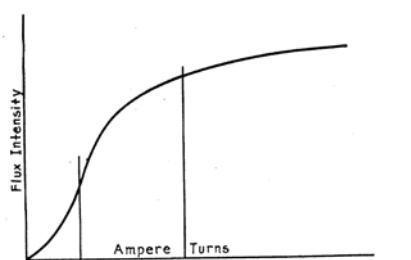Old power supply chokes typically don't come with a rating plate stating their inductance and DC current rating. Manufacturers like Rola were an exception, with labelling such as 14H at 60mA measured at 10V 100Hz, with 560Ω DC resistance for the choke type 14/60.

Within a valve amplifier, the high voltage (HT) DC supply with "choke input" filter applies a very large 100Hz AC voltage across the choke which is much greater than 10V, and contains substantial higher harmonic levels (one end of the choke cycles from 0V to the peak of the AC supply, and the other end of the choke is pinned to the HT DC voltage). Whereas a smoothing choke application, where the choke is connected between two capacitors, experiences a much lower AC voltage (likely to be less than 10V at 100Hz, with relatively low harmonic levels).
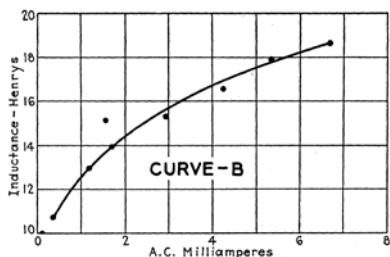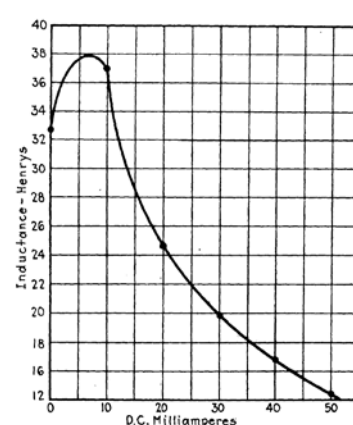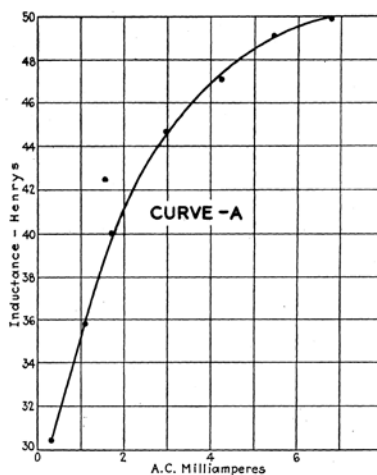

ROLA 14/60 choke

The inductance of an iron-cored choke can vary significantly with applied AC voltage (ie. ac current), and with the level of DC current passing through the choke. Results below, from [1], show those characteristics. So it is important to compare choke ratings only when similar operating conditions are being applied, and to be aware that the choke inductance value by itself is only half the story for power supply use.

Typical Magnetization Curve of Transformer Iron.

CURVE –B

Frequency 60 cycles. Curve A—with no direct current. Curve B—with 50 milliamperes of direct current flowing.
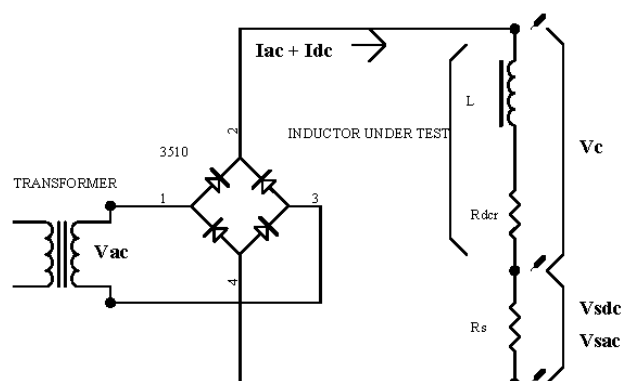

CURVE –A

Frequency 60 cycles
5 milliamperes of alternating current.

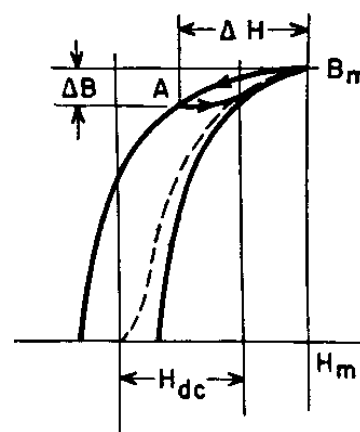Choke inductance measurements [1] showing variation with AC & DC current.

Simple measurement scheme

Choke inductance can be measured using a relatively simple method that passes DC plus AC current through the choke. The test circuit uses the choke to load the rectified output of a transformer power supply. A low value sense resistor Rs is used to make Idc and Iac current measurements. The choke is shown as an inductance L and a DC resistance Rdcr. The total DC resistance of the loading circuit is Rdcr + Rs.

By using different AC supply voltage levels, Vac (rms), the level of DC current can be varied. The AC waveform applied to the choke is a rectified sinewave with a DC level of 0.9*Vac, and so a DC current of about Idc = 0.9*Vac/(Rdcr + Rs) flows through the choke.

The AC voltage across the choke has a level of $Vc=1.27*Vac/(n^2-1)$, where n=2,4,6.. (ie. the even harmonics of the mains frequency) [2]. The harmonic levels drop off rapidly, so simply using just the n=2 (ie. 100Hz) harmonic frequency indicates that the applied AC voltage on the choke is approximately $Vc = 0.42*Vac$. The AC current can be approximated by $Iac = Vac/(1500*L)$, where L is in Henry - this approximation assumes f=100Hz, the choke reactance $(2.\pi.f.L)$ is much larger than Rdcr, and only 2nd harmonic current is significant. If we assume Rdcr>>Rs, then the previous equations can be rejigged to show that DC current is larger than the AC current by the ratio of about $Idc/Iac = 1350*L/Rdcr$, which is 38 times for the Rola choke example.

So this simple test method measures the small signal (incremental) inductance of the choke, where a relatively large DC current is passing in comparison to the AC current, and is similar to a smoothing choke

application. With respect to what the choke core experiences for this application, the graph on the right shows the choke core magnetised with the DC magnetising force Hdc, and a smaller AC magnetisation level ΔH is superimposed which causes a cyclical magnetisation loop to be followed between A and Bm.

This measurement scheme does not inherently measure inductance at a given frequency and excitation voltage, due to the measurement waveform including mains frequency harmonics and waveform distortion from the mains voltage/transformer/diode rectifier. The influence of shunt capacitance is neglected, as it is likely to be >> 100x the inductive impedance. In practise the scheme gives good inductance precision for power supply choke design purposes, as the test frequency and waveform are typical of that application, and especially given that choke inductance can vary so much with operating conditions.

The above measurement is made at twice the mains frequency, and a separate measurement is needed to determine the general self-resonant frequency (SRF) of the choke. The self-capacitance in the choke winding causes the rising choke impedance with frequency to level off at the SRF and then impedance falls for ripple frequencies higher than SRF. Vintage power chokes of 10-14H, and DC current ratings of 60-125mA are likely to have a self-resonant frequency of about 3-5kHz.

When the mains supply is turned off, or the supply disconnected in some manner, and twice during each mains cycle, the DC current in the test circuit commutates through the diode bridge, which acts as a free-wheeling diode (similar in action to the protection/suppression diode typically placed across a DC relay coil).

Test Method

Use a true-rms meter to measure Vsac across sense resistor Rs (to derive Iac=Vsac/Rs), and to measure Vc across the choke. Choke impedance Z is then Z= Vc / Iac. For most types of choke, the choke inductance can be approximated by the impedance, such that choke inductance $L = Z/(2.\pi.f)$, as $|Z| = \sqrt{((2.\pi.f.L)^2+Rdcr^2)}$ and $(2.\pi.f.L)^2$ >>Rdcr². A calculation spreadsheet is available [4], and accounts for the effect of Rdcr on the choke inductance calculation. Measure the DC Voltage Vsdc across sense resistor Rs. DC current through choke is then Idc=Vsdc/Rs.

Using a small value for Rs (ie. 10Ω) will require a meter with at least 1-10mV resolution, such as a cheap Aneng AN8009. Some DVM's like a Fluke 115 handheld won't do (although it has a 600mV AC-DC range, this can over-range due to the DC level exceeding 600mV even though the AC level being measured is low, and so 6VAC range is only available). Raising Rs value to say 100Ω will help with poorer resolution meters, and shouldn't really affect accuracy or be significant compared to Rdcr for many chokes. Check your meter performance specification as part of preparing to take measurements. Choke input filter parts are designed for higher applied AC voltage – this requires a larger Rs (eg. 470Ω with higher power rating >20W) to apply say 50Vrms and pass over 100mAdc, otherwise the measured inductance will be lower than rated.

A tapped transformer can be used to change the Vac level, to apply different DC current levels, and allow inductance droop to be plotted. My first test setup used 12V, 20V, 32V and 52VAC secondaries, and two multi-tapped 0-24VAC transformers would be quite practical, but I now use the heater supply of a vintage valve tester with 0.6 to 117V in 19 steps. The supply needs sufficient current rating to suit the DC current being applied to the choke (eg. a 1A secondary rating would suit many chokes used in valve amps). Any diode bridge with 6A or more rating should be fine.

If needed, the value of the sense resistor Rs can be increased in order to lower the DC current level relative to the applied inductor AC voltage level, as $Idc/Vac \sim 0.9/(Rdcr + Rs)$. If needed, the rectified waveform could be RC filtered before the choke is connected, so as to attenuate higher ripple frequencies.
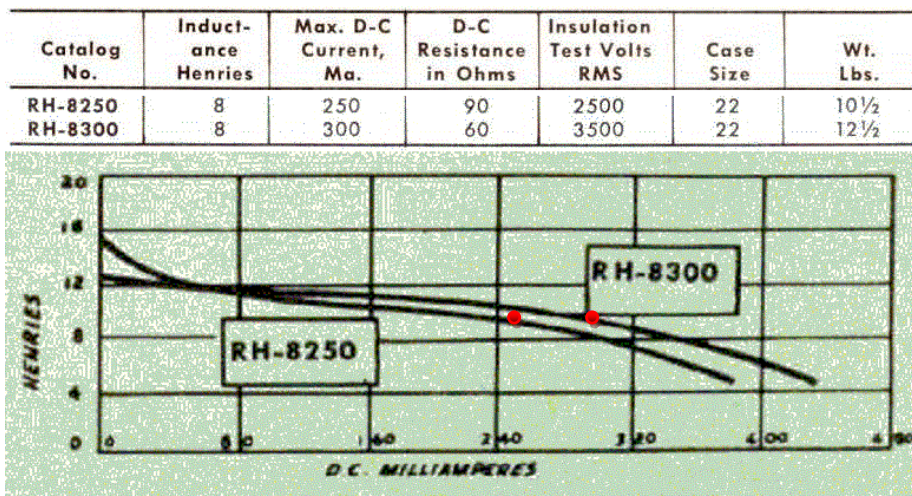
Choke Performance

The example 14H Rola choke was measured using the described test method. The nominal transformer voltage Vac used for four measurement points is given in the following table. Rdcr was measured at 535Ω, and SRF at 6kHz (C≈50pF).

Vac	12 V	20 V	32 V	52 V
Idc	17 mA	30 mA	50 mA	82 mA
Iac	0.6 mA	0.9 mA	1.4 mA	2.7 mA
Vc	5.85 V	9.17 V	14.1 V	23.1 V
L	15.5 H	16.2 H	16.1 H	13.6 H

The test results agree well with the 14H at 60mA DC part rating, noting that Vc is greater than the spec level of 10Vrms for Idc=50mA, and hence measured L would be a bit lower at the Vc spec level. As Vc increases when larger Vac is applied, the measured inductance can increase even though Idc has increased.

The measured drop in inductance with DC current, along with the DC resistance of the choke, can provide a good estimate of the manufacturer's DC current rating for the part. The following product curves of inductance are from Chicago Transformer chokes at 10V 60 Hz excitation [3]. The power loss at rated max DC current is about 5.5W for each choke (note that these are large chokes). The much smaller example Rola choke has a max power loss of only 2W at rated 60mA DC. Hubelhank presented a consistent test result using a similar measurement technique, circa 1956 [5].

Catalog No.	Induct-ance Henries	Max. D-C Current, Ma.	D-C Resistance in Ohms	Insulation Test Volts RMS	Case Size	Wt. Lbs.
RH-8250	8	250	90	2500	22	10½
RH-8300	8	300	60	3500	22	12½

Uncommon iron-cored chokes for valve amp power supplies

The typical flouro ballast choke is compact, double insulated, uniformly gapped by two rows of C laminations butting to a square lamination central core, and appears fine to sit at 600VDC or more and be used for a choke-input filter. A 240VAC 18/20W choke is very common, measures about 1.5-2H, and would be suitable for up to 300mA DC (power dissipation up to 5W). A 240VAC 9/13W choke measures 3H at 100mAdc and 2.7H at 200mAdc, with Rdc=140Ω and SRF=5kHz, and would be fine for up to about 200mAdc (power dissipation about 5W).

An ATCO EC18/20 240VAC 50Hz choke gave measurement levels of Rdcr=54Ω, SRF=10kHz (150pF shunt):

Vac	12 V	20 V	32 V	52 V
Idc	147 mA	260 mA	420 mA	517 mA
L	1.88 H	1.69 H	1.45 H	1.26 H

Some Wurlitzer organs included a large number of note inductors (iron-cored with variable gap setting), of which a few provide up to 4H inductance and are suitable for up to 30mA DC (eg. suitable for screen and preamp filtering).

A Wurlitzer 500407 inductor from a 4100B organ (set with minimum gap) gave measurement levels of Rdcr=266Ω:

Vac	12 V	20 V	32 V
Idc	30 mA	50 mA	90 mA
L	4.1 H	2.3 H	0.9 H

Ripple trap assessment

The test circuit can be used to measure the changing AC current harmonics passing through a choke with a parallel capacitor (and series dampening resistance), sometimes referred to as a ripple trap (a technique used in power supplies to enhance the attenuation of the dominant 2f ripple component – see [6]). Displaying the ripple current (voltage across sense resistor) on a spectrum analyser shows the increasing attenuation of the 2f harmonic as the parallel capacitance value is increased towards LC resonance, but also shows a corresponding increase in the magnitude of higher ripple frequencies being passed through. The filter capacitor following the choke bypasses the ripple currents, with the net result of a lower rms ripple voltage across that capacitor. Given the likelihood of choke inductance being higher than its rated value when DC current is below the rated level, and given the increase in higher order harmonics with increasing capacitance, it is recommended that a lower capacitor value is used than what would be expected to tune the rated inductance at 2f – perhaps at least 20% lower. The dampening resistance R_C in series with the capacitor is typically twice the choke R_L, although the Q can be calculated as $\sqrt{(LC)} / (R_C+R_L)$.
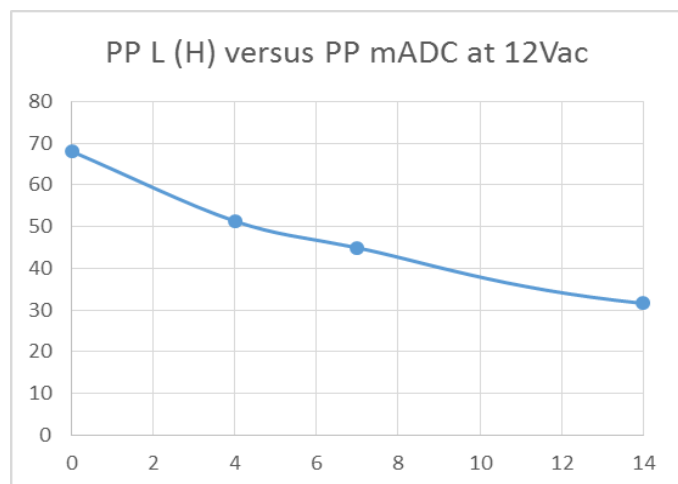
Output Transformer Primary Inductance

OT primary inductance influences the low frequency roll off of an amplifier, and forms an RL high pass filter with the output stage valve's internal resistance Ra. The choke test circuit can be used to measure primary winding inductance at a given DC current level for an SE output transformer, and to indicate the change in inductance at zero, idle and twice idle current. In a PP amp, apart from the OT design itself, a DC imbalance from valve mismatch and/or bias mismatch can significantly lower primary inductance L.

Plate-Plate winding inductance of a PP output transformer can be measured with an unbalanced DC current level. When testing the P-P inductance of an output transformer, the test circuit applies DC current in both half-primary windings, but as the DC current is not being cancelled by the CT feed location, then the DC current level equates to an imbalance level twice as large. It is likely that the test circuit Rs will need to be made fairly large in order to suppress Idc down to a level typical of an unbalanced output stage.

The plot on the right includes a 68H P-P inductance value from a simple transformer fed test circuit (ie. no DC bias), as well as 3 test values taken in the choke test circuit when using high values of Rs (up to 6k8Ω).

The transformer is a Red Line AF5/20 with 5kΩ PP, and 15W hi-fi ratings. If idle bias current was 50mA nominal, then the 4mA test value would be equivalent to an 8mA imbalance between valves (eg. 46mA + 54mA). In that situation, the primary inductance would be down about 25%, compared to a balanced output stage.

Similarly, a common-mode choke can be measured for differential inductance with an unbalanced DC current level.

References

[1] 'The Measurement of Choke Coil Inductance', C.A.Wright & F.T.Bowditch, 1927.

[2] Fourier Analysis, Lucas Illing, 2008

[3] Chicago, Transformers and filter reactors, CTC-58.

[4] http://www.dalmura.com.au/projects/OT%20calcs.xls

[5] 'Use those "junk-box" chokes' by S.H. Hubelhank, 1956. Reprinted in Sound Practices, Fall 1994.

[6] "Smoothing Circuits: (2) Inductance-capacitance", 'Cathode Ray', WW Nov, 1949