# Platinum-cored Thermionic Valves in the Transatlantic Telephone Cable

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After a year of heavy and growing traffic the submarine telephone cable linking London, Montreal and New York has become a commonplace and is unlikely to attract further public interest until it fails. What would be involved in a failure and what might be its most likely causes?

A breakdown would require one of the larger cable-ships—probably *Monarch*—to locate, lift, and replace the faulty section, and in the event of bad weather this operation might cost £100,000 in direct charges and loss of traffic revenue. The causes of failure are probably limited to direct damage to the cable by trawling operations (the excursions of the Portuguese fishing fleet off Newfoundland in the summer of 1957 caused severe damage to telegraph cables and must have come close to the transatlantic cable) and to electrical breakdown of components in the thermionic valve amplifiers or repeaters.

## Success of the British Repeater

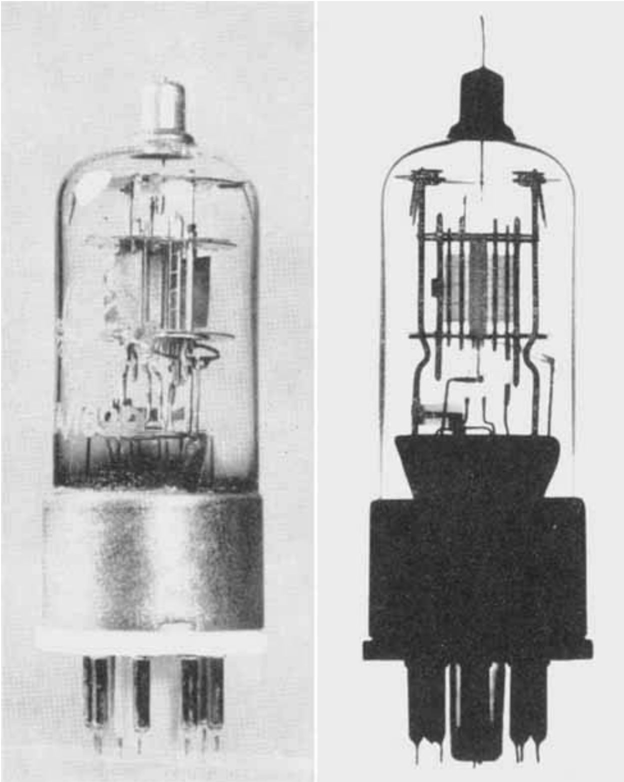
These repeaters spaced at regular intervals along the cable are a complex of thermionic valves, transformers, resistors, capacitors and so on, and each component has its individual probability of failure. Due to its inherent complexity the thermionic valve is probably the weakest link in the component chain, and for this reason it has been designed, tested and selected with the greatest care. Two distinctive types of valve are used in the system; an American type 175 HQ used on the main crossing from Scotland to Newfoundland and a British type 6P12, employed in the shorter Newfoundland–Nova Scotia section.

The use of two different valve types on the route reflects the present formative state of the submarine telephone art. When the cable was jointly planned it was decided to use the American repeater with the 175 HQ valve on the main deep-water crossing as the system had some fifteen years of solid development experience behind it compared with about five years in the case of the British system.

British repeaters have, of course, been in extensive use since the war on the shallow water continental shelf around the United Kingdom but the first prototype deep-water system was only laid in 1954 between Scotland and Norway. Against this relative lack of experience the British system has certain inherent advantages over the American in that it gives a lower channel-cost-per-mile due to its higher performance valve, and uses parallel amplifiers in its repeaters; that is, failure of a valve or other component leaves a repeater operating normally. As matters have turned out, the British repeater has proved a success and is likely to set the general pattern for future systems.

## Development of the British 6P12 Valve

Compared with the American system the British repeater is remarkable for two reasons; it employs parallel amplifiers and introduces high-slope valves which greatly increase its frequency coverage or traffic handling capacity. The relative ratings of the two valves are shown in the table.



*Thermionic valves suitable for use in submarine telephone cable repeaters must be capable of operating for many years. In the new transatlantic telephone cable system the section between Nova Scotia and Newfoundland incorporates repeaters developed by the British Post Office Research Station and built around the platinum-cored valve developed there. The illustration shows a submarine repeater valve as now manufactured by Standard Telephones and Cables Ltd., together with an X-ray view to indicate its structure.*

The economic advantages of the British valve have not, of course, been bought without cost. The gain has been purchased at the price of smaller diameter grid wires and much closer electrode spacings within the valve structure. Both of these moves lead to a higher probability of failure by internal short-circuit, and this probability is countered by the use of parallel amplifiers. On balance the gain seems to be a very real one, and operating experience so far has been encouraging. Up to the present time the 6P12 type valve has given five million valve-hours of service in working submarine repeaters with only one recorded case of mechanical fault. This single case incidentally was unconnected with the close-spaced structure and was due to the fracture of a

## Comparison of Valve Types in the Transatlantic Cable

| Type | Mutual Conductance | Cathode Heater Power | Performance Factor* |
|---|---|---|---|
| **American 175 HQ** | **1.0 mA/volt** | **4.0 watts** | **0.25** |
| **British 6P12** | **6.0 mA/volt** | **1.5 watts** | **4.00** |

*The performance factor is a measure of mutual conductance per watt of cathode heater power

*An Atlantic telephone cable repeater about to be laid from the Post Office cable-laying ship HMTS " Monarch "*

hot platinum connecting tape under tension. The tension in the tape has since been removed and trouble due to this cause is unlikely to recur.

Generally speaking, it seems then that the early British decision to use a high-slope valve with an economical heater power has proved a wise one.

## Life Aspect of the 6P12 Valve

To decide on the right basic valve type is a relatively simple proposition; to induce into it an indefinitely long electrical life is another order of problem altogether.

It was recognised by the Post Office in 1946 that the successful development of its submarine telephone ambitions were wholly dependent on a reliable long-life valve and to this end a Thermionics Group was set up at Dollis Hill to study the basic electrical life processes of high-slope oxide cathode valves. The efforts of this group have led to the conviction that all changes of electrical performance in valves have their origin in chemical or electro-chemical actions occurring in the valve on a micro- or milli-micro scale of magnitude. The form of change of most importance to the repeater engineer is decay of mutual conductance, and this will be considered in brief detail as typical of the development effort put into the 6P12 valve.

Mutual conductance decay in common receiving valves results from two separate and distinct chemical actions occurring in the oxide cathode itself. Both actions are side issues in no way essential to the basic functioning of the cathode and it seems probable that both can be eliminated if sufficient understanding of their nature is available. The first action is the growth of a resistive interface layer between the oxide matrix and its supporting nickel core. This effect is assumed to be due to silicon contamination of the nickel core metal:

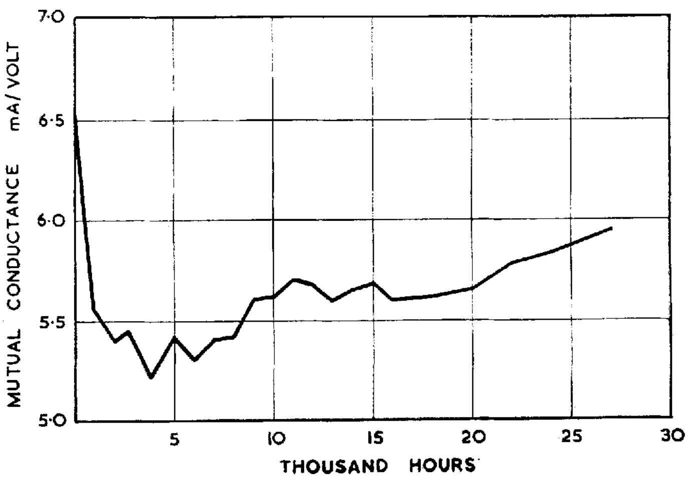
$$4\ BaO + Si = Ba_2SiO_4 + 2\ Ba$$

The resistance of the layer of barium orthosilicate rises as it loses its barium activator and approaches the intrinsic state. The effect of the interface resistance is to bring negative feedback to bear on the valve with resulting loss of transconductance. The second deleterious action is loss of electron emission from the oxide cathode by direct destruction of its essential excess barium metal by oxidising action of residual gases. Such gases result from an imperfect processing technology.

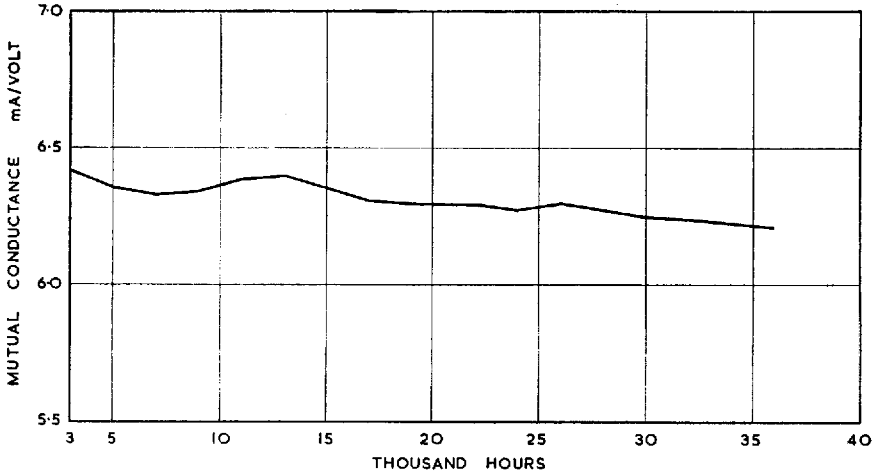
## The Platinum Cored Cathode

These two problems have been approached in the 6P12 valve in a somewhat novel manner. The conventional nickel core is replaced by platinum of such high purity (99.999 per cent) that the possibility of appreciable interface growth from impurities can be disregarded. The only factor to be considered is the appearance of high resistive products of a possible interaction between platinum and the alkaline earth oxides. Batch tests over a period of 30,000 hours have failed to show any sign whatever of such an action occurring and workers at Dollis Hill now regard the pure platinum-cored valve as free from the interface resistance phenomenon.

The problem of avoiding gas deactivation of the cathode is a more difficult one and so far has been reduced in magnitude rather than eliminated. It is now appreciated that the dangerous condition arises from "gas generators" left in the valve and not from a true form of residual gas pressure left after seal-off from the pump. These gas generators are solid components of the valve which give off a continual stream of gas over a prolonged period of time. The gas evolution rates are usually so small that they cannot be detected by reverse grid current measurement but they tend to integrate gas by absorption on the cathode and to destroy its activity. The gas generators are usually of finite magnitude and, depending mainly on diffusion phenomena, evolve gas at a rate which falls in roughly exponential fashion with time. The probability of mutual conductance failure is therefore highest in early life and tends to lessen with time as the generators move to exhaustion.




*Behaviour of a group of platinum-cored valves left with a "gas" generator in the valve envelope*




*Typical life characteristics of a group of 6P12 valves*

One particularly useful feature of the platinum-cored cathode is its freedom from core oxidation during gas attack and this leaves the valve free to recover from trans-conductance failure when the gas attack has passed. The graph on page 5 shows the behaviour of a group of 50 valves which have been deliberately left in possession of a component capable of generating carbon-monoxide over a prolonged period and the characteristic recovery of a platinum-cored oxide-cathode with the gradual passing of a typical gas attack.

One problem that has attracted much attention at Dollis Hill is the actual manner in which a platinum-cored cathode recovers from a gas attack. The mechanism must involve the dissociation of a small fraction of the oxide cathode itself with the retention of barium metal in the oxide lattice and the evolution of oxygen. That such an essential mechanism does in fact exist has been proved by the slow accumulation of barium metal in the platinum core. This accumulation takes the form of a distinctive alloy of barium and platinum and only occurs when the cathode is passing current. The barium regenerative process seems therefore to be electrolytic in nature and, depending only on current flow and a stock of oxide, would appear to be virtually inexhaustible.

Typical life test data for the platinum-cored 6P12 valve are shown in the graph above. The characteristic is drawn as the mean of a group of 100 samples and shows that the mutual conductance has changed by around 2½ per cent in a period of four years.

## The Platinum Core as a Cathode Research Tool

In basic research on the nature of the oxide cathode the use of platinum as a core metal has proved remarkably helpful in a number of ways of which one may be mentioned as illustrative. Platinum forms no stable oxide at red heat and this property has assisted the study of an oxygen gas attack on the barium strontium oxide cathode. It has been found that the cathode, in the absence of a confusing core chemistry, behaves in relatively simple fashion, losing its electron emission in the presence of the gas but showing a natural inclination to resume its useful active state on restitution of the vacuum condition. The permanent and irreversible loss of emission suffered by nickel-cored cathodes under oxygen attack is therefore due to core metal oxidation, rather than to any damage to the barium strontium oxide matrix itself.