報　文

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Combination of the Sparking Sonic Prospecting System, the Gas Exploding Sonic Prospecting System and the Proton Magnetometer

by

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1. Introduction

Marine geophysical prospecting has been developed recently in Japan both quantitatively and qualitatively. K. Mori and the writer had accomplished the sparking sonic prospecting system in 1960, and we got useful results in the field survey[3]. In future we expect to be able to prospect various fields.

Advantages of this system are simple handling, high power of resolution, very economical and need not indemnify for fishing as marine seismic prospecting. But the prospected depths of structure by the sparking sonic prospecting are usually shallower than 50 m below the sea bottom, occasionally 200 m deep.

In order to explore deeper structure by the sonic prospecting system, we have made the gas exploding sonic prospecting system, which generates sound wave by exploding mixture of combustible gases, for instance propane or acetylene, and oxygen firing by synchronized small spark. As it generates larger energy wave and longer wave than conventional sparking system, not only we can prospect deeper structure by reflection but also we shall be able to apply to refraction shooting. We have to use suitable one of them in consideration of their characteristics and purposes.

Marine magnetic survey has been developed rapidly by the proton magnetometer. If the sonic prospecting system is combined with it and the field survey is conducted on the same lines simultaneously by the same boat, we shall get much more useful informations, and exploration will be developed qualitatively. We obtained some sonic prospecting records of which we could not make clear their geological meaning. But if we would get the magnetic informations, we might find to interprete them. The writer showed these examples in the sonic prospecting of the Shimabara Kaiwan[2]. On the other hand, the magnetic prospecting will obtain better interpretation also if it is combined with the sonic prospecting, for example, in the prospecting for iron sand in the sea bottom deposit.

Moreover in this case we can economize in expense than two prospectings which

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are carried out independently, because charges of the observation boat and surveying are common and occupy a large part of expenses. But the interference between three kinds of prospectings must be avoided. The sparking sonic prospecting uses electric current of some thousand amperes though spark time is very short less than 0. 1m-sec, consequently the interference may be occurred by both induction and magnetic field produced by large current.

The writer has designed and constructed the control system between the sparking sonic prospecting, the gas exploding sonic one and the proton magnetometer.

Acknowledgement

Acknowledgement is made to Mr. Tetsuo Nishimura of NEC, who suggested and discussed with me about the whole system, especially the v-t converter.

2. Direction of Design

2. 1 There are two ways in sonic prospecting. One is the sparking sonic prospecting and the other is the gas exploding sonic one. As the latter generates large energy sound and longer wave, it can explore deeper structure. But the former has high power of resolution. When we wish to realize advantages of two methods simultaneously we consider two techniques as follows.

1) To use two methods alternatively avoiding the interference of each firing

2) The reflecting sounds produced by large energy with wide frequency spectrum are recorded once on the tape recorder and later suitable reflecting waves are reproduced and separated by various filters and compose the records according to their purposes.

The writer adopted the former technique, because it is rather easy and has few troubles, but the latter has some difficulties on the accuracy of mechanical device and stillmore equipment will be large and expensive. The present controller is designed so that we can realize this purpose.

2. 2 When the sonic prospecting system and the proton magnetometer are used simultaneously on the observation boat, interference must be avoided by controlling these systems, as the sparking sonic prospecting uses about 1, 500 amperes pulse current through 100m cable from the boat to the sparking electrode set in water and pulse width is about 50 micro-sec. As this time is very short, the interference to the magnetometer is sometimes negligible if accuracy is not required. But since induction may be changed by the observation conditions, it is difficult to keep always the same accuracy. We can avoid interference completely if we stop to spark when the magnetometer is operating. In this interval the sparking sonic prospecting makes a blank on the recording paper, therefore we had better record the output signal of the proton magnetometer on this blank. The proton magnetometer makes the DC voltage proportional to magnetic field. The controller receives this signal and converts to time. Then the recorder of the sonic prospecting draws the black lines on the blank of recording paper by converting time proportional to magnetic field intensity. We call this circuit as the proton printer not to be confused with the recorders.

In order that the controller may be used conveniently, the exciting switch is given paralleled to manual exciting switch on the proton magnetometer which is operated in the manual operating position (not automatic).

On the other hand, there is no interference between the proton magnetometer and the gas exploding sonic prospecting.

The interference relation between three methods is shown in Fig. 1, and the controller must avoid interferences and arranges every system for all sorts of combinations of three methods. There are many possible control relations. Fig. 2 shows our

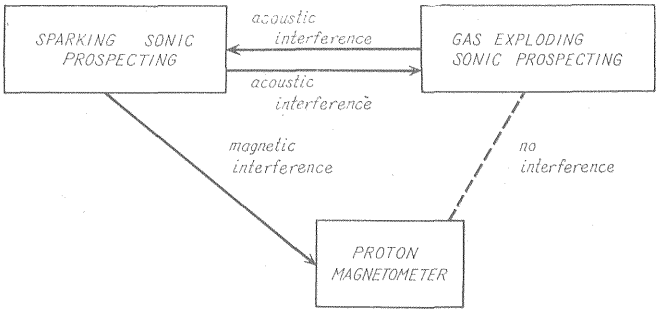

Fig. 1 Interference relation between three methods

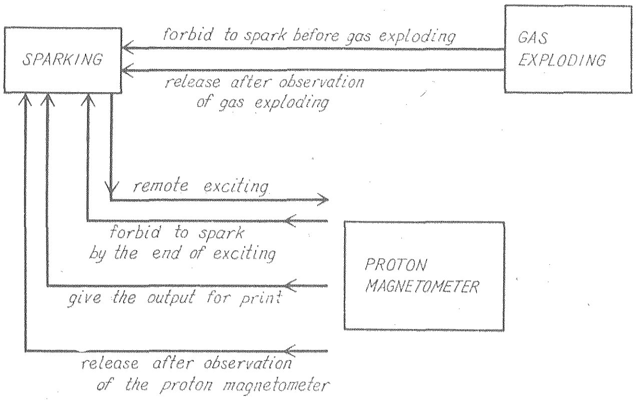

Fig. 2 Control between three methods

control system and it has no connection to synchronize or not.

2.3 The hydrophone and amplifiers are used commonly in both the sparking sonic prospecting and the gas exploding sonic one, and filters and gains should be adjustable independently in both methods. It is unnecessary, however, to make two sets of filters for both methods, as filters work in different times. For two prospectings, the filters are changed by a relay which is energized by forbidden signals.

The power amplifiers of recorders were improved to the direct current amplifiers for wide frequency response and portability.

3. Function and Construction

3.1 In obedience to direction of the design mentioned above, the block diagram of whole system is constructed as shown in Fig. 3. The sonic signal comes to the hydrophone and is converted to the electric signal, and is fed to the preamplifier through the cable. The preamplifier amplifies it and compresses the beginning part of

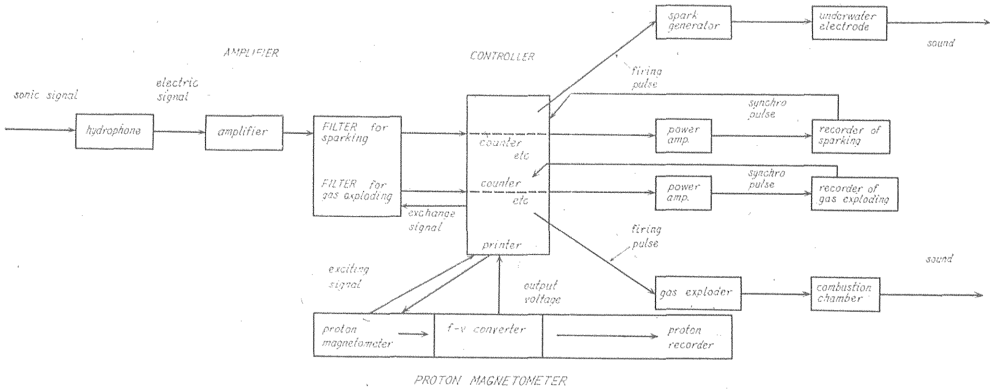

Fig. 3 Block diagrams of the sparking sonic prospecting, gas exploding sonic prospecting and the proton magnetometer

signals according to the compression pulse coming from firing signal. Next the signal goes to the main amplifier where it is amplified and is added to the AGC (automatic gain control) action. From the hydrophone to this stage, signals either sparking sound or gas exploding one are amplified under the same condition in different times. But in the filter stage different filters and gains are applied for their frequency band and output level, and they are changed by the relay which is controlled by the controller, as they don't operate in the same time. One filter set and changing circuit is better than two filter sets because the former is not only economical but also in the quite same characteristics. The amplifiers have a channel switch which selects the inputs of channels I and II. The signals of four outputs (sparking and gas exploding, every two channels) go to the controller.

3. 2 In the controller the signals of every channel go to rectification circuits. Every channel I has only one mode of rectification but every channel II has three urectification modes +, − and F. The plus + is positive half rectification, which is usually written +1/2. It means when positive pressure of sound comes to the hydrophone, the recording paper is blackened and by negative pressure the paper is blank. The F is the full rectification. As the channel I is usually for regular use, rectification is always plus half. In practice, the full rectification is not so important, but minus half rectification is sometimes useful. The time marker and the proton printer signals superpose on them, and they go out from the controller to the power amplifiers, and they go to the recorders.

3. 3 The recorders of the sparking sonic prospecting and gas exploding sonic one generate the synchro pulses with their sweeps by rotations of the herical wires drum. There is no connection between two series of synchro pulses, as those are non-synchronization system. The synchro pulses come to the controller and are counted for the program, phase and firing and the controller works to avoid the interference of mutual systems.

The mutual control is as follows.

1) To forbid the firing pulse of sparking prospecting at the synchro pulse of one pulse before the firing pulse of gas exploding

In this interval the noise caused by sparking disappears in the water.

2) When the channel II of gas exploding finishes to be observed, it releases to forbid after arbitrary delay time, in order to run away from the noise of gas explosion. Usually the channels II are used at the same depth or deeper place than the channels I.

3) The first synchro pulse after releasing is made to firing pulse of sparking prospecting.

Fig. 4 shows these time diagrams.

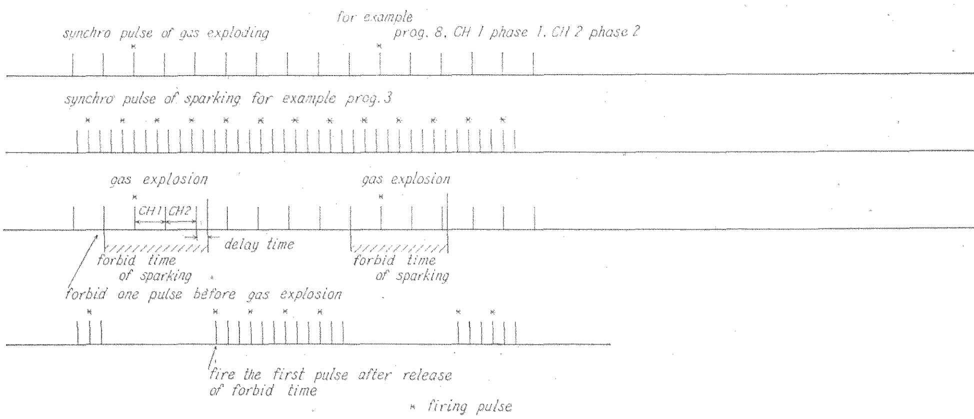

Fig. 4 Time relation between the sparking sonic prospecting and the gas exploding sonic prospecting

3.4 The mutual control between sparking sonic prospecting and proton magnetometer is as follows.

1) At the end of exciting (2.5—4 sec) of the proton magnetometer, the firing pulse of sparking must be forbidden to prevent the magnetic interference.

2) In the proton magnetometer the damping oscillation generates in coil and the frequency of oscillation is proportional to the total magnetic field intensity (geomagnetism). This damping oscillation makes beat with the standard oscillation, and the f-v converter converts this beat to the DC voltage proportional to frequency, which attains to the stational state after 0.1 sec from the end of exciting and it continues approximately during 1 to 4 seconds.

Where the magnetic gradient in the field is large, the oscillation continues short and damping is fast.

3) In the stational voltage duration, the preset number of output of printer must be printed on the recording paper, that is, the printer generates the time proportional to DC voltage (magnetic field) and during this time the recording paper is blackened, and after printing it releases to forbid firing pulse.

4) Even when the printer is not used, sparking must be forbidden. Product of print number and sweep time is forbidden time.

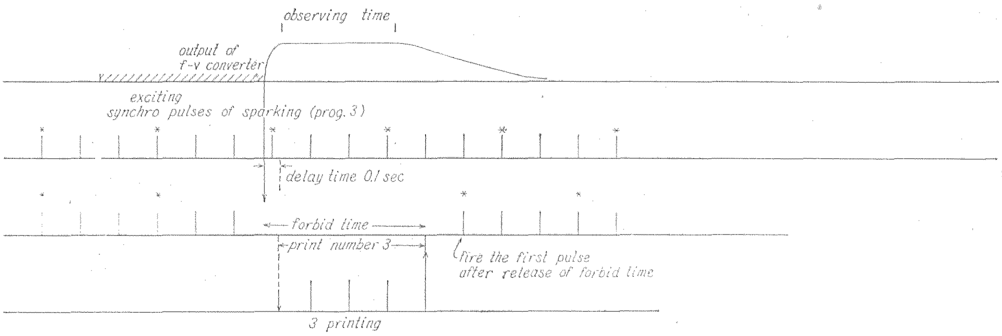

Fig. 5 Time relation between the sparking sonic prospecting and the proton magnetometer

5) The first synchro pulse after releasing is the firing pulse. Time relation is shown in Fig. 5.

6) When the proton magnetometer is on the manual exciting position, the manual exciting on the controller is available.

4. Circuit

4.1 Input circuit of synchro pulse

Input synchro pulses are generated at both the sparking sonic recorder and the gas exploding one by rotations of drum.

Synchro pulses are generated by light of DC lamp and photo-transistor.

This system has neither friction part as the mechanical contacts nor miscontact and delay. Synchro pulses of photo-transistor come to the controller as input pulses.

It goes to the transistor schumidt circuit at first in order to match impedance and to shape.

4.2 Counter and counter matrix

The counter has some stages of biestable multivibrators of a pair of transistors. It counts pulses, and if it has n stages, it can count up to 2^n according to the binary system theory. Counter matrix introduces every signal of number not in pulse but square wave which duration is a sweep time. This theory is shown in many electronic text books. Biestable multivibrator circuit is shown in Fig. 6.

In our case, stages of the sparking sonic prospecting are 4, and it counts up to 16. Stages of the gas exploding are 5, and it counts up to 32.

The initial condition of counters is reset, that is, every input side transistor of biestable multivibrator is off transistor and opposite side is on transistor.

It means that reset is zero.

When the first pulse comes from input circuit, the first stage of biestable multivibrator works to opposite state and signal comes to program and phase control switches at 1 through counter matrix.

Rising of signal of program 1 is used as firing pulse. It satisfies the postulation that the first synchro pulse after releasing from forbidding is the firing pulse, for counting after releasing starts from reset 0.

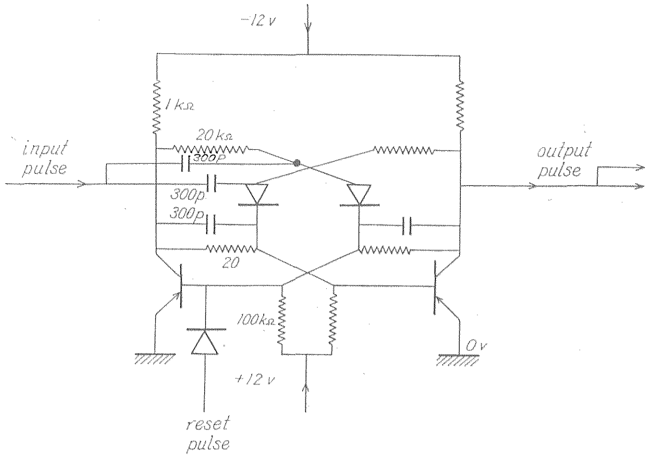

Fig. 6 Biestable multivibrator (Flip-Flop) of counter
(a pair of transistors is 2SA206.)

Next synchro pulse changes to the first stage again and restores to off-transistor. This restoring makes pulse by differential circuit and it goes to the next stage through diodes. It makes change of state. Pulse of off to on is able to go and change, but pulse of on to off is unable. Square wave signal of program 1 finishes and it comes to program 2 through the counter matrix.

Output of program is progressed by number of input pulses. When it comes to program position, that is, if program position is 5 and 5 pulses enter and square wave signal comes here, the reset circuit works and counters reset to 0. This cycle repeats again.

Phase switch selects the sweep number after firing, which drives the phase relay in order to pass sound signals from filter to power amplifier. Phase position is just equal or smaller than program.

The reset circuit uses the monostable multivibrator. It has one stable state, and input side is usually on-transistor, but when input pulse comes to it, on-transistor changes to off untill restoring. The time untill restoring is decided by CR time constant

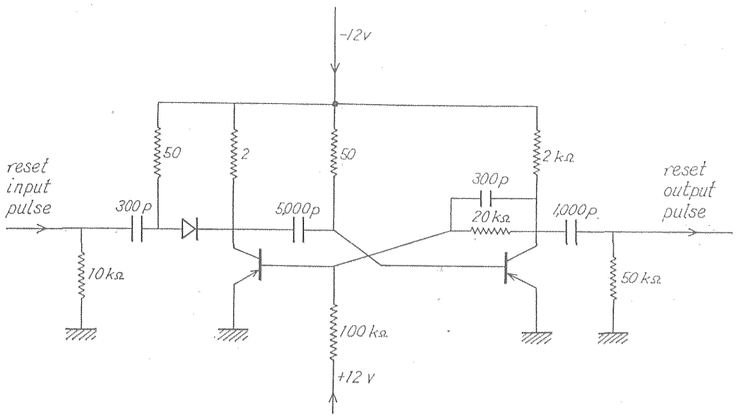

Fig. 7 Monostable multivibrator of reset circuit

of base and collector circuit. Fig. 7 shows monostable multivibrator.

In this controller there are four kinds of fundamental circuits except v-t converter, and those are biestable multivibrator (it is sometimes called flip-flop, so it stands for FF.), monostable multivibrator, schumidt circuit and relay.

All of them are logical circuits and have 2 states. They are all insensitive to characteristics of temperature compared with the ordinal transistor amplifier.

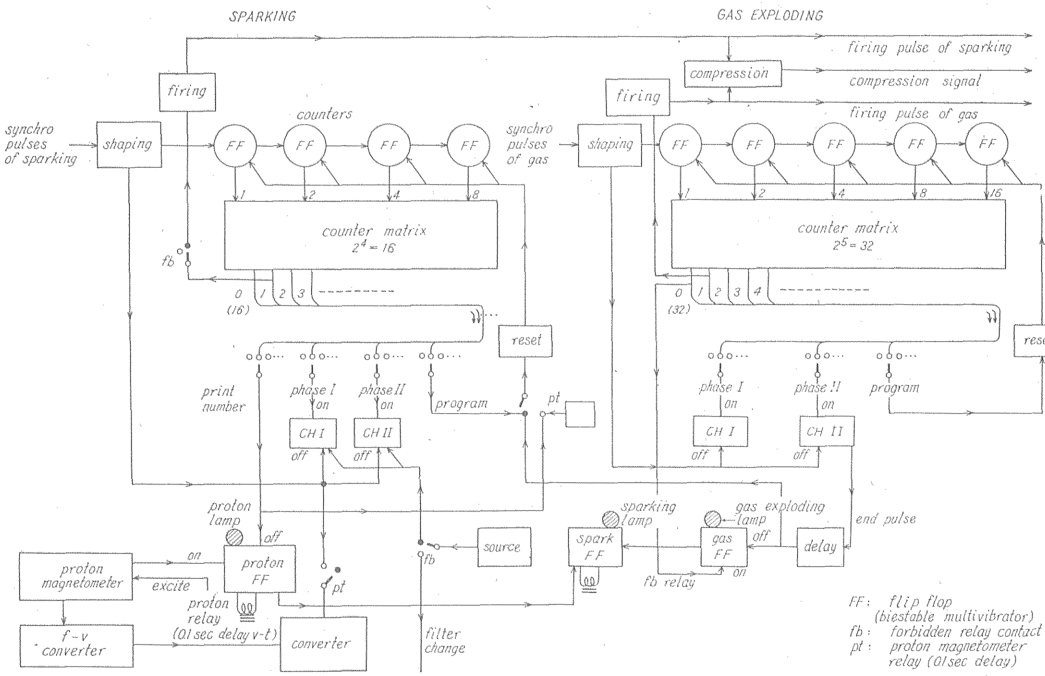

Fig. 8 Block diagram of controller

4.3 Forbidding of sparking by the gas exploding

Gas exploding counter comes to 0 by reset signal, and signal of 0 position of counter matrix goes to gas FF (flip-flop circuit). When this gas FF works, sparking forbidding relay is energized by the sparking forbidding FF. It is energized not only by gas FF but proton FF.

Function of sparking forbidding relay is as follows.

1) To cut circuit of firing pulse of sparking
2) To cut phase relay circuit
3) To change the filter circuit

When synchro pulse comes to the counter, output of matrix moves to 1 and it becomes firing pulse. Channels I and II of gas exploding select the observing depth range by the position of phase switches. Usually II is at the same depth or deeper place than I. End of observing time of II is sent to delay circuit, where is monostable multivibrator with 0, 0.1, 0.2, 0.3, 0.6, and 1.0 sec delay times in order to prevent the sparking sonic prospecting from the noise of gas exploding.

Output of delay circuit restores gas FF, and then forbidding relay is unenergized. In the same time output signal of delay circuit goes to the reset circuit of sparking, so the synchro pulse appeared first after releasing becomes the firing pulse. Sparking sonic prospecting operates again untill gas exploding goes to program number and its counter is reset. This process repeats.

Working time of gas exploding is indicated by the lamp attached to gas FF. Working time of sparking is done in the same way by the forbidding relay. They don't switch on in the same time.

4.4 Proton magnetometer

The exciting method of the proton magnetometer and input circuit of controller is shown in Fig. 9. The exciting switch in the controller is parallel to the manual

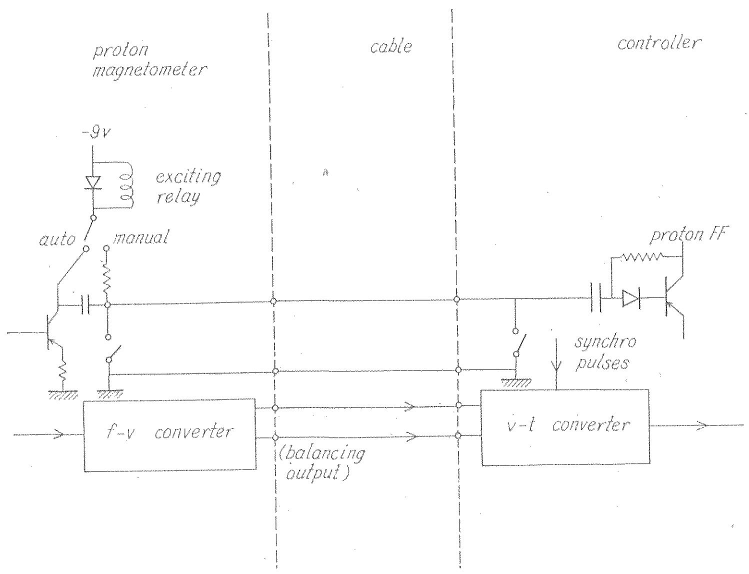

Fig. 9 Output of the proton magnetometer, input of the controller and exciting switches

exciting switch in the magnetometer. The exciting signal of both manual and automatic positions goes through differential circuit, and end pulse goes to proton FF (flip-flop), and this pulse is negative. Proton FF works by this pulse and proton relay is energized immediately, but as it is a delay relay its contacts make after delay time. It is purpose of delay that the beginning part of signal from the proton magnetometer must not be used as the signal after delay time is stational value which is proportional to intensity of geomagnetic field.

Principle of delay relay is eddy current loss of core and delay time is about 0.1 sec, but there is no time delay in restoring. Output of proton FF, which has no delay time, goes to energize the sparking forbidding relay. Proton FF switches on the lamp of indication. Proton relay changes three circuits.

1) To reset sparking counter

2) To close the synchro pulse input of v-t converter
3) To change the sonic signal circuits to the proton print relay

When input of reset circuit is changed from sparking to proton position, the circuit resets instantly at contact when the pulse is sent to it. But it does not reset at restoring. After resetting the counter counts synchro pulses till the signal appears on print number position. When it appears, it goes to reset circuit, and in the same time it goes to proton FF in order to be off. Sparking works again and it is one cycle.

Proton relay closes the synchro pulse input of v-t converter and it begins to write lines on the recording paper. The length of lines is proportional to the magnetic field.

4.5 V-T converter

F-v converter of the proton magnetometer generates the DC voltage being proportional to frequency independently for the amplitude, using the saturable core transformer. This voltage feeds to the v-t converter of the controller. It is amplified by the DC amplifier.

The synchro pulse goes to v-t converter through the proton relay when the proton relay is energized by the exciting signal. It is fed to the saw tooth circuit, and then the saw tooth wave begins to rise instantly, feeding the synchro pulse. After the saw tooth wave rised, it is cut off by cutoff voltage proportional to input voltage which is the output of DC amplifier. So time of saw tooth wave is proportional to input voltage. It must keep quite linear and constant slope. On rising duration of saw tooth wave the oscillator oscillates and the recording paper blackens in its duration. Fig. 10 shows this time relation. Fig. 11 is the block diagram of v-t converter.

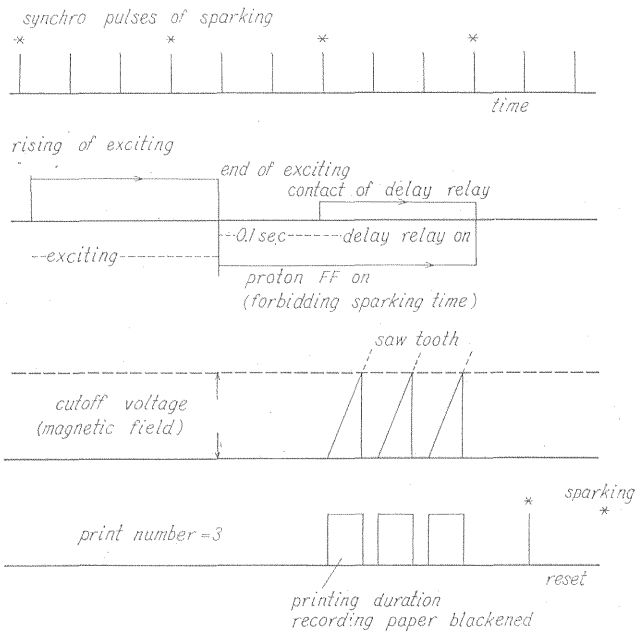

Fig. 10 Time relation of v-t converter

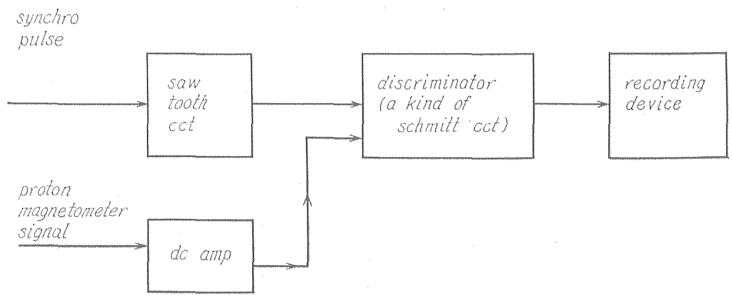

Fig. 11 Block diagram of v-t converter

4.6 Sonic signal circuit

Sonic signals come from filters and at first they go to rectifiers. Rectifiers of channel I of both sparking and gas exploding are a positive half denoted as +1/2. Rectifiers of both II have rectification mode selector which are +1/2, -1/2 and F.

Sonic signal goes to the phase relay which is normally off. Next it goes through time mark relay contact. Then it goes to the proton relay contact which is delay relay.

When it is excited, the proton print relay, which is the reed relay, feeds DC voltage to the power amplifier. As the power amplifier is DC amplifier, actual DC voltage circuit is a little complicated. Operation of proton printing is preferential to time mark and phase relay. When three relays work in the same time, the proton signal goes out as output signal.

Print selection has three positions of 0, 1 and 2. Position 0 is off state of printer. In case of 1, the print relay operates only in channel I. So when time mark and print relay work in the same time, I shows the proton print and II, time mark. In case of 2, proton relays work on both I and II.

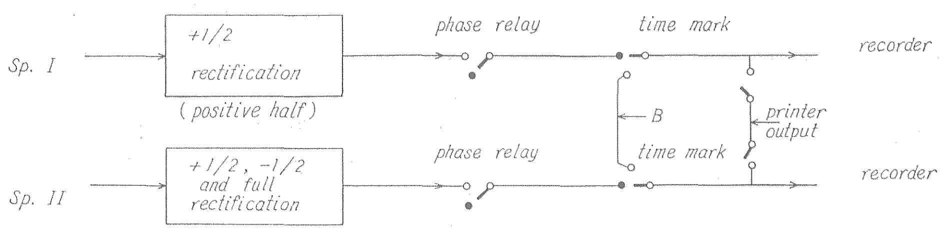

Fig. 12 Block diagram of the sonic signal circuit of sparking system

5. Conclusion

Concerning the combination of the sparking sonic prospecting system, the gas exploding prospecting system and the proton magnetometer, this investigation adopted above-mentioned methods in order to realize requirements which occur in marine works, though there may be many possible control systems.

If we use the synchronized method between the sparking sonic prospecting system and the gas exploding prospecting system, the controller becomes much more simple system and it uses only one counter. Though it may be very simple, it requires the synchronizing apparatus or synchronizing monitor.

The writer believes that the construction of this control system brings the increasing of cases in which survey will be carried out in many-sided characters and unifying.

The history of marine geophysical works is short in Japan and technique is unskilled yet. But the weight of geophysical works is rather heavy, as the conventional geological work is difficult in marine surveys.

As sonic prospecting has ample possibilities to apply for their purpose, realization of this system means to approach one edge of possibilities.

This equipment was made in 1961.

The writer was indebted to Shigemasa Furuya and Kiyoshi Mori in Geophysical Department, Geological Survey of Japan, who helped and discussed with him.

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放電音波探査とガス爆発音波およびプロトン磁力計の共同観測装置

中 条 純 輔

放電による音波探査とガス爆発によるそれとは原理は似ているがその発生する音波のエネルギや周波数が違うので，探査深度や分解能が異なる。目的により両者を併用したいが，たゞ併用したのでは音響的干渉が生ずる。それで発振時刻をずらせて使用せねばならない。プロトン磁力計も音波探査と一緒に用いたいがそのまゝで使用すれば放電の際の大電流が干渉してしまう。

それでこの3つの方法をお互いの干渉のないように時間をずらせて使用する共同観測のための制御装置を試作した。プロトン磁力計の動作中放電音波探査が止まつているので，このブランクに磁力計の出力を記録せしめる。こうしてこの3つの方法の同時使用で探査が質的に向上するだけでなく，測量と船の費用が共通なので探査費用を安くできる。

この制御装置はほとんどフリップフロップ回路やモノステーブル・マルチバイブレータ回路のような論理的な回路素子で構成されている。