1. Summary

Gambrell Bros. & Co. Ltd. London   4x decade resistance box 1Ω to 9,999Ω.
S/N 722

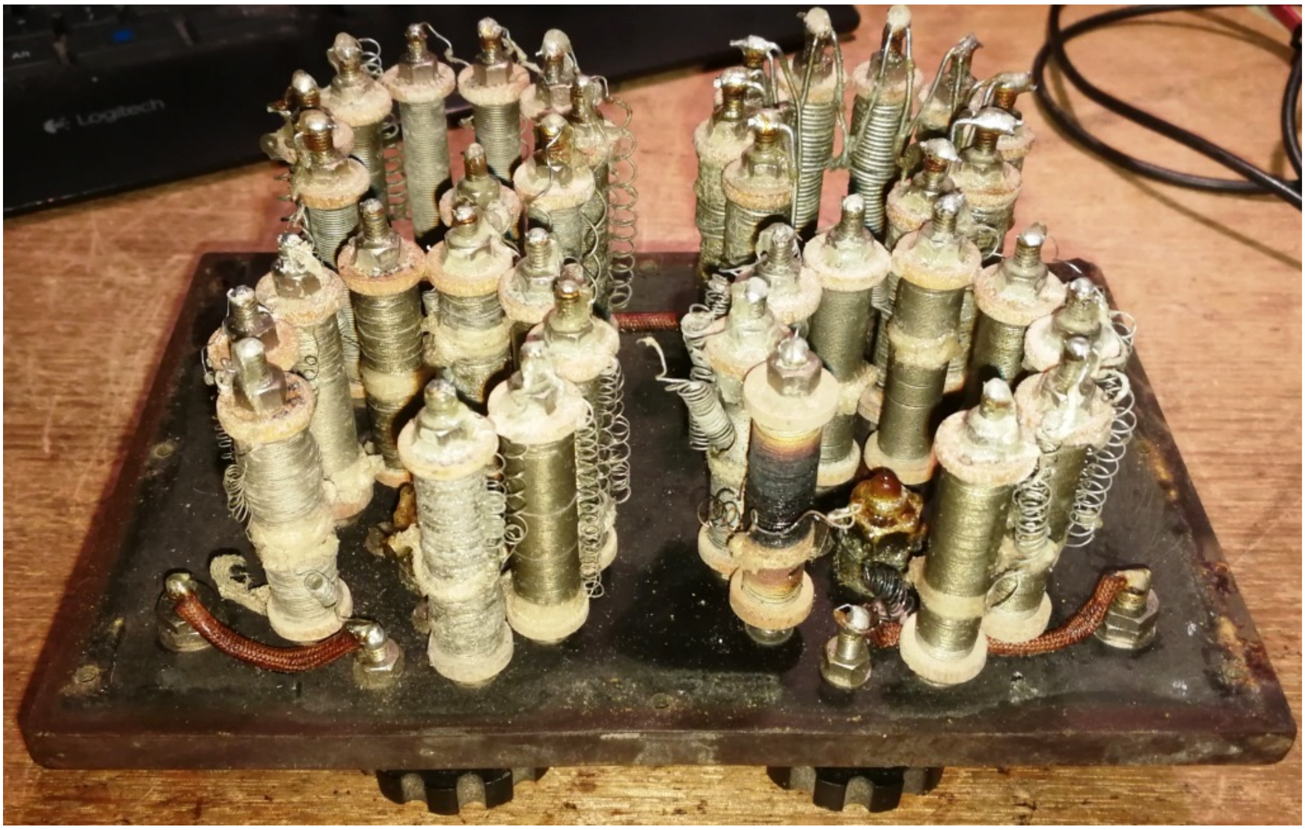
Bakelite front panel, with metal enclosure and 2 side mounting tabs. 4 rotary switches with three contacts between each rotary shaft and a commoning ring and each resistor element pad.

(Likely) Manganin coil resistor elements. Wooden coil bobbins on (likely) brass mounting bolts that act as rotary switch contact pads on one end, and termination solder joint for the element wires on the other threaded end. Coils wound as a bifilar winding.

Poor external and internal condition. Missing cracked corner of top bakelite. Burnt 100Ω element. Poor resistance contacts on rotary switches. 3 resistor elements with slightly high levels (70Ω; 5kΩ; 9kΩ; and 1 with slightly low level (5Ω). 1 element with broken connection wire (1kΩ).

Gambrell Bros exhibited in the late 1920's and early 1930's in England.
Wireless Engineer magazine 1931 extract:

GAMBRELL BROS. had a good display of laboratory and testing equipment. A useful type of condenser bridge was shown, for the rapid comparison of ganged variable condensers, giving the difference of capacity throughout the scale and also the deviation from normal at minimum and maximum settings. Standard fixed condensers, a new standard variable condenser and the McLachlan modulated C.W. wavemeter were also on view. Bridge components and accessories included a valve source of 300–2,000 c/s., balanced and screened bridge transformers and screened boxes of non-reactive resistances. Other laboratory items included a range of very sensitive galvanometers, standard Wheatstone bridges, potentiometers, etc.



2. Restoration

The mounting bolt lower nuts were checked for tightness. One was quite loose.

The burnt 100Ω element bobbin was removed and the retaining wire wrapping removed to allow the outer layer of burnt wire to be free, but with the next layer of wire held so as not to uncoil. The burnt layer wire had its carbonised insulation dusted off and the un-tensioned layer was then fixed in place with an archive pva glue. Insulation tape was wrapped around part of the length and the final turns were separated and moved down to be over the insulation tape until no turns were touching (slightly lowering the net resistance) or shorting (due to the bifilar wound configuration). The loose coil turns were fixed in place and the element re-mounted and reconnected.

The broken connection wire on one of the elements was repaired as an in-line soldered joint.

The 5k and 9k elements were similarly repaired – a weak/broken point was identified ~4Ω in to one end (underneath the cotton tie), and that point was extended out and re-terminated to about 3Ω of the broken extension (using a shoe-lace lug and solder). The loose ends were soldered to end posts for latter use if needed.

The resistor element mounting bolt contact pads had the top oxide layer sanded down using 1000 grit paper until rotary contact operation was generally ok (some caution is needed as contact resistance variation can occur). Each pad clearly shows three parallel wear tracks. Contact cleaner lubricant was then used.

5 resistor elements were trimmed using parallel resistors, and one element trimmed with a series resistor. 28 resistor elements were within 0.1% tolerance.

Pass through resistance was somewhat reduced by soldering in parallel cables.

Later, the series interconnections between decades were modified to allow use for Hamon divider configurations, as well as additional terminals added for Hamon divider connections.

3. Measurements

HP3497A with Kelvin connection resistance measurements at 1mA (consistent with initial Keithley 197 measurements, and cross-compared to 19.999k 0.01% Fluke 192583). Still to do a +10ºC rise test for TCR. All settings above 4Ω were withing 0.1% tolerance, and most were within 0.05%.

Phase shift at 60kHz is about 10deg inductive for 1Ω elements.
Phase shift at 60kHz is about 2-3deg inductive for 10 Ω elements.
Phase shift at 60kHz is about -0.5deg capacitive for 100 Ω elements.
Phase shift at 60kHz is about -16deg capacitive for 1k Ω elements, and needs about 560uH series to reduce to near 0 deg.
Impedance phase shift for 1Ω and 10Ω elements was reduced to less than 1deg at 90kHz using shunt capacitors soldered across tops.

Setting	Ohm	Note	Tolerance	Comment
	0.000			Shorted kelvin leads
0	0.007			minimised - variance due to knobs
1	1.001		0.10%	//100Ω//300nF
2	2.003		0.15%	//200nF
3	3.004		0.13%	//250nF
4	4.007		0.17%	//200nF
5	5.003		0.06%	//200nF
6	5.999		-0.02%	//200nF
7	6.994		-0.09%	//200nF
8	7.994		-0.08%	//100nF

9	8.999		-0.01%	//100nF
10	9.992		-0.08%	//(2k7+330)//10nF
20	20.000		0.00%	//4k7Ω//10nF
30	30.001		0.00%	//10nF
40	39.961		-0.10%	//10nF
50	49.968		-0.06%	//10nF
60	59.981		-0.03%	//10nF
70	69.993		-0.01%	//2k2Ω//10nF
80	79.998		0.00%	//10nF
90	90.018		0.02%	//6.8nF
100	99.997	overload repair	0.00%	+0.3Ω
200	200.04		0.02%	
300	300.11		0.04%	
400	400.18		0.05%	
500	500.21		0.04%	
600	600.22		0.04%	
700	700.25		0.04%	
800	800.29		0.04%	
900	900.32		0.04%	
1000	999.90	fixed broken wire	-0.010%	
2000	2000.0		0.00%	
3000	3001.1		0.037%	//2M2//330k
4000	4000.9		0.022%	
5000	4999.2	stress issue repair	-0.016%	
6000	5999.4		-0.010%	
7000	7000.3		0.004%	
8000	8000.4		0.005%	
9000	8999.0	stress issue repair	-0.011%	
10	9.995		-0.05%	HOLCO H8 Y 0.05% reference

4. Operation

Take care to confirm that rotary contact resistance is nominal for a particular setting. Forcing the knob down, or rocking it, can slightly modify the reading.

Try and limit current to:

<220mA for 1Ω decade to limit dissipation of each coil to 50mW.
Overload would be >1W or 1A (ie. 1V per 1Ω)
<70mA for 10Ω decade to limit dissipation of each coil to 50mW.
Overload would be >1W or 0.3A (ie. 3V per 10Ω)
<22mA for 100Ω decade to limit dissipation of each coil to 50mW.
Overload would be >1W or 0.1A (ie. 10V per 100Ω)
<7mA for 1000Ω decade to limit dissipation of each coil to 50mW.
Overload would be >1W or 30mA (ie. 30V per kΩ)

Take care in removing front panel from enclosure as metal cut-outs can easily catch a coil end (especially the 40R coil).

5. Conversion to Hamon 10:1 and 100:1 divider

Hamon's technique of building up an accurate resistor divider network, using smaller resistor steps is applied to this decade box using the method described by Conrad Hoffman in this link.

The box has a link between each decade, but the original links are from input terminal to 100 decade, 100 to 1 decades, 1 to 10 decades, 10 to 1k decades, and then to the other input terminal (as that provides the lowest series resistance path). These links were modified to sequentially connect through the decades.

All 100 and 1k decade resistors were within 0.05% of nominal value, indicating that resulting divider ratios may achieve nominal 0.005% tolerance. All decade resistors likely have similar tempco, and added 1Ω resistor (from LO to Hamon 0V terminals) is 1% of value so tempco difference is 1%. A wire-wound 0.87Ω part used with added 0.22//0.22//0.22 in series.

The top of the 100 decade, and the top of the 10 decade were accessed with new front panel 4mm terminals for divider connections.

100:1 divider comprises a 9.9kΩ:100Ω divider

- between HI to Hamon 10-100 to Hamon 0V terminals.
- 9.9kΩ upper arm of all 1kΩ steps in series (9k), plus all 100Ω steps in series (900Ω)
- 100Ω lower arm of all 10Ω steps in series (90Ω), plus all 1Ω steps in series (9Ω), plus 1Ω.

10:1 divider comprises a 900Ω:100Ω divider:

- between HI to Hamon 10-100 to Hamon 0V terminals.
- 900Ω upper arm of all 100Ω steps in series (900Ω)
- 100Ω lower arm of all 10Ω steps in series (90Ω), plus all 1Ω steps in series (9Ω), plus 1Ω.

100:1 divider changes to 10:1 divider by switching 1k decade switch from 9k to 0k. The 10:1 divider then includes any parasitic resistance due to the 1k decade series switch/link resistance unless the HI terminal connection is changed to the Hamon 100-1k terminal.

To apply the Hamon method, internal setup calibration links were added on the 100Ω and 1kΩ decades. These setup links were soldered together for 1:1 cal, then unsoldered and insulated with heatshrink.

The basis for using the decade resistance box is that the 1-3, 4-6, 7-9 steps in the 100Ω decade and the 1kΩ decade are acceptably matched. Measured results were: 100Ω and 1kΩ groups matched to within 0.01% but one 1kΩ group at 0.05%, so not too bad.

Cal the 10:1 divider as a 2:1 divider by adjustment of the added 1Ω value, with the 1k decade set to 0k, and using the original HI terminal and the added Hamon 10-100 terminal, and the added Hamon 0V terminal. 1, 10 and 100 decades set to 9, 90, 900, and the four 100 decade calibration links in shorting mode.

- 300//300//300=100Ω from HI to Hamon 10-100
- 90+9+1=100Ω from Hamon 10-100 to Hamon 0V.

Cal the 100:1 divider as a 2:1 divider by adjustment of the 1k end link to the original HI terminal, with the 1k decade set to 9k, and using the added top panel Hamon 100-1K terminal, and the added Hamon 0V terminal. 1, 10, 100 and 1k decades set to 9, 90, 900, 9k, and the two 1k decade calibration links in shorting mode. 0.6Ω added for balance.

- 3k//3k//3k=1kΩ from HI to Hamon 100-1K
- 900+90+9+1=1kΩ from Hamon 100-1K to Hamon 0V.

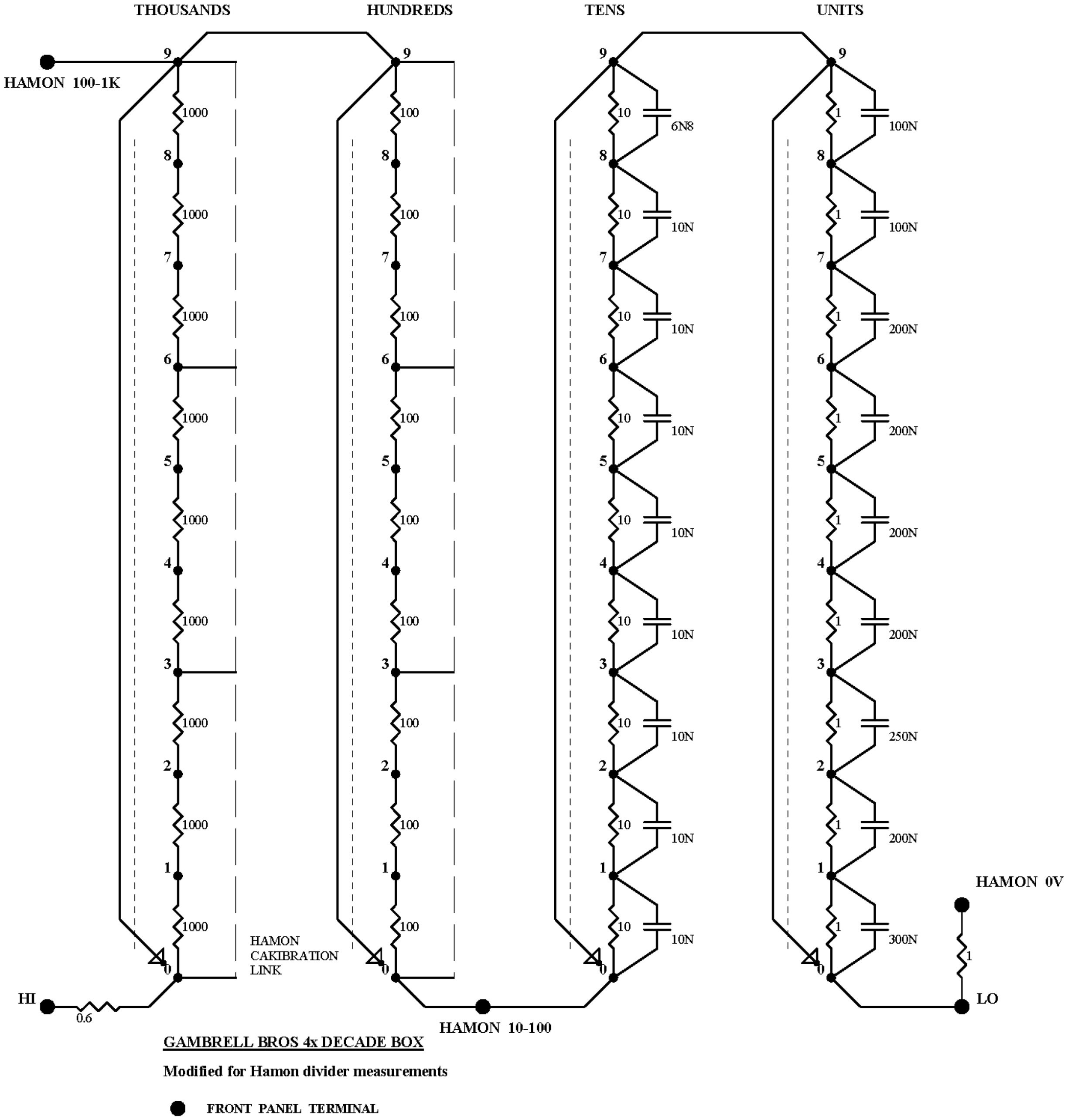
To do:

- Increase 5k and 9k to avoid need to add 0.6Ω to balance top 2:1 divider (ie. add ~1.2Ω to the 4-6k series group and to the 7-9k series group). On review the 7k section is ~1Ω high so //1M2, and add 1.8 to 5k and add 1.5 to 9k., and then recheck 2:1 divider.

Front panel terminal locations:

HI **LO**

HAMON 100-1K **HAMON 10-100**
HAMON 0V


THOUSANDS
HUNDREDS
TENS
UNITS
HAMON 100-1K
1000
100
10
1
6N8
10N
100N
200N
250N
300N
HAMON CAKIBRATION LINK
HI
0.6
HAMON 10-100
HAMON 0V
LO
GAMBRELL BROS 4x DECADE BOX
Modified for Hamon divider measurements
FRONT PANEL TERMINAL