Once upon-a-time there were . . .

Water-driven microphones!

Following on from our story on gas-powered microphones in the December 1980 issue, the saga continues with the development of water driven microphones. Does your microphone leak?

by DR CLIVE COOGAN*

About 70 years ago veritable miniature torrents of water flowed over micro-cascades or mini-waterfalls in the pursuit of the perfect microphone to modulate the new arc and spark radio-telephony. The water-powered microphone stood at the top of the pecking order for some years before finally disappearing over the edge of the waterfall itself.

The great texts of the time, like the "Electricity in the Service of Man" by Mullineux-Walmsley of 1911, or "Telephony Without Wires" by Phillip Coursey of 1919, and the state-of-the-art journals and magazines like "Nature" and "The Electrician" all treated water microphones with the utmost respect. In fact, for a few glorious years, from 1908 to 1914, apparatus using liquid microphones held the world long-distance records for successful telephony broadcasting!

One of the telling points in favour of the water-microphones at that time was that they were capable of dealing with up to 500W of power! In the early spark and arc transmitters, microphones were placed in parallel with the arc and had to deal with large powers if they were to effect an appreciable modulation of the amplitude of the outgoing radio-frequency waves. In fact, all maritime wireless operators were then called "Sparks", a name which has persisted.

The first of the liquid, or as they were sometimes called, "hydraulic", microphones came "on stream", as one might say, as early as 1879, three years after the introduction of Alexander Graham Bell's telephones, and a good deal prior to the introduction of radio-telephony. Bell's "mouthpiece" of 1876 (the term "microphone" had to await the invention of the carbon microphones by Hughes two years later) was an electromagnetic device identical with the earpiece. The earpiece was marvellously successful and sensitive, but the "mouthpiece" was not able to generate nearly as much audio modulation as might have been desired for long-distance phone calls.

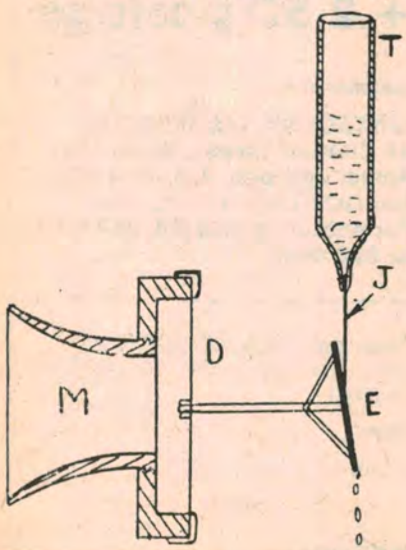

Fig. 1: Jervis-Smith's simple form of variable resistance microphone.

In 1879, Jervis-Smith produced the liquid microphone of Fig. 1. A liquid jet, J, came out of the tube T and struck the inclined plate E, which was attached to the diaphragm D. As the diaphragm vibrated, the length of the jet between tube and plate was varied, and so the resistance of the current path between tube and plate was modulated according to the diaphragm vibration. The liquid was electrolysed by adding soda ($Na_2 2CO_3$) or NaOH (sodium hydroxide) or KOH (potassium hydroxide) to make it a better conductor. And of course the tube had to be refilled by pumping the liquid around the circuit.

The Jervis-Smith microphone illustrated the use of a jet of constant cross-section in which the jet length was varied. Another type which arose in parallel with it was one in which a fixed length of jet path was used but the jet cross-section was modulated by the sound vibrations. This is shown in Fig. 2, and it is easy to see why this finicky device soon died a natural death. It had lots of pivots to stick and go wrong, the needle valve N had to fit smoothly and precisely and there was a lot of inertia to push around.

In both these early cases, as in later electrolytic microphones, only AC could be tolerated, to reduce electrolytic erosion, and the electrodes had also to resist chemical corrosion by the salts in the liquid. For this reason, platinum was the favourite metal.

The successor to this principle was Vanni's liquid microphone. Just as the Italians were very active in early radio in general, they were leaders in the liquid microphone business. Vanni's double-cascade microphone is shown in Fig. 3. Here the jet tumbled from the vibrating electrode A to the fixed electrode B, the length of the path being governed by the vibration of the diaphragm C.

The most popular form of the Vanni microphone is shown in Fig. 4. It is virtually a microphone amplifier (reminiscent of Hortons' gas flame amplifier of the previous article on gas microphones) in which the primary microphone was a con-

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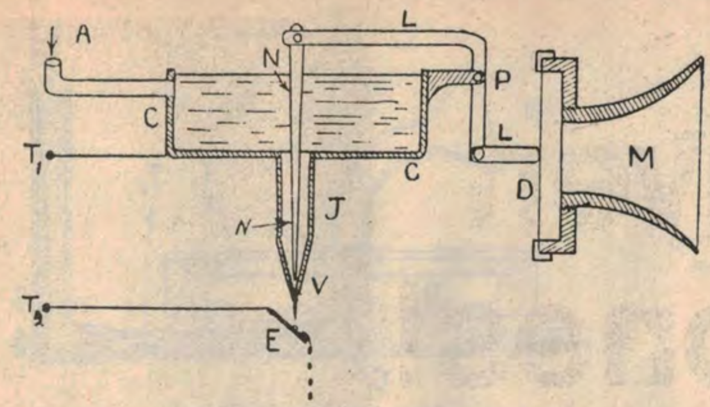


Fig. 2: A variable-jet-width variable-resistance liquid microphone.

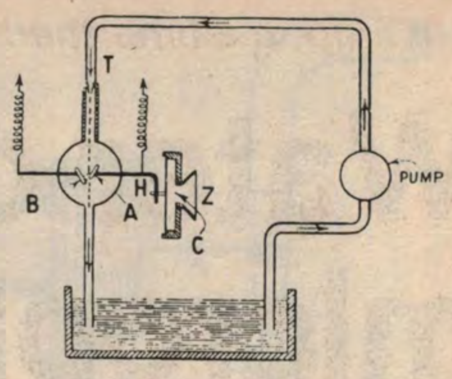
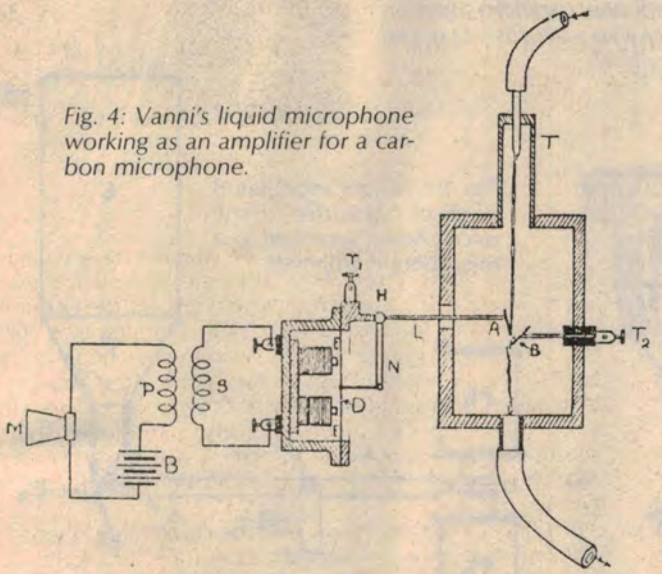


Fig. 3: Vanni's double cascade jet liquid microphone.

Fig. 4: Vanni's liquid microphone working as an amplifier for a carbon microphone.



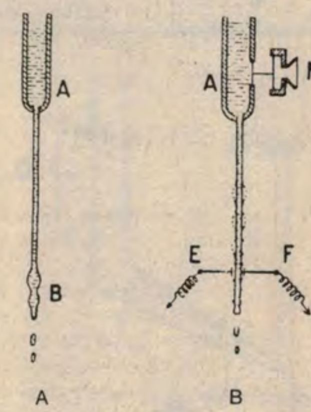


Fig. 5: (a) the Bell effect. (b) Majorana's liquid microphone using the Bell effect and voice-modulated pressure.

ventional carbon microphone which was used to vibrate a diaphragm D and hence vary the double-tumble path between A and B.

Microphones of this type were used successfully to control antenna currents of up to 15 amps! With this type of apparatus, Vanni obtained a speech range of 960km between Rome and Tripoli in 1912.

A quite different type of effect arose from experiments which Lord Rayleigh did in the Cavendish Laboratory in Cambridge in 1879. Rayleigh studied the way in which water jets broke up into drops under the effects of vibrations, electricity, etc. Many useful things originated in this "curiosity-oriented" research, including modern computer "jet-printers", biological cell sorting, atomization of liquids, and very recently a wind driven electrical generator, besides one of the types of liquid microphone.

Alexander Graham Bell was not the only bright star in the Bell family. The Scot had enlisted his English cousin, Chichester Bell, to run the forerunner of the Bell Telephone Company's giant research laboratory at Murray Hill. Following Rayleigh, Chichester Bell observed that sound waves made a significant difference to the way in which a jet formed isolated beads a little down stream from the jet orifice. This is known as the Bell Effect. His apparatus is shown in Fig. 5, together with the way in which Majorana, another Italian, developed it into a microphone.

As can be seen in the sketch, the voice modulated the hydrostatic pressure in the tube and "wiggled" the beads up and down at the point in the jet stream where they were forming, thus varying the area of contact between the electrodes. Majorana also developed a "microphone amplifier" version, operating on a variant of the Bell principle, shown in Fig. 6. The flexible tube T is vibrated transversely, thus varying the contact overlap between the electrodes T_1 and T_2. In 1906, using his liquid microphone, Majorana transmitted from Rome to Sicily, about 500km.

Another successful type was Chambers' liquid microphone (1910) shown in Fig. 7, which has a complicated relationship to both the microphones of Majorana and of Vanni. In this case a jet of acidulated water pumped through C hit the vibrating diaphragm D, and the jet length, width and general conformation were all varied by the position of the diaphragm, and so the resistance between T_1 and T_2 was modulated. It could handle 400W and was highly regarded because it was so well damped (sic!) and did not exhibit distorting resonances.

Incidentally, the rate of flow was throttled until the outflowing liquid reached 80°C, which might give a clue to the origin of the term "hot" microphone!

Yet another clever principle was used to modulate not the length or breadth of the jet, or the position of formulation of "beads", but to vary the actual conductivity of the electrolyte itself. This type, invented by Sykes and Ford in 1914, and known as the Sykes liquid microphone, is shown in Fig. 8.

The liquid in the tube X is pure water (a poor conductor) which flows in orderly stream-line due to the anti-splash glass fibre filter A. The tube T contains a strong electrolyte, the amount of which emerging into the flow of tube X depends on the pressure modulation exerted by the diaphragm D. Thus the resistance between B and B_1, a finite phase lag down the line, was governed by the vibrations of the diaphragm.

Contrary to what one might dream up about liquid diffusion, and other horrific complicating factors, the microphone was

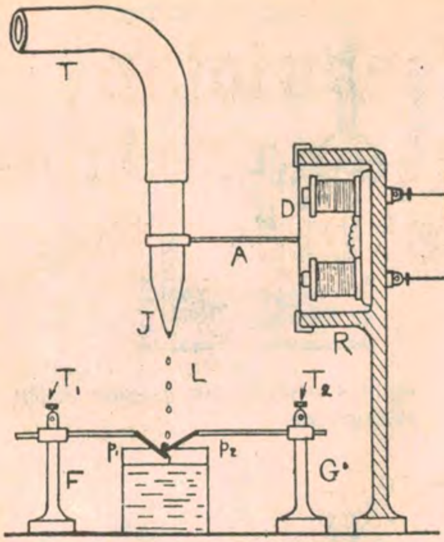


Fig. 6: The transverse vibration microphone amplifier version of Majorana's liquid microphone.

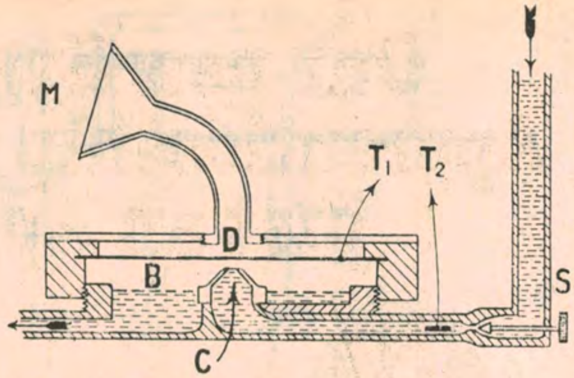


Fig. 7: Chamber's liquid microphone.

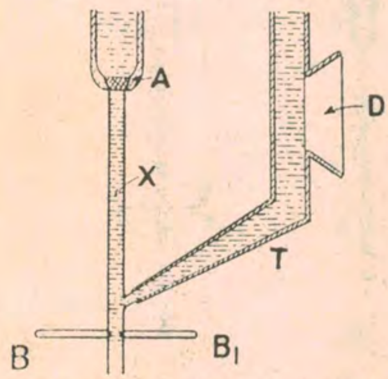


Fig. 8: Sykes and Ford's liquid microphone with modulated electrolyte injection.

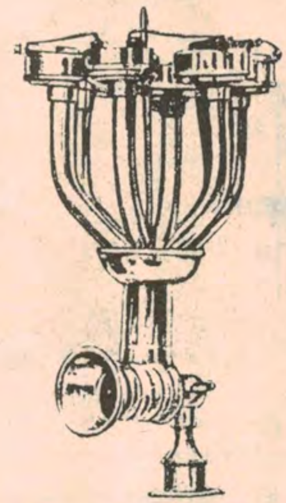


Fig. 9: Dublier's multiple carbon microphone with six heads.

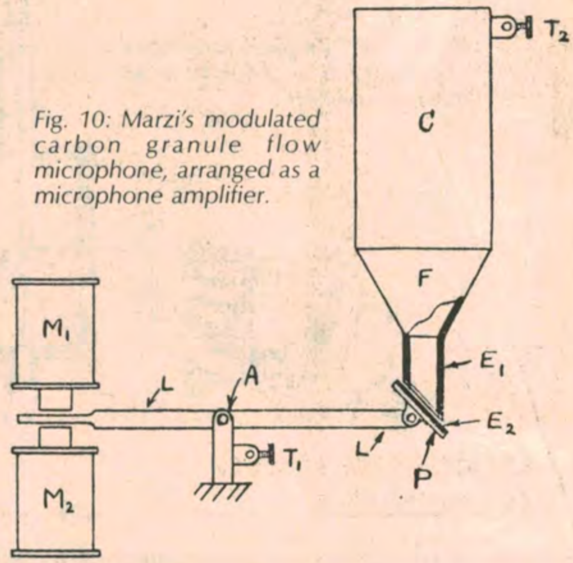


Fig. 10: Marzi's modulated carbon granule flow microphone, arranged as a microphone amplifier.

highly regarded as it could handle high power and rendered excellent fidelity.

Liquid microphones were asserting ascendancy over carbon microphones due to their better power-handling abilities, as the carbon granules tended to sinter together when hot. Several attempts were made to overcome this defect. As mentioned in the previous article, Dubilier developed a water-cooled carbon microphone capable of handling up to 750W. Dubilier also developed a Medusa-like multiple carbon microphone, with six microphones fed by a single mouthpiece. Fig. 9 shows this plumber's nightmare.

About 1910 Marzi invented a carbon granule microphone which was analogous to the liquid microphones and could deal with large currents. This is shown in Fig. 10. Once again it is really a microphone amplifier, as the coils M_1 and M_2 needed to be fed by a conventional carbon microphone and the resultant motion of the electrode E_2 varies the distance between it and the fixed electrode E_1 between which the carbon granules stream from the hopper C. The variation in the distance between E_1 and E_2 modulates the current between them. Announcers emerging from the studio must have resembled the late shift from a coalmine!

In parallel with these liquid microphones myriads of electrolytic receivers, relays and amplifiers sprang up. Some, for example, used the rectifying properties of the "double-layers" at the surface of metallic electrodes, and others made use of the apparent change of surface tension of a mercury drop in dilute sulphuric acid when there is a small potential difference between the mercury and the acid.

When the triode valve became established, it swept away the arc oscillators and with them the need for high-power microphones. Thus the carbon microphones came back into favour and the liquid microphones disappeared. It was not that better microphones swept them from the scene but that the requirements for microphones changed dramatically.

No account of these jet devices is complete without a brief description of an allied device invented by Alexander Graham Bell to act as a light modulating voice transducer. He came up with it at the time of his intense work on his "photophone" which started in 1880, and used it to make what was undoubtedly the first photo-recorded speech track on a glass photo plate using a circular track. For details of the device I am indebted to Dr Elliot Sivowitch of the Smithsonian Institution in Washington, who also sent me a tape recording of the sound from this strange track. I make it out to say "oomph woof" — some claim to discern actual human words!

Bell used a jet of black ink impinging on a window through which a focused beam of light passed. As in the liquid microphones the jet was modulated by sound vibrations, and thus the light transmission was also modulated.

Of course there were many other peculiar microphones: carbon, liquid and gas by no means exhausts the list. For example the hot wire microphone once looked promising. But let these be decently interred. If both readers and editor permit, I might later outline a few of the fascinating early attempts at earphones and loudspeakers.