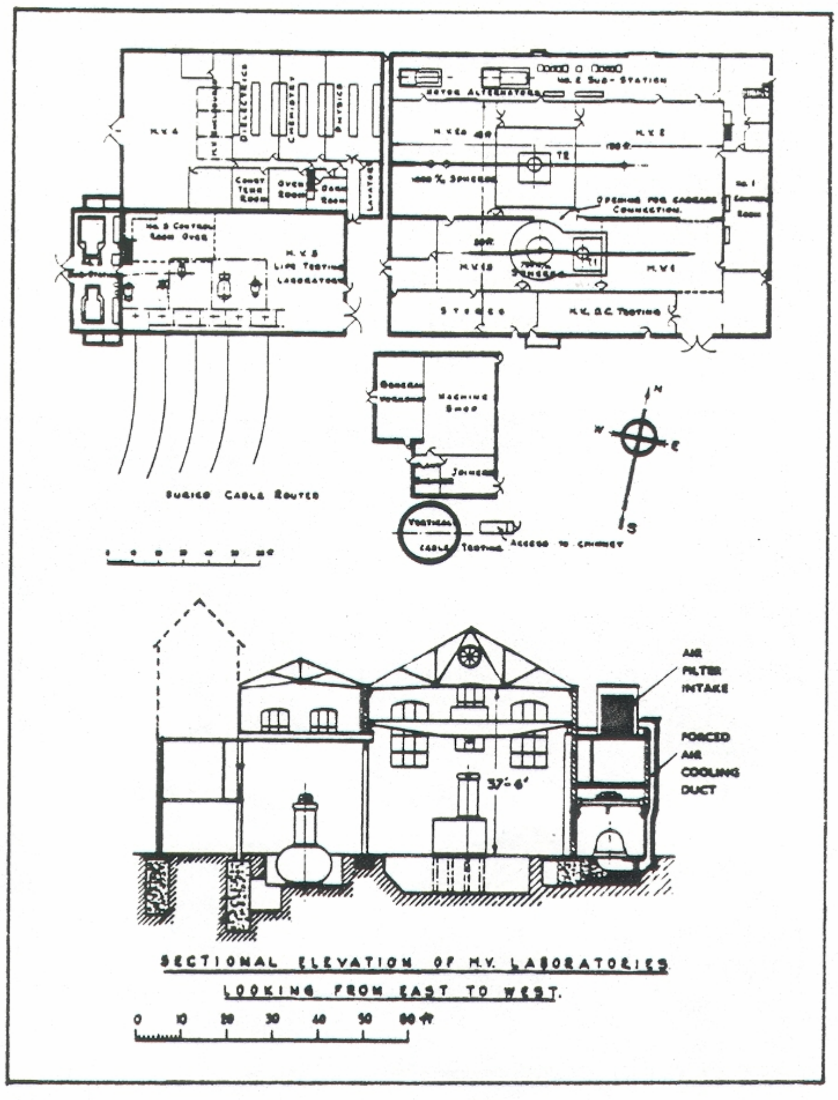
Chapter Five

THE MOVE TO WOOD LANE

The Building; - Ferranti Transformers - The Chimney
Alarms and Excursions - Research Problems - "Arrested Failures"
Magenta Dye Test - Application of Pressure

WHEN CALLENDER'S finally moved into Wood Lane, they were confronted with buildings which, so far as the north side of the site is concerned, have not greatly altered to this day. We refer the reader to the plan shown in Chapter Two and to the picture of the "Exterior of Works" which accompanied it. The bunkers depicted over the south side of the works (later HV 1) still existed, and similar bunkers had also been erected over

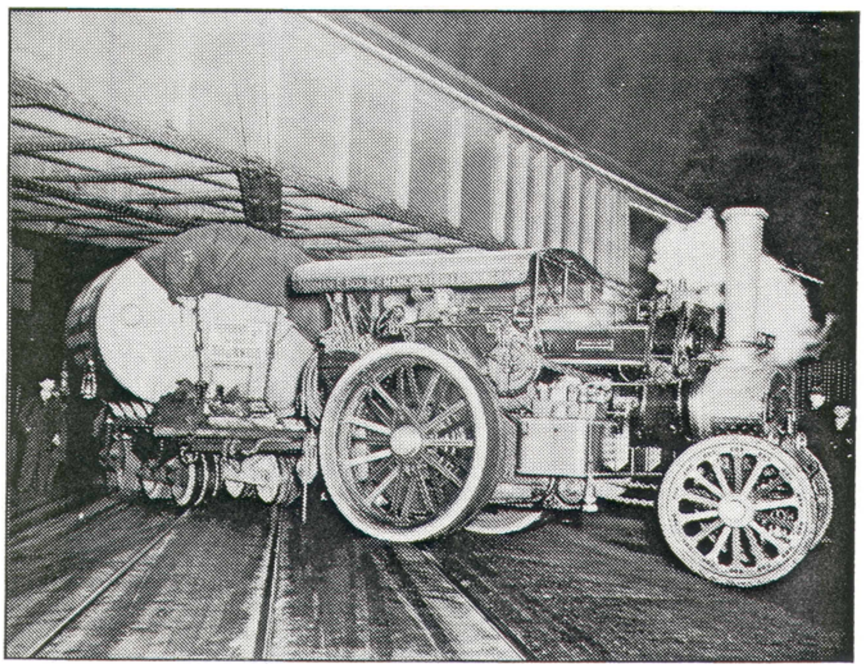


General Plan of Laboratories
taken from Souvenir Booklet, 1934.
(We have added the outline of the bunkers: shown dotted, which were not
to be seen on the 1934 plan although they existed until the 1950s).

the "second part" of the works (IN3), already mentioned in that Chapter. In other words, the buildings consisted generally of what we still know as HV1, HV2, HV3 and HV4, and the "shell" of these main buildings has remained. In addition, there was the chimney stack, and to the north of this was a low building (the "economiser house", etc. - see plan, Chapter Two) which later became the machine shop, general workshop and joiners' shop (see 1934 plan).

Alterations to suit the type of work to be carried out were soon commenced and these continued right up to the official opening in 1934. Initially, HV3 was used as a garage, but soon a control room was built on a mezzanine floor (still there today, used as office accommodation) and life testing equipment was purchased and installed. This became the initial home of O. T.D. The end of HV3 w~ extended to provide Substation No. 3 (see plan) which now houses the emergency stand-by generator. In HV 4 the end section was originally built of corrugated iron and this was rebuilt by Callender's. Small laboratories were installed in HV4 to house Dielectrics, Chemistry, Physics and Photography.

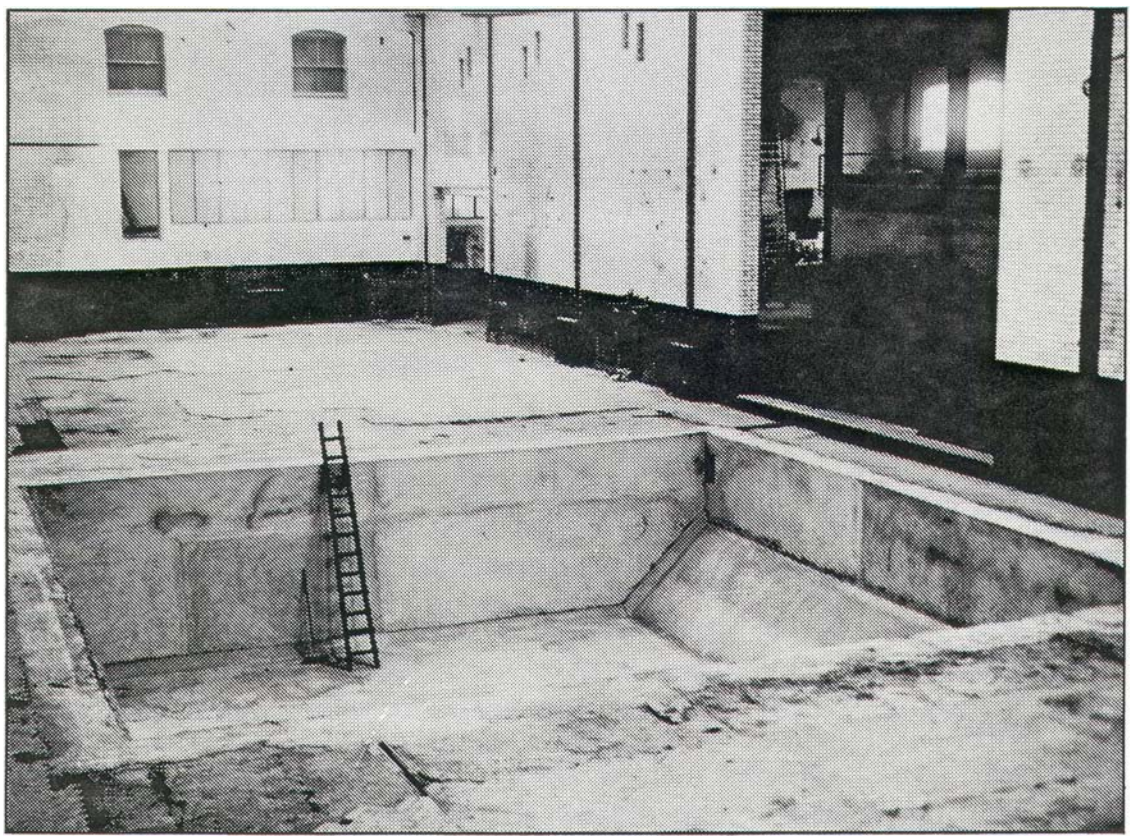
In addition, a medium-sized laboratory was created for general purpose investigations up to 120 kV. Here, investigations into joint and sealing end design and tests on short lengths of high voltage cable were carried out. This laboratory was generally concerned with the theory and mechanism of breakdown of cable dielectrics. The two main easterly buildings (HV1 and HV2) were allocated to high voltage life tests on cables and auxiliary apparatus, and flashover tests on porcelains. In a corridor to the north of these two sections were installed the switchgear and motor alternators supplying the transformers necessary for this work.



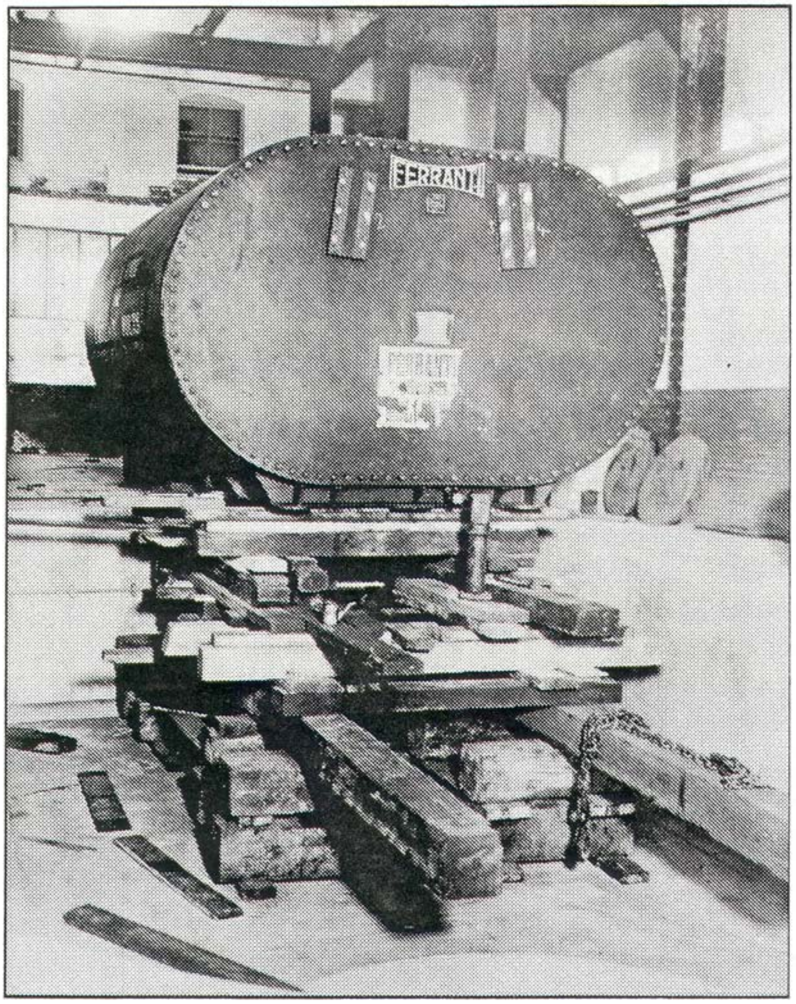
Arrival of the Ferranti transformers, 1933
(Note tram-lines in Wood Lane)

Two Ferranti transformers were purchased and these arrived at the beginning of 1933, being hauled all the way from the north of England by a fine specimen of a traction engine owned by Norman E. Box Limited of Manchester. Photographs taken from the Company's files indicate that the transformers which, of necessity, arrived late at night, presented a difficult problem in negotiating the turn from Wood Lane into the private road (which is now Ariel Way and no longer private) and it was necessary to remove the central gate-post. The traction engine was eventually "parked" in HV2. Whilst the engineers were installing the transformers they lived in a caravan on the site.

Before installation could be effected and, indeed, before the transformers had arrived, a great deal of time and energy had to be spent in the preparation of the pits. Early on it was discovered that the concrete floor of HV1 and HV2 was so hard that the ordinary pom-pom drills were useless. Granite aggregate had been used in the concrete and eventually the pits could only be prepared by using rock drills! Even when the pits had been made a difficulty still arose in the form of flooding. One of the pits continually filled with water despite repeated attempts at waterproofing the walls and floor. Eventually it was discovered that a water main had been damaged when the pit was originally dug.

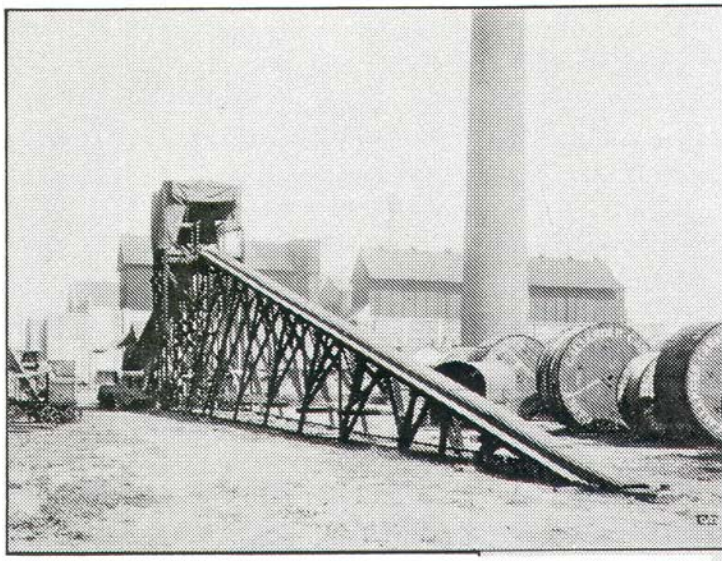


Preparation of the pits prior to the arrival of
the transformers

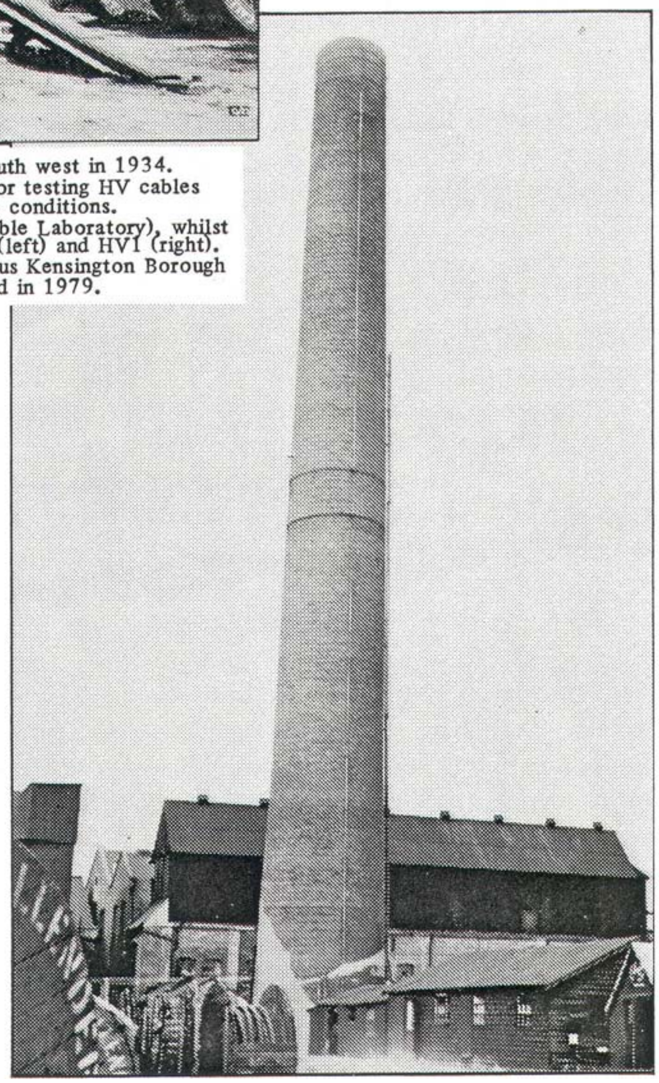


Installation of one of the transformers

Much has been written about the various departments at Wood Lane, but little mention has been made of the chimney stack. This was converted for use as a vertical cable testing laboratory. Originally the chimney was 210 ft. high. In November 1931, however, the top 20 ft. was removed owing to cracks. At the same time the fire-brick lining was removed, a concrete roof put on the chimney, an entrance cut to the base at ground level and a steel stairway installed up to the first 120 ft., consisting of six ladders with landing) at every 20 ft. level. A working platform was erected at the top of the stairway. By these arrangements it became quite easy for clear vertical runs of 100 ft. of high voltage cable, such as may be required in power stations, for example, to be installed and tested. This "laboratory" was connected by duct line to the life testing laboratory so that tests could be carried out either with transformers located in the base of the chimney, or with transformers located in HV3. Work on the chimney was carried out by Altitude Limited, and to complete the work a new lightning conductor was installed. Later, in 1934, the chimney was rebanded.



General view of the site from the south west in 1934.
The ramp in the foreground was used for testing HV cables and joints under difficult laying conditions.
In mid-ground is the chimney (Vertical Cable Laboratory), whilst in the background are the buildings HV3 (left) and HV1 (right).
The distant chimney is that of the infamous Kensington Borough refuse incinerator, demolished in 1979.



Original Power Station chimney.
Converted to vertical cable draining activities.

Before the installation of the Ferranti transformers, a hodge-podge of high voltage equipment which had been collected at Ormond Yard was used. Temporary cages were erected around this equipment with whatever safety measures could be rigged up. Dr. D. M. Robinson, who joined Callender's at Wood Lane in 1931 and who later became President of the High Voltage Engineering Corporation of Massachusetts (suppliers of our Van der Graaff accelerator), tells an amusing story of how one evening just as he was going home he became a little concerned that the jointers might get one of their ladders too near a temporary high voltage line. This was 20 ft. in the air and the wire cage only extended for about 10 ft. He cautioned Alf Rawlings (whom some at Wood Lane may still remember) and his mate about this. "The mate was a small man", Dr. Robinson goes on. "I said, 'Watch out! There is 60,000 volts on that line'. The plumber's mate cocked one eye up at it and in inimitable Cockney accents said, 'That's all right mate - I don't mind the even numbers'!".

As stated before, in those early days the site still bore the signs of the old Power Station. Railway tracks covered much of the ground and there was a large grass area on which cricket was played in the lunch hour. The railway lines also had two platelayers' trolleys running on them of the type that are moved by two people facing each other and pumping levers in a see-saw fashion. Part of the line was traversed by big double doors in one of the blocks, these usually being open. One day the inevitable happened. Somebody closed the doors without giving due notice. From that day on, the railway ceased to function at Wood Lane. Another escapade of those days was largely the result of the then current spate of gangster films starring James Cagney, George Raft and other tough guys. In these films, the gangster was inevitably led to the electric chair and when this happened all the other inmates of the prison learned of it by tapped messages on the pipes that ran through the cells, which caused a terrific din. Wood Lane had such a system of pipes running through the various departments and again the inevitable happened, causing some of the "hierarchy" to throw fits because they could never trace the origin of the noise.

To anyone but an electrical engineer the role played by apparatus such as was installed at Wood Lane may seem a little puzzling. It is necessary, therefore, to consider what happened to a cable when it fails and how such failures can be accounted for by laboratory tests. In those early days informative laboratory tests were limited, but soon new testing techniques were developed - many at Wood Lane.

As already stated, it had been found that breakdowns on solid cables were attributed to successive heating cycles which caused the formation of voids in the impregnating compound, i.e. weak areas which could break down by ionization due to high stress.

The next logical step, therefore, was to study the exact process by which a cable failure developed when the cable was tested under severe conditions in the laboratory.

Some breakdowns were very simple in appearance, consisting of a clean radial hole between conductor and earth. In others, scorched and brittle papers were found, particularly in the inner portions of the dielectric. Others were accompanied by treelike or fern-like patterns of carbon, which usually occurred near the centre of the dielectric wall and were associated with dry patches where scarcely any free impregnating oil remained. On the other hand, there were in existence lengths of cable which had given satisfactory operation for years and were perfectly dry throughout, the impregnating oil having been replaced by a yellow wax-like substance (familiarly referred to in those days as "cheese") which was neither fusible nor soluble in the usual organic solvents.

Small wonder then that the early investigators were baffled by the complexity of the breakdowns, and turned with relief to the Schering bridge as a method of keeping a watch on the dielectric losses during the life of the cable.

Unfortunately, a sufficiently sensitive recording wattmeter or recording bridge did not exist, and when the measurements could only be taken at intervals ,it was very easy to miss the small overall rise of power factor which was caused by a severe local loss. A cable on a life test, or under conditions closely simulating service operation, might behave excellently for months and then fail suddenly, without any previous warning obtained from the daily or weekly loss measurements. This became such a common experience that some engineers were led to believe that cable breakdown was a mysterious affair, taking place suddenly without apparent reason. Obviously little progress could be made from examination of faults occurring in service, partly because the exact conditions and past history were unknown and also because the fault-arc invariably burnt out most of the evidence before the protective equipment could operate.

Investigations of the mechanism of breakdown necessarily started in the laboratory, but in order to be certain that the conclusions were applicable the laboratory had to be capable of "full scale" research and, furthermore, the results had to be correlated with all possible evidence collected from cables in service.

Many kinds of test were suggested and used with the object of assessing the quality or determining the safety factor of impregnated cables. There appeared to be three types to which most of these tests belonged, viz:

(1) The voltage/time-to-breakdown test;

(2) The stability test;

(3) The accelerated ageing test.

For many years it had been known that a cable subjected to excess voltage might develop local hot spots and that if the voltage was maintained the cable frequently failed at or near the hottest of these points. By attaching a large number of thermometers or thermocouples to the cable and keeping a continuous watch on these, it was possible to obtain advance information on the condition of the dielectric all along the cable without cutting the lead sheath and disturbing the normal pressure conditions. It became particularly easy to obtain such information by use of an automatic thermocouple recorder developed at Wood Lane by Dr. Brazier.

This device became of the greatest assistance in the laboratory examination of the mechanism of cable failure, and it is no exaggeration to say that without some such system much useful information on cable behaviour would never have been obtained.

In the past laboratory tests on cables had generally been continued to breakdown, largely because no warning of failure was available. It was felt, however, that it would be more instructive to stop the test before the final arc occurred as the latter generally destroyed much of the evidence of interest. The "arrested failure" could then be examined, as described later. Frequently some hours elapsed between the first observation of the rise of temperature on the recorder chart and the actual breakdown, and with the help of the temperature recorder it was found possible to stop tests in all the various stages, and thus to show how the deterioration progressed to breakdown.

The cable, the failure of which had been arrested in this way, was then subjected to a post-mortem. The papers were removed from the section near the "hot spot" until anything unusual was noticed. When any doubts existed as to the mechanism of the failure, or the point of origin of the trouble, the magenta dye test was applied. This test, which had been developed at Wood Lane by the then Chief Chemist, Mr. G. M. Hamilton (later Director of the Paint Industries Research Institute at the University of Natal in Durban) made use of the fact that the wax formed from the cable oil as a result of ionization was insoluble in the usual organic solvents (petrol, benzene, etc.) and, further, that this wax remained on the papers where it was formed, adhering closely to the paper fibres. Thus the tapes taken from the cable could be extracted in petrol to remove the oil and if they were then dyed, the wax, which would not take up the dye, would show up very plainly. Magenta dye had the further advantage of giving good contrast in photographs. By means of this test traces of wax quite invisible on the original papers could be clearly seen, the wax taking on different shapes and forms according to its position and method of formation.

The mode of formation of voids in the cable dielectric and the mechanism of their subsequent breakdown were thus elucidated, but the problem of the prevention of such failures still remained as a serious challenge to the cable manufacturer.

An increase in pressure does not result in any radical alteration in the mechanism of breakdown. The pressure results in the suppression or extinction of the ionization until the electric stress has reached a higher level, but at this level the same phenomena occur.

The whole field had been thoroughly surveyed in a comprehensive manner in patents taken out by Fisher and Atkinson in America in 1922, in which every possible method of utilizing pressure in conjunction with a cable was covered. These patents, however, appeared to have been in advance of their time, and it was not until about 1930 that the matter was actively investigated by cable makers.

The first question to be determined was the amount of pressure necessary to prevent the ionization of cable voids and the highest pressure that could be used in order to obtain the maximum advantage. To answer this question a pressure vessel was constructed in the laboratories incorporating two electrodes between which were sandwiched layers of plain or impregnated paper. To such a system a variable gas pressure could be applied at various voltages between the electrodes. It was possible to watch through a viewing window the extinction of the ionization as the pressure in the container was raised.

It was soon learned that above a pressure of 200 Ib/in2 there was little improvement obtained on further rise of pressure. This figure became generally accepted and proposals for gas pressure cables were largely based upon a maximum pressure of 200-2501b/in2.

The next problem was a method of applying such a gas pressure to a cable. Fisher and Atkinson proposed using a high pressure gas, such as dry compressed air for instance, applied to the dielectric of a cable in such a manner as to raise its breakdown strength to a point at which ionization of the vacuous spaces was completely suppressed. Furthermore, they thought that since voids no longer constituted a menace there would be no need for the elaborate precautions hitherto adopted to eliminate them during manufacture. Pursuing the idea to its logical conclusion they reasoned that the impregnating medium itself was unnecessary, and that dry paper alone could be used as the dielectric, the occluded air being maintained under compression would thereby have its breakdown strength raised and ionization would not occur. The patent, however, gave no indication of the practical methods of implementing this technique and as Ferranti was heard to remark, "Ideas are generally cheap and easy, but to carry them out is a very difficult matter".

In Great Britain, where no corresponding patents had been taken out, lively attention to the problem was given by four of the largest cable makers, including Callender's.

There was general agreement, in the initial stages at least, that the proposal to dispense with impregnating compound altogether was too sanguine, but this raised a major issue on which opinion was sharply divided.

One school of thought maintained that the use of gas in contact with the impregnant oil was unsafe, and that the gas pressure should be exerted on the dielectric via an impermeable membrane or diaphragm, e.g. a thin lead sheath. Others held the view that, provided an inert and therefore non-reacting gas such as nitrogen was used, no adverse effect need be expected from contact between the gas and cable compound; also that the introduction of a diaphragm would unnecessarily increase the weight and cost" of the cable.

Thus, though the fundamental principle of the application of high pressure gas provided the basis for all cables of this type, this early divergence of opinion resulted in the development of two major classes of gas pressure cable, which may conveniently be referred to as the indirect pressure (or diaphragm) type, and the direct pressure (or non-diaphragm) type.

Of all the ideas that were put forward, probably the design which came the closest to the original Fisher-Atkinson conception was the dry gas pressure cable, designed at Wood Lane by Dr. A. N. Arman , and which is best described in his comprehensive paper which was published in 1937. The paper was entitled "The Gas Impregnated Cable" and described six years of experimentation which commenced early in 1930.

Whilst considerable time and energy were spent on the design of the, dry gas pressure cable, Callender's were also interested during the early thirties in other designs of cable which would be capable of withstanding still higher voltages. The work culminated in the successful design of the compound impregnated gas pressure cable and will be described later.