the remarkable fact remains, established by the previous long research, namely that there are long periods in which the snaps, identified by their characteristic sound as definitely microseismims, are the only type heard.

To sum up: Microseismims may be induced by pressure alone as evidenced by the experiments reported above. The microseismic method has been successful in its application by Obert and his associates in some relatively simple problems encountered in shallow mining. The method gave most promising results in the west pillar of Lake Shore Mines in January, 1943. But, in spite of persistent study it has so far proved valueless as an indicator of bursting conditions in the past year's work at Lake Shore.

It has seemed to those working directly on the problem and to the Management of Lake Shore Mines that the method has too much of promise to be abandoned without trying several other suggested methods of application. These are now being undertaken. In the meantime, the writer wishes to go on record as stating that, while much has been learned and while the method seems worthy of further testing, it cannot at the present time be considered a protective measure of any immediate practical value in the mine. It is a disappointing report, but it seems best to admit the fact and to hope that the new technique will ultimately be more successful.

E. A. H.

Lake Shore Mines
Kirkland Lake, Ont.
December 1, 1944.

APPENDIX III

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Seismicity Factor

TENTATIVE DRAFT

SEISMICITY FACTOR ON SCALE OF TEN

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The Seismicity Factor or index of critical conditions is an attempt to permit a daily plotting of underground data as they appear to the operator. Evidently, the counts alone are not sufficiently indicative. Subject to change as the idea is worked out, the following significance should be attached to the factor by the management:

0 to 5 : No special indication unless it has changed markedly since the day before.

5 to 6 : Activity just becoming worthy of notice by those in charge underground.

6 to 7 : Shift boss or captain should examine the ground reported.

8 : Conditions definitely acute but not critical. Examination should not be neglected.

9 : Conditions critical, but there may be explanatory circumstances (heavy blast, sill removed, etc.). Operator could possibly concur in decision to continue work.

10 : Conditions definitely critical in operator's opinion.

Again, subject to change as the idea is worked out, the following significance will be given the factor by the operator:

0 : Trace only.

1 : Quite subnormal for hole concerned.

2 : Low normal activity.

3 : Count about normal but no definite D or L of any considerable amount.

4 : Normal activity for the hole concerned. Some D and/or L. No trace of "viciousness" in sound of the snaps.

5 : High normal for hole. Trace of viciousness and/or moderately high D-count. Not markedly sporadic. No salvos.

6 : Higher than normal count. High D and/or definite viciousness and/or sporadic occurrence and/or salvos.

7 : Vicious local snaps. Counts at least twice normal. Possibly sporadic and/or salvos and/or with D-type snaps too high to count accurately.

8 : Counts definitely high, at least four times normal for hole concerned. Vicious local snaps or salvos.

9 : High vicious local activity which can be counted. Association with any particular stope uncertain and/or leaving some doubt with the operator as to immediate critical conditions.

10 : Very high, vicious local activity, near or above possibility of counting, definitely identified with a given stope or stopes. No doubt in operator's mind that work should be suspended.

The letter D or the letter L will follow the factor number. The former indicates that the condition reported was not exactly at the hole but that it was determined by data obtained at the hole with which the factor is associated. The letter L indicates that the condition reported was evidently quite close to the hole concerned. In plotting the factors on the graph at the office, the operators use a circle for a D point, and a small cross (x) for an L point ("x marks the spot").

Lake Shore Mines,
Kirkland Lake, Ont.
November 29, 1944.

E.A.H.
F.J.H.

APPENDIX IV

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Test Holes Assigned
to
Rock Burst Research

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(Continued from Appendix IV)
(Report No. 12)

Test Holes Assigned to Rock Burst Research

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H	DD	Date	Location and Wall	Depth	Remarks
55	4038	Mar. 23'44	4704XC-E	53'	Drilled diagonally E40°S. A
56	2959	Mar. 23'44	4701E-4-S	72'+	Old DD hole. B
57		May 26'44	4702E-2-N	4'+	Bootleg to check 4702E-2-N.
58	4083	Aug. 7'44	4702E-2-N	56'	Special diagonal hole. C
59	4084	Aug. 9'44	4702E-4-S	30'3"	Replacing H39. D
60	4055	Aug. 16'44	4401E-6-S	30'	Replacing H49. E
61		Sept. 9'44	4502E-2-S	4'+	Bootleg replacing H43.
62	4112	Oct. 27'44	4502E-3-S	30'4"	Replacing H43 and H61. F
63	4111	Oct. 27'44	4502E-6-S	31'9"	Replacing H48. G
64	4124	Nov. 29'44	4802E-3-S	29'10"	Replacing H41. H
64A		Dec. 21'44	4802E-0-N	4'+	Replacing H64. I
65	?	Feb. 9'45	4701E-6-S	30'	Replacing H51. J
66		Dec. 15'44	4701W-1-N	4'+	Bootleg. K
67	?	"	4701W-1-N	30'+	Old DD hole. "
68		"	4701W-2-N	4'+	Bootleg. "
69		"	4701W-2-N	4'+	Bootleg. "
70		"	4702E-2-S	4'-6'	MP —4700 M
71		"	4702E-2-N	"	" "
72		"	4702E-2-S	"	" "
73		"	4702E-2-N	"	" "
74		"	4702E-2-S	"	" "
75		"	4702E-3-N	"	" "
76		"	4702E-3-S	"	" "
77		"	4702E-3-N	"	" "
78		"	4702E-3-S	"	" "
79		"	4702E-3-N	"	" "
80		"	4702E-3-S	"	" "
81		"	4702E-4-N	"	" "
82		"	4702E-4-S	"	" "
83		"	4702E-4-N	"	" "
84		"	4702E-4-S	"	" "
85		"	4702E-4-N	"	" "
86		"	4702E-4-S	"	" "
87		"	4701W-1-S	"	Bootleg. L

Test Holes Assigned to Rock Burst Research

H	DD	Date	Location and Wall	Depth	Remarks	
88		Dec. 15'44	4701W-1-S	4'-6'	Bootleg.	L
89		"	4702W-1-S	"	"	"
90		Feb. 1'45	4802E-2-S	"	NP-4800.	M
91		"	4802E-2-N	"	"	"
92		"	4802E-2-S	"	"	"
93		"	4802E-2-N	"	"	"
94		"	4802E-2-S	"	"	"
95		"	4802E-3-N	"	"	"
96		"	4802E-3-S	"	"	"
97		"	4802E-3-N	"	"	"
98		"	4802E-3-S	"	"	"
99		"	4802E-3-N	"	"	"
100		"	4802E-3-S	"	"	"
101		"	4802E-4-N	"	"	"
102		"	4802E-4-S	"	"	"
103		"	4802E-4-N	"	"	"
104		"	4802E-4-S	"	"	"
105		"	4802E-4-N	"	"	"
106		"	4802E-4-S	"	"	"
107	4158	Feb. 9'45	4704XC-E	50'		N

NOTES

A. Log H55 : 0'-28' Badly broken and shattered porphyry; much lost core; 24 pulls; several weak seams, some stronger ones at 19', 23', and 27'.

28'-53' Porphyry, less broken up and shattered; 10 pulls; possible seams at 31', 38', and 45'; no casing.

B. H56 is an old DD hole in very good condition; canted slightly upward from the collar; cleaned out to a depth of 72' on or about March 23'44; extends to a much greater depth.

C. H58 is a specially-drilled DD hole running diagonally NW. from a collar on the north wall of 4702E2; cuts directly across behind the anvil of the tapper; emerges in 4700 main XC; hole cased at both ends to a depth of about 6'; core shows porphyry; small slips at 12' and 45'10".

D. Log H59 : 0'-30'3" Badly broken up; 50 % lost core; weak fractures 19!5, 23', and 26!5; no sludge return.

E. H60 : A DD hole run for sampling but taken over to replace H49 which was lost by closure; cants downward from the collar at about 19°.

F. Log H62 : 0'-19' Core slightly broken; good recovery; 7 pulls.

19'-30'4" Good solid rock.

G. Log H63 : 0'-7'4" Very badly crushed porphyry; much lost core; 8 pulls; calcite seam 7'4".

7'4"-23' Not so badly broken; 11 pulls; strong break 16'-18'.

23'-31'9" Good ground; good core recovery.

H. Log H64 : 0'-29'10" Very badly broken all the way; 23 pulls; core losses up to 10" in places.

I. H64A is a bootleg in 4802E near the main XC and in the north wall.

J. H65 was drilled in 4701E-6-S to replace H51 which had been lost due to closure.

K. H66, H67, H68, H69 are holes, in order going west, in the north wall in 4701W1 to 4701W2. H67 is an old DD hole in very good condition. It is over 30' deep, for a geophone was located in it at that depth. The others are old PD test holes, shallow but clean and in good condition.

L. H87, H88, H89 are old PD test holes, in order going west, in the south wall in 4701W1 to 4701W2. They are shallow but clean and in good condition.

M. Holes 70 - 86 were drilled on 4702E, the even-numbered holes in the south wall, the odd-numbered holes in the north wall. H70 is 50' east of the main XC and successive even-numbered holes are at 30' intervals to H86. H71 is 65' east of the main XC and successive odd-numbered holes are at 30' intervals to H85. Holes 90 - 106 were drilled on 4802E, the even-numbered holes in the south wall, the odd-numbered holes in the north wall. H90 is 50' east of the main XC and successive even-numbered holes are at 30' intervals to H106. H91 is 65' east of the main XC and successive odd-numbered holes are at 30' intervals to H105. All the holes 70-106 are PD type, as deep as they could be drilled in what was often very poor wall. The effective depths vary from 4' or less to about 6'. All were drilled for use in the Intensive Seismic Program (NP).

N. H107 was drilled parallel to H55, which was lost due to slippage along a diagonally-crossing fault plane.

Dominion Observatory,
Ottawa, Ontario,
June 26, 1945

E. A. H.

APPENDIX V

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Recording from Holes 36 - 107
February, 1944 - June, 1945

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Recording from Holes 36 - 107

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The following tables show the records obtained from Holes 36 - 107, the total list of holes contributing to the recording program during the period covered by this report. Appendix V of Report No. 12 gives a history of the recording up to the end of January, 1944. It shows that holes 37 and 39 were lost prior to that time and that hole 45 was abandoned as of January 31, 1944. Thus, the holes in service ran from 36 to 54, with the exception of the three named above. The notes given below show when each of the holes 55 - 107 inclusive came (later) into service and the tables indicate the extent to which each hole has contributed to the recording program. There was, of course, a listening program which used some holes not connected to recorders.

The holes in the Intensive Program are also included, being entered simply as NP (new program) when on schedule and as a hole only when the commutating switch was not operating, e.g. H96 and H71 on occasion. Holes 66, 68, 69 were selected bootlegs, chosen only for the listening program, and holes 87, 88, 89 were not drilled, as planned (in the back on 4702E4). See further details in the Notes below.

The figure at the intersection of any hole line and date column is the units digit of the number of the record which began to register from that hole on that date. The hundreds and tens digits of the number are given in the bottom (double) line, in the order reading down. A dash in any position indicates that one is to read the figure next on the left in the same line, the record bearing that number having been continued for more than one day. An oblique bar through a units digit couples it to the hundreds and tens digit next on the left of those immediately below in the double line. This arrangement is exactly the same as in Appendix V of Report No. 12 and may be considered a continuation of the table and notes there given.

NOTES

A. Hole 46 was registering on Recorder 2X. On Feb. 21'44 this recorder was undergoing repairs to the paper feed - hence no record was begun on that date.

B. The geophone in H51 was found to have been damaged by a burst on Feb. 10'44. It was replaced on Feb. 11.

C. Recorder 5AB developed a burned out choke. Repairs were made Mar. 6'44.

D. Recorder 6AB was taken to surface to make repairs to burned out writer coil on Mar. 31'44 and returned to service Apr. 8.

E. H46 was used only for listening after Mar. 12'44.

F. H55 began recording on Mar. 28'44.

G. H55 and H40 were fed through an input divider so that they recorded simultaneously on recorders 5AB and on 2X from Apr. 3 to Apr. 6'44 inclusive.

H. H51 connecting cable was found damaged by blasting on Apr. 1'44. It was repaired and H51 put in service on Apr. 17.

K. Recorder 5AB was removed to surface for overhauling on Apr. 20'44. H40, H47, H54 and H55 were thereby affected. H55 was run with H56 on 2X, while H40 and H51 were run with H54 and H47 on 3AB (which replaced 5AB on 4700), to get as much coverage as possible in 4701E.

L. H36, H38 and H49 were taken off recording on Apr. 20'44 when 3AB was moved to 4700 to replace 5AB. (See note K above). They were thereafter serviced only by listening with LSM11 till May 11. At that date H36 and H49 were again run on recorder 3AB (returned to 4400) but H38 continued to be serviced only by listening.

M. Recorder 2X was taken to surface for repairs on May 10'44. It was returned to service May 15.

N. Lines to H41 and H52 were taken down May 17'44 to avoid damage by blasting in 4802E3. They were returned to service June 9.

P. H57, a bootleg in 4702E2, began recording on June 1'44, being run on 2X together with H55 and H56, while listening was done each day. As only a short recording was made each day, the same strip of tape was left unbroken for a week or more. H57 was abandoned July 31'44.

Q. H55 was run on recorder 5B on June 17-18'44 in place of H54 and H47 but was returned to recorder 2X with the former record number 567 on June 18.

R. H55 was used on the listening program, but no records were made from it in July, 1944.

S. The line to H49 was damaged by blasting. It was replaced by H60 on Aug. 18'44 as the geophone was damaged and H49 closed in. It was abandoned as of July 25.

T. H43 was damaged by blasting Aug. 30'44. It was replaced by a bootleg, H61, beginning Sep. 8.

U. H47 was discontinued as a recording hole on Aug. 17'44, used in listening program only.

V. Sets were not turned on when left on Sep. 22'44 so no recording was done till 3:40 a.m. Sep. 23, when the set was turned on by E.A.H. The same numbers were used from Friday a.m. (Sep. 23) over the week end. Hence double dash entries on these dates.

W. H48 was removed from service on Oct. 7'44. It was lost in mining operations.

X. Recorder 4AB removed to surface Oct. 12'44 for adaptation to High Speed Chronograph service. It was returned to service Nov. 9. The chronograph was installed on Nov. 15 but the styli were found unsuitable for service and the instrument was returned to surface.

Y. H54 and H59 were removed from service on Oct. 9'44 to permit timbering in 4702E. H58 was used on the recorder in the meantime. Holes 54 and 59 were replaced in service Oct. 18 and Oct. 20.

Z. Holes 62 and 63 were drilled in 4502E and placed in service Nov. 8'44. H61 was then abandoned.

a. The record numbers passed the 2,000 mark on Nov. 29'44 and the third series began Nov. 30.

b. H41 was lost in mining operations about Nov. 1'44 and replaced by H64 which began operation on Dec. 1.

c. H64A is a bootleg at the junction of 4802E with the main XC. It was used in place of H64 when the latter was endangered by mining operations on Dec. 20'44. H64 was restored temporarily to the program on Jan. 17'45 but was later lost in mining operations.

d. H52 was disconnected on Dec. 12'44 to allow for timbering in 4802E.

e. On Dec. 14'44 holes 65, 66, 67, 68, 69 were placed in listening service only.

f. Record 156 was put on recorder 2X on Jan. 24'45 and used only for listening time records till Feb. 19.

g. On Jan. 24'45 the new "Intensive Seismic Program" began from the holes in 4702E only, those on 4802E not having been drilled as yet and the commutating switch not being finished. On Feb. 19'45 the first hole of 4800 set (H96) went into operation with no commutation switch and on Mar. 26 both levels began regular schedule recording.

h. On Feb. 10'45 H51 was replaced by H65. This is a hole which had been newly drilled in 4701E6 to replace H51 which had been badly distorted by mining and from which the geophone could not be removed.

i. H107 was drilled in 4704XC to replace H55, lost by reason of shifts along fault planes cutting the holes diagonally. It was placed in operation on Feb. 12'45 but was used mostly on the listening program.

j. With the inauguration of the Intensive Program, the recorder 3AB was moved to 4700'-level to service that project. LSM11 was installed on 4450'-level to serve for listening from holes 36, 38 and 60. There was no further recording from those holes after Jan. 19'45.

k. Beginning Feb. 19'45 H56 was serviced by recorder 2X during the listening period, the record being numbered R156.

l. H107, drilled to replace H55, as indicated in (i) above, was found so quiet that, after being tried out for two days on the recording program early in February, 1945, it was serviced only by listening until April 20.

m. Recorder 5AB was on surface for adjustment Mar. 20 to Mar. 27'45 inclusive.

n. Recorder 4AB was on surface for adjustment Apr. 9 to Apr, 17'45 inclusive.

p. H56 was removed from recorder 2X on Apr. 20'45 and H47 substituted. H56 and H65 were temporarily discontinued on that date to permit mining operations in 4701E. Service was restored on June 11.

q. Falling rock damaged the line to H59 and caused a break in recording from May 12 to May 14'45 inclusive.

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Dominion Observatory,
Ottawa, Canada,
June 30, 1945.

E. A. H.

26

	February, 1944																														
H										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
36	8	2	6	0	4	-	8	2	6	0	4	8	-	2	6	1	6	1	6	-	1	5	0	5	0	5	-	0	5		
38	8	2	6	0	4	-	8	2	6	0	4	8	-	2	6	1	6	1	6	-	1	5	0	5	0	5	-	0	5		
40	0	4	8	2	6	-	0	4	8	2	6	0	-	4	8	3	8	3	8	-	3	7	2	7	2	7	-	2	7		
41	1	5	9	3	7	-	1	5	9	3	7	1	-	5	9	4	9	4	9	-	4	8	3	8	3	8	-	3	8		
42	1	5	9	3	7	-	1	5	9	3	7	1	-	5	9	4	9	4	9	-	4	8	3	8	3	8	-	3	8		
43	9	3	7	1	5	-	9	3	7	1	5	9	-	3	7	2	7	2	7	-	2	6	1	6	1	6	-	1	6		
44	9	3	7	1	5	-	9	3	7	1	5	9	-	3	7	2	7	2	7	-	2	6	1	6	1	6	-	1	6		
46															0	5	0	5	0	-	A	9	4	9	4	9	-	4	9		
47	0	4	8	2	6	-	0	4	8	2	6	0	-	4	8	3	8	3	8	-	3	7	2	7	2	7	-	2	7		
48	9	3	7	1	5	-	9	3	7	1	5	9	-	3	7	2	7	2	7	-	2	6	1	6	1	6	-	1	6		
49	8	2	6	0	4	-	8	2	6	0	4	8	-	2	6	1	6	1	6	-	1	5	0	5	0	5	-	0	5		
50	9	3	7	1	5	-	9	3	7	1	5	9	-	3	7	2	7	2	7	-	2	6	1	6	1	6	-	1	6		
51	0	4	8	2	6	-	0	4	8	2	6	0	-	4	8	3	8	3	8	-	3	7	2	7	2	7	-	2	7		
52	1	5	9	3	7	-	1	5	9	3	7	1	-	5	9	4	9	4	9	-	4	8	3	8	3	8	-	3	8		
53	1	5	9	3	7	-	1	5	9	B	7	1	-	5	9	4	9	4	9	-	4	8	3	8	3	8	-	3	8		
54	0	4	8	2	6	-	0	4	8	2	6	0	-	4	8	3	8	3	8	-	3	7	2	7	2	7	-	2	7		
	1	-	-	1	-	-	1	-	-	1	-	1	-	-	1	-	2	-	2	-	-	-	2	-	2	-	-	2	-		
	4	-	-	5	-	-	6	-	-	7	-	8	-	-	9	-	0	-	1	-	-	-	2	-	3	-	-	4	-		

	March, 1944																														
H										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
36	0	5	0	5	-	0	-	8	-	4	-	-	2	-	9	-	6	-	-	3	-	0	7	-	-	-	-	-	-	-	-
38	0	5	0	5	-	0	-	8	-	4	-	-	2	-	9	-	6	-	-	3	-	0	7	-	-	-	-	-	-	-	-
40	2	7	2	7	-	C	4	8	2	6	0	-	4	7	1	4	8	1	-	5	8	2	5	9	2	-	5	8	2	5	7
41	3	8	3	8	-	2	5	9	3	7	0	-	5	8	2	5	9	2	-	6	9	3	6	0	3	-	6	9	3	6	8
42	3	8	3	8	-	2	5	9	3	7	0	-	5	8	2	5	9	2	-	6	9	3	6	0	3	-	6	9	3	6	8
43	1	6	1	6	-	1	3	7	1	5	8	-	3	6	0	3	7	0	-	4	7	1	4	8	1	-	4	7	1	D	
44	1	6	1	6	-	1	3	7	1	5	8	-	3	6	0	3	7	0	-	4	7	1	4	8	1	-	4	7	1	D	
46	4	9	4	9	-	-	-	0	-	-	1	E																			
47	2	7	2	7	-	C	4	8	2	6	0	-	4	7	1	4	8	1	-	5	8	2	5	9	2	-	5	8	2	5	7
48	1	6	1	6	-	1	3	7	1	5	8	-	3	6	0	3	7	0	-	4	7	1	4	8	1	-	4	7	1	D	
49	0	5	0	5	-	0	-	8	-	4	-	-	2	-	9	-	6	-	-	3	-	0	7	-	-	-	-	-	-	-	-
50	1	6	1	6	-	1	3	7	1	5	8	-	3	6	0	3	7	0	-	4	7	1	4	8	1	-	4	7	1	D	
51	2	7	2	7	-	C	4	8	2	6	0	-	4	7	1	4	8	1	-	5	8	2	5	9	2	-	5	8	2	5	7
52	3	8	3	8	-	2	5	9	3	7	0	-	5	8	2	5	9	2	-	6	9	3	6	0	3	-	6	9	3	6	8
53	3	8	3	8	-	2	5	9	3	7	0	-	5	8	2	5	9	2	-	6	9	3	6	0	3	-	6	9	3	6	8
54	2	7	2	7	-	C	4	8	2	6	0	-	4	7	1	4	8	1	-	5	8	2	5	9	2	-	5	8	2	5	7
55																											F	0	-	4	9
	2	-	2	-	-	2	-	2	-	-	2	-	-	-	3	-	-	3	-	-	-	3	-	3	-	-	-	3	-	-	-
	5	-	6	-	-	7	-	8	-	-	9	-	-	-	0	-	-	1	-	-	-	2	-	3	-	-	-	4	-	-	-

April, 1944

H										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
36	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	L											
38	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	L											
40	0	-	2	5	8	1	4	7	-	2	6	0	2	6	0	-	2	6	0	4	8	2	-	6	0	4	8	2	6	-	
40		G	4	7	0	3	6	0	-	4	-	-	-	-	-	-															
41	1	-	3	6	0	2	5	8	-	3	7	0	3	7	0	-	3	7	1	5	0	3	-	7	1	5	0	3	7	-	
42	1	-	3	6	0	2	5	8	-	3	7	0	3	7	0	-	3	7	1	5	0	3	-	7	1	5	0	3	7	-	
43	C							0	-	1	5	8	1	5	8	-	1	5	0	3	7	1	-	5	0	3	7	1	5	-	
44	C							0	-	1	5	8	1	5	8	-	1	5	0	3	7	1	-	5	0	3	7	1	5	-	
47	0	-	2	5	8	1	4	7	-	2	6	0	2	6	0	-	2	6	0	4	8	2	-	6	0	4	8	2	6	-	
48	C							0	-	1	5	8	1	5	8	-	1	5	0	3	7	1	-	5	0	3	7	1	5	-	
49	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	L											
50	C							0	-	1	5	8	1	5	8	-	1	5	0	3	7	1	-	5	0	3	7	1	5	-	
51	H																2	6	0	4	8	2	-	6	0	4	8	2	6	-	
52	1	-	3	6	0	2	5	8	-	3	7	0	3	7	0	-	3	7	1	5	0	3	-	7	1	5	0	3	7	-	
53	1	-	3	6	0	2	5	8	-	3	7	0	3	7	0	-	3	7	1	5	0	3	-	7	1	5	0	3	7	-	
54	0	-	2	5	8	1	4	7	-	2	6	0	2	6	0	-	2	6	0	4	8	2	-	6	0	4	8	2	6	-	
55	0	-	2	5	8	1	4	7	-	2	6	0	2	6	0	-															
55		G	4	7	0	3	6	0	-	4	-	-	-	-	-	-	4	8	2	6	0	4	-	8	2	6	0	4	8	-	
56																					0	4	-	8	2	6	0	4	8	-	
	3	-	-	-	3	-	-	3	-	-	-	3	-	-	3	-	-	-	4	-	4	-	-	-	4	-	4	-	-	-	
	5	-	-	-	6	-	-	7	-	-	-	8	-	-	9	-	-	-	0	-	1	-	-	-	2	-	3	-	-	-	

May, 1944

H										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
36										N	7	8	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-
38																				4	-	-	-	-	-	-	-	-	-	-	-
40	0	4	8	2	6	0	-	4	8	2	5	0	3	-	6	0	4	8	1	6	-	0	3	7	1	5	0	-	2	5	8
41	1	5	0	3	7	1	-	5	0	3	6	1	4	-	7	1	N														
42	1	5	0	3	7	1	-	5	0	3	6	1	4	-	7	1	5	9	2	7	-	0	4	8	2	6	0	-	3	6	9
43	0	3	7	1	5	0	-	3	7	1	4	0	2	-	5	0	3	7	0	5	-	8	2	6	0	4	8	-	1	4	7
44	0	3	7	1	5	0	-	3	7	1	4	0	2	-	5	0	3	7	0	5	-	8	2	6	0	4	8	-	1	4	7
47	0	4	8	2	6	0	-	4	8	2	5	0	3	-	6	0	4	8	1	6	-	0	3	7	1	5	0	-	2	5	8
48	0	3	7	1	5	0	-	3	7	1	4	0	2	-	5	0	3	7	0	5	-	8	2	6	0	4	8	-	1	4	7
49										N	7	8	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-
50	0	3	7	1	5	0	-	3	7	1	4	0	2	-	5	0	3	7	0	5	-	8	2	6	0	4	8	-	1	4	7
51	0	4	8	2	6	0	-	4	8	2	5	0	3	-	6	0	4	8	1	6	-	0	3	7	1	5	0	-	2	5	8
52	1	5	0	3	7	1	-	5	0	3	6	1	4	-	7	1	N														
53	1	5	0	3	7	1	-	5	0	3	6	1	4	-	7	1	5	9	2	7	-	0	4	8	2	6	0	-	3	6	9
54	0	4	8	2	6	0	-	4	8	2	5	0	3	-	6	0	4	8	1	6	-	0	3	7	1	5	0	-	2	5	8
55	2	6	0	4	8	2	-	6	0	M					8	2	6	-	3	-	-	1	5	9	3	7	-	-	-	-	P
56	2	6	0	4	8	2	-	6	0	M					8	2	6	-	3	-	-	1	5	9	3	7	-	-	-	-	P
	4	-	4	-	-	4	-	-	4	-	-	4	-	-	-	4	-	-	5	-	-	5	-	-	5	-	5	-	-	-	-
	4	-	5	-	-	6	-	-	7	-	-	8	-	-	-	9	-	-	0	-	-	1	-	-	2	-	3	-	-	-	-

June, 1944

H										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		6	-	-	-	-	-	-	-	-	-	-	-	
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		6	-	-	-	-	-	-	-	-	-	-	-	
40	1	4	7	-	0	3	6	9	2	5	-	9	2	5	8	1	4	-	8	1	4	8	1	4	-	7	0	3	6	0	
41	N											0	3	6							5	9	2			8	1	4	7	1	
42	2	4	8	-	1	4	7	0	3	6	-	0	3	6							5	9	2			8	1	4	7	1	
43	0	3	6	-	9	2	5	8	1	4	-	8	1	4	7	0	3	-	7	0	3	7	0	3	-	6	9	2	5	9	
44	0	3	6	-	9	2	5	8	1	4	-	8	1	4	7	0	3	-	7	0	3	7	0	3	-	6	9	2	5	9	
47	1	4	7	-	0	3	6	9	2	5	-	9	2	5	8	1	Q		8	1	4	8	1	4	-	7	0	3	6	0	
48	0	3	6	-	9	2	5	8	1	4	-	8	1	4	7	0	3	-	7	0	3	7	0	3	-	6	9	2	5	2	
49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		6	-	-	-	-	-	-	-	-	-	-	-	
50	0	3	6	-	9	2	5	8	1	4	-	8	1	4	7	0	3	-	7	0	3	7	0	3	-	6	9	2	5	9	
51	1	4	7	-	0	3	6	9	2	5	-	9	2	5	8	1	4	-	8	1	4	8	1	4	-	7	0	3	6	0	
52	N								3	6	-	0	3	6	9	2	5	-	9	2	5	9	2	5	-	8	1	4	7	1	
53	2	5	8	-	1	4	7	0	3	6	-	0	3	6	9	2	5	-	9	2	5	9	2	5	-	8	1	4	7	1	
54	1	4	7	-	0	3	6	9	2	5	-	9	2	5	8	1	Q		8	1	4	8	1	4	-	7	0	3	6	0	
55	-	-	-		-	-	-	-	-	7		-	-	-	-	-	4	-	Q	-	6	-	-	-		-	-	-			
56	-	-	-		-	-	-	-	-	7		-	-	-	-	-	-		-	-	-	-	-	-		-	-	-		2	
57	P	-	-		-	-	-	-	-	7		-	-	-	-	-	-		-	-	-	-	-	-		-	-	-	8	2	
	5	-	-	-	5	-	-	5	-	-	-	5	-	-	-	5	-	-	-	5	-	-	6	-	-	-	6	-	-	6	
	4	-	-	-	5	-	-	6	-	-	-	7	-	-	-	8	-	-	-	9	-	-	0	-	-	-	1	-	-	2	

July, 1944

H										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
36	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	0	-	4	7	1	5	8	1	-	-	4	7	1	4	7	-	0	3	6	9	2	5	-	8	2	5	8	1	4	-	7
41	1	-	5	8	2	6	9	2	-	-	5	8	2	5	8	-	1	4	7	0	3	6	-	9	3	6	9	2	5	-	8
42	1	-	5	8	2	6	9	2	-	-	5	8	2	5	8	-	1	4	7	0	3	6	-	9	3	6	9	2	5	-	8
43	9	-	3	6	0	4	7	0	-	-	3	6	0	3	6	-	9		5	8	1	4	-	7	1	4	7	0	3	-	6
44	9	-	3	6	0	4	7	0	-	-	3	6	0	3	6	-	9	2	5	8	1	4	-	7	1	4	7	0	3	-	6
47	0	-	4	7	1	5	8	1	-	-	4	7	1	4	7	-	0	3	6	9	2	5	-	8	2	5	8	1	4	-	7
48	9	-	3	6	0	4	7	0	-	-	3	6	0	3	6	-	9	2	5	8	1	4	-	7	1	4	7	0	3	-	6
49	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S						
50	9	-	3	6	0	4	7	0	-	-	3	6	0	3	6	-	9	2	5	8	1	4	-	7	1	4	7	0	3	-	6
51	0	-	4	7	1	5	8	1	-	-	4	7	1	4	7	-	0	3	6	9	2	5	-	8	2	5	8	1	4	-	7
52	1	-	5	8	2	6	9	2	-	-	5	8	2	5	8	-	1	4	7	0	3	6	-	9	3	6	9	2	5	-	8
53	1	-	5	8	2	6	9	2	-	-	5	8	2	5	8	-	1	4	7	0	3	6	-	9	3	6	9	2	5	-	8
54	0	-	4	7	1	5	8	1	-	-	4	7	1	4	7	-	0	3	6	9	2	5	-	8	2	5	8	1	4	-	7
55	R																														
56	-	-	-	-	3	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-
57	-	-	-	-	3	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-
	6	-	-	-	6	-	-	6	-	-	-	-	6	-	-	-	6	-	-	6	-	-	-	6	-	-	-	6	-	-	-
	2	-	-	-	3	-	-	4	-	-	-	-	5	-	-	-	6	-	-	7	-	-	-	8	-	-	-	9	-	-	-

	August, 1944																														
H	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
36	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-
40	0	3	6	1	4	-	7	0	3	6	9	2	-	5	8	1	4	7	1	-	4	7	0	3	6	9	-	2	6	9	2
41	1	4	7	2	5	-	8	1	4	7	0	3	-	6	9	2	5	8	2	-	5	8	1	4	7	0	-	3	7	0	3
42	1	4	7	2	5	-	8	1	4	7	0	3	-	6	9	2	5	8	2	-	5	8	1	4	7	0	-	3	7	0	3
43	9	2	5	0	3	-	6	9	2	5	8	1	-	4	7	0	3	6	0	-	3	6	9	2	5	8	-	1	5	T	
44	9	2	5	0	3	-	6	9	2	5	8	1	-	4	7	0	3	6	0	-	3	6	9	2	5	8	-	1	5	8	1
47	0	3	6	1	4	-	7	0	3	6	9	2	-	5	8	1	U														
48	9	2	5	0	3	-	6	9	2	5	8	1	-	4	7	0	3	6	0	-	3	6	9	2	5	8	-	1	5		
50	9	2	5	0	3	-	6	9	2	5	8	1	-	4	7	0	3	6	0	-	3	6	9	2	5	8	-	1	5	8	1
51	0	3	6	1	4	-	7	0	3	6	9	2	-	5	8	1	4	7	1	-	4	7	0	3	6	9	-	2	6	9	2
52	1	4	7	2	5	-	8	1	4	7	0	3	-	6	9	2	5	8	2	-	5	8	1	4	7	0	-	3	7	0	3
53	1	4	7	2	5	-	8	1	4	7	0	3	-	6	9	2	5	8	2	-	5	8	1	4	7	0	-	3	7	0	3
54	0	3	6	1	4	-	7	0	3	6	9	2	-	5	8	1	4	7	1	-	4	7	0	3	6	9	-	2	6	9	2
55	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				1
56	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
58			8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			8	1
59																	4	7	1	-	4	7	0	3	6	9	-	2	6	9	2
60																		9	-	-	-	-	-	-	-	-	-	-	-	-	-
	7	-	-	7	-	-	-	7	-	-	7	-	-	-	-	7	-	-	7	-	-	-	7	-	-	7	-	-	-	7	-
	0	-	-	1	-	-	-	2	-	-	3	-	-	-	-	4	-	-	5	-	-	-	6	-	-	7	-	-	-	8	-

	September, 1944																														
H	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
36	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	
38	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	
40	5	9	-	2	5	8	1	4	7	-	0	3	6	9	2	5	-	9	2	5	8	1	-	-	6	9	3	6	9	2	
41	6	0	-	3	6	9	2	5	8	-	1	4	7	0	3	6	-	0	3	6	9	2	-	-	7	0	4	7	0	3	
42	6	0	-	3	6	9	2	5	8	-	1	4	7	0	3	6	-	0	3	6	9	2	-	-	7	0	4	7	0	3	
61								3	6	-	9	2	5	8	1	4	-	8	1	4	7	0	-	-	5	8	2	5	8	1	
44	4	8	-	1	4	7	0	3	6	-	9	2	5	8	1	4	-	8	1	4	7	0	-	-	5	8	2	5	8	1	
48								3	6	-	9	2	5	8	1	4	-	8	1	4	7	0	-	-	5	8	2	5	8	1	
50	4	8	-	1	4	7	0	3	6	-	9	2	5	8	1	4	-	8	1	4	7	0	-	-	5	8	2	5	8	1	
51	5	9	-	2	5	8	1	4	7	-	0	3	6	9	2	5	-	9	2	5	8	1	-	-	6	9	3	6	9	2	
52	6	0	-	3	6	9	2	5	8	-	1	4	7	0	3	6	-	0	3	6	9	2	-	-	7	0	4	7	0	3	
53	6	0	-	3	6	9	2	5	8	-	1	4	7	0	3	6	-	0	3	6	9	2	-	-	7	0	4	7	0	3	
54	5	9	-	2	5	8	1	4	7	-	0	3	6	9	2	5	-	9	2	5	8	1	-	-	6	9	3	6	9	2	
55	4	8	-	1	4	7	0																								
56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	3	-	-	-	1	-	-	-	-	
58	4	8	-																												
59	5	9	-	2	5	8	1	4	7	-	0	3	6	9	2	5	-	9	2	5	8	1	-	-	6	9	3	6	9	2	
60	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	
	-	7	-	-	-	-	8	-	-	-	8	-	-	8	-	-	-	8	-	-	-	8	-	-	-	8	-	-	8	-	
	-	9	-	-	-	-	0	-	-	-	1	-	-	2	-	-	-	3	-	-	-	4	-	-	-	5	-	-	6	-	

October, 1944

H										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
36	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	-	5	0	3	6	0	2	-	5	8	1	5	7	9	-	2	5	7	9	1	3	-	5	7	9	1	3	5	-	7	9
41	-	6	0	4	7	0	3	-	6	9	2	X																			
42	-	6	0	4	7	0	3	-	6	9	2	X																			
44	-	4	0	2	5	0	1	-	4	7	0	4	6	8	-	1	4	6	8	0	2	-	4	6	8	0	2	4	-	6	8
48	-	4	0	2	5	0	W																								
50	-	4	0	2	5	0	1	-	4	7	0	4	6	8	-	1	4	6	8	0	2	-	4	6	8	0	2	4	-	6	8
51	-	5	0	3	6	0	2	-	5	8	1	5	7	9	-	2	5	7	9	1	3	-	5	7	9	1	3	5	-	7	9
52	-	6	0	4	7	0	3	-	6	9	2	X																			
53	-	6	0	4	7	0	3	-	6	9	2	X																			
54	-	5	0	3	6	0	2	-	Y									7		1	3	-	5	7	9	1	3	5	-	7	9
56	-	-	1	-	-	-	-	-	-	-	3	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58									5	8	1	5	7	9	-	2	5		9												
59	-	5	0	3	6	0	2	-	Y									7		1	3	-	5	7	9	1	3	5	-	7	9
60	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
61	-	4	0	2	5	0	1	-	4	7	0	4	6	8	-	1	4	6	8	0	2	-	4	6	8	0	2	4	-	6	8
	8	-	8	-	-	8	-	-	-	-	8	-	-	-	-	9	-	-	-	9	-	-	-	-	-	9	-	-	-	-	-
	6	-	7	-	-	8	-	-	-	-	9	-	-	-	-	0	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-

November, 1944

H										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
40	1	3	5	7	-	0	2	4	6	0	2	-	5	8	1	5	8	1	-	4	7	1	4	7	0	-	3	6	0	3	
41	b																														
42			4	6	-	0	1		7	0	3	-	6	9	2	6	9	2	-	5	8	2	5	8	1	-	4	7	1	4	
44	0	2	4	6	-	0	1	3	5	0	1	-	4	7	0	4	7	0	-	3	6	0	3	6	0	-	2	5	0	2	
50	0	2	4	6	-	0	1	3	5	0	1	-	4	7	0	4	7	0	-	3	6	0	3	6	0	-	2	5	0	2	
51	1	3	5	7	-	0	2	4	6	0	2	-	5	8	1	5	8	1	-	4	7	1	4	7	0	-	3	6	0	3	
52																														3	
53									7	0	3	-	6	9	2	6	9	2	-	5	8	2	5	8	1	-	4	7	1	4	
54	1	3	5	7	-	0	2	4	6	0	2	-	5	8	1	5	8	1	-	4	7	1	4	7	0	-	3	6	0	3	
55									7	0	3	-	6	9	2	6	9	2	-	5	8	2	5	8	1	-	3	6	0		
56	-	-	-	8	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	5	
61	0	2			Z																										
59	1	3	5	7	-	0	2	4	6	0	2	-	5	8	1	5	8	1	-	4	7	1	4	7	0	-	3	6	0	3	
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
62					Z			3	5	0	1	-	4	7	0	4	7	0	-	3	6	0	3	6	0	-	2	5	0	2	
63					Z			3	5	0	1	-	4	7	0	4	7	0	-	3	6	0	3	6	0	-	2	5	0	2	
	9	-	-	-	-	9	-	-	-	9	-	-	-	-	9	-	-	9	-	-	-	9	-	-	9	-	-	-	0	-	
	3	-	-	-	-	4	-	-	-	5	-	-	-	-	6	-	-	7	-	-	-	8	-	-	9	-	-	-	0	-	

	December, 1944																														
H									1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
36	-	-	-	-	5	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
38	-	-	-	-	5	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
40	7	0	-	3	7	0	3	6	9	-	3	6	9	3	7	0	-	3	6	9	2	6	9	-	-	2	5	8	1	6	-
42	8	1	-	4	8	1	4	7	0	-	4	7	0	4	8	1	-	4	7	0	3	7	0	-	-	3	6	9	2	7	-
44	6	9	-	2	6	9	2	5	8	-	2	5	8	2	6	9	-	2	5	8	1	5	8	-	-	1	4	7	0	5	-
50	6	9	-	2	6	9	2	5	8	-	2	5	8	2	6	9	-	2	5	8	1	5	8	-	-	1	4	7	0	5	-
51	7	0	-	3	7	0	3	6	9	-	3	6	9	3	7	0	-	3	6	9	2	6	9	-	-	2	5	8	1	6	-
52	8	1	-	4	8	1	4	7	0	-	4	d																			
53	8	1	-	4	8	1	4	7	0	-	4	7	0	4	8	1	-	4	7	0	3	7	0	-	-	3	6	9	2	7	-
54	7	0	-	3	7	0	3	6	9	-	3	6	9	3	7	0	-	3	6	9	2	6	9	-	-	2	5	8	1	6	-
56	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	3	-
59	7	0	-	3	7	0	3	6	9	-	3	6	9	3	7	0	-	3	6	9	2	6	9	-	-	2	5	8	1	6	-
60	-	-	-	-	5	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
62	6	9	-	2	6	9	2	5	8	-	2	5	8	2	6	9	-	2	5	8	1	5	8	-	-	1	4	7	0	5	-
63	6	9	-	2	6	9	2	5	8	-	2	5	8	2	6	9	-	2	5	8	1	5	8	-	-	1	4	7	0	5	-
64	8	1	-	4	8	1	4	7	0	-	4	7	0	4	8	1	-	4	7	c											
64A																			c	0	3	7	0	-	-	3	6	9	2	7	-
	-	0	-	-	-	0	-	-	0	-	-	-	0	-	-	0	-	-	-	0	-	-	0	-	-	-	-	-	0	-	-
	-	1	-	-	-	2	-	-	3	-	-	-	4	-	-	5	-	-	-	6	-	-	7	-	-	-	-	-	8	-	-

	January, 1945																														
H									1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
36	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-													
38	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-													
40	-	9	2	5	8	1	-	4	7	0	5	8	1	-	4	7	0	3	7	0	-	3	6	9	4	9	3	-	7	1	5
42	-	0	3	6	9	2	-	5	8	1	6	9	2	-	5	8	1	4	8	1	-	4	7	0	5	0	4	-	8	2	6
44	-	8	1	4	7	0	-	3	6	9	4	7	0	-	3	6	9	2	6	9	-	2	5	8	3	8	2	-	6	0	4
50	-	8	1	4	7	0	-	3	6	9	4	7	0	-	3	6	9	2	6	9	-	2	5	8	3	8	2	-	6	0	4
51	-	9	2	5	8	1	-	4	7	0	5	8	1	-	4	7	0	3	7	0	-	3	6	9	4	9	3	-	7	1	5
53	-	0	3	6	9	2	-	5	8	1	6	9	2	-	5	8	1	4	8	1	-	4	7	0	5	0	4	-	8	2	6
54	-	9	2	5	8	1	-	4	7	0	5	8	1	-	4	7	0	3	7	0	-	3	6	9	4	9	3	-	7	1	5
56	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	5	-	-	-	-	-	1	2	7	1	-	5	9	3
59	-	9	2	5	8	1	-	4	7	0	5	8	1	-	4	7	0	3	7	0	-	3	6	9	4	9	3	-	7	1	5
60	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-													
62	-	8	1	4	7	0	-	3	6	9	4	7	0	-	3	6	9	2	6	9	-	2	5	8	3	8	2	-	6	0	4
63	-	8	1	4	7	0	-	3	6	9	4	7	0	-	3	6	9	2	6	9	-	2	5	8	3	8	2	-	6	0	4
64																c	1	4	8	1	-	4	7	0	5	0	4	-	8	2	6
64A	-	0	3	6	9	2	-	5	8	1	6	9	2	-	5	8	c														
NP																								1	2	7	1	-	5	9	3
	-	0	-	-	-	1	-	-	-	[illegible]	-	-	1	-	-	-	1	-	-	1	-	-	-	1	-	1	-	-	-	1	-
	-	9	-	-	-	0	-	-	-	[illegible]	-	-	2	-	-	-	3	-	-	4	-	-	-	5	-	6	-	-	-	7	-

February, 1945

H										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
40	8	3	-	-	0	4	8	2	5	0	-	4	8	2	6	0	3	-	7	1	5	0	3	7	-	2	6	0			
42	0	4	7	-	1	5	9	3	6	1	-	5	9	3	7	1	4	-	8	2	6	0	4	8	-	3	7	1			
44	7	2	6	-	0	3	7	1	4	0	-	3	7	1	5	0	2	-	6	0	4	8	2	6	-	1	5	0			
50	7	2	6	-	0	3	7	1	4	0	-	3	7	1	5	0	2	-	6	0	4	8	2	6	-	1	5	0			
51	8	3	-	-	0	4	8	2	5	h																					
52	d																														
53	0	4	7	-	1	5	9	3	6	1	-	5	9	3	7	1	4	-	8	2	6	0	4	8	-	3	7	1			
54	8	3	-	-	0	4	8	2	5	0	-	4	8	2	6	0	3	-	7	1	5	0	3	7	-	2	6	0			
56	0	1	5	-	8	2	6	0	-	7	8	2	6	0	4	8	5	-	k	-	-	-	-	-	-	-	-	-			
59	8	3	-	-	0	4	8	2	5	0	-	4	8	2	6	0	3	-	7	1	5	0	3	7	-	2	6	0			
62	7	2	6	-	0	3	7	1	4	0	-	3	7	1	5	0	2	-	6	0	4	8	2	6	-	1	5	0			
63	7	2	6	-	0	3	7	1	4	0	-	3	7	1	5	0	2	-	6	0	4	8	2	6	-	1	5	0			
64	0	4	7	-	1	5	9	3	6	1	-	5	9	3	7	1	4	-	8	2	6	0	4	8	-	3	7	1			
65									h	0	-			2	6	0	3	-	7	1	5	0	3	7	-	2	6	0			
107												4	8																		
96																			9	3	7	1	5	9	0	4	8	2			
NP	0	1	5	-	8	2	6	0	-	7	8	2	6	0	4	8	5	-	9	3	7	1	5	9	0	4	8	2			
	1	-	-	-	1	-	-	2	-	2	-	-	-	2	-	2	-	-	-	2	-	2	-	-	2	-	-	2			
	8	-	-	-	9	-	-	0	-	1	-	-	-	2	-	3	-	-	-	4	-	5	-	-	6	-	-	7			

March, 1945

H										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
40	4	8	2	-	8	2	6	0	4	8	-	3	7	1	5	0	4	-	0	m								7	1	5	0
42	5	0	3	-	0	3	7	1	5	0	-	4	8	2	6	1	5	-	0	3	6	0	2	5	-	0	3	8	2	6	0
44	3	7	1	-	7	1	5	0	3	7	-	2	6	0	4	0	3	-	8	2	5	8	1					6	0	4	8
50	3	7	1	-	7	1	5	0	3	7	-	2	6	0	4	0	3	-	8	2	5	8	1					6	0	4	8
52	d																														
53	5	0	3	-	0	3	7	1	5	0	-	4	8	2	6	1	5	-	0	3	6	0	2	5	-	0	3	8	2	6	0
54	4	8	2	-	8	2	6	0	4	8	-	3	7	1	5	0	4	-	0	m				4	-	0	2	7	1	5	0
56	-	-	6	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	8	-	-	5	-	-	-	3
59	4	8	2	-	8	2	6	0	4	8	-	3	7	1	5	0	4	-	0	m				4	-	0	2	7	1	5	0
62	3	7	1	-	7	1	5	0	3	7	-	2	6	0	4	0	3	-	8	2	5	8	1	4	-	0	2	6	0	4	8
63	3	7	1	-	7	1	5	0	3	7	-	2	6	0	4	0	3	-	8	2	5	8	1	4	-	0	2	6	0	4	8
64	5	0	3	-	0	3	7	1	5	0	-	4	8	2	6	1	5	-	0	3	6	0	2	5	-	0	3	8	2	6	0
65	4	8	2	-	8	2	6	0	4	8	-	3	7	1	5	0	4	-	0	m								7	1	5	0
96	6	0	4	5	0	4	8	2	6	0	1	5	9	3	7	2	6	7	1	4	7	0	3	6	7	g					
NP	6	0	4	5	0	4	8	2	6	0	1	5	9	3	7	2	6	7	1	4	7	0	3	6	7	1	4	9	3	7	1
	-	2	-	-	2	-	-	3	-	3	-	-	-	3	-	3	-	-	3	-	-	3	-	-	-	3	-	-	3	-	3
	-	8	-	-	9	-	-	0	-	1	-	-	-	2	-	3	-	-	4	-	-	5	-	-	-	6	-	-	7	-	8

April, 1945

										1										2										3	
H	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
40	-	5	9	3	7	0	4	-	9	2	5	7	9	2	-	7	0	3	7	1	5	-	0	4	8	2	-	6	-	1	
42	-	6	0	4	8	1	5	-	n									4	8	2	6	-	1	5	9	3	-	7	-	2	
44	-	4	8	2	6	9	3	-	8	1	4			1	-	6	9	2	6	0	4	-	9	3	7	1	-	5	-	0	
47																				q	-	-	-	-	-	-	-	-	-	-	
50	-	4	8	2	6	9	3	-	8	1	4			1	-	6	9	2	6	0	4	-	9	3	7	1	-	5	-	0	
52			0	4	8	1	5	-	n									4	8	2	6	-	1	5	9	3	-	7	-	2	
53	-	6	0	4	8	1	5	-	n									4	8	2	6	-	1	5	9	3	-	7	-	2	
54	-	5	9	3	7	0	4	-	9	2	5	7	9	2	-	7	0	3	7	1	5	-	0	4	8	2	-	6	-	1	
56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	q											
59	-	5	9	3	7	0	4	-	9	2	5	7	9	2	-	7	0	3	7	1	5	-	0	4	8	2	-	6	-	1	
62	-	4	8	2	6	9	3	-	8	1	4			1	-	6	9	2	6	0	4	-	9	3	7	1	-	5	-	0	
63	-	4	8	2	6	9	3	-	8	1	4			1	-	6	9	2	6	0	4	-	9	3	7	1	-	5	-	0	
64	-	6	0	4	8	1	5	-	n									4	8	2	6	-	1	5	9	3	-	7	-	2	
64A																															
65	-	5	9	3	7	0	4	-	9	2	5	7	9	2	-	7	0	3	7												
107																				1	5	-	0	4	8	2	-	6	-	1	
NP	2	7	1	5	-	2	6	7	0	3	6	8	0	3	4	8	1	5	9	3	7	8	2	6	0	4	-	8	9	3	
	-	-	3	-	-	4	-	-	4	-	-	-	4	-	-	-	4	-	-	4	-	-	4	-	4	-	-	-	-	4
	-	-	9	-	-	0	-	-	1	-	-	-	2	-	-	-	3	-	-	4	-	-	5	-	6	-	-	-	-	7

May, 1945

										1										2										3	
H	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
40	5	9	3	7	1	-	6	0	4	8	2	6	-	1	5	9	3	7	1	-	6	0	4	8	2	6	-	1	5	9	4
42	6	0	4	8	2	-	7	1	5	9	3	7	-	2	6	0	4	8	2	-	7	1	5	9	3	7	-	2	6	0	5
44	4	8	2	6	0	-	5	9	3	7	1	5	-	0	4	8	2	6	0	-	5	9	3	7	1	5	-	0	4	8	3
47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
50	4	8	2	6	0	-	5	9	3	7	1	5	-	0	4	8	2	6	0	-	5	9	3	7	1	5	-	0	4	8	3
52	6	0	4	8	2	-	7	1	5	9	3	7	-	2	6	0	4	8	2	-	7	1	5	9	3	7	-	2	6	0	5
53	6	0	4	8	2	-	7	1	5	9	3	7	-	2		0	4	8	2	-	7	1	5	9	3	7	-	2	6	0	5
54	5	9	3	7	1	-	6	0	4	8	2	6	-	1	5	9	3	7	1	-	6	0	4	8	2	6	-	1	5	9	4
59	5	9	3	7	1	-	6	0	4	8	2	q			5	9	3	7	1	-	6	0	4	8	2	6	-	1	5	9	4
62	4	8	2	6	0	-	5	9	3	7	1	5	-	0	4	8	2	6	0	-	5	9	3	7	1	5	-	0	4	8	3
63	4	8	2	6	0	-	5	9	3	7	1	5	-	0	4	8	2	6	0	-	5	9	3	7	1	5	-	0	4	8	3
64																															
64A	6	0	4	8	2	-	7	1	5	9	3	7	-	2		0	4	8	2	-	7	1	5	9	3	7	-	2	6	0	5
65	p																														
107	5	9	3	7	1	-	6	0	4	8	2	6	-	1	5	9	3	7	1	-	6	0	4	8	2	6	-	1	5	9	4
NP	7	1	5	9	3	4	8	2	6	0	4	8	9	3	7	1	5	9	3	4	8	2	6	0	4	8	9	3	7	1	6
	-	4	-	-	4	-	-	5	-	5	-	-	-	5	-	5	-	-	5	-	-	5	-	5	-	-	-	5	-	5	-
	-	8	-	-	9	-	-	0	-	1	-	-	-	2	-	3	-	-	4	-	-	5	-	6	-	-	-	7	-	8	-

June, 1945

N										1										2										3	
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
40	8	2	-	7	1	5	0	3	7	-	2	6	0	4	8	2	-	7													
42	0	3	-	8	2	6	0	4	8	-	3	7	1	5	0	3	-	8													
44	7	1	-	6	0	4	8	2	6	-	1	5	0	3	7	1	-	6													
47	-	-	-	-	-	-	-	-	-	-																					
50	7	1	-	6	0	4	8	2	6	-	1	5	0	3	7	1	-	6													
52	0	3	-	8	2	6	0	4	8	-	3	7	1	5	0	3	-	8													
53	0	3	-	8	2	6	0	4	8	-	3	7	1	5	0	3	-	8													
54	8	2	-	7	1	5	0	3	7	-	2	6	0	4	8	2	-	7													
56											-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
59	8	2	-	7	1	5	0	3	7	-	2	6	0	4	8	2	-	7													
62	7	1	-	6	0	4	8	2	6	-	1	5	0	3	7	1	-	6													
63	7	1	-	6	0	4	8	2	6	-	1	5	0	3	7	1	-	6													
64A	0	3	-	8	2	6	0	4	8	-	3	7	1	5	0	3	-	8													
65											2	6	0	4	8	2	-	7													
107	8	2	-	7	1	5	0	3	7	-																					
NP	0	4	5	9	3	7	1	5	9	0	4	8	2	6	0	4	5	9	0	1	2	3							4	5	6
	5	-	-	-	6	-	6	-	-	6	-	-	6	-	6	-	-	-	6	-	-	-							6	-	-
	9	-	-	-	0	-	1	-	-	2	-	-	3	-	4	-	-	-	5	-	-	-							6	-	-

N O T E S

r. Recorder 2X carried H47 up to June 10, after which H56 was run, using the same record number, 582, and recording only during the listening period.

s. The supply of Teledeltos paper ran out due to a delay in shipping an order. The dwindling supply was used to keep the NP work going as long as possible, the holes in the old program being left out of service after June 18. Some old Teledeltos rolls, oversize, were trimmed down and used on the NP recorder toward the end of the month.

Dominion Observatory,
Ottawa, Canada,
July 3, 1945.

E. A. H.

APPENDIX VI

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Rockbursts Located in Lake Shore Mines
February, 1944 - June, 1945

Rock Bursts Located in Lake Shore Mines
February, 1944 - June, 1945

	Date	No.	Time	Class	Location	Rock Displacement
A	Feb. 9	350S	3:15 p.m.	-	4901E-6	42 tons
B	" 15	309C	3:32 a.m.	light	4704XC 4801E-5 4801E-Dr	5 tons 25 tons 40 tons
C	Mar. 11	351S	3:30 p.m.	-	4801E-7	15 tons
D	" 14	352S	3:03 p.m.	-	4902E-Dr at XC	total of 28 tons
E	Apr. 6	353S	3:33 p.m.	-	4502E-5:3	4 tons
F	" 18	354S	10: a.m.	-	4501E-5:3	small amount
G	" 20	355S	7:15 p.m.	-	5001E-Dr	15 tons
H	" 22	356S	3:30 p.m.	-	4801E-7	5 tons
I	" 29	357S	3:35 p.m.	-	4401E-6	10 tons
J	May 8	310C	3:45 p.m.	med'm	3209E-Dr 3202E-Dr	90 tons 30 tons
K	" 19	358S	10:05 a.m.	-	4501W-8:1	1 ton
L	June 1	359S	bet.shfts.	-	4701E-6	10 tons
M	" 2	360S	2:35 p.m.	-	4502E-5:3	2 tons
N	" 19	311C	11:01 a.m.	light	4701E-Dr 4801E-7	total of 100 tons
O	" 24	361S	2:35 p.m.	-	4501E-Dr	25 tons
P	Aug. 12	312C	11:08 a.m.	med'm	4001W-Dr 4201W-Dr 4201W-11	50 tons 25 tons 75 tons
Q	" 15	362S	2:35 p.m.	-	4501E-5:3	2 tons
R	" 29	363S	2:30 p.m.	-	4401E-6	10 tons
S	Sept. 6	313C	2:55 p.m.	med'm	4401E-Dr 4501E-Dr 4701E-Dr	5 tons 50 tons 5 tons
T	Oct. 5	364S	2:35 p.m.	-	4401E-6 4401E-Dr 4301E-Dr	small " "

	Date	No.	Time	Class	Location	Rock Displacement
U	Oct. 25	314C	5:30 p.m.	med'm	4801E-Dr 4901E-Dr	100 tons 120 tons
V	Jan. 15	365S	bet.shfts.	-	4802E-Dr	10 tons
W	" 22	366S	9:30 a.m.	-	4701E-Dr	2 tons
X	" 27	315C	2:50 p.m.	light	4301W-Dr 4408W-Dr	25 tons 5 tons
Y	Feb. 15	367S	3:33 p.m.	-	4901E-6:2	55 tons
Z	" 21	368S	bet.shfts.	-	5001W-Dr	30 tons
a	Apr. 9	369S	8:10 a.m.	-	4901W-9	2 tons
b	" 17	316C	2:05 p.m.	light	4001W-15	80 tons
c	" 20	370S	1:50 a.m.	-	No. 4 shft 4825'+	25 pounds of concrete
d	May 22	317C	2:35 p.m.	med'm	4002E-Dr 4202E-Dr	50 tons 100 tons
e	" 26	318C	2:40 p.m.	light	3001W-Dr 3201W-1 3051XC 3075XC No. 1 shft	total given as much loose shaken down
f	" 28	319C	9:45 p.m.	med'm	4901E-Dr 4901E-6:3	250 tons cannot estimate
g	June 4	371S	9:10 a.m.	-	4301XC No. 1 shft	about 3 tons
h	" 26	320C	1:15 p.m.	light	5001W-8	70 tons

NOTES

The above list shows only the bursts which occurred during the period indicated and which were located and investigated in Lake Shore Mines. The seismograms indicated many more small strain bursts, nearly all of which occurred with the blasting.

Of the 34 bursts listed above, 12 were identified as crush type and 22 as strain. The crush bursts were, in each case, either light or medium. None of them were heavy.

The time of occurrence was associated with the blasting on 18 occasions, 3 were "between shifts", and 6 others were reported at times which were on the night off-shift. The remaining 7 occurred between 8 a.m. and 10 a.m. These are the ones which might have been detected by the microseismic service. They are listed as: F, K, N, P, W, a, g.

Of these, K, P, a and g were located so far out of the territory under study that microseismims could not have been picked up from them. We may refer to the listening data for the other three, F, N, W.

Burst F: April 18, 1944, No. 354S, 10 a.m., 4501E-5:3, "small" rock displacement. Listening report No. 414 shows that full-time listening was done on April 18 from 6:08 a.m. to 7:08 a.m., by F.J.H. There was a moderately high count (20+) on H49 in 4401E6 of D-type snaps. This hole is just above the burst. H50, just below it, had a count of (10+), which happens to be rather high for H50 which has shown a consistently low count. The activity on H50, moreover, includes L-type snaps. On the whole, there is very little indication that a burst was imminent. It would certainly not have been predicted. It must be noted, however, that H50 is definitely in a non-sensitive position. The rockburst report shows that only a "small amount of muck was blown off the north wall" of stope 4501E5:3 at a point about half way between the 4450' and 4575'-levels. It was definitely a minor disturbance.

Burst N: June 19, 1944, No. 311C, 11:01 a.m., 4701E-Dr and 4801E-7, total of 100 tons. Listening report No. 467 shows that full-time listening was done on June 19, from 6:08 a.m. to 6:57 a.m. by F.J.H. The rockburst report shows that stope 4801E-7 had its south wall shattered from the 4700' to 4825'-levels at section 7. Much loose was shaken down also on 4701E-Dr, above this stope. The holes nearest to this burst were: H55 in 4704XC, H51 in 4701E and H53 in 4801E. There was a high count (20+) from H55 with L-type snaps included, and the operator notes: "A large amount of distortion was recorded on all the records but records more from the 6-section holes. Interference seems to be seismic." H51 showed a count of 0+, the snaps being only of the general type. H53 is given exactly the same rating as H51. Except for the general interference mentioned by the operator and the high count on H55, there was no indication of this burst on the nearby geophones, some 5 hours before the burst. This is, of course, quite a long time but there was no blasting in the meantime nor at the time of the burst. Fortunately, it occurred at lunch time so no one was injured.

Burst W: Jan. 22, 1945, No. 366S, 9:30 a.m., 4701E-Dr, 2 tons. Listening report No. 649 shows that full-time listening was done on Jan. 22 from 3:47 a.m. to 5:11 a.m. by E.A.H. The comment given is: "None very active". The rockburst report shows that about 2 tons of rock was shaken off the drift wall at about Sec. 4. The hole nearest to this is H40 or H56. H40 showed a count of 0+, the snaps being all G-type. The seismicity factor (adopted shortly prior to the time of this burst) was given as 1D, about the lowest that can be assigned. The operator notes that: "H40 does not pick up the tapper", indicating that the geophone there had deteriorated to very low efficiency. H56, however, had a count of 20- and a factor of 4D.

Thus, after almost a year and a half of study, in which every effort was made to have as complete coverage as possible of the territory assigned, only three bursts occurred in place and time to give any chance of prediction. Of these, one (F) was very small. Another (W) was also small (2 tons displacement). The third (N) was the one case in all that time which definitely was of considerable magnitude (100 tons) and even this was classed as "light" in the rockburst report made by the mine engineers, Furthermore, it occurred some four hours after the listening. For this, there was some fair measure of prediction from H55 and the operator's comment of considerable interference in section 6 which he stated "seems to be seismic".

We must conclude that the rockburst activity was too low, on account of the reduced mining schedule under wartime conditions, to afford the necessary experience in the block of ground under survey.

Dominion Observatory,
Ottawa, Canada,
July 4, 1945.

E. A. H.

APPENDIX VII

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Intensive Seismic Program

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INTENSIVE SEISMIC PROGRAM

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The "Intensive Seismic Program", so-called, was proposed in December, 1944, as a means of applying the microseismic method, using many geophones, to a limited section of the mine known to be under serious pressure. The history of the project to June 30, 1945, is given in the body of this report, but it seemed advisable to relegate the account of the set-up of the equipment and the reporting of the data to this appendix.

The bare details of the set-up and procedure appear in the left-hand margin of the reduced photographs of the daily records. Two samples of these daily photographs are given in this report. The reduction makes the text a little tedious to read without a glass. For convenience of reference, therefore, this material is reproduced here as follows:

INTENSIVE SEISMIC PROGRAM
Lake Shore Mines
Kirkland Lake, Ontario

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Location: Sections 2E to 4E; Drifts 4702E and 4802E
On 4702E: 17 percussion drill holes, Nos. 70-86 inclusive
On 4802E: 17 percussion drill holes, Nos. 90-106 inclusive

Holes were drilled about ten feet deep, breast high, horizontal. Even-numbered holes are in the hanging (south) wall in each drift. Odd-numbered holes are in the foot (north) wall in each drift. Holes 70 and 90 are each 50 ft. east of the main crosscut and succeeding even-numbered holes on each level are at intervals of 30 ft. in the hanging-wall, to Holes 86 and 106 respectively. Holes 71 and 91 are each 65 ft. east of the main crosscut and succeeding odd-numbered holes on each level are at intervals of 30 ft. in the foot-wall, to Holes 85 and 105 respectively.

An eleven-contact switch, operated at eleven equally-spaced intervals each hour, is installed in drift 4702E3 and feeds the output of geophones in each of nine selected holes to Recorder 3A. An eleven-contact switch, operated at eleven equally-spaced intervals each hour, is installed in drift 4802E3 and feeds the output of geophones in each of nine selected holes to Recorder 3B.

Of the nine holes used on each level, the hole-geophone combination found by experience to be the most informative is switched-on three periods per hour as a check. The check geophone on each level records during the second, sixth and tenth intervals in each hour, the sets being operated six hours daily in offshift time: 3:30 to 6:30 afternoon and morning.

The nine selected holes on either level may be designated by X, A, B, C, D, E, F, G, H, where X indicates the check-geophone location and the others range always from west to east. The switch on each level operates to record in the order AXH; GFXBC; DXE. The record is cut into sections, three per hour, as indicated by the grouping of the letters above.

Each photograph shows six groups of three sections, each recorded in order from top down: 3:30-4:30; 4:30-5:30; 5:30-6:30, all P.M. on the first date, and three similar A.M. hours for the second date.

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As indicated above, a day's recording in this program covers six hours: 3:30-6:30 a.m. and p.m. As the record tape runs 90" per hour, a roll of 45' of tape is produced each day. Rather than tabulate readings and notes of these records, it seemed desirable to devise a method of showing the entire run in a form which would permit all interested to examine the data conveniently as a whole.

The lay-out of the holes and their numbering were devised to permit ready location of any hole from its number. Any number from 70 to 89 was planned to be on 4700, any number from 90 to 109 on 4800. It was found impractical to drill holes in the backs of the drifts, as they were badly broken and lagged over. Hence, Nos. 87 to 89 inclusive, planned for the backs in 4702E, were not drilled, nor were Nos. 107 to 109 inclusive, planned for the backs in 4802E. But holes 70 to 86 inclusive are all in 4702E and holes 90 to 106 inclusive are all in 4802E. Even-numbered holes are always in the hanging-wall, odd-numbered holes in the foot-wall. Thus, H96, for example, is in 4802E, in the hanging-

(south) wall, 140' (50+3x30) east of the main crosscut, while H83 is in 4702E, in the foot (north) wall, 245' (65+6x30) east of the main crosscut.

The nine holes chosen for use in either drift were selected on the basis of experience. Some could not be used because they were in such bad ground that they closed by rock slips almost as soon as the drill was removed. One closed on the drill so that it could not be removed. Others were found to be in blocks of rock which seem isolated by fractures so that they do not pick up snaps. The best hole-geophone combination on each level was chosen as the check run for that level. The commutating switch connections were arranged so that this check is switched on during the second, sixth, and tenth of the eleven intervals per hour. Each interval being one-eleventh of an hour long, a section of a little more than 8" of record tape is produced at each setting of the switch.

The order in which the holes were arranged on the switch was designed to:

(a) Compare similarly-placed east and west positions with each run of the check geophone.

(b) Secure as much consecutive recording as possible.

Thus, regardless of what holes are in use, it was planned to have them run in the order:

A, X, H
G, F, X, B, C
D, X, E

where X is the check-geophone and the other eight are: A, B, C, D, E, F, G, H (reading west to east). In this way, the first three sections compare the extreme west and extreme east with the check, the next five compare the two next to the extreme east and the two next to the extreme west with the check, and the final three compare the one just west of the centre and the one just east of the centre with the check. Moreover, the arrangement permits two fairly long consecutive or almost consecutive runs, e.g. H, G, F, and B, C, D, — E.

As any eight of the seventeen available holes might be chosen in the strictly west-to-east order: A, B, C, D, E, F, G, H, and any one other might be chosen as the check, it was necessary to provide some ready means of coupling in the selected holes after any change. Hence, each geophone was fitted with 150' of lead-in cable, permitting it to be placed in any hole on the level. Now, when any selection is decided on, it is necessary only to plug the check-geophone into the top jack of the telephone bank and plug in the others, in ascending numerical order, in the successively-descending jacks. The excess cable on each geophone is coiled up in the lower compartment of the box housing the commutating switch. (See Fig. 8) This system has worked out very satisfactorily in practice.

When the day's run is received, it is cut into 18 pieces, each three or five recording sections long and having the check-geophone run in the central position. The record number, followed by two digits (in order 01, 02, to 18) showing the order of the piece, is stamped in the upper right-hand corner of the central section. The record is made on a two-channel recorder. As it appears on the tape when placed to read from left to right, the top recording is from 4702E and the lower recording from 4802E.

A display board made of reinforced Masonite 50"x60" was provided. This was painted with a black border enclosing a white rectangle 40"x50" designed to be photographed exactly on an 8"x10" plate. On this rectangle was painted the space designed to be covered by the 45' of tape received each day. The pieces of tape being three per hour and, in order, of lengths three sections, five sections, three sections, there are six groups of three pieces pèr day.

As the tape is 2" wide and as experience showed the tape would lie flat on the vertically-placed board if held top and bottom every 2" along its length, a series of carefully-spaced holes were drilled at approximately 2" intervals. Into these were driven ordinary upholstering tacks spaced out from the board by a thickness gauge as shown in Fig. 17. The space between successive rows of holes was a little over 2" to permit the record tape to slide readily under the quarter-inch heads of the tacks. The space between successive columns of holes was such that the length of a record section (8"+) was divided into four equal parts (i.e. about 2"). The device worked out surprisingly well in practice. It requires only two or three minutes to mount a day's record ready for photographing.

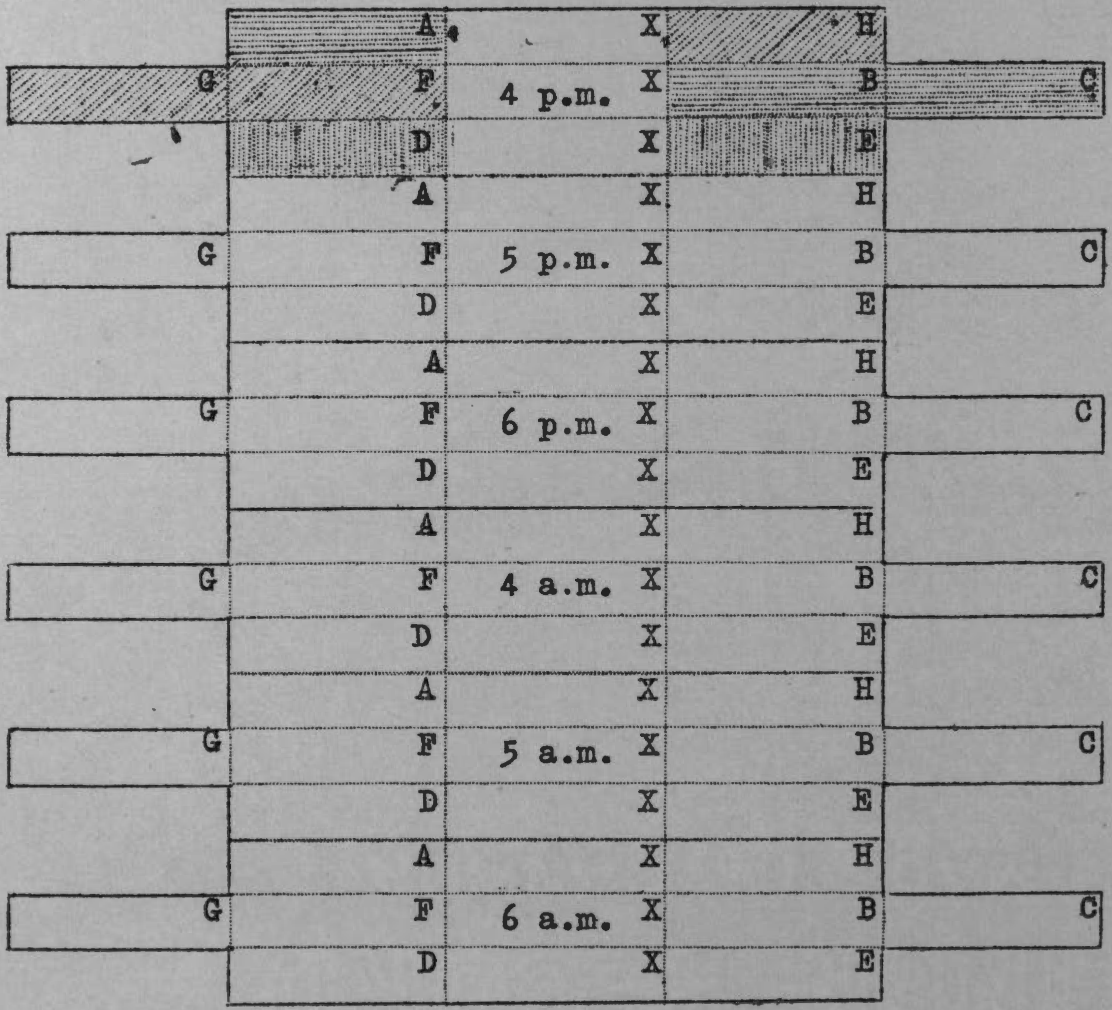
The tack heads were painted to facilitate reading. Black headed tacks in vertical columns separate the record sections. Black headed tacks in horizontal rows separate P.M. recording (the first three hour-groups) from A.M. recording (the last three hour-groups). (The records are changed after the A.M. recording - about 7 a.m. each day.) The hour groups are separated by horizontal rows of gray painted tacks. Those not black or gray were painted white.

The indented edge on the left side of the records (due to some being three sections long and some five) was used to display the text reproduced at the beginning of this appendix. Thus anyone seeing only one photograph would be sure to have the necessary explanations before him. This material is changed only if it becomes smudged or wrinkled.

The indented edge on the right side is used to display the data associated with that particular record: on and off dates serial number, hole and geophone numbers in use on each level, listening data for each level, blasting data, and notes.

When removed from the board, the sections are fastened loosely in order again with small pieces of cellulose tape and the record re-wound (not booked as are those of the regular series) with the daily data strips coiled in its centre. An identifying label is stuck on the end of the central core and the whole enclosed in a cylinder of cover paper similar to that used in the cover of this report. The spools are stored in order in special boxes, one month to a box.

Two 8"x10" prints are made from each negative. At the


A X H
G F 4 p.m. X B C
D X E
A X H
G F 5 p.m. X B C
D X E
A X H
G F 6 p.m. X B C
D X E
A X H
G F 4 a.m. X B C
D X E
A X H
G F 5 a.m. X B C
D X E
A X H
G F 6 a.m. X B C
D X E

end of each month these prints are divided into two sets, each packed in a special box. Space is provided in each box to accommodate a short mimeographed discussion of the month's records. One of the two copies is supplied to the mine and one held by the operators.

A few observations regarding the finished photograph may make the lay-out a little more easily followed by those not making use of it regularly. The adjacent diagram will be used to assist in making clear the various points raised.

(1) Each successive group of three pieces (3 sections, 5 sections, 3 sections) shows an hour's recording.

(2) The hour falls on the exact centre of the 5-section piece in each case as indicated.

(3) The records from the check-geophone, X, are grouped in the central section, the intervals between successive recording, being 3/11 or 2/11 of an hour (3 sections or 2 sections) i.e. approximately 16 min. or 11 min., except when passing from PM to AM recording when there is a hiatus of a little over nine hours.

(4) In any one hour-group, the top piece shows the extreme west position A contrasted with the extreme east position H after an interval of 5 5/11 min. during which check-geophone X is recording. The long piece of five sections shows the two holes nearest the east but one (G, F) contrasted with the two holes nearest the west but one (B, C) after the check-geophone interval X. The final short piece of three sections shows the two central holes D (west) and E (east) contrasted about the check-geophone X.

(5) The sections H, G, F are recorded in succession from the extreme east end of the lay-out and the sections B, C, D are recorded in succession from almost the extreme west end.

(6) To compare any hole with itself in successive hours