A General-Purpose Communication Receiver for Military Aircraft

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ABSTRACT. A description is given of a general-purpose communication receiver which forms part of a transmitter-receiver installation for military aircraft. The receiver provides reception of cw, mcw and telephony in the range 140—20,000 kc. Provision is made for setting up a medium and a high reception frequency, with an immediate change-over from one to the other. Facilities are provided for aural direction finding and homing at frequencies between 140 and 2,000 kc.

1—Introduction

The receiver has been designed to operate as part of the installation described elsewhere in this issue (Honnor and Blom, 1946). It can be used independently if so desired, since, with the exception of power supplies, the unit is self-contained; the simple omission of the wiring which would normally interconnect with the transmitter provides complete independence.

2—Summary of Design

The principal mechanical and electrical features of the design are illustrated in the photograph of figure 1 and the block-schematic diagram of figure 2. The receiver front panel is divided into two parts; the left-hand portion carries the medium-frequency tuning unit and the right-hand portion the high-frequency unit. These two units may be removed from the main frame which contains the intermediate- and audio-frequency stages. The receiver framework is of spot-welded light-gauge steel angle. Anodised aluminium sheet is used for the chassis and front panels, the latter being dyed black. The two tuning controls are fitted with dual-ratio drive knobs and carry illuminated calibrated scales; all other controls are fitted with moulded knobs with large tails suitable for operation with gloved hands.

Frequency Coverage—The nominal range of 140 to 20,000 kc is covered in six bands:

Medium frequency	A	136 — 340 kc
	B	300 — 740 kc
	C	765 — 2,050 kc
High frequency	D	1,956 — 4,500 kc
	E	4,200 — 9,660 kc
	F	9,000 — 20,700 kc.

Overlap is provided between all bands except B and C; a gap from 740 to 765 kc is allowed for the intermediate frequency of 755kc.

Two independent r-f amplifiers and converters are provided; these are designated 'medium-frequency' and 'high-frequency,' abbreviated m-f and h-f for convenience. These units are each provided with a ganged tuning capacitor and band switch. Facilities are provided so that a frequency of reception may be set up in each of the m-f and h-f ranges; one or the other of these two frequencies may be selected at will by means of a simple m-f/h-f changeover switch on the panel.

On the m-f range additional input coils are provided which, in conjunction with loop and sense aerials, provide for aural direction finding.

Input Circuits—The aerial coils in the receiver are designed for optimum performance with a capacitive aerial on the m-f bands and for a resistive aerial on the h-f bands; the latter is naturally a compromise.

A socket is provided for the attachment of a loop aerial by means of a balanced shielded cable. For sense determination, the normal open aerial provides the vertical-aerial input.

Output Circuits—A single triode valve provides a maximum power output of 200 mW into a load of 2,000 ohms. In practice, several telephone headsets are connected in parallel, 2,000 ohms being considered to be a typical average load under such conditions.

Controls—The receiver is designed for telephony, telegraphy, and aural direction finding. The provision of facilities for many types of reception, in addition to rapid changeover from a medium to a high frequency, requires a large number of controls:

(1) Main tuning, m-f range
(2) Main tuning, h-f range
(3) Band switch, m-f range
(4) Band switch, h-f range
(5) M-f/h-f changeover switch
(6) Traffic/d-f/sense switch
(7) Reciprocal/bearing switch
(8) Sense resistance control
(9) M-f aerial trimmer
(10) C-w/m-c-w/d-f/r-t switch
(11) Beat-oscillator tuning
(12) Volume control
(13) Tone control, intertuning switch.

Power Supply—When used as part of the complete installation the receiver draws its high- and low-tension power requirements from the combined transmitter-receiver power unit. The receiver heater circuits are arranged in a series-parallel group suitable for either 12- or 24-volt operation. The circuit is floating and may be used with primary sources

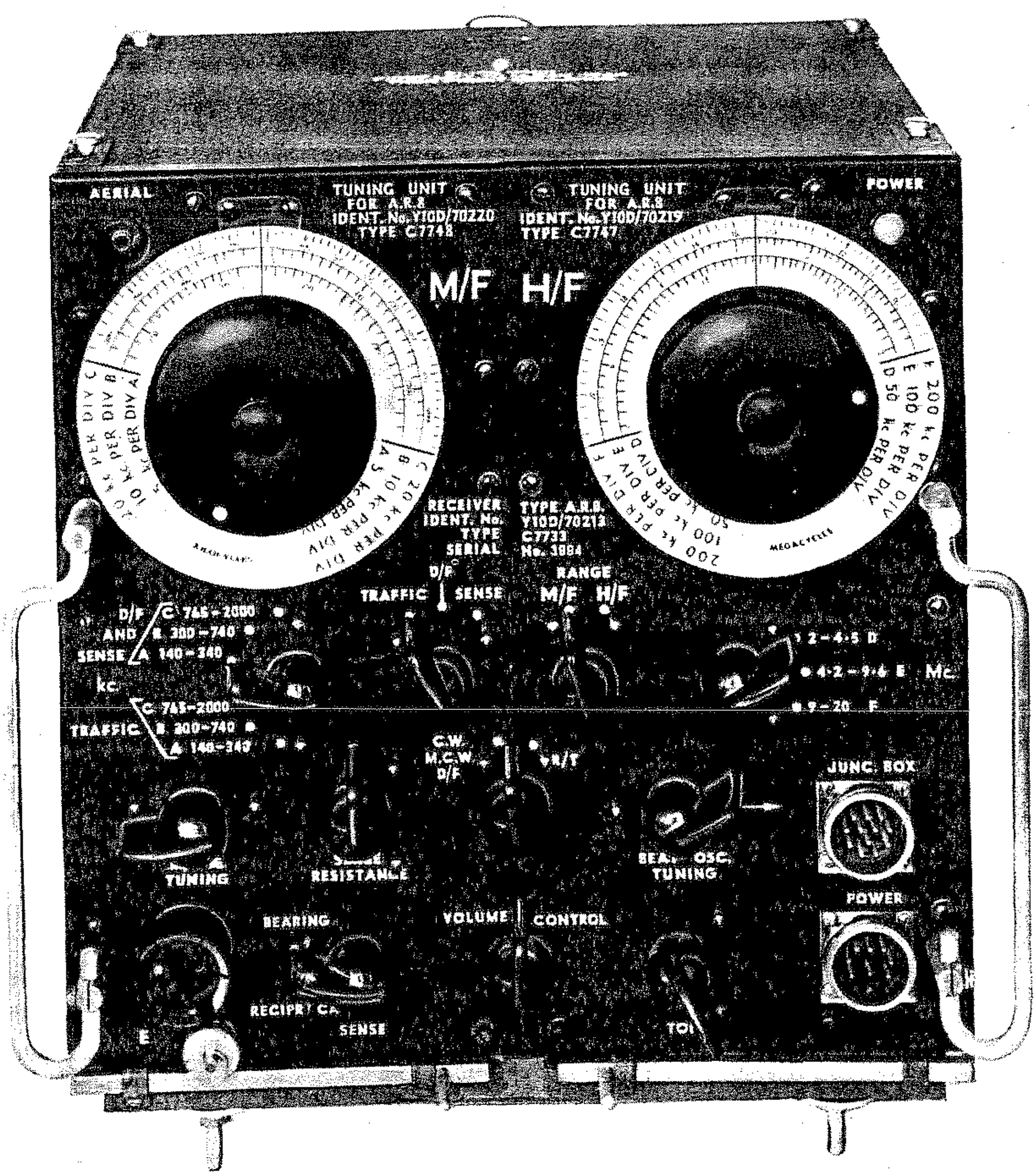

FIGURE 1—Photograph of the receiver.

in which either, or neither, pole of the battery is grounded. For independent operation a power unit capable of supplying 12 volts, d.c. or a.c., at 2.4 amperes and 250 volts d.c. at 100 mA is adequate.

Plugs and Sockets—The open-aerial lead plugs into a socket near the top left-hand corner of the panel and the loop aerial input is by means of a socket in the lower left corner. Sockets for connection to the junction box and power unit are provided at the right-hand lower corner.

3—Technical Description

A full detailed description of the circuit will not be attempted but, rather, the general form of the design will be discussed.

Aerial Input Circuits—On the m-f tuning unit, which covers the range from 136 to 2,050 kc in three switched bands, two separate sets of aerial coils are provided, (i) for use in normal reception with an open aerial, and (ii) for use with a loop aerial for direction finding. The band switch has six positions; in the first three positions normal input coils suitable for connection to an open aerial are selected; in the second three positions loop-input coils with balanced primaries are selected to cover the same frequency range; the same set of three r-f and oscillator coils serves in each instance.

Three types of loop aerial have been used with the equipment; all have the constants:

Self inductance	120 μH
Self resonance of loop and cable	1.3 Mc.

The only difference in the three loops is in their effective height and Q value. The gain from the voltage induced in the loop to the voltage at the grid of the r-f amplifier valve is approximately 100 times on band A, 37 on band B, and 12 on band C. The gain varies with frequency in such a way that the effective height of the loop, when referred to the grid of the r-f valve is almost independent of frequency; expressed in another way, the receiver has the same signal-to-noise ratio for the same field strength irrespective of the actual frequency in the range 136 to 2,050 kc.

For figure-of-eight bearings the loop is rotated and the two minima observed at points spaced 180 degrees apart. To determine sense, the loop is rotated 90 degrees from one of the minima and the traffic/d-f/sense switch placed in the sense position; this leaves the loop aerial connected but also connects the vertical aerial through a phasing resistor. The sense resistor is varied as the bearing/reciprocal switch is operated to reverse the loop connections; a particular setting of the sense resistor is found where there is a large difference in audio output for the two settings of the switch; the setting corresponding to the minimum output is noted and interpreted as either bearing or reciprocal, as the case may be, on a sense scale displaced 90° from the main scale.

On the high-frequency tuning unit the aerial coils are quite conventional; they are designed for an input impedance of approximately 400 ohms.

Radio-Frequency Amplifiers—Independent r-f amplifier valves are used in the m-f and h-f tuning units. A single stage of amplification is used in each case. This is quite adequate for all frequencies except band F in the h-f range where more amplification would be useful in reducing the noise from the converter; however, in the limited space available some sacrifice of performance was allowable at these frequencies.

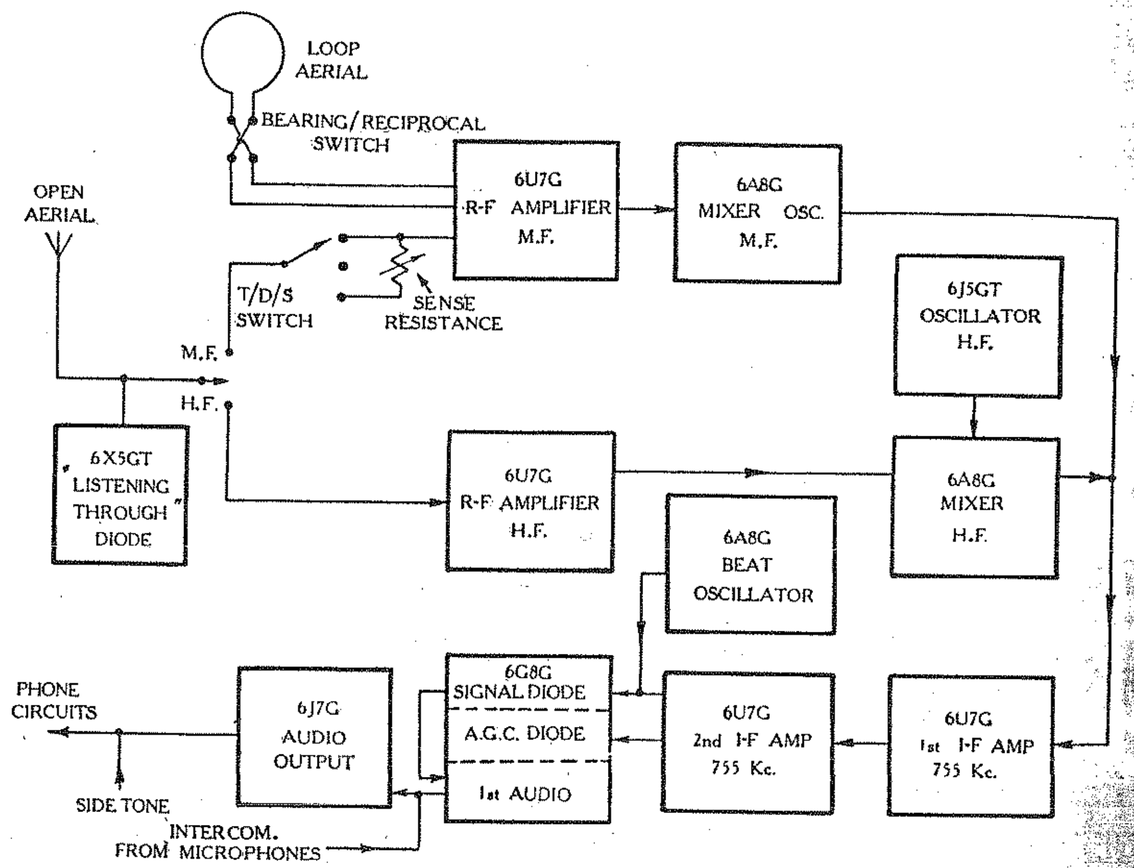

FIGURE 2—Block-schematic diagram of the receiver unit showing the circuit arrangement.

Mixer-Oscillator Stages—On the m-f tuning unit a 6A8G converter valve is used in a normal circuit; on the h-f tuning unit a 6A8G valve is used with a separate oscillator; in early models the oscillator was a 6V6G, but this was later replaced by a 6J5GT.

The two tuning units are quite independent up to the output anodes of the 6A8 valves; the two anodes are here joined in parallel to the input of the first intermediate-frequency transformer. One tuning unit is selected at a time by switching the high-tension supply to the desired unit; the heaters are left on all the time.

Intermediate-Frequency Amplifier—The intermediate-frequency amplifier consists of a two-stage amplifier using four double-tuned transformers; the mid-band frequency is 755 kc. A link line is used between the second and third transformers. This, while allowing the incorporation of the added selectivity of a fourth transformer, allows flexibility in the mechanical layout.

Automatic Gain Control—Delayed-diode A.G.C. is applied to the r-f amplifier in each tuning unit, to the m-f converter, and to both i-f amplifier valves. A portion of the A.G.C. is applied as audio A.G.C. to the first audio amplifier. This forward-acting control tends to counteract the normal rising characteristic of conventional automatic gain control (Watson, 1939).

The A.G.C. bias is switched away from the tuning unit not in use for the following reason. The valves in this unit, while disconnected from the high-tension supply lines, still have their cathodes heated, and, if the A.G.C. line were left connected, would draw diode current and disturb the bias to other valves.

Beat Oscillator—The triode section of a 6A8G valve is used as a Hartley oscillator; the anode of the amplifier portion is paralleled with the anode of the last i-f amplifier. In this way a degree of electron coupling exists and freedom from locking of the oscillator and intermediate frequencies is obtained. The frequency of the beat oscillator is varied above and below the intermediate frequency by means of a magnetite core which may be moved in and out of the oscillator coil by means of a micrometer screw controlled from a panel knob.

Signal Diode—The detector diode is incorporated in the 6G8G valve which functions as first audio amplifier and A.G.C. diode. The signal-diode load is in the form of a potentiometer-type volume control. The output from the slider is taken to the grid of the first a-f amplifier.

Audio Output—A 6J7G valve, connected as a triode, is used as the output valve. The load circuit is arranged to provide power to a 2,000-ohm load; a maximum power of 200 milliwatts is available.

Intercommunication Amplifier—The power valve of the receiver is arranged to act as an intercommunication amplifier. The input from the microphone circuits is injected by means of a step-up transformer having its secondary in series with the load resistance of the first a-f amplifier valve. By injection at this point, the audio level in the intercommunication system is unaffected by the setting of the receiver volume control.

Limiting Diode—Associated with the open-aerial terminal is a 6X5GT diode. This diode is provided with a small delay bias which prevents any diode current for normal signal inputs. In the event of excessive voltage being produced at the aerial terminal of the receiver during transmission, the diode conducts and protects the receiver input coils. As an additional safeguard, the transmitter send-receive relay opens the cathode circuits of the receiver valves normally controlled by the gain control, and puts the radio-frequency sections out of operation; the audio side-tone circuit is not affected.

4—Controls

A list of the controls fitted to the receiver has been given in section 2.

Main Tuning Controls—The three-gang capacitor in each radio-frequency unit is operated by a dual-ratio knob. The ratios are direct drive for quick searching, and a reduction of 50 : 1 for fine tuning. The two knobs are coaxial and are 3 inches in diameter. The scales are screen printed on translucent material with illumination from the rear; only the tuning unit in use is illuminated.

Band Switches—On the m-f tuning unit the band switch has three positions for normal traffic operation and three further positions, covering the same frequency bands, for direction-finding purposes. The switch simultaneously selects the correct aerial, radio-frequency, and oscillator coils as well as suitable trimming and padding capacitors. All unused coils are shorted to prevent interaction with the working set.

M-F/H-F Changeover Switch—This switch allows rapid changeover between a frequency in the m-f range and one in the h-f range; both frequencies must be initially tuned in the normal manner. The switch performs the fourfold function of switching (i) the aerial lead, (ii) the high-tension supply, (iii) the A.G.C. line, and (iv) the pilot lamp supply, to the desired unit.

Traffic/D-F/Sense Switch—This switch is in series with the aerial section of the m-f/h-f switch. When the m-f unit is in use the open aerial (i) may be switched directly through to the normal aerial coil, (ii) may be disconnected completely, and (iii) may be diverted through the sense resistance to the loop aerial input coils for cardioid reception in association with the loop aerial.

Reciprocal/Bearing Switch—The two leads from the loop aerial are brought to this switch which enables their connections to the primaries of the loop aerial input coils to be cross-connected. This is essential in resolving the sense ambiguity which exists with the simple d-f system employed in the receiver.

M-F Aerial Trimmer—On the m-f bands the first section of the three-gang capacitor is paralleled by a small knob-controlled trimming capacitor. This allows correct tuning of the aerial stage despite the type of aerial employed. On the bands A and B, when the loop coils are in use, one setting of this trimming capacitor is correct for all frequencies within the bands; on band C, however, the loop inductance and capacitance are such that a resonance occurs at 1.3 Mc which disturbs the tracking of the aerial circuit with the r-f and oscillator circuits; the trimmer must then be adjusted at each frequency.

C-W, M-C-W, D-F/R-T Switch—Despite its cumbersome title, this switch performs only simple functions. It is standard practice with the service using this equipment to receive mcw and to take bearings with the beat oscillator operating; for this reason mcw and d.f. are associated with cw. In the first position of the switch, (i) the A.G.C. circuit is disconnected, (ii) the audio control potentiometer is switched out of circuit, and (iii) the beat oscillator is switched on; control of receiver gain is now entirely by means of a cathode bias control on the r-f and i-f valves. In the alternative position of the switch, labelled 'R/T' (radio-telephony), (i) the A.G.C. circuit is allowed to function, (ii) the cathode bias gain control is switched out of circuit, and (iii) the beat oscillator is switched off; control of volume is now carried out by means of the diode-load potentiometer.

Beat-Oscillator Tuning—This control allows the beat note to be varied to suit reception conditions. In taking bearings on a voice-modulated transmission it is possible to choose a beat note that will tend to mask the normal modulation of the carrier.

Volume Control—Although this control is designated 'volume,' it is really a dual-purpose control; its actual function depends upon the setting of the c-w/r-t switch. Two rotary controls are ganged together and controlled from a single knob; one potentiometer serves as a cathode bias 'gain' control, and a second as a diode load 'volume' control. When the automatic gain control circuit is not operating, the cathode bias gain control is allowed to function; if the automatic system is operating, only the diode load volume control is effective in adjusting the audio output.

Tone Control, Intertuning Switch—The tone control is of the simple type and attenuates the higher audio frequencies. The control is fitted with a switch which operates in the first few degrees of rotation. This switch is normally open when the transmitter and receiver are being used for common frequency working. When the tone control shaft is fully anticlockwise the switch closes and earths the cathode bias line within the receiver; this allows operation of the receiver independently of the position of the keying relay.

5—Performance

The performance characteristics of the receiver may be summarised in terms of the test specification. The equipment was put through a series of tests before its acceptance by the Service for which it was designed. The following performance figures indicate the minimum allowable and are not necessarily the recorded figures.

Overall Gain—For standard output of 6 mW into a load of 2,000 ohms the input required shall be not more than 3 μV on any frequency below 9,000 kc and not more than 10 μV above 9,000 kc, all inputs to be modulated 30 per cent at 400 cycles.

Selectivity—The bandwidths at any frequency within the tuning range shall be not greater than those shown in the table :

Input (db)	20	40	60
Bandwidth (kc)	15	24	36.

Audio Characteristic—The audio output shall be within plus or minus 4 db from 100 to 3,000 cycles. The output at all frequencies above 5,000 cycles shall be at least 15 db down on the 1,000 cycle level.

Harmonic Distortion—When adjusted for 100 mW output, with an input level between 20 and 500,000 μV, the total harmonic distortion in the audio output shall not exceed 10 per cent for a modulation frequency of 400 cycles.

Automatic Gain Control—The output shall not vary by more than 6 db for an input range of 20 to 500,000 μV except above 9,000 kc where it shall not vary by more than 6 db for an input range of 30 to 500,000 μV. During this test the volume control shall be set to limit the output to a maximum of 100 mW.

Manual Gain Control—With the receiver tuned to a 1,000 kc signal the manual gain control must provide for a gain change of 90 db. During this test the bandwidth of the i-f amplifier shall remain within the limits given under 'Selectivity.'

Image Ratio—The image ratio shall be not less than 50 db at any input frequency below 9,000 kc and not less than 30 db above 9,000 kc. (In the actual test the image ratio was 60 db at 9,000 kc and 40 db at 20,000 kc.)

Noise—The equivalent-noise-sideband-input (ensi) shall be not more than 1.5 μV below 9,000 kc, and not more than 3 μV above 9,000 kc. (In the actual test the ensi was 1.25 μV at 9,000 kc and 1.6 μV at 20,000 kc.)

Effect of Ambient Temperature—The frequency shift of the first oscillators of the receiver shall not exceed 150 parts per million per degree Centigrade at any temperature within the range -40°C. to $+50$°C.

Effect of Atmospheric Pressure—The frequency shift of the first oscillators shall not exceed 500 parts per million for a pressure change from normal to one quarter of normal atmospheric pressure.

Effect of Humidity—The receiver shall be capable of complying with the overall gain test after not more than 10 minutes normal operation subsequent to having been immersed in an atmosphere of clear vapour at not less than 95 per cent relative humidity at a temperature of 50°C. for a period of 6 hours.

Direction-Finding Characteristics—The equipment shall be tested with a given loop of the following characteristics :

Inductance	116 μH
Self-capacitance	129 $\mu\mu$F
High-frequency resistance, at 1,000 kc	less than 20 ohms

(i) *Overall Gain with Loop*—The voltage input into the loop, for 6 mW output, shall not exceed 2F μV where F is the frequency in megacycles ; the input signal is to be modulated 30 per cent at 400 cycles.

(ii) *Noise with Loop*—The equivalent-noise-sideband input shall be not more than 0.6F μV where F is the frequency in megacycles.

Intercommunication Amplifier—An audio output of 200 mW shall be available with less than 10 per cent total harmonic distortion. The response characteristic of the intercommunication amplifier shall be within plus or minus 3 db between 400 and 3,000 cycles ; the input required for normal test output of 6 mW shall be less than 0.2 V at 400 cycles at the 50-ohm input terminals.

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