Mechanical Amplifiers.

A celebration of an almost forgotten technology.

Mechanical Amplifiers in Cable Broadcasting. (External link)

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The year is 1900. Cost and attenuation are seriously limiting the growth of long-distance telephony, particularly in the USA.This needs a little explanation. You can always reduce the attenuation per mile of a telephone line by using thicker copper to reduce the resistance. Copper is however expensive, and there are limits to what is practical in this direction.

Digression on Line Losses in Telephony.

To us, the obvious solution is to apply some amplification to boost signal strength; but it is long before the invention of the transistor, and even the valve (the vacuum tube to US readers) is still years away.

Mere lack of resource has never blocked human ingenuity, and there was a handy fact to exploit. Carbon microphones, as used universally in telephones until the mid-1960's, are not mere transducers that turn sound power into electrical power, but actually give a power gain of about a hundred times. The microphone is a variable resistance, made up of fine carbon granules, that controls the flow of current from a DC power supply; it does not merely convert acoustic energy into electricity. This power-amplification technology was the essential basis of the first practical telephone systems.

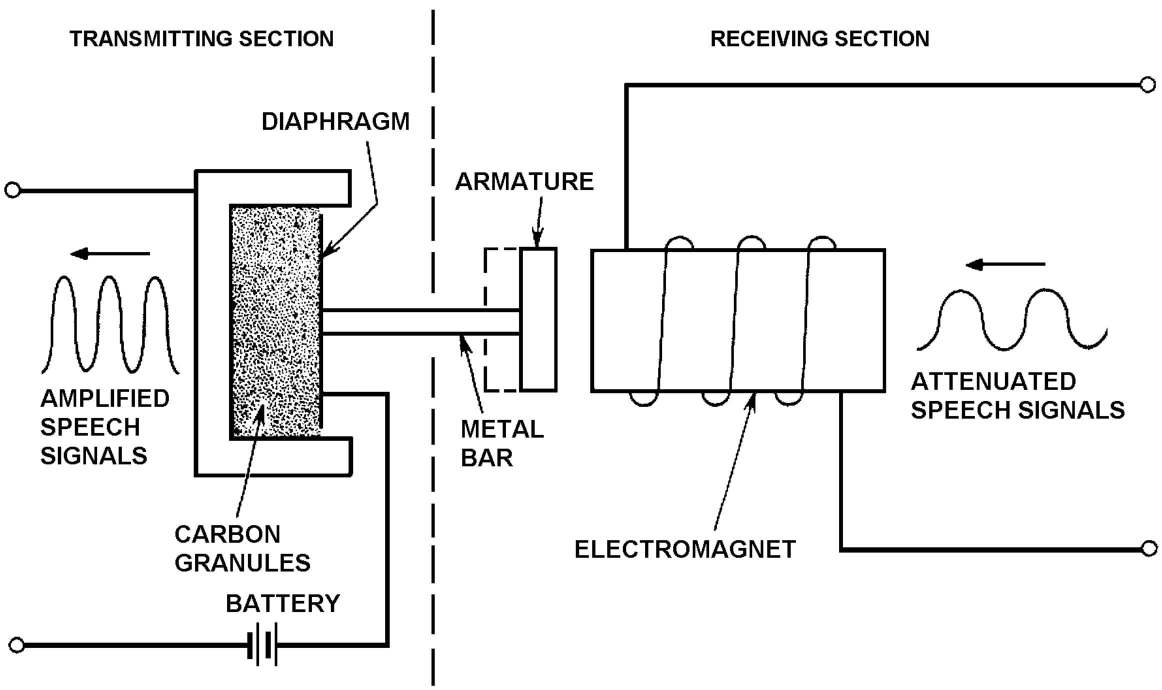
From this, it is but a short step to the concept of coupling a telephone receiver to a carbon microphone to make an amplifier, and several people took it. Within a few years of the original Bell invention, patents on this notion had been taken out by Edison, Houston, Lodge and Hughes, not to mention others less famous. By 1896, 27 patents for a mechanical-electrical amplifier- though it was then called a "repeater"- had been taken out.

Carbon microphones are not high-fidelity devices. Anyone who has used an old-fashioned telephone will recall that they would intermittently go low-gain or noisy, due to the granules packing, and a sharp rap of the handset against the wall was required to restore normal service. It was clear that the mechanical amplifier was far from perfect, but it was the only amplification option that looked practical.

In 1903 H E Shreeve was given the job of designing a practical mechanical amplifier. He discarded the microphone and earpiece diaphragms, and replaced them with a

simple plunger that was driven by the receiving coil and pressed against the carbon granules of the transmitter.

One of the requirements of a practical amplifier was stability over time, which meant a solution to the problem of granule packing was needed. Shreeve found that this was due to thermal expansion caused by the heat liberated in the carbon chamber. This reduced the resistance, causing an increase in DC current but reduced audio output. This problem was controlled by designing the transmitter so that expansion of its parts did not increase the pressure on the carbon; and this led to the 1904 model below.



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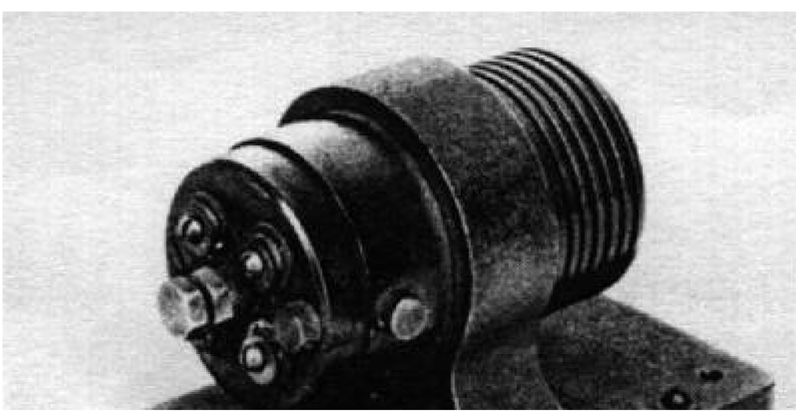
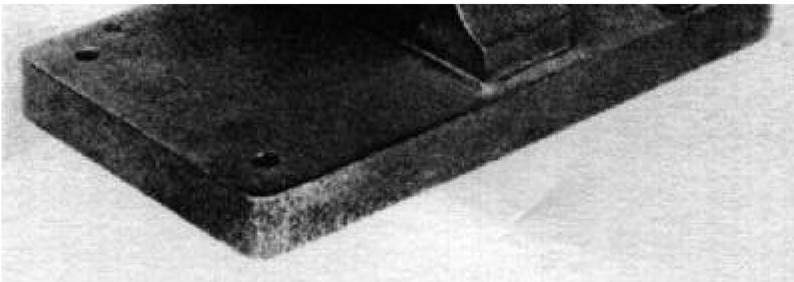
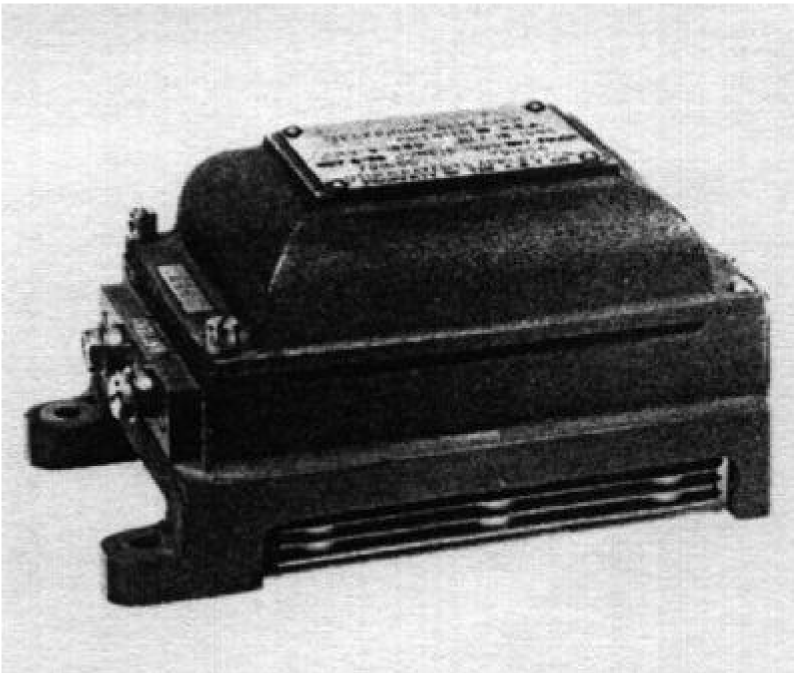


The first Shreeve mechanical amplifier. Date approx 1904.

This model saw commercial use on a New York - Chicago circuit between August 1904 and February 1905.



Note the cooling fins for the carbon microphone section at the right.



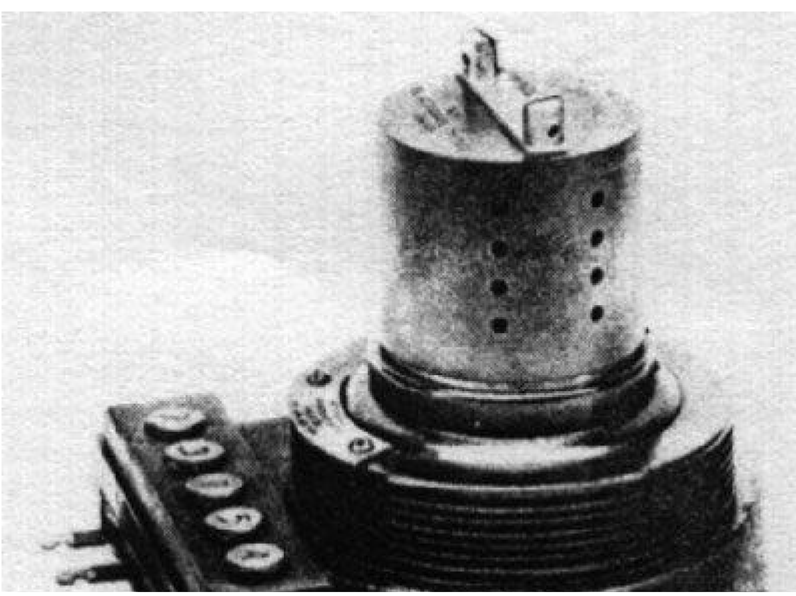
The early Shreeve 1a amplifier.

The 1a worked reasonably well, and saw some use. However it was not possible to run more than two in series without the audio degrading too much, and three were needed for transcontinental USA operation.

The degradation was usually referred to as "distortion" but this seems to have meant a poor frequency response rather than non-linearity.

The cooling fins appear to be at the bottom.

The Shreeve 1a included a simple form of feedback control to reduce packing. The transmitter current heated a zinc strip which withdrew the rear electrode to act against increases in this current. This was twenty years before the formal invention of negative feedback, though the principle had been in use for many years in the form of Watt governors.

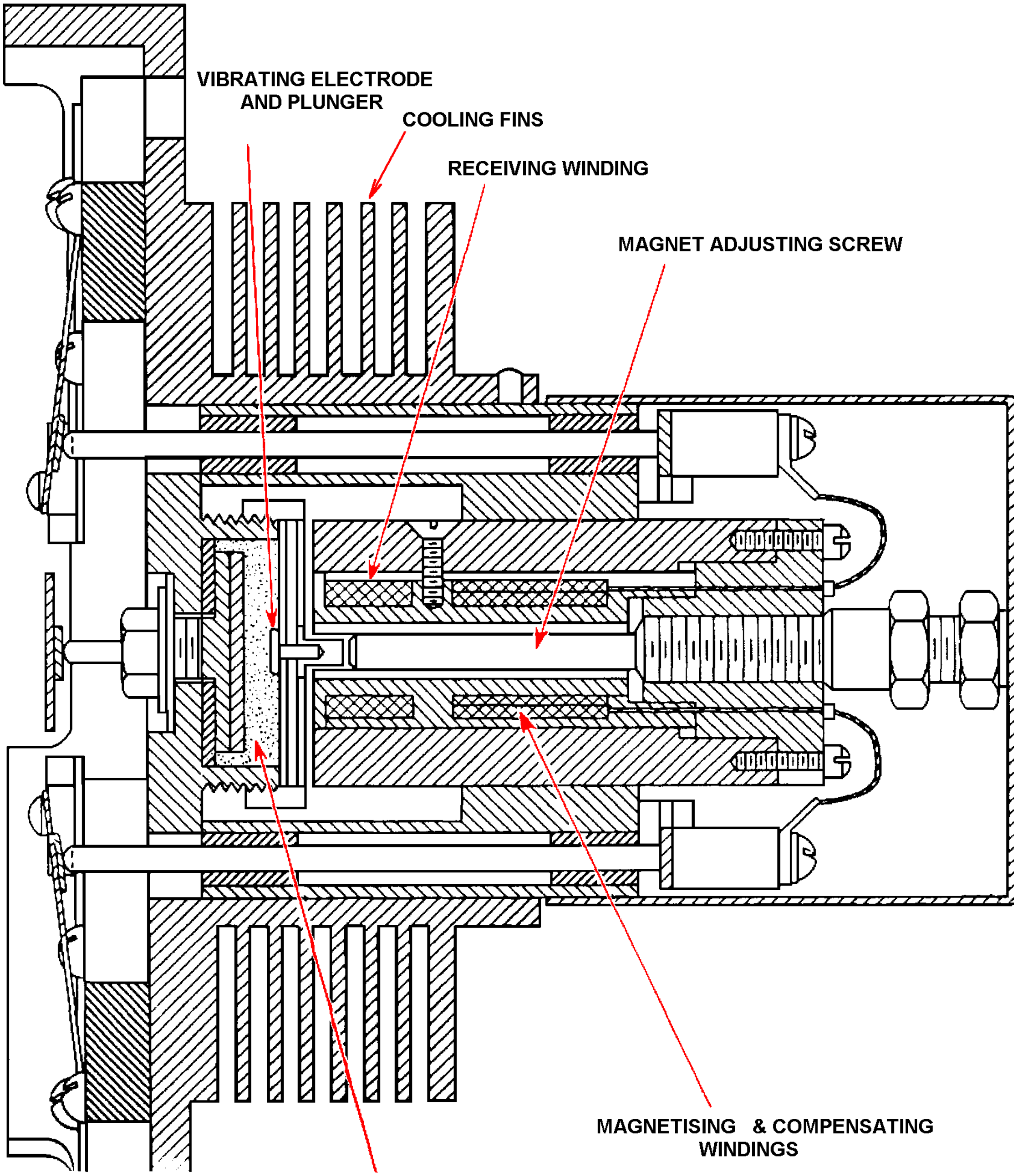


A cartridge type amplifier, Model 3A. This became the standard type of amplifier until valves were introduced.

It was developed in 1912 and standardised in 1914. Parts likely to need replacement were packaged in an easily replaceable cartridge.

Performance was still limited by poor frequency response and a rapid falloff of gain at low levels; three in series was the limit.

Here fixed annular cooling fins surround the base of the cartridge. The purpose of the two round things on top is unknown.



The internal construction of the Model 3A.
The basic principle appears to be minimising the mass of the vibrating electrode, push fundamental resonance to as a high a frequency as possible. The function of the "com winding" is obscure; since there appear to be only 5 terminals, presumably the magne compensating windings have a common terminal.

There were other attempts to achieve amplification before the valve. In 1912 Dr H D Arnold had developed an amplifier in which beams of mercury ions were deflected by electromagnetic coils. It worked, and had a good frequency response, but had such severe starting and maintenance difficulties it was unsuitable for unattended operation. It was used experimentally on the transcontinental circuit, but never commercially.

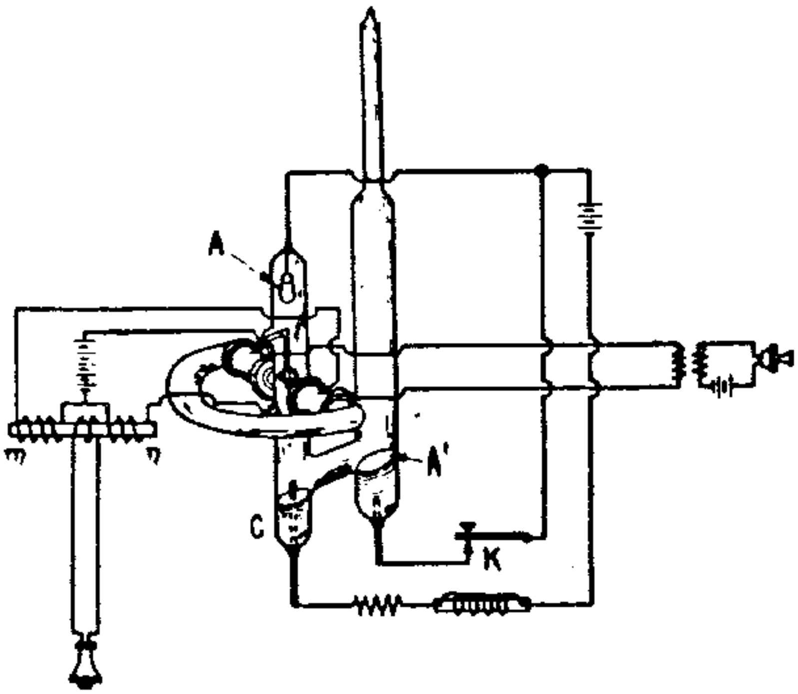
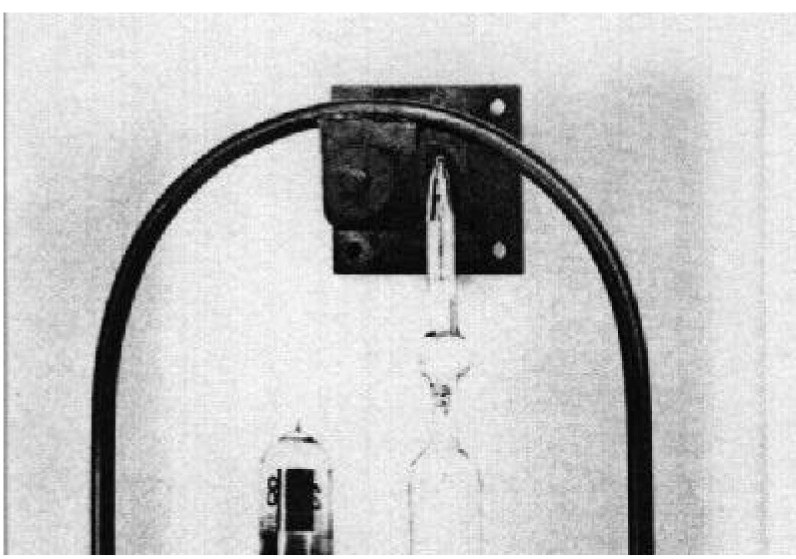


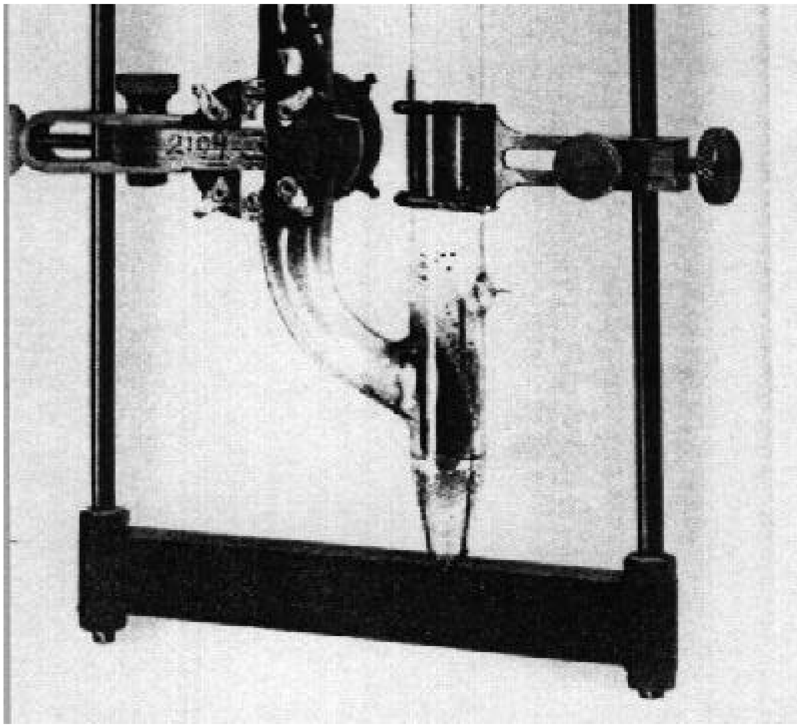
Fig. 4-39. Drawing from patent of Arnold's mercury-arc amplifier.

The Arnold mercury-arc amplifier.

The details of operation are not too clear, but it appears the input is the carbon mic on the right, while the output is taken from the balanced to unbalanced transformer marked "m n", to the earphone at lower left. I suspect K is the starting key.



The Arnold mercury-arc



amplifier.

It looks somewhat different to the patent drawing; there is only one reservoir of Hg at the bottom.

Another possibility investigated was the von Lieben cathode-ray amplifier; this proved to be no more promising.
The 1905 von Lieben amplifier was a cathode-ray tube, its electron beam being steered towards or away from a target electrode by magnetic coils. A patent was granted in 1906, and based on this, the two German companies AEG and Siemens founded Telefunken AG to build electron tubes.

Dieckman & Clag (of Strasbourg) filed for a patent on a similar device in 1906. This used electrostatic rather than magnetic deflection of the beam.

Meanwhile, the vacuum tube was being created. Fleming produced a thermionic diode in 1904, and in 1907 a US Patent was granted to Lee de Forest for adding a control grid, to make the first triode. By October 1912 de Forest was demonstrating a valve audio amplifier to Bell officials. By October 1913 improved valves had been built and tested on commercial circuits between New York and Baltimore, and at the end of 1914 valve amplifiers were in use on the transcontinental circuit. It was clear that valves were the way ahead, and the mechanical amplifiers built for this service were placed on standby.

I would be very glad to hear from anyone who has any more information on this remarkable piece of technology.

Acknowledgement: This article draws heavily on the book "Engineering and Science in the Bell System". All speculation is mine.

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