Corrosion of Lead Sheathed Cables in Plastics Multiway Ducts (Part I)[1]

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1 Introduction

Ever since telecommunications cables have been laid in the ground, it has been necessary to locate and clear faults caused by corrosion damage to the lead sheaths of the cables. Lead has been used as a cable sheath material since the beginning of underground cable manufacture and is still by far the most commonly used material. Lead is and will continue to be an excellent sheath material not only because, in contrast to plastics, it is absolutely impermeable to water vapour but also because it can be extruded around the bundle of wires at a relatively low temperature without damaging it by heat. It is flexible in the solidified state and can, in addition, be jointed permanently and in a waterproof manner by simple soft soldering. It is reasonable to suppose that, when lead was chosen as a cable sheath material, its good resistance to chemicals was a decisive factor.

Unfortunately, however, it became clear after a short time that lead sheaths have only a limited resistance against ground water and become leaky in the ground after a short or a long period of time, depending on local conditions. Whereas, in the beginning, the only action taken was to repair corrosion damage where it occurred, increased attention was paid to the matter in the course of time and as the frequency of faults increased, and attempts were made to classify the individual cases according to external characteristics and to the causes suspected on the basis of these. Thus, a survey of the significance and frequency distribution of different types of corrosion was obtained in the course of time. However, many questions regarding reaction mechanisms and environmental conditions have remained unanswered and for this reason it has not been possible to adopt any effective countermeasures.

As the total length of the cables within the network grew and their service age increased, corrosion damage became more frequent (3...4 cases per day) so that it was decided in 1956 to set up a corrosion laboratory in the Research and Development Division of the PTT. By means of precise investigation of all the identifiable factors involved in naturally occurring corrosion damage using a mobile field laboratory [1] and of numerous model experiments [2...11], the group of experts which was formed succeeded within the space of approximately 15 years in largely elucidating the reaction mechanisms of various types of corrosion and also in suggesting suitable countermeasures [12]. However, the success of these measures, most of which have been put into practice, cannot yet be seen in the form of a decrease of the annual number of faults. On the contrary, the number of reported faults resulting from lead sheath corrosion has further increased partly because the total length of the cable network has been growing increasingly rapidly up to the last few years and partly because the cables which have been laid underground continue to age. If, however, one compares the instances of corrosion occurring after a small number of service years, the beneficial effect of the countermeasures initiated from 1960 onwards is clearly apparent. While, for example, in 1965 26 pc of all instances of corrosion damage occurred in cables less than 12 years old, the proportion of all recorded instances of corrosion in cables less than 12 years old was only 2 pc in 1974.

At the beginning of 1971, a new type of corrosion appeared unexpectedly which causes the cable sheath to be perforated within a small number of years. This type of corrosion, which had hitherto been unknown, was first discovered in a cable with a bare lead sheath (Cable Type A) in a plastics multiway cable duct. This new type of ducting, which was first introduced towards the end of the 1960s, was used instead of the armoured spun concrete pipe systems, which had been widespread for some decades, in many cases during the subsequent years and has since become very common. It was apparent even from the results of the investigation carried out on the first instance of corrosion of this type that there was a strong link between the hitherto unknown corrosion phenomenon and the new ducting system. In order to prevent a renewed increase in the annual corrosion damage figure, all the lead sheath perforations in plastics multiway ducts reported in the years 1971 to 1977 were investigated.

2 Comments on the construction of plastics multiway ducts

In 1970, a detailed report by *P. Grossniklaus* on the construction and design of plastics multiway ducts appeared in this journal [13] so that we need do no more than point out the special circumstances attaching to the corrosion phenomena.

A plastics multiway duct substantially consists of an array of a specific number of ducts (3...24 ducts, depending on capacity) which are fixed and encased in lean concrete (PC 100...150) and are thus combined to form a block which is protected against external damage. Individual ducts normally consist of hard PVC tubes with a wall thickness of 2 mm, a nominal diameter of 100 mm and a length of 10 to 15 m, joined by double connecting sockets, the duct connections being sealed by conical rubber rings inserted into the sockets. In the case of abrupt changes of direction and for avoiding obstacles (for example underpasses for streams), soft polyethylene duct inserts with thicker walls are incorporated by means of suitable transition sockets.

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[1] Die deutsche Originalfassung ist in den Techn. Mitt. PTT Nr. 1/1979, S. 16...24 erschienen

[1] La version française est parue dans le Bull. techn. PTT N° 1/1979, p. 16...25

As a matter of principle, one expects that the ducts in a complete installation remain dry; for this reason, a great deal of importance is attached to precise and clean assembly. For example, jointing chambers must be equipped with drainage systems in order to prevent the ducts from being flooded via the jointing chambers. It should also be noted that soiled duct ends and connecting sockets must be carefully cleansed before they are slid together and that the circular rubber gaskets must be correctly located in the connecting sockets and fit against them perfectly in order to prevent leakages. In construction zones with a high ground water level, it is recommended that connecting sockets for use with an adhesive be employed. On the assumption that waterproof installations are available as a result of these measures, bare lead sheathed cables have been pulled into the ducts. In this way, one saves not only an envelope for protecting the lead sheath against corrosion but also the tension armouring because of the low friction between the plastics wall and the lead surface. However, it was necessary to accept leakage in the whole system from the beginning. This applies to the duct inlets to the jointing chambers. Because it is not possible to achieve tight, leakproof connection between the external plastics duct walls and the surrounding concrete of the jointing chamber wall, it is possible for ground water or mountain pressure water to seep through between the two materials, possibly by capillary action. However, it was not thought that this exposed the lead sheaths to the danger of corrosion because the water seeping through cannot get into the ducts but drains away via the jointing chamber wall and leaves the jointing chamber via the drainage pipe.

Unfortunately, the real facts are slightly different because it is precisely at these points that particularly aggressive conditions prevail. It appears that waterproof conditions do not always exist even within the ducts; this is demonstrated by the following description of a few installations investigated because of corrosion damage.

3 Description of the locations of the faults in some of the instances of damage investigated

31 The Auvernier plastics multiway duct system (JC 20084 Colombier—Auvernier)

The junction cable (JC) 20084 between Colombier and Auvernier was newly clad and pulled as Cable Type A into a newly constructed plastics multiway duct system in the autumn of 1970. In March 1971, the Neuchâtel Regional Telephone Directorate reported that it was necessary to repair a fault because the lead sheath in manhole no 134 was perforated as a result of corrosion immediately at the outlet of the plastics duct.

The location of the fault was inspected on 29th March 1971. The section of the installation being investigated is located beneath the asphalt surface of a minor road which traverses vineyards sloping down towards the lake of Neuchâtel. Accordingly, the entire route is subject to slope pressure water. A drainage system is therefore provided for the jointing chambers within the duct system. Jointing chamber no 134, converted in April

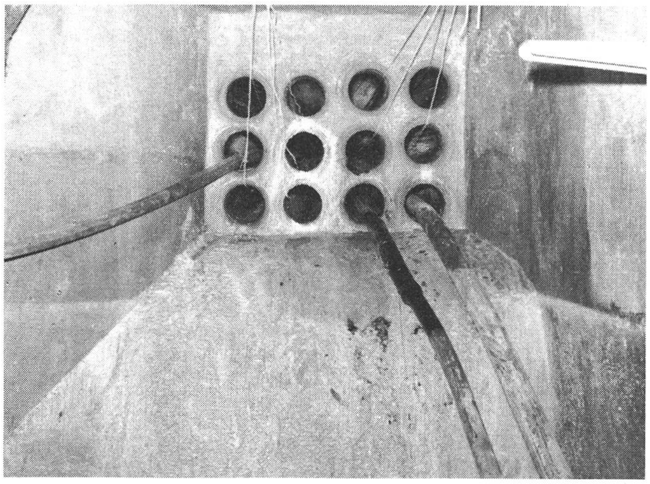

Fig. 1
Multiway duct at Auvernier, site of fault
Water is entering the jointing chamber chiefly through the lower joint between the multiway duct and the concrete inlet funnel. Thick layers of lime sediment have been deposited on the arch of the funnel. The area of greater thickness, painted black, shows where the corroded lead sheath had to be mended

1970 for the duct installation, nevertheless temporarily contained so much water that it could drain off through the lowest row of ducts of the twelve-duct block into the next jointing chamber in the direction of Colombier which is located at a lower level. At the time of inspection the jointing chamber had been largely emptied of water. The maximum water level could however be clearly determined from the marks remaining on the chamber walls. We were informed that the drainage system in this jointing chamber had failed because the outlet pipe had been blocked by extraordinary mud deposits. Although the jointing chamber had been cleaned, considerable amounts of fine lime sediment could again be seen on the floor. Thick crusts of precipitated material had been deposited particularly on the lower arch of the concrete inlet funnel through which the cables enter the jointing chamber from the direction of Neuchâtel as is shown in *Figure 1.* It was quite obvious that the water which flows over the funnel arch in large amounts enters the jointing chamber mainly through the lower connection joint between the inlet funnel and the multiway duct. However, some of the water enters the jointing chamber via the plastics tubes. As can be seen from Figure 1, only three of the 12 ducts are occupied by one cable each. Illumination of the individual ducts allowed inspection to a depth of approximately 3 m, revealing that only five of the 12 duct pipes were dry and free of sediment while six contained, as far as it was possible to see, a white, wet deposit with a small stream of water trickling along. In the case of one duct pipe, sediment had been deposited at the inlet only. Some of the ducts affected by sediment can be identified in Figure 1 by the white traces of the deposit.

While the cable from Neuchâtel to Areuse is located in a clean and dry duct (centre row, left) and therefore does not show any signs of corrosion, the ducts containing junction cable 20084 and long distance cable 20010 (bottom row, ducts 3 and 4) carry some water. The lead sheaths of these cables are affected by corrosion not so much in the region of the ducts as immediately after the duct outlet and particularly in where the cable sheaths

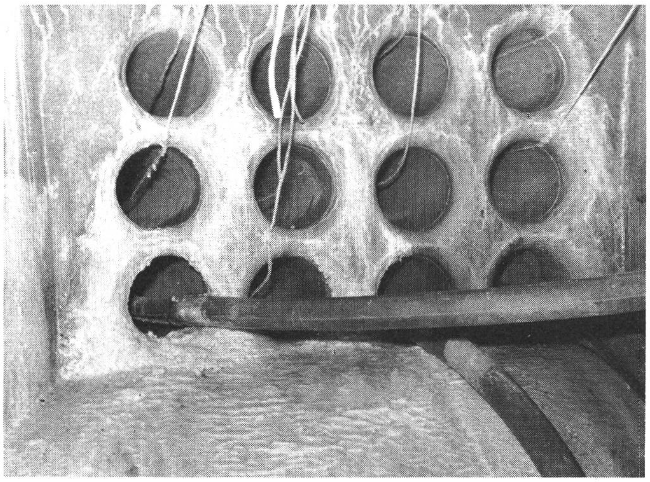

Fig. 2
Multiway duct at Auvernier
The white traces show that lime-precipitating water is penetrating through all the joints of a chamber adjacent to the site of the fault

rest on the arc of the concrete inlet funnel. The junction cable was corroded through at that point and had to be mended by means of a lead pipe insert. The lead sheath of the long distance cable is affected to a depth of approximately 1 mm at the area of contact with the inlet funnel but is not yet perforated. Slope pressure water has penetrated even into the three next following jointing chambers in the direction of Colombier where the terrain slopes gently. For example, *Figure 2* shows the entry of the ducts in one of these neighbouring jointing chambers. The white traces of lime deposit show that in this case water has seeped through all the connection joints between the multiway duct and the concrete inlet funnel and also between the plastics ducts and the surrounding concrete.

32 The plastics multiway duct system in the local network of Eschen

The lead sheath of a Type A cable was corroded through after a service life of only one year. The cable was pulled into the multiway duct system — completed in the autumn of 1969 — in June 1970. The corrosion damage was detected at the end of May 1971. The fault is located just before a bend in the duct (change of direction by 90°) which runs below the surface of a new road. The duct has not been uncovered for this reason and it is therefore not known whether it is damaged at this point or leaky for some other reason. In this case, the cable is not corroded in the region of entry into the jointing chamber but within a duct. No water has reached the duct from the jointing chamber. The leak is obviously located at the transition of the straight PVC pipe to the bent section consisting of soft polyethylene — at any rate, this is suggested by the location of the corrosion site on the cable sheath.

33 The plastics multiway duct system at Altdorf (JC 80056, Altdorf—Unterschächen)

The junction cable Altdorf—Unterschächen was pulled into the plastics multiway duct system at Altdorf as Cable Type A in 1969. Between jointing chambers no 7 and no 8, the duct sections, 191 m in length, traverse a valley. In December 1971, i. e. after less than three years, a fault appeared in the junction cable in the region of this valley. When the cable was removed, it was found that the cable sheath was corroded through at several closely spaced sites 68 m before the entry into jointing chamber no 8. The corrosion was limited to a site 2.5 m in length. No further corrosion sites could be found outside this short cable section. At the same time, it was observed that the cable sheath was wet within the corroded zone although the duct section was completely dry as far as could be seen from jointing chambers 7 and 8. In the region of this wet zone, the duct sections run below a tiled chamber. This suggests that, in this case also, the connection between a soft polyethylene insert piece and the PVC duct section is leaky.

34 The plastics multiway duct system at Arbon (JC 60139, Arbon—Romanshorn)

The section of the plastics multiway duct system being of interest here is located below the asphalt surface of a road running along a hillside with a gentle slope from the jointing chamber designated S. 67 in the direction of jointing chamber S. 66. The distance between the jointing chamber located at a higher level, S. 67, and the exchange is approximately 270 m. The length of the section S. 67/66 is 216 m. At a distance of 67 m from the jointing chamber closer to the exchange, i. e. S. 67, the junction cable passes through an intermediate manhole containing the distribution jointing of a 100-pair subscriber cable (SC), on which a fault resulting from breakdown due to corrosion had to be repaired.

The multiway duct system was completed about one year prior to pulling in the cables. The lead sheath of the subscriber cable, which is 2 mm thick, was corroded through within less than two years. *Figures 3* and *4* show the condition found in E. 6, the jointing chamber containing the fault, on 24. 8. 1972. The inlets of the duct

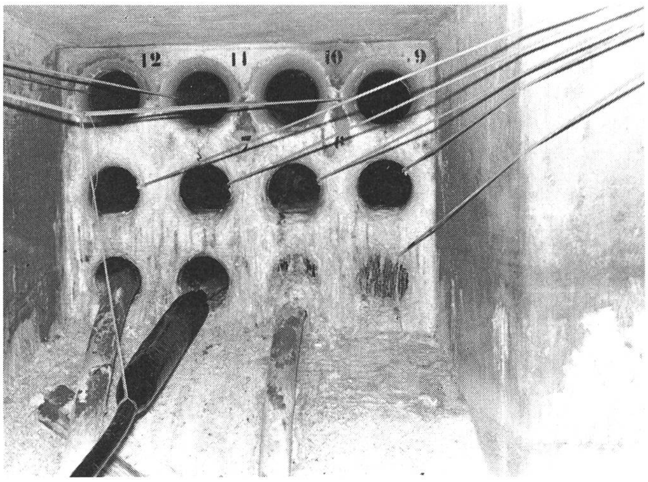

Fig. 3
Multiway duct at Arbon, site of fault
The front of the multiway duct is largely covered by a thick lime crust. In some places, stalactite-type structures have formed. Highly basic water is flowing into the jointing chamber between the layers of lime and in the stalactite tubules. All the cables are corroded at the point of contact with the arch of the concrete funnel. The area of increased thickness which is painted black shows where the corroded cable has been mended

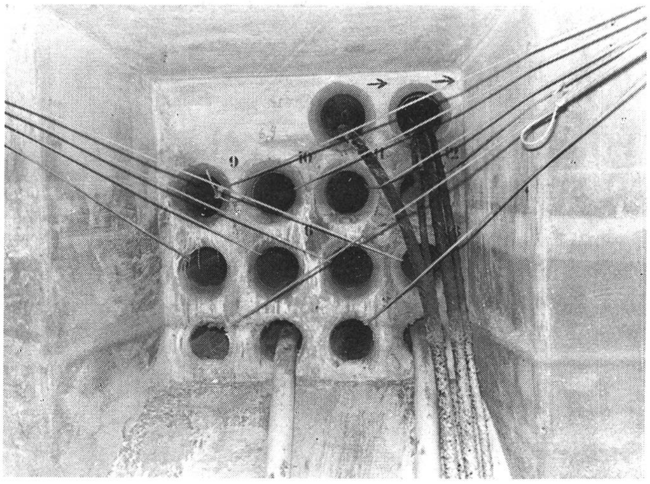

Fig. 4
Multiway duct at Arbon
At the multiway duct inlet opposite to the fault site, white traces of lime show that, at times, small quantities of water have seeped through between the plastics ducts and the concrete block. Lime sediment precipitated from the accumulated water in the jointing chamber due to atmospheric carbonic acid is deposited on the arch of the concrete funnel and on the cables

sections coming from the exchange are shown in Figure 3. Duct section 2 is occupied by junction cable 60139 St. Gall—Romanshorn. Duct sections 3 and 4 contain subscriber cables. The corrosion breakthrough at the 100-pair subscriber cable has been repaired by means of a lead pipe as can be seen from the illustration. The junction cable and an 800-pair subscriber cable pass through the opposite jointing chamber wall (Fig. 4) using the same duct section numbers as before, while the 100-pair subscriber cable is divided into four smaller Type B cables which leave the multiway duct system by two unnumbered outlets.

The first thing noticed on entering the jointing chamber was the extraordinarily large amount of deposits in the form of white crusts or yellow sediment. The floor of the jointing chamber was covered with water approximately 2 cm deep at the time of inspection. Level marks at the jointing chamber walls show however that the water had temporarily risen to the level of the duct inlets so that it was possible for water to flow through the duct sections into the adjacent jointing chamber, S. 66, which is located at a lower level. At least part of this water flowed in via the multiway duct inlet on the exchange side. This is proved by the stalactite-type lime deposits (Fig. 3). At the opposite wall, with the duct outlets towards jointing chamber S. 66, located at a lower level, no stalactites can be observed (Fig. 4). The only deposits to be found here are lime sediment on the rounded part of the concrete inlet funnel and on the cable bunches. The entire floor area of the jointing chamber is also covered by this yellowish, very fine sediment and the soakaway is blocked by sediment and crustaceous material.

If one breaks off the stalactites, clearly visible in *Figure 5,* one can observe that these are of the form of tubules and contain dripping water which, if tested by means of indicator paper, exhibits a considerably stronger alkaline reaction than the water flowing in the duct sections. Wiping off the stalactites revealed a «water spring». The hand in *Figure 6* points at this site from which approximately 0.25 l of water were obtained within about five minutes. The fact that water emerges between the plastics inlet funnels and the concrete in which they are packed is obvious from the opposite wall (Fig. 4) because it is only slightly encrusted so that one can see exactly how the white traces of eliminated lime emanate from the boundary line between the external surface of the plastics duct and the concrete.

Although the duct sections contain running water throughout between the intermediate manhole and jointing chamber no 66, the cables are not affected by deep corrosion at any point along this length but are merely covered by yellow lead oxide in some areas. The junction cable on the other hand had deep corrosion grooves on the support surface over about 2 m of its length at a distance of 16 m from the intermediate jointing chamber in the direction of jointing chamber S. 67; this could be seen after the cable had been pulled out.

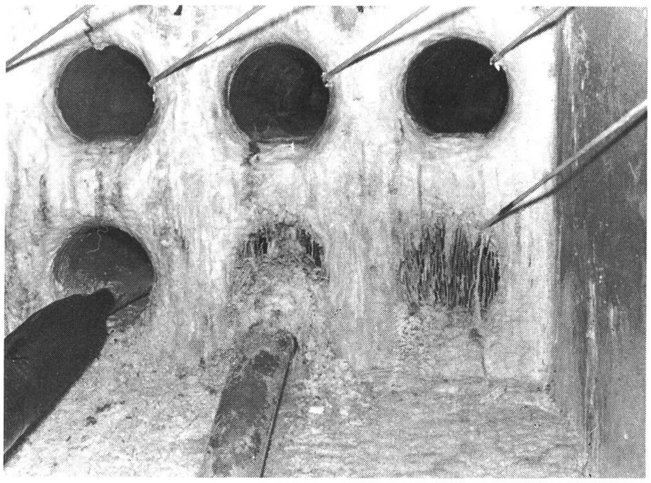

Fig. 5
Multiway duct at Arbon, fault site
Here, the thick lime crusts deposited round the plastics duct inlets can be recognized particularly clearly. Water-carrying stalactite-type lime tubules overhang two of the duct section inlets

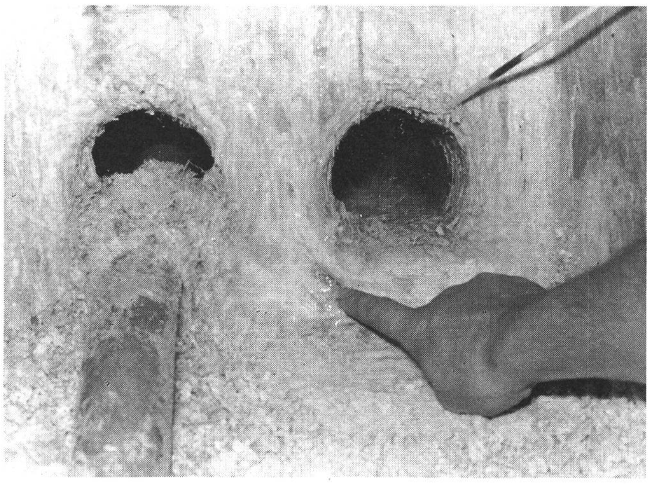

Fig. 6
Multiway duct at Arbon, fault site
The hand in this illustration points at a «water spring» which appeared when the stalactites had been wiped away. The highly basic water (pH 12.6) is emerging between the plastics inlet funnel and the concrete packing

Fig. 7
Multiway duct at Egnach
In this chamber, water has penetrated at the point where the steel profile has been set into the floor of the chamber, as can be seen from the lime crust formation

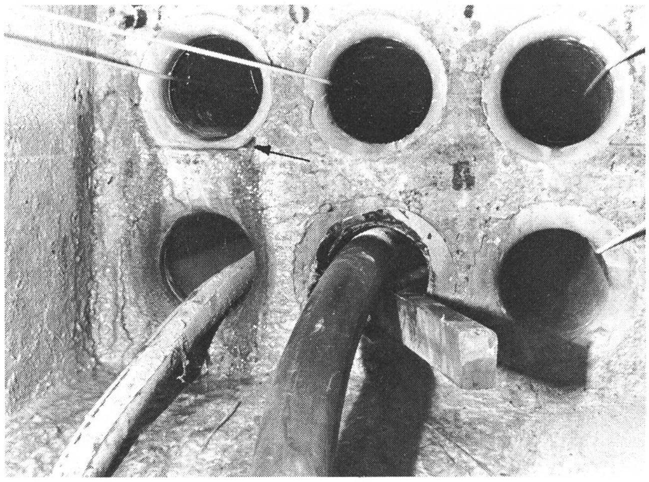

Fig. 9
Multiway duct at Egnach
In the same chamber as that shown in Figure 8 about 5 l of water per hour flow into the chamber at duct no 5 between the plastics tube and concrete packing (arrow)

35 The plastics multiway duct system at Egnach (JC 60139 Arbon—Romanshorn)

In 1974, it was found that the conditions existing in the 1400 m plastics multiway duct system at Egnach were similar to those found at Arbon two years earlier. The system, which has a capacity of eight ducts, extends over sections S. 81a to S. 88 of JC 60139 and passes through the village of Egnach along the right-hand side of the road in the direction of Romanshorn. The duct system begins at the perimeter of the village at jointing chamber S. 81a in manhole E. 50 and ends after the jointing chamber S. 88 in the intermediate manhole E. 38 between Egnach and Salmsach. It was possible to inspect a total of 13 manholes. Of these, 7 were filled with water to a greater or lesser extent, which had penetrated at various points. *Figure 7* illustrates an unusual phenomenon. Lime deposits show that in this case water has penetrated through the concrete where the galvanized steel profiles are set into the floor of the chamber. In another chamber we detected water break-throughs at several points in the concrete wall; 20 hours after the chamber had been pumped dry the floor was covered once more with water to a depth of 7 cm. This corresponds to a water inflow of about 20 litres per hour. *Figure 8* provides proof that water can break through massive concrete walls. Here, water is penetrating at a rate of about 2 l per hour at two points in the chamber wall. In addition, water is flowing at the rate of 5 l/h by capillary action between the plastics duct no 5 and the concrete in the same chamber, as is indicated in *Figure 9* (arrow). In spite of this, the cable fault in a subscriber cable did not occur in the area of the chamber inlet but instead 30 m inside the duct, where an obstacle had to be avoided by means of a soft polyethylene insert. In this installation, the bare lead sheaths had been protected two years previously against direct contact with water emerging at the vulnerable outlet points by means of polyethylene hose sections slit open and wrapped around the cable sheaths.

Fig. 8
Multiway duct at Egnach
In another chamber, strongly basic water penetrates the concrete at two points on a longitudinal wall — marked by two arrows in the Figure

36 Plastics multiway duct Wollerau—Freienbach (JC 70016, Pfäffikon—Richterswil)

At the end of 1974, a cable fault had to be cleared on the junction cable Pfäffikon—Richterswil. The fault occurred in the multiway duct Wollerau—Freienbach, which is about 4 km long, within the section 32/33. The affected cable length of 304 m had to be pulled out and exchanged because the leak site was located 12 m deep in the duct section. The plastics multiway duct had been constructed in 1968 as one of the first of this type and consists of eight — in places ten — ducts. In 1969 the JC 70016 had been pulled into duct no 2 as a Cable Type A, having an antimony alloyed (0.7 Sb) lead sheath of 2.1 mm thickness.

Of ten manholes inspected in March 1975, six contained water while three were completely flooded. Jointing chamber 32 was two thirds filled with water and it was observed after the chamber had been pumped out that the water ingress was occurring predominantly via the ventilation pipe. In chamber 29 also, which was filled with water to the level of the lower row of ducts, the water entered mainly through the ventilation pipe. Level marks and lime sediments on the walls and in the upper ducts show that an even higher water level prevailed for a sometime. A particularly gross example of lime deposits produced by water seepage was encountered in chamber 28 where the water had spread and rippled down over the whole width of the concrete inlet funnel and formed centimetre thick lime crusts so that the cable resting on the funnel was virtually petrified as can be seen in *Figure 10.*

There were certain differences in this case compared to the cases described previously. Thus the leak occurred after almost six years of operation and not in the first one to three years. The cable sheath consisted of 0.7 pc antimony alloyed lead and not of pure lead or tellurium lead (0.04 pc Te) as in the other cases. Finally, the corrosion did not occur in locally limited deep grooves or craters but in the form of planar removal of material and the formation of thick crusts of red lead oxide until a rupture eventually occurred in the region of the seam of the cable sheath.

(to be continued)

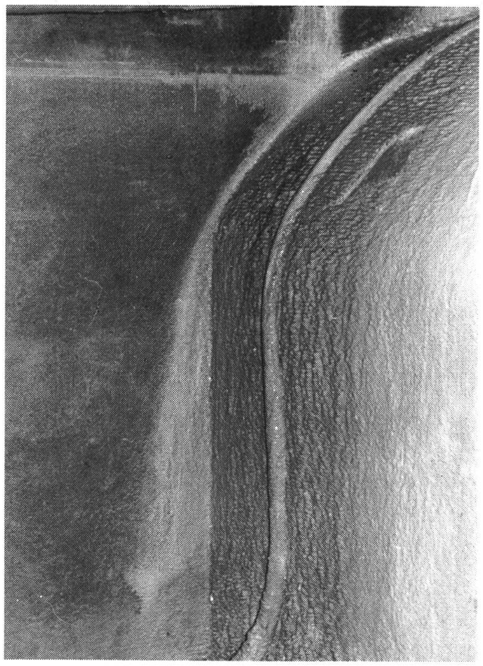

Fig. 10
Multiway duct at Wollerau
In this chamber strongly basic water flows into the chamber distributed over the full width of the concrete inlet funnel so that the precipitating lime crust has virtually petrified the cable resting on the funnel