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(54) Electronic system for sequential blasting.

(57) This system consists of a multiprogrammable electronic exploder-detonator set, which is able to time a blasting and to establish a two-adress communication providing full data about the detonator, by using a two-wire FSK system of frequency modulation. The electronically programmable blasting is based on the connection in parallel of two wires in order to achieve two or more different times for each loop. The system includes different loops in order to repeat or not to repeat the firing sequence. These loops are started simultaneously with the firing order; a cascade performance can he achieved, if necessary, by means of programming. The system is applicable to blastings in mining and similar ones.

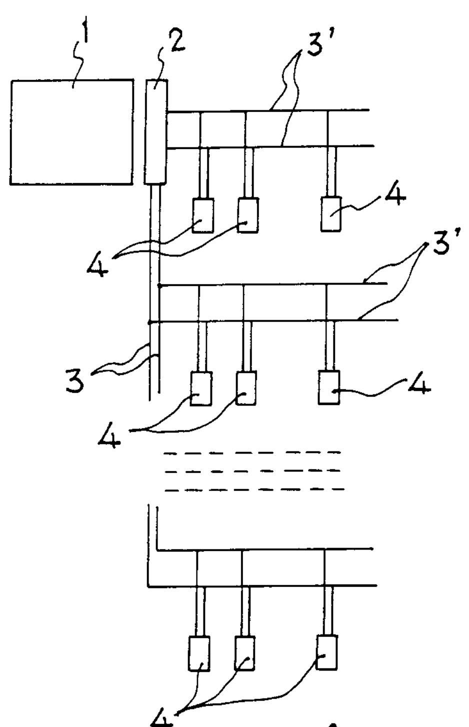

Fig. 1

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The invention consists of an electronic exploder-detonator system, which is sequential and multiprogrammable, designed to time a blasting in such a way that its sequentiality enables different times to be achieved in the same circuit, as well as being applicable to sequent circuits in a reiterative way.

The exploder itself shall command the explosion sequence of several electronically delayed detonators, connected in parallel by a two- wire line; a distinctive feature being that the whole process up to the final detonation is to be performed by stages including specific actions such as safety codes and control of each stage.

The detonator shall be provided with means of protection against any unwanted electrical phenomenon.

Another remarkable feature is that both the exploder and the detonator are provided with a two-address communication system, enabling to know the proper performance of each specific detonator as well as its connection in blasting.

Nowadays, retarded ignition with electric detonators used in blasting, connected in series or in parallel, is based on the burning of a pyrotechnic composition. Due to this, precision of response time is limited. Further, such detonators are not customer-tailored to enable variations in burning times; response times cannot be adjusted by the user to optimum blasting conditions.

On the other hand, response time can be programmed in some electronic detonators currently known, which enables blasting conditions to be better adjusted to the features of the rock and geometric structure to be blasted. However, almost all the electronic detonators studied and analyzed lack a two-address communication between exploder and detonator which ensures the proper connection to the line and the correct performance of the detonator. In the detonators which do provide it, this two-address communication is very complex.

One of the most common types of blasting is the so-called coyote-hole blasting. It requires detonators to be placed in special arrangements, known as burn cut, reverse burn cut, etc. Various cartridges with detonators with different response times have to be primed. This is not possible with electronic detonators, where just a single time can be programmed for the whole line or circuit.

Frequently the number of detonators which are used in a single blasting may be as large as one wishes, since there is no trouble with the amounts of explosive used, these problems being particularly brought about by the environment. The indefinite increase in the number of detonators demands very large and costly stocks.

The system herein referred to solves the above problem by providing a sequentiality to the blasting; that is, the blasting can be repeated in different loops or connection lines so that each loop programming is reiteratively repeated.

Further, this system is designed with a two-wire two-address communication and with blasting and sequentiality features enabling different times to be programmed in the same blasting, as well as the same or other programming to be sequentially repeated on other blasting circuits which are connected to the same exploder.

In regard to the exploder itself, it has been designed to include the required components for power supply and switching, as well as an intelligent circuit based on a microprocessor, which by means of a specific software developed for this system, enables communication with the detonators, as well as its control and the basic operations of detonation and abortion. Communication is carried out by means of a keyboard, the instructions being displayed on an alphanumerical screen.

The communications system is supported by a 300 baud FSK frequency modulation system. The FSK system has been chosen for the safety of the data which can be transmitted, since there are only two communication wires and the system should be able to work in difficult environments, from the communications point of view. A CRC is also included, that is, a logical character which is added to the instructions to check that commands are properly received and transmitted.

The system performs individual communications, detonator by detonator, general instructions being simultaneously generated.

The electronic detonator is made on a hybrid circuit upon which a specific integrated circuit is installed. Intelligence is provided by the latter, which controls as well time and call and response functions, giving fire or abort commands. The main function of this specific integrated system is to act as a precision and safety timer. Different delay times can be programmed by a controlling central unit.

To facilitate understanding of this invention features, a detailed description shall be given, based on the set of drawings which is enclosed with this descriptive report and is an integral part of this. As a general guidance only, the following has been shown:

Figure 1 shows a diagram of the system.

Figure 2 shows a block diagram of the detonator included in the system. Its main block is an integrated circuit for specific application (ASIC). In accordance with the invention, a detonator is required for each explosive load to be activated, these loads being able to be separately activated.

Figure 3 shows a block diagram of the above-referred to ASIC circuit.

Figure 4 shows the diagram of the data receiver in the ASIC circuit.

Figure 5 shows a block diagram of the emitter in the ASIC circuit.

These figures show how the system is built on a central control unit (1) which forms the exploder, basically made up by a personal computer with its power supply and a number of switches and connectors (2).

From the central control unit (1) a bifilar line (3) extends, which includes a series of branches (3') in parallel, to which, in turn, a number of detonators (4) are connected in parallel, with each detonator causing an explosive load to set off, by means of the central control unit (1).

Such central control unit (1) is provided with a keyboard and display of instructions, on an alphanumerical screen, for programming the system.

The detonator (4) consists of one cell for supply stabilizing and rectifying (5), plus a protection circuit (6) connected to an ASIC circuit (8) through a condenser (7). This circuit (8) is connected to a coding circuit (9), a firing circuit (10) and a switching circuit (12), the latter being in turn connected to the condenser (7) and the firing circuit (10), which is also connected to the pyrotechnic match (11), which rules the explosion of the load.

Through the coding circuit (9) a code is assigned to the ASIC circuit (8), so that the latter is identified by the said code, enabling each ASIC circuit to be separately monitored from the central unit (1) by programming the circuit.

The detonator (4) and the central unit (1) have a two-address communication, so that the proper performance of each detonator (4) can be checked, as well as their programming. To this end, the said ASIC circuit (8) is provided with one data receiver (12) and one emitter (13), the block diagrams of which are shown in figures 4 and 5.

The system operation is as follows:

The first operation is feeding the circuit. This is done by means of one battery which is controlled by a mechanical key. The central unit (1) then requires the access code or PASSWORD to be entered. Once the correct password has been entered by using the keyboard, the central unit (1) checks the battery status and shows whether it is able to program the subsequent operations.

Communication is then established with the line of detonators, according to the following sequence:

- The central control unit requests the line (3') to be programmed and asks how many detonators (4) there are on that line (3').
- The same question is made for every line (3') which is programmed; shift from one line to another is made through a switch -- possibly a mechanical switch - or by means of software.
- Once the number of detonators (4) is found out, the central unit (1) calls the register of those already connected which are then displayed.
- This operation is carried out on every connected line.
- Then the central unit (1) requests the type of programming. The system has the ability to program one or several times along the lines (3'), since each detonator (4) is separate and has its own identity after having been assigned a code. The system is able to synchronize the detonators' (4) reference clocks with the master clock in the central unit (1).
- Finally the correct connection of the circuit is checked.
- If properly connected, the system requests the load command and then the fire command. If the fire switch is started, detonators (4) will carry out the programmed explosions, without any possible stop, since by then the said detonators (4) are isolated from the central unit (1), which previously has assigned explosion times to each detonator as programmed.
- After the load command, it is still possible to disconnect the circuit by operating the switch which will show "operation abortion". Once this command is given, the whole process has to be reinitiated.

Once the central unit (1) has been disconnected from the detonators (4), the condenser (6) takes over the function of feeding the ASIC circuit (8), at the same time storing power enough as to spark the pyrotechnic match (11), with the circuit (8) acting on the switching circuit (12) whenever the explosion is wanted to take place, according to the time programmed in the central unit (1) and reprogrammed by the central unit in each detonator (4).

The ASIC circuit is provided with a clock generator (14), the performance of which is based on one RC circuit, its precision being thus limited. Therefore a precision clock signal from the central unit (1) is entered into the generator's (14) input (16). In addition, the former sends a start counter signal (IC) and an end of counter signal (FC). (IC) starts the precision counter (15) and (FC) stops it after a time controlled by the central unit (1), the quartz clock of which is extremely accurate. Following the reading command (LC), the ASIC circuit (8) answers through the emitter (13), sending the time it has counted from (IC) up to (FC), so that the central unit (1) can know the clock error generated by the circuit (RC) of each detonator (4) and program a delay time adjusted in order to reach the precision required to carry out the detonation in the required time.

Time for each detonator (4) is programmed by the time programming command. Delay time is a value between 0 and 250 ms. The time an ASIC circuit (8) takes to detonate is calculated by multiplying delay time by a multiplication factor which is intrinsic to each detonator (4) and determined by its address. This is the time elapsed from the moment the detonation message is received until actual detonation takes place.

To perform the above-quoted functions, the data receiver (12), the input area of which (23) is the communication line input, is connected to a message decoder (17), the output of which decodes messages from the central unit (1). The product of delay time is calculated by a coding factor decoder (19), whilst delay time is stored in one LATCH (18), which like the decoder (19), is connected to a timer (20), from which real and precise time is obtained for timing the explosion. Therefore, its output area (21) controls the firing circuit (10).

In figure 3, RL means line revision; PT means time programming; DDT means to cause detonation; ABORT means to abort the whole process to reinitialize it.

The ASIC circuit is protected by an electronic device which prevents any reset as well as protecting it against any kind of signals which might damage the circuit.

Communication between the central unit (1) and detonators (4) is performed by FSK modulation, at a 300 baud rate. FSK was selected because of the safety of the data which can be transmitted, since only one bifilar line is used (3-3') and the system should be able to operate in environments which are difficult from the point of view of communications.

For safety reasons, along with modulation and frequency a Manchester code is emitted, acting as another reference and control element to verify that data sent and received are correct.

Along with the above data, the system is provided with a redundancy code, that is, a logical character which is added to the instruction in order to check that commands are properly sent and received.

Therefore, the receiver (12) at the ASIC circuit (8) receives as input (23') all data being generated by the central unit (1). These data are decoded by the FSK decoder (23), which is connected to a Manchester decoder (24) where the above-quoted code is obtained.

The redundancy code check is carried out on a redundancy code check circuit (26) which is also connected to the Manchester decoder (24), thus providing the data plus the redundancy code.

All these circuits (23, 24, 26) are connected to the clock signal (14') provided by the clock generator (14) on the ASIC circuit.

The redundancy code check circuit (26) generates an output signal (26') showing the said code.

Further, the receiver is provided with a shift register (25) which is connected to one LATCH (27), which is in turn connected to the redundancy code check circuit (26). Its output is applied to the message decoder (17) and to the delayed time LATCH (18).

The emitter (13) is also provided with a control circuit (28) onto which signals RL, LF are applied, as well as the input (15') pertaining to the precision counter (15). This emitter (13) is provided as well with a logical unit (29) controlling the generation of the redundancy code in order to ensure a correct communication between detonator (4) and central control unit (1). This emitter (13) is also provided with one redundancy code generator (30) and one Manchester coder (31) where the said code is coded. Thus all required functions are performed and communication between detonators (4) and central unit (1) is highly safe, in order to prevent any accident.

Obviously, the emitter (13) is provided with a FSK modulation generator (32), the output of which (22) includes the required data to be sent to the central unit (1). A two-address communication is thus achieved, ensuring a higher system safety.

Claims

1. Electronic exploder-detonator system, similar to those provided with a central control unit (1), on which the detonation of the explosive loads is programmed. As distinctive features, this control unit (1) is connected to a bifilar line (3) which is able to include several branches (3') to which the detonators (4) are connected in parallel. Each detonator is connected to an explosive load and to a decoding circuit (9), which assigns an identification code to each detonator. It is provided as well with a data receiver (12) and emitter (13), to enable communication and addressing between the various detonators (4) and the control unit (1), ensuring its correct performance and allowing the individual or collective programming of each detonator (4).

2. Electronic exploder-detonator system, as in claim 1st., characterized by the fact that the detonator (4) is provided with a stabilizing and rectifying circuit (5), which is connected to a protection circuit (6). The latter is connected to the specific application integrated circuit (8)

through a condenser (7). This in turn is connected to a pyrotechnic match (11) through the firing circuit, which interfaces a switching circuit (12) monitored by the integrated circuit (8), as well as being connected to the condenser (7). This enables disconnection from the central unit (1), once the programming in the integrated circuit (8) has been completed and the firing command has been sent, thus improving safety, with the integrated circuit (8) being fed through the condenser (7), which supplies the power required to the pyrotechnic match (11), once the programmed time for the explosion has elapsed.

3. Electronic exploder-detonator system, as in the above-quoted claims, characterized by the fact that the specific application integrated circuit (8) is provided with a clock generator (14), which basically consists of a RC circuit which receives a precision clock signal from the central unit (1), and is connected to a precision counter (15), both being connected to the emitter (13). This enables the central unit (1) to send a counter start signal (IC) and a counter end signal (FC). During this time, the precision counter (15) counts the pulses being received and sends them through the emitter (13) to the central unit (1) so that the latter determines the error of the clock generated by the clock generator (14), programming an adjusted delay time and increasing precision. Detonators (4) are designed to include a multiplication factor detonator (19) and one LATCH for storing up delay time (18), which are connected to a timer (20), to be able to enter a delay time, determined by the time elapsed from the moment the detonation message is received until actual detonation takes place.

4. Electronic exploder-detonator system, as in the above-quoted claims, characterized by the fact that the emitter (13) in the integrated circuit (8) is provided with a generator of FSK modulation (32), whilst its data receiver (12) is provided with a FSK modulation decoder (23), to enable switching through FSK modulation from the central unit (1) and the detonators (4). As a distinctive feature, the receiver (12) includes a Manchester decoder (24) and a redundancy code check circuit (26); the emitter (13) includes a redundancy code generator (30) and a Manchester coder (31), all this for the purpose of verifying that data being sent and received are correct.

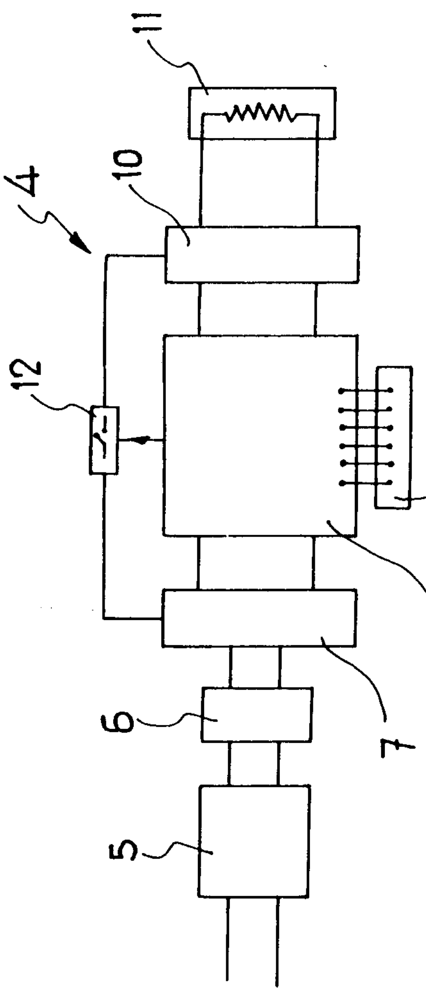

Fig. 2

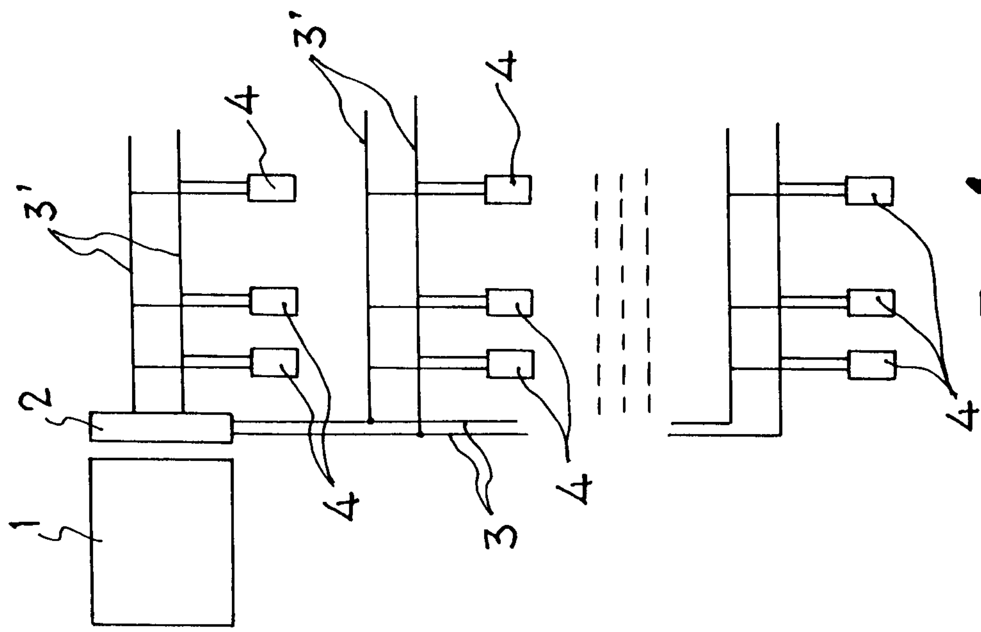

Fig. 1

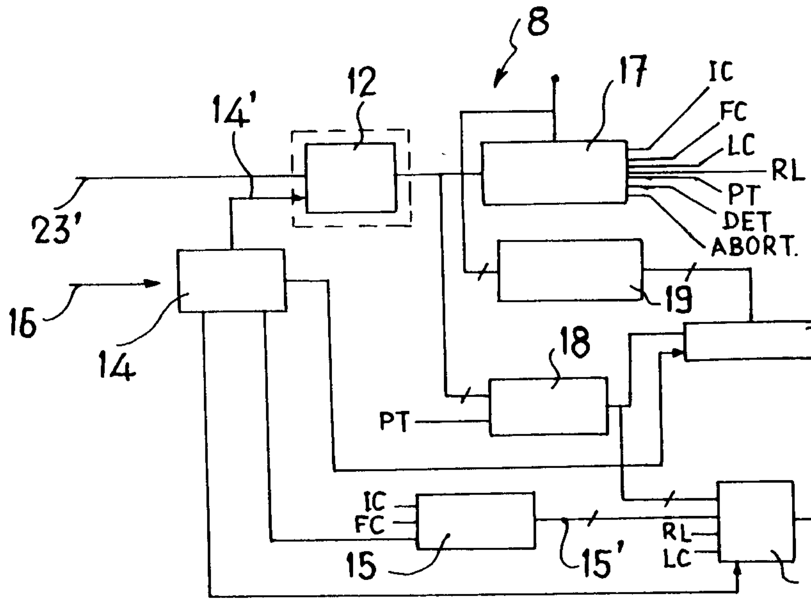

Fig.3

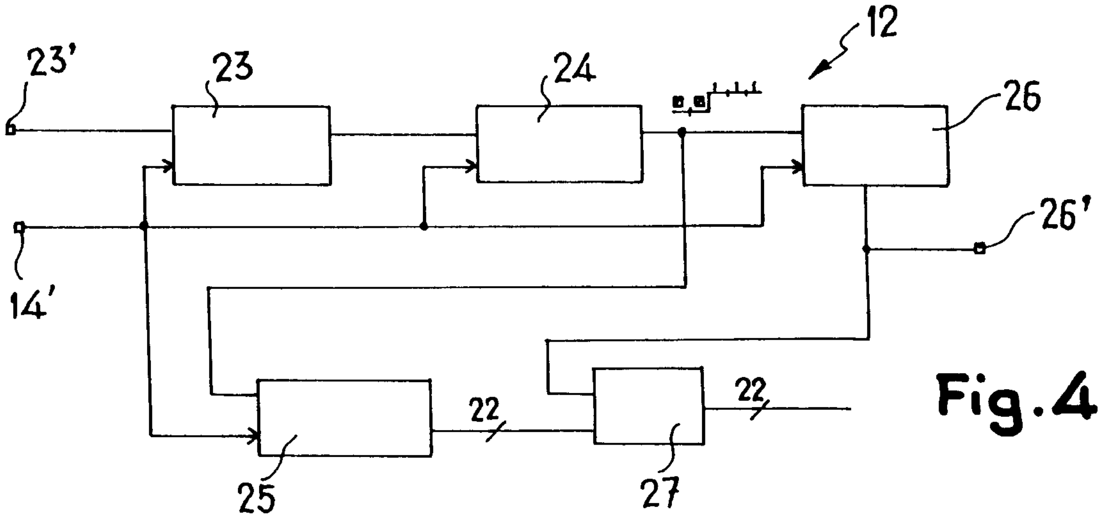

Fig.4

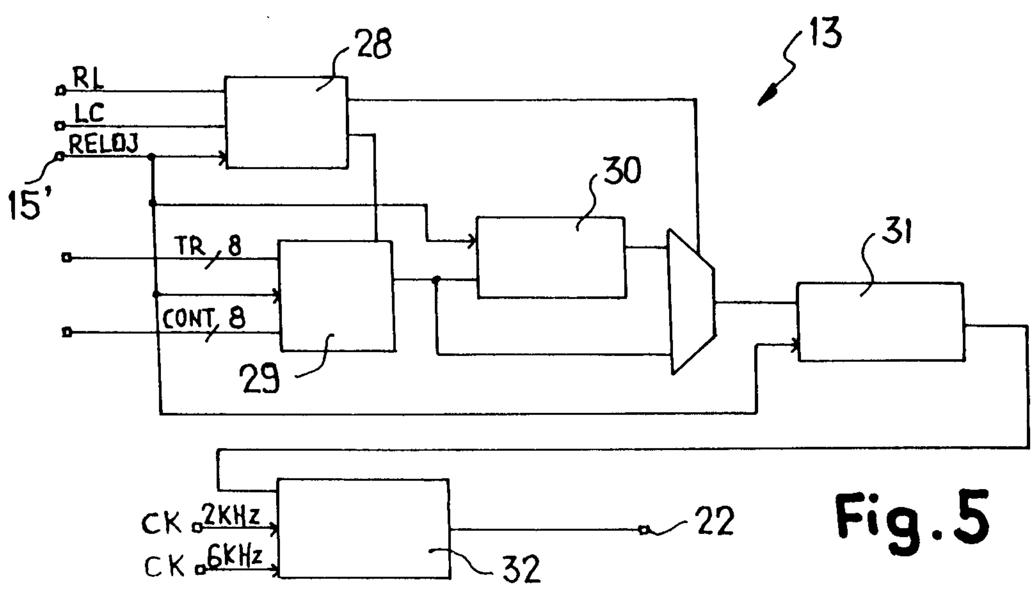

Fig.5

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EUROPEAN SEARCH REPORT

Application Number

EP 92 50 0173

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X Y	US-A-4 674 047 (L.J.TYLER) * the whole document * ---	1-3 4	F42D1/055
Y	US-A-4 672 365 (S.E.GEHMAN) * column 9, line 40 - column 10, line 25 * ---	4	
X	EP-A-0 434 883 (UNION ESPAÑOLA DE EXPLOSIVOS SA) * page 3, line 24 - page 6, line 58 * ---	1	
A	PATENT ABSTRACTS OF JAPAN vol. 012, no. 044 (E-581)1987 & JP-A-62 194 758 (MITSUBISHI HEAVY IND LTD) * abstract * -----	4	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
F42D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	15 JULY 1993	P. TRIANTAPHILLOU

CATEGORY OF CITED DOCUMENTS

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