July 21, 1936. H. A. AFFEL ET AL 2,048,091

POWER LINE CARRIER SYSTEM

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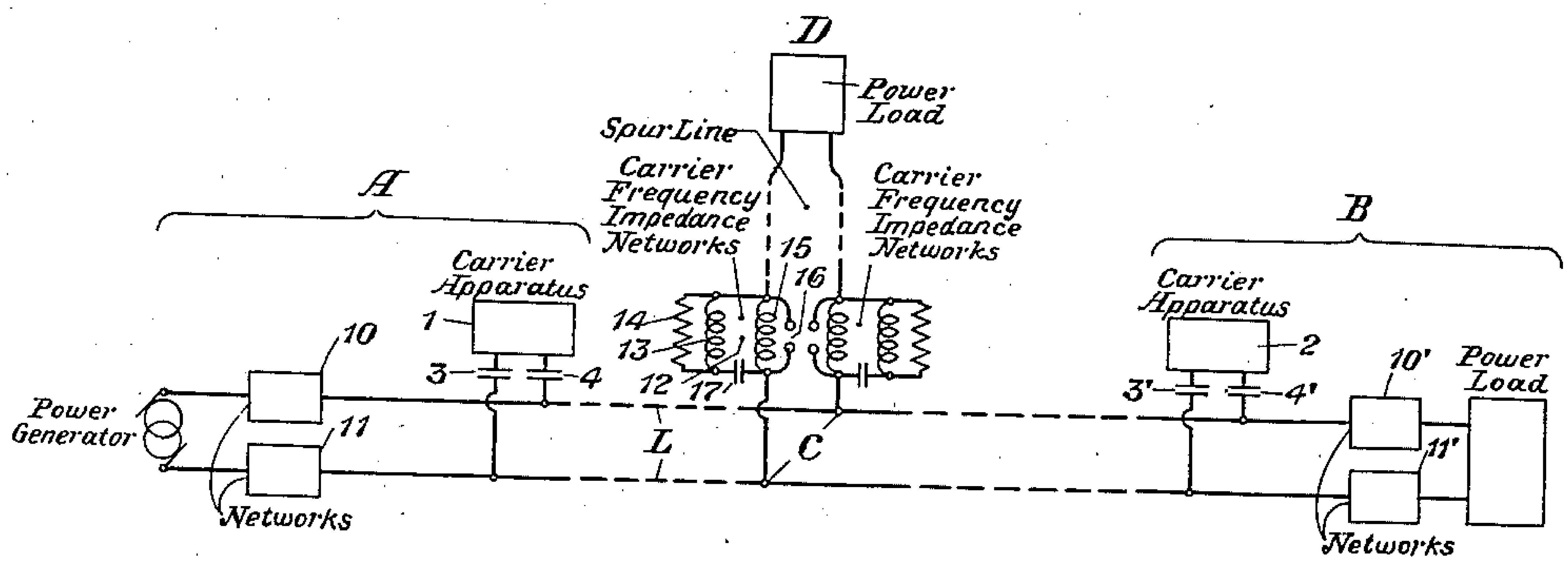

Fig. 1

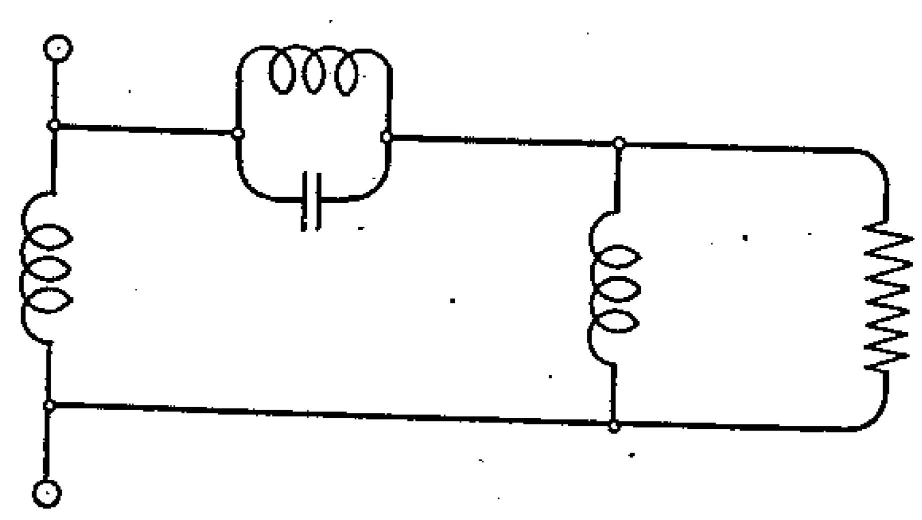

Fig. 2—High Pass Type

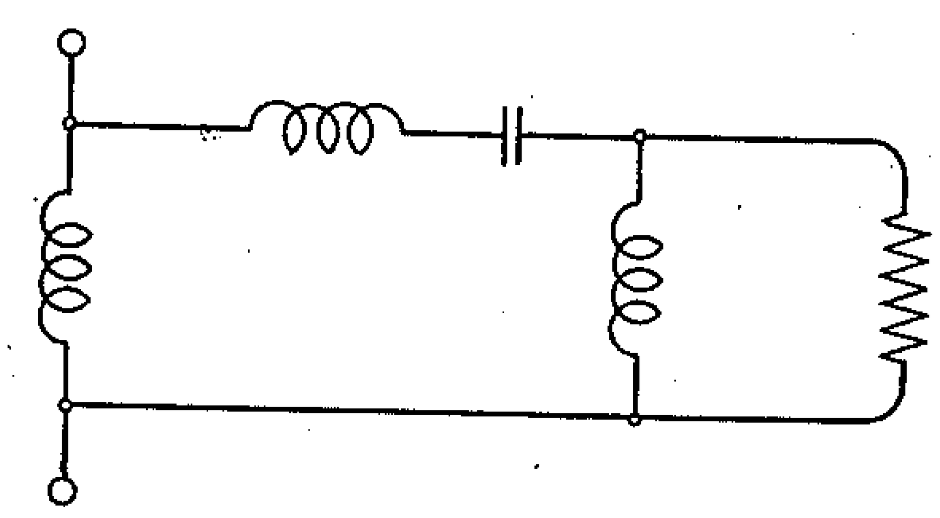

Fig. 3—Band Pass Type

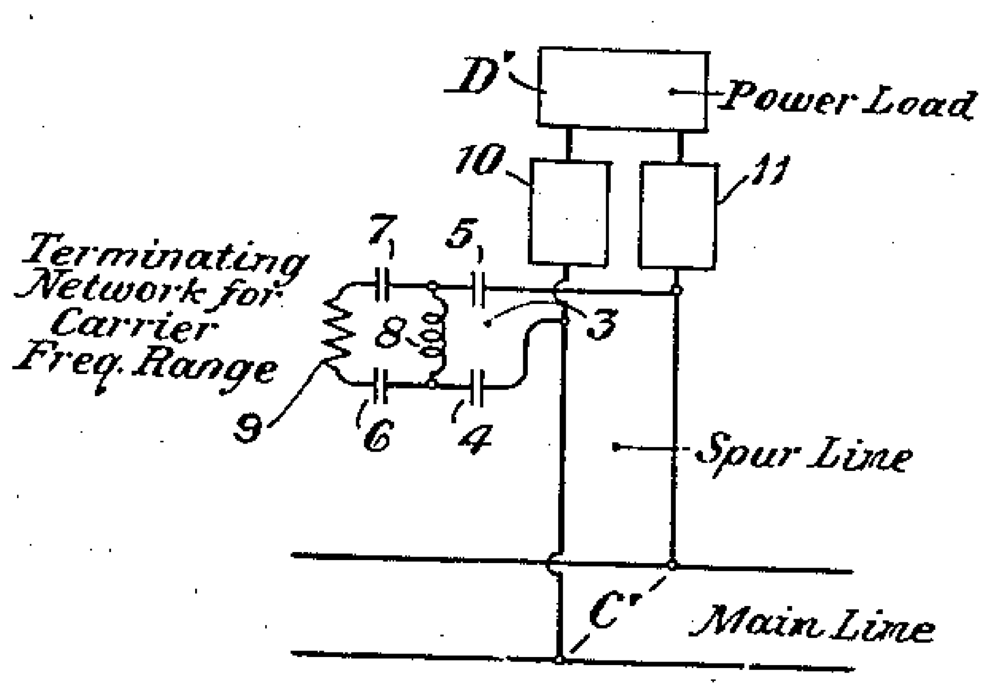

Fig. 4

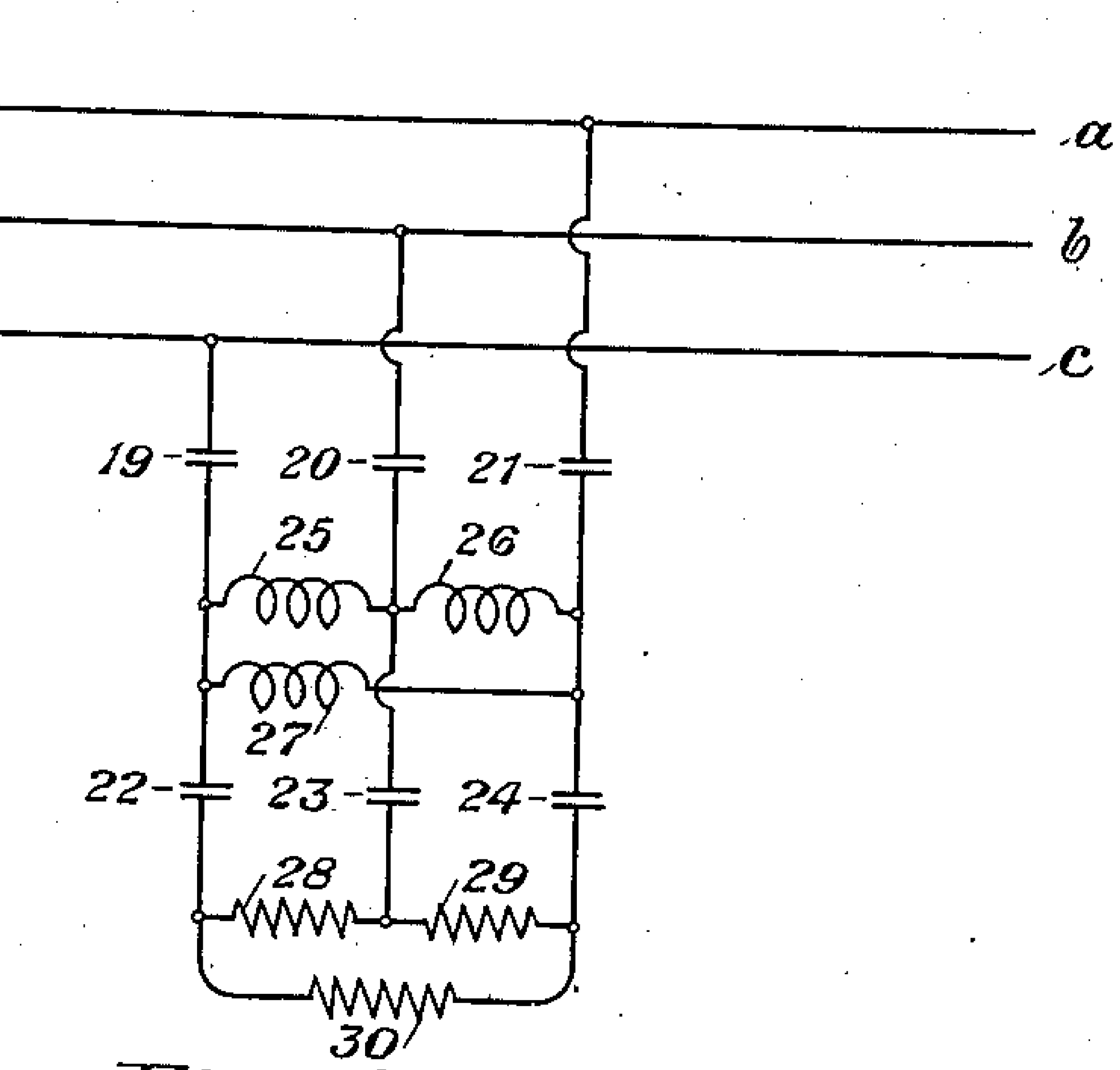

Fig. 4a

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POWER LINE CARRIER SYSTEM

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3 Claims. (Cl. 177—352)

This invention relates to the transmission of signals at carrier frequencies over power lines, and particularly to means for terminating the power line for the said carrier frequencies, to avoid reflection effects, and means to effectively isolate a section of power line from its branches at carrier frequencies.

Since a power line network comprises numerous interconnections, loops, and spur lines, it is less well adapted for carrier communication than the ordinary telephone circuit. The reflection effects resulting from the complex nature of the power line connections and also from the improper terminating impedances cause a carrier circuit, superimposed upon such a power line, to have characteristics that are extremely erratic in the range of frequencies employed. Furthermore, switching operations in the power system will have an important effect upon the carrier frequency characteristics.

For example, let it be assumed that a carrier system is superimposed upon a power transmission line that has a spur connection at a point along the main transmission line between the terminals of the carrier system. Unless such spur line is isolated from the main line in some way or is terminated in an impedance approximating its characteristic impedance, the carrier frequency impedance that is presented by the spur line will vary widely with frequency and at certain frequencies will resemble a short circuit, thus preventing satisfactory transmission between the carrier terminals. The employment of anti-resonant circuits or choke coils has been suggested as a remedy to prevent the disturbing effect produced by such detrimental paths. Such choke circuits have the disadvantage that their impedance varies with frequency and that they may require tuning to the working frequency.

This invention resides, in part, in a network that may be connected in series with each wire of a power line, which network, while offering low impedance to the power frequency current, at the same time presents a constant resistance over a band of frequencies in the carrier range, and requires no special tuning.

This invention furthermore resides in a network for reducing reflection effects in power lines, by terminating the power lines at carrier frequencies in their characteristic impedance.

Other objects of this invention will be apparent from the following description when read in connection with the attached drawing, of which Figure 1 shows schematically a transmission line adapted for the simultaneous transmission of power currents and carrier signaling currents embodying the series impedance network referred to hereinbefore; Figs. 2 and 3 show schematically other impedance networks that may be substituted for the impedance network shown in connection with the spur line of Fig. 1; Fig. 4 shows an arrangement of networks for terminating a power line; and Fig. 4*a* shows a terminating network for a three-phase line.

In Fig. 1 the line L represents the main transmission line of a power system extending from a generator station A to a station B at which there is a power load. Connected with the main line at C is a spur line that extends to another power load at station D. 1 and 2 represent carrier apparatus that may be of any well-known type for the transmission of carrier frequency signals over the line L. The carrier apparatus may be coupled to the power line by means of coupling condensers 3 and 4 and 3' and 4'. Since carrier apparatus is generally designed to match the impedance of the power line, a proper high-frequency termination is obtained wherever carrier apparatus is connected to the power line. As will later be shown, when a high-frequency termination is desired at a point where carrier apparatus is not connected to the power line, other expedients may be employed. Connected in series with the line conductors at station A are the networks 10 and 11, each of which may be similar to the network 12 which will be described hereinafter. The purpose of the networks 10 and 11 is to effectively increase the impedance of the power generator at carrier frequencies to prevent a dissipation of the carrier currents in that apparatus. Networks 10' and 11', similar to 10 and 11, are connected to the conductors of line 11 at station B. By inserting networks, such as 10 and 11, in series with the line conductors, the said line, when looking in the direction of the generator, is caused to have a high impedance at the carrier frequencies; and the use of properly designed carrier apparatus provides a smooth termination for the carrrier frequency currents employed. Similar networks at station B serve the same purpose as networks 10 and 11, so that the transmission of carrier signals by the apparatus 1 and 2 will be free from the difficulties inherent in carrier signaling over power lines in which the improvements set forth hereinbefore are not employed.

The effect upon carrier signaling of the impedance represented by the spur line connected with the main transmission line at C is prevented by the insertion of carrier frequency impedance networks in series with the conductors of the spur line. In the arrangement shown, it is assumed that the impedance networks can be placed at the junction of the spur line with the main line. To obtain a low impedance for the power frequencies it is necessary to use a shunt terminated filter whose shunt member includes an inductance connected directly across the two sides of the filter. Such construction makes it possible to connect in series with the line wire an inductance coil similar to a lightning arrester choke coil and comprising one or two layers as desired. In the drawing, the network 12 includes in a π type filter section consisting of inductances 13 and 15 and condenser 17, the inductance 13 being shunted by a resistance 14, and the inductance coil 15 being in series with the conductor of the spur line. Preferably the resistance 14 is made at least equal to the "iterative impedance" of the filter section. A spark gap 16 serves to protect the entire network. The network 12 uses a high pass filter structure. It may be designed to present in the power conductor a constant resistance of suitable value over the range of carrier frequencies employed. Another impedance network of the high pass type is shown in Fig. 2 and a band pass type in Fig. 3; either of the latter types may be substituted for the type represented by 12 of Fig. 1, if desired.

Fig. 4 shows a mode of treatment of the spur line when it is not desired to insert the series high-impedance networks in the spur line at the junction with the main line. In such a case, high-impedance networks 10 and 11, which may be similar to 12 of Fig. 1, or to Fig. 2 or Fig. 3, are inserted in series with the spur line conductors near the point of connection of the power load D′, thus rendering the power load a high impedance at carrier frequencies. In some cases the networks 10 and 11 of Fig. 4 might consist of an inductance shunted by a condenser, or if the impedance of the power apparatus at carrier frequencies is high, they might be omitted entirely. To effect a smooth termination of the spur line throughout the range of carrier frequencies employed, a network 3 may be bridged across the spur line conductors. That network comprises condensers 4, 5, 6 and 7, an inductance 8, and a resistance 9, which will be recognized as constituting a filter structure with terminating resistance. Preferably the resistance 9 is made substantially equal to the iterative impedance of the filter. Thus network 3 terminates the line L in an impedance that is equal to the characteristic impedance of the line throughout the range of carrier frequencies employed. Under the arrangement of Fig. 4 carrier currents flow in the spur line. This makes it possible to connect one or more sets of carrier apparatus, preferably of high impedance, to the spur circuit.

For the sake of simplicity the terminating network in Fig. 4 has been disclosed as applied to two wires of a power circuit. These wires may be part of a multi-phase line. Fig. 4*a* shows a network for terminating a three-phase line at high frequencies. In Fig. 4*a* the condensers 20, 21, 23, 24, the inductance 26, and resistance 29 are connected across the phase *ab*; condensers 19, 20, 22 and 23, the inductance 25, and resistance 28 are connected across the phase *bc*; and the condensers 19, 21, 22 and 24, inductance 27, and resistance 30 are connected across the phase *ac*. Other well-known types of high-pass or band-pass filter structures may be used in Fig. 4 and Fig. 4*a* if desired.

It is desirable to point out that the terminating networks shown in Figs. 4 and 4*a* may be advantageously employed in reducing the effect upon a power system of high frequency transient currents that result from short circuits, lightning, or other causes in or adjacent to such system. Such networks may be inserted in a power line at the terminals or other points where impedance irregularities are present. Since those networks effectively terminate the line in an impedance simulating the characteristic impedance of the line throughout the higher frequency range, they prevent the building up of high potentials by resonance action when the line is shocked by transients, lightning, etc. No loss is introduced by the networks to the power currents. While the invention has been disclosed as embodied in certain forms, it is to be understood that such showing is purely schematic and is not intended to limit the invention, as defined in the following claims.

What is claimed is:

1. In a system for the simultaneous transmission of low frequency currents and carrier frequency signaling currents, the combination with a power circuit having a load at the end thereof, of a network connected near the end of the said circuit for terminating it in the carrier frequency range, the said network presenting at high frequencies a constant impedance substantially equal to the characteristic impedance at those high frequencies of the power circuit to which it is connected and presenting at low frequencies a very high impedance, the said network being terminated in a resistance substantially equal to the iterative impedance of the network.

2. In combination, a three-phase power transmission line, and a network for terminating said line in substantially its iterative impedance in the carrier frequency range, said network comprising three symmetrical wave filter sections each terminated in a resistance substantially equal to the iterative impedance of the section in which the resistance is located.

3. In a system for the simultaneous transmission of low frequency currents and carrier frequency signaling currents, the combination with a power circuit having a load at the end thereof, of a terminating network, connected near the end of the said circuit for terminating it in the carrier frequency range, the said terminating network for carrier frequency currents being bridged across the circuit conveying the said currents and comprising condensers in series with an inductance bridged across the said circuit, and condensers in series with a resistance connected in shunt with the said inductance, the said resistance being substantially equal to the iterative impedance of the said network throughout the carrier frequency range.

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