8 TECHNICAL MEETING
TEGNIESE VERGADERING

THE ASSOCIATION OF MUNICIPAL ELECTRICITY UNDERTAKINGS OF SOUTH AFRICA
DIE VERENIGING VAN MUNISIPALE ELEKTRISITEITSONDERNEMINGS VAN SUID-AFRIKA

FIAT LUX

6 — 7 May 1980
6 — 7 Mei 1980

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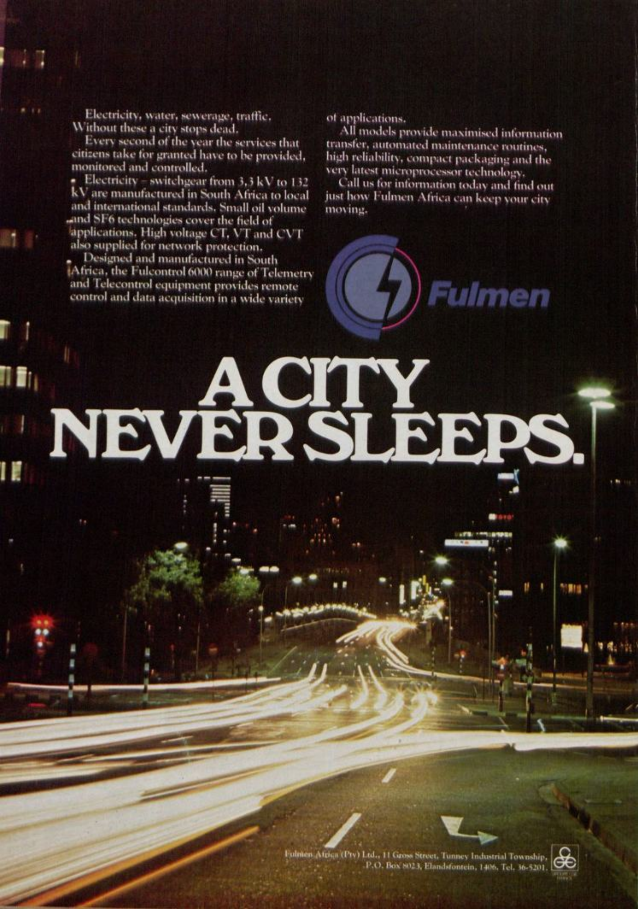
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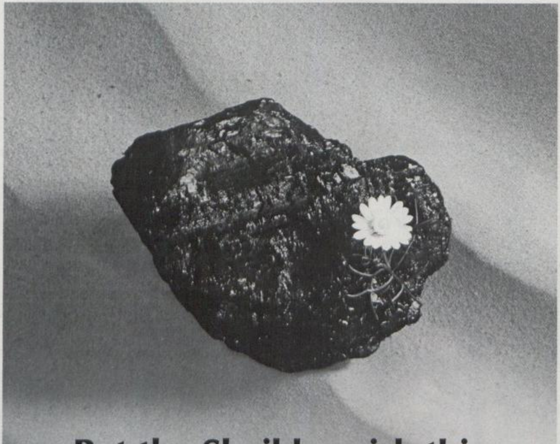

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PROCEEDINGS
8TH TECHNICAL MEETING
6—7 MAY 1980

VERRIGTINGE
8STE TEGNIESE VERGADERING
6—7MEI 1980

The Rev. A. Pelser opened the proceedings with scripture reading and prayer
Ds. A. Pelser het die verrigtinge geopen met skriflesing en gebed

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Engineers	65	Ingenieurs
Associates	17	Geassosieerdes
Local Authorities	12	Plaaslike Besture
Affiliates	93	Geaffilieerdes
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MAY — MEI 1980

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AMPTELIKE OPENING/OFFICIAL OPENING

Mnr. Piet Botes, President, verwelkom die afgevaardigdes.

Mnr. P. J. Botes: President

Sy Agbare die Burgemeester, raadslid W. ODENDAAL en mev. Odendaal, Raadslede, erelede, gaste, dames en here, dit is vir my 'n groot eer om u almal hartlik welkom te heet by die 8ste Tegniese Vergadering van die Vereniging van Munisipale Elektrisiteitsondernemings van Suid-Afrika hier in die groot stad Welkom.

As you no doubt will recall the first technical meeting of this association was held in Bloemfontein in 1966, and this meeting is the first time since 1966 that the Association set foot on the Free State soil.

Mr. Mayor we are pleased to be in the Free State again after an altogether too long absence of 14 years and we are also pleased to hold this meeting here in this progressive city of yours. We wish to thank you for extending the invitation to hold this meeting here.

Dit is vir my nou 'n groot voorreg om sy agbare die Burgemeester, Raadslid ODENDAAL te vra om die 8ste Tegniese Vergadering van die VMEO te open.

It is with pleasure that I now call on His Worship, the Mayor, Councillor Odendaal to open this the 8th Technical Meeting of the AMEU.

WELCOME ADDRESS BY THE MAYOR OF WELKOM COUNCILLOR W. A. ODENDAAL

Sy Agbare, die Burgemeester, Rld. W. Odendaal.

Mr. President, Councillors, Electrical Engineers and other delegates, Ladies and Gentlemen, it is my wish to bid you all a very hearty welcome to our City. CB Radios' nickname for Welkom is Circle City. I hope you have encountered a few negotiable circles on your way to the City Hall.

Dit is die eerste keer dat 'n Tegniese Vergadering hier aangebied word en ons is geëerd om soveel van u hier in ons midde te hê, en ek wens julle namens my Raad 'n aangename verblyf in Welkom toe.

Welkom is 'n unieke Stad in baie opsigte. Ons is sowat 30 jaar oud en volgens vorige ingeligtes en ekonome (ons noem hulle doemprofete) sou ons net 'n bestaan van 25 jaar beleef het. Uitbreidings aan bestaande myne en ontwikkeling aan nuwe myne oor 'n periode van 5 jaar sal meer as 1 000 miljoen Rand bedra. Die ingeligtes is nou bang om verdere voorspellings oor ons toekoms te waag. Met 'n bouprogram wat in 1979 R42 miljoen Rand beloop het, (hierdie tendens duur steeds voort) is ons as Raad en inwoners baie optimisties oor die toekoms van Welkom.

Wat ons elektrisiteitverspreiding betref mag u opgemerk het dat ons geen oorhoofse kabels het nie. Ons maak ook ten volle van ons elektrisiteit gebruik. Elke elektriese rekening wat die inwoners ontvang is 'n geweldige skok vir hulle. Die skok is gratis. Welkom verwag in die huidige boekjaar meer as R10 miljoen Rand inkomste uit elektrisiteit.

Few people realize the vast activities associated with the mining industry. To take electricity as an example. The maximum demand of the smallest mine in our area is the same as that of Welkom. That is 60 Mw per month. The figure for Free State Geduld Mine is between 90 to 110 Mw per month; that is an electricity account of approximately 1 to 2 million Rand per month.

Namens die Stadsraad en al die inwoners van Welkom moet u ons gasvryheid geniet. Mag die referate julle die nodige rus verskaf . . . ons sal julle besig hou. Waar ons vanaand op informele wyse gaan braai, wil ek noual almal daar welkom heet en u verseker dat u spysvertering nie daar deur 'n enkele woord van my kant af vertroebel sal word nie.

Once again may you enjoy your stay in our Vrystaatdorpie and remember that tonight you should eat and drink wisely but not too well and at your conference talk well but not too wisely.

With these words I now declare this 8th Technical Meeting as officially opened.


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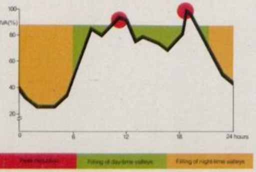

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The cost of power will rise in proportion to capital expenditure requirements – and this capital will be raised locally to an ever increasing extent.

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An electricity network is like a hi-fi system – the flatter the curve the better the response.
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To Brown Boveri this means designing a ripple control system that:
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- is compatible with higher level control systems.

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- traffic light control
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Studies have shown that a ripple control system will:
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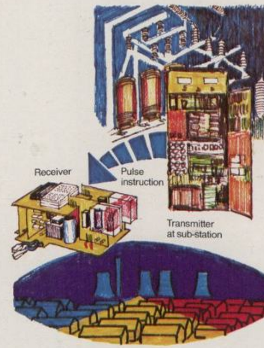

Controller monitors demand continuously. When peak level approaches, transmitter emits pulse-instruction to receiver. Receiver interrupts selected services. When demand falls below peak level, transmitter sends pulse-instruction to receiver to reinstate services.

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Mnr. P. J. Botes: President

U Agbare, die Burgemeester, dames en here, graag wil ek Ds. Pelser bedank vir die treffende wyse waarop hy ons voorgegaan het met skriflesing en gebed.

Mnr. die Burgemeester, baie dankie vir u vriendelike verwelkoming, asook vir die opening van hierdie verrigtinge. Die van u wat teenwoordig was met die opening van die konvensie in die Randse Afrikaanse Universiteit, sal onthou hoe liries ek geraak het oor die grootmanne wat skoolopleiding op die dorpie Vrede, in die O.V.S., geniet het. Ongelukkig moet ek u weer daaraan herinner, want u mnr. die Burgemeester, of Billy, soos ek hom op skool geken het, kom ook van daardie skool. Dit is dus vir my 'n nog groter eer om vandag hier saam met u op te tree.

As ons kyk na dit wat reeds hier vir ons voorgesit is, na die pragtige saal, dan wil dit my voorkom asof hierdie tegniese vergadering ook een van die hoogtepunte in die gebied van die VMEO sal wees.

Dit was vir my 'n besondere voorreg om verlede jaar die takvergadering van die Oos-Kaap-tak te Queenstown te kon bywoon. Die hoofstraat in Queenstown is baie breed, en daar is melding gemaak dat die breedte bepaal is volgens die grootte van die draai van 'n ossewa met 'n span osse. Nou wonder ons of u ook hierdie maatstaf gebruik het in u jong stad, maar ek dink die Queenstowners wat vandag hier is, het seker nie verwag dat hulle maatstaf so maklik oortref kan word nie. Ek is uiters beïndruk met u breë strate, dit gee 'n besondere atmosfeer aan u stad, en die feit dat hier in u stad nie verkeersligte is nie, nog meer so. As oud-Vrystater, mnr. die Burgemeester, weet ek dat die afgevaardigdes die Vrystaatse gasvryheid oorweldigend sal vind. Ons sien uit na die reëlings vir 'n braai, wat u vir ons gereël het.

Mnr. Botha, my innige dank vir die reëlings wat u getref het vir hierdie vergadering en die sosiale funksies. My dank ook aan die Stadsklerk, mnr. Van Zyl, asook aan mnr. R. F. Davidson van die kantoor van die Provinsiale Sekretaris van die Provinsie Oranje-Vrystaat, wie vandag hier teenwoordig is; aan hom en mnr. Haasbroek, Direkteur van Plaaslike Bestuur, my innige dank vir die bekendstelling van die vergadering.

Soos u moontlik reeds weet, gaan hier vandag ook geskiedenis gemaak word, want onmiddellik na afsluiting van die verrigtinge vanmiddag, sal nog 'n streektak van die VMEO gestig word. Dit is 'n groot stap vorentoe, want dit beteken dat kleiner dorpe in die Vrystaat, wat miskien nie die voorreg het om konvensies en tegniese vergaderings te kan bywoon nie, vergaderings van die streektak sal kan bywoon en dus ook voordeel trek uit die kennis wat aldus aan hulle oorgedra kan word.

Sedert die laaste konvensie, het die dood van 2 persone onder my aandag gekom. Dié van mevrou dr. Strazacker, wat gereeld die VMEO saam met die dames bygewoon het, prof. Reuter, 'n klasmaat van my, en dekaan van die fakulteit van ingenieurswese en wat die VMEO by geleenthede bygewoon het, is skielik aan die begin van die jaar oorlede. Ek vra u om 'n paar oomblikke te staan om ons medelye te betoon.

May I ask all the honorary members and past presidents present here today to stand up, in order that we may greet them and see who they are.

The good lady of our President Elect, Mr. Jennis Frazer, is not with us, as she is recuperating after an operation.

Ons vertrou dat sy gou gesond sal word. Dra asseblief ons groete oor aan haar.

We are pleased to have so many honorary members, and past presidents with us, and we welcome you all here today.

I wish to record my thanks to our Secretary, Mr. Bennie van der Walt, for the organising of this meeting. We accept your work for granted, but there is a lot of hard work involved. Thank you Bennie.

May I draw your attention to the revised official programme: You will note that the paper scheduled for Wednesday morning, viz: "Groundline inspection and treatment service for electric transmission and streetlighting poles", is deleted from the programme and the whole day will be spent on the members' forum only.

REFERAAT 09h30 PAPER

GEVULKANISEERDE POLIËTILEEN-GEÏSOLEERDE ELEKTRIESE KABELS VIR KRAGVERSPREIDING

deur H. F. FORSYTH, B.Sc., M.I.E.R.E., M.S.A.I.E.E.

CROSS-LINKED POLYTHENE INSULATED CABLES FOR ELECTRICAL POWER DISTRIBUTION

by H. F. FORSYTH, B.Sc., M.I.E.R.E., M.S.A.I.E.E.

REFERENT

Mnr. D. H. Forsyth Tegniese Bestuurder, African Cables

SPEAKER

Mr. D. H. Forsyth Technical Manager, African Cables

INLEIDING

Gevulkaniseerde poliëtileen (GPE) kabels is reeds vir sowat tien jaar in Suid-Afrika vervaardig en gebruik, en oorsese ondervinding strek oor ten minste tweemaal hierdie tydperk. Gedurende hierdie tyd is heelwat ondervinding beide in Suid-Afrika en oorsee opgedoen en baie inligting is gepubliseer (en selfs meer geskryf) oor die ontwerp en werkverrigting van kabels met uitgepersde isolering in verskillende spanningsreekse.

INTRODUCTION

Cross-linked polythene (XLPE) cables have been manufactured and used in South Africa for over ten years and overseas experience extends for at least twice that length of time. During this period a considerable amount of experience has been built up both locally and overseas, and much information has been published on design and performance of extruded dielectric cables in different voltage ranges.

Heelwat gepubliseerde inligting staan in verband met laboratorium-bereide monsters en sommige instansies mag dus die toepaslikheid op kabels bevraagteken.

Die afgelope twee jaar is daar gewerk op 'n Suid-Afrikaanse nasionale standaard vir 6,6 tot 33 kV GPE-kabels en met dié skrywe is dit byna voltooi.

Hopelik sal die publikasie van hierdie nasionale standaard stu-krag gee aan die gebruik van GPE-kabels in Suid-Afrika. Hierdie referaat trag om 'n oorsig van die huidige tegnologie te gee sodat gebruikers meer realisties die geldigheid van die nasionale standaard kan vasstel en ook miskien rigting kan kry met die keuse van kabelkonstruksies geskik vir hulle gebruik.

DIËLEKTRIESE STELSEL

Die hoof komponent in enige kabel is wesentlik die diëlektriese-stelsel en daarom is dit paslik om die bespreking te begin met diëlektriese oorwegings. Hulle effek op ander kabelkomponente kan dan logies ontwikkel word.

ONTWERP-OORWEGINGS

Die isoleringsdikte is die eerste ontwerpbeslissing en ekonomiese oorwegings vereis dat dit dun moet wees in ooreenstemming met genoegsame lewensverwagting. Aangesien die lewensverwagting ooreenkom met 'n maksimum diëelektriese spanningspeil, wil teorie hê dat isoleringsdikte bereken word ooreenkomstig 'n uitverkose ontwerp-spanningspeil. Meganiese oorwegings dra egter ook by, en is oorheersend by lae spannings. Isoleringsdiktes by laer spannings neem gevolglik toe met leiergroote en werk teen betreklik lae diëlektriese spannings; selfs in die geval van die kleinste geleiers. Elektriese oorwegings speel egter 'n al groter rol met toename in kenspannings. Dit is internasionaal gebruiklik dat vir die spanningsreeks tot en met 33 kV, isoleringsdikte vir die kleinste aanbevole geleier bepaal word en dat dit gebruik word vir die reeks geleiergroottes. Slegs vir superspanningskabels word die isoleringsdiktes bepaal suiwer volgens diëlektriese spanningspeil.

Tabel 1 dui aanbevole isoleringsdiktes aan vir GPE-kabels in die erkende kenspannings tussen 1 000 V en 33 kV

Much of the published information relates to laboratory prepared samples and not to actual cable samples and some people may therefore question its relevance.

For something over two years now work has been proceeding on preparation of a South African national standard for XLPE cables in the voltage range 6,6 to 33 kV and at the time of writing this is nearing finality.

It is to be hoped that publication of this national standard will give more impetus to the use of XLPE cables in South Africa and this paper attempts to review the "state of the art" in order that users may more realistically assess the validity of this national standard and perhaps be guided in selecting the cable construction best suited to their requirements.

DIELECTRIC SYSTEM

The heart of any cable construction is essentially the dielectric system and it is convenient therefore to commence this discussion with dielectric considerations. The effect of these on other cable components can then be logically developed.

DESIGN CONSIDERATIONS

A major design decision relates to thickness of insulation and economic considerations demand that this should be as small as is consistent with satisfactory life expectancy. Since life expectancy is related to stress level, theory suggests that thickness of insulation should be calculated to conform to a selected design stress level. However mechanical considerations also play their part and at low voltages these are predominant — thus, at the lower voltages, thickness of insulation increases with conductor size and even on the smallest conductor sizes cables operate at relatively low electrical stress levels. As the rated voltage increases electrical considerations play an increasing part. However it is international practice in the voltage ranges up to and including 33 kV that electrical considerations only determine the thickness of insulation on the smallest recommended conductor size and this thickness is then maintained through the range of conductor sizes. It is only in supertension cables that thicknesses of insulation are determined purely by stress levels. Table 1 gives the recommended thicknesses of insulation for XLPE cables in the recognised voltage ranges from 1 000 V to 33 kV.

TABEL 1 TABLE 1

Conductor Size Geleier-grootte mm^2	Thickness of XLPE at Rated Voltage (kV) * Isoleringsdikte by Kenspanning, (kV) *					
	0,6/1,0	1,9/3,3	3,8/6,6	6,35/11	12,7/22	19/33
1,5	0,7	—	—	—	—	—
2,5	0,7	—	—	—	—	—
4	0,7	—	—	—	—	—
6	0,7	—	—	—	—	—
10	0,7	2,0	2,5	—	—	—
16	0,7	2,0	2,5	3,4	—	—
25	0,9	2,0	2,5	3,4	—	—
35	0,9	2,0	2,5	3,4	5,5	—
50	1,0	2,0	2,5	3,4	5,5	8,0
70	1,1	2,0	2,5	3,4	5,5	8,0
95	1,1	2,0	2,5	3,4	5,5	8,0
120	1,2	2,0	2,5	3,4	5,5	8,0
150	1,4	2,0	2,5	3,4	5,5	8,0
185	1,6	2,0	2,5	3,4	5,5	8,0
240	1,7	2,0	2,6	3,4	5,5	8,0
300	1,8	2,0	2,8	3,4	5,5	8,0
400	2,0	2,0	3,0	3,4	5,5	8,0
500	2,2	2,2	3,2	3,4	5,5	8,0
630	2,4	2,4	3,2	3,4	5,5	8,0
800	2,6	2,6	3,2	3,4	5,5	8,0
1 000	2,8	2,8	3,2	3,4	5,5	8,00

LW Klein geleiers, waar daar nie isoleringsdiktes vir sekere spannings getoon word nie, word nie aanbeveel nie. As kleiner geleiers egter noodsaaklik is, moet of die geleierdeursnee vergroot word met 'n dikker semi-geleidende skerm of die isoleringsdikte (of albei) sodat die maksimum diëlektriese spanningspeil beperk word tot die waarde bereken vir die kleinste aanbebole grootte.

* Suid-Afrikaanse standaarde.

NB Conductor sizes smaller than those for which thicknesses are quoted in each voltage range are not recommended. However if a smaller conductor is necessary either the conductor diameter must be increased by a thicker semi-conducting screen or the insulation thickness increased (or both) so that the maximum stress level is limited to the value calculated for the smallest recommended conductor size.

* System voltages quoted are to South African Standards.

Die tabel illustreer die stellings so pas gemaak. Die 600/1 000 V isoleringsdiktes is suiwer volgens meganiese oorwegings bepaal. By 1,9/3,3 kV bepaal elektriese oorwegings die isoleringsdiktes vir die kleinste aanbevole geleier, terwyl meganiese oorwegings van toepassing is op groter geleiers.

Let wel dat, vanaf 400 mm^2 en groter, 660/1 000 V en 1,9/3,3 kV diktes identies is.

This table illustrates the points just made. In the 600/1 000 volt range thickness of insulation is determined purely by mechanical considerations. At 1,9/3,3 kV electrical considerations determine thickness of insulation on the smallest recommended conductor size but mechanical considerations apply to the larger conductor sizes. Note that from 400 mm^2 upwards the 600/1 000 V and 1,9/3,3 kV thicknesses are identical. From 6,35/11 to 19/33 kV thickness of insulation is deter-

Die ontwerp-diëlektriese spanningspeil, vir die kleinste aanbevole geleier, bepaal die isoleringsdikte vanaf 6,35/11 kV tot 19/33 kV; en word behou vir al die geleiers in die reeks.

Daar is gou besef dat, om die diëlektriese spanningspeil te beheer in hoogspanningskabels, 'n radikale-veldkabel nodig was wat die gebruik van aarskerms genoodsaak het. Metaalbande aangebring direk oor die isolering was nie 'n oplossing nie, aangesien die skerp kante teen die oppervlak van die isolering en luggevulde blasies onder die band, inherente diëlektriese spanningsverhogings gevorm het. Die buitelyn van stringgeleiers, selfs as hulle saamgepers is, veroorsaak ook konsentrasie van die elektriese veld in die binne-oppervlakte van die isolering. Die probleem is om noue en permanente kontak met 'n gladde tussenvlak te handhaaf tussen die binne en buite oppervlakke van die uitgepersde GPE en die metaalkomponente wat bepaal wat die spanning sal wees wat die diëlektrikum verwag word om onder werkstoestande te weerstaan.

Die voorsiening van 'n buigbare laag van halfgeleidende materiaal tussen die geleier en die oppervlak van die isolering (die geleierskerm) en tussen die buite oppervlak van die isolering en die metaalomhulsel van die kabel (die aarskerm), bied 'n oplossing vir dié probleem. Hierdie skerms is aanvanklik voorsien in die vorm van half-geleidende bande wat vervaardig is deur nylon- of katoenweefstof te impregneer met 'n buigsame semi-geleidende materiaal. Los veselpunte wat ontstaan het tydens die sny van die band kon ongelukkig diëlektriese spanningsverhogers vorm en dus 'n vermindering in die kabel-leeftyd veroorsaak.

Moderne praktyk is gevolglik die voorsiening van 'n reëlmatige oppervlak tussen die geleier en die isolering deur die halfgeleidende materiaal saam met die isolering uit te pers. In die geval van aarskerms word dit voorsien deur middel van 'n uitgepersde halfgeleidende laag direk oor die isolering. Andersins kan dit in die vorm van 'n halfgeleidende vernis saam met 'n ontwikkelde halfgeleidende band wees (die vernis bewerkstellig die noue kontak met die isolering terwyl die band die vernislaag beskerm teen beskadiging). Waar uitgepersde skerms gebruik word, is dit ideaal as al drie lae saam uitgepers word (nl. die drielaag-uitpersing van die geleierskerm, isolering en aarskerm). Goeie resultate kan egter verkry word deur die twee-gang proses (geleierskerm en isolering saam uitgepers en die aarskerm afsonderlik aangebring).

By stelselspannings groter as 3,3 kV is ten volle afgeskermde diëlektriese stelsels nodig. Isoleringsdiktes aangedui in tabel 1 vir 3,8/6 kV tot 19/33 kV-kabels neem hierdie stipulasie in ag.

Fig. 1 toon grafies die berekende diëlektriese spanningspeile wat van toepassing is op elke geleiergrootte waarvoor 'n isoleringsdikte getabuleer is. Voordat die betekenis van fig. 1 bespreek word, is dit egter nodig om die benaderinggebruik vir die berekening van die spanningspeile, te verduidelik. Al die berekenings veronderstel ronde geleiers.

"Denkbeeldige" geleiersdeursneë is gebruik naamlik dié vab 'n soliede ronde geleier. Hiérdie is waarskynlik kleiner as wat selfs met saamgeperste gestringde geleiers verkry word en is dus 'n voorstelling van die "slegste toestand".

'n Een mm deursnee-toename is toegelaat vir die geleierskerm in gevalle waar skerms voorgeskryf word. Hiérdie kan ook beskou word as die "slegste toestand".

Die berekende diëlektriese spanningspeile is van toepassing op die binne-oppervlakke van die isolering — die gebied waar die maksimum spanningspeil in 'n ideale kabel ontwikkel word.

Daar sal gelet word dat die afgeskermde konstruksie in die figuur 'n band van spanningspeile het vir stelselspannings vanaf 6,6 kV tot 33 kV.

Die onderste kant of hoogste perk van elke band toon berekende spanningspeile van toepassing op 'n volkome konsentriese kabel met die bepaalde minimum-gemiddelde isoleringsdikte. Die bokant of boonste perk van die band stel die vermeerderde spanningspeile voor wat verwag kan word wanneer die vervaardiger ten vo-le gebruik maak van die toleransie toegelaat; dus in hierdie geval is die isolering eksentries aangewend sodat die minimumdikte by 'n punt 90% onder die minimum-gemiddelde waarde val, minus 'n verdere 0,1 mm. In die praktyk kan geen vervaardiger egter bekostig om by 'n gemiddelde dikte te werk gelyk aan die vasgestelde minimum-gemiddelde nie. 'n Sekere vervaardigingstoleransie op die deursnee sal bygevoeg word, afhangende van die mate waarmee die deursnee beheer kan word. Eksentrisiteit word ook beheer in die praktyk en die minimum dikte-by-'n-punt sal selde die absolute minimum bereik wat toegelaat is. Berekende spanningspeile in werklike kabels sal waarskynlik as gevolg daarvan laer wees as wat in die figuur getoon word.

Die enkel-lyn grafieke vir spanningspeile by 1,1 kV en 3,3 kV is slegs van akademiese waarde aangesien dit nie in die praktyk voorkom nie. By hierdie spannings word geen skerms gebruik nie en die spanningspeile is slegs van toepassing op die spesiale geval waar soliede ronde geïsoleerde geleiers in water getoets word of wanneer 'n buite-elektrode op een of ander manier voorsien en in kontak met die isolering gebring word.

In die praktiese geval van 'n veelaarkabel, byvoorbeeld, sal die werklike spanning aangewend oor die isolering, laer wees, met 'n gevolglike vermindering in spanningspeile. Die nie-radiale veld sal die spannings-

mined by design stress level on the smallest recommended conductor sizes and this thickness is maintained throughout the range of conductor sizes.

To control stress levels it was early appreciated that at the higher voltage ranges the use of radial field cables would be necessary, thus requiring the provision of a core screen. Metallic tapes applied directly over the insulation were not the answer since these inherently provide stress raising components in the form of air filled voids and sharp edges at the surface of the insulation. Furthermore the profile of stranded conductors, even when compacted, also results in regions of stress concentration at the inner surface. The problem is to ensure that intimate and permanent contact with a smooth interface is maintained between the inner and outer surfaces of the extruded XLPE insulation and the metallic components which define the voltage which the dielectric is required to withstand under service conditions. The solution to the problem lies in providing a pliable semi-conducting layer of material between the conductor and the inner surface of the dielectric (the conductor screen) and between the outer surface of the insulation and the metallic enclosure of the cable (the core screen). Initially these screens were provided in the form of semi-conducting tapes produced by impregnating a nylon or cotton woven fabric with a pliable semi-conducting compound. Unfortunately loose fibre ends arising in the tape-slitting operation can act as stress raisers with consequent reduction in cable life. As a result modern practice is to provide the smooth interface between conductor and insulation in the form of a co-extruded layer of semi-conducting material under the insulation. In the case of core screens these are provided either in the form of an extruded semi-conducting layer immediately over the insulation or in the form of a semi-conducting varnish with a lapped semi-conducting tape, (the varnish provides the intimate contact with the insulation surface and the tape inhibits damage to the varnish layer). Where extruded core screens are used it is ideal if all three layers (conductor screen, insulation and core screen) are co-extruded (i.e. three layer extrusion). However good results can be achieved with two-pass processes (conductor screen and insulation xo-extruded with core screen applied in a separate operation) provided the necessary care and attention to detail is exercised. At system voltages greater than 3,3 kV fully screened dielectric systems are necessary and the thicknesses of insulation quoted in Table 1 for cables in the voltage ranges from 3,8/6,6 kV to 19/33 kV take this stipulation into account.

What do the thicknesses of insulation in Table 1 mean in terms of design stress levels? Figure 1 shows graphically the calculated stress levels applicable to each conductor size for which a thickness is tabulated. Before discussing the implications of this figure, it is necessary to clarify the approach to the calculation of these stress levels.

All calculations are made on the assumption of circular conductors.

Diameters of conductors are "fictitious diameters" — the diameter of a solid circular conductor. These are smaller than what is likely to be achieved in practice with stranded conductors even when compacted, and thus represent a "worst Condition".

An allowance of 1 mm diameter increase to allow for the conductor screen has been taken into account in the cases where screening is stipulated. This also can be taken as a "worst condition".

The stress levels calculated are those applicable at the inner surface of the insulation — the region where maximum stress is developed in the ideal cable.

Now looking at the figure itself it will be noted that the screened constructions have a band of stress levels plotted for each system voltage from 6,6 kV to 33 kV. The bottom edge or lower limit of each band represents calculated stress level applicable to a perfectly concentric cable with the stipulated minimum average thickness of insulation. The top edge or upper limit of the band represents the increased stress level to be expected if the manufacturer makes full use of permitted tolerances and the insulation is applied eccentrically with the minimum thickness at a point falling to 90% stipulated minimum average less a further 0,1 mm. In practice no manufacturer can afford to work to a mean thickness equal to a stipulated minimum average but will add a certain manufacturing tolerance on diameter depending on the degree to which he can control actual diameters. In practice eccentricity is also carefully controlled and minimum thickness at a point will seldom fall to the absolute minimum allowed. Consequently calculated stress levels on actual cables are likely to be rather lower than shown in this figure. The single line graphs of stress levels for 1,1 kV and 3,3 kV systems are of rather academic interest as they do not in fact represent a practical case. Since at these voltages no screening is used, these stress levels can only be regarded as applicable to the special case of solid circular insulated conductors tested in water or by some other means providing an electrode in contact with the outer surface of the insulation. In the practical case of a multicore cable for example the actual voltage applied across the insulation will be reduced thus reducing stress levels but the non-radial field configuration will enhance stress levels in certain regions. Furthermore the effect of the strand profile in the case of stranded conductors will also contribute to stress enhancement. This combination of factors will probably result in maximum stress levels appreciably greater than those represented in this figure — approximately peil egter in sekere gebiede verhoog. Die profiel van stringgeleiers sal ook bydra tot 'n verhoging in spanningspeil.

Hierdie kombinasie van faktore lei tot 'n maksimum spanningspeil vir 3,3 kV-kabels wat heelwat groter is as dié in die figuur; ongeveer gelyk aan die peile van toepassing op 6,6 kV-kabels.

Dit is paslik om die onderwerp van "boomvorming", wat met betrekking tot GPE genoem word, te bespreek voordat die betekenis van die spanningspeile verder ondersoek word.

In 'n onlangse referaat voor die IEE het Eichorn opgemerk dat dit nie 'n nuwe verskynsel is nie en dat honderde verwysings na bibliografie tot so ver terug as 1912 gemaak kan word. Navorsing en ondersoek in die meer onlangse jare op hierdie gebied blyk meer toegespits te wees op GPE, moontlik omdat dit toenemend gebruik word as 'n diëlektrikum en ook omdat "bome" makliker in 'n deursigtige materiaal waargeneem en in laboratoriums ondersoek kan word.

Daar word oor die algemeen saamgestem dat, onder toestande van hoë diëlektriese spanning, afbreking of erosie van die soliede organiese diëlektrikum kan plaasvind. As gevolg daarvan ontstaan "kanale" wat verleng of groei tot vorms soos dié van bome.

Drie basiese tipes boomvorms kan onderskei word — elektriese bome, waterbome en elektrochemiese bome.

Elektriese Bome

Fig. 2 illustreer die verskynsel van elektriese bome. Soos die naam aandui word hierdie beskou as geheel van al te wyte aan diëlektriese spanning. Eichorn[3] stel voor dat die redelikste teorie voorgehou oor die meganika waardeur elektriese bome begin, dié van elektroninspuiting is. Hierin word veronderstel dat elektrone vanaf skerp geleidende punte in die omringende diëlektrikum gestraal word tydens die negatiewe halfsiklus van die aangewende spanning. Sommige van die elektrone kry genoeg energie om ionisasie en gevolglik die afbreking van die diëlektrikum te veroorsaak. Uiteindelik lei dit tot 'n "leemte" in die diëlektrikum waarin gedeeltelike elektriese ontlading kan plaasvind. Deur erosie groei die leemte tot 'n kanaal wat lei tot 'n elektriese boom. Uiters hoë spanningspeile word vir hierdie effek benodig en dit is betekenisvol dat Ashcraft, Eichorn en Shaw[2] na laboratorium-ondersoeke rapporteer dat 'n spesiale skerpgemaakte elektrode (puntstraal minder as 2,5 micron) in hul toetsapparaat gebruik is. In welke geval 'n diëlektriese spanningspeil van 500 kV/mm volgens berekening ontstaan het. Onder hierdie toestand word bome binne minder as 'n uur in GPE-monsters gevorm.

Waterbome

Betreklik hoë spanningspeile, in die teenwoordigheid van water, word hier benodig om groei te begin. Hierdie peile is egter laer as wat nodig is om die groei van elektriese bome aan die gang te sit. Onder invloed van 'n hoë diëlektriese spanning, sal vogtigheid skynbaar die diëlektriese materiaal in 'n hoeveelheid fyn "are" binnedring en 'n "breuk" veroorsaak sonder om die materiaal af te breek. Waterbome lyk gevolglik minder skerp omlyn as elektriese bome. Eichorn[1] gee te kenne dat die hoë diëlektriese spanning, tesame met water, moontlik klein gedeeltelike ontladings by die boompunt veroorsaak. Gevolglik breek die water op in suurstof en waterstof. Dié vrystelling van gas vind plaas by 'n druk hoog genoeg om gelokaliseerde skade en gevolglik 'n verlenging van die aartjies te veroorsaak om sodoende 'n waterboom te vorm.

Verder, as die aangewende spanning en die bron van die vogtigheid verwyder word, sal die waterbome verdwyn nadat die monster toegelaat is om droog te word. Dit dui aan dat die "breuke" in die diëlektrikum van so 'n aard is dat die aartjies toemaak nadat die water in hulle versprei en verdamp het. Hierdie feit kompliseer die bestudering van waterbome maar die probleem kan oorbrug word deur die monster in 'n kleurstof te kook, wat dan die vorm van die boom bevestig.

Elektrochemiese Bome

Hierdie is in effek 'n spesiale vorm van 'n waterboom (met dieselfde groei-meganisme) waar die water ione van opgeloste stowwe bevat, wat as soute waargeneem word binne die diëlektrikum. Dit kan die bome permanent verkleur sodat hulle nie verdwyn met uitdroging nie.

Alle bewyse toon dat, watter boom dit ook al is, hul groei by punte van hoogste konsentrasie van elektriese veld begin. So 'n hoë veldkonsentrasie kan op die volgende maniere in die diëlektrikum van 'n kabel ontstaan:

- By 'n gebrek of growwigheid in die oppervlakke tussen die isolering en skerm.
- By enige besoedelende, geleidende deeltjie, gedeeltelik of algeheel ingesluit in die isolering.
- By enige besoedelende deeltjie met 'n permitiwiteit wat wesentlik verskil van dié van die isolering.
- By 'n leemte wat ontstaan het deur inkrimping binne die isolering of in die oppervlakke tussen die isolering en skerm.

Bo en behalwe hoë diëlektriese spanning is 'n verdere faktor in die groei van bome geleë in die mate van toegang tot lug, water en elektroliet waar elektriese veld-konsentrasies ontstaan binne die isolering. By 'n leemte of besoedeling, is daar slegs baie beperkte toegang tot boge-

to the levels applicable to 6,6 kV cables in the case of the 3,3 kV cables.

Before further considering the significance of these stress levels it is appropriate to discuss the subject of treeing which is frequently mentioned in connection with XLPE.

Eichorn in a recent paper[1] presented to the IEE observes that this is not a new phenomenon and hundreds of references to the literature can be quoted dating back to 1912. In more recent years research and investigation in this field seems to have concentrated on XLPE, possibly because of its increasing use as a dielectric material but also since detection of trees in translucent material is easier and thus facilitates laboratory investigation.

What is treeing? There is general agreement that under conditions of high electric stress there can be disruption or erosion of solid organic dielectrics into channels which extend or grow into forms resembling trees. Three basic types of treeing are recognised — electrical trees, water trees and electrochemical trees.

Electrical Trees

Figure 2 illustrates the appearance of electrical trees.

These, as the name implies, are considered to be entirely due to high electrical stress. Eichorn[1] suggests that of all the ideas which may be advanced as to the mechanisms whereby electrical trees are initiated the idea of electron injection seems the most reasonable. This postulates that on a negative half cycle of applied voltage electrons are emitted from sharp conductive points into the surrounding dielectric. Some of these electrons acquire sufficient energy to cause ionisation and consequent decomposition of the dielectric molecules — ultimately leading to formation of a void in which partial discharge can occur and by erosion propagate a channel leading to an electric tree. Extremely high stress levels are necessary to produce this effect and it is significant that in laboratory work Ashcraft, Eichorn and Shaw[2] report a test configuration using a specially sharpened needle electrode (point radius less than 2,5 micron) which, by calculation, at the voltages used gives a maximum stress level at the needle point in excess of 500 kV/mm and under these conditions trees are initiated in less than an hour in moulded XLPE samples.

Water Trees

These also require relatively high stress levels together with the presence of water for growth to be initiated. However the stress levels involved are very much lower than those necessary for electrical trees to be initiated. It would seem that under the influence of the high electrical stress the moisture penetrates in a number of fine paths, rupturing but not decomposing the dielectric material. Consequently water trees have a much more diffuse appearance than electrical trees. Eichorn[1] suggests that the conjuction of high stress with water may result in very small partial discharges at the tips of trees which decompose water into hydrogen and oxygen which are evolved at pressures high enough to cause local damage and the extension of the fine channels which make up the water tree.

Furthermore, if the applied voltage and the source of moisture are removed and the sample allowed to dry out, the water trees disappear. This suggests that the disruption of the dielectric is such that when the water in the channels of the tree diffuses away and evaporates, the channels close up. This fact complicates the study of water trees but the difficulty can be overcome by boiling the sample in a staining solution which imparts permanent form to the water tree.

Electrochemical Trees

These are effectively a special form of water tree (with similar growth mechanism) in which the water contains solute ions which can be detected as salts within the dielectric and may provide permanent "staining" of the trees so that it does not disappear when the sample is dried out.

Whatever the type of tree all evidence shows that tree growth starts at points having a high concentration of electrical stress. Such high concentration of stress can arise in the dielectric system of a cable in a number of ways:

- At an irregularity or roughness of the interface between the insulation and a screen;
- At any conducting contaminant particle partially or wholly embedded in the insulation;
- At any contaminant particle having permittivity differing significantly from that of the insulating material;
- At a contraction void within the insulation or at the interface between insulation and screen.

In addition to high electrical stress a further factor in tree growth lies in the degree of access to air, water or an electrolyte. When concentrations of stress arise within the insulation at a void or contaminant

noemde stowwe. Interne bome se groei neem dus selde ernstige afmetings aan op hul eie — tensy hulle naby die oppervlak van die isolering is, in welke geval 'n deurbraak die ingang van water of lug kan bewerkstellig. Solank as wat die bome ongeventileer is, sal hulle teen 'n verminderende tempo groei in 'n rigting parallel aan die elektriese veldlyne wat gekonsentreer is in die omgewing van die besoedeling of gebrek. Die vorm wat hieruit ontstaan, gee aanleiding tot die beskrywende naam van "strikdas"-bome. Uiteindelik sal die veldkonsentrasie, wat die nie-geventileerde strikdasboom laat ontstaan het, met die groei van die boom verminder tot 'n vlak waar geen afbreking van die diëlektrikum kan plaasvind nie en die boom ophou met groei. Fig. 3 illustreer 'n strikdasboom.

As die spanningsverhoger (hetsy besoedeling, leemte of gebrek) egter op of naby die tussenvlak van die isolering of skerm is, en die gevolglike bome radiaal na binne of buite deur groei, mag hulle maklik toegang tot water, lug of elektroliet kry en so hul groeitoestande handhaaf. In 'n onlangse gesaghebbende oorsig deur Wiersma [3] (namens CIGRE Werkgroep 21.11) word verskeie aspekte van die waterboomverskynsel oorweeg. Die skrywer dek onder andere die effek van diëlektriese spanning, frekwensie, temperatuur, aard en grootte van soliede besoedelingsdeeltjies en die teenwoordigheid van leemtes. Saam met dit bespreek hy ook die effek op die kabel as waterbome teenwoordig is. In dié verband is dit die moeite werd om sy verklaring ten volle weer te gee:

"Dit is bekend dat die lewe van 'n kabel verminder kan word in die teenwoordigheid van vogtigheid.

"Of die faling van die kabel toegeskryf kan word aan die teenwoordigheid van waterbome, is nog onbekend."

Dit is interessant om daarop te let dat onlangse werk van 'n groot kabelmaker in die VK aandui dat die teenwoordigheid van waterbome in GPE-isolering nie die korttermyn elektriese sterkte in werklikheid verminder nie. Monsters met strikdas-waterbome se afbreekspannings is nie noemenswaardig laer as dié wat sonder waterbome is nie.

Noudat die noodwendig kort oorsig van boomvorming en in besonder waterbome in soliede diëlektrikum afgehandel is, is dit paslik om weer die berekende spanningspeile, voorgestel in fig. 1 in oënskou te neem.

Die bespreking word nou tot radiale elektriese-veldkabels beperk. Fig. 1 toon duidelik dat ontwerp-spanningspeile toeneem met spanning. Die kleinste aanbevole geleier by 6,6 kV het 'n maksimum ontwerp-spanningspeil van 2,25 tot 2,51 kV/mm terwyl die ooreenkomstige peile 4,14 tot 4,47 kV/mm by 33 kV is.

Wat beteken die grootte van hierdie spanningspeile? In afdeling 5 van sy referaat [3] bespreek Wiersma die effek wat waterbome op die kabelleeftyd het. Hy beskryf die uitgebreide werk op werklike kabelmonsters om die leeftyd-eksponent van kabels in omgewings wat waterbome stimuleer, vas te stel.

(Die leeftyd-eksponent is die waarde van 'n' in die vergelyking

$$\frac{t_1}{t_2} = \frac{(E_2)^n}{(E_1)}$$

Waar t_1 = tydsduur-tot-afbreek by spanningspeil E_1

en t_2 = tydsduur-tot-afbreek by spanningspeil E_2)

Wiersma illustreer deur middel van grafieke die tydsduur-tot-afbreek vir verskeie waardes van hierdie eksponent en stel voor dat die resultate aandui dat n = 8 van toepassing op GPE in nat toestande is. In sy grafiese voorstelling sal hierdie waarde van 'n' die tydsduur-tot-afbreek van waarskynlik meer as 'n 100 jaar aandui, vir 'n goed-gemaakte kabel wat ontwerp is vir 'n maksimum spanningspeil onder 6 kV/mm. Klaarblyklik sal kabels, wat ontwerp is vir spanningspeile 4,5 kV/mm dus 'n voldoende leeftydsverwagting besit op voorwaarde dat versigtigheid aan die dag gelê word om spanningsverhogende onreëlmatighede uit te skakel.

Ekonomiese oorwegings bepaal dat by spannings groter as 33 kV die isoleringsdiktes self hoër spanningspeile veroorsaak. 'n Ontleding van 'n hoeveelheid spesifieke GPE-kabelstelsels vanaf 66 kV tot 154 kV gee 'n aanduiding dat prominente vervaardigers in dié gebied op 'n ontwerp-spanningspeil van 6 tot 6,5 kV/mm werk en vir hoër spannings word spanningspeile van 10 tot 15 kV/mm genoem. Vanselfsprekend sal groter voorsorg nodig wees by hierdie spanningspeile, as in die geval van tot 33 kV.

Verdere besprekings sal nou oor die algemeen beperk word tot kabels vanaf 6,6 kV tot 33 kV, met verwysing na superhoogspanningskabels waar van toepassing.

Wat is die betreklike belangrikheid van die verskillende defekte, wat die kabel se lewensverwagting kan verminder, en wat kan daaromtrent gedoen word tydens vervaardiging? Laat ons eers die betreklike belangrikheid van die verskillende defekte, of faktore, bekyk wat die elektriese sterkte op die lange duur en dus die lewensverwagting van die GPE-kabel sal bepaal. Daar is heelwat eenstemmigheid dat die faktore in orde van belangrikheid as volg gegroepeer kan word:

there is very restricted access to these substances and such internal trees seldom grow to any serious extent on their own — unless they are close to the surface of the insulation in which case they may break through and allow the ingress of water or air. As long as such trees remain non-vented, growth proceeds at a decreasing rate in a direction parallel to the lines of electrical force which are concentrated in the vicinity of the contaminant or imperfection and the resultant form of the tree gives rise to their description as bow-tie trees. Ultimately the stress concentration which initiates growth of these non-vented or bow-tie trees is dissipated by the growth of the tree to a level at which no further disruption of the dielectric takes place and growth of the tree ceases. Figure 3 illustrates an electrical bow-tie tree. Where however, the stress raiser, (whether contaminant), void or other imperfection) lies at or very close to the interface between dielectric and screen any resultant trees growing radially outwards or inwards though the insulation may have ready access to air, water or an electrolyte and conditions for growth of the tree are maintained.

A recent authoritative review by Wiersma(3) (on behalf of C.I.G.R.E. Working group 21.11) gives consideration to various aspects of the phenomenon of water treeing. Inter alia he covers the effects of voltage stress, frequency, temperature, nature and size of solid contaminants and the presence and size of voids. In addition he discusses the effects on cable of the presence of water trees and, in this connection, it is worth while quoting one statement in full:

> "It is known that the life of cables can be reduced by the presence of moisture. It is still unknown, however, whether these failures have to be attributed to the presence of water-trees."

It is of interest to note that work done in the U.K. by a large cable maker suggests that the presence of water trees in XLPE insulation does not in fact reduce the short term breakdown strength of the insulation. Samples with bow-tie type water trees do not breakdown at significantly lower voltages than samples without water trees.

Having made this of necessity a rather brief review of treeing, and in particular water treeing in solid dielectrics, it is appropriate to revert to consideration of the calculated stress levels depicted in Figure 1.

Confining discussion to the radial field cables the figure shows clearly that design stress levels increase as system voltage increases. At 6,6 kV the smallest recommendedd conductor size has a maximum design stress level of 2,25 to 2,51 kV/mm while at 33 kV the corresponding levels are 4,14 to 4,47 kV/mm.

What is the significance of the magnitude of these stress levels? Wiersma in section 5 of his paper [3] discusses the effect of water treeing on cable life and mentions extensive work carried out on actual cable samples to determine the life exponent for cables in water-tree stimulating environments.

(The life exponent is the value of 'n' in the equation

$$\frac{t_1}{t_2} = \frac{(E_2)^n}{(E_1)}$$

Where t_1 = time to breakdown at stress E_1

and t_2 = time to breakdown at stress E_2)

He illustrates graphically the time to failure for various values of this exponent and suggests that provisional results indicate that for XLPE under wet conditions n = 8. Taking this value of 'n' his graphical illustration suggests that for a well made cable designed with the maximum stress level below 6 kV/mm time to failure is likely to exceed 100 years.

It would seem therefore that cables manufactured to design stress levels less than 4,5 kV/mm have a more than adequate life expectancy provided care is exercised to eliminate stress raising imperfections.

At system voltages in excess of 33 kV economic considerations dictate thicknesses of insulation which result in even higher stress levels and analysis of a number of specific XLPE cable systems in the range from 66 kV to 154 kV suggests that the prominent manufacturers in this field are all working to design stress levels on these XLPE super tension cables of the order of 6 to 6,5 kV/mm and for higher voltages mention is being made of stress levels in the range 10 to 15 kV/mm. At these stress levels it is obvious that greater precautions will be necessary than is the case in the ranges up to 33 kV.

It is proposed however to confine further discussion generally to cables in the 6,6 to 33 kV range with possible occasional reference, when appropriate, to the supertension range.

In the manufacturing environment what can be done to eliminate or reduce the imperfections which can reduce life expectancy and what is the relative significance of the various types of imperfection?

Let us first consider the relative significance of the various imperfections or factors which will determine the long term electrical strength and hence the life expectancy of XLPE cable. A substantial body of opinion ranks these various factors in order of significance as follows:

1. Elektriese egaligheid van die geleierskerm en isoleringtussenvlak
2. Besoedeling binne-in die isolering
3. Leemtes binne-in die isolering en by die skermtussenvlakke
4. Mikroporositeit in die isolering
5. Elektriese egaligheid van die aarskerm en isoleringtussenvlak
6. Polimeer-tipe gebruik in die GPE.

Elektriese Egaligheid van Geleierskerm/Isoleringtussenvlak

Die geleierskerm word sonder uitsondering saam met die isolering uitgepers en hierdie faktor is dus grootliks 'n uitpersingsprobleem. Die reëlmatigheid of uniformiteit van enige uitpersing word in 'n groot mate geaffekteer deur die vorm en reëlmatigheid van die onderlaag waarop uitgepers word. Defekte kan ontstaan in 'n gewone stringgeleier weens "insinkings" om die tussenruimtes onder die buitenste draadlaag van die geleier te vul. Sulke onreëlmatighede is heeltemal onaanvaarbaar in hierdie tipe kabel. Kompakte geleier word gevolglik gebruik om 'n so naby as moontlike egalige geleieroppervlak te vorm vir die uitpers van die geleierskerm. Versigtige beheer van die samestelling van die stringgeleier en die mate van verdigting, maak dit moontlik om direk op die geleier uit te pers.

Bo en behalwe die verdigting van geleiers, voorsien sommige vervaardigers ook 'n half-geleidende band of bande wat styf om die geleier gewikkel word. Die geleierskerm word dan voltooi met die uitpers van 'n laag half-geleidende verbinding tesame met die GPE-isolering.

Die uitgepersde laag kan voue maak as die betreklike skroefsnelhede van die persmasjiene nie korrek met mekaar en met die lynspoed gekorrelleer is nie. 'n Growwe uitpersel weens verkeerde temperatuurtoestande, saam met swak vloeibane deur die uitperskoppe en matryse, kan lei tot voorvulkanisering van die half-geleidende materiaal. Enige van hierdie defekte kan tot skerp punte in die tussenvlak, en dus tot 'n onaanvaarbare verhoging van die spanningspeil lei.

Dit is duidelik dat heelwat aandag aan besonderhede gegee moet word en dat die produksie van geleiers en die vasstelling en beheer van uitpersingstoestande met sorg gedoen moet word. Moderne toerusting voorsien die nodige fasiliteite en die nodige beheer word uitgeoefen. Gereedskapontwerp is ook van belang.

Besoedeling binne-in die Isolering

Hiérdie kan uit verskeie tipes bestaan. Metaalbesoedeling is besonder nadelig en sekere ongepubliseerde eksperimentele werk bevestig dat metaaldeeltjies van die orde van 30 mikrongrootte, elektriese bome kan opwek by betreklik lae spanningspeile, selfs as hulle goed in die uitpersel gebind is. Sellulose vesels is besonder gevaarlik en moet geheel en al uitgeskakel word. Stofbesoedeling is oor die algemeen van minder belang. In die geval van materiaal vir superspanningskabels, moet deeltjiebesoedeling van metaal beslis uitgeskakel word.)

Tensy aandag in gelyke mate aan die verwerkings-, materiaalbergings-, en vervoertoestande gegee word, is dit nutteloos om aan te dring op die absolute suiwerheid van die GPE-samestelling voorsien deur die vervaardiger. Dit is moontlik om in die praktyk fasiliteite te voorsien wat ooreenkom met die gehalte van verpakking en om ook van algehele geslote vervoerstelsels gebruik te maak, sodat besoedeling op 'n paslike lae vlak gehou word. Die ingebruikneem van gefiltreerde lug of vertrekke voorsien met lug-en-drukreëling by belangrike punte, neem toe en vervaardigers is deeglik bewus van hierdie voorsorgmaatreëls (en pas dit toe waar nodig).

Leemtes binne die Isolering en by Skermtussenvlakke

Leemtes kan op verskeie wyse ontstaan. Een van die hoofoorsake van beduidende leemtes is te wyte aan differensiële verkoeling van die hele massa isolering- en afskermingmateriaal na die vulkaniseringsproses. Hiérdie staan bekend as "inkrimpingsleemtes". Analise van hittespannings kan gebruik word om leemteformasie te voorspel en om verwerkingstoestande (temperatuurprofiele) te bepaal, wat die vorming van krimpleemtes sal onderdruk.

Leemtes kan ook gevorm word deur vlugtige of gasagtige newe-produkte van die chemiese vulkaniseerproses. Dit word ook gevorm as die materiaal wat uitgepers word, nie volkome droog is nie. Die vorming van gasleemtes word onderdruk deur die kabel onder paslike positiewe eksterne druk te hou, beide gedurende die vulkaniserings- en afkoelingsgedeeltes van die produkproses. Leemtes van beduidende grootte word gewoonlik deur een van bogenoemde maniere gevorm en kan in tiene van mikrons gemeet word. Gevolglik word hulle maklik met die gedeeltelike ontladingstoets opgemerk. Gedeeltelike ontladings kan in 'n 30 mikron leemte gegin word as die spanningspeil 6 kV/mm bereik. Aangesien die leemte op sigself dien as 'n spanningspeilverhoger, kan hierdie peil by 'n betreklike lae toetsspanning betreklik maklik. In dié verband is dit moontlik van belang om daarop te let dat dit nie die ontlading-ontstaan-spanning (OSS) wat die hoofsaak is nie — maar dat die ontlading-blus-spanning (OBS) van veel groter belang is. Die OBS moet redelik hoër as die werkspanning wees, maar die betreklike verhouding tussen OSS en OBS is van heelwat minder belang. As die OBS by onder die normale stelselspanning is, sal ontladings voortduur regdeur die wer-

1. Electrical smoothness of the interface between conductor screen and insulation;
2. Contaminants within the insulation;
3. Voids within the insulation and at screen interfaces;
4. Microporosity of the insulation;
5. Electrical smoothness of the interface between core screen and insulation;
6. Type of polymer used for the XLPE insulation.

Electrical smoothness of Conductor screen/insulation interface

The conductor screen is invariably co-extruded with the insulation and this factor is thus largely an extrusion problem. In any extrusion the regularity or uniformity of the extrusion is affected to a considerable extent by the form and regularity of the substrate on to which the extrusion is made. With a normal stranded conductor imperfections can arise due to "sink-in" between the wires of the strand to fill interstices below the outer layer or wires. Such irregularities are completely unacceptable in this type of cable. Consequently compacted strands are used to provide as nearly as possible a completely uniform conductor surface on to which the conductor screen can be extruded. With careful control of strand make-up and degree of compaction it becomes possible to extrude directly on to the conductor. Some manufacturers in addition to compacting the conductors retain a semi-conducting support tape or tapes tightly lapped on to the conductor over which the conductor screen is completed by extrusion of the layer of semi-conducting compound together with the XLPE insulation. Folding of the extruded semi-conducting layer can occur if relative scroll speeds of the extruders are not correlated correctly with each other and with the line speed. Incorrect temperature conditions can result in a rough extrudate and in conjunction with poor flow paths through extrusion heads and tooling can lead to pre-curing of the semi-conducting material either of which defects can give sharp points at the interface which will have unacceptable stress enhancement factors.

It is evident there must be considerable attention given to detail and care must be exercised both in the production of the conductor and in the establishing and control of extrusion conditions. Modern plant provides the necessary facilities and this control is exercised. Tooling design is also of importance.

Contaminants within the insulation

These can be of a variety of types. Metallic contaminants are particularly deleterious and it is known from certain unpublished experimental work that metallic contaminants of the order of 30 micron size can generate trees at relatively moderate stress levels even when well bonded into the extrudate. Cellulose fibres are particularly dangerous and must be completely excluded. Dust contaminants are in general of less significance. (In the case of supertension cable material metallic particle contamination must be positively excluded.)

It is obvious that it is pointless to insist on the absolute cleanliness of XLPE compound as supplied to the manufacturing plant unless equal consideration is given to the cleanliness of processing conditions including material storage and conveying systems. In practice it is possible to provide facilities consistent with the packaging of the raw material and to utilise completely closed conveying systems so that contamination is restricted to suitably low levels. The introduction of filtered air or air conditioned and pressurised enclosures at critical points is increasing and manufacturers are well aware of the necessity for these precautions (and have introduced them where necessary).

Voids within the insulation and screen interfaces

These can arise in various ways. One of the chief causes of significant void formation is the differential cooling of the whole mass of insulation and screening material after the curing process. These voids are referred to as contraction voids. Thermal stress analysis can be used to predict void formation and to determine operating conditions (temperature profiles) which inhibit contraction void formation. Voids can also be formed by volatile or gaseous by-products of the chemical cross-linking process or if the material being extruded is not thoroughly dry, (i.e. incorporates no trace of moisture). Inhibition of gaseous void formation is achieved by maintaining the cable under appropriate positive external pressure during both the curing and cooling portions of the production process. Voids of significant size are usually formed in one of these ways and can normally be measured in tens of microns. Consequently they are relatively easily detected by partial discharge test methods. Detectable partial discharges can be initiated in a 30 micron void if the stress level reaches about 6 kV/mm. Since the void itself acts as a stress raiser this stress level is reached at relatively low test voltage levels of 1,5 to 2 times design working voltage and detection is therefore comparatively easy. In this connection it is perhaps important to note that it is not the discharge inception voltage (DIV) which is of major significance — of considerably greater significance is the discharge extinction voltage (DEV). The DEV must be appreciably above working voltage but the relationship of the DIV to the DEV is of considerably less significance. If the DEV lies at or below normal system working voltage discharges could continue throughout the working life of the cable, which will consequently be relatively short, since discharge erokende leeftyd van die kabel. Dit sal gevolglik kort wees aangesien ontladings die diëlektrikum erodeer sodat die vroeg faal.

sion of the dielectric will result in early breakdown.

Mikroporositeit in Isolering

Die belangrikheid van leemtes, kleiner as 20 mikrons, hang geheel en al af van die ontwerpspanningspeile. As dié op 'n betreklik lae vlak gehou word (soos in die geval van kabels by spanning op tot 33 kV) is dit baie onwaarskynlik dat die leemtes enigsins die huidige beraamde leeftyd van die kabel sal beïnvloed. Vanselfsprekend sal dit nie die geval wees by hoër spanningspeile nie. Hierdie standpunt het besonder betrekking op die huidige kritiek op stoom-gevulkaniseerde GPE-kabels deur ondersteuners van die nuwe "droëvulkaniserings-waterverkoelingsproses lei tot mikroleemtes in die isolering in 'n reeks groottes heelwat kleiner as 20 mikron. Dié leemtes is te wyte aan die feit dat 'n sekere hoeveelheid water in oplossing gaan in die poliëtileen onder hoë druk en temperatuur. Tydens daaropvolgende verkoeling raak die oplossing oorversadig en die surplus water kondenseer en vorm mikroleemtes. In nuutgemaakte stoom-vulkaniseerde GPE kan 'n "wolkerige" sone in die middelste gedeelte van 'n dun deursnit van die isolering met die blote oog gesien word. Hierdie "stralekrans" is sigbaar weens die betreklike ligbrekingsindeks van water en poliëtileen. Die mikroleemtes is gevul met water. Die water versprei na 'n tyd deur die isolering en verdamp en die stralekrans verdwyn as gevolg daarvan. Onder abnormale diëlektriese spanning sal gedeeltelike ontlading binne die grootste mikroleemte ontstaan. Dit mag erosie begin, wat lei tot elektriese strikdasbome in die middel-gedeelte van die isolering. Onder toestande bevorderlik vir waterbome, mag 'n strikdaswaterboom ontstaan. Soos egter vantevore aangedui, sal strikdasbome nie lei tot 'n beduidende afname in elektriese sterkte nie.

Lawson en andere[60] het in hul referaat oor die ontwikkeling van GPE op superspanningsgebied verklaar: "Met die oog op die toekoms het die kabelingenieur drie moontlikhede vorentoe:

- Om die teenwoordigheid van mikroleemtes en sommige onsuiwerhede te aanvaar en om dan 'n betroubare kabel te produseer wat 'n inherente nie-homogene-isolering gebruik. (In hierdie geval sal, gevolglik, 'n lae spanningspeilontwerp gebruik moet word. Vanselfsprekend sal dit die spanning waarteen die kabel gebruik kan word, beperk).
- Om materiaal te verbeter of te wysig, moontlik deur die toevoeging van bymiddels, om sodoende die effek van onsuiwerhede en leemtes op die werkverrigting van die kabel te verminder.
- Om vervaardigingstegnologie te verbeter met die doel om kabels te vervaardig wat minder en kleiner onsuiwerhede of leemtes bevat."

Moontlik kan bogenoemde nie as 'n gesaghebbende verklaring beskou word nie, maar dit gee 'n getroue aanduiding waarom die droog-vulkaniseerproses ontwikkel is, naamlik om die superspanningsmark binne te dring. Daar is geen tegniese rede waarom 'n lae spanningspeil, sê 5 kV/mm, 132 kV-kabel nie ontwerp kan word nie. So 'n kabel sal egter nie ekonomies mededingend met die beproefde olie-gevulde of gas-druk papiergeïsoleerde tipe kabels wees nie. Hoë spanningspeilontwerpe (6 kV/mm of groter) sal gevolglik noodsaaklik wees om ekonomiese lewensvatbare superspanningskabels te voorsien. Vandaar die verskeidenheid droog-vulkaniseerprosesse wat die mikroleemte-probleem oplos maar nie 'n oplossing bied vir die belangriker elektriese reëlmatigheid van die geleierskerm/isoleringtussenvlak of die besoedeling binne die isolering waarna reeds verwys is nie. Die voorstel dat bymiddels gebruik word om die effek van leemtes en besoedeling te verminder, is interessant. Is dit egter nie beter om die aantal en grootte van die leemtes en besoedelingselemente tot 'n vlak te beperk ooreenkomstig die kabelontwerpspanningspeil nie?

Microporosity of the Insulation

What of the smaller voids? Those of less than 20 microns diameter. The significance of these is entirely dependant on design stress levels — if these are maintained at relatively low values (as is the case in the voltage range up to 33 kV) they are extremely unlikely to have any effect on current estimates of life expectancy. Naturally at high stress levels this is not the case. This point is particularly relevant to current criticism of steam cured XLPE cables by advocates of the newer dry cure processes. It is well known that the conventional steam curing and water cooling process produces microvoids in the insulation extending in size range to something rather less than 20 microns. This is due to the fact that at high temperature and pressure a certain amount of water enters into solution in polythene. On subsequent cooling the solution supersaturates and the surplus water condenses and forms these microvoids. With newly manufactured steam cured cross linked polythene a cloudy zone in the central region of a thin cross-section of the insulation can be seen with the naked eye. This "halo" is visible because of the relative refractive indices of water and polythene and the voids are filled with water. After some time the water diffuses through the insulation and evaporates and the halo disappears. Under normal conditions of electrical stress partial discharges within the largest of such microvoids may start erosion leading to the growth of electrical bow-tie trees in the central region of the insulation. In conditions conducive to water tree growth bow-tie type water trees may grow but as previously indicated such bow-tie type trees do not lead to any significant reduction in breakdown strength.

Lawson et al[60] in their paper directed at development of XLPE cables into the supertension field state "that in looking to the future the cable engineer faced three possible ways forward:

- to accept the presence of microvoids and some impurities and to attempt to produce a reliable cable using an inherently non-homogeneous insulation. (In this case, of course, a low stress design will have to be employed and this will obviously limit the voltage at which such cables can be used).
- to improve or modify material, possibly by the introduction of an additive to minimise the effect of impurities and voids on cable performance.
- to improve manufacturing technology with the aim of producing cables with fewer and smaller impurities or voids".

This may not be regarded as an authoritative statement but it certainly does give a true indication as to why dry cure processes came to be developed.

It was in order to penetrate the supertension market. There is no technical reason why a low stress level, say 5 kV/mm 132 kV cable cannot be designed but such a cable would not be economically competitive with the tried and proved oil filled or gas-pressure type paper insulated cables. Thus high stress designs (6 kV/mm or greater) were essential in order to produce an economically viable supertension cable. Hence the variety of dry cure processes which solve the microvoid problem but do nothing to solve the higher ranked factors of electrical smoothness of conductor screen/insulation interface or contaminants within the insulation to which reference has already been made. The suggestion that additives be used to minimise the effect of voids and contaminants is interesting. Is it not better to reduce void and contaminant size and count to a level appropriate to the cable design stress level?

Elektriese Reëlmatigheid van die Aarskerm/Isoleringtussenvlak

Defekte in hierdie tussenvlak ontstaan op dieselfde wyse, maar is betreklik van minder belang as dié van die geleierskerm/isoleringtussenvlak, aangesien hulle geleë is in die gebied van minimum spanningspeil in die diëlektrikum. Die aandrang van gebruiker dat die aarskerms maklik afgestroop moet word, het egter gelei tot die algemene gebruik van die twee-gang proses vir die vervaardiging van afgeskermde are in die laer spanningsreekse.

Afstroopbaarheid kan ook bewerkstellig word deur die gebruik van spesiale half-geleidende samestellings, wat nou beskikbaar word vir evaluasie. Dit kan saam met die isolering uitgepers word (drie-laag-uitpersing), sonder om so styf vas te sit soos die gewone half-geleidende GPE.

Baie maklike afstroopbaarheid beteken dat die nousluitende kontak in die tussenvlak verbreek kan word. Dit kan tot groot defekte lei as die aar uitermate gedraai word tydens daaropvolgende prosesse of installasie. Versteuring van die nousluitende kontak tussen isolering en aarskerm kan lei tot betreklik groot leemtes en ontladingerosie wat die vroeë afbreek van die kabel tot gevolg kan hê. Dus, terwyl afstroopbaarheid voordelig vir die installeerder/gebruiker is, kan dit 'n potensiële swakheid wees indien dit te ver gevoer word.

Polimeertipe

In hierdie verband is dit slegs van akademiese belang aangesien daar net

Electrical smoothness of the core screen/insulation interface

Imperfections at this interface arise in the same manner but have relatively less significance than at the conductor screen/insulation interface since they lie in the region of minimum stress level in the dielectric system. However, the demand by users that core screens should be easily strippable has resulted in general use of the two-pass process for production of screened cores for the lower voltage ranges. The requirements can also be met by using special semi-conducting compounds which are now becoming available for evaluation and can be co-extruded with the insulation (triple layer extrusion) without forming the tight bond that arises with normal semi-conducting XLPE. Very easy strippability means that the intimate close contact at this interface can be broken and this can result in gross imperfections arising if core is unduly twisted in subsequent processing or during installation. Disruption of intimate contact between insulation and core screen may lead to relatively large voids from which discharge erosion could lead to early breakdown. Thus while core screen strippability offers advantages to the installer/user, if carried to excess it presents a potential breakdown hazard.

Type of Polymer

In the South African context this point is only of academic interest. At

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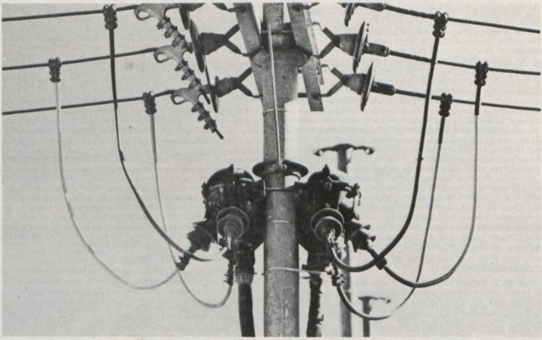

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een bron in Suid-Afrika bestaan. Gelukkig is hierdie plaaslike materiaal as baie bevredigend bewys en vergelyk gunstiglik met vroeër ingevoerde GPE-verbindings.

Voordat daar afgestap word van die diëlektriese stelsel, is daar nog een punt wat genoem moet word. Die geleier- en aarskerms is slegs half-geleidend soos die beskrywing te kenne gee. Weens die kort afstand is die weerstand gemeet in 'n radiale rigting vanaf die as van die geleier betreklik laag, selfs om die buitekant van die ten volle afgeskermde aar. Die weerstand van hierdie semi-geleidende elemente is egter betreklik hoog gemeet in die lengte van die kabel, en kan etlike duisende ohm per meter wees. Hierdie is nie die hoofsaak in die geval van die geleierskerm nie weens die noue kontak met die geleier wat op sigself die nodige geleiding in die lengte voorsien.

In die geval van aarskerms, egter, wat nominaal by aardpotensiaal moet wees, is 'n bykomende aardingstelsel noodsaaklik om die kabellaaistroom te dra en sodoende die opbou van uitermatige potensiale in die lengte van kabel te verhoed. Die aanbring van hierdie aardingstelsel sal later in meer besonderhede bespreek word.

Noudat die diëlektriese stelsel in redelike besonderhede bespreek is, is dit paslik om die ander komponente in die kabelkonstruksie te beskou; en om die produksieprosesse te bespreek waar nodig.

GELEIERS

Beide aluminium- en kopergeleiers word in GPE-kabels gebruik en die keuse van geleiermateriaal sal van die verbruiker se benodighede afhang. Weens die aard van die isoleringsproses (uitpersing binne-in 'n vulkaniseringsmedium onder druk) is ronde geleiers tot op die hede gebruik — selfs vir meerarige kabels. Soos vantevore aangedui, is hierdie geleiers gewoonlik saamgepers en die stringproses versigtig beheer om 'n uniforme, reëlmatige basis te verseker vir die bevredigende aanwend van die geleierskerm en isolering. Die gebruik van saamgepersde profielgeleiers in meerarige kabels kan besparing in die hand werk, weens die vermindering van die deursnee en gevolglik die volume bedekkingsmateriaal oor die saamgeslaande are. Profielgeleiers kompliseer egter die ontwerp van uitpersingsgereedskap en bemoeilik die handhawing van die nodige elektriese reëlmatigheid in die geleierskerm/isoleringtussenvlak. Daar is egter neigings oorsee om hierdie ontwikkeling in gebruik te stel en daar moet dus kennis geneem word van moontlike risiko's. Groot versigtigheid moet aan die dag gelê word — selfs as bogenoemde produksieprobleme uitgestryk kan word, sal spanningspeile verhoog (weens die elektriese veldkonsentrasie by die profielhoeke). Hierdie toename in spanningspeil moet nie oormatig wees nie en die ontwerp van geskikte profielgeleier sal dus 'n belangrike rol speel.

DIE ISOLERINGSPROSES

Alhoewel die diëlektriese stelsel bespreek is, is slegs terloopse opmerkings gemaak oor die prosesse waardeur die diëlektrikum op die geleier aangebring word. Almal het een ding in gemeen, naamlik die aanbring van die ongevulkaniseerde afskerming en isolering deur middel van die uitpersingsproses. Die verskille is geleë in die metode waardeur die GPE gevulkaniseer word, naamlik hoe kruisbinding ontstaan. Konvensionele GPE gebruik dikumielperoksied vir kruisbinding en 'n temperatuur van ongeveer 150 — 200°C word benodig om die kruisbindingsproses te begin. Die vlugtige en gasagtige neweprodukte van die chemiese kruisbindingsproses noodsaak die aanwend van positiewe druk tydens vulkanisering en dit moet tydens verkoeling gehandhaaf word totdat die uitpersel se temperatuur tot 90 — 100°C gedaal het om die "opblaas" d.w.s. leemtevorming te verhoed. Hierdie toestande kan verkry word deur uitpersing op 'n gewone deurlopende vulkaniseringsaanleg, bestaande uit geskikte uitpersers, binne 'n stoomatmosfeer wat gehandhaaf word in 'n stoombuis, verseël by die uitperskop en afgesluit van die atmosfeer by die verste ent deur middel van hoë druk water, wat ook dien as die verkoelingsmedium. Sulke deurlopende vulkaniseringslyne (DV) kan gebruik word in die horisontale (HDV), kettinglyn (KDV) of vertikale (VDV) vorms. Die VDV is die veelsydigste met betrekking tot die bestek van geleiergrootte en is die standaard vir die stoomvulkaniseer en waterverkoelings-stelsel vir GPE-kabels. Soos voorheen aangedui, weens die oplosbaarheid van water in poliëtileen, sal die proses mikroleemtes in die isolering vorm, die "stralekrans"-effek, sigbaar in onlangs-gevulkaniseerde isolering.

Hierdie mikroleemtes is van die orde van 10 mikron in grootte en volgens die nuutste mening sal hulle geen nadelige effek toon solank die ontwerpspanningspeil onder 6 kV/mm gehou word nie. By dié spanningspeile, in die spanningsbestek tot 33 kV, sal die leeftydsverwagting van stoomgevulkaniseerde GPE-isolering meer as voldoende wees, mits die nodige aandag aan ander faktore gegee word, wat elektriese veldkonsentrasies in die diëlektrikum kan vorm.

Wanneer die veld van superspanningskabel met GPE-isolering egter betree word, sal baie hoër spanningspeile nodig wees en die kenmerkende mikroleemtes van konvensionele stoomvulkanisering moet dus verkieslik uitgeskakel word. Aldus die ontwikkeling van die droogvulkaniseringsproses. Hiérdie val in vier kategorieë.

gasvulkanisering met water- of gasverkoeling
olievulkanisering en olieverkoeling

this stage there is only one source of supply. Fortunately this local source material has proved very satisfactory and compares favourably with previously imported XLPE compounds.

Before leaving the subject of the dielectric system there is one point that needs to be mentioned. The conductor and core screens which have been referred to as semi-conducting are precisely that. In the direction radial to the axis of the conductor and even round the periphery of the fully screened insulated core the resistance is relatively low due to the short path lengths. However, in the longitudinal direction of the cable axis resistance of these semi-conducting elements is relatively high and can be some thousands of ohms per metre. This is not of major significance as far as the conductor screen is concerned since this is in intimate contact with the conductor itself which provides the necessary longitudinal conductance. In the case of the core screen, which should nominally be at earth potential, the provision of a supplementary metallic earthing system is essential to carry the cable charging current and prevent the build up of excessive potentials along the length of the cable. The provision of this earthing system is discussed in more detail later in this paper.

Having discussed the dielectric system in some detail it is now appropriate to consider some other components in the cable construction and where necessary to discuss some of the manufacturing processes.

CONDUCTORS

Both aluminium and copper stranded conductors are used in XLPE cables and choice of conductor material depends on consumer requirements. Because of the nature of the process used in applying the insulation (extrusion into a pressurised curing medium) it has hitherto been the practice to use circular conductors even in multi-core cables and as indicated earlier, these are usually compacted and the stranding process controlled carefully to provide the required uniform and regular substrate for satisfactory extrusion of the conductor screen and insulation. The use of compacted sector shaped conductors in multi-core cables can offer savings, due to the reduction in cable diameter and thus reduction in volume of covering materials over the laid up cores, but the sector shaped profile complicates design of extrusion tooling and makes it more difficult to achieve the necessary electrical smoothness of the interface between conductor screen and XLPE insulation. There are however moves overseas to introduce this development but a note of warning must be sounded. Great care needs to be exercised — even if the production difficulties mentioned can be overcome, stress levels will increase (due to the stress enhancement at the corners of the sector). This increase in stress level must not be excessive and design of the conductor sector shape will be an important factor.

THE INSULATING PROCESS

Although the dielectric system has been discussed, only brief mention has been made of the various processes by which the dielectric system is applied to the conductor. All have one thing in common and that is application of the uncured screening and insulating material by an extrusion process — the differences arise in the method by which the curing of the XLPE, i.e. the cross linking, is achieved. Conventional XLPE utilises dicumyl peroxide as a cross linking agent which requires a temperature of approximately 150 — 200°C for the cross linking process to be initiated. The volatile and gaseous by-products of the chemical cross linking process necessitates the application of a positive pressure during curing and this pressure has to be maintained during cooling until temperature of the extrudate has fallen to 90 — 100°C to prevent "blowing" of the extrudate i.e. void formation. These conditions can be satisfied by extruding on a normal continuous vulcanising line, incorporating suitable extruders, into a steam atmosphere maintained in a steam tupe sealed on to the extrusion head, and closed at the remote end by a water leg in which high pressure water is used as a cooling medium. Such continuous vulcanising (CV) lines are employed in horizontal, catenary or vertical configuration. There are maximum size limitations on an HCV and the majority XLPE cables are produced on catenary (CCV) or vertical (VCV) lines. Of these the VCV is the most versatile in terms of conductor size range. This then is the standard steam cure and water cooling system for XLPE cables. As previously indicated because of solubility of water in polythene the process produces an insulation in which microvoids are formed — the "halo" effect visible in recently cured insulation.

These microvoids are of the order of 10 micron in size and modern thinking is that their presence is not deleterious provided design stress levels are kept below 6 kV/mm. At the stress levels applicable in the voltage ranges up to 33 kV life expectancy of steam cured XLPE insulation is more than adequate provided the necessary attention has been paid to the other factors which introduce stress concentrations in the dielectric system.

However, when entering the super tension field with XLPE insulation much higher stress levels become necessary and under such conditions it is desirable that the microvoids inherent in the conventional steam cure system are eliminated. Hence the development of the dry cure process. These fall into four categories.

gas curing with either water or gas cooling
oil curing and oil cooling

eutektiese soutvulkanisering met waterverkoeling
matryse met lang perstuite en waterverkoeling

Drie van hierdie vier stelsels gebruik toerusting gelyksoortig aan dié van konvensionele stoomvulkanisering. Die langperstuitmatrysproses is egter 'n horisontale aanleg waar die verlengde matrysperstuit (wat tot 25 m lank kan wees) dien as 'n vulkaniseringsbuis. 'n Dun lagie silikonolie word as smeermiddel en vir hittegeleiding tussen die aar en die matrys gebruik. Verskeie variante van die gasvulkaniseringstelsel is in gebruik maar hulle val wesentlik in twee groepe — waar die vulkaniseringsbuis verhit en die kabel gevulkaniseer word met stralingshitte, terwyl gas die nodige druk voorsien, en waar die gas verhit word om gebruik te word vir druk èn vulkanisering. Al hierdie stelsels het getoon dat GPE-isolering vervaardig kan word met minder mikroleemtes, wat werking by aanmerklik hoër spanningspeile moontlik maak.

'n Ander ontwikkeling is die gevolg van die ingebruikneem van 'n ander chemiese metode van kruisbinding waardeur die liniêre poliëtileen molekules ingeënt word met silaanradikale wat na uitpersing, soos vir konvensionele termoplastiek, kruisbind met mekaar in die teenwoordigheid van watermolekules.

Heelwat werk word gedoen om variante op hierdie proses te ontwikkel, wat ook nie die vorm van mikroleemtes sal bevorder nie.

Van watter belang is die keuse of spesifisering van die isoleringsproses in die praktyk?

Die prosesse verskil slegs in die metode van vulkanisering en verkoeling en hierdie vraag kan bes moontlik beantwoord word deur die verskeie faktore te neem, wat as belangrik beskou word om die leeftydsverwagting van die kabel te bepaal, en elke proses te ondersoek met betrekking tot elke faktor. Die volgende kommentaar kan, gevolglik, gemaak word met betrekking tot die ses faktore voorheen genoem:

Elektriese Reëlmatigheid van Geleierskerm/Isoleringtussenvlak

Hierdie is 'n blote uitpersingsprobleem en daar is weinig te kies tussen genoemde prosesse. Voorsorgmaatreëls wat getref moet word, is dieselfde vir al die prosesse.

Besoedeling binne-in die Isolering

Weereens is daar geen keuse tussen die verskillende prosesse nie aangesien dit suiwer 'n basiese grondstof-, opberging- en hanteringsprobleem is. Dieselfde voorsorgmaatreëls moet vir alle prosesse getref word.

Inkrimp/Gasagtige Leemtes binne die Isolering en by Skermtussenvlakke

Al die prosesse vereis beheer van die vulkaniserings- en verkoelingstoestande, naamlik die temperatuurprofiele, lynspoed en (in die geval van stoom- of droogvulkanisering) die betreklike lengtes van die vulkaniserings- en verkoelingsbene, sowel as die druk toegepas. Gegradeerde verkoeling mag nodig wees in die geval van die silaanproses.

Mikroporositeit in die Isolering

Dit is inherent deel van die stoomproses en kan deur die gebruik van die droogvulkaniseer- of silaanproses uitgeskakel word. Die nuutste gedagte is dat mikroporositeit onbelangrik is tensy ontwerpspanningspeile van die orde van 6 kV/mm of hoër is.

Augood [1] het in hierdie verband gerapporteer dat die mikroleemtegetal in die stralekransomgewing verminder het na die "uitgloei" van stoomgevulkaniseerde monsters in lug by 120°C — 130°C. Verhitting van droog-gevulkaniseerde monsters op dieselfde wyse het, egter gelei tot die vorming van mikroleemtes. Hy vestig die aandag daarop dat: "Na verskeie verhittings- en/of kookbehandelings is ongeveer dieselfde leemte-toestand uiteindelik met materiaal verkry, hetsy vervaardig met stoomvulkanisering of die nuwe proses (droogvulkanisering), of drukvulkanisering. Dus mag dit moeilik wees om die meerderwaardigheid van 'n gegewe GPE-isolering te bewys — formulering en ander veranderings buite rekening gelaat — aangesien kragkabels in gebruik verskeie kombinasies van hitte, vog en elektriese spanningspeile teëkom." Tydens normale werking is dit natuurlik onwaarskynlik dat temperature van 120 — 130°C bereik sal word.

Elektriese Reëlmatigheid van Aarskerm/Isoleringstussenvlak

Probleme in verband met hierdie faktor is gemeenskaplik vir al die prosesse.

Tipe Polimeer wat gebruik word vir GPE-Isolering

Dit is uitsluitlik 'n grondstofprobleem wat dieselfde is vir al die prosesse.

DIE AARDINGSTELSEL EN KABELSAMESTELLING

Soos vantevore genoem, is 'n metaalonderdeel nodig om die potensiaal van die halfgeleidende aarskerm in die kabel se lengte te stabiliseer. In die geval van enkelare word hierdie aardingstelsel gewoonlik voorsien deur koperbande wat spiraalgewys aangewend is. Koperband direk op die uitgepersde aarskerm kan egter gevaarlik wees weens die veel hoër hitte-uitsettingskoëffisiënt van GPE. Tydens sikliese belasting kan die kante van die koperband die aarskerm binnedring en 'n ontladingspunt laat ontstaan, wat weer tot die vroegtydige swigting van die kabel kan lei. Daarom mag 'n halfgeleidende tekstielband aanbeveel word, wat moet dien as 'n onderlaag vir die metaalband. Die aantal en/of dikte van die metaalbande sal afhang van die verwagte foutstroom wat moontlik

eutectic salt curing with water cooling
long land die with water cooling

Of these four types the first three use equipment very similar to the conventional steam cure plant but the longland die process is a horizontal plant in which the extended die land (which may be as much as 25 metres long) acts as a curing tube in which a thin film of silicone oil between the die and the core acts as a lubricant and heat transfer medium. Several variants of the gas cure system are in use but essentially these fall into two groups — those in which the cure tube is heated and the cable cured by radiant heat with the gas as a pressurising medium and those in which the gas is heated and serves as both curing and pressurising medium. All these procedures have been demonstrated to produce XLPE insulation with significantly reduced microvoid structure capable of operating at significantly higher stress levels.

Another development has resulted from the adoption of a different chemical method of crosslinking in which the linear polythene molecules have grafted on to them silane radicals which after extrusion on a conventional thermoplastic extrusion line will in conjunction with water molecules crosslink with each other. Considerable work is being done in development of the variants of this process, which also does not promote the development of microvoids.

What significance must be attached to the choice or specification of the type of insulating process in practice? These differ only in methods of curing and cooling and this question is probably best answered by taking the various factors considered important in determining life expectancy and examining what each process offers in respect of each factor. Adopting this procedure and taking the six factors previously listed, the following brief comments can be made:

Electrical smoothness of conductor screen/insulation interface

There is nothing to choose between the processes mentioned — this is a pure extrusion problem. Precautions to be taken are common to all processes.

Contaminants within the insulation

Again there is nothing to choose between the various processes — this is purely a basic raw material and a storage and handling problem. Precautions are common to all processes.

Contraction/gaseous Voids within the insulation and at screen interfaces

All processes require control of cure and cooling conditions, i.e. temperature profiles, line speeds and (in the case of steam or dry cure) relative lengths of curing and cooling legs and curing and cooling pressures.

In the case of the silane process graded cooling may be necessary.

Microporosity of the insulation

This is inherent in the steam cure process but can be avoided by using a dry-cure or a silane process. Modern thinking is that microporosity is not of significance unless design stress levels are of the order of 6 kV/mm or higher.

In this connection Augood [1] reports that annealing of steam-cured samples at 120°C — 130°C in air reduces the microvoid count in the "halo" region significantly. Furthermore heating of dry-cured samples in the same way results in the formation of microvoids in the sample. He draws a conclusion "Through various heating and/or boiling treatments approximately the same final void condition is obtained whether one starts with steam cured, new process (dry-cure) or press cured material. It may, therefore, be difficult to prove the superiority of a given XLPE insulation — discounting formulation and other changes — in that power cable in service encounters various combinations of heat, moisture and electrical stress". Of course in normal operation temperatures of 120 — 130°C are unlikely to be reached.

Electrical Smoothness of core screen/insulation interface

Problems in respect of this factor are common to all curing processes.

Type of Polymer used for the XLPE insulation

Purely a raw material problem this also is common to all processes.

THE EARTHING SYSTEM AND CABLE ASSEMBLY

It was mentioned earlier that a metallic component is necessary to stabilise the potential of the semi-conducting core screen along the cable. In the case of single core cables this earthing system is usually provided by means of helically applied copper tapes but there is some danger in applying these directly over the extruded core screen — XLPE has a very much higher thermal co-efficient of expansion than copper and under conditions of load cycling the edges of the copper tapes may penetrate the core screen and give rise to discharge sites leading to premature failure. It may be recommended therefore that a semi-conducting fabric tape should be applied under the copper tape to provide a bedding for the metallic tape.

sal vloei in die stelsel waar die enkelaarkabels geïnstalleer sal word.

In die geval van meerarige kabels kan 'n aantal verskillende konstruksies gebruik word. 'n Geheelomsluitende metaalomhulsel word in elke geval benodig en dit word voorsien deur middel van koper- of geelkoperbande of draadpantser. Waar die aardingstelsel alleenlik deur die draadpantser voorsien word, is 'n halfgeleidende onderlaag nodig om elektriese kontak met die aarskerms te bewerkstellig sodat die kabellaaistroom versamel kan word. Waar geelkoper- of koberbande gebruik word, is hulle individueel oor elke aar aangebring of gesamentlik oor drie saamgeslaande are.

Net soos in die geval van enkelaarkabels, sal 'n halfgeleidende band as onderlaag vir die metaalbande nuttig blyk te wees.

Fig. 4 illustreer etlike verskillende konstruksies wat vervaardig en aan die Suid-Afrikaanse mark voorsien is. Daar sal gemerk word dat die voorsiening van 'n aardingstelsel in meeste gevalle die saamstel van die kabel kompliseer (die saamslaan proses).

Hierdie proses word of met 'n planetêre saamslaanmasjien gedoen (toegerus met die bykomende tolmonterings/wieë en geskikte koppe vir die metaalbande) of met 'n toldraaimasjien (ook toegerus met geskikte koppe vir die metaalbande en fasiliteite vir die voer en plasing van die aardingsgeleiers). In die geval van die toldraaimasjien is dit uiters belangrik dat die afrolstaanders voorsiening maak vir terugdraaiing sodat, net soos in die geval van die planetêre masjien, minimum torsie op die ten volle afgeskermde are aangewend word. Die versteuring van die nou kontak tussen die skerm en die are moet vermy word en enige verdraaiing van die are, met betrekking tot hul as, is gevaarlik. Enige skerp draaie in die pad wat die aar volg deur die masjien tot by die saamgeslaande kabel is nadelig, aangesien oneweredige meganiese spannings wat die skerm/isoleringstussenvlakke kan versteur, kan ontstaan. Dit is van belang om kennis te neem dat in verband met die aardingstelsel onlangse "pik"-toestande bevestig het dat, gedurende aardfouttoestande, heliesomwikkelde koperbande 'n stroomdigtheid van 50 ampère/mm² een sekonde lank kan dra; bereken op 'n dwarsdeursnee-oppervlakte van 'n deurlopende buis. In dieselfde reeks toetse op kabels waarvan die aardfoutstroomvermoë aangevul is deur middel van bykomende aardingsgeleiers, is die belangrikheid van die eweningsverbinding tussen die aardingsgeleiers self en aardingsgeleiers met die aarskerms, beklemtoon.

In een geval waar die pen 'n aardingsgeleier en 'n fasegeleier direk verbind het, was eersgenoemde nie in staat om die volle foutstroom te dra sonder uitermatige oorverhitting nie, en het gevolglik gesmelt. Die implikasie van hierdie twee faktore is belangrik wanneer werklike stelseltoestande oorweeg word. Baie stelsels, heelwaarskynlik die meerderheid, bevat een of ander vorm van beperking of die aardfoutstroom. 'n 600 ampère aardfoutstroom verg 12 mm² effektiewe koperoppervlakte in die vorm van 'n buis wat verkry word deur 'n 0,1 mm dik koperband helies om 'n kern van saamgeslane are met 'n deursnee van 38,2 mm te draai. Die 38,2 mm kom ooreen met 'n drie-arige 11 kV-kabel met 35 mm² geleiers. Dus, waar moontlike aardfoutstrome ooreenkomstiglik beperk is, blyk bykomstige aardgeleiers onnodig te wees as die metaalomhulsel voorsien is deur middel van 'n enkele laag koperband. Hierdie oorweging is in gelyke mate van toepassing as elke aar in die kabel 'n afsonderlike koperbandomwinding het. In hierdie geval sal die massa van die koperband ongeveer 40% meer wees vir dieselfde geleiergrootte.

Waar moontlike aardfoutstrome nie paslik beperk word nie, is bykomende onderdele nodig. Hiérdie kan bestaan uit bykomende koperbande, aanvullende aardingsgeleiers (wat, waar moontlik, saam met are met afsonderlike koperbandomwindings gebruik word) of standaard enkeldraadpantsering (wat weer aangevul kan word deur die byvoeging van vertinde koperdrade).

DAAROPVOLGENDE PROSESSE

In die verband van hierdie referaat is daar min rede om daaropvolgende prosesse te bespreek, wat konvensioneel, wel bekend en op alle tipes kabels van toepassing is. Standaard afwerkings vir 'n GPE-geïsoleerde kabelsamestelling is PVC-mantel of PVC-onderlaag, EDP en PVC-buitemantel.

The number and/or thickness of copper tapes will depend on anticipated earth fault currents likely to flow in the system in which the single core cables are to be installed.

In the case of multi-core cables a number of different constructions have been used. In all cases an overall metallic enclosure of the cable has been required and this has been provided in the form of copper or brass tapes or by means of wire armour. Where wire armour alone constitutes the earthing system it is necessary to provide a semi-conducting bedding for the armour in intimate contact with the core screens so as to collect the cable charging current. Where brass or copper tapes are used these can be applied to each core individually or collectively over the assembly of three cores. As in the case of single core cables a semi-conducting tape bedding under the metallic tapes may be a desirable feature.

Figure 4 illustrates several different constructions that have been manufactured and supplied to the South African market. It will be seen that provision of the earthing system in most cases complicates the process of assembling the cable — the laying up operation. This operation is carried out either on a conventional planetary cabling machine (fitted with the necessary additional bobbin mountings/cradles and metallic taping heads) or on a drum twisting machine (also equipped with suitable taping heads and facilities for feeding in earthing conductors positioned appropriately). In the case of the drumtwister it is extremely important that let off stands make provision for back twisting so that, as is the case with the planetary cabling machine, minimum torsion is applied to the fully screened cores. Disruption of the intimate contact between screens and insulation has to be avoided and any twisting of the core relative to its own axis is dangerous. Furthermore any sharp bends in the route followed by the core in its path through the machine into the cable assembly are dangerous since these can produce differential mechanical stresses to cause disruption at screen/insulation interfaces.

In connection with the earthing system it is of interest to note that the results of recent spiking tests confirm that under earth fault conditions helically applied copper tapes can safely carry for one second a current density of 50 amps/mm² of cross-sectional area calculated as a continuous tube. The same series of spiking tests also showed that where earth fault current carrying capacity is provided by supplementary earthing conductors in the interstices the importance of cross bonding between earthing conductors and between earthing conductors and core screens cannot be overemphasised — in one instance when the spike made direct connection between an earthing conductor and a phase conductor, the earthing conductor proved incapable of carrying the full fault current without excessive temperature rise and consequently fused.

The implications of these two factors are important when actual system conditions are considered. Many systems, probably the majority, incorporate some form of earth fault current limitation. An earth fault current level of 600 amps demands 12 mm² of effective copper area in the form of a tube which can be achieved by 0,1 mm thickness of copper tape applied helically over a core assembly of diameter 38,2 mm. This at 11 kV corresponds to a three-core x 35 mm² conductor cable. Consequently where probable earth fault currents are limited appropriately it would seem supplementary earthing conductors are unnecessary if the required metallic enclosure is provided by a single thickness of copper tape. These considerations are of course equally applicable if each core of the cable is individually copper taped — which results in an increase of approximately 40% in mass of copper tape for the same conductor size.

Where probable earth fault currents are not appropriately limited, additional components are necessary. These could be additional or thicker copper tapes, supplementary earthing conductors (which should possibly be used in conjunction with individually copper taped cores) or standard single wire armouring (which, in turn, can be supplemented by incorporation of tinned copper wires).

Figure 5 shows the constructions which at the time of writing will be permitted in the proposed SABS Specification. At 6,6 and 11 kV both individually and collectively copper taped cores/core assemblies will be catered for and each type will be available in unarmoured or armoured versions. At 22 and 33 kV only the individually copper taped core constructions will be permitted but again in both unarmoured or armoured versions.

Before deciding on the construction to be used in any specific application careful consideration must be given to possible fault levels, in particular earth fault levels, and fault location capability of the people (and their equipment) operating the system. Where earth fault levels are limited, unarmoured cables may be used, provided care is exercised during installation. Where rapidity of fault location is of minor significance or where sophisticated fault location equipment is readily available collectively screened constructions are an economic choice.

SUBSEQUENT PROCESSING

In the context of this paper there is little point in discussing subsequent processes which are conventional, well known and applicable to all types of cable. Standard finishes over a XLPE insulated cable assembly are PVC sheath or PVC bedding, SWA and PVC serving.

Dit is egter nodig om een finale aspek te dek —

TOETSING

Toetse kan beskou word asof hulle in verskillende kategorië val. 'n Persoonlike mening is dat daar vier moontlike kategorië bestaan —

Ontwikkelingstoetse
Tipetoetse
Monstertoetse
Roetinetoetse

Ontwikkelingstoetse

Hierdie word beskou as spesiale toetse, soms van lange duur en moontlik deel van navorsings- en ontwikkelingsprogramme, om die geskiktheid van nuwe materiale en nuwe prosesse vas te stel. Tiperend hiervan is die statiese benadering om die leeftydsverwagting of waarskynlikheid van swigting vir GPE-kabels te skat, wat oorspronklik aan Weibull te danke was. 'n Uitgebreide reeks toetse op veelvuldige monsters is nodig om die statistiese parameters vas te stel. Dit betrek nie net korttermyn elektriese sterkte op 'n verteenwoordigende getal eenderse monsters nie, maar ook die tyd tot swigting of leeftyd van 'n getal eenderse monsters by elk van verskeie kontante spanningspeile. Daar word gemeen dat sulke toetse nie in 'n spesifikasie hoef te verskyn nie.

Tipetoetse

Tipetoetse kan ook toetse oor die lang termyn insluit. Die bedoeling van hierdie toetse is om te bewys dat 'n spesifieke vervaardiger bekwaam is om 'n besondere tipe kabel, wat voldoen aan die vereistes van 'n besondere spesifikasie, te vervaardig. As die kabel slaag in die tipetoetse wat in die spesifikasie voorgeskryf is, hoef die vervaardiger nie die toetse te herhaal nie, tensy daarby betekenisvolle veranderings in die vervaardigingsprosedure, aanleg of materiaal is.

Monstertoetse

Sulke toetse word op redelike tussenposes uitgevoer om te verseker dat die nodige standaard van gehalte gehandhaaf word. Vernietigende toetse op monsters en nie-vernietigende toetse op 'n deel van die volle kabellengtes, is ingesluit. Spesifikasies mag die tussenproses, of die tempo, van monsterneming aandui vir gewone toetse of vir arbitrasiedoeleindes.

Roetinetoetse

Hierdie toetse word uitgevoer op 'n iedere en elke kabellengte vervaardig, soos in die spesifikasie gestipuleer.

Toetse sal binne elke kategorie verdeel wees in elektriese en fisiese toetse. Daar kan egter heelwat argumente ontstaan oor kategorisering van 'n besondere toets.

Watter toetse word benodig in die voorgestelde SABS-spesifikasie?

Die formaat van SABS-spesifikasie onderskei ongelukkig nie tussen roetine-, monster- en tipe-toetse nie. Basies is alle SABS-spesifikasies geformuleer op die veronderstelling dat 'n besending kabels getoets word vir aanvaarding of verwerping.

Sekere elektriese toetse moet egter op elke voltooide dromkabel uitgevoer word en is dus roetine-toetse.

Hiërdie is:

Geleierweerstandstoets
Hoogspanningstoets op die diëlektrikum
Hoogspanningstoets op die PVC-mantel (waar 'n grafietlaag op die mantel benodig word)
Gedeeltelike-ontladingstoets.

Uit bogenoemde hoef slegs op die gedeeltelike-ontladingstoets uitgebrei te word. Hierdie toets is in effek die meting van kontaminante of leemtes in die diëlektrikum en is dus waarskynlik die belangrikste van al die toetse wat uitgevoer word. Met hierdie skrywe benodig die voorgestelde toets 'n "soek" spanning van 2,5 E_0 vir een minuut gevolg deur die meting van gedeeltelike ontlading by 2,0 E_0. Die maksimum grootte van die ontlading vir 6,6 11 en 22 kV-kabels is 20 pC, terwyl dit 10 pC vir 33 kV-kabels is. Dit kan vergelyk word met IEC 502 se "soek" spanning van 1,5 E_0 en die meet van gedeeltelike ontlading wat nie 20 pC mag oorskry by 1,25 E_0 vir 6, 11, 20 en 30 kV-kabels nie. Praktiese ondervinding in die maatskappy waar ek werk toon dat daar in werklikheid min te kies is tussen hierdie standaarde. Oor die algemeen is die grootte van die gedeeltelike-ontladings hoog, selfs by 1,25 E_0, as daar noemenswaardige onreëlmatighede bestaan wat nadelig vir die kabel se dienslewe kan wees. Ons ondervinding met beide toetsvlakke dui aan dat 'n aar wat voldoen aan IEK-vereistes ook die SABS-toets sal slaag. Die nuwe toetsvlakke sal gevolglik geen probleem tydens vervaardiging wees nie. Dit kan egter 'n probleem met toets wees, want dit is moeiliker om die punt van 'n kabel voor te berei wat geen ontlading het by 2 E_0 as by 1,25 E_0.

Met betrekking tot die grootte van gedeeltelike ontladings, is dit interessant dat die Nederlandse KEMA die maksimum toelaatbare ontlading in verband met spanningspeile bring. Fig. 6 is 'n herhaling van Fig. 1, maar met die byvoeging van KEMA-ontladingsgroottes. Dit is bete-

It is necessary however to cover one final aspect —

TESTING

Tests can be considered as falling into a number of different categories. A personal opinion is that there are four possible categories —

Development Tests
Type Tests
Sample Tests
Routine Tests

Development Tests

These are considered to be the special tests, sometimes of long duration and possibly forming part of a research and development programme, to establish the suitability of new materials or new processes. Typical of this in XLPE cables is the statistical approach to estimating life expectancy or probability of failure originally due to Weibull. To establish the statistical parameters it is necessary to carry out an extended series of tests on multiple samples. These involve not only determining short term ac electric strength on a representative number of equal samples but also measuring the time to failure or lifetime of a number of equal samples at each of several constant stress levels. It is not considered such tests should appear in specifications.

Type Tests

These may also include long term tests. The intention of these should be to prove the capability of a specific manufacturer to produce a particular type of cable to conform to the requirements of a particular specification. However, having produced cable which passes the type tests written into the specification, the manufacturer should not be required to repeat such tests unless the specification is significantly changed or there are significant changes in manufacturing procedures, plant or materials.

Sample Tests

These are tests carried out sufficiently frequently to ensure the required standard of quality is being maintained. They will include destructive tests on samples and non-destructive tests on a proportion of full cable lengths. Specifications may stipulate a frequency or a sampling rate either for normal testing or for arbitration purposes.

Routine Tests

These are tests stipulated by specification to be carried out on each and every length of cable produced.

Within each category tests will be divided into electrical tests and physical tests but whether electrical or physical there can be considerable argument as to the categorisation of a particular test.

What does the proposed SABS specification call for as far as testing is concerned?

Unfortunately the format of SABS specifications is such that they do not distinguish between routine, sample and type tests. All SABS specifications are basically formulated on the premise that a consignment of drums of cable are to be tested and accepted or rejected.

However certain electrical tests are required to be carried out on each and every completed drum length of cable and these then are the routine tests.

They are:

Conductor Resistance Test.
High Voltage withstand test of dielectric.
High Voltage Test of PVC Outer Sheath (where graphite coating of outer sheath is stipulated).
Partial Discharge Test.

Of these only the partial discharge test need be discussed in any detail. This test is effectively the measure of contaminants and/or voids in the dielectric system and consequently is probably the most important of all tests carried out. As at the time of writing this proposed test calls for application of a "search" Voltage of 2,5 E_0 for one minute followed by a measurement of discharge magnitude at 2,0 E_0 at which Voltage discharge magnitude must not exceed 20 pV for 6,6, 11 and 22 kV cables and 10 pC for 33 kV cables. For comparison the IEC 502 requirement is a "search" Voltage of 1,5 E_0 and measurement of a discharge magnitude not exceeding 20 pC at 1,25 E_0 for 6, 10, 20 and 30 kV cables. Practical experience in the company by which I am employed shows that there is in fact little to choose between these standards. In general where any significant imperfection exists which may be deleterious to the life of the cable the magnitude of discharges is high even at 1,25 E_0 and our experience after using both test levels suggests that a core which meets IEC requirements also meets the proposed SABS requirements. Consequently these new levels do not in fact pose any manufacturing problems, but they may pose a testing problem. It is more difficult under circumstances applicable to routine testing to prepare a cable end to be discharge free at 2 E_0 than at 1,25 E_0.

On the subject of permissable partial discharge magnitudes the attitude of the Netherlands authority KEMA, may be of interest — they relate maximum permissable discharge magnitude to stress level. Figure 6 is a repetition of figure 1, but with KEMA discharge levels superimposed. It kenisvol dat slegs in die geval van die kleinste geleiers by 22 en 33 kV 'n gedeeltelike ontlading van onder die 20 pC-vlak benodig word. Tolleransies tydens vervaardiging sal heelwaarskynlik verseker dat die spanningspeil in elk geval onder die 3,5 kV/mm-vlak sal daal.

Wat van tipe-toetse? Die voorgestelde nasionale standaard noem hiérdie "addisionele elektriese toetse" en stipuleer dat die aankoper in die tenderuitnodiging duidelik moet aandui of hierdie toetse benodig word. Die standpunt van die vervaardigers is dat gebruikers hopelik hierdie toetse as tipe-toetse sal aanvaar en nie op nuwe sertifikate sal aandring met elke nuwe kontrak nie. Die toetse benodig in die voorgestelde nasionale standaard is:

'n las-siklustoets
'n impulsebestandheidstoets
'n kortsluitingstoets

In elke geval moet die toetsmonster 'n buigtoets ondergaan; en 'n slaag in las-siklus- en kortsluit-toetse word aangedui ooreenkomstig die streng vereistes vir die gedeeltelike-ontladingstoets.

SLOTSOM

'n Poging is aangewend om 'n agtergrond te gee van probleme wat verwag kan word en voorsorgmaatreëls vir die spesifisering, vervaardiging en gebruik van GPE-kabels in die lig van huidige kennis betreffende die leeftydsverwagting van GPE-isolering. Daar word gemeen dat ten spyte van onsekerheid oor die afbreekmeganisme, genoegsame ondervinding beskikbaar is sodat GPE-geïsoleerde kabels met vertroue vervaardig en geïnstalleer kan word, mits die nodige voorsorg getref word met die keuse van grondstowwe, beheer van vervaardigingsprosesse (insluitende toetse) en die hantering en installering van die voltooide kabel.

VERWYSINGS

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3. Wiersma J. A. (on behalf of CIGRE Working Group 21.11) "Water Treeing in Cables with Extruded Insulation." (Electra No. 55 pp 25 — 38).
4. Lawson W. G., Rechovicz M., Rigby S. J. "Developing Cross-Linked Polyethylene Cables for High Voltage Power Transmission." (Electronics and Power February 1978 pp 116 — 120).
5. Augood D. R. "Some Properties of XLPE Cable Material." (IEEE PES Summer Meeting July 1976).

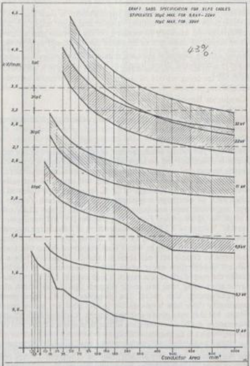

FIGURE 1 — THEORETICAL STRESS LEVELS AND KEMA DISCHARGE LEVELS

may be significant that only in the case of the smallest conductor sizes at 22 and 33 kV, is a discharge level of less than 20 pC required and manufacturing tolerances will more than likely ensure that even on these conductor sizes stress levels will reduce to near the 3,5 kV/mm level.

What of type tests? The proposed national standard calls these "additional electrical tests" and stipulates that any purchaser requiring such tests to be carried out, must state this clearly in any invitation to tender. From the manufacturer's point of view, it is to be hoped that users will accept these as type tests and not insist that new certificates are required for each contract. The tests required in the proposed national standard are:

A load cycling test.
An impulse test.
A short-circuit test.

In each instance the sample submitted for test is required to be subjected to a bending test and satisfactory performance in the load cycling and short-circuit tests is indicated by compliance with rigorous partial discharge requirements.

CONCLUSION

An attempt has been made to provide a background to problems that may be anticipated and precautions that have to be taken in the specification, manufacture and use of XLPE cables, in the light of current knowledge regarding life expectancy of XLPE insulation. It is considered that despite some uncertainty as to breakdown mechanisms sufficient experience is available for cables incorporating XLPE insulation to be confidently manufactured and installed provided the necessary care is exercised in selection of raw material, control of manufacturing processes (including testing) and handling and installation of the finished cable.

ACKNOWLEDGEMENT

Acknowledgement is made to the Board of Directors of African Cables Limited for permission to present this paper. In addition acknowledgement and thanks for helpful comment and criticism is due to colleagues.

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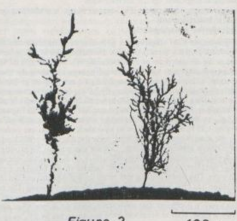


Figure 2

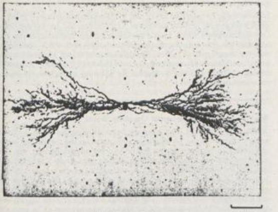


Figure 3

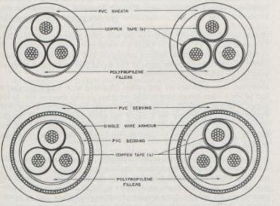


FIGURE 5

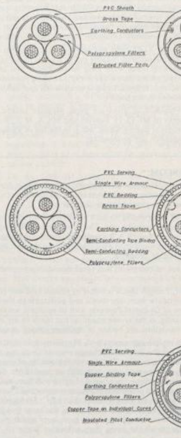


Figure 4

BESPREKINGS/DISCUSSIONS

M. W. Odendaal: Alberton

Mnr. die President, ek voel besonder geëerd dat die geleentheid aan my gebied is om die bespreking te open na aanleiding van die twee referate wat pas gelewer is.

Dit is my beskeie mening dat die einde van die era vir kabel met papier-isolering nou aangebreek het. Net soos P.V.C. papier vervang het vir die vervaardiging van laagspanningskabel, sal kruisgebonde poliëtileen (XGPE) papier vervang vir die vervaardiging van kabels vir spannings van 6,6kV tot 132kV.

Ek herinner my nog die dae daar in 1952, toe die kleiner Stadsrade begin het om kabels met P.V.C.-isolering te gebruik terwyl die groter Stadsrade eers jare daarna begin het. Vandag weet ons nie meer hoe lyk 'n laagspanningskabel met papier-isolering nie. Op dieselfde wyse het die kleiner Stadsrade vanaf die laat sestiger jare begin met die gebruik van XGPE-geïsoleerde kabel vir spannings van 6,6kV en 11kV.

Die eerste 33kV XGPE wat deur 'n Stadsraad in die Republiek aangekoop is, is op Alberton teen die einde van 1971 in gebruik geneem en word reeds vry algemeen deur 'n hele aantal Stadsrade gebruik. Boksburg het uiteindelik die groot sprong geneem met die ingebruikneming van 132kV XGPE-kabel gedurende Junie 1977.

Die Suid-Afrikaanse Buro vir Standaarde se standaard-spesifikasie vir Elektriese kabels met kruisgebonde Poliëtileen-isolering sal eersdaags die lig sien en nou het mnre. Forsyth en Fortmann die finale spyker in die doodskis van kabel met papier-isolering geslaan.

Mnr. D. H. Forsyth is 'n kenner op die gebied van kabelvervaardiging en het dan ook 'n leidende rol gespeel in die opstel van die spesifikasie waarna hierbo verwys is. Hy het in sy referaat op meesterlike wyse daarin geslaag om vir die ingeligte sowel as vir die oningeligte al die belangrikste aspekte wat verband hou met die gebruik van kruisgebonde, poliëtileen as isoleermiddel uit te lig. Hy kom dan na my mening tereg tot die slotsom dat XGPE-geïsoleerde kabels met vertroue vervaardig en geïnstalleer kan word, mits die nodige voorsorg getref word met die keuse van grondstowwe, beheer van vervaardigingsprosesse (insluitende toetse) en die hantering en installering van die voltooide kabel.

Mnr. A. H. L. Fortmann is 'n brawe jong man wat sy huiswerk baie deeglik gedoen het en toe die wêreld deurreis het. Hy het sy ore en oë oopgehou. Toe hy tot die oortuiging gekom het dat kabel met XGPE-isolering die ware Jakob is, het hy 'n projek wat beslis 'n eerste in die Republiek is, aangepak en suksesvol deurgevoer. Vir hierdie prestasie en die knap wyse waarop hy sy kennis aan ons meegedeel het, is ons hom baie dank verskuldig.

It has been my good fortune to visit the factory where the Boksburg cable was manufactured. The vertical continuous vulcaniser using the radiant curing process with the extrusion plant capable of extruding the conductor screen the dielectric and core screen in tandem and housed in an air-conditioned room where dust particles exceeding 5μ are screened, leaves a lasting impression of efficiency and cleanliness. This manufacturer succeeded to my mind to eliminate the six imperfections or factors enumerated in Mr. Forsyth's paper which will determine the life expectancy of XLPE cables.

In his paper Mr. Forsyth states, on the strength of work done by

Wiersma, that the time to failure of a well made cable designed to a stress level below 6kV/mm and operated in watertree stimulating environments is likely to exceed 100 years. With the Boksburg cable manufactured to a stress level of 6,25kV/mm and covered by a metallic sheath, Mr. Fortmann need have no fears and may soon find that his colleagues are no longer sceptical, especially those with oil problems.

In most of the literature on XLPE cable one gets the impression that the three basic types of treeing occured in cable manufactured in the early days when semiconducting tapes were used as conductor and core screens. Will Mr. Forsyth please pass his remarks on treeing in modern cables with extruded screens manufactured to stress levels applicable to 33kV cables as mentioned in his paper.

In conclusion Mr. President, it gives me great pleasure indeed to propose a vote of thanks to Mr. D. H. Forsyth and Mr. A. H. L. Fortmann for the very excellent papers which will join the list of valuable contributions that appear in our proceedings.

Mr. W. A. Bowen: ESCOM

Mr. Forsyth is to be complimented on his paper, in my opinion, for its explicit reasoning, conclusions and the manner in which the facts of XLPE insulation have been placed before the user.

This makes the task of contributing to such a paper, a hard one, for I cannot but agree with everything he says. The culmination of his paper with the mention of the proposed S.A.B.S. specifications for this type of cable makes me more convinced than ever that cables to the specification will be very reasonable products.

There are, however, one or two points that I feel should, in my opinion, be emphasized.

I firmly agree with Mr. Forsyth that it is better to reduce void and contaminant size than introduce more chemicals and pollutants to the insulation. The presence of Di-cumyl Peroxide with its resultant water in the insulation after curing, is really one chemical too many in my opinion. The purer the insulation, the better, in the high voltage ranges.

This leads me to a complete agreement with Mr. Forsyth in that the most significant tests are the Partial Discharge ones as these are the guarantee of manufacturing quality. This covers the quality of the insulation and the fitting of screens to core. Although on page 18 Mr. Forsyth refers in a sentence beginning "In general" I agree with him, but, at this stage it is the non-general problems that cause worries and I would like to ensure that testing be just that bit better than I.E.C. Standards to guarantee peace of mind. The extra cost in obtaining discharge free factory test ends at high test voltages is, I am sure, very much more preferable at this stage, to all the users, than a flock of faults.

With reference to page 9 on the discharge in cables perhaps Mr. Forsyth could give some indication of discharge levels in 11, 33 and 42 kV paper insulated cable at working voltages. I feel that we may we surprised at the figures of these discharge levels when compared with XLPE cables.

On page 7 Mr. Forsyth mentions that the value of N for XLPE insulation under wet conditions equals 8. Would he please confirm that the dry value for N should be in the region of 9 to 12.

On page 14 he mentioned the microporosity of the insulation. It is interesting that in the region of 120°C to 130°C steam cured samples have their microvoid count reduced whereas dry cured samples heated in the same way have an increase in microvoids. Could Mr. Forsyth confirm that these are the reasons for preferred reduction in overload temperatures from 130°C and that it has something to do with the total overload time per annum of XLPE insulated cables.

From page 14 onwards Mr. Forsyth mentions the earthing system and cable assembly. It was in the interest of safety and considering the number of Third Party incidences to cables of some 120 per annum that I had spiking tests carried out. One thing is certain and that is that users of XLPE insulated cables will have to give values of their earth fault currents to the manufacturers. In order that cables which are safe when damaged will be installed on the systems. The proposed S.A.B.S. specification caters for these eventualities.

With such a comprehensive paper as this it is difficult to pick on really controversial points but if I may digress a little from the theme of this paper to add what I believe to be an item of interest and that is on the question of joints and jointing. On this matter I would like to refer interested parties to an article that appeared on page 11 of the Electrical Times dated 8 February 1980 and this gives a resume on the experiences and practices of an English Electricity Board when they come to join paper cables. I would like to briefly mention the 22 kV joint that we designed with basic materials. It was subsequently tested to 345 kV at 3,5 and 4,5 microseconds wave/front impulses, number unknown, without failure.

There are some 12 joints still in service at 10-12 years of service without failure.

I don't wish to take up any further time describing the materials and method of making this joint but should anyone be interested please contact me after this meeting or at any time and I will only be too pleased to give them the necessary information.

In conclusion I would like to say that Mr. Forsyth has definitely given a good background into the subject of XLPE cables for normal distribution and purposes which should provide a greater appreciation the effort that has gone into the drafting of the proposed S.A.B.S. specification for these types of cables, a specification in which users will have every confidence. My thanks go to both the AMEU and the Regional Manager, Rand and O.F.S. Region for allowing me to present these comments today.

Mnr. F. J. Prins: Departement Openbare Werke

Meneer die President, soos u uit my bekendstelling kan aflei, is ek nie meer in diens van die SABS, die organisasie waar die meeste van u my deur die jare leer ken het en waarmee u my geassosieer het, nie. Ek neem vandag aan hierdie verrigtinge deel as gas van die VMEO en wil dan ook hulle bestuur bedank vir die uitnodiging en die moeite wat hulle gedoen het om dit vir my moontlik te maak om hier te wees. Ook wil ek my werkgewer bedank, wat so goedgunstiglik toegestem het dat ek die uitnodiging mag aanvaar. Die menings wat ek hier gaan lug, sal dus in 'n persoonlike hoedanigheid geskied en weergee hoe ek as persoon oor 'n saak voel en dink, in die lig van my ondervinding en kennis van die onderwerp.

Mr. President, gentlemen, for the benefit of those delegates and guests who are not too familiar with Afrikaans and especially the Afrikaans technical terms, I will continue in English. Those of you who know me, know that I am basically conservative and not given to discarding the old, faithful, time-proven servant in favour of the flashy newcomer. And this statement especially applies to the well-tried paper-insulated cable. I know of two 11 kV cables in South Africa that are now very close to 70 years service and still in perfect condition and there must be many cables in the UK and other parts of the world that must have given at least a 100 years reliable service.

However, time marches on and cables insulated with XLPE is today a fact of life — they have come to stay, whether we like them or not. In his paper, which is essentially a repeat of the paper he delivered at the 1979 Power Cable Conference Mr Forsyth has given us an excellent insight into the factors governing the manufacture of these cables and this, inter alia, gives us a lead as to what should be specified in specifications for this type of cable.

A lot of information has become available as field experience with XLPE insulated cables has accumulated and this is one instance where we really learned from past mistakes. From my observations I would say that the two most important parameters as far as XLPE cables is concerned, are the voltage stress levels and partial discharges. Just as power factor is the parameter that tells us what we have in a paper-insulated cable, so the partial discharge at 2 E_o or 2,5 E_o will tell us whether we have an acceptable XLPE-insulated cable. I would say that one is now in a position to write a good specification that will ensure that the user can buy and use XLPE-insulated cables with confidence. Such a specification has been completed technically by the responsible committee and is now awaiting final editing by the SABS before being circulated for general comment.

As a potential user I would list my basic requirements for XLPE-insulated cables as follows:

1. CONDUCTOR MATERIAL AND SIZES:

   These could be either copper or aluminium and should follow the standard range of metric sizes adopted. For the reasons enumerated by Mr Forsyth, the conductors should be circular and reasonably compacted to facilitate a smooth, regular interface between the conductor screen and the dielectric.

2. DIELECTRIC:

   In the term dielectric I include the conductor and core screens as ideally the three should be co-extruded to ensure proper bonding and the exclusion of contaminants and voids. Mr. Forsyth gave us an indication of how important the characteristics of XLPE dielectric are. This material is very susceptible to voltage stress and partial discharges. The life expectancy can be directly related to these two parameters. I have been informed by an overseas cable company that research work carried out by them would indicate that if the design stress level is increased from 4 kV/mm to 6 kV/mm, the life expectancy is halved (it should be pointed out that steam cured cables were involved). Hence, I would like to see dielectric thicknesses based on design stress levels not exceeding 4 kV/mm and preferably much less. However, this poses problems in the design of cables for voltages exceeding 33kV. If one had to stay within the limit of 4 kV/mm, cables would become exceedingly bulky and expensive and non-competitive with paper insulated cable. You are therefore forced to consider design levels of 6 kV/mm and higher. In his paper Mr. Forsyth refered to the work done by Wiersma in connection with the life exponent for cables operated in water-tree stimulating environments. Using this as criterion one would say that a life of at least 100 years could be expected if you stayed within a design limit of 6 kV/mm., And yet certain authorities estimate a life of only 50 years and others hope for 30 years. One is reminded of the remark made by a cable expert at the Power Cables Conference — namely that the one certain way of avoiding trees is not to put any voltage on the cable.

From information supplied by Mr. Fortmann, it would appear that at the time of his investigation, i.e. 1974, 77 kV cable was in common use in Japan and satisfactory tests had been carried out on 154 kV cable. In Puerto Rico 138 kV cables had been in use since the mid 60's. In Sweden a 22 kV cable had been in use for about nine years and a 145 kV cable had been in service for one year. It is thus obvious that field experience over extended periods with H.V. XLPE cables is still very lacking, and one will have to wait and hold thumbs.

Before leaving the subject of dielectric, I want to expand on the question of core screens. I would like to see a core screen of nominal thickness 1 mm and a linear resistance not exceeding 50 kΩ/m, solidly bounded to the dielectric. I know that this will entail a lot of care and elbow grease when jointing or terminating, but I also know that this construction will give me the most reliable cable. It is well known that the user wants an easily strippable screen, but I wonder how many of them realise on what thin ice they are skating. Various techniques are being investigated to provide an easy strippable screen that will still ensure partial discharges within an acceptable level. Some of these show promise. One of the methods is to coat the dielectric with a conducting layer, such as graphite, and to extrude a semi-conducting layer over it. But have you thought of a jointer working under cramped conditions in a jointing bay trying to work clearly and not contaminating the joint with, say, graphite particles?

3. METALLIC SCREENING

A metallic screen must be provided over the semi-conducting core screen to carry the charging current. In the case of certain cable designs it must also be able to carry the related earth fault current for a long enough period to allow the protection to operate. In the case of an aluminium sheathed cable a soft aluminium tape applied directly over the core screen and in contact with the aluminium sheath will be adequate.

As pointed out in Mr. Forsyth's paper various approaches and designs have been tried out in the case of cables with no metallic sheaths. Various parameters have to be considered — whether the cable is armoured or not, the magnitude of fault currents it may be subjected to, how it will be protected, how it will be used. The last mentioned point is quite important. A municipal engineer would expect a service life comparable to that of a paper-insulated cable, i.e. better than 50 years. But in the mining industry a service life of two to three years may be all that is required and hance first cost becomes very important. The cable will probably be wrecked mechanically long before it's electrical service life expires. This, however, raises a problem for the municipal engineer. He would like to limit the choice of cables to the absolute minimum and then only to those types that will ensure a long, trouble-free service life. To this end, I would personally prefer as my No. 1 choice the cable with individual copper taped cores plus an overall copper tape over the laid-up cores and in contact with the core tapes. My No. 2 choice would be the cable with individual copper taped cores. The effective cross-sectional area of the tapes must be adequate for the earth fault current that could flow, should the cable be spiked when in use.

4. MECHANICAL PROTECTION

A cable could be plain PVC sheathed or PVC bedded, armoured and PVC served. Where earth fault levels are limited and the cable is installed in ducts or on racks, unarmoured cables may be used. Where earth fault levels are not limited or the cable is to be installed by direct burial, I would prefer an armoured cable.

There is, however, an additional aspect that should be considered, namely the presence of water. In the light of available information it can be assumed that water in contact with XLPE is not desirable. Opinion as to how one should tackle this problem is divided. Personally I would think that if there is any doubt, an extruded metallic sheath should be provided.

5. TESTING

Certain tests are basic to all cables, i.e. conductor resistance, dimensions, insulation resistance, high voltage, etc. However, as pointed out by Mr. Forsyth, there are tests, denoted as type tests by him, which have particular significance in the case of XLPE cables. These include load cycling, short-circuit, bending and partial discharge tests. As far as I am concerned, the one test that will tell you whether you have a good cable is the partial discharge test. A properly made cable will have negligible partial discharge up to at least 3 E_o. That is why I disagree with the values specified by the IEC. I would like to see no more than 5 pc discharge at 2 E_o on all cables. The Netherlands authority KEMA may have a valid point in relating maximum permissable discharge magnitude to stress level, but this approach will complicate matters for the ordinary user.

It is agreed that to measure partial discharges at this low level, poses practical problems, especially to a manufacturer in a factory where modern thyristor controlled plant makes it wellnigh impossible to reduce background noise to a level sufficient to obtain reliable readings. Apart from this, a lot of time and care is required in preparing the ends of a cable for test so as not to introduce discharges at these positions. I can, therefore, well understand that a manufacturer would prefer test parameters that will ease his job in the factory. In practice the position may therefore well develop that the manufacturer, to save time in testing, will develop short cuts and carry out routine tests at higher discharge levels.

In conclusion, I would like to refer to a remark made by Mr. Coe of BICC at the cable conference last year i.e. "one must remember that quality control is a difficult thing to measure or specify. It is quite easy to specify in terms of thicknesses and that type of thing, but quality control is rather more difficult. Also the routine testing of cables doesn't necessarily identify the contaminant that can cause problems in later life." In other words, gentlemen, you are, regardless of what you specify, still largely in the hands of the manufacturer i.r.o. how clean he operates and how well he applies quality control.

En dan wil ek graag net een puntjie regstel. "Cross-linked polyethylene" is niks anders as poliëtileen wat met 'n peroksied gevulkaniseer is nie — die identiese vulkaniseerproses wat op rubber gebruik word. Die korrekte Afrikaanse benaming is dus "gevulkaniseerde poliëtileen" — die naam wat algemeen in Europa gebruik word.

Mnr. P. J. Botes: President

Mnr. Prins, sal u ook asseblief ons dank oordra aan die Departement Openbare Werke wat goedgunstiglik ingestem het om dit vir u moontlik te maak om hierdie bydrae te lewer. Ons wil ook langs hierdie weg ons dank oordra aan die jarelange samewerking met u, en ons wil u toewens alles van die beste met die nuwe betrekking.

Baie dankie.

Dr. A. Ericksen: CSIR

For this oppertunity, we only learned last night that I might be asked to comment on these papers. My comments are essentially goint to be informal and short and of a fair and general nature, but as you mentioned Mr. Chairman, about 8 years ago I gave a paper to a technical meeting of the AMEU, in fact it wasn't on cross-linked polyethylene cable at all, it was on the general development of insulating material across the high voltage field, but I expected to get a bit picked out on the cross-linked aspect, because at the time, rather rashly probably, I expressed the belief that cross-linked polyethylene or "vulcanized polyethylene-Felix", as a cable dielectric through its obvious advantages almost inevitably showed the future direction of development of application of power cables. At that time there was considerable resistance to this view, I think largely because of the various problems and somewhat bitter experience of users, but in this country and the United States for example, however, I believe that we are moving through a period of revolution here of a completely new technology and completely new dielectric and inevitably there must be problems and as Felix has said, we have to learn from the mistakes in this field, I do believe that many of the earlier problems in this technology arose through a combination of factors, firstly, what we might call today in terms of modern practice, inadequate use of the cable. At that time we just did not understand many of the points that have been raised by this morning's speakers. In addition the first users of these cables didn't appreciate the differences in this cable technology from the earlier paper technology, and I think it was in some sense "the blind leading the blind" at that time, and so inevitably we had problems.

Mr. Fortmann in his paper this morning, however, has indicated to us the tremendous wealth of knowledge that there is now about the basic characteristics of the dielectric about the many facts that have to be taken into account in the design and manufacture of these cables.

Mr. Fortmann's paper has demonstrated how far this technology has evolved and what is already practicable in terms of this type of cable. The points I really would like to emphasise this morning, and it is one that is addressed more toward the manufacturers, is that we have a need here for a complete cable technology. I am concerned that perhaps we are over-emphasising the basic cable, the basic design of the cable itself. Several of the speakers have already drawn attention to the importance of jointing and terminations here, and Mr. Fortmann in particular has shown us the complexity and the care that was necessary to follow in providing the joints and terminations of these cables. This I believe is eually, if not more important than quality insurance during the manufacturing phase of the cable, and this is an area where I am concerned that the manufacturers perhaps are lagging behind the stage of advancement that they have reached with the basic manufacture of the cable. So, my prime plea is to the manufacturers here to advance the technology of the hardware, the whole practice of jointing and terminations to a stage which is compatible with the point we have already reached with the basic dielectric structure itself. For our part we recently became aware of the possibility of problems with EHT cross-linked polyethylene cables on another installation apart from that of Mr. Fortmann's where the possibility exists that the use of incompatible materials and joints and possibly inconsistant hardware and terminations may be giving rise to problems and failures to cables of this type, and this is the type of area that I think the manufacturers need to address themselves too, to make sure that they have hardware kits, that they have jointing practice, that they provide the training of artisans in the field, that the degree of quality insurance that they achieve with manufacture can be maintained in the field of jointing and terminations, also. So this was the main point I wished to make and I would like thereafter just to commend these speakers for their extremely interesting papers and in particular I would like to thank them for ushering us in to, what I hope is an era of respectability for cross-linked polyethylene.

Mr. W. B. Stewart: Affiliate

Ladies and Gentlemen, we have heard quite a lot today on testing and the need for discharge magnitude detection. Cross-linked polyethylene is far more susceptible to discharge erosion than paper cables. Consequently the need to determine accurately the amount of discharges taking place is very essential. Now the paper, and Mr. Bowen, and let it be known Mr. Prins, they refer to testing for discharges and the fact that discharge detection is the most critical test for the life expectancy determination of XLPE dielectrics. I won't say cross-linked, I'll keep it at XLPE.

The accuracy of testing is then of paramount importance. It is well known worldwide that testing of long lengths of XLPE cable, now I emphasise, long lengths is not accurate unless special apparatus and measuring techniques are used.

The critical lengths appears from laboratory tests to be about 250 metres. So, from one metre to 250 metres, the cable acts as a lumped capacitance and inductance and little or no reflections take place. However, at longer than 250 metres the cable behaves as a transmission line. And then we have reflections taking place and this, within the frequency spectrum encountered in discharged detection which can be of the order of 80 000 cycles. These reflections and standing waves which are encountered introduce as much as 50% in error to the discharge measurement: So now with values that are being banded about down to 10 PCor even 5 PC is being very critical. We now have to determine these values with apparatus and which, unless we have the necessary correcting means to this apparatus, are going to give you an error if your measured lengths are longer than 250 metres.

The present IEC working group has worldwide sent out papers at the moment on the problems of determination of discharges in long lengths of cross-linked polyethylene cables. Now on Mr. Formann's paper, he mentioned that 50 PC has been detected on steam cured cables in Japan, now it would appear that this level is due to the fact of being steam cured. But work that I did in Holland in the research laboratories, we never found any microvoids, and I'm not holding the flag for steam, please, but I just want to put the record straight. We never found microvoids, larger than 10 microns, and produced by dry curing, larger than 1 micron. Now, if here we took micro photographs of 1 200 magnifications, of the steam cured, it looks like somebody with smallpox, and the dry curing of course, has much smaller voids. But there is no discharge detection apparatus available worldwide that can detect a microvoid of 10 microns.

With regard to water treeing, Mr. Fortmann mentioned that water trees grow from the conductor screen. But I have personally grown water trees from both conductor and core screens, and the Cigre working group 21 have to date, after examining something of the order of 400 to 500 cable failures worldwide, have found no evidence of water treeing near, or in the side of a cable failure.

Mr. Fortmann's paper also shows a vertical vulcanisation line which tends to give the impression that 132 kV cables can only be produced on a vertical line. Now I must correct that which may give the impression to some members here. It is being produced in Europe on catenary lines up to 275 kV.

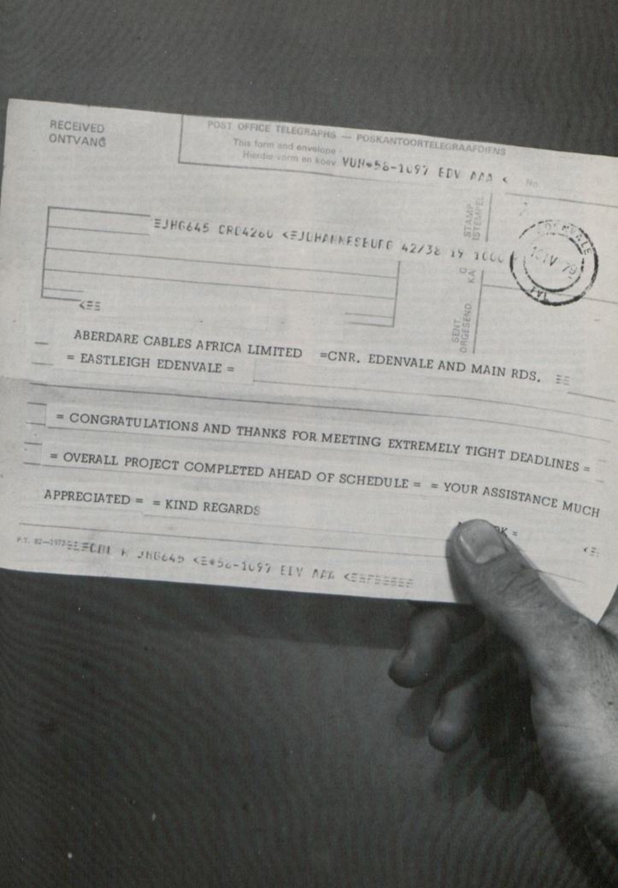
So, once again Mr. President, I must thank the gentlemen for their very enlightning papers.

D. C. Palser, Cape Town

Mr. President

In the introduction to his excellent and lucid paper the author mentions that a South African national standard for XLPE cables up to 33 kV is nearing finality. He then goes on to state that "it is to be hoped that the publication of this national standard will give more impetus to the use of XLPE cables in South Africa."

I find this a most disconcerting statement, implying as it does that because we will soon have a standard for XLPE cable we must now accordingly all rush out and buy this type of cable! I am sure that this was not the author's intention and I trust that he will clarify this point. I presume that what was intended was that the ready availability of a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= CONGRATULATIONS AND THANKS FOR MEETING EXTREMELY TIGHT DEADLINES =
= OVERALL PROJECT COMPLETED AHEAD OF SCHEDULE = = YOUR ASSISTANCE MUCH
APPRECIATED = = KIND REGARDS

national standard will facilitate the issuing of specifications for this type of cable by municipalities.

The author has covered very concisely the design of XLPE cable and the various types of treeing and their causes and prevention. It was to be expected that emphasis would be placed on these aspects since these are the ones that have up to now technically militated against the more extensive employment of XLPE cable.

Mr. Forsyth has also covered in a very logical manner the various insulating processes, namely the various processes by which the dielectric system is applied to the conductor. It is a pity no conclusion was drawn as to what is considered to be the best process. Perhaps Mr. Forsyth could expand on this point and let us have his views. Coming next to earthing systems it is clear that because of the high thermal coefficient of expansion of XLPE relative to copper, there are problems in the provision of either external sheaths or metal tapes to provide adequate facilities for these cables.

The methods of obtaining a good earthing system for an XLPE cable installation are discussed and it is evident that special care has to be taken when jointing XLPE cables if good earth conductivity is to be achieved. Despite the claims made by the author I very much doubt if an XLPE earthing system, with a fault level equivalent to that obtained with conventional paper insulated lead sheathed cables, is at all achievable without resorting to a relatively expensive form of sheathing. Could the author comment on this point please.

Considering next the tests covered by the proposed SABS standard it is significant to note that the partial discharge test is essentially a routine test that has to be carried out on each and every completed drum length of cable. Such is the sensitivity of this type of cable to the quality of insulating material and its method of application!

It would appear from the paper that the constructional standards proposed by SABS place more emphasis on low cost construction than they do on safety. Mechanical protection is most important since my experience has been that most high voltage cable faults are attributable to external mechanical damage, either during laying or subsequently, particularly through the use of mechanical excavators. It would be interesting to have the author's views on the possibility of serious accidents arising from the types of construction proposed for XLPE cables.

In conclusion, I would state that I am still not convinced that XLPE cable is the answer for high voltage applications, particularly at voltages of 33 kV and above. The conventional paper insulated oil-filled cable has served us well for many years now and unless it can convincingly be proven that an XLPE cable of comparable quality and safety can be produced at equal or lower cost I am afraid I see no reason for switching my allegiance at this stage!

Mr. J. Loubser: Benoni

Mr. President, I am one of those engineers who, regardless of many problems experienced with XLPE cables still insist on using it, mainly because of the fact that every single fault experienced on our cables was because of manufacturing faults and not because of inherent faulty design.

I had faults on two different manufacturers' cables: Don't worry I am not going to name them.

In the first case I had many, literally dozens of faults on a batch manufacture of cables and every single one occurred where the semi-conductor tape round the individual core insulation was damaged during manufacture thereby causing a high stress point.

In the second case a fault occurred and after localising and opening it a piece of silver paper was found underneath the semi-conductor tape. I understand that this is being used to test the cable during the manufacturing process.

My question to Mr. Forsyth is this: Can't something be done to have continuous quality control during the manufacturing of this cable? And if this is not possible, isn't it possible to test and localise faults of this nature before installation or even better, before it is sold to the customer?

In conclusion, Mr. President, may I add my congratulations to Messrs. Forsyth and Fortmann for their very interesting papers read in a very able and efficient manner.

Mnr. E. de C. Pretorius: Potchefstroom

Mnr. die President, ek wil net seker maak of Welkom in die kiesafdeling van Fauresmith val of nie, want netnou voel ek skuldig as ek politiek praat. Wat gevulkaniseerde poliëtileenkabel betref, Mnr. die President, was ek op 'n stadium baie konserwatief gewees. En skielik het ek progressief geword. Ek dink Potchefstroom was een van die eerste munisipale elektrisiteitsondernemings wat die kabel gebruik het met aluminiumgeleier.

Dis 'n aantal jare gelede. Nadat ons die kabel geïnstalleer het, het 'n vooraanstaande persoon wat baie weet van kabels, hy is vandag hier in die gehoor, vir my gesê: "Eugene daardie kabel gaan nie langer as 8 jaar hou nie." Hy was reg.

Ek is weer konserwatief. Dit gaan baie vat om my weer tot progressiewe oortuigings te beweeg.

Mr. A. Fortmann: Boksburg

Mr. President, it is a paper of this nature that we, as users and especially the prospective users, need, to gain confidence in the use of high voltage XLPE cable and I congratulate Mr. Forsyth on the clear and informative manner in which he has presented his paper.

I hope that the few "Sceptics" will show a change of heart as far as XLPE cable is concerned and especially with the new SABS Specification which will probably shortly be ready for use and which should allow for cable with a high standard to be manufactured.

Q1. Under the heading "Water Trees" on page 5, I wonder if Mr. Forsyth could enlarge a little on the first sentence of the second paragraph which reads:

"Furthermore if the applied voltage and the source of moisture are removed and the sample allowed to dry out, the water trees disappear."

Presumably the channels remain, but as they have no water in them, are not visible.

Q2. Under the heading "Microporosity of the Insulation" on page 10, first paragraph, what is the relatively low stress level referred to?

This has to do with the significance of voids and design stress level.

Is it below 6 kV/mm?

Q3. Under the heading "The Earthing System And Cable Assembly" on page 15, Mr. Forsyth states that it may be a desirable feature to have semi-conducting tape bedding under the metallic tapes on single core cables. This to protect the core screen.

The first question that comes to mind is — why should this condition not apply to three-core cables which in effect are three single-core cables laid up to form a three-core cable?

Secondly, and this point I raised at the SABS committee meeting on XLPE cable, was why should the semi-conducting tape bedding be optional in the specification?

In fact, I consider the conclusion of a bedding tape under the metallic tape, to protect the core screen, an important feature.

Mr. D. H. Forsyth: Affiliate

Lady and gentlemen, I think if I deal with the contributors in reverse order as I go back, I think I must thank Mr. Barnard for his contribution, although he did not raise at any specific question as far as I am concerned.

Mr. Fortmann asked me to clarify this question of the visibility of water trees. The situation is that water trees in the insulation are very fine channels of disruption and when the water evaporates away, these close up again. The disruption is there but it is not visible. It can be made permanently visible but boiling as samply exhibiting a water tree in a solution of methylene blue or some other staining agent to give permanent form to the tree. When I say it disappears, it does not mean that it is not there, its just not visible unless you have water in the channel.

I would also support Mr. Fortmann in personal preference for the use of bedding tape under copper tape screens, because of the thermal characteristics of cross-linked polythene relative to the thermal characteristics of copper. It has a very much higher thermal coefficient of expansion and there are cases on record where lapped mechanic tapes over a single core cross-linked polythene cable have in fact been stretched beyond the limit of elasticity by expansion of the cross-linked polythene.

Mr. Pretorius queried the vulnerability of cross-linked polythene cable to system surges. This may well be true but I don't think that they are necessarily anymore a well-made cross-linked polythene cable, is necessarily anymore vulnerable than any other type of cable. System surges tend to surge out the weakest point in any cable and if you do get failures as a result, it was not obviously good enough at that point.

Mr. Loubser raised the question of was it not possible to have some form of continuous quality assurance in the manufacture of these cables. This is perfectly possible and is an ideal, I think, all cable manufacturers aim at. But cable manufacturers, like municipal electrical engineers are human beings and we do all make mistakes from time to time, and where you get trouble it is almost inevitably human error in the course of operation of plant. There is at the moment a considerable drive not just in the electric cable industry but throughout industry in South Africa with the publication of the Bureau of Standards Code of Practice for quality management systems, SABS 0157, and the decision by the Bureau of Standards to implement the provisions of the SABS 0157 in all their application of mark schemes. Those manufacturers who have to carry the SABS mark for particular products will in fact have to satisfy the Bureau to hold that mark that they have incorporated quality management systems which are giving you the necessary assurance of quality in the finished product.

Mr. Palser posts three questions. He asked me to clarify what I meant by the effect or rather to clarify the effect of the national standard. And I think his assumption, I would agree that his assumption is correct. The publication of the national standard will, I think, give an emphasised on cross-linked polythene cables, because quite rightly a lot of users of cable are very very conservative and would prefer not to buy a cable for which there is no standard specification and this is essentially why I think that the cable making industry in this country pressed for the preparation of this national standard. Because we felt that until such time when there is a national standard for cross-linked polythene cables, there will be many people, possible users of these cables who would prefer not to make the change.

The question by Mr. Palser on the possibility of accidents, the safety of the cables, I think was answered very adequately by Mr. Bowen. Because he was closely involved in the spiking tests that were carried out and were part of the information in front of the committee considering the national standards specification. And essentially the cable supplied do incorporate a metallic enclosure and the cables to the new national standard, when it is finally issued, will certainly be able to withstand spiking and therefore be perfectly safe as far as the external damage is concerned.

Mr. Palser also asked me to express some opinion as to the best insulating process. This is a bit of a loaded question. I mean what is the best motor car? Do you buy a Rolls Royce when a Ford would do? And this I think is essentially the point. There is no doubt that with a dry curing process you achieve an insulation which does not incorporate the micro voids that appear in a steam cured cross-linked polythene insulation.

In my paper I listed six factors in a sequence of importance. This question of presence of micro voids was only the forth factor. Now the other three factors are in my opinion of more significance as far as life expectancy of the cable is concerned. And those three factors, the type of insulating process, whether it is dry cure or steam cure, is proposed common problems in both processes so that there is no question of a choice between the processes as far as those factors are concerned. So the only reason for selecting the dry cure process, is to eliminate micro voids and at distress levels applicable at the lower voltage levels, that is up to 33 kV. The presence or absence of micro voids is irrelevant to the life expectancy of the cable. I hope that that has clarified at least my feelings on the matter and satisfacturily answers on Mr. Palser's questions.

I would like to thank Mr. Ericksen for his contribution, which I think was summarised very well. My very own personal feelings as far as cross-linked polythene are concerned, is the insurance of the future. Mr. Ericksen asked what about the technology of jointing? I would agree with him there certainly at the lower voltage ranges, the expertise is there. But when you move to the higher voltages, it is not enough to sell cables. You have to sell a system and consequently I can assure him that those of us who are looking at this movement into higher voltages would certainly can't go that way without being satisfied that one could offer the accessories to make the cables one supplies.

The only comment I would like to make on Mr. Prins's comments, he did make in his introductory remarks the statements about the tried and proven hypercable. My response to that is, well we haven't had cross-linked polythene around that long. But given time we will be able to make the same sort of statements about cross-linked polythene.

Mr. Bowen raised two queries and asked me to comment on the discharge levels in paper cables. The thought horrifies me. There is, I am glad we don't have to do partial discharge on paper cables. There is in fact an ERA report published on a result long term programme of tests carried out on various cables. Some of which were taken from a route which have given considerable troubles and some of which were used cables which did not give many trouble. And this spread over several years and the final report comes to the conclusion that if you got a discharge level of up to about 2 000, you got nothing to worry about. This is a measure of how much more resistant the partial discharge paper as a dielectric is. Cross-linked polythene is susceptible the partial discharge damage. But if you make the cable that it doesn't have significant partial discharges, then it is a good insulate. What is the dry value? Well under dry conditions your life exponent will be at least one order of magnitude better, in other words it will be a figure of 9. As a result of further work that has been done, certain people are proposing values of the life exponent up to 18. But if we use a value of 9, what exactly does this mean? What does it mean relative to the value of 8 that was quoted in the paper? Well using a value of 9 means that if the cable will withstand twice working voltage for 30 days continuously, then your life expectancy, at working voltage, is theoretically 40 years. If on the other hand, your cable is operating in an enviring wind, which leads you to feel to use a life exponent value of 8, then to be sure, or to have a life expectancy of 40 years, then the cable must be able to withstand twice working voltage for a period of 57 days. But as Mr. Ericksen has commented on other occasions, cables do not just have to withstand working voltage. And when we look at life expectancy of a cross-linked polythene cable, we have got to look at what is that cable going to be expected to withstand. And this means that one has to be a little bit more conservative in the figures I have just quoted mean. Because cables do suffer, they do have surges on them. We operate in an area where lightning disturbances can get onto cable systems with serious affects and consequently one has to be a little bit more conservative than that, and certainly I would hesitate to say that I would guarantee a 40 year life expectancy, if the cable had only withstood twice working voltage. Because it might, in its working life, has to withstand the cumulative sum of far more than 30 days of about twice working voltage. So you've got to treat it as you got to be a little more conservative in your approach. Now it is for this reason, perhaps this whole question of the national standard specification has, and I hope would use the necessary results or the required results in that it has been. These factors have all been considered. It will make recommendations which should, I hope, give people confidence that the cables they buy to that specification, will in fact give them an adequate life expectancy.

Mr. President, I hope I have answered the queries that were raised as a result of the paper and finally I would like to thank you again for the opportunity to present this paper. Thank you.

REFERAAT

DIE EERSTE 132 kV XLPE-KABELINSTALLASIE IN SUID-AFRIKA

deur A. H. L. FORTMANN, Pr. ING.

REFERENT

Mnr. A. H. L. Fortmann
Elektrotegniese stadsingenieur, Boksburg

SPEAKER

Mr. A. H. L. Fortmann
Town Electrical Engineer, Boksburg

PAPER

THE FIRST 132 kV XLPE CABLE INSTALLATION IN SOUTH AFRICA

by A. H. L. FORTMANN, Pr. ENG.

1. OPSOMMING

In hierdie referaat word die omstandighede weergegee wat die Elektrotegniese Stadsingenieur genoop het om ondersoek na die moontlike installasie en die betroubaarheid in gebruik van 132 kV kruisgebonde poliëtileengeïsoleerde kabel, wat vir die eerste keer in Suid-Afrika gebruik sou word, in te stel.

2. INLEIDING

2.1. Die merkwaardige ontwikkeling van Boksburg se nywerhede en woongebiede met inagneming van waarskynlike toekomstige ontwikkeling binne Boksburg se uitgestrekte grense, het 'n algehele herbepaling van die dorp se behoeftes aan elektriese krag genoodsaak.

Gedurende 1972 was hierdie saak vir die eerste keer met EVKOM bespreek en na oorlegpleging was daar tot die gevolgtrekking gekom dat 'n toevoerpunt teen 132 kV naby die noord-oostelike dorpsgrens nodig sou wees.

Dit was beplan om die Raad se toevoer teen 33 kV en met 'n vermoë van 90 MVA aan te vul en die vorige 11 kV-toevoerpunt te vervang.

Die Raad het toe besluit om 'n 132 kV-grootmaattoevoerpunt by Witkoppie met 'n primêre verspreidingstelsel aan te bring wat bykomende twee 132/11 kV-substasies, een by Witfield en die ander by Anderbolt, sou behels.

Die hoofvoorsieningspunt het 'n vaste vermoë van 250 MVA wat beplan is om hoofsaaklik die noordelike helfte van die dorpsgebied te voorsien. Die Munisipale gebied van Boksburg is naastenby 28 km lank en 8 km wyd. Dit is ongeveer 19 700 h.a.

Die kragvoorsiening aan die suidelike gebiede sal na verwagting teen 1987 versterk moet word en dan sal waarskynlik 'n verdere 132 kV-toevoerpunt van EVKOM benodig word.

So vroeg as teen die middel van 1973 was die mikpunt gestel om kragvoorsiening van EVKOM gedurende Mei 1977 te verkry en gedurende November 1973 was die Ooreenkoms vir kragvoorsiening teen 132 kV tussen EVKOM en die Raad aangegaan.

Die eerste van drie 132 kV-substasies was in Junie 1977, slegs 'n maand later as die voorgenome voltooiingsdatum in werking gestel, maar omdat EVKOM se toevoer toe nog nie beskikbaar was nie, was 'n tydelike 132 kV-toevoer daargestel deur 'n bestaande 33 kV-baan wat die Anderbolt 132 kV-substasie en die 33 kV-hooftoevoerpunt by "Les Smith"-substasie, deur middel van 'n 45 MVA, 132/33 kV-transformator verbind.

EVKOM se 132 kV-toevoer was eindelik op 29 Augustus 1978 aangeskakel.

Die buitemuurse 132 kV-substasies is met 132 kV lae olie-inhoud stroombrekers, in Switserland vervaardig, en elke substasie met twee 40 MVA, 132/11 kV, vektorgroep Yyn 0, 22% impedansietransformators in parallel, vervaardig deur 'n firma in Boksburg, en 11 kV, 350 MVA dubbelgeleistam, hoë olie-inhoud binnemuurse skakeltuig, deur dieselfde firma vervaardig, toegerus.

Die skema bestaan uit 'n rekenaar- en telekontrole-beheerstelsel wat toesighouding en beheer van die nuwe en 'n groot deel van die bestaande verspreidingstelsel van een punt af bewerkstellig.

Die beheerstelsel bestaan uit 'n hoofstasie by die beheersentrum en 'n totaal van 32 buitestasies wat die primêre en sekondêre substasies insluit.

1. SUMMARY

In this paper the factors which induced the Town Electrical Engineer to pursue investigations into the use of 132 kV cross-linked polyethylene insulated cable, the subsequent investigations into the feasibility and reliability of its use and the installation of the first 132 kV XLPE cable installation in South Africa, are described.

2. INTRODUCTION

2.1. The phenominal development of Boksburg's industries and residential townships, coupled with the potential future development within Boksburg's spacious boundaries, necessitated a radical reassessment of the town's electricity needs.

During 1972, this matter was first discussed with ESCOM and in consultation with them, it was agreed that the provision of a point of supply, at 132 kV near the north-eastern boundary of the town, was necessary.

This supply was planned to augment the Council's supply received at 33 kV and with a capacity of 90 MVA and to replace the old supply point received at 11 kV.

The decision was then taken by the Council to establish the 132 kV bulk intake point at Witkoppie and a primary distribution system involving a further two 132/11 kV substations, one at Witfield and the other at Anderbolt.

The main supply point has a firm capacity of 250 MVA and is planned to cater for the northern half of the town. The Municipal area of Boksburg is roughly 28 km long and 8 km wide, constituting the 19 700 h.a.

The future needs of the southern area which it is anticipated will need to be reinforced by 1987, will probably be by means of a further 132 kV intake point from ESCOM.

As early as mid-1973, the target date for receiving power from ESCOM was set for May 1977 and in November 1973, the Agreement for a supply at 132 kV was concluded between ESCOM and the Council.

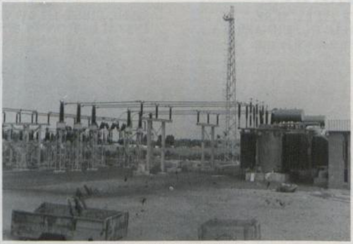
The first of the three 132 kV substations was ready in June 1977, only about a month behind schedule, but as ESCOM was not yet ready with their supply, the 132 kV system was temporarily supplied by means of an existing 33 kV circuit linking Anderbolt 132 kV substation and the "Les Smith" 33 kV main supply point through a 45 MVA, 132/33 kV transformer at Anderbolt 132 kV substation.

ESCOM power at 132 kV was finally switched in on 29 August 1978.

The 132 kV substations consist of outdoor type switchyards, equipped with 132 kV small oil volume circuit breakers, manufactured in Switzerland, each substation having 2 x 40 MVA, 132/11 kV, vector group Yyn 0, 22% impedance transormers in parallel, manufactured by a company in Boksburg and 11 kV, 350 MVA, double busbar bulk oil, indoor type switchgear, also manufactured by the same company.

The scheme incorporates a computer-driven supervisory and telecontrol system which allows supervision and control of the new and a large part of the existing distribution system from one central point.

The system consists of a master station situated at the control centre and a total of 32 outstations, the outstations being the primary and secondary substations.



Part View of Witfield 132/11 kV Substation.
Gedeeltelike Aansig van 132/11 kV-substasie by Witfield.

3. 132 kV-KABEL

3.1. Toe dit duidelik word dat die Stadsraad van Boksburg hom op die voorsiening van 'n 132 kV-stelsel, waar dit nodig was om die hoofverspreiding-substasiestelsels met 132 kV-kringbane te koppel, moes begewe, moes oorweging aan die mees wenslike manier van toevoergeleiding geskenk word.

Die twee moontlike maniere was óf met bogrondse geleidings, óf deur middel van ondergrondse kabels.

Aangesien die roetes wat gevolg moes word oor klein plotte, beboude woon- sowel as nywerheidsgebiede sou lei, was die gebruik van 'n bogrondse stelsel uitgesluit. Behalwe vir moeilikhede wat met die oorgange oor beboude eiendomme ondervind word, was daar ook probleme met die estetiese sy van die saak — 'n vername bydrae tot omgewingsbesoedeling en, natuurlik, is bogrondse geleidings in stedelike gebiede uiters ongewild.

Die afstande tussen die drie substasies is soos volg:

Van Witkoppie na Witfield	— 8 467 meters
Van Witfield na Anderbolt	— 6 088 meters
Van Anderbolt na Witkoppie	— 5 890 meters

Die totale lengte van die roete is dus 20 445 meters.

3.2. KABELTIPE

Nadat die keuse op kabel geval het, was die vraag watter tipe kabel gebruik moes word.

Boksburg was een van die eerste verbruikers van 11 kV-kruisgebonde poliëtileengeïsoleerde kabel en het gedurende 1968 tot die uitsluitlike gebruik daarvan oorgegaan. Na jare se gebruik was die uitslag uiters bevredigend.

'n Verdere oorweging was die gebruik van die XLPE-geïsoleerde kabel teen 132 kV in teenstelling met die gebruiklike 132 kV oliegevulde kabel. Waar gereelde nagaanwerk en instandhouding op die oliedrukstelsel en die alarmkringbane op die oliegevulde kabel uitgevoer moet word, is instandhouding van kruisgebonde poliëtileengeïsoleerde kabel feitlik nie nodig nie.

Indien herstelwerk aan die XLPE-kabel, wat meganies beskadig word, uitgevoer moet word, is dit veel makliker en goedkoper in vergelyking met die oliegevulde kabel waar duur en bypassende vaktoerusting gebruik moet word.

Die kabel-isolasie van XLPE-kabel het die vermoë om op 'n hoër temperatuur as dié van oliegevulde kabel in werking te bly en die diëlektriese verlies van XLPE-kabel is veel laer as dié van oliegevulde kabel. Gevolglik het die XLPE-kabel 'n hoër stroomdravermoë vir dieselfde grootte van geleier en is om hierdie rede meer doeltreffend.

3.3. ONDERSOEKE

Op die tydstip, 1973/1974, was geen 132 kV XLPE-kabel in Suid-Afrika in gebruik nie en die kabel kon ook nie plaaslik vervaardig word nie.

Navrae het getoon dat die mees gevorderde vervaardigers van XLPE-kabel in die 132 kV- tot 154 kV-reeks in Japan en Swede gesetel was.

Toe die Raad tot die slotsom geraak het dat XLPE-kabel uitstaande voordele inhou, was die Elektrotegniese Stadsingenieur afgevaardig om oorsese vervaardigers en gebruikers vir verdere ondersoek met die oog op die moontlike gebruik van die kabel, te besoek.

Die voorwaartse stap van die Stadsraad van Boksburg om die Elektrotegniese Stadsingenieur op 'n oorsese studie te stuur, word as baie wys beskou. Die toer was uiters vrugbaar en insiggewend, waarby onskatbare ondervinding tot die Raad se voordeel opgedoen is. 'n Magdom van inligting word verkry wanneer 'n mens met ingenieurs en wetenskaplikes, buite jou eie vergelykende klein sfeer van ondervinding in ingenieurswese, in aanraking kom.

Die volgende stap is om sommige van die bevindings van die ondersoek aan te haal.

138 kV kruisgebonde poliëtileen-geïsoleerde kabel, vervaardig in Japan, was in gebruik in Puerto Rico deur die Puerto Rico Water and Power Resources., waar die eerste kabel teen die middel van die sestigerjare geïnstalleer was.

Die tyd aan die oorsese besoeke het ongeveer ses weke in beslag geneem en die eerste land besoek was Japan waar met twee firmas besprekings gevoer was.

In die V.S.A. was met een firma in verbinding getree, dog met weinige sukses.

In Swede was 'n ander wêreldbekende firma in die vervaardiging van kabel besoek.

As grondslag vir bespreking met die ingenieurs van hierdie firmas het die Elektrotegniese Stadsingenieur 'n vraestel opgestel en dit voor sy vertrek oorsee, deur middel van plaaslike firmas of agente aan die oorsese firmas laat bekom. Dit was vir twee kabelvervaardigers in Japan, een in die Verenigde State van Amerika en 'n ander in Swede.

Die opgestelde vrae sluit die onderstaande items in en dek sommige kante van die saak wat opgehelder moes word en is kortliks soos volg:

3.3.1. Ontwikkeling van e.h.s. XLPE-geïsoleerde kabel en bybehore.

3. 132 kV CABLE

3.1. When it became evident that the Town Council of Boksburg was to embark on the provision of a 132 kV scheme, where it would be necessary to couple the main distribution substations with 132 kV circuits, consideration had to be given to the most desirable method of transmitting power.

The two possibilities were either by overhead lines or underground cable.

Because the routes to be followed were through areas with small plots, built-up residential areas, as well as industrial areas, the use of overhead lines was ruled out. Besides the difficulty of crossing properties with overhead lines, there were also the problems of aesthetics — a major factor in environmental pollution and, of course, overhead lines in urban areas are generally resented.

The distances between the three substations are as follows:

From Witkoppie to Witfield	— 8 467 metres
From Witfield to Anderbolt	— 6 088 metres
From Anderbolt to Witkoppie	— 5 890 metres

A total route length, therefore, of 20 445 metres.

3.2. TYPE OF CABLE

After the decision had been taken to use cable, the crucial question that arose was, what type of cable should be used.

Boksburg was one of the main pioneers in the use of 11 kV cross-linked polyethylene insulated cable and around 1968 went over to its exclusive use. The results of its use after a number of years were promising indeed.

The next consideration was the use of XLPE insulated cable at 132 kV as opposed to the conventional 132 kV oil-filled cable. Whereas regular checks and maintenance has to be carried out on the oil pressure system and alarm circuitory of oil-filled cable, cross-linked polyethylene insulated cable was considered virtually maintenance-free.

Should the cable require repairs to be done to it following mechanical damage, it was also considered far simpler and cheaper to carry out these repairs to cross-linked polyethylene cable as opposed to oil-filled cable, where costly and sophisticated equipment is required.

The cable insulation of XLPE cable is able to operate at a higher temperature than oil-filled cable and the dielectric loss of XLPE insulated cable is lower than that of oil-filled cable. The result is that XLPE cable has a higher current rating for an equivalent conductor size and, therefore, has a better efficiency.

3.3 INVESTIGATIONS

At the time, 1973/1974, no 132 kV XLPE cable had been in use in South Africa and this cable could not be manufactured locally.

Enquiries about the cable indicated that the manufacturers who were most advanced in the field of XLPE cable-making in the 132 kV to 154 kV voltage range, were situated in Japan and Sweden.

When the Council decided that XLPE cable might hold distinct advantages, the Town Electrical Engineer was delegated to visit overseas manufacturers and users for further investigations into the feasibility of using this cable.

The progressive step taken by the Town Council of Boksburg to send the Town Electrical Engineer on the overseas study tour, was considered very wise. The tour was most fruitful and enlightening where invaluable experience was gained to the benefit of the Council. A wealth of information is gained when one is able to make contact with engineers and scientists outside one's own relatively small sphere of engineering experience.

The next step is to relate some of the findings of the investigation.

138 kV cross-linked polyethylene insulated cable manufactured in Japan, was in use in Puerto Rico at the Puerto Rico Water and Power Resources Co., where the first cable was installed in the mid-60's.

The time spent overseas on this investigation was about sinx weeks. The first country visited was Japan where discussions were held with two companies.

In the U.S.A. contact was made with one company, but with little success.

In Sweden another company of world-renown in the cable-making field was visited.

For the basis of discussion with engineers at these companies, a set of questions was drawn up by the Town Electrical Engineer prior to leaving South Africa and were sent via local companies or agents, to two cable companies in Japan, one in the United States of America and another to a company in Sweden.

The question compiled included the following items covering some of the aspects which needed clarification and are briefly described.

3.3.1. Development of e.h.v. XLPE insulated cable and their accessories.

3.3.2. Die gebruik van spanningstabiliseerders en anti-oksideermiddels.

3.3.3. Probleme in verband met gedeeltelike ontladings en die voorkoming daarvan.

3.3.4. Uitstakeling van onsuiwerhede by die isolasiemateriaal.

3.3.5. Verwagte lewensduurte van XLPE-kabel.

3.3.6. Werkdrukspanning van XLPE-isolasiemateriaal

3.3.7. Konstruksie, materiaal en vervaardigingsproses van e.h.s. XLPE-geïsoleerde kabel.

3.3.8. Waterboomvorming en die voorkoming daarvan.

3.3.9. Sulfiedboomvorming.

3.3.10. Nadelige uitwerking van koper op XLPE-isolasiemateriaal.

3.3.11. Konstruksie van kabelendstukke.

3.3.12. Konstruksie van kabellasse.

3.4. BESPREKINGS MET VERBRUIKERS

3.4.1. In Japan is die buitengewoon hoëspanning XLPE-kabel nogal uitgebreid in gebruik, maar in betreklike kort lengtes.

Besprekings was met senior lede van die Kansai Electric Power Co. gehou. Dié kragverskaffingsfirma is die tweede grootste van tien kragverskaffingsfirmas in Japan en van wie die maksimum aanvraag gedurende 1974 17 000 MW beloop het.

Kabel van tot 77 kV van die XLPE-tipe was algemeen in gebruik en hulle het geslaagde toetse met 154 kV XLPE-kabel uitgevoer.

Hulle enigste besorgdheid was oor die feit dat water in die isolasiemateriaal mag deursyfer wat nie wenslik was nie — veral in die baie laagliggende Osakagebied. Osaka is 'n stad met meer as 5 000 000 inwoners en is die grootste ladingsgebied van die Kansai Electric Power Co.

Alhoewel sommige ingenieurs die mening toegedaan was dat die probleem van waterdeursyfering in die isolasiemateriaal in die Witwatersrandgebied nie 'n oorwegende faktor sou wees nie, was die gedagtewisselings met Kansai Electric Power Co. die hoofrede wat daartoe gelei het dat die Elektrotegniese Stadsingenieur metaalomhulde kabel gespesifiseer het.

3.4.2. Die Puerto Rico Water Resources Co. van Puerto Rico het 138 kV-graad XLPE-kabel sedert die middel sestigerjare gebruik. Hier het die Algemene Skema Superintendent, Elektrotegniese Beplanning, sy volle vertroue in hierdie tipe kabel uitgespreek en gesê dat hulle dit sal aanhou gebruik — afgesien van die lengtes benodig.

3.4.3. Waar die Japanese verbruikers versigtiger in hulle benadering in verband met oorgang tot die gebruik van XLPE-kabel was, was die gebruiker in Puerto Rico en die Swedish State Power Board baie meer waagsaam.

Gedurende 1974 was laasgenoemde vir ongeveer 45% van die kragverskaffing in Swede verantwoordelik.

Volgens die Hoof van die Elektrotegniese Ontwikkelingsafdeling en die Hoofingenieur van die Elektrotegniese Navorsing en Ontwikkelingsafdeling, het die gebruik van XLPE-kabel van 75% tot 100% van alle kabelreekse van 11 kV, 22 kV, 52 kV, 84 kV tot 145 kV uitgemaak.

Die eerste XLPE-kabel geïnstalleer was 'n 22 kV-kabel wat toe reeds vir nege jaar in gebruik was.

Verskeie duisende kilometer XLPE-kabel is in Swede in gebruik en gedurende 1974 was 350 km teen spannings van 52 kV en hoër in werking. Dertig kilometers (enkelaar) 145 kV-kabel was toe vir 'n jaar al in gebruik.

'n Vyf-en-vyftig kilometer 88 kV ondersese kabel is tussen die Sweedse vasteland en Oland in werking.

3.5. BEVINDINGS VAN DIE ONDERSOEK EN ANTWOORDE OP DIE VRAE

3.5.1. Die antwoorde van die Japanese firmas op die vrae was uiters bemoedigend. Die Elektrotegniese Stadsingenieur het verwag dat die ingenieurs redelik goed vir die besprekings in verband met die XLPE-kabel voorbereid sou wees, maar die ingenieurs het in werklikheid die verlangde inligting reeds volledig in dokumentvorm gereed gehad.

Dit het destyds geblyk dat die ontwikkeling van 132 kV XLPE-kabel in die V.S.A. minder gevorderd was as in Japan.

In Swede is blykbaar twee firmas by die vervaardiging van e.h.s. XLPE-kabel betrokke en 'n besoek was by een afgelê. Hier was die ontwikkeling ook goed gevorderd. Gedurende 1974 was die verduursamingsproses egter nog met die "stoomproses" gedoen, terwyl die twee firmas in Japan die "droë gas en infrarooi-straal en trae gas"-manier toegepas het.

3.5.2. SOMMIGE VAN DIE GESIGSPUNTE OOR DIE ONTWIKKELING VAN XLPE-KABEL IN JAPAN

3.5.2.1.

(1) Dit was duidelik dat die toentertydse nuwe kruisgebonde manier waarby infrarooi-strale en trae gasse onder hoë druk in plaas van gebruiklike "versadigde" stroom aangewend was, 'n ontsaglike verbete-

3.3.2. The use of voltage stabilisers and anti-oxidants.

3.3.3. Partial discharge problems and their prevention.

3.3.4. Elimination of impurities from insulating material.

3.3.5. Life expectancy of XLPE insulated cable.

3.3.6. Working stress of XLPE insulation.

3.3.7. Construction, material and manufacturing process of e.h.v. XLPE insulated cable.

3.3.8. Water treeing and prevention.

3.3.9. Sulphide treeing.

3.3.10. Detrimental effect of copper on XLPE insulation.

3.3.11. Construction of cable terminations.

3.3.12. Construction of cable joints.

3.4. DISCUSSIONS WITH USERS

3.4.1. In Japan, supertension XLPE cable had been in use fairly extensively, but in relatively short lengths.

Discussions were held with senior members of the Kansai Electric Power Co., which is the second largest of the ten power companies in Japan, with a maximum demand in 1974, of 17 000 MW.

Cable up to 77 kV of the XLPE type was in common use and they had carried out satisfactory tests on 154 kV XLPE cable.

The only concern they expressed, was the fact that water could permeate into the insulation which was not a desirable feature, especially in the very low lying Osaka area. Osaka, a city with a population in excess of 5 000 000 inhabitants, constitutes the largest load area for the Kansai Electric Power Co.

Although some engineers felt that the problem of water permeating into the cable in the Witwatersrand area, would be of no consequence, the discussions with the Kansai Electric Power Co. was the main influence which induced the Town Electric Engineer to specify cable with a metallic sheath.

3.4.2. The Puerto Rico Water Resources Co. in Puerto Rico has been using 138 kV grade XLPE cable since the mid 60's. Here the General Project Superintendent, Electrical Design, voiced complete confidence in this type of cable and stated that they would continue using it irrespective of the lengths.

3.4.3. Where there was possibly a more cautious approach observed with the change to the use of XLPE cable by the Japanese users, the confidence shown by the user in Puerto Rico and the Swedish State Power Board, was far bolder.

In 1974, the Swedish State Power Board was responsible for approximately 45% of the total power generation in Sweden.

According to the Head of the Electrical Development Section and the Chief Engineer of the Electrical Research and Development Section, the use of XLPE type cable constituted about 75% — 100% of all cable used in the voltage ranges 11 kV, 22 kV, 52 kV, 84kV and 145 kV.

The first XLPE cable installed was a 22 kV cable which had been in use for about nine years.

Several thousand kilometres of XLPE cable is in use in Sweden and in 1974 350 km was in operation at voltages of 52 kV and higher. Thirty kilometres (single core kilometres) of 145 kV cable had been in service for one year.

A 55 km long, 88 kV submarine cable was in operation between the Swedish main land and Oland.

3.5. FINDINGS OF THE INVESTIGATION AND ANSWERS TO QUESTIONS POSED

3.5.1. The response to the questions by the Japanese companies was extremely heartening. Where the Town Electrical Engineer expected to find the engineers reasonably prepared for discussions on XLPE cable, they had in fact prepared complete dossiers on the queries submitted.

It appeared at the time that development of XLPE cable in the 132 kV range in the U.S.A. was less advanced than the development in Japan.

In Sweden, there are apparently two companies involved in the manufacture of e.h.v. XLPE cable of which one company was visited. The progress in development here was also well advanced. However, in 1974, the curing process was still done by a steam process whereas in Japan dry-gas curing and infrared rays and inert gases processes had been adopted by the two companies visited.

3.5.2. SOME ASPECTS ON THE DEVELOPMENT OF XLPE CABLE IN JAPAN

3.5.2.1.

(1) It was evident that the then new cross-linking method using infrared rays and high pressure inert gases instead of conventional saturated steam, was a vast improvement, especially for e.h.v. cables. With this

ring veral in die geval van e.h.s.-kabel was. Op hierdie manier is die uiters klein blasies in die isolasiemateriaal, sowel in aantal as in grootte, merkwaardig verminder, met die gevolglike vermindering van waterinhoud. 'n Weinig water was nog merkbaar — moontlik van die verkoelingswater.

Dit word aangeneem dat die onderstaande omstandighede die verswakking van die isolasiemateriaal beïnvloed:

(a) Water in die materiaal opgesuig.
(b) Blasies of lugleegtes in die materiaal.
(c) Onsuiwerhede in die materiaal.
(d) Onewredighede en uitsteeksels in beide die geleier- en aardeelsgeleierskerms.

By die stoomverduursamingsmetode kan spoed ook beperking hê as gevolg van die buissterkte wat met hoër druk van versadigde stoom en meegaande hoër temperature benodig word — met ander woorde, hoe hoër die temperatuur, hoe hoër die druk.

Met die "verduursaming-met-bestraling-metode" (RCP) kan die verwarmingstemperatuur onafhanklik van die druk van die trae gas verhoog word sodat die isolasiemateriaal teen 'n temperatuur van 300° Celsius, waar die materiaal byna ontbind, kruisgebind kan word.

Fig. 1 dui die vertikale verduursaming-met-bestraling-metode aan.

FIG. 1

RCP Regopstaande Deurlopende Vulkaniseerder
80 m Hoog: Uiterste voorsorg word met die samestelling- en by deurpersprosesse teen stof en onsuiwerhede geneem

Die kruisbindingbuis is saamgestel uit 'n bestralingsverhittingsone langs die inleigedeelte van die buis, 'n verkoelingsgedeelte by die uitlei-end van die buis en 'n tussengeplaasde voorverkoelingsone.

Binne die bestralingsverhittingsone en die voor-verkoelingsone word trae gasse soos stikstof teen 980 kPa of hoër verseël. Binne die verkoelingsone is water onder dieselfde drukking as dié van die trae gas. Water vir verkoeling word voorsien deur 'n inlaatluik in die laer gedeelte van die verkoelingsone en loop by 'n uitlaatluik by die boonste gedeelte van die sone uit. Die trae gas word deur die boonste luik van die verhittingsone ingelaat en by die laer uitlaatluik van die verkoelingsone uitgelaat, en word in omloop gehou en gekondenseer om sodoende die indringing van stoom uit die verhittingsone te hou.

Gegewens van toetse in verband met vergelykings van die groottes van lugleegtes het getoon dat by XLPE-kabel wat met die verduursamingsproses met stoom onder goed-beheerde toestande vervaardig was, 'n aantal lugleegtes van ongeveer 10 µm het. Sommige lugleegtes so groot as 50 µm was gevind.

By XLPE-kabel wat met die verduursamingsmetode met bestraling vervaardig is, het die meeste lugleegtes nie 1 µm oorskry nie en slegs 'n paar van 5 — 10 µm was gevind.

Rede vir bogenoemde word aanvaar as synde die verskil in molekulêre kenmerkendheid van stikstofgas en stoom.

3.5.2.1.1.
(2) Gedurende 1976 het Dr. Ikeda en 'n span Navorsers van 'n ander Japanese kabelvervaardiger hulle bevindings in verband met die voginhoud van die isolasiemateriaal en die water-absorberende eienskappe

method the microvoids in the insulation were markedly reduced both in number and size, also with a resultant reduction in water content. A little water was still evident, presumably from the cooling water.

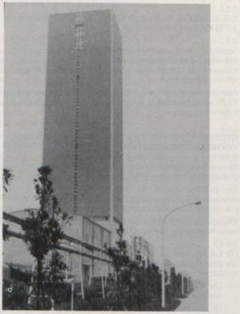
The following factors are considered to affect the deterioration of insulation:

(a) Water absorbed in the insulation.
(b) Voids in the insulating material.
(c) Contaminents in the insulating material.
(d) Irregularities and projections of both the conductor and core semiconducting screens.

With the steam curing process there could also be limitations in the cross-linking speed, because of cross-linking tube strengths required for higher saturated steam pressures and associated temperatures. In other words, the higher the temperature, the higher the pressure.

With the radiant curing process (RCP), however, the heating temperature can be raised independently of the inert gas pressure so that the insulation can be cross-linked at a temperature of about 300° Celcius, where the insulation nearly decomposes.

Fig. 1 illustrates a vertical type of radiant curing process.



RCP Vertical Continuous Vulcanizer
80 m in height: Great care is taken in the compounding and exstruding process to prevent dust and other impurities from entering.

The cross-linking tube is comprised of a radiant heating zone located adjacent to the lead-in portion of the tube, a cooling zone provided at the lead-out end of the tube and an intermediately located pre-cooling zone.

Inside the radiant heating zone and pre-cooling zone, inert gases such as nitrogen at 980 kPa or more are sealed. Inside the cooling zone, there is pressurized water with the same pressure as the inert gas. Cooling water is furnished from an inlet port at the lower portion of the cooling zone and exhausted from the outlet port at the upper portion of the zone. The inert gas which is furnished from the upper inlet port of the heating zone and exhausted from the lower outlet port of the pre-cooling zone, is circulated and condensed so as to prevent the intrusion of steam into the heating zone.

Data obtained from tests carried out regarding the comparison of the size of voids, showed that in XLPE cable manufactured with the steam curing process under well-controlled conditions, had a number of voids of about 10 µm. Some voids as large as 50 µm were found.

In the XLPE cable manufactured with the radiant curing process, most of the voids did not exceed 1 µm and only a few 5 — 10 µm voids were found.

The reason for the above is assumed to be due to the difference of the molecular characteristic between nitrogen gas and steam.

3.5.2.1.1.
(2) In 1976, Dr. Ikeda and a team of Researchers of another Japanese cable manufacturer, presented their findings of a study made with regard to the moisture content in the insulation and the water absorbing

van kruisgebonde poliëtileen-geïsoleerde kabels wat met gas en wat met stoom behandel is, opgestel.

Die bevindings was soos volg:

(a) Die aanvanklike voginhoud by kruisgebonde poliëtileenkabel, met gas behandel in vergelyking met stoombehandelde kabel, was laer as 100 g p m van gas en 3 000 g p m van stoom

Selfs by elke kabel, in water gedompel nadat dit gedroog was, was die waterinsypeling by gasbehandelde kabel laer as dié by stoombehandelde kabel.

(b) Die versadigde voginhoud van kruisgebonde poliëtileen-geïsoleerde kabel is in noue verhouding met sy digtheid, dit wil sê hoe hoër die digtheid, hoe laer die voginhoud.

3.5.2.2.
(1) Elektriese werkverrigtingtoetse was uitgevoer en daar was gevind dat die breekpuntkarakteristieke by beide stoom- en bestralingsbehandelde kabel so te sê eners is. Dit was egter van 'n "breek onder drukspanningkurwe" duidelik dat daar by bestralingbehandelde (RCP) kabel minder gebreke in die isolasiemateriaal was as dié by stoombehandelde kabel.

3.5.3.
DIE GEBRUIK VAN SPANNINGSTABILISEERDERS EN ANTI-OKSIDEERMIDDELS

3.5.3.1.
Skynbaar bestaan daar by vervaardigers twyfel oor die gebruiksduur van kabel met spanningstabiliseerders en vulsels en hoofsaaklik om hierdie rede word dit nie algemeen gebruik nie — veral nie by kabel in die hoër spanningsreekse nie.

Aan die anderkant word anti-oksideermiddels by die samestelling van XLPE-isolasiemateriaal gevoeg ten einde die hittelewensduur te verleng.

3.5.4.
GEDEELTELIKE ONTLADINGSPROBLEME EN DIE VOORKOMING DAARVAN

3.5.4.1.
Die teenwoordigheid van lugleegtes in die isolasiemateriaal veroorsaak gedeeltelike ontlading.

Die teenwoordigheid van onsuiwerhede in die diëlektrikum en uitsteeksels op die oppervlakte van die aar en geleier se halfgeleierskerm veroorsaak boomvorming waardeur gedeeltelike ontladings plaasvind.

Gedeeltelike ontlading beskadig die diëlektrikum en mag tot algehele onderbreking van die kabel lei.

3.5.4.2.
(3) Die vervaardiger wat 132 kV-kabel aan Boksburg voorsien het, het die onderstaande teenmaatreëls getref om gedeeltelike ontlading te verminder.

(a) Die aanbring van deurperste geleier en diëlektriese halfgeleierskerms.

Dit skakel uitsteeksels tussen die vlakke van die isolasiemateriaal en die halfgeleierskerms uit.

(b) Die toepassing van die drielaag-deurpersstelsel — een laag volg op die ander — naamlik, die geleierskerm, diëlektrikum en die diëlektriese skerm.

Hierdie drielaag-deurpersstelsel bring mee dat die drie lae stewig aanmekaar gebonde raak en verhoed die inbring van onsuiwerhede op die oppervlak van die isolasiemateriaal.

(c) Die toepassing van die bestralinghitte-behandeling.

Soos in paragraaf 3.5.2.1. beskryf, word die grootte sowel as die aantal lugleegtes met hierdie tegniek tot 'n baie hoë mate verminder en dra as sulks tot die voorkoming en drastiese vermindering van gedeeltelike ontlading by.

3.5.5. UITSKAKELING VAN ONSUIWERHEDE BY DIE ISOLASIEMATERIAAL

3.5.5.1.
Streng maatreëls word nie slegs teen die inbring van onsuiwerhede in die fabriek self getref nie, maar word ook op spesifikasies deur die vervaardigers van XLPE-mengsel streng toegepas.

Die XLPE-mengsel word in verseëlde houers met saamgeperste stikstofgas vervoer.

Klein hoeveelhede anti-oksideermiddels en kruisbindingsmiddels kan moontlik in "onsuiwerhede" ontwikkel, tensy dit egalig gemeng word. Die meng van bestanddele word met uiterste versigtigheid en behoorlik gedoen.

By die werksplek word die mengsel deur lugdrukpypleidings na die deurpersstelsel gevoer.

Die deurpersing word in 'n afsonderlike stofbeheerde "skoon"vertrek uitgevoer. Stoffiltreerders word gebruik om stofdeeltjies groter as 5 µm uit te sluit.

properties of cross-linked polyethylene insulated cables cured in gas and steam.

The study revealed the following:

(a) Initial water content in cross-linked polyethylene cable manufactured by the gas curing process compared with that of the steam curing process, is below 100 p p m for the gas curing process and 3 000 p p m for the steam curing process.

Even when each cable is immersed in water after drying, the absorbed moisture content in the gas-cured XLPE cable is lower than that in the steam-cured XLPE cable.

(b) Saturated moisture content of cross-linked polyethylene is closely related to its density, i.e. the larger the density, the lower the moisture content.

3.5.2.2.
(1) Electrical performance tests were conducted and it was found that the breakdown characteristics for both XLPE cable manufactured by the steam cured process and XLPE cable manufactured by the radiant curing process, are almost the same. However, from a breakdown stress probability curve, it was evident that there are less insulation by the RCP than XLPE cable manufactured by the steam curing process (SCP).

3.5.3.
THE USE OF VOLTAGE STABILISERS AND ANTI-OXIDANTS

3.5.3.1.
There appears to be some doubt by manufacturers as to the service life of cable containing voltage stabilisers and fillers and mainly because of this, is not generally used, especially in cable in the higher voltage ranges.

Anti-oxidants, on the other hand, are introduced in the XLPE compound to extend the thermal life of XLPE.

3.5.4.
PARTIAL DISCHARGE PROBLEMS AND THEIR PREVENTION

3.5.4.1.
The presence of voids in the insulating material causes partial discharges.

The presence of impurities in the dielectric and protrusions on the surface of the conductor and core semi-conducting screens, causes treeing in which partial discharges occur.

Partial discharges damage the dielectric and may lead to cable breakdown.

3.5.4.2.
(3) The manufacturer who supplied the 132 kV cable for Boksburg adopted the following counter-measures to reduce partial discharges.

(a) Application of extruded conductor and dielectric semi-conducting screens.

The application of extruded conductor and dielectric semi-conducting screens eliminates protrusions between the interfaces of the insulating material and the semi-conducting screens.

(b) Application of the three-layer tandem extrusion of the conductor screen, the dielectric and the dielectric screen.

The three-layer tandem extrusion allows the three layers to bond firmly and prevents the introduction of impurities onto the surface of the insulation.

(c) Application of the radiant heat curing process (RCP).

As described under clause 3.5.2.1., the RCP technique reduces both the size and number of micro voids drastically and as such contributes to the prevention or drastic reduction of partial discharge.

3.5.5. ELIMINATION OF IMPURITIES FROM THE INSULATING MATERIAL

3.5.5.1.
Not only are strict measures adopted to control the introduction of impurities at the factory, but strict specifications and measures are adopted by the manufacturers of the XLPE compound.

The compound is then transported in sealed containers filled with compressed nitrogen gas.

Small quantities of anti-oxidants and cross-linking agents can possibly become impurities if not uniformly mixed. Great care is, therefore, taken that this mixing is properly done.

Once the material is on site, the compound is conveyed to the extruder through pneumatic pipelines.

The extrusion is conducted in a specially dust-controlled "clean" room. Dust filters are used to exclude dust particles exceeding 5 µm.

Persons working inside this room wear special clothing and shoes to prevent foreign particles being present.

Persone wat hier werk, dra uitsonderlike kleding en skoene om die aanwesigheid van ongewenste deeltjies te vermy.

Die deurperstoerusting word rekenaar-beheer en ongewenste metaalvoorwerpe wat in die rou-materiaal teenwoordig mag wees, word met gebalanseerde magnetiese veldspoele opgespoor.

Inspeksietoetse vir onsuiwerhede word ook voortdurend op monsters uitgevoer.

3.5.6. VERWAGTE LEWENSDUURTE VAN KRUISGEBONDE POLIËTILEEN-GEÏSOLEERDE KABEL

3.5.6.1.
Die verwagte lewensduurte van kruisgebonde poliëtileen-geïsoleerde kabel onder gewone werkstemperatuur van 90° Celsius, dit wil sê onder volle ladingtoestande, is dertig jaar.

Die V — t toets, waar oorspanning aangebring word, is die mees algemene metode om die lewensduurte van kabel te bepaal.

'n Aantal kabelmonsters word onder verskillende spannings en in verskillende omstandighede geplaas, byvoorbeeld sommige in lug, ander in water en nog ander met of sonder 'n ladingstroom.

Die tydsduur totdat breekpunt bereik word, word dan teen die toegepaste spanning van die betrokke monster uitgestip.

Van die uitslae hiervan verkry, kan die toelaatbare drukspanning, dit wil sê die dikte van die isolasiemateriaal, vir dertig jaar se doeltreffende diens onder gewone omstandighede bereken word.

3.5.7. WERKSPANNING VAN XLPE-ISOLASIEMATERIAAL

3.5.7.1.
Die maksimum werkspanning van stoombehandelde XLPE-geïsoleerde kabel is ongeveer 7 kV/mm in nat toestande, terwyl die toelaatbare maksimum spanning tot so hoog as 10 kV/mm in droë toestande kan wees.

Kruisgebonde poliëtileen-geïsoleerde kabel tot op 33 kV-spanning mag stoombehandel word, maar die opsteller is persoonlik die mening toegedaan en verkies dat 33 kV XLPE-kabel met die droëmetode behandel behoort te word. Die droëmetode word egter gewoonlik vir hoër spannings gebruik.

Die maksimum beplande werkdrukspanning teen 33 kV is gewoonlik tot 4 kV per mm beperk, teenoor hoër werkdrukspanning wat in die 42 tot 132 kV-reeks gebruik word.

Hoewel die toelaatbare werkspanning van die bestralingbehandelde kabel hoër mag wees, het die vervaardigers besluit om 'n laer waarde, naamlik 6,4 kV/mm, as die maksimum toelaatbare werkspanning te gebruik.

Die grootte van die geleier beïnvloed die ontwerp van die dikte van die kabelisolasie insoverre dat, vir 'n sekere vasgestelde spanning, die dikte van die isolasiemateriaal vir 'n kleiner geleier dikker as vir 'n groter geleier vir dieselfde drukspanning moet wees.

Die onderstaande formule is by die berekening van drukspanning van toepassing:

$$\text{Drukspanning (S)} = \frac{2 \times E_o}{d \text{ Log}_e \frac{D}{d}}$$

Waar S = Drukspanning in kV/mm
E_o = Fase-na-aardspanning in kV
d = Deursnee van geleier oor geleierskerm gemeet in mm
D = Buitedeursnee van diëlektrikum in mm

Hoewel die kabel wat in Boksburg geïnstalleer is vir 'n drukspanningvlak van 6,4 kV/mm ontwerp is, is die drukspanning van die voltooide kabel, gegrond op werklike afmetings, ongeveer só:

$$S = \frac{2 \times 76{,}21}{23{,}6 \times \text{Log}_e \frac{66{,}3}{23{,}6}}$$

$= 6{,}25$ kV/mm

3.5.8. KONSTRUKSIE, MATERIAAL EN VERVAARDIGINGSPROSES VAN e.h.s. XLPE-GEÏSOLEERDE KABEL

3.5.8.1.
Hierdie item word verderaan in hierdie referaat met besonderhede van die spesifikasie beskryf.

3.5.9. WATERBOOMVORMING EN DIE VOORKOMING DAARVAN

3.5.9.1. Wanneer water by die geleiers inkom, of deur die isolasiemateriaal insypel, vind boomvorming van die geleierskermend af straalsgewys uitwaarts deur die XLPE-isolasiemateriaal plaas. Dit gebeur onder betreklik lae drukspanningstoestande.

The extruder is computer-controlled and foreign metal objects which may be present in the raw plastic material are detected by balanced magnetic field coils.

Impurity tests by continual sampling are also carried out.

3.5.6. LIFE EXPECTANCY OF XLPE INSULATED CABLE

3.5.6.1. The life expectancy of XLPE insulated cable is 30 years at a normal operating temperature of 90° Celsius, i.e. full load conditions.

The V — t test, where over-voltage is applied, is the most common test method of determing the cable life.

A number of cable samples are taken and each electrically stressed to a different value and different test conditions, i.e. some in air, some in water and some samples with load current and others no load current.

The time to break-down of the various samples is then plotted against the stress applied to the cable test piece.

The results obtained are then used to determine the permissible stress, therefore the thickness of the insulation, for thirty years of satisfactory operation in normal service.

3.5.7. WORKING STRESS OF XLPE INSULATION

3.5.7.1.
The maximum working stress of XLPE insulated cable cured by steam, is approximately 7 kV/mm in wet conditions, while in dry conditions, the permissible maximum stress could be as high as 10 kV/mm.

Cross-linked polyethylene insulated cables up to 33 kV can be steam cured, but it is the author's personal opinion and preference that 33 kV XLPE insulated cables should be dry cured. Dry curing, however, is normally adopted at higher voltages.

Maximum design stress at 33 kV is normally limited to 4 kV per mm, whereas higher stresses are used in the voltage range 42 to 132 kV.

Although the XLPE cable cured by the radiant heat curing process is capable of a higher permissible stress, the manufacturers decided to use a lower design value. i.e. 6,4 kV/mm as a maximum permissible working stress.

The size of conductor affects the design of thickness of cable insulation in that, for a specific voltage, the insulation thickness is greater for a small conductor than for a large conductor to maintain the same stress level.

The following formula applies to the calculation of stress:

$$\text{Stress (S)} = \frac{2 \times E_o}{d \text{ Log}_e \frac{D}{d}}$$

Where S = Stress in kV/mm
E_o = Phase to earth voltage in kV
d = Diameter over conductor screen in mm
D = Outside diameter of dielectric in mm

Although the cable installed in Boksburg was designed to a stress level of 6,4 kV/mm, the stress of the completed cable, based on actual measurements, is approximately as follows:

$$S = \frac{2 \times 76{,}21}{23{,}6 \times \text{Log}_e \frac{66{,}3}{23{,}6}}$$

$= 6{,}25$ kV/mm

3.5.8. CONSTRUCTION, MATERIAL AND MANUFACTURING PROCESS OF e.h.v. XLPE INSULATED CABLE

3.5.8.1.
The construction of the cable, the material used, etc. is described later in the paper where details of the specification are given.

3.5.9. WATER TREEING AND PREVENTION

3.5.9.1.
When water enters a cable via the conductor, or permeates through the insulation, water trees grow from the conductor screen end and radially outwards through the XLPE insulation. This occurs in relatively low field stress conditions.

Dit is gevind dat hierdie verskynsel by kabel voorkom waar die halfgeleierskerm met band omwind was, maar nie by kabel waar die halfgeleierskerm met die deurpersstelsel behandel was nie. Dit is dus duidelik dat die deurpersstelsel by geleierskerms onontbeerlik vir die voorkoming van boomvorming in water is.

3.5.9.2.
Oor die saak of boomvorming in water, waar dit uit lugleegtes en onsuiwerhede spruit, die lewensduurte van kabel nadelig beïnvloed of nie, bestaan daar verskillende menings.

V — t toetse oor lang tydperke dui daarop dat XLPE-geïsoleerde kabel wat met die bestraling-hitte-stelsel behandel is en wat kleiner en 'n minder aantal lugleegtes bevat, 'n lang genoeg lewensduurte het, selfs by toetse uitgevoer terwyl die kabel onder water was. Dit dui aan dat die bestraling-hitte-stelsel 'n verdere teenmaatreël teen waterboomvorming is.

3.5.10. SULFIED-BOOMVORMING

3.5.10.1.
(4) Waar kabel in grond, waar ontbindingsmikrobes swaelwaterstof vrystel, gelê word, dring die swaelwaterstof deur die polivinielchloriedomhulsel en die isolasiemateriaal waar dit dan met die geleier in aanraking kom. Dit word gewoonlik in die omgewing van besoedelde strome, riole en afloopwater van chemiese fabrieke teëgekom.

Swaelwaterstof reageer heel maklik met 'n aantal metale en metaaloksides en wanneer dit met koper reageer, gee dit 'n swart koperhoudende sulfide af. Die verweringsmateriaal vermeerder tot drie keer die oorspronklike volume en dit word aangeneem dat hierdie uitset in volume 'n geweldige druk op die isolasielaag uitoefen.

Dit word veronderstel dat die verweringsmateriaal geleidelik 'n weg deur die swakste punte na buite vind en stervormige krake veroorsaak. Die krake raak met die verweringsmateriaal gevul en veroorsaak sulfide-boomvorming, algemeen bekend as die verskynsel van chemiese boomvorming.

3.5.10.2.
Waar kabel in grond, waarin swaelwaterstof aanwesig is, gelê moet word, en om sulfiedvorming te voorkom, is die mees doeltreffende manier om die kabel met 'n metaalomhulsel te dek.

3.5.11. NADELIGE UITWERKING VAN KOPER OP DIE XLPE-ISOLASIEMATERIAAL

3.5.11.1.
Dit is bekend dat koper 'n nadelige uitwerking, as gevolg van katalitiese werking, op polipropileen het. Op XLPE-isolasiemateriaal is die uitwerking egter onbeduidend.

Die voorsieners van die kabel het toetse uitgevoer ten einde die tydsbestek, wat dit die XLPE met verskillende tipes van geleiers sal neem om met suurstof deurdring te word, te bepaal.

Katalitiese uitwerking van koper was bemerk, maar was van 'n onbelangrike aard.

Toetse is ook uitgevoer om vas te stel of 'n hoeveelheid anti-oksideermiddel die XLPE-isolasiemateriaal beïnvloed. Dit is gevind dat die byvoeging van 'n klein hoeveelheid anti-oksideermiddel die XLPE-isolasiemateriaal teen die invloed van die kopergeleier vrywaar.

3.5.12. KONSTRUKSIE VAN KABELENDLASSE

3.5.12.1.
Instruksie Handboek

'n Goed-voorbereide handboek met volledige uiteensetting word by buitemuurse kabelendlasse verskaf.

Toe kruisgebonde poliëtileen-geïsoleerde kabel in die 11 kV-reeks vir die eerste keer, ongeveer gedurende 1967 op die Suid-Afrikaanse mark verskyn het, was die indruk geskep dat hierdie kabel ru en onverskillig hanteer kon word.

Lateraan is hierdie misverstand uit die weg geruim toe besef is dat, hoewel hierdie tipe kabel stewiger as papier-geïsoleerde en die hoër spanning oliegevulde-tipe kabel is, die kabel tog redelik hanteer behoort te word.

Dit is daarom betekenisvol dat in die handboek uit die staanspoor benadruk word dat teen die teenwoordigheid van stof en vogtigheid gewaak moet word.'n Lys van materiaal by endlasse benodig, word voorsien en moet nagegaan word voordat met die werk begin word.

3.5.12.2.
Verseëlde endlasse is vir buitemuurse gebruik ontwerp en bestaan uit voorafgevormde drukweerstandskeëls wat van halfgeleier etileen-propileen-rubber en etileen-propileen-rubber-isolasiemateriaal saamgestel is en wat dan om die kabelend aangebring en met 'n drukring op 'n epoksi-eenheid vasgepers en uiteindelik in 'n wit porselein-deurvoerder gehuisves word.

By koppeling van geleiers word die vaspersmetode teen 306 MPa-druk (25 ton p.vk.dm.) gebruik.

Die porseleindeurvoerder word met silikonolie gevul.

This phenomenon, it was found, occured in cables with taped semi-conducting conductor screen, but not in cables with extruded semi-conducting screen. It is, therefore, evident that extruded conductor screens are vital to prevent water treeing.

3.5.9.2.
As for water treeing from voids or contaminants, there were differing opinions whether these trees formed had detrimental effects on cable life or not.

Long term V — t tests indicate that XLPE insulation cured by the radiant heat curing process, where less and smaller voids and water is present, has enough service life even when the cable is tested while submersed in water. This would indicate that the use of the radiant heat curing process is a further counter-measure to prevent water treeing problems.

3.5.10. SULPHIDE TREEING

3.5.10.1.
(4) When cable is buried in soil where hydrogen sulphide, produced by anaerobic microbes, is present, the hydrogen sulphide penetrates the PVC sheath and insulation where it reaches the conductor. The environment where these conditions are often found, is in polluted rivers, sewers and drain water from chemical factories.

Hydrogen sulphide reacts readily with a number of metals and metal oxides, and when it reacts with copper, produces black supric sulphide. The corrosion product increases to three times the original volume and this volume inccrease is thought to create tremendous pressure in the insulation layer.

The corrosive product is presumed to find its way gradually through the weakest parts, radially extending outwards, while cause cracks, which are filled with the corrosive product to form sulphide trees or as this phenomenon is also known, chemical trees.

3.5.10.2.
When hydrogen sulphide exists in soil where cable is to be laid, the most effective method of preventing sulphide permeation, is to cover the cable with a metallic sheath.

3.5.11. DETRIMENTAL EFFECT OF COPPER ON XLPE INSULATION

3.5.11.1.
It is known that copper has a detrimental effect on polypropylene due to catalytic action. On XLPE insulation, the effect is, however, considered to be negligible.

The suppliers of the cable carried out tests to determine the induction of oxygen absorption in XLPE with various types of conductors.

The catalytic influence of copper was observed, but the effect proved to be negligible.

Tests were also carried out to determine the effect a quantity of anti-oxidant would have on the XLPE insulation and it was found that by adding a small quantity of anti-oxidant, the XLPE insulation was protected from the influence of the copper conductor.

3.5.12. CONSTRUCTION OF CABLE TERMINATIONS

3.5.12.1.
Instruction Manual

A detailed and carefully prepared instruction manual was provided for the outdoor type terminations.

When cross-linked polyethylene insulated cable in the 11 kV range first appeared on the market in South Africa about 1967, the impression was gained that this type of cable could be rough-handled and mistreaded.

Subsequently, however, this misconception has been cleared with the realisation that this cable must also be given fair treatment in spite of the fact that it is more robust than paper insulated and the higher voltage oil-filled cables.

It is, therefore, significant to note that at the outset, the instruction manual stresses the fact that care must be taken against the presence of dust and moisture.

A material list was provided for the operation, which is required to be checked before proceeding with the work on the terminations.

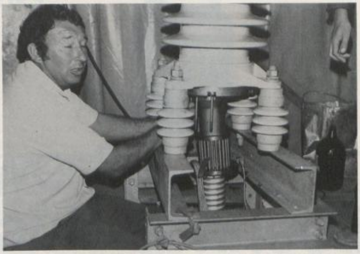
3.5.12.2.
The sealing ends are designed for outdoor use and utilise pre-moulded stress relief cones which are made of semi-conducting EP rubber and insulating EP rubber, which is put on the cable and pressed on to an epoxy unit by a compression ring. This is housed in white porcelain bushings.

The compression method using a 306 MPa (25 tons p.s.i.) press is used for the conductor connection.

The porcelain bushing is filled with a silicone oil.

Al om die vierde dag was drie verseëlde endstukke gemonteer en voltooi. In die hele voltooide stelsel is daar agtien sulke endlasse en honderd en sewentien deurlasse.

Three sealing ends were erected and completed every four days. In the completed system, there were 18 sealing ends and 117 straight-through joints.



132 kV Cable Sealing End Under Construction
132 kV-Kabel Verseëlde Endlas Onder Konstruksie

3.5.13. KONSTRUKSIE VAN KABELLASSE

Een lasvlak met drie deurlasse, skakelkassies en aarding was elke vyf dae voltooi. Die las van die geleiers word met 'n persbeslagring uitgevoer. Die lengte van die beslagring voordat dit gepers word, is 150 mm. Die perstoerusting van 'n drukking van 306 MPa (25 ton p. vk. dm.) ontwikkel. By elke las word 104 x 10 m rolle silikon-selfkleer-butiel rubberband gebruik. 'n Pypvormige koperhuls vorm die skerm van die las en dien as aarddeurlopenheid. Die huls, op sy beurt, word deur 'n fabrieksgemonteerde hitteverkrimpte PVC-omhulsel beskerm. Die koperhuls word met 'n hars-isoleermengsel, in blywende gedeeltelike vloeibare staat, gevul.

Die isoleerband word met 'n bandmasjien, wat deur die vervaardigers uitsluitlik vir hierdie doel ontwerp en ingevoer is, aangebring. Die masjien verseker die egalige trekspanning en oorvleueling van die band en word voortdurend verstel om die verlangde profiel te bewerkstellig.

4. INWAG VAN TENDERS VIR XLPE-KABEL

4.1. ALGEMEEN

4.1.1. Om maar een van 'n handjievol ingenieurs in die Republiek van Suid-Afrika te wees wat die gebruik van XLPE-kabel in die e.h.s.-reeks voorstaan, terwyl die meerderheid van jou kollegas en ingeniers van ander organisasies skepties daarteenoor staan, laat 'n mens werklik alleen voel. So was dit in 1974.

Die uitslag van die ondersoek in verband met die moontlike gebruik van XLPE-geïsoleerde kabel in die 132 kV-reeks, was egter so bemoedigend dat die Elektrotegniese Stadsingenieur die gebruik daarvan kon aanbeveel.

Boksburg se leuse "RESPICE FINEM", wat "let op die einde" of in ander woorde "kyk vooruit" beteken, was in hierdie geval regtig van toepassing.

4.1.2. Tenders was gedurende Maart/April 1975 ingewag en teen die end van Junie 1975 toegewys.

Wat die spesifikasie aanbetref, was tenderaars versoek om aanbiedings te doen vir, eerstens, gespesifiseerde groottes van kabel, dit wil sê vir 500 mm² aluminiumgeleiers en 300 mm² kopergeleiers of XLPE-geïsoleerde kabel, òf oliegevulde kabel en, tweedens, kabel geskik vir 'n dravermoë van 100 MVA. Die redes hiervoor was, (a) dat alle tenderaars vir dieselfde grootte kabel 'n prysopgawe sou gee en (b) dit was verwag dat die grootte van kabel vir 100 MVA groter vir 500 mm² aluminium- of vir 300 mm² koperkabel sou wees. Aanbiedings vir oliegevulde kabel het dieselfde groottes vir sowel 500 mm² aluminium- asook vir 300 mm² koperkabel vir 100 MVA aangebied en die vervaardigers van XLPE-geïsoleerde kabel het kleiner groottes van geleiers vir 100 MVA kabel aangebied. Om hierdie rede was dit aanbeveel dat die aanbiedings van 100 MVA XLPE-kabel nie oorweeg word nie en dat slegs 500 mm² aluminium- en 300 mm² koperkabel oorweeg behoort te word.

Die prys vir 300 mm²kopergeleier XLPE-kabel was ongeveer 18,3% hoër as dié van 300 mm² kopergeleier oliegevulde kabel.

Die maksimum ononderbroke stroomdravermoë van oliegevulde kabel was 440 amp. en dié van XLPE-kabel was 571 amp. teen 'n geleier-tem-

3.5.13. CONSTRUCTION OF THE CABLE JOINT

One joint bay comprising 3 straight joint link boxes and earthing was completed every 5 days. The conductor jointing was effected by using a compression ferrule. The ferrule was 150 mm long prior to compression. The compression tool develops a pressure of 306 MPa (25 tons p.s.i.) Each joint requires 104 x 10 m rolls of silicone based self amalgamating butyl rubber tape. A cylindrical copper sleeve forms the joint protection and provides earth continuity. The sleeve is protected by a factory-applied heat shrink PVC sheath. The copper sleeve is filled with an insulating resin compound. This compound remains in a semi-fluid state.

The insulating tapes are applied with the aid of a taping machine especially imported and developed by the manufacturers. This machine ensures that the tapes are applied with the correct tension and overlap. The machine is constantly adjusted to give the desired profile.

4. TENDERING FOR THE 132 kV XLPE CABLE

4.1. GENERAL

4.1.1. To be one of a small handful of engineers in the Republic of South Africa who favours the use of XLPE insulated cable in the e.h.v. range, when the majority of one's colleagues and engineers from other organisatios stand sceptical towards its use, is indeed an experience of loneliness. This was the case in 1974.

The result of the investigation into the possible use of XLPE insulated cable in the 132 kV range was, however, so encouraging that the Town Electrical Engineer recommended its use.

Boksburg's motto "RESPICE FINEM", which means "heed the end" or interpreted "look ahead", can in this instance be taken that Boksburg really looked ahead, when it was decided to use XLPE cable at 132 kV.

4.1.2. Tenders were called for during March/April 1975 and accepted at the end of June 1975.

As far as the specification was concerned, tenderers were asked to quote, firstly, for specified sizes of cable, viz. 500 mm² aluminium conductor and 300 mm² copper conductor cable, either ELPE or oil-filled and, secondly, cable suitable for a capacity of 100 MVA. The main reasons for this were (a) all tenderers would quote on the same size cable and (b) it was thought that the size of cable for 100 MVA may have to be larger than 500 mm² aluminium or 300 mm² copper cable. The tenders received for oil-filled cable retained the sizes of 500 mm² aluminium and 300 mm² copper cable for 100 MVA and the XLPE insulated cable manufacturers offered reduced sizes of conductor for the cable for 100 MVA. In view of this, it was recommended that the offers for XLPE cable with a capacity of 100 MVA be not considered and that only the 500 mm² aluminium and 300 mm² copper conductor cable be given consideration.

The price for the 300 mm² copper conductor XLPE cable was approximately 18,3% higher than the 300 mm² copper conductor oil-filled cable, but the XLPE cable had a capacity of approximately 29,8% higher than the oil-filled cable.

132 kV, 1 x 300 mm²-kabel met geriffelde aluminium omhulsel en met PVC buite-omhulsel

peratuur van 85° Celsius vir die oliegevulde kabel en 90° Celsius vir XLPE-kabel. Ander aanvaarde toestande vir beide tipes was soos volg:

Grondtemperatuur van 23° Celsius
Diepte gelê — 1,0 meter
Omgewingslugtemperatuur van 25° Celsius
Hitteweerstand van grond — 140° C cm/watt

Met inagneming van die hoër dravermoë van XLPE-kabel in vergelyking met oliegevulde kabel en wat meer as vir die hoër prys vergoed, was die aankoop van XLPE-kabel dus as gunstig geag.

Behalwe ander omstandighede, baie waarvan reeds gemeld is, was die aankoop van XLPE-kabel, wat meer voordele as oliegevulde kabel inhou, ekonomies 'n goeie belegging.

4.1.3. TENDER VIR KABEL

4.1.3.1. BESTEK VAN DIE KONTRAK

Die bestek van die kontrak het die voorsiening, aflewering, installering, toets en inwerkingstelling van 132 kV-kabel en toebehore behels.

Loodskabel was deur die Raad aangekoop en aan die kontrakteur vir die lê daarvan oorhandig. Die laswerk was die Raad se verantwoordelikheid.

Grawe van slote is nie by die kontrak ingesluit nie en is deur die Raad uitgevoer.

Die voorsiening van 'n geskikte onderlaag van gesifte of ander geskikte grond op die bodem van die sloot moes deur die kontrakteur met die Raad se arbeid aangebring word. 'n Geskikte bedekking met grond en betonblokke bo-oor die kabel, was ook deel van die kontrakteur se verantwoordelikheid. Die orige opvulling van slote is deur die Raad onder die toesig en leiding van die kontrakteur uitgevoer.

Die arbeid deur die Raad verskaf het uit 'n meganiese slootgraafmasjien, wat onder die Raad se jaarlikse kontrak gehuur word, en 'n ploeg van ongeveer vyftig ongeskoolde arbeiders onder 'n opsiener, bestaan.

Die lê van die kabel en die meganiese toerusting benodig by die uittrek van die kabel, was die verantwoordelikheid van die kontrakteur. Die ploeg arbeiders, slegs met grawe en pikke vir die grawe van slote toegerus, was met die lê van die kabel en beskermende betonblokke behulpsaam.

Al het die Raad die bogenoemde toerusting en hulp verskaf, het die beveiliging teen beskadiging van die kabel uitsluitlik op die kontrakteur gerus.

Van die kontrakteur is verlang om die lasvakke met sy eie arbeid uit te grawe en voor te berei.

Hierdie werkstelsel van hulpverlening by die installering, het uitstekend gewerk in dié opsig dat die kontrakteur nie met die verkryging van 'n groot aantal ongeskoolde arbeiders en bygaande wetlike maatreëls (rompslomp) belas was nie.

Nog 'n voordeel wat hierdie werkstelsel ingehou het was dat, wat die Raad betref, die administratiewe werk verbonde aan die opmeet van uitgrawings deur die kontrakteur in sagte en/of klipperige grond uitgevoer, veel minder was.

Vir geskoolde en ongeskoolde arbeid by lasse en endstukke, was die kontrakteur verantwoordelik.

Hoewel die Raad by sekere take hulp verleen het, was dit 'n voorwaarde dat die beveiliging teen beskadiging van die kabel uitsluitlik op die kontrakteur rus. Hierdie stelsel het tot bevrediging van albei partye uitstekend gewerk.

4.1.3.2. HITTEWEERSTAND VAN DIE GROND

Die WNNR was versoek om die hitteweerstand van die grond langs die hele roete, behalwe 'n kort afstand waar dit as gevolg van die voorge-

132 kV, 1 x 300 mm² corrugated aluminium sheathed and PVC outer sheathed cable

The maximum continuous current-carrying capacity of the oil-filled cable was 440 amps and that of the XLPE cable 571 amps, at conductor temperatures of 85° Celsius for the oil-filled cable and 90° Celsius for the XLPE cable. The other conditions assumed for both cables were:

Ground temperature of 23° Celsius
Depth of laying 1,0 metre
Ambient air temperature of 25° Celsius
Thermal resistivity of soil 140° C cm/watt

Due, therefore, to the higher capacity of the XLPE cable as compared with the oil-filled cable which more than offset the higher price, the purchase of the XLPE cable was considered a proposition.

So, economically, the purchase of the XLPE cable was a good proposition, besides the many other factors, mentioned earlier in the paper, which held numerous advantages over oil-filled cable.

4.1.3. CABLE TENDER

4.1.3.1. SCOPE OF THE CONTRACT

The scope of the contract called for the supply, delivery, installation, testing and commissioning of 132 kV cable and accessories.

(5) Pilot cable was purchased by the Council and handed over to the contractor for laying, with the jointing being the Council's responsibility.

The scope did not include trenching, which was also carried out by the Council.

The provision of a suitable bed of screened or other suitable earth at the bottom of the trench was the contractor's responsibility, using Council labour. A suitable covering of earth over the cable, together with the concrete slabs, was also part of the contractor's responsibility. The balance of the back-filling was the Council's responsibility under the supervision and direction of the contractor.

The labour supplied by the Council consisted of a mechanical trench digger hired under the Council's annual contract arrangement, together with a gang of approximately fifty unskilled labourers with an overseer.

The laying of the cable and mechanical equipment required for pulling out the cable, was the contractor's responsibility. The gang of labourers was only equipped with picks and shovels for trench digging purposes and assisted with the cable laying, and laying of the protective concrete slabs.

Although Council labour and mechanical equipment was provided for trenching and assistance was given with the laying, screening the soil and back-filling, the responsibility for the safety of the cable against damage rested entirely with the contractor.

The contractor was required to dig and prepare the joint bays using his own labour.

This system or method of installation worked extremely well in that the contractor was not burdened with having to obtain a large number of unskilled labourers with all the associated legal proceedings — red tape.

A further advantage with this method was that, for the Council, administrative work was considerably reduced with no measurements having to be taken for trenching through soft and/or rocky conditions, for work carried out by the contractor.

The skilled and unskilled labour for the jointing and terminations was, however, the contractor's responsibility.

Although the process was adopted to carry out certain work using Council labour, it was conditional that the entire responsibility for the safety of the cable was the contractor's. The principle worked extremely well to the satisfaction of both parties.

4.1.3.2. SOIL THERMAL RESISTIVITY

The CSIR was employed to carry out soil thermal resistivity tests along

stelde PWV 15-deurpad gewysig is, te bepaal. Die uitslag van hierdie toetse was in die tenderdokumente ter inligting ingesluit. Tenderaars is egter versoek om hulle tender op 'n hitteweerstand "g" van 140° C cm/watt te grond ten einde die kabelgroottes en/of die kabel se vermoë aan te dui.

Die spesifikasie het bepaal dat, waar die grondtoestande ongunstig was, geskikte grond met 'n hitteweerstand wat nie 140° C cm/watt oorskry nie, onder en bo-op die kabel tot die hoogte van die betonblokke aangebring moet word.

Die waardes van die hitteweerstand van die grond al langs die roete met tussenafstande van ongeveer 250 meter geneem, word op onderstaande Tabel 1 aangedui.

the entire route except for a short distance where the route was altered due to the proposed PWV 15 road. The results of these tests were included in the tender document for the tenderer's information. However, tenderers were required to base their tender on a thermal resistivity "g" of 140° C cm/watt for dedtermining cable sizes and/or cable ratings.

The specifications stipulated that where soil conditions were unfavourable, suitable fill, having a thermal resistivity not exceeding 140° C cm/watt, had to be imported for the soil under and over the cable to the height of the slabs.

The values of thermal resistivity of the soil along the cable route, taken approximately at 250 m intervals, are shown in Table 1 below.

TABEL 1:
Waardes Van Hitteweerstand Van Die Grond Langs Die Kabelroete:

TABLE 1:
Values Of Thermal Resistivity Of The Soil Along The Cable Route:

Point No. Punt Nr.	Thermal Resistivity cm °C/W Hitteweerstand cm °C/W	Point No. Punt Nr.	Thermal Resistivity cm °C/W Hitteweerstand cm °C/W	Point No. Punt Nr.	Thermal Resistivity cm °C/W Hitteweerstand cm °C/W
1	146	31	299	61	54
2	183	32	82	62	96
3	125	33	175	63	15
4	44	34	42	64	48
5	94	35	125	65	158
6	68	36	124	66	111
7	52	37	41	67	286
8	31	38	243	68	101
9	79	39	120	69	228
10	56	40	91	70	182
11	113	41	45	71	239
12	35	42	48	72	185
13	42	43	192	73	168
14	173	44	164	74	163
15	91	45	158	75	21
16	141	46	145	76	160
17	197	47	102	77	299
18.	228	48	396	78	390
19	80	49	178	Alternative	Route
				Alternatiewe	Roete
20	49	50	99	79	24
21	407	51	74	80	74
22	285	52	97	81	208
23	106	53	313	82	119
24	94	54	30	83	113
25	90	55	24	84	48
26	253	56	133		
27	159	57	520		
28	280	58	155		
29	42	59	156		
30	132	60	63		

4.1.3.3. SPESIFIKASIE VIR KABEL

4.1.3.3.1. KOPERGELEIER

Die geleier bestaan uit uitgegloeide onbedekte koperdrade, saamgepers en in ronde vorm in ooreenstemming met IEK Uitgawe 228, Eerste Uitgawe.

4.1.3.3.2. GELEIERSKERM

Die geleierskerm bestaan uit deurperste halfgeleier poliëtileen.

4.1.3.3.3. DIËLEKTRUM

Die diëlektrum is uit ongevulde kruisgebonde poliëtileen vervaardig. Die ontwerp was vir 'n spanningsvlak van 6,4 kV/mm.

4.1.3.3.4. AARSKERM

Die aarskerm bestaan uit 'n deurperste en gevulkaniseerde halfgeleierlaag en is van die betreklik maklik verwyderbare tipe.

4.1.3.3.5. DEURPERSPROSES

Die geleierskerm, diëlektrum en aarskerm word in hierdie volgorde, die een volgende op die ander, by wyse van die deurpersproses, aangebring.

4.1.3.3.6. METAALAFSKERMING

Bo-oor die aarskerm word 'n sagte aluminiumband met 'n tussengevoegde band gewind.

4.1.3.3.7. METAALOMHULSEL

'n Gerieflike aluminiumomhulsel word oor die metaalafskerming aangebring.

4.1.3.3. CABLE SPECIFICATION

4.1.3.3.1. COPPER CONDUCTOR

The conductor consists of annealed uncoated copper wires, compacted and circular in accordance with IEC Publication 228, 1st Edition.

4.1.3.3.2. CONDUCTOR SCREEN

The conductor screen consists of extruded semi-conducting polyethylene.

4.1.3.3.3. DIELECTRIC

The dielectric is manufactured from unfilled cross-linked polyethylene. The design was for a stress level of 6,4 kV/mm.

4.1.3.3.4. CORE SCREEN

The core screen consists of an extruded and vulcanised semi-conducting layer and is of the free-strippable type.

4.1.3.3.5. EXTRUSION PROCESS

The conductor screen, dielectric and core screen were extruded in a tandem operation.

4.1.3.3.6. METALLIC SHIELDING

Over the core screen, a soft aluminium tape with intercalated tape is applied.

4.1.3.3.7. METALLIC SHEATH

A corrugated aluminium sheat is applied over the core screen metallic shielding.

4.1.3.3.8. ANTI-CORROSION OUTER COVERING

The corrugated aluminium sheath is covered with a 4,5 mm thick black PVC anti-corrosion sheath.

4.1.3.3.8. **ANTI-VERWERPING BUITEDEKKING**

Die geriffelde aluminiumomhulsel word met 'n 4,5 mm dikte swart PVC anti-verweringomhulsel gedek.

4.1.3.3.9. **TREKLUSSE**

Elke lengte van kabel is met 'n treklus vir die lê van die kabel voorsien.

4.1.3.3.10. **TOETSE VIR GEDEELTELIKE ONTLADING**

Toetse vir gedeeltelike ontlading is aanhoudend teen 2 E_0 vir die hele kabellengte met 'n toelaatbare gedeeltelike ontlading van nie meer nie as 5 pico coulombs uitgevoer.

4.1.3.3.11.

Die aangehegte bylae, Bylae 1, dui sommige besonderhede van toepassing op 132 kV-kruisgebonde poliëtileen-geïsoleerde kabel aan.

5. INSTALLASIE VAN 132 kV XLPE-KABEL

5.1. **132 kV XLPE-Kabelstelsel**

Figuur 2, aangeheg, toon die skematiese diagram van die 132 kV-kabelstelsel.

Op die diagram word die aardingspunte en verbindingskaste met afleiers vir dwarsdeur-verbinding, ens., aangedui.

Kabellengtes is ongeveer 500 m en dwarsdeur-verbindings word by elke twee lengtes, of elke 1 000 meter, aangebring. By elke 3 000 meter, of drie seksies van 1 000 meter, word die kabelomhulsel geaard.

By die substasie word die omhulsel by die kabelente ook geaard.

Alle aarding word deur middel van koppelstukke in waterdigte verbindingskaste al langs die roete, en waar die kaste op die kabelendstrukture by die substasies gemonteer is, aangebring.

5.2. LÊ VAN DIE KABEL

Gedurende April 1976 was met die lê van die kabel begin en op 6 April 1977 volgens rooster voltooi.

5.2.2. Meganiese toerusting, deur die kontrakteur voorsien, gebruik om die kabel van die tol af te trek en slegs tot 'n baie klein mate is hande-arbeid hiervoor gebruik.

Rollers is op die lêvlak van die slote en teen 'n skuinshoek waar die kabel om 'n draai getrek moes word, geplaas.

5.2.3. Kabels is plat op die lêvlak van die sloot en 200 mm middellynafstand van mekaar af gelê met die loodskabel tussen twee van die fases aangebring.

6. TOETSE OM DIE KABEL IN WERKING TE STEL

Die uiteindelike toets om die stelsel in werking te stel, was om 'n spanning teen 264 kV gelykstroom vir 'n tydsduur van vyftien minute, met die drie geleiers oorbrug en omhulsel na aarding, te bewerkstellig. In der waarheid was die aanbevole spanning vir die toets op 300 kV GS gestel, maar die toerusting destyds beskikbaar, kan as gevolg van die hoogte bo seespieël slegs 'n spanning van 264 kV bereik.

Die lekstroom was ongeveer 0,5 mA per kilometer.

6.2. Toetse op die buiteomhulsel van elke fase was teen 'n spanning van 10 kV-gelykstroom tussen die aluminiumomhulsel en aarding vir 'n tydsduur van een minuut toegepas ten einde die ongeskondenheid van die buiteomhulsel te toets. Die aanvaarde lekstroom het tussen ongeveer 0,1 mA en 0,3 mA per kilometer gewissel.

6.3. Lesings van geleierweerstand was geneem en het heel goed met die beraamde waardes vergelyk.

INSTANDHOUDING

7.1. BUITEOMHULSEL-TOETS

Een keer per jaar word 'n spanning van 6 kV gelykstroom tussen die aluminiumomhulsel en aard vir 'n tydsduur van een minuut bewerkstellig, ten einde die ongeskondenheid van die PVC-omhulsel te toets.

7.2. SKAKELKASSIES

Elke jaar word alle skakelkassies vir sigbare foute nagegaan om seker te maak dat:

(i) die stuwingafleier-isolasie nie gebreek is nie;
(ii) die metaaldoppe van die stuwingafleier by die bo- en onderente van die isolator nie gebreek of verwronge is nie;
(iii) daar geen water in die kassies is nie; en
(iv) die pakstukke in goeie toestand is. Indien nie, word dit vervang.

7.3. TOETS VAN ISOLASIEWEERSTAND VAN STUSINGAFLEIERS

Een keer per jaar word die stuwingafleier-isolasie met 'n 500 V megger getoets. Indien die lesing laer as 10 Megohms is, word die stuwingafleier vervang.

4.1.3.3.9. **PULLING EYES**

Each length of cable was provided with a pulling eye for laying purposes.

4.1.3.3.10. **PARTIAL DISCHARGE TESTS**

Partial discharge tests were carried out continuously at 2 E_0 on the total length of the cable with a permissible partial discharge not greater than 5 pico coulombs.

4.1.3.3.11.

The attached schedule, Schedule 1, gives some of the technical details applicable to the 132 kV cross-linked polyethylene insulated cable.

5. THE INSTALLATION OF THE 132 kV XLPE CABLE

5.1. **132 kV XLPE Cable System.**

Figure 2, attached, shows the schematic diagram of the 132 kV XLPE cable system.

On this diagram, the earthing points, link boxes with arrestors for cross-bonding, etc. are indicated.

The cable lengths are approximately 500 metres and cross-bonding is carried out every two lengths or 1 000 metres. After every 3 000 metres or three sections of 1 000 metres, the cable sheaths are earthed.

At the substation end of the cable, the cable sheaths are also earthed.

All the earthing is done through links, which are situated in water-proof link boxes along the cable route and link boxes mounted on the cable end structures at the substations.

5.2. LAYING OF THE CABLE

5.2.1. Cable laying commenced about April 1976 and was completed on schedule on 6 April 1977.

5.2.2. Mechanical equipment supplied by the contractor, was used to pull out the cable, while manual labour was only used to a small degree with the pulling.

Cable rollers were placed at the bottom of the trench and angled at the corners for pulling around corners.

5.2.3. The cables were laid in the trench in a flat formation at 200 mm centres, and the pilot cable was placed between the centre phase and an outer phase.

6. COMMISSIONING TESTS

6.1. Final commissioning tests were carried out at 264 kV DC for 15 minutes between the three conductors bridged out and earth/sheath. The recommended test voltage was in fact 300 kV DC, but equipment available at the time was only able to hold a voltage of 264 kV due to the high altitude conditions.

The leakage current was approximately 0,5 mA per kilometre.

6.2. Commissioning tests on the outer serving was carried out on each phase at 10 kV DC applied between the aluminium sheath and earth, for one minute, to test the integrity of the serving. The acceptable leakage current varied between approximately 0,1 mA to 0,3 mA per kilometre.

6.3. The conductor resistance measurements were carried out and compared favourably with the calculated values.

7. MAINTENANCE

7.1. SERVING TEST

Once every year 6 kV DC is applied between the aluminium sheath and earth for one minute to test the integrity of the PVC serving.

7.2. LINK BOXES

Once every year all link boxes are visually inspected to ensure that:

(i) the surge diverter insulation is not broken;
(ii) the metal caps of the surge diverters at the top and bottom of the insulator are not broken or distorted;
(iii) there is no water in the boxes, and
(iv) that the gaskets are in good condition. If not, they are replaced.

7.3. TESTING INSULATION RESISTANCE OF SURGE DIVERTERS

Once a year the insulation is tested by using a 500 V megger. If the reading indicates less than 10 Megohms, the surge diverter is replaced.

7.4. Apart from the abovementioned regular maintenance detailed under 7.1, 7.2 and 7.3, no maintenance is necessary.

7.4. Behalwe gereelde instandhouding wat onder 7.1, 7.2 en 7.3 uiteengesit is, is geen instandhouding nodig nie.

7.5. Ingeval van 'n kabelonderbreking en na die aanbring van 'n nuwe deurlas, word 'n toets met 'n spanning van 108 kV gelykstroom tussen die geleier en aluminiumomhulsel vir 'n tydsduur van tien minute uitgevoer.

8. SLOTSOM

Die eerste gedeelte van die kabel was op 9 Junie 1977 aangeskakel.

Die huidige lading op die kabels is betreklik laag, ongeveer 110 Amp. op een been van die kring, aangesien die stelsel beplan is om vir 'n ladingsgroei oor 'n aantal jare voorsiening te maak. Tot op datum, ongeveer drie jaar na inwerkingstelling, is nog geen moeilikheid ondervind nie, behalwe in 'n minder belangrike geval waar beskadiging van die PVC-omhulsel met die jaarlikse toets van die buiteomhulsel aan die lig gekom het en 'n ander geval waar die kabel vermoedelik deur 'n tandploeg, agteraan 'n stootskraper, beskadig was. Die stewigheid van die kabel is egter só, dat alhoewel die aluminiumomhulsel op al drie are beskadig was — twee nogal erg — daar geen fisiese beskadiging van die isolasie en aarskerm in 'n laboratoriumtoets, in Japan, van die twee beskadigde gedeeltes gevind kon word nie.

Indien die beskadiging nie deur die toets van die buite-omhulsel aan die lig gekom het nie, sou die kabel moontlik vir 'n onbeperkte tyd in werking gebly het.

Gegrond op die diens oor die afgelope drie jaar, kan die Raad met vertroue na nog baie jare van bevredigende diens uitsien.

9. ERKENNINGS

Die opsteller wens die Stadsraad van Boksburg te bedank vir die geleentheid gegun om hierdie referaat te kon voorlê.

Verder wil die opsteller ook Mnre. Republic Power & Communications bedank vir die hulp wat hulle met die tegniese besonderhede wat in hierdie referaat vervat is, verleen het.

7.5. In the event of a cable failure and after a new straight through joint has been inserted, a voltage of 108 kV DC is applied between the conductor and aluminium sheath for ten minutes.

8. CONCLUSION

The first section of cable was switched on, on 9 June 1977.

The loading on the cables is at the moment relatively light, approximately 110 amps on one leg of the ring, as the system is planned to cater for load growth over a number of years. To date, nearly three years after commissioning, no problems have occurred, except minor damage to the outer PVC sheath, which was detected through the annual serving tests, and on one occasion mechanical damage was done to the cable, presumably by a ripper attached to a bulldozer. The strength of the cable was such that, although the aluminium sheath was damaged on all three cores, two of them seriously, subsequent laboratory checks in Japan, on the two badly damaged portions, indicated no physical damage to the insulation and core screen.

Had the damage not been detected by serving tests, it is probable that this cable would still have been in service and operated indefinitely.

Based on three years operating experience, the Council can confidently expect many more years of satisfactory performance.

9. ACKNOWLEDGEMENTS

The author wishes to thank the Town Council of Boksburg for the opportunity given to him to present this paper.

In addition, the author wishes to thank Messrs. Republic Power and Communications for the assistance given ith technical details used in the preparation of this paper.

SCHEDULE 1/BYLAE 1
SCHEDULE OF TECHNICAL DETAILS/BYLAE VAN TEGNIESE BESONDERHEDE

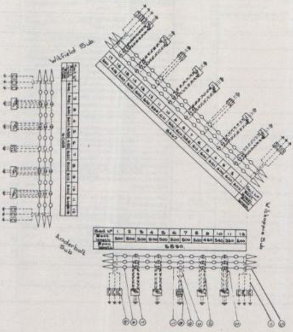
CLAUSE NO.	DESCRIPTION		COPPER CONDUCTOR CABLE KABEL MET KOPERGELEIER	KLOUSULE NR.	BESKRYWING	
1	Normal working voltage between phases	kV	132	1	Normale werkspanning tussen fases	kV
2	Number of cores		3 x single cores/3 enkelare	2	Aantal are	
3	Size of conductor	mm²	300	3	Grootte van geleier	mm²
4	Shape of conductor		(compact in Circular) (Saamgepers in ronde vorm)	4	Vorm van geleier	
5	Outer diameter of conductor	mm	20,9	5	Buite-deursnee van geleier	mm
6	Maximum DC resistance of conductor per 1 000 metres of completed cable at 20° Celsius	ohms	0,0590	6	Maksimum gelykstroom weerstand van geleier per 1 000 meter van volledige kabel by 20° C.	ohms
7	Equivalent star reactance per 1 000 metres of three phase circuit at 50 Hz	ohms	0,223	7	Eweredige ster-reaktansie per 1 000 meter van drie-fasige baan teen 50 Hz	ohms
8	Maximum electrostatic capacitance per core per 1 000 metres of completed cable	µ	0,15	8	Maksimum elektrostatiese kapasitansie per 1 000 meter van volledige kabel	µF
9	Maximum charging current per conductor per 1 000 metres of completed cable at nominal voltage	amps	3,6	9	Maksimum laaistroom per geleier per 1 000 meter van volledige kabel teen normale spanning	amps
10	Minimum insulation thickness including conductor screen	mm	22,70	10	Minimum dikte van isolasiemateriaal met inbegrip van geleierskerm	mm
11.	Insulation (a) Material	XLPE	(Unfilled XLPE/Ongevulde XLPE)	11	Isolasie (a) Materiaal	XLPE
	(b) Method of curing		(Radiant Curing Process) (Bestralingsproses) (RCP)		(b) Verduursamingsmetode	
12	Semid-conducting compound screen around conductor (a) Material		(Extruded semi-conducting Polyethylene) (Deurperste halfgeleier Poliëtileen)	12	Halfgeleiersamestellingskerm rondom geleier (a) Materiaal	
	(b) Nominal thickness	mm	1,35		(b) Nominale dikte	mm
13	Semi-conducting compound screen over insulation (a) Material		(Extruded semi-conducting Polyethylene) (Deurperste halfgeleier Poliëtileen)	13	Halfgeleiersamestellingskerm bo-oor isolasie (a) Materiaal	
	(b) Nominal thickness	mm	1,5		(b) Nominale dikte	mm
14	Binder tape (a) Material		(Aluminium Tape/Band)	14	Bindband (a) Materiaal	
	(b) Nominal thickness	mm	0,1		(b) Nominale dikte	mm
15	Nominal diameter over binder tapes	mm	68,3	15	Nominale deursnee met inbegrip van bindbande	mm

SCHEDULE 1/BYLAE 1 (contd./Verv.)

CLAUSE NO.	DESCRIPTION		COPPER CONDUCTOR CABLE KABEL MET KOPERGELEIER	KLOUSULE NR.	BESKRYWING	
16	Metallic sheath (a) Material		Aluminium	16	Metaalhuls (a) Materiaal	
	(b) Minimum radial thickness of sheath	mm	1,7		(b) Minimum radiale dikte van huls	mm
	(c) Nominal radial thickness of sheath	mm	2,0		(c) Nominale radiale dikte van huls	mm
	(d) Nominal diameter of sheath	mm	80,3		(d) Nominale deursnee van huls	mm
17	Outer protective sheath: (a) Material		Black PVC/Swart PVC	17	Beskermingshuls buite-om: (a) Materiaal	
	(b) Nominal radial thickness	mm	4,5		(b) Nominale radiale dikte	mm
	(c) Minimum thickness	mm	3,15		(c) Minimum dikte	mm
18	Nominal overall diameter of completed cable core	mm	89,5	18	Nominale totale deursnee van volledige kabel-aar	mm
19	Nominal mass of completed cable core per metre	kg	9,7	19	Nominale massa van volledige kabel-aar per meter	kg
20	Minimum radius of bend round which cable core can be laid	m	1,4	20	Minimum straal van boog wanneer kabel-aar om 'n draai gelê word	m
21	Nominal internal diameter of pipes or ducts through which the cores of the cable can be laid	mm	130	21	Nominale binne-deursnee van pype of deurgange waardeur die are van die kabel gelê kan word	m
22	Maximum continuous current — carrying capacity	amps		22	Maksimum aanhoudende-stroomdravermoë as veronderstel word dat die onderstaande omstandighede van toepassing is:	amps
	* Assume: Ground temperature of 23° C Depth of laying 1,0 metre Maximum conductor temperature 85° Celsius Alt. Maximum conductor temperature 90° Celsius Ambient air temp. of 25° C Thermal resistivity of soil 140° C cm/watt (a) Amps @ 85° Celsius		562		Grondtemperatuur van 23° C Diepte gelê — 1 meter Maksimum temperatuur temp. van 85° Celsius Alternatief: Maksimum temp. van geleier 90° Celsius Omgewingstemperatuur van 25° C Hitteweerstand van grond 140° C cm/watt (a) Amps teen 85° Celsius	
	(b) Amps @ 90° Celsius		571		(b) Amps teen 90° Celsius	
23	Maximum operating conductor temperature	° Celsius	90	23	Maksimum werktemperatuur van geleier	° Celsius
24	Maximum power factor of charging kV.A of completed cable when laid direct in the ground at nominal voltage, normal frequency, operating pressure and at a conductor temperature of: (a) 15° Celsius	%	0,1	24	Maksimum arbeidsfaktor van laai-kV.A van volledige kabel as dit regstreeks in grond gelê is teen 'n nominale spanning, normale frekwensie, werkdrukspanning en teen 'n geleiertemperatuur van: (a) 15° Celsius	%
	(b) Maximum working temperature	%	0,1		(b) Maksimum werktemperatuur	%
25	Maximum dielectric loss of completed cable per 1 000 metres of three-phase circuit when laid direct in the ground at nominal voltage, normal frequency and normal operating pressure at maximum conductor temperature	kW	0,82	25	Maksimum diëlektriese verlies van volledige kabel per 1 000 meter van drie-fasige kringbaan wanneer kabel regstreeks in die grond teen 'n nominale spanning, normale frekwensie en normale werkdrukspanning teen 'n maksimum geleiertemperatuur, gelê word	kW
26	Maximum power factor of charging kV.A at normal frequency and operating pressure at a conductor temperature of 20° Celsius (a) 50% nominal voltage	%	0,1	26	Maksimum arbeidsfaktor van laai-kV.A teen normale frekwensie en werkdrukspanning teen 'n geleiertemperatuur van 20° Celsius (a) 50% van nominale spanning	%
	(b) Nominal voltage	%	0,1		(b) Nominale spanning	%
	(c) 150% nominal voltage	%	0,1		(c) 150% nominale spanning	%
	(d) 200% nominal voltage	%	0,1		(d) 200% nominale spanning	%
27	Loss in sheath including reinforcement of completed cable per 1 000 metres of three phase circuit at nominal voltage, normal frequency and operating pressure at maximum current rating laid direct in ground	kW	1,2	27	Verlies in omhulsel, insluitende pantsering van volledige kabel per 1 000 meter van drie-fasige kringbaan teen nominale spanning, normale frekwensie en werkdrukspanning teen maksimum stroomdravermoë wanneer regstreeks in grond gelê	kW
28	Dielectric stress at the surface of the conductor screen	kV/cm	64	28	Diëlektriese spanning by die vlak van die geleierskerm	kV/cm
29	Dielectric stress at the screen over the insulation	kV/cm	24	29	Diëlektriese spanning by die skerm bo-oor die isolasiemateriaal	kV/cm
30	Impulse withstand voltage: (a) Positive 1/50 wave	kV	650	30	Impulsspanningsbestandheid: (a) Positiewe 1/50-golf	kV
	(b) Negative 1/50 wave	kV	650		(b) Negatiewe 1/50-golf	kV

CLAUSE NO.	DESCRIPTION		COPPER CONDUCTOR CABLE KABEL MET KOPERGELEIER	KLOUSULE NR.	BESKRYWING	
31	Withstand re-striking voltage on breaking the circuit under the following conditions: (a) Fault at 5 000 MVA		650 kV Peak/650 kV Spits	31	Teen-opvolgspanning wanneer kring onder die volgende omstandighede onderbreek word: (a) Fout teen 5 000 MVA	
	(b) Fault at 3 500 MVA		650 kV Peak/650 kV Spits		(b) Fout teen 3 500 MVA	
	(c) Rated full load		650 kV Peak/650 kV Spits		(c) Aangeslane vollasstroom	
	(d) 10% Full load		650 kV Peak/650 kV Spits		(d) 10% volle lading	
32	2-second short circuit rating of cable conductor	in amps	30 000	32	Twee-sekonde kortsluitdravermoë van kabelgeleier	in amp.
33	2-second short circuit rating of cable sheath	in amps	30 000	33	Twee-sekonde kortsluitdravermoë van kabelomhulsel	in amp.
34	Conductor temperature at end of 2 seconds assuming cable fully loaded prior to fault	°Celsius	250	34	Temperatuur van geleier aan die einde van twee sekondes as aangeneem word dat die kabel voor die fout onder volle lading was	°Celsius
35	Sheath temperature at end of 2 seconds assuming cable fully loaded prior to fault	°Celsius	120	35	Temperatuur van omhulsel aan die einde van twee sekondes as aangeneem word dat die kabel voor die fout onder volle lading was	°Celsius
36	Insulation resistance per 1 000 metres of serving corrected to 20° Celsius	megohm	0,05	36	Weerstand van isolasie per 1 000 meter van buite-omhulsel teen 20° Celsius ingestel	megohm
37	Insulation resistance per 1 000 metres of serving within two hours after filling in trench	megohm	0,05	37	Isolasieweerstand per 1 000 meter van die buite-omhulsel binne twee uur na opvul van sloot	megohm
38	Maximum period for which spare cable can be stored at site and remain suitable for use. (All parts including anti-corrosive serving)		At least 20 years if stored in proper warehouse Minstens twintig jaar indien behoorlik in 'n skuur berg.	38	Maksimum tydperk wat kabel in voorraad ter plaatse geberg kan word en nogtans bruikbaarheid behou. (Alle toebehore, insluitende anti-verweringsbuite-omhulsel)	
39	Conditions under which spare cable should be stored to obtain the life specified in Item 38. Please detail. Also detail recommended treatment for wood cable drums		Cable should be stored under conditions of minimum humidity. No treatment required. Steel cable drums are used./ Kabel behoort onder omstandighede met die minste voginhoud geberg te word. Geen behandeling word benodig nie. Staaltolle word gebruik.	39	Toestande waaronder voorraadkabel geberg behoort te word ten einde lewensduurte, in Item 38 gemeld, te verkry. Gee besonderhede asseblief, asook besonderhede in verband met behandeling aanbeveel vir houttolle.	
40	Minimum barrel diameter of cable drums	m	1,61	40	Minimum rompdeursnee van kabeltolle	m
41	Maximum dimensions of cable drums: (a) Diameter	m	2,65	41	Maksimum afmetings van kabeltolle (a) Deursnee	m
	(b) Width	m	1,85		(b) Wydte	m
42	Maximum gross drum mass	kg	5 650	42	Maksimum bruto massa van kabeltol	kg
43	Maximum drum length of cable	m	500	43	Maksimum kabellengte op 'n kabeltol	m
44	Zero phase sequence impedance per phase	/km	0,1437 + j 0,105 ohms	44	Zero-fase opvolgimpedansie per fase	/km
45	AC Resistance	/km	0,0763 ohms	45	Wisselstroomweerstand	/km

FIGURE 2/FIGUUR 2



Item	Description
1	132 kV, 1 × 300 mm² XLPE insulated cable
2	Insulating Joint
3	Earthing normal Joint
4	Non-earthing normal Joint
5	Outdoor type termination
6	Link box for earthing
7	Link box + Arrestor for cross-bonding
8	Link box for earthing
9	
10	Earthing Wire (1 × 100 mm²) copper
11	

Item	Beskrywing
1	132 kV, 1 × 300 mm² XLPE-geïsoleerde kabel
2	Isolasielas
3	Gewone aardingslas
4	Gewone nie-aardingslas
5	Buitelugtipe endstuk
6	Skakelkas vir aarding
7	Skakelkas en afleier vir regkruisverbinding
8	Skakelkas vir aarding
9	
10	Aardedraad (1 × 100 mm²) koper
11	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by/deur

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(2) Hitachi Review Vol. 25 (1976) No. 4, "Moisture Absorption of Cross-Linked Polyethylene Insulated Cables Cured in Gas or Steam".

(3) Messrs. Sumitomo Electric Industries, Japan.

(4) Chemical Tree Deterioration in the Insulation of Plastics-insulated Wires and Cables

by/deur

Shichiro Kawawata and Jiro Ogura of the Research Laboratory, Hitachi Cable, Limited.

(5) The Main Contractor for the Contract:
Die Hoof-Kontrakteur vir die Kontrak:

Messrs./Mnre. Republic Power and Communication Co. (Pty) Ltd.

The Main Sub-Contractor for the Contract:
Die Hoof-Onderkontrakteur vir die Kontrak:

Messrs./Mnre. Power Installations (Pty) Ltd.

BESPREKINGS/DISCUSSIONS

Mr. W. A. Bowen: ESCOM:

Mr. Fortmann is to be congratulated not only on his paper, which is indeed comprehensive, but also for his pioneering spirit.

In offering these comments I would like to put this paper into an Escom environment and try and give potential users of 132 kV and say 88 kV cable some different points of view.

So taking Mr. Fortmann's paper section by section — here goes.

3.1

Let me take the point of aesthetics. Yes, cable is certainly better than overhead lines but it must be remembered that cables of the power ratings and voltages covered by this paper can be adversely affected in operation by trees on their routes just the same as lines but for different reasons. Cables require moisture in the ground to keep them thermally stable, a point of which, environmentalists are, I think, completely unaware.

3.2

Cross-linked versus oil-filled. In the Rand and O.F.S. Region oil-filled cables were required in 1964. So consequently in order to be autonomous we acquired oil-filled cable servicing equipment. So that now, we can cut up and joint 132 kV cable as easily as some supply authorities can cut say an 11 kV cable. So that, economically speaking, we can, and do, consider oil-filled cables subject to them being in the P.W.V. triangle and therefore readily accessible to specialised repair teams.

The higher temperature referred to here is the conductor temperature. Potential users should note that the S.A.B.S. have stated that in their investigations sheath temperatures ought not to exceed 50° Celsius, generally speaking, in South African soils.

3.3.1. to 3.3.12

It is interesting to note that Mr. Fortmann did not discuss retraction of the core insulation. He is indeed fortunate in having cable from a reputable manufacturer.

The question of retraction of the insulation is an important consideration as it is to me an indication of the correctness of the way the cable has been extruded. This is from the conductor speed to extruder screw speed point of view.

I do not think that retraction is so much of a problem up to 33 kV but in voltages above this and with the thicker insulation it does assume some significance.

Retraction of some 2 mm is considered to be satisfactory.

3.4.1.

The previously mentioned list of questions is comprehensive and complete enough.

The Kansai Electric Power Company engineers, I believe, are correct in their requirements of a metal sheath. I know that cables are made without them and the Dutch for instance bury their XLPE cables in water-logged ground and are not worried, but at the same time, they do not export them. Presumably this is because they themselves are not sure and want to get local service experience.

My experience tells me that if one does not ensure a safe system for any environment, some non-technical big shot will call the tune in event of a power failure. I am not quite sure how some manufacturers get away without a metal sheath but they do. In this respect I would require a lot of convincing before accepting cables without metal sheaths under South African conditions.

3.5.2.1

I agree that dry cured processes are infinitely better than steam cured ones at this voltage due to the more homogeneous insulation obtained with this process. The other thing that one must remember is that there is also water present in the XLPE from the di-cumyl peroxide which is normally used in the cross-linking process, even with dry curing processes.

3.5.7.1

The safer stress level of 6,6 kV/mm is, from a pioneering point of view, very sensible even if a more robust cable is provided.

3.5.9

One can only agree wholeheartedly with Mr. Fortmann on this section that water in the conductor is fatal. But I would also confirm that water trees can occur with an extruded conductor screen, as I have had one in a 21 kV cable.

3.5.11.1

It should be pointed out here that copper does have an effect of degrading the semi-conducting screen if the polymer is constituted of certain chemicals.

One manufacturer actually uses tinned copper strands as the outer layer of his stranded copper conductor to obviate this phenomenon.

I believe it is necessary to include in the specification that all materials must be compatable under all foreseeable circumstances of installation. This may be a bit vague at the specification preparation stage but at least it will ensure that a reliable manufacturer investigates your cable environments.

3.5.12.1

Nothing is more true than the statements about "rough handling" and "fair treatment". An excess of the former and deficiency of the latter can have serious adverse consequences with all types of cable not only XLPE cables.

3.5.12.2

The sealing ends used are conventional for this type of cable. Of interest to me would be the use of heat shrink materials for use during emergencies and, following upon this experience, possibly for commercial use. This is what we did at 42 kV with satisfactory results.

3.5.13

I have no doubt that the Japanese have tested their taped type joints very thoroughly and, I hope, with a bias towards thermal tests.

During an overseas study tour I learnt that some cable companies had de-rated their joints thermally because of relative movements between tapes, insulation and conductor, with these in various orders. I will be very interested in any experiences recorded when these cables get to full load in a very cyclic manner over a long period.

A moulded joint must surely be a better joint as it is thermally controlled by a process timer during curing. This process ensures that the joint has been made close to the way that the cable was made. This is a very desirable requirement with any joint. While on the subject of joints I should record that in my experience single core oil-filled cable joints are as quick, if not quicker, to make than XLPE ones.

4.1.3.2.

The soil resistivity readings are, to me, of interest and I would like to expand on this matter for prospective users of E.H.V. cable.

The soil resistivities to me are of no use unless the moisture content is included for each reading, realising that this could be a bit difficult in rock. I would have thought that if weak mix concrete has been specified and used in the places of high "g", that this would have been better than the selected backfill, which I take to mean, a soil.

In any case a proper transformed cable and trench map for where cables run through high "g" areas is essential as the selected backfill to height of cables may not really be sufficient.

This transformed trench map had to be done for one of our installations which was in ash.

5.1

The cross-bonding system. The diagram on Fig. 2 covering the one portion of the Witfield to Witkoppie Route is not clear to me. The sections do not appear equal. The cross-bonding minor sections on systems that we have installed were strictly maintained to + 1% of each other. Were the cable spacings varied in any of the apparently unbalanced sections?

6.

Commissioning tests. A commissioning check test that we have carried out is a low voltage 3 phase injection test with about 200 amperes per phase into the completed cable system to check the balance of induced voltages on the cable sheaths. Can Mr. Fortmann confirm if the voltages are balanced in his system and if any circulating currents flow in the sheaths.

7.1

I assume that a P.O.P.I.E. type of instrument is used for detecting serving faults.

With a serving fault which could be undetected for nearly one year the corrosion of the aluminium sheath could be extensive. Is there any continuous monitoring of the integrity of the sheath? I like the idea of using helium at some moderate pressure under the sheath. Any gas low pressure could trigger a low pressure alarm and the gas itself is very easily detected as it perculates through ground or tarmac.

I hope that potential users have been able to see a few more aspects of what to be aware of when deciding on E.H.V. cables of this nature.

In conclusion I would like to say that generally speaking the cable is generously rated from a stress point-of-view and load wise from the present system and it should have a trouble-free service life.

My thanks go to the A.M.E.U., the Regional Manager Rand and O.F.S. Region and Escom for allowing me to present these comments.

D. C. Palser, Cape Town

Mr. President,

Without any shadow of doubt Mr Fortmann is the main advocate of XLPE cable in South Africa — so much so that he could well be styled "Mr XLPE"!

But seriously though, Mr. President, I think Mr. Fortmann has done possibly more than any other engineer in municipal service to foster and promote this type of cable, particularly at extra high voltage. Only time will tell, however, whether he was right!

I consider it significant, though, that on the basis of experience in Japan he decided to include a metallic sheath, namely corrogated aluminium, to counter the possible ingress of water or moisture into the insulation. Clearly the provision of a metallic sheath adds to the cost of the cable; I believe about 30%. In the case of Boksburg the cost of the cable amounted to a premium of 18% over the more conventional oil-filled cable. It's true that the rating of the XLPE cable in this case was some 30% higher, but this would be largely academic if the increased rating could not be practically and profitably employed. Perhaps Mr. Fortmann would comment on this point.

But basic cable cost is only one factor. To make a proper and valued economic assessment it is necessary to consider all aspects of a cable installation, including jointing costs and the guaranteed life of the cable installation. For example, a number of Japanese firms that have approached us in Cape Town, and although they have been prepared to guarantee a 40 year life for oil-filled cable they have only been prepared to offer 15 years for XLPE cable.

Regarding jointing costs, I doubt whether it is any cheaper to joint a XLPE cable than it is to joint an oil-filled cable. Although not mentioned in the paper, I believe that a special and expensive lapping machine was required to apply the insulation to the joints. Also, the jointing of high voltage XLPE is by no means a semi-skilled process as a lot of engineers imagine. It would be of interest if Mr. Fortmann would comment on this aspect and whether he considers his staff to be sufficiently well trained and experienced to undertake all jointing maintenance and repair work on this particular cable installation without the specialised jointing assistance of the manufacturer.

Finally, Mr. Fortmann also briefly mentions damage to XLPE cables by mechanical plant which highlights one of the dangers of this type of cable which is not of the self-monitoring type as is oil-filled cable.

In conclusion, Mr. President, Mr. Fortmann is to be congratulated on his pioneering work in the high voltage XLPE field — I for one certainly admire his courage!

Mr. W. Barnard: Johannesburg

Mr. President I feel I would like to join in this debate and add our position to the general views that have been given here today. We in Johannesburg, I think we have gone one further than Boksburg, have put in to date 30 000 meters of cable at 88 000 volt, we have not provided a metal protective sheath over the cable, we have over the screen tape, we put the water-proof tape and then a PVC outer sheath. I cannot agree with Mr. Palser that any cable can withstand the mechanical excavator being run over it, we in fact accept the fact that if your cable is exposed to that sort of treatment, it is going to fail. But I would recommend to you that he should particularly for a higher voltage cables adopt the practice of putting some sort of slabs over the cable, we put ash slabs over our cable, and we have never had any damage to the cable. Personally I must associate myself very much with the comments made by Dr. Ericksen. I was also one of those people who many years ago forecast that the day of the paper cable was rapidly coming to an end. And I am still convinced that that is the position today. When I went over a couple of years ago to Japan to examine the manufacture of our cable there, I was quite interested and surprised to find that you could no longer anywhere in Japan buy paper cables. In fact they had closed down their paper cable factories in many areas, and I cannot see how an outmoded insulant like paper and oil can survive against the modern solid insulants.

Thank you.

Mr. J. T. Grundy: Affiliate

As you know, I am not an e.h.v. cable specialist, lighting is my speciality. However, having read and listened to the presentation of your Paper, I would like to make some comments to you.

1. Of all the Technical Papers I have seen over many years, this is one of the best set out, comprehensive and cleanest I have come across. Even an "ehv cable layman" like myself can clearly and fully appreciate the data and problems.
2. Your 3.3 "a wealth of information — when one is able to — outside one's own relatively small sphere —" Generous of you to admit it and I most certainly emphatically agree with the statement.
3. Your 3.4.2. I used to know Puerto Rico and the soil conditions. I was surprised at your statement that 138 kV grade XLPE had been in use since 1960's, I assume without failures?
4. Your 3.5.3.1. Anti-oxidents used to extend thermal life. Do you know what these are?
5. Your 3.5.6.1. I note 30 years life with great interest. In a totally different field, we are now using polyethylene on road lighting lanterns (e.g. Eloff Street, Johannesburg) and the life of the material in whatever sphere is to me unknown, accelerated life tests not being feasible.
6. Your 3.5.10.1 (4) Corrosion increased to three times, very useful information indeed.
7. 3.5.11.1 Catalytic action. Very useful to know, also to ascertain the anti-oxident.
8. Your 3.2. and 3.4.1. I have in past years had oil leaking from oil filled cable in ships, water getting into paper insulated underground cable on road lighting contracts and corrosion of underground PVC, sheathed cable in Kuwait, all of which problems are difficult. Hence I note the protective measures you noted and took, with some admiration. Finally, your 4.1.1. "— when the majority — engineers stand sceptical towards its use, is indeed an experience of loneliness —" Only another engineer working alone can fully appreciate that statement and it is well worth having it put on one's desk with the additional word "But I am never Alone."

Once again my congratulations on an excellent Paper.

Mr. A. Fortmann: Boksburg

Ek wil graag mnre. Odendaal en Bowen en al die ander sprekers wat kommentaar gelewer het oor die twee referate baie bedank. Mnr. Odendaal het nie baie vrae gevra nie, maar baie dankie vir u kommentaar, mnr. Odendaal. Now Mr. Bowen asked a few questions and made a few comments.

About the insulation retraction, I think the problem is known, the second installation at this voltage was at SASOL where another manufacturer for this type of cable was responsible and it has to do with the speed of curing and so this problem is known and can of course be overcome with the manufacture of cables.

The question was posed, if heat shrink terminations can be used at 132 kV. Well, I do not know if this could be done at this voltage and I think the manufacturers are in a better position to answer that question. I do not know of any installation like this.

Moulded type joints, well moulded type joints now appear to be the trend, I think in preference to taping. Even the manufacturer who supplied our cable has this type of joint. About soil thermal resistivity, Mr. Bowen mentioned that the water content of the soil must be taken into account, and I think this is pretty obvious. When in fact we did these tests, we got the CSIR to do these tests in the dry season, the driest part of the year.

Cable spacing is the same throughout, irrespective of the slight differences in cable section lengths and I think you asked if this affected the voltage balance on the sheaths. I suppose it would to a small degree but I am sure that it was not more than 1 or 2%. The standing voltage on the system, on the underground buried cable is 65 volts. this is under full load conditions.

Now, there is an interesting point which goes with voltage induction on the pilot cable, if I could just add that point here. We actually found that, for balanced feeder protection, we had a voltage induction in the pilot cable under through fault conditions, even with faults on the 11 kV system, where the present fault conditions are very high, including our earth faults. Now, we actually had a high enough voltage induced to operate the balance feeder relays. What we did there, this is in the 14 core pilot cable we use, we tested to find which two cores in the cable had the least potential and those two cores we used for the relays and so far this has worked very well.

Cable sheaths monotoring, continual monotoring, that is — no, we do not have that, but I guess that this is a fairly good solution or good principle to do, but we don't use it. We test once a year and so far it has been satisfactory. The aluminium sheath has not been eaten away or corroded away due to exposure where it has been exposed, which has only been at one or two minor points, anyway. Now, Mr. Palser of Cape Town — I am not sure if I have got the question clearly, but he stated that the lowest tender was 18% lower than the cable that we actually purchased. Now, I think that percentage could be correct. Whether this was justified, well I think certainly it was justified and warranted to carry future load. It was a proposition in our case. The staff cannot do the jointing in our case but less still on oil-filled cable and I think that will apply to any organisation. We could possibly train someone to do jointing on supertension cable in the XLPE range, I think you could do that relatively easily, but certainly that would not be the case with oil-filled cable. I think there is a vast difference between these two types of cable.

Thank you, Mr. Barnard, for your positive contribution.

Incidentally just a short comment on the negative approach by Mr. Palser and also from Mr. Pretorius. I have heard some of the engineers state that once the SABS specification is out, they will consider buying cables. I do not say these two gentlemen have said that, but in general I think this is the approach, and I think certainly this should be the approach.

We must not be negative for the sake of being negative. I think we must look at this objectively, study the new specifications which should be available soon and see how we can take it from there.

Thank you.

REFERAAT

VERSPREIDINGSTRANSFORMATORS — MODERNE FASETTE IN ONTWERP EN PRODUKSIE-ONTWIKKELING

REFERENT

Mnre. H. Salomons en B. Sollergren, Hoofbestuurder, Kapasitorfabriek, ASEA Electric S.A. Bpk.

PAPER

DISTRIBUTION TRANSFORMERS — MODERN TRENDS IN DESIGN AND PRODUCTION DEVELOPMENT

SPEAKER

Messrs. H. Salomons and B. Sollergren, General Manager, Capacitor Factory, ASEA Electric S.A. Ltd.

S. H. Salomons

S. H. Salomons joined ASEA Electric South Africa Limited in 1956 as a draughtsman.

He was transferred to the Design Department in 1957 and became Chief Electrical Design Engineer of the Transformer division in 1967. In this function he was inter alia responsible for the design of the first 275 and 400 kV transformers built in South Africa.

In 1957 he was appointed Sales Manager of the company.

His present position is that of General Manager of the Distribution Transformer and Capacitor Division of ASEA Electric South Africa Limited, to which he was appointed in 1979.

B. Sollergren

Mr. B. Sollergren graduated as an engineer in 1938. He thereafter joined ASEA AB in Sweden where he started his career in the High Voltage and High Power testing department. Thereafter he spent some years in surge arrester development, and from there moved to Transformer design and development.

He became Chief Engineer of the Transformer factory in 1957 and in 1966 was appointed as Consulting Director, a position he held until his retirement in 1979.

For the last twenty years he has been involved in the international CIGRE and IEC activities and has been Chairman of the CIGRE Transformer Group since 1974.

INLEIDING

Internasionaal dek die term verspreidingtransformators kragvermoëns tot en met 2 500 kVA met die laagste vermoë wat huidig normaalweg 50 kVA is. Die hoogste primêre spanning vir die toerusting (volgens 'IEC Publication 38') is 3,6 kV tot 24 kV met sekondêre spannings van hoogstens 1,1 kV. Die spektrum vir verspreidingtransformators is aansienlik wyer gedek deur die SABS 780 spesifikasie, beide vir kragvermoëns sowel as spanningreekse. Tipies vir die RSA, is die bestaan van klein transformators vir afgeleë gebiede met vermoëns van laer as 50 kVA (3 fase sowel as enkelfase). Verder, met die uitbreiding van kragvermoëns tot 3 150 kVA, primêre en sekondêre spannings van 36 kV en 12 kV respektiewelik deur die SABS 780 spesifikasie, beteken dat klein kragtransformators deur die spesifikasie ingesluit word.

Die praktiese gevolge hiervan is dat die produkreeks volgens die SABS 780 aansienlik varieerbaar is ten opsigte van ontwerp en produksie. Dié sal later bespreek word.

Die basiese standardisasie van elektriese gegewens in die SABS 780 is besonder bevredigend. In die algemene spesifikasie is dit vanselfsprekend dat die konstruktuele gegewens nie in detail gespesifiseer kan word nie.

Die drie olie-preserveringsisteme en die spesiale en verskillende meganiese vereistes wat deur klante gespesifiseer kan word, bemoeilik sake vir die vervaardigers. Die tipe probleme verg deeglike aandag en daar word vertrou dat met die konkrete aspekte wat weergee word in die verslag tot 'n vrugtevolle bespreking sal lei.

1. KERNTIPES VAN VERSPREIDINGSTRANSFORMATORS

Die moderne laeverlies kernmateriaal wat reeds geruime tyd al beskikbaar is, vereis 'n 45° versteklas om sodoende die beste werkverrigting te verkry ten opsigte van verliese, magnetiseerstroom asook klankpeil. Die prinsiep van 'n versteklas vir 'n 3-fasige kern word geïllustreer in Fig. 1. Vir beide die twee sykerns en die middelste kern kan klein verskille ten opsigte van die snypatroon voorkom, maar aangesien dit 'n geval is van noukeurige ontwerp, is dit nie van algemene groot belang nie. Die klassieke kern-ontwerp is opgebou in stappe soos aangedui in Fig. 2. Die aantal stappe en plaat-wydtes is 'n praktiese ontwerpaangeleentheid en die stappe word vermeerder namate die kern vergroot.

Die stappe van kerns het sy ontstaan te wyte aan die sirkelvormige windings. Slegs hierdie tipe ontwerp word vir groot kragtransformators gebruik. Vir die hele reeks van verspreidingstransformators is die reghoekige kern 'n interessante alternatief (Fig. 2b). Dit is vanselfsprekend dat 'n reghoekige kern, waar slegs een plaatwydte benodig word, die maklikste is om te produseer. 'n Derde alternatief word geïllustreer in Fig. 2c, waar daar van 3 plaatwydtes gebruik gemaak word met ovaal windings. Vir reghoekige kerns word daar gebruik gemaak van 'n windingvormer waarvan die dimensie so na as moontlik om die reghoekige kern aangepas is. Histories bestaan die reghoekige kern langer as die gestapte kern wat nie verbasend is nie. Sonder inagname van die manteltipe transformators, is die reghoekige kern baie min gebruik, selfs ook vir verspreidingtransformators, of te wel ten minste in Europa. Alombekend is dat die reghoekige gewinde kern nog steeds oorheersend is in die ontwerp van enkelfase transformators in Noord-Amerrika. Spesiale ontwerpe vir gewinde kerns vir 3-fasige transformators bestaan ook. Vroeër dae (sowat 25 jaar gelede en heelwat later in die RSA) was en kon die vervaardiging van kerns van verspreidingstransformators deur eenvoudige goedkoop toerusting gemaak word. Met die moderne kernstaal wat in rolle voorkom en die verbeterde ontwerpe van die kerns, het die ou metodes onvanpas geword. Beide die kwaliteit sowel as die verhoogde arbeidskoste ten opsigte van die materiaalkostes was verantwoordelik vir 'n totale nuwe vervaardigingstegnologie.

'n Gesofistikeerde outomatiese hoëspoed kernstaal snymasjien is die sleuteltoerusting (Fig. 3). Vir 'n gegewe kern en bepaalde stap word die drie verskillende plate outomaties gesny in die regte volgorde om sodoende die regte aantal plate te verkry vir 'n aantal kerns. Elke plaat word outomaties gepak tot 'n volledige pak en die alternatiewe lae word akkuraat in posisie geplaas waardeur die volledige aanmekaarsit van die kerns op spesiale tafels grootliks vergemaklik word. By die beginpunt van die masjien kan rolle kernstaal van verskillende wydtes gemonteer word en die omskakeling van een wydte na 'n ander vind baie vinnig plaas. Dit is vanselfsprekend dat die kapasiteit van die masjien (gemeet volgens totale aantal plate) verhoog word indien reghoekige kerns in plaas van gestapte kerns gebruik word. Hoe meer stappe die kern vereis, hoe laer is die uitset. Geen algemene gevolgtrekking kan gemaak word nie, maar dis voor die hand liggend dat klein kerns bestaande uit stappe in onguns raak. In die optimiseringsproses van ontwerpe van 'n reeks transformators, word 'n groot aantal faktore oorweeg en as gevolg hiervan kan daar nie veralgemeen word ten opsigte vanaf watter grootte transformator, gestapte kerns in onguns raak nie.

Die moderne toerusting vir die produsering van transformatorkerns wat kortliks bespreek is, het 'n absolute noodsaaklikheid geword om bestendige en goeie resultate te verkry ten opsigte van al die kerneienskappe. Hedendaagse hoë kwaliteit kernstaal is 'n delikate materiaal wat baie sensitief is vir verskeie afbrekende faktore. Die kante waar die kernplaat gesny word, moet sover moontlik vry wees van enige defekte. Dit word vereis dat die dimensionele toleransies besonder klein moet

INTRODUCTION

Internationally the term 'distribution transformer' covers power ratings up to 2 500 kVA, the lowest rating at present normally being 50 kVA. Primary voltages for equipment (acc. to IEC Publication 38) cover the range 3,6 kV up to 24 kV and the secondary voltage for equipment has an upper limit of 1,1 kV. The scope of distribution transformers according to SABS 780 is wider, both with regard to the power rating range and the voltage range. Typical for South Africa is the existence of small rural distribution transformers with ratings lower than 50 kVA (both three-phase and single-phase). Further, the extension of power ratings up to 3 150 kVA, primary and secondary voltages up to 36 kV and 12 kV respectively in SABS 780 also includes small power transformers in the standard. The practical result is that the product range according to SABS 780 becomes extremely wide both from the viewpoint of design and production. The consequences of this will be further commented on in the paper.

The basic standardisation of electrical data in SABS 780 is quite satisfactory. It is natural that in a general specification the constructional requirements cannot be defined in detail. There are three 'oil preservation' systems in use and together with special and diverse mechanical requirements, which may be specified by users, complications arise for the manufacturers. These problems deserve a thorough treatment and it is hoped that some of the concrete viewpoints given in the paper will stimulate a fruitful discussion.

1. THE CORE ALTERNATIVES FOR DISTRIBUTION TRANSFORMERS

Modern low loss core material available for quite a long time requires 45° mitred joints for obtaining the best possible performance with regard to losses, magnetizing current and also sound level.

The principle of obtaining mitred joints for a three-phase core is illustrated in Fig. 1. For both side limbs and the centre limb slightly different blading patterns are possible but this is a matter of detailed design and therefore not of general interest.

The classical core design has a stepped cross section (Fig. 2a). The coice of the number of steps and resulting plate widths is a matter of practical design, but in general with increasing core size it is usual to increase the number of steps. The stepped core is adapted for the use of circular coils. Only this design can be used for large power transformers. For the entire range of distribution transformers, the rectangular core section is an interesting alternative (Fig. 2b). Obviously a rectangular core of only one plate width is the simplest possible core to produce. An alternative third core is illustrated by Fig. 2c, typically making use of three plate widths and adapted to oval coils. For the rectangular core a coil form is used which is as close as practically possible to the rectangular shape.

Historically the rectangular core is older than the stepped core, which is, of course, not surprising. Not considering shell type transformers, even in the distribution range the rectangular core has been very little used, at least in Europe. As is well known, the rectangular core has been and is still the dominating design for single-phase distribution transformers in North America. Special designs of wound cores also exist for three-phase transformers.

In the old days (say 25 years ago and more recently in South Africa) the fabrication of cores for distribution transformers could be, and was, typically made with simple, inexpensive equipment. The modern core steel in roll form and improved core designs have made the old methods entirely obsolete. Both quality considerations and increasing labour costs relative to material costs have resulted in an entirely new manufacturing technology. A sophisticated high speed automatic core cutting machine has become indispensable (Fig. 3). For a given core design the several different plates are automatically cut in sequence to obtain the right number of plates for a desired number of cores.

Each plate type is automatically stacked as a complete package and alternate layers accurately positioned so that the assembly of complete cores on special core laying tables (Fig. 4), is greatly facilitated. At the starting end of the machine, several rolls of different widths can be mounted and a rapid change-over from one width to another, can be achieved.

Obviously the capacity of a machine of this kind (expressed in total quantity of finished plates) becomes larger for simple rectangular cores than for stepped cores. With an increased number of steps the output is reduced. No generalised conclusions can be made, but the obvious trend is away from small cores of the stepped type. In an optimization process of the design of a certain range of transformers, many variables must be considered and therefore no valid generalisations can be made with regard to the ratings for which stepped type cores become unfavourable.

This modern equipment for core production is essential for obtaining consistently good results with regard to all core properties. Today's high quality core steel is a delicate material very sensitive to various 'destructive' factors. All slitting and cutting must provide burr free edges within reason. The dimensional tolerances have to be extremely small in order to obtain smallest possible 'air gaps' in the overlap joints between limbs and yokes. The final criterion for judging the total core fabrication wees om sodoende die kleinste moontlike luggapings te verkry tussen die laspunte van die kern en die juk.

Die finale kriterium vir die bepaling van die goeie funksionering van die kernstaal lê in die akkurate meting van die nullasverliese en dit te vergelyk met die spesifieke verliese van die materiaal wat gebruik is. Die toetse vereis spesiale toerusting, 'n sogenaamde plaattoetser (Fig. 5), waarmee verliese direk en akkuraat gemeet word van elke individuele plaat. Hierdie is 'n relatiewe nuwe ontwikkeling en die apparaat is sover bekend die enigste van sy soort in die RSA.

In hierdie kort beskouing van die basiese kerntipes en die nuutste ontwikkelings in die vervaardigingstegnologie, moet daar ook melding gemaak word van 'n paar praktiese ondervindings met die super-georiënteerde kernstaal, wat al verskeie jare beskikbaar is. Die spesifieke-verliese is ongeveer 10% laer in vergelyking met die beste graad gewone kernstaal. Dit is egter baie moeilik om dieselfde klas vermindering in verliese van 'n kompleet kern te verkry. Die verliesvermindering is egter binne bereik as die vervaardigingsproses baie noukeurig beheer word. 'n Ander alternatief is om die vloeddigtheid ietwat te verhoog indien die mikpunt is om dieselfde nullasverliese te verkry. Die ekonomiese aspek van die super-georiënteerde kernstaal is die koste ten opsigte van dié van normale georienteerde kernstaal en die verlies-evaluering.

Tipiese verlies-evaluerings wat deur EVKOM en sommige munisipaliteite gebruik word, is egter heelwat laer as die internasionale trant. Die transformatorverliese wat deur SABS 780 gegee word, is gebaseer op 'n relatiewe lae verlies-evaluering, selfs ook vir die laeverlies kategorie. Dat daar 'n verhoging van die verliesevaluering sal plaasvind tesame met stygende inflasiekoste, is natuurlik te wagte.

2. DIE NUWE LAAGSPANNINGWINDINGSTEGNOLOGIE

Vir die volledige reeks SABS verspreidingstransformators is die stroom vir 400V kernspanning ongeveer in die verhouding 1:100 met die hoogste stroom in die orde van 3 000 A. Hoofsaaklik vir die hoë strome word die konvensionele windings uiters gekompliseerd ten opsigte van elektriese en meganiese aspekte.

'n Drastiese verandering ten opsigte van windings is die foelie of strookwinding. Die geleier-materiaal kan koper of aluminium wees, met laasgenoemde egter dominerend vir die meeste toepassings. Die term foelie word slegs vir dun materiaal gebruik, maar vir gemaklikheidshalwe sal die uitdrukking "strookwinding" gebruik word, onafhanklik van die materiaaldikte. Die wydte van die strook is die effektiewe windinghoogte. Die strookwindings word vervaardig met spesiale masjienerie. Fig. 6 illustreer 'n besonder groot windingmasjien wat gebruik word vir die vervaardiging van die reeks 800 — 2 500 kVA (400 — 550V). Die masjien kan egter windings vervaardig met groter vermoëns, aangesien dit twee stroke in parallel kan wind. Die isolasiemateriaal tussen die draaie, waar daar van relatiewe dik geleiers gebruik gemaak word, is 'n spesiale kwaliteit pressphan. Aangesien die spanning tussen die draaie besonder laag is (maksimum 25 V/draai), word die isolasiemateriaal uitsluitlik deur meganiese vereistes bepaal. Dit geld ook waar daar van baie dun foelie gebruik gemaak word, so min as 0,1 mm. Uit 'n praktiese oogpunt gesien, gee die dun materiaal die laagste limiet ten opsigte van die oppervlaktebenuttings en meganiese aspekte

Daar is heelwat nuwe kwaliteitsvereistes vir die tipe koper- en aluminiumgeleiers, en is noodsaaklik om windings van 'n hoë gehalte te verkry. Aluminiumstroke van bevredigende kwaliteit word plaaslik vervaardig. Koperstroke is egter nie beskikbaar nie, maar veroorsaak geen terugslag nie, aangesien aluminium verskeie belangrike voordele ten opsigte van koper het. Die hoof en feitlik die enigste nadeel van aluminium is sy laer geleidingsvermoë (63% in vergelyking met koper). Die baie lae spesifieke digtheid van aluminium (30% in vergelyking met koper) is egter 'n beslissende kompenseringsfaktor. Die huidige prysverhouding tussen koper en aluminium het tot gevolg dat die transformator se prys ongeveer dieselfde is vir beide geleiers. 'n Vergelyking in die koste is egter nie vir verspreidingtransformators gedoen nie, maar vir 'n relatiewe klein kragtransformator waar koper deur aluminium vervang kan word. Dit is vanselfsprekend dat die strookwindings heelwat makliker is om te vervaardig as die konvensionele windings. Die tipe winding het ook heelwat meer moontlikhede gesien uit 'n ontwerp-oogpunt. Met die beperkte aantal strookwydtes (5 wydtes) en die verskillende diktes waarin hulle beskikbaar is, word feitlik enige moontlikheid gedek. Dit is vanselfsprekend dat enige aantal draaie gekies kan word om te voldoen aan die vereiste spesifikasie wat op sigself van beslissende belang is vir die verskillende laagspannings.

Vir die strookwindings is dit natuurlik nodig om terminaalverbindings aan die begin en eindpunte van die winding te maak. In die laer stroomreeks word gebruik gemaak van plat kopergeleiers. Vir die hoër stroomreeks word gebruik gemaak van 'n masjien soos getoon in Fig. 6, wat koper-, sowel as aluminiumverbindings kan maak. 'n Besonder swaar aluminiumgeleier word vereis by baie hoë strome en die verbinding word gedoen deur middel van die TIG-sweisproses. Die sweisproses word outomaties gedoen en verseker 'n veilige elektriese en meganiese verbinding.

Vir verbindings met kopergeleier (in strook- of stamvorm), word gebruik gemaak van 'n koue sweisproses. Vir verskillende variasies van ko-

process is to measure accurately the no-load losses and compare with the specific loss of the actual material used. This has to be measured with special equipment, a so-called sheet-tester (Fig. 5), which allows a direct and accurate loss measurement of an individual sheet. This is a relatively recent development and as far as is known, the instrument shown is the only one of this kind in South Africa.

In this very brief review of basic core types and the newest development of the manufacturing technology, some practical experiences with the super-oriented core steel, available on the market for a few years, should also be mentioned. The specific loss is about 10% lower as compared with the best grade of oriented steel. The same loss reduction is not easily obtainable for complete cores, but can, however, be approached if the manuacturing technique is tightly controlled. If the aim is to maintain the same no-load loss, an alternative use of this material would be to operate the core at a somewhat increased flux density. The economy of the super-oriented core steel depends naturally on its cost relative to the normal oriented steel and the loss evaluation. Typical loss evaluations used by ESCOM and also by the larger municipalities for special tenders, are still quite low compared with the trend internationally. The fixed losses according to SABS 780 can, even for the low loss category, be considered to be based on a relatively low loss evaluation. An increase of the loss evaluation in step with the general inflationary cost increase would, of course, be natural.

The fixed losses in SABS 780 are, however, well balanced and there should be no need for a revision of the values for some years to come. The SABS losses are also reasonably in line with the latest proposal for a new European (CENELEC) standard.

2. THE NEW TECHNOLOGY FOR LOW VOLTAGE WINDINGS

For the entire range of SABS distribution transformers, the current for 400V rated voltage covers a ration approximately 1:100, the highest current being of the order of 3000A. Especially for the upper current range, conventional windings become quite complicated both electrically and mechanically.

A radically different winding is the foil or band winding. The conductor material can be either copper or aluminium, the latter however dominating for most applications. The term foil is used for thin material only, but for simplicity reasons the expression 'band winding' will be used here independent of material thickness. The width of the band is the effective winding height.

Band windings are made on special machines. Fig. 6 illustrates a large machine used for the upper size range 800 — 2 500 kVA (400-550V) and the machine is basically capable of handling still larger sizes, as two bands can be wound in parallel. The inter-turn insulation for the thicker bands uses a special quality of presspahn. The electrical stresses between adjacent turns are naturally quite low (operating voltage max 25 V/turn) and therefore the insulation is exclusively determined by mechanical requirements. This is also the case for the thinnest band in use, which may be as little as 0,1 mm. From a practical point such a thin material represents the lowest limit with regard to space factor and mechanical reasons.

For the aluminium or copper band material there are several special quality requirements which are essential for obtaining windings of a high standard. Locally produced aluminium bands of a satisfactory quality are available. Copper bands are not available which is no serious drawback, as aluminium has several important advantages compared with copper. Naturally the main disadvantage of aluminium is its lower conductivity (63% compared with copper). The very low specific density for aluminium (30% compared with copper) is a decisive compensating factor. The present price ration between copper and aluminium results in very nearly the same transformer cost for both winding materials. These cost comparisons have, however, not been made for distribution transformers, but instead for relatively small power transformers, in which aluminium can be a substitute for copper.

Obviously band windings are considerably easier to manufacture than corresponding conventional windings. From the design viewpoint they are further much more flexible. With a limited number of band widths (for instance, five sizes) and some different thickness values for each width, almost complete design flexibility is obtained. Further, the number of turns can be chosen freely to fit required data, which is of decisive importance because of different LV voltage requirements.

For band windings it is of course necessary to fit terminal connections at the start and end of the windings. In the lower current range the connections are made of copper strip. In the higher current range the machine, as illustrated in Fig. 6, is equipped for making connections either of copper or aluminium. Rather heavy aluminium bars are needed for the largest currents and they are welded to the aluminium band (TIG welding technique). The welding process is automatic and gives safe joints both electrically and mechanically.

When the connections are of copper (strip or bar form) the jointing technique is a cold welding process. For different combinations of aluminium and copper thickness, special hydraulically operated dies fuse the two metals together at a number of points across the width of per- en aluminiumdiktes, word 'n spesiale hidrouliese stempel gebruik wat die twee materiale in 'n "smeltproses" oor 'n groot gedeelte van die strookwydte vasheg. (Fig. 7). 'n Baie veilige elektriese en meganiese verbinding word hierdeur verkry. Selfs in die RSA is toetse gedoen om die veilige verbinding te bevestig. 'n Beslissende toets vir die bepaling van die elektriese karakteristieke van die verbinding is met hoë strome. Tipetoetse met 'n tydsbestek van 1 sekonde en 'n kortsluitstroom van tot twee maal die normale waarde (ongeveer 40 x die kenstroom) is uitgevoer. Al die toetse wat uitgevoer is, het bevredigende resultate gelewer, selfs met 2 maal die kortsluitvermoë-waarde (geen toename in die kontakweerstand asook enige opsigtelike fisiese verandering).

In die RSA word die kouedruk-sweisproses al vir ses jaar gebruik vir die laer en medium stroomreeks sonder 'n enkele faling. Ondervinding in die hoë stroomreeks (2 000 — 3 000 A) is egter meer beperk, maar nogtans voldoende om volle vertroue uit te spreek oor die spesiale en gevorderde tegnologie.

3. HOOGSPANNINGWINDINGS

Vir verspreidingsisteme in die RSA is 11 kV en 22 kV oorheersend, alhoewel 'n paar 6,6 kV-stelsels nog voorkom. Planne vir die latere oorskakeling na 11 kV vir laasgenoemde stelsels het 'n vraag geskep na dubbelspanning verspreidingstransformators 6,6 — 11 kV. Die toekomstige vraag vir die tipe transformators behoort dus relatief klein te wees.

As gevolg van die verskillende spannings wat nog voorkom, is die totale stroomreeks egter nog groter as vir die laagspanningskant, beskouend oor die hele reeks vermoëns. Dit word slegs genoem om klem te lê op die wye reeks wat gedek moet word.

Alhoewel aluminium verkies word vir strookwindings en daarom ook slegs gebruik word, kan daar vir die hoogspanningswindings in teenstelling hiermee van koper of aluminium gebruik gemaak word. Die trant deur van aluminium gebruik te maak, is dominant in Europa en Noord-Amerika.

'n Belangrike faktor is natuurlik die prysverskil tussen die twee materiale. As gevolg van die koper se prys wat grootliks varieer, kan daar slegs gebruik gemaak word van 'n gemiddelde prys vir koper, wat oor 'n periode van 'n paar jaar gemonitor is, om 'n kostevergelyking vir die twee tipes transformators te maak. Vir so 'n vergelyking is die verliesevaluering van groot belang. Die gestandardiseerde verliese vir verspreidingstransformators in die RSA volgens SABS 780, word redelik algemeen aanvaar wat meebring dat die komplikasies ten opsigte van die verlies-evaluering grootliks ge-elimineer word. Indien daar somtyds 'n verlies-evalueringsformule gespesifiseer word, is dit gewoonlik te laag om enige invloed uit te oefen om van 'n kopergeleier gebruik te maak in plaas van aluminium. Aangesien standardisering dit gunstig gemaak het vir die gebruik van slegs een tipe materiaal, is die gevolgtrekking dat aluminium 'n algemene keuse is vir hoogspanningwindings vir Suid-Afrikaanse toestande.

Die ontwerp probleme vir hoogspanningwindings 11 — 22 kV asook 33 kV, kan as redelik trivaal beskou word. Belangrike faktore, behalwe dat die winding ook die standaard diëlektriese toetse moet slaag, maak deel uit van die gevorderde tegnologie vir die ontwerp van die windings. Die keuse van die mees geskikte geleier is natuurlik van uiterste belang vir 'n goeie en voortdurende kwaliteit. Gerasionaliseerde produksie was 'n sleutelfaktor in die ontwikkeling van die windings. Die multi-laag windingtipe is veral baie geskik in die kombinasiegebruik van die laagspanningstrookwindings waar elke laag oor die volle windinghoogte strek, soos aangedui in Fig. 9. Die tipe winding kan gebruik word vanaf die kleinste transformator, waar dun draad geleiers gebruik word tot die grootste transformator waar daar van reghoekige draad gebruik gemaak word.

Verskeie faktore begunstig die gebruik van die tipe winding, maar die volgende faktore behoort genoem te word:

- Uniforme ampere-draaie verspreiding, veral belangrik by groot transformators.
- Besonder goeie stootspanning karakteristieke.
- Uitsonderlik geskik vir gerasionaliseerde produksiemetodes.

Die ampere-draaie verspreiding is 'n belangrike faktor by kortsluitkragte en sal behandel word in die volgende hoofstuk. Die stootspanning karakteristieke is sodanig dat die spanningverspreiding vir 'n normale golfvorm van 1.2/50 μs nie meer as tweemaal die spanning tussen die lae oorskry vir 'n liniêre geval nie. Die praktiese resultaat hiervan is dat 'n addisionele grens vir die stootspanningskragte verkry word waar daar andersins as gevolg van volgehoue kragte wat deur die toevoerspanning veroorsaak word, die faktor is wat normaalweg die isolasiedikte bepaal. Die multi-laag winding is egter nie 'n nuwe ontwikkeling nie. Ons oorsese genote het, by uitstek, slegs van die tipe winding gebruik gemaak vir die hele reeks verspreidingstransformators vir 20 jaar. In die RSA is dit in gebruik vir byna 10 jaar.

4. KORTSLUITKRAGTE

As gevolg van die gekompliseerde probleme wat gepaard gaan met kortsluitkragte en vermoëns vir transformators sal dit slegs op 'n elementêre vlak bespreek word. Beskou 'n 2 000 kVA, 11 000/400 V transformator wat ontwerp en gebou is volgens konvensionele metodes vir krag-

the band (Fig. 7). Safe joints electrically and mechanically are obtained. Special tests have been made locally to verify this. The decisive electrical performance is best checked by high current tests. For instance, for a duration of one second type tests have been made up to twice the maximum short time current values (approximately 40 x rated current). All tests made have proved a satisfactory performance of the joints even during such an extreme test, (no measurable change of the contact resistance and no other measurable or observable change). Locally the cold press welding technique has been used in the lower and medium current range during six years with no failure in service. The experience in the highest current range (2000 — 3000A) is mere limited but sufficient to justify full confidence in this special and advanced technology.

3. HIGH VOLTAGE WINDINGS

For distribution systems in South Africa, the dominating voltages are 11 and 22 kV. Also some 6,6 kV systems still exist. Planned change-overs of these to 11 kV result in the need of so-called dual voltage transformers 6,6 — 11 kV. The future need of such transformers ought, however, to be relatively small.

Because of the different voltages, the total current range from the smallest to the largest sizes becomes even greater than the relative range for the low voltage windings. This is mentioned only to illustrate the wide range to be covered.

Although the preferred conductor material for low voltage band windings is aluminium and in fact is the only one used, complete freedom exists technically to combine these windings with either aluminium or copper in the high voltage windings. The dominating trend both in Europe and North America, is however, to use aluminium. An important factor is naturally the price difference between the two materials. Because the copper price fluctuates quite widely, only the average price over a period of some years can be used in a cost comparison between the two kinds of transformer. In such a comparison the loss evaluation is also an important factor. The standardised losses for distribution transformers in South Africa according to SABS 780, and the rather general acceptance of these loss values eliminates to a large extent the complications of loss evaluation. When buyers do specify a loss evaluation formula, the typical trend is that the loss evaluation is not sufficiently high to result in a preference for copper. As standardisation viewpoints make it favourable to use one material only, the conclusion is that aluminium becomes the natural choice also for the high voltage windings for South African conditions.

The design problems for high voltage windings 11 — 22 kV and even 33 kV may be considered as rather trivial. Including, however, important properties other than passing the standard dielectric tests, even these windings require quite an advanced technology. The selection of the best possible and most suitable materials is naturally essential for obtaining a consistently high quality. Rational production is also a key factor and has contributed decisively in the winding development process.

The type of winding especially well suited in combination with low voltage band windings, is the multi-layer type, each layer extending over the full winding height as schematically illustrated in Fig. 8. This type of winding can be used from the smallest size transformers with thin wire conductors to the largest sizes of rectangular conductors used for the very largest transformers. Among the factors which make this winding type so favourable are:

- Uniform ampere-turn distribution, especially important for large transformers.
- Exceptionally good impulse voltage characteristics.
- Particularly well suited for rational production.

The empere turn distribution is an important factor for short-circuit strength and will be treated in the next section. The impulse voltage characteristic is such, expressed simply, that the voltage distribution for the normal wave shape 1,2/50 us results in a maximum voltage between layers not more than twice the value calculated from linear distribution. The tractical effect of this is that it is relatively easy to obtain an extra margin in the impulse strength, as in fact the continuous stresses, caused by the operating voltage decide the layer insulation.

The multi-layer type winding is not a new development. Our overseas associates have used this winding type exclusively for the entire range of distribution transformers for 20 years. Locally it has been used for almost 10 years to date.

4. SHORT CIRCUIT STRENGTH

The complicated problems of short circuit forces and short circuit strength for transformers can in a short paper be treated only in a rather elementary way.

Consider a 2000 kVA transformer 1100/400 V designed and built in a transformators. Selfs met koper as geleier moet die laagspanningwindings uit verskeie parallel paaie bestaan (32 geleiers vir 'n praktiese geval). Dit is 'n sogenaamde heliese of skroefwinding. Die hoogspanningwinding, volgens konvensionele ontwerp beginsels, sal 'n skyfwinding wees. Die normale ± 5% tappe is in die middel van die winding. Rekenaarberekenings van die aksiale kragte gee 'n waarde van ongeveer 300 KN vir die minus tap en ongeveer 150 KN vir die normale tap. Die kragte is bepaal vir 'n maksimum assemetriese stroompiek vir 'n transformator met 'n impedansie van 5,5%. Sulke berekenings, wat slegs met behulp van 'n gevorderde program en groot rekenaars gedoen kan word, wys op die praktiese probleme wat ondervind word in die ontwerp en vervaardiging van groot verspreidingstransformators wat aksiale kragte van dié ordegrootte moet weerstaan. Vir 'n soortgelyke transformator, waar daar gebruik gemaak word van 'n strooklaagspanningswinding en 'n multi-laag hoogspanningswinding, word die aksiale kragte feitlik geelimineer. Die fisiese aspek is dat die ampere-draaie verspreiding in die hoogspanningswinding byna uniform is vir enige tapposisie. Aangesien die laagspanningsgeleier oor die volle hoogte van die hoogspanningswinding strek, word die stroomdigtheid op enige hoogte outomaties aangepas vir 'n byna perfekte ampere-draaie balans. Die lekvloed tussen die windings is slegs aksiaal en die enigste radiale komponent kom by die ente van die winding voor. Kortsluittoetse is uitgevoer waar die windings slegs op die ondersteuningspunte van die onderste juk gerus het en aangesien geen beweging van die windings plaasgevind het nie, word die uniforme ampere-draaie balans bevestig. Die baie belangrike praktiese voordeel hiervan is dat geen aksiale vashegting benodig word nie, terwyl vir konvensionele windings daar van swaar strukture gebruik gemaak moet word om die windings in posisie te hou tydens kortsluiting. Die radiale kortsluitkragte veroorsaak 'n krag inwaarts op die binneste laagspanningswinding en 'n uitwaartse krag op die buitenste hoogspanningswinding. Die radiale kragte kan maklik en akkuraat bereken word. Die kragte vergroot namate die transformatorvermoë vergroot. Vir ontwerpe met reghoekige en ovaal windings, word demping van radiale kragte genoodsaak, behalwe vir baie klein transformators. 'n Praktiese voorbeeld hiervan word geïllustreer in Fig. 9. Tydens kortsluiting is, vir sirkelvormige windings, die trekkrag in die geleiers van die buitenste winding nie genoegsaam om enige probleme te veroorsaak nie, selfs nie eers vir groot kragtransformators nie en daaroor ook nie vir die hele reeks van verspreidingstransformators nie.

Die radiale inwaartse krag op die binneste winding gee egter aanleiding tot 'n meer gekompliseerde teorie. Indien die kragte groot genoeg is, kan die winding faal as gevolg van die "kronkeling" van die geleiers. Die tipe tendens is redelik algemeen wanneer kragtransformators faal tydens 'n kortsluiting. Konvensionele laagspanningwindings vir verspreidingstransformators het normaalweg genoegsame inherente sterkte om die kronkeleffek te weerstaan. Die basiese metode om 'n hoë weerstand teen die kronkeleffek te bied vir strookwindings, is om 'n effektiewe vashegting te bewerkstellig tussen die verskillende lae. Dit word verkry deur gebruik te maak van 'n spesiale isolasie tussen die lae.

Praktiese ondervinding ten opsigte van transformators wat faal tydens kortsluiting, kom heeltemal bevredigend voor, alhoewel daar nie akkurate statistieke beskikbaar is nie. Volgens inligting uit die VSA van ongeveer tien jaar gelede, was transformators wat tydens kortsluiting gefaal het, verantwoordelik vir ongeveer 25% van al die falings. Dit mag miskien hoog voorkom, maar daar moet in ag geneem word dat die kortsluit-impedansies in die VSA laer is as elders.

5. TERMIESE KARAKTERISTIEKE EN VERKOELING

Die temperatuurstygingslimiete vir boonste olie en windings, volgens SABS 780, is in ooreenstemming met die IEC-reëls (Publikasie 76-2). 'n Spesiale bepaling van SABS 780 is dat daar na waardes verwys word vir 'n hoogte van 1 800 m, en afhangende van die werklike hoogte waarop die metings gedoen is, word aangepaste waardes gespesifiseer vir laer hoogtes in stappe van 500 m.

Volgens praktiese ondervinding en gepubliseerde data beskikbaar, is die veroudering van die isolasiemateriaal nie 'n ernstige probleem nie, selfs nie vir dienstydperke van solank as 20 — 30 jaar nie. Die voorhandliggende verklaring hiervoor is dat die transformator normaalweg so belas word dat die windingtemperatuur selde die waarde bereik wat 'n vinnige verouderingstempo veroorsaak. As voorbeeld kan genoem word dat 'n transformator wat aan die SABS 780-spesifikasie voldoen, 'n warmpunt windingstemperatuur van ongeveer 80°C sal hê vir 'n volgehoue las van 75% en 'n omgewingstemperatuur van 25°C. By 80°C is die verouderingstempo baie stadig. Transformators met vaste verliese en standaard temperatuurstygingswaardes (vir windings en boonste olie) kan slegs in 'n beperkte mate in die ontwerpstadium beïnvloed word ten opsigte van die warmpunt windingstemperatuur. Dit moet egter beklemtoon word dat die windingsgradiënt die werklike windingstemperatuur is bo dié van die gemiddelde olietemperatuur. In vergelykende toetse is die olie se temperatuur op verskillende hoogtes bepaal, asook in die hoofkanaal tussen die twee windings met behulp van 'n hittesensor. Die gemiddelde van die waardes kan beskou word as 'n ware weergawe van die gemiddelde olietemperatuur. Gedurende die eksperimente is egter

conventional way like a power transformer. Even with copper as conductor material, the low voltage winding would have to be built up of quite a large number of parallel parts (32 conductors in a practical case). The type of winding would be a so-called helical or screw winding. The high voltage winding according to conventional design principles would be of the disc type. The normal ± 5% taps would be at the winding centre. Computer calculations of axial forces give for the minus tapping approximately 300 kN and for the principal tapping 150 kN.

These forces are calculated for the maximum assymetrical current peak for a transformer with a 5,5% impedance. Such calculations, which can only be made with advanced programmes on large computers, clearly prove the practical difficulties encountered in the design and building of large distribution transformers capable of withstanding axial forces of this magnitude.

For the corresponding transformer with a low voltage winding and a high voltage layer winding, the axial forces are virtually eliminated. The physical mechanism is that the ampere-turn distribution in the high voltage winding for any tapping is fairly uniform. As the low voltage conductor has a width extending over the entire high voltage winding height, its current density at any height level automatically adjusts itself to exact ampere-turn balance. The leakage flux between the windings becomes strictly axial and a radial component appears only near the winding ends. Actual short-circuit tests carried out on transformers where the windings only rest on their supports at the bottom yoke and are completely free to move axially, prove that no measurable movement takes place. The very important practical consequence is that winding assemblies of this kind need no axial clamping while obviously conventional windings need massive clamping structures to be able to withstand the maximum peak forces resulting from full short-circuit currents.

The radial short-circuit forces create an inward pressure on the inside low voltage winding and outward pressure on the outside high voltage winding. The radial forces can be calculated with sufficient accuracy in an elementary way. The forces and resulting stresses increase with the transformer size. For designs with rectangular or oval windings radial blocking becomes necessary except for small transformers. A practical example of this type of design is illustrated in Fig. 9. For circular windings the tensile stresses in the conductors of the outside winding do not become high enough to cause any problems even for quite large power transformers and are thus not problematic for the entire size range of distribution transformers.

The radial inward forces on the inside low voltage windings give rise to more complex phenomena. If the forces are sufficiently large, the winding can collapse locally by 'buckling'. This failure mode is typical for power transformers under short circuit failure.

Conventionally built low voltage windings even for the largest distribution transformers, however, normally have sufficient inherent strength to resist buckling. The basic method to obtain a high strength and resistance against buckling forces for band winding is to create an efficient bond between adjacent turns. This is achieved by using special inter-turn insulation.

The practical service experience with regard to short-circuit failures seems to be quite satisfactory, although no accurate statistical data are available. According to some (more than 10 years old) data from the USA, short-circuit failures constitute about 25% of the total failure rate. This figure may seem somewhat high, but it must be taken into account that short-circuit impedances in the USA are typically lower than elsewhere in the world.

5. THERMAL CHARACTERISTICS AND COOLING

The temperature rise limits for top oil and windings according to SABS 780 corresponds to the IEC rules (publication 76-2). A special requirement of SABS 780 is that the values refer to an altitude of 1 800 m and, depending upon the real altitude at which the measurements are made, corrected values are specified for lower altitudes in steps of 500 m.

According to practical experience and published data, ageing of the insulation is not a serious problem even with service periods of 20-30 years. This is because transformers are normally loaded so that the winding temperature seldom reaches the high values needed for a fast ageing rate. As a typical example, transformers with data according to SABS 780 will have a winding hot spot temperature of approximately 80° at a continuous load of 75% and an ambient temperature of 25°. At 80° C the ageing rate is quite low. It should also be pointed out that for transformers with fixed losses and standard temperature rise values (winding and top oil) the winding hot spot rise can only marginally be influenced by practical design. This is because the possible variation range of the 'winding gradient' in any specific case is rather small. It must be emphasised that the winding gradient is the real winding temperature above the temperature of the 'average oil', surrounding the windings. In comparative tests the oil temperature must be measured at different height levels both outside the windings and at least also in the main duct between the two windings with thermocouples to determine the 'true' average oil temperature. It has been established by some experimental investigations that particularly the oil temperature in the main duct between windings is hardly influenced by different external gevind dat die olietemperatuur in die hoofkanaal feitlik geensins beïnvloed word deur die verkoelingspype op verskillende metodes te monteer nie. Die verskillende rangskikkings gee dus dieselfde windingstemperatuur. Die normale metode vir die bepaling van die gemiddelde olietemperatuur is deur die boonste olietemperatuur te verminder met die helfte van die temperatuurdaling oor die verkoelingspype wat op die konvensionele vertikale wyse gemonteer is. Die metode kan egter nie uitgebrei word ten opsigte van ander rangskikkings van die verkoelingspype nie.

Gevolglik kan uit die kort bespreking afgelei word dat twee transformators van verskillende ontwerpe waarvan die verliese sowel as windingstemperatuur dieselfde is, nie veel kan verskil ten opsigte van termiese eienskappe wat die oorbeladings karakteristieke-en-kapasiteit beïnvloed. Dit geld, as aanvaar word dat daar van soortgelyke isolasiemateriale gebruik gemaak word wat dieselfde verouderingseienskappe besit. Indien die elektrisiteitsvoorsieningsondernemings sou vind dat die probleem van oorbelasting van transformators meer aandag moet geniet, kan eenvoudige reëls saamgestel word vir verspreidingstransformators wat deur die SABS 780-spesifikasie gedek kan word. Die beginsels hiervan sal egter gebaseer word op die IEC 'Loading guide for oil-immersed transformers' (Publikasie 354). Die gids word egter normaalweg as te gekompliseerd beskou vir praktiese aanwending. Deur die periodes waartydens belading plaasvind, te beperk tot die werklike hoeveelheid benodig, kan daar vir 'n sekere kategorie transformators, 'n eenvoudige handleiding saamgestel word. Vir Suid-Afrikaanse toestande sal dit voldoende wees om die reëls te beperk tot 'n temperatuur van 20° — 40°C.

6. VERSKILLENDE METODES VAN OLIEPRESERVERING

Die term oliepreservering word algemeen gebruik (alhoewel nie ingesluit in die SABS 780-spesifikasie nie) om die wyse waarop die olie en isolasiesisteem beskerm word teen die atmosfeer, te definieer. Soos wel bekend, verlaag die diëlektriese vermoë van olie en oliedeurweekte isolasiemateriaal vir 'n verhoogde inhoud van voggehalte. Transformatorolie kan slegs 'n baie beperkte hoeveelheid water in oplossing opneem, en selfs vir 'n waterinhoud van so laag as 50 d.p.m. (dele per miljoen), verminder die diëlektriese vermoë aansienlik. Die diëlektriese vermoë van die soliede isolasiemateriaal word egter nie in so 'n groot mate beïnvloed vir 'n waterinhoud van tot 2% nie. Selfs al verdubbel die waarde na 4%, het dit nogtans nie ernstige gevolge vir die relatiewe eenvoudige isolasiesisteme van 22 — 22 kV vir verspreidingstransformators nie. Ondervinding het egter getoon dat die stootspanningsterkte minder beïnvloed word as die kragfrekwensiesterkte deur die teenwoordigheid van water. Dit is 'n baie belangrike aspek, aangesien ou transformators wat moontlik 'n hoë waterinhoud bevat, 'n aansienlike verminderde kragfrekwensiesterkte toon, terwyl die stootspanningsterkte nie naastenby dieselfde vermindering wys nie.

Dit bring mee dat die uitdroging van die transformators nie noodwendig perfek hoef te wees om te verseker dat die standaard diëlektriese toetse geslaag word nie. Dit is egter vanselfsprekend dat nuwe transformators wat die nywerheidsperseel verlaat, voldoende uitgedroog is en 'n baie lae waterinhoud bevat. Na jare van diens sal enige addisionele vog van die atmosfeer natuurlik die oorspronklike waterinhoud verhoog. 'n Maksimum waterinhoud van 1,5% word aanbeveel en is vasgestel deur praktiese eksperimente. 'n Geskikte metode vir die bepaling van voldoende uitdroging is om soliede pressphan (50 x 50 mm deursnee) blokkies saam met die transformators uit te droog en dan die waterinhoud van die blokkies m.b.v. die Karl Fisher-metode te bepaal. Die pressphan-blokkie verteenwoordig 'n voorstelling van die isolasiemateriaal van die transformator wat opsigself baie moeilik uitdroog. Indien die waterinhoud van die pressphan-blokkie 'n maksimum waarde van 1,5% toon, is die waterinhoud van die isolasiemateriaal altyd laer.

Inligting beskikbaar oor hoogspanning kragtransformators wat met 'n uitsettingstenk en ontwaterpyp toegerus is, dui op 'n waterinhoud van 3 — 4% in die isolasiemateriaal na 'n 10 — 20 jaar dienstydperk. Die beskikbare inligting is relatief skaars, maar die waardes aangegee, is 'n praktiese bewys dat die oliepreserveringsmetode 'n baie lae tempo van voginname tot gevolg het. Selfs ondervinding van die grootste transformators met hoogspannings van 400 — 700 kV, bewys bo enige twyfel dat die oliepreserveringsmetode uiters goed funksioneer.

Vir 'n transformator sonder 'n ontwaterpyp, sal dit uiteindelik lei tot 'n baie hoë waterinhoud. Die fisiese meganisme wat die vogversadigingsvlak bepaal, is eintlik die gemiddelde relatiewe humiditeit van die atmosfeer wat in kontak met die olie oppervlakte is. Die funksie van die olie is hier slegs as 'n oordragingsmedium en beïnvloed nie die finale vogewewigstoestand nie.

'n Uitsettingstenk dra aansienlik by om te verhoed dat die olie se toestand verswak word deur oksidasie-prosesse ens., deurdat die kontak van die olie met die atmosfeer grootliks beperk word en die temperatuur op die oppervlakte laer is. Transformatorolie wat al verskeie jare gebruik word, het uitstekende eienskappe en die geleidelike verswakking van olie wat met normale lastoestande gepaard gaan, behoort nie 'n beperkende faktor te wees nie. Die volgende gevolgtrekkings kan dus gemaak word en is geheel en al onafhanklik van die spanningsklas van die transformator (maks. 12 kV en hoër as 12 kV).

cooling arrangements. Various arrangements would thus result in virtually the same winding temperature. The normal method of calculating the average oil temperature as the top oil temperature minus half the temperature drop over the radiators seems to agree reasonably well for the contentional radiator arrangement. Its use can, however, not be generally extended to any type of radiator arrangement.

It follows that two transformers of different design, but having the same loss data and the same winding temperature rise cannot differ significantly with regard to thermal properties, influencing the overload characteristic and capability. This is with the assumption that similar insulating materials having the same ageing properties are used. If the electricity undertakings find the overloading problem sufficiently important, simple generalised overloading rules could easily be worked out for transformers with data according to SABS 780. The principles would be based on the IEC 'Loading guide for oil-immersed transformers' (Publication 354). This guide is generally considered to be too complicated for practical use. For a certain category of transformers and limiting the load cycles to what is really needed, a simple guide for practical use could be obtained. For South African conditions it would probably also be sufficient to limit the rules to an ambient temperature range 20-40°C.

6. THE DIFFERENT METHODS OF OIL PRESERVATION

The term oil preservation is generally used (although not included in SABS 780) to define how the oil and thus also the complete insulation system is protected from the atmosphere. As is well known, the dielectric strength of oil and oil-impregnated cellulose material insulation is gradually reduced with an increasing moisture content. Transformer oil can hold only extremely small quantities of water in solution, and already at a water content of 50 ppm (parts per million) the dielectric strength of the oil falls rather rapidly. The dielectric strength of solid insulation is not much affected with a water content of up to 2%. Even doubling this figure to 4% is not catastrophic for the relatively simple insulation systems used for 11-22 kV distribution transformers. General experience is that the impulse strength is less affected by moisture than the power frequency strength. This is an important practical point, as very old transformers may have a high moisture content resulting in an appreciably reduced power frequency strength but not nearly the same reduction of the impulse strength.

Therefore the drying of the transformers in the factory need not be perfect in order to pass the standard dielectric tests. It is, however, self evident that new transformers leaving the factory, ought to have a reasonably low moisture content. During service over many years, all moisture which is picked up from the atmosphere, will naturally be added to the original content. A maximum moisture content which can be recommended and which is obtainable practically, is 1,5%. The verification of a figure of this kind is of a quality control nature. A suitable test is to dry solid presspahn blocks (50 x 5 mm cross section) together with the transformers and measure the moisture content after completed drying in the centre of the block (Karl Fisher method). The presspahn block is intended to represent the insulation pieces which are most difficult to dry in the transformer. If the moisture content in the centre of the block is max. 1,5%, the moisture content for the real insulation is always below this figure.

Data available from high voltage power transformers of the conservator type fitted with dehydrating (silica gel) breathers indicate that the typical moisture content of the insulation is 3-4% after 10-20 years of service. The available data are relatively meagre and the figures mentioned serve only as a practical proof that this oil preservation system results in a very slow rate of moisture absorption. All service experience, even for the largest transformers and the highest system voltages in use (400 — 700 kV) proves also without any doubt, that this oil preservation system functions very well.

For a transformer without a dehydrating breather, the moisture content will finally reach considerably higher levels. The physical mechanism which determines the moisture saturation level, is actually the average relative humidity of the air in contact with the oil surface. The oil is only a transfer medium and does not affect the final moisture equilibrium.

A conservator helps considerably to protect the oil itself from deteriorating by oxidation processes etc., because the oil surface in contact with the air is much reduced and the temperature at the surface is lower. Transformer oils in use for many years have, however, excellent properties and for normal loading conditions the gradual deterioration of the oil may not be a limiting factor. The following can therefore be concluded and these conditions are entirely independent of the voltage class of the transformer (max. 12 kV or higher than 12 kV):

(1) Vir die verskillende metodes wat vir vrylugtransformators gebruik word, is die gebruik van 'n uitsettingstenk met 'n ontwaterpyp die suksesvolste en behoort sonder uitstek voorkeur te geniet. Die alternatief om nie van 'n ontwaterpyp gebruik te maak nie, word nie aanbeveel nie.

(2) Indien daar as gevolg van ruimte of ander praktiese omstandighede nie van 'n uitsettingstenk gebruik gemaak kan word nie, moet die vrylugtransformators nogtans met 'n ontwaterpyp toegerus word.

Dit moet egter uitgewys word dat die tweede alternatief geensins 'n kostebesparing meebring indien al die faktore vir die bepaling van die werklike koste in ag geneem word nie. Die reëls soos gespesifiseer in Tabel 1 van SABS 780 gee geen leiding nie, gee vrye teuels vir enige verskillende metode om te gebruik en dui ook geen voorkeur aan nie.

Wanneer die verskillende oliepreserveringsisteme beskou word, moet die onderhoudaspekte ook in ag geneem word. 'n Ontwaterpyp waarvan die silika kristalle versadig is as gevolg van die vog, het dan natuurlik ophou funksioneer. Veral vir klein transformators, is die onderhoud van ontwaterpype 'n groot probleem. 'n Verseëlde transformator sal natuurlik voorkeur geniet vir lae kragvermoëns, maar dis nie moontlik om dit aan te beveel vir transformators met hoë kenwaardes nie. Die tipe transformator beskerm die olie en isolasiemateriaal natuurlik heelwat beter as enige van die voorafgaande tipes. Die versigtige neiging om geseëlde transformators meer algemeen aan te beveel, is hoofsaaklik gebaseer op die feit dat nie net in die RSA, maar ook in Europa, die tipe transformators in te 'n klein spektrum gebruik is om voldoende ondervinding op te doen.

Om 'n geskikte standaard stelsel op te stel, word die volgende voorstel gemaak vir bespreking:

< 100 kVA	Slegs geseëlde tipe transformators.
200 — 500 kVA	Vrylugtransformator met uitsettingstenk en ontwaterpyp of geseëlde tipe (gebaseer op die verbruikersaanvraag met inagname van ondervinding in die vervaardiging).
> 500 kVA	Slegs met uitsettingstenk en ontwaterpyp.

In hierdie aanbeveling van vrylugtipetransformators is eenhede sonder uitsettingstenk heeltemal uitgesluit om praktiese redes. Deur die bogenoemde faktore te oorweeg, is die besluit vanselfsprekend.

7. SIENSPUNTE VAN DIE SPESIFIKASIE EN MEEGAANDE KONSTRUKSIE-BESONDERHEDE

Die standardisering van elektriese gegewens in die SABS 780-1979, word geheel en al deur die nywerheid aanvaar en hou aansienlike voordele in vir elektrisiteitsondernemings. Die voordeel vir beide groepe lê hoofsaaklik in die laer en medium reeks tot ongeveer 800 kVA. Vir die hoë reeks word standaard verliese en impedansies gespesifiseer, en alhoewel dit met die eerste oogopslag aanvaar word, is dit beslis nie voldoende vir alle toepassings nie. Die tipe transformator het 'n verskeidenheid gebruike in die nywerheid, en al die spesifikasies neig om verskillend te wees. As voorbeeld word die probleem van verliese genoem. Sekere transformators funksioneer by 'n relatiewe lae lasfaktor terwyl vir sekere industriële toepassings die lasfaktor baie hoog is. Dieselfde transformator kan dus nie die optimum wees vir beide gevalle nie.

Alle moderne standardisasie het 'n modulêre neiging. Vir klein transformators is 'n volledige standardisasie wenslik, ook ten opsigte van vaste elektriese gegewens. Vir groot transformators (1 000 kVA en hoër) is vaste elektriese data (verliese en impedansie) slegs van baie klein voordeel gesien uit 'n ontwerpoogpunt. Die koper kan eerder 'n verliesevalueringsformule en 'n aanvaarde impedansie spesifiseer. Die modulêre ontwerp konsep en die uitgebreide gebruik van spesiale programme van rekenaars, maak dit moontlik om die ontwerp te optimiseer. Ten opsigte van die vervaardiging moet die transformator egter gestandardiseerd wees om aan te pas vir alle produksie-aspekte. Standaard elektriese gegewens is van minder belang vir 'n produksie-georiënteerde fabriek. Die transformator met die laagspanningstrookwinding en die hoogspanning-multi-laagwinding, soos voorheen bespreek, vind baie byval vir die tipe ontwerpkonsep en is besonder geskik vir gerasionaliseerde produksie.

Aangaande die konstruksiebesonderhede, word slegs noodsaaklike aspekte ten opsigte van die aktiewe gedeeltes van die transformator in die SABS 780 — 1979 gespesifiseer. Dit is voldoende aangesien dit sinneloos sal wees om die kern en windings in detail te spesifiseer.

Die volgende gedeelte sal dus slegs die tenk, toebehore en konstruksiebesonderhede behandel.

Die meegaande bewerings mag tot 'n sekere mate van 'n afkeurende aard wees, maar die doel is om 'n produktiewe bespreking te stimuleer.

7.1. Konstruksiebesonderhede vir die verskillende Oliepreserveringsisteme

Veronderstel die oliepreserveringsisteme kon gekies en beperk word vir verskillende transformators soos aangewys is in die vorige hoofstuk. Dit sou meebring dat vir tot en met 100 kVA slegs verseëlde transformators en vir hoër waardes sê tot 500 kVA 'n alternatiewe tipe verkry kan word. Die limiet van 500 kVA word gestel, aangesien daar nog onvoldoende

(1) Among the different free-breathing systems possible, the conservator type with a dehydrating breather is the best and should be given absolute preference. The alternative to omit the dehydrating breather cannot be recommended.

(2) If space restrictions or other practical circumstances do not allow fitting of a conservator, free breathing transformers ought definitely to have dehydrating breathers.

It should also be clearly pointed out that the second alternative results in no cost saving if all factors affecting the actual costs are considered. The rules in Table 1 of SABC 780 do not give the users guidance, as all possible combinations are left open and no clear preferences are stated.

When the different oil preservation systems are judged, maintenance viewpoints ought naturally also to be considered. A dehydrating breather in which the silicagel has been saturated with moisture has of course ceased to function. Especially for the small sizes of transformers the maintenance of the breathers is a major problem. The hermetically sealed transformer becomes the natural preferred solution in this lower size range, but it is not possible to recommend any upper size limit for this category of transformer. The protection of oil and insulation from moisture is naturally even better than for the best type discussed above. The cautious attitude in recommending the hermetically sealed transformer more generally is mainly based on the fact that not only in South Africa, but also in Europe, the type has not yet actually been used widely enough for obtaining the necessary experience in all respects. In the interest of obtaining a desirable sound standardisation, a proposal for discussion is, however, made:

< 100 kVA	Only hermetically sealed type.
200 — 500 kVA	Conservator type with dehydrating breather or hermetically sealed type (based on user's preference and taking into account manufacturer's preference).
> 500 kVA	Only conservator type with dehydrating breather

In this recommendation the free-breathing type without conservator has been entirely omitted as a practical alternative. Considering the facts mentioned above this conclusion is fairly obvious.

7. VIEWPOINTS ON SPECIFICATIONS AND ASSOCIATED CONSTRUCTIONAL MATTERS

The standardisation of electrical data in SABS 780-1979 is entirely acceptable to the industry and ought to be a substantial advantage for the electricity undertakings. The advantage for both groups is probably mainly in the lower and medium size range up to approximately 800 kVA. For the largest size range standardised loss values and impedances, although acceptable as a first approach, will certainly not be ideal for all applications. This class of transformer has also a wide industrial use, and the requirements tend to be rather individual. Take for instance the loss problem. Certain transformers are running at a comparatively light load factor, while for certain industrial applications the load factor can be very high. The same transformer cannot be the optimum for both cases.

All modern standardisation is of a modular nature. For the smaller sizes of transformers, a complete standardisation is desirable, which implies also fixed electrical data. For large transformers (say 1 000 kVA and up) fixed electrical data (losses and impedance values) is only of little advantage from the viewpoint of design. The purchaser can instead specify a loss evaluation formula and the acceptable impedance range. The modular design concept and the extensive use of specially developed computer programmes makes it possible to produce an optimum design. For the factory the resulting transformer has to be standardised with regard to all production aspects. Standard electrical data is of minor interest for a production-orientated factory. The type of transformer which has been described with LV band windings and HV layer windings, is best fitted for this kind of design concept and most suitable for rational production.

Regarding constructional matters, all requirements in SABS 780-1979 dealing with the active part include only the essential aspects. This is good, as it would serve no useful purpose to go into detail regarding core and windings. The following comments will therefore deal only with the tank, associated fittings and constructional details. What is said may to a certain extent be considered to be of a provocative nature, but intended only to stimulate a productive discussion.

7.1. Constructional details for the various oil preservation systems

Assuming the oil preservation systems can be chosen and limited for different transformer sizes as outlined in the previous section, up to 100 kVA we would have only sealed transformers and an alternative type for larger sizes up to, say, 500 kVA, this limit recommended mainly because of insufficient experience for still larger sizes.

ondervinding vir groter vermoëns bestaan. Die hoof konstruksiebesonderhede vir verseëlde transformators, wat hoogs verkieslik asook in basiese beginsels aanvaarbaar is, is:

- Die uitsettingsruimte relatief tot die olievolume (X%).
- Aanvaarbare metodes van afsluiting.

Daar bestaan geen goeie tegniese redes om X (20 en 25%) te differensieer vir spannings van tot 12 kV en hoër respektiewelik. Die hoër waarde het tot gevolg dat die uitsettingsruimte vir die olie aansienlik verhoog word vir ongekontroleerde oorbelasting, wat natuurlik voordelig is. Die tenkhoogte word ook aansienlik vergroot en daarom is dit dus voordelig om algemeen die 25% uitsettingsruimte te spesifiseer. EVKOM het bo alle twyfel die meeste ondervinding van verseëlde transformators en spesifiseer 'n 25% uitsettingsruimte onafhanklik van die spanning.

Die enigste redelike aanvaarbare metode om 'n transformator betroubaar te verseël, is deur die tenkdeksel aan die tenkflens vas te sweis. Behoorlike uitrusting om die taak te verrig is noodsaaklik, asook vir die verwydering van 'n gesweisde tenkdeksel. Die taak kan vinnig en netjies verrig word. Beide die flens en kant van die tenkdeksel is besonder egalig na so 'n proses, indien die korrekte toerusting gebruik word.

Die hele agtergrond van hermetiese verseëlde transformators met gesweisde tenkdeksels lê in die kostebesparing wat gepaard gaan met die tradisionele kontrolering en onderhoudswerk wat deur die verbruiker uitgevoer word voor installering. Hierdie metode vereis natuurlik hoë betroubaarheid van werkverrigting, asook vervoer vanaf die nywerheid. Die hele konsep van verseëlde transformators val in duie indien die betroubaarheid nie op 'n aanvaarbare vlak is nie.

Vir verseëlde transformators word geen kleppe van watter aard ookal gebruik nie. Dieselfde geld ook vir druk/vakuummeters, asook die termometerholte. Hierdie is ook in ooreenstemming met die EVKOM-spesifikasie. Uit die voorafgaande bespreking is verseëlde transformators, waarvan die tenkdeksel vasgebout is, 'n ongunstige alternatief. Om permanente verseëling van 20 — 30 jaar te verkry, is baie moeilik of byna onmoontlik. Dit moet in gedagte gehou word dat 'n defekte seël die risiko om water in die transformator te kry, heelwat groter is as vir 'n ontwaterpyp. 'n Volledige bespreking van die probleme wat geassosieer word met die tegnologie en ondervinding van verseëlde transformators sal verwelkom word, veral dié van die verbruikers.

7.2. Konstruksiebesonderhede vir Transformators met Uitsettingstenks

Uit 'n praktiese oogpunt kan die tenk en uitsettingstenk in 'n kort en eenvoudige wyse gespesifiseer word. Dit word dan wel ook so aangegee in die nuwe SABS 780-spesifikasie. Vanuit 'n ontwerp- en vervaardigingsoogpunt vir die hele reeks van tenks, uitsettingstenks, verkoelingspype en bybehore, is dit 'n baie gekompliseerde aangeleentheid. Die ontwerp van 'n sekere grootte reeks tenks, moet sodanig wees dat 'n produk van uitstaande gehalte gelewer kan word vir rasionele metodes. Dit bespaar natuurlik koste wat tot die voordeel van die verbruiker strek. In teenstelling met 'n eenvoudige praktiese spesifikasie, is die trant in die RSA om in te groot detail te gaan vir die konstruksiebesonderhede. Indien al of sommige van die verbruikers tot dieselfde gevolgtrekking gekom het ten opsigte van die konstruksiebesonderhede, sou die toestand minder kritiek gewees het. Die voorstelle wat alreeds gemaak is vir verseëlde transformators, het natuurlik die doel voor oë gehad om die wye verskeidenheid tenks aansienlik te verminder. Daar word egter verskeie probleme ondervind as gevolg van die wye reeks alternatiewe wat genoodsaak word vir spesiale doeleindes.

Die doel hier is egter nie om elke individuele geval te behandel nie, maar deur wat alreeds genoem is alle betrokkenes sonder twyfel van die probleme te laat. Daar word eerder 'n basiese bespreking verlang wat beperk kan word tot transformators met uitsettingstenks wat die ou konvensionele tegnologie verteenwoordig.

7.3. Bybehore

'n Aantal aspekte aangaande termometers en gas- en olieaangedrewe relês sal bespreek word.

Termometers

Volgens die SABS-spesifikasie word die gebruik wyserplaattipetermometers beperk tot 500 kVA en hoër en sal slegs gebruik word indien dit gespesifiseer word. 'n Termometer van enige soort dui slegs die boonste olietemperatuur aan, en die waarde van die informasie is eintlik baie beperk, aangesien baie faktore die temperatuur beïnvloed waarvan daar nie met almal heeltemal vertroud is nie. Basies dui die boonste olietemperatuur nie direk aan enige informasie aangaande die windingtemperatuur nie. Selfs in uitsonderlike gevalle, waar die oliekanale geblokkeer is, het dit baie min invloed op die boonste olietemperatuur.

Hierdeur kan daar dus gesien word die beperkte waarde wat 'n termometer bied. Die termometerholte kan derhalwe aanbeveel word vir algemene gebruik, behalwe vir verseëlde transformators.

Gas- en Olieaangedrewe Relês

Volgens die SABS-spesifikasie word die gebruik van gas- en olieaangedrewe relês beperk tot 500 kVA en hoër en sal slegs gebruik word indien dit gespesifiseer word. Vir sekere tipes beginstadium interne foute vir groot kragtransformators is die gasopsporingsfunksie van die relê

The main constructional details for sealed transformers, for which it is highly desirable or even necessary to agree on basic principles, are:

- The expansion space relative to the volume of the oil (X%).
- Acceptable types of joints.

There are no good technical reasons to differentiate X (20 and 25%) depending on the highest voltage up to 12 kV and above 12 kV, respectively. The higher value results in a considerably increased margin for the oil expansion caused by uncontrollable over-loading, and is therefore naturally an advantage. The resulting tank height increase is quite marginal and therefore the 25% expansion space ought to be chosen generally. Escom has no doubt the more extensive experience in the use of sealed transformers and specifies 25% independent of voltage data.

The only reasonable method to seal a transformer reliably for the whole lifetime is by means of a welded cover to the tank flange. Proper equipment to do the job is of course essential, also including the method to remove a welded cover. This can be done very neatly and fast. Both cover edge and flange are quite smooth after such an operation, if the right equipment is used.

The whole philosophy with hermetically sealed transformers by means of welded covers is to eliminate most of the traditional checking and maintenance work carried out by the users before installing them and in service. This necessitates naturally a high degree of reliability, including also the transport from factory to site. The whole concept of sealed transformers fails completely, if the reliability is not at an acceptable level.

For sealed transformers with welded covers no valves of any kind shall be used. The same applies to pressure/vacuum gauge and also thermometer pocket. This agrees also with the ESCOM specification.

It follows from what has been stated that a sealed transformer by means of a bolted cover is considered to be an inferior alternative. A permanent seal lasting 20-30 years is difficult or impossible to achieve with this method. It has to be remembered that a defective seal is actually worse than free-breathing with regard to the risk of getting moisture into the transformer. A full discussion on all the problems associated with the technology and experience with sealed transformers would be most welcome especially regarding users' experience.

7.2. Constructional details for conservator transformers

From a functional viewpoint the tank with its conservator can be specified in a short and simple way. This is reflected in the new SABS 780 specification. From the point of view of design and fabrication, the whole range of tanks with conservators, radiators and accessories is a very complicated matter. The design of tanks over a certain size range, must be such that a high quality product can be produced in a rational way. This reduces the cost considerably, to the users' ultimate benefit.

In contrast to a simple functional specification the trend in South Africa is to go into constructional details to a considerable extent. If all or at least most users had come to the same conclusions, resulting in the same detailed specifications the situation would have been less severe than it now actually is. The proposals already made regarding sealed transformers, have naturally had the purpose of reducing the number of individual tanks considerably. There are, however, several difficulties due to the wide range of alternatives necessitated by diverse special requirements.

The purpose here is not to treat any individual details, as what has been mentioned no doubt is quite clear to those concerned. Instead a basic discussion is wanted, and it could be limited to conservator type transformers, representing the old conventional technology.

7.3. Accessories

A few comments will be given regarding the use of thermometers and gas- and oil-actuated relays.

Thermometers

According to SABS the use of indicating thermometers is limited to 500 kVA and larger, and shall be used only when specified. A thermometer of any kind in the top oil gives no other information than just the temperature of this oil, and the "informafion value" is actually quite limited, because several variables are influencing the temperature and they are not too well known. Basically the top oil temperature does not give direct information about the winding temperature. Even in the extreme case of blocked cooling ducts for the windings, this would have little influence on the top oil temperature.

Therefore we can see the quite limited practical value which an indicating thermometer has. The simple thermometer pocket can, however, be recommended for general use except for sealed transformers.

Gas- and Oil-actuated relays

According to SABS the use of gas- and oil-actuated relays is limited to 500 kVA and larger, and shall be used only when specified. For certain types of internal incipient faults for large power transformers, the gas volgens ondervinding aansienlik beperk. Selfs vir die grootste verspreidingstransformators, is dit te betwyfel of die gasopsporingsfunksie enige waarde het vir beginstadiumfoute. Weereens kan die laaste bewering met praktiese ondervinding bevestig word. Indien 'n interne fout skielik sou voorkom, wat 'n kortsluiting met oorvonking laat ontstaan, is die skade alreeds verrig en die reaksie wat daarop volg (die olievloei deur die relê) sal die transformator nie gouer kan afskakel as die oorstroom beveiligings nie. Volgens beskikbare inligting oor 'n periode van meer as tien jaar, het die skrywers nie 'n enkele geval gevind waar die gas en olieaangedrewe relê verantwoordelik was vir enige beveiliging nie. 'n Ondervinding in teenstelling hiermee sal van groot belang wees vir die bespreking.

8. BETROUBAARHEID VAN VERSPREIDINGS-TRANSFORMATORS

Die reeks van verspreidingstransformators is besonder groot en dit sal nie sinvol wees om almal gesamentlik te groepeer nie. 'n Redelike homogene klas, is die relatiewe klein paal-platformmonteringsverspreidingstransformators van 50 — 100 kVA.

Volgens inligting wat deur EVKOM beskikbaar gestel is tydens 'n simposium in 1978, was die gemiddelde jaarlikse tempo van falings in die Hoëveld 1,3% vir 'n totaal van 19 000 transformatorjare wat bestudeer is. Hewige weerlig was blykbaar verantwoordelik vir die meeste falings. 'n Belangrike faktor, wat verantwoordelik was vir 'n toenemende falingstempo, en intussen gewysig is, was deur die stuwingweerders aan die lynkant van die sekerings te geplaas het, wat tot gevolg gehad het dat die stuwingweerders verskeie meters vanaf die transformator was. Die afstand moet egter baie kort wees. Indien nie, sal die beskermingseienskappe van die stuwingweerders feitlik vernietig word vir direkte weerligslae wat gekarakteriseerd word deur die geweldige hoë stygtempo van die deurstroom.

Deur die stuwingweerders direk op die transformator te monteer, word die probleem opgelos. 'n Spesiale toets is verskeie jare gelede uitgevoer om die basiese vermoë van 'n standaard 25 kVA 22 kV 3-fasige transformator teen nagemaakte weerligslae te toets. 'n Standaard verspreidingstipe stuwingweerders wat langs die transformator-isolators gemonteer is, is gebruik. Verskeie stootspannings van 1 000 — 2 000 kV is aangewend sonder dat enige sigbare beskadiging opgemerk kon word. Die toets het egter geen statistiese waarde nie. Dit demonstreer slegs dat indien 'n transformator behoorlik beveilig is, dit die inherente diëlektriese sterkte het om weerligslae te kan weerstaan.

Daar is geen soortgelyke statistiese gegewens beskikbaar van falings vir groter transformators nie. Die trant is egter duidelik dat dit heelwat laer is, miskien in die orde van 0,5% of selfs minder.

OPSOMMING VAN GEVOLGTREKKING

Hierdie verslag beskou oorsigtelik die karakteristieke fasette van die nuwe verspreidingstransformatortegnologie wat in die afgelope jare in die RSA bekend gestel is. Die mees belangrike veranderings in die ontwerp, is die gebruik van aluminium-windings en die nuwe tipe laagspanningswindings. Hierdie tipe winding word nou vir die hele reeks verspreidingstransformators gebruik, behalwe vir baie klein eenhede. Tesame met die gebruik van die multi-laagwinding aan die hoogspanningskant, word die aksiale kortsluitkragte geëlimineer, wat dit moontlik maak om die ontwerp van die windings te vereenvoudig en te verbeter. Die kernmateriaal, ook in gebruik vir aantal jare, is van die supergeoriënteerde tipe. Die nuwe ontwerpe het aanleiding gegee tot die noodsaaklikheid van spesiale produksi-e-toerusting, veral vir die kern en windings.

In die latere helfte van die verslag is sommige tegniese probleme van algemene belang bespreek om 'n bespreking te stimuleer tussen die vervaardiger en verbruiker. Die aangeleenthede is van algemene aard en dus nie gekoppel aan enige spesiale ontwerp nie; die meeste egter handel oor die konstruksiebesonderhede en ooreenstemmende spesifikasies.

Verwysings: Simposium oor die weerligbeveiliging van verspreidingskraglyne, Oktober 24 — 26 1978, aangebied deur die Wetenskaplike Nywerheidsnavorsingsraad.

detection function of the relay has a certain value, but actually quite limited, according to all practical experience. For distribution transformers, even of the highest ratings, it is doubtful whether the gas detection function would have any real practical value in protecting against incipient faults. This is again confirmed by the practical experience. With a sudden internal fault, causing a high power arc, the damage is already done and the backup function (oil flow through the relay) will not trip the transformer faster than the over-current protection. According to available records over a 10-year period, the authors have not found one single case where gas- and oil actuated relays have had any protective value. Any experience to the contrary would be of great interest to bring out in the discussion.

8. RELIABILITY OF DISTRIBUTION TRANSFORMERS

The range of distribution transformers is extremely large and it is therefore not meaningful to lump all together in a common group. A fairly homogeneous class are the relatively small pole-mounted distribution transformers up to 50-100 kVA. According to data made available by ESCOM at a symposium in 1978, the mean annual failure rate in the Highveld was 1,3%, the total number of transformer years being studied as high as 19 000. Severe lightning seems to have been responsible for the majority of faults. An important factor, resulting in an increased failure rate, was verified, namely the placing of surge arresters on the line side of the fuses resulting in a distance of some metres between surge arresters and transformer bushings.

This distance has to be extremely short. If not, the protective properties of the arresters shall be more or less nullified for direct strokes to lines, characterised by an extremely high rate of rise of the surge current.

Direct mounting of the arresters on the transformer, solves this problem completely.

A special test was made several years ago to check the basic ability of a standard 11 kV 25 kVA three-phase transformer to withstand simulated strokes when protected with standard distribution type surge arresters, mounted immediately adjacent to the bushings. Several impulse voltages were applied in the range 1 000 — 2 000 kV without causing any apparent damage to the transformer and arresters. The test has, of course, no statistical significance. It demonstrates only that a properly protected transformer may have the basic inherent dielectric strength to withstand extremely severe lightning.

There are no similar statistical data available of failure rates for the larger sizes of transformers. The trend is, however, quite clear that the failure rate is much lower, probably in the order of 0,5% or even less.

SUMMARY AND CONCLUSION

This paper reviews briefly the characteristic features of a new technology for distribution transformers, introduced in South Africa in recent years. The most important change in design is the use of aluminium windings and a radically new type of low voltage winding, the so-called band winding. This type of winding is now used over the entire range of distribution transformers except for the very smallest sizes. In combination with the layer type winding on the high voltage side, the elimination of axial short-circuit forces makes it possible to simplify and improve the design of the complete active part. The core material has been for some years of the super-oriented type. The new designs have also necessitated special production equipment especially for cores and windings.

In the latter half of the paper some technical problems of common interest are raised to stimulate discussion between users and manufacturers. The matters are of a general nature and thus not related to any special designs, actually mostly dealing with constructional matters and corresponding specifications.

Reference: Symposium on the lightning protection of distribution lines, October 24 — 26 1978, sponsored by Council for Scientific and Industrial Research.

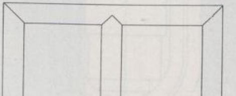


Fig. 1

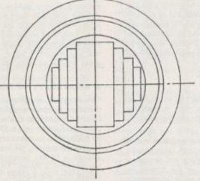


Fig. 2a

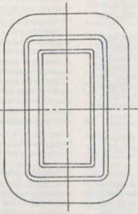


Fig. 2b

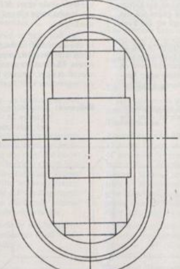


Fig. 2c

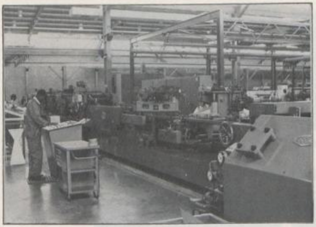


Fig. 3

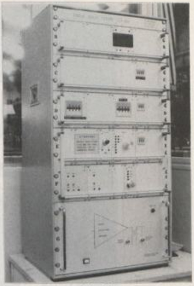


Fig. 5

Fig. 4

Fig. 6

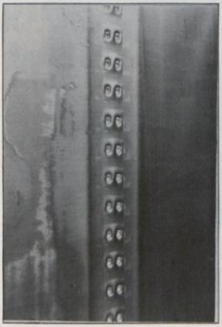


Fig. 7a

Fig. 7b

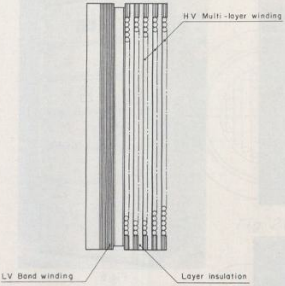


Fig 8

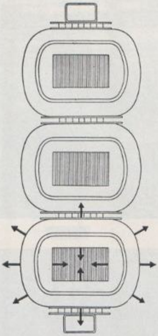


Fig 9

VRYSTAAT — NOORD-KAAPTAK
GESTIG 6 MEI 1980

SITTENDE L.n.R.: Bennie van der Walt (Sekretaris VMEO), Piet Botes (President VMEO), N. S. Botha (Voorsitter, Bloemfontein), J. J. Botha (Ondervoorsitter, Welkom) en J. G. Grobler (Sekretaris, Bethlehem).

STAANDE L.n.R.: J. J. van Tonder (Ventersburg), Fanie Jansen (Henneman), G. Myburgh (Kuruman), D. Brider (Edenburg), W. J. de Beer (Brandfort), R. F. Davidson (Vrystaat Provinsiale Administrasie) en C. Vosloo (Kimberley).

TUSSEN L.n.R.: J. F. Pienaar (Winburg), M. R. Pritchard (Virginia).

AGTER L.n.R.: C. R. Grové (Harrismith), C. H. Marais (Parys), P. Goussard (Koppies), D. Briers (Kroonstad), F. C. Swart (Petrus Steyn) en C. J. van Tonder (Odendaalsrus).

BESPREKINGS/DISCUSSIONS

Mnr. D. E. T. Potgieter: Verwoerdburg

Mnr. Salomons moet gelukgewens word met 'n interessante en goed voorbereide referaat.

In die gemiddelde munisipale elektrisiteitsnetwerk maak verspreidingstransformators ongeveer 6% van die kapitaalkoste van die totale skema uit of ongeveer R85,00 per residensiële erf. Om hierdie rede glo ek dit is tydig dat munisipale ingenieurs weer kyk na die korrekte gebruik van die transformator.

Die Uitvoerende Komitee verdien 'n woord van dank vir die keuse van die onderwerp van die referaat.

Ek praat onder korreksie, maar vandat aluminium-windinge oorheersend gebruik word in transformatorvervaardiging, is hierdie eerste referaat wat voo die VMEO gelewer word oor verspreidingstransformators.

Vanweë die hoë inflasiesyfer is dit vir Plaaslike Owerhede voordelig om sy kapitaalgoedere oor die langste moontlike leningstermyn aan te koop. Die kopergewinde transformator het homself vir baie jare as baie betroubaar bewys en dit kon met veiligheid deur middel van 'n lening oor 'n 20 jaar delgingstermyn aangekoop word.

Kan dieselfde lewensduurte van die aluminium-transformator verwag word en sou mnr. Salomons sy verwagte lewensduurte op 30 jaar en langer stel, sodat lenings oor langer tydperke aangegaan kan word? Veral as in ag geneem word dat die verwagte lewensduur van die ander komponente van 'n elektriese netwerk op 30 jaar en langer gestel word? Gesien in die lig van die hoë koste van kapitaaltoerusting is die maksimum oorbelasting van 'n verspreidingstransformator ook 'n belangrike faktor om in ag te neem tydens die ontwerp van die elektrisiteitsnetwerk vir 'n residensiële dorpsgebied. Die maksimum oorbelasting duur slegs vir 1 na 2 ure gedurende die koudste winteraande. Dit mag ook soms slegs 2 of 3 aande per jaar wees.

Dit sou gevolglik onekonomies wees om 'n stelsel te ontwerp om vir hierdie enkele dae voorsiening te maak sonder om transformators tot hul maksimum te oorbelas nie. Die SABS-spesifikasie lê nie 'n maklike en eenvoudige reël neer waarvolgens die maksimum oorbelasting bepaal kan word nie.

In Verwoerdburg word paalgemonteerde transformators beskerm om 'n oorbelastinbg van 35% toe te laat. Ons verloor nie transformators deur oorbelasting nie, ongelukkig het ek nie statistiek oor die moontlike hoër oksidasie van die transformatorolie as gevolg van die hoër temperature nie.

Kan mnr. Salomons miskien iets byvoeg oor transformator-oorbelasting?

Mnr. Salomons versoek in sy referaat bespreking oor hermeties-geseëlde transformators sowel as die standaard-gebruik van 'n uitsettingstenk en ontwaterpyp vir sekere groottes transformators.

Indien 'n gebruiker van transformators wel skepties staan oor die gebruik van 'n hermeties-geseëlde groter transformator, om watter rede word die uitsettingstenk en ontwaterpyp soms weggelaat? Kan mnr. Salomons 'n aanduiding gee of daar 'n groot verskil in prys is tussen 'n transformator wat voorsien is van 'n uitsettingstenk en een sonder 'n uitsettingstenk.

Is verbruikers se traagheid om in te skakel by die voorstelle van die vervaardiger om 'n standaardstelsel van hermetiese verseëling en die gebruik van uitsettingstenk met ontwaterpyp nie te wyte aan 'n traagheid om sy spesifikasie te verander eerder as uit oortuiging daarteen nie?

Die plasing van die stuwingsweerders of weerligafleier direk op die transformator vir beter beskerming teen direkte weerligslae is interessant. Aangesien die deurstroom a.g.v. weerlig dan deur die sekering wat die transformator beskerm sal vloei, i.p.v. om weggelei te word deur die weerligafleier, moet 'n mens meer onderbrekings as gevolg van smelting van sekeringe verwag.

Hoewel mnr. Salomons meld dat die waterinhoud van transformatorolie beperk moet word tot 1,5%, bestaan daar heelwat verskil van opinie onder munisipale ingenieurs oor die noodsaaklikheid al dan nie om die olie van kleiner verspreidingstransformators (onder 500 KVA) te suiwer en uit te droog. Wil mnr. Salomons miskien sy opinie hieroor uitspreek?

Mnr. L. D. M. de Wet, Brakpan:

Mnr. die President, graag wil ek mnr. Salomons gelukwens dat hy 'n referaat gelewer het oor so 'n alledaagse onderwerp soos 'n transformator. Vir die meeste Munisipale Elektrotegniese Ingenieurs is die transformator die eenvoudigste stukkie toerusting om aan te koop en te installeer.

Met die hulp van die S.A.B.S.-spesifikasie nr. 780, kan 'n verspreidingstransformator volledig gespesifiseer word in ongeveer agt tot tien reëls. Die aanvaarding van 'n tender is net so maklik aangesien daar geen noemenswaardige verskil is tussen verspreidingstransformators wat deur verskillende vervaardigers aangebied word as gevolg van die standaardisasie wat bewerkstellig word deur spesifikasie S.A.B.S. 780, en wanneer die transformator eers eenmaal geïnstalleer is, kan 'n mens gelukkig daarvan vergeet behalwe om so nou en dan 'n olielek te herstel.

Dit is interssant om daarop te let dat inligting daarop dui dat termometers en Buchholzrelês van weinig waarde blyk te wees en gevolglik heeltemal weggelaat kan word.

During the last century the basic design principles of the transformer have remained the same and no substitute to fulfil the function of the transformer has as yet been found. However, in one low power application of a transformer, it has been successfully eliminated. In transforming AC to DC, it was normal practice to use a transformer to lower the AC voltage before rectifying it. With new technology the switching regulator was invented in which the transformer was replaced by a switching SCR. Would it be far-fetched to wonder if the same principle might not lead to the replacement of a transformer where an AC voltage has to be lowered?

In closing, I would appreciate it if Mr. Salomons could give us some guidelines to follow whenever a transformer has to be overloaded during an emergency. What percentage overload could be applied, for how long and how does ambient temperature affect the percentage overload?

J. C. van Alphen: SABS

As Chairman of the committee responsible for the drawing up of SABS 780 "Distribution Transformers", it was a pleasure to me to read Mr. Salomons's paper on Distribution Transformers. His paper is in some parts a tribute to SABS 780, which appeared as Revision No. 1 last year, and we, at the SABS, are very conscious of the fact that this particular document was the result of a spirit of sincere co-operation between the various sectors of industry and users.

The following are comments on some points in particular:

1. Losses

We can indeed foresee an ever increasing cost benefit in the low-loss range of the standard losses of SABS 780.

Certain buyers are still being persuaded to buy high-loss transformers, as their first cost are lower. I believe, for instance, that certain mining houses justify high loss transformers because of their high loading factor, a limited life of a particular mining operation and therefore a tendency for a rapid amortisation, which places a premium on the purchasing price.

While this may be so in certain industrial sectors, the bureau feels that public buyers should rather stick to the low loss range, especially with regard to

1) a generally low loading factor
2) rapidly rising cost of energy which becomes very important if evaluated over a life of 20 years.

The author's opinion in Section 7, that loss standardisation in transformers of a rating of 1 000 KVA and greater are of little benefit, is regrettable.

The loss values have been established in committee and if the standard loss values should be reviewed, the Bureau should be notified.

The use of capitalisation formula, as advocated by the Author for units of 1 000 KVA and over, is also viewed with scepticism.

Many of the quantities in such formula are products of guess work as to the loading cycle and future cost of energy to be expected, that no greater accuracy in adjudication can normally be expected than by adjudication on price only.

2. Temperature Rise

As the Author can confirm, the Bureau demands from time t0 time a temperature rise to be conducted to confirm compliance with the specification.

IEC 76 is indeed departed from as the standard reference altitude is 1 800 m and not sea-level. At the coast, the users get a slightly cooler transformer, which gives him a better overloading characteristic. As transformers may be passed on to users at higher altitudes, a standardisation of the reference altitude of 1 800 m is therefore a practical policy.

With respect to the overloading capabilities, SABS 780 states on p.21 that distribution transformers can generally tolerate temporary overloads of up to 150% of rated current.

3. Surge Arrestors Transformers

In section 6, the author proposes the general adoption of sealed transformers with welded cover. In the present state of art, the distribution transformer generally meets all expectations of consistent performance and long life.

The Bureau would therefore gladly support the author's plea for buying transformers of up to 500 KVA with a sealed cover, provided an appropriate sealing test is performed after the welding operation to prove that sealing is indeed hermetic.

Dangers! (See SABS 780)

As far as expansion space is concerned, for many years 15% expansion space was regarded as adequate, bearing in mind the ability of oil to absorp gas when pressure is increasing and releasing it when pressure drops.

For practical purposes 20% is already a relatively large increase of ⅓ over the previous 15%. That ESCOM is very happy with 25% is no proof that 25% is necessary, and the cost increase for the 25% expansion space is borne by the tax payer anyhow.

Also, with greater cost consciousness, tanks today are more flexible than the extremely rigid designs of the past, which further decreases the pressure fluctuations in the expansion space.

In the Bureau's view, 20% is a liberal expansion space, and should not be pushed up again to 25%.

A concession of 25% was made for 22 and 33 kV transformers for only three reasons:

1) Dielectric stresses in 22 kV and 33 kV transformers are greater, and an additional degree of safety is warranted.
2) The 22 kV transformer is not a common product and bought in great quantities by ESCOM only.
3) 22 kV transformers are not used in minisubs and height restrictions are not important.

4. Fittings

The Bureau cannot but support the author's opinion that buyers are too often inclined to order additional fittings over and above the standard fittings specified in SABS 780.

Omitting such specials reduces not only first cost, but also helps the industry in standardising more effectively with further cost benefits, which are passed on to the buyers. This, incidentally, also applies to the standardisation of losses.

Mr. D. C. Palser: Cape Town

Mr. President, the authors are to be congratulated on producing such an interesting and thought provoking paper.

Consideration, however, has been confined largely to transformers employing band-type low-voltage windings, with layer-type high-voltage windings, the material of the band windinb being aluminium since copper bands are not available locally. As pointed out this is no serious drawback since at current metal price levels, there is little difference in final cost.

If it is conceded that this type of transformer is at least technically as satisfactory as a conventionally wound transformer, and I am not altogether convinced on this point, then it will require a lower price to persuade users to switch from the type of construction that they know to be sound, to this rather unconventional design. Could the authors therefore give some indication of the relative differences in costs across the range between band winding type transformers and conventionally wound transformers.

Unless there are sound technical reasons justifying conversion to band winding types, and I doubt that there are, then I would think that a significant financial inducement would be necessary to persuade users to move away from conventional transformers to this relatively new type.

In South Africa the total capital outlay required on generation, transmission and distribution capacity to supply a consumer is around R1 000 per kilowatt of ADMD, with about half this figure being attributable to the generatión component. If the distribution transformer costs, say, only around R10 per kilowatt this represents only about 1% of the total capital outlay necessary to supply one kilowatt of load. If, for arguments sake, band winding type transformers are, say, 10% less in cost than conventional types, then this represents a relatively insignificant 0,1% in overall capital cost.

I would accordingly submit that price here is not all important. What is important is that the highest pôssible degree of service reliability be designed into the transformer. Reliability must not be sacrificed merely to achieve a slightly lower price. The authors comments on this point would be appreciated.

Turning now to oil preservation systems I fully agree with the authors' proposals, namely that only hermetically sealed types be employed up to 100 kVA, conservator types with dehydrating breathers or hermetically sealed from 100 kVA to 500 kVA, and only conservator types with dehydrating breathers for units above 500 kVA. This is the practice currently followed in Cape Town and one which has been found to be quite satisfactory.

I agree with the authors' views on the fitting of gas and oil actuated relays and see no advantage in fitting them to the smaller units. In Cape Town we only fit them to units about 12,5 MVA.

In conclusion, I would refer to the figures quoted by the authors for the failure rates of pole mounted transformers and distribution transformers. The quoted figures are about twice those experienced in Cape Town, possibly because of the far lower incidence of lighting in this area.

Mr. M. W. Walter: ESCOM R & O.F.S. Region

Mr. President,

I would offer a few observations on the authors' paper on Distribution Transformers.

L.V. BAND WINDINGS

Escom has many hundreds of Distribution transformers in service and although not all transformers which become defective are returned to our Central Workshop, to date we have not had one Band wound unit in the Workshops for repair. Presumably this can, at least in part, be accounted for by the increased axial strength of this type of design of transformer.

The one disadvantage of this type of winding is that rewinding of a band wound unit requires very sophisticated and expensive winding equipment which would not normally be available to users other than in the manufacturers works.

HERMETICALLY SEALED UNITS

Escom stipulates hermetically sealing for all units up to 500 kVA. Escom has found that sealed units can be ground open and rewelded up to 5 times before the available metal is used up.

I cannot comment on Mr. K. van Alphen's questioning Escom's insistence on requiring 25% air space in place of the 20%. I will have to refer this to Escom's transformer specialist, Mr. Andrews, to ascertain the reasons behind this requirement.

GAS/OIL ACTUATED RELAYS

Although I can only speak for myself and not for Escom, I must also question , with the authors, the value of fitting these type of relays to transformers. Although these relays undoubtedly have value in transformer protection, the high incidence of earth tremors in the Reef area has necessitated time delaying the tripping of these relays to prevent nuisance tripping. Thus the advantage of fast tripping of normal Gas/oil actuated relays has been lost. This, together with the authors' views, makes me also question whether the fitting of Gas/oil actuated relays to distribution transformers can be justified.

Mr. D. H. Fraser: Durban

Ageing of insulation even with 20 — 30 years service. Is this for indoor or outdoor service in S.A.? If SABS 780 assumes a winding hot spot of 80°C with an ambient of 25°C what actually is the likely temperature for an outdoor or pole-mounted transformer in full sun? Maybe SABS 780 is too conservative?

Regarding absorption of water. At 20°C water saturated oil contains some 40 mg/ℓ (45 ppm) of dissolved water and may rise to 400 mg/ℓ (450 ppm) at 80°C if sufficient free water is available. **Dissolved** water can only be reduced by evaporation — not filtration. Agree strongly with recommendation (last paragraph Clause 6 Page 14) that a free breathing type of transformer without conservator is not a practical alternative.

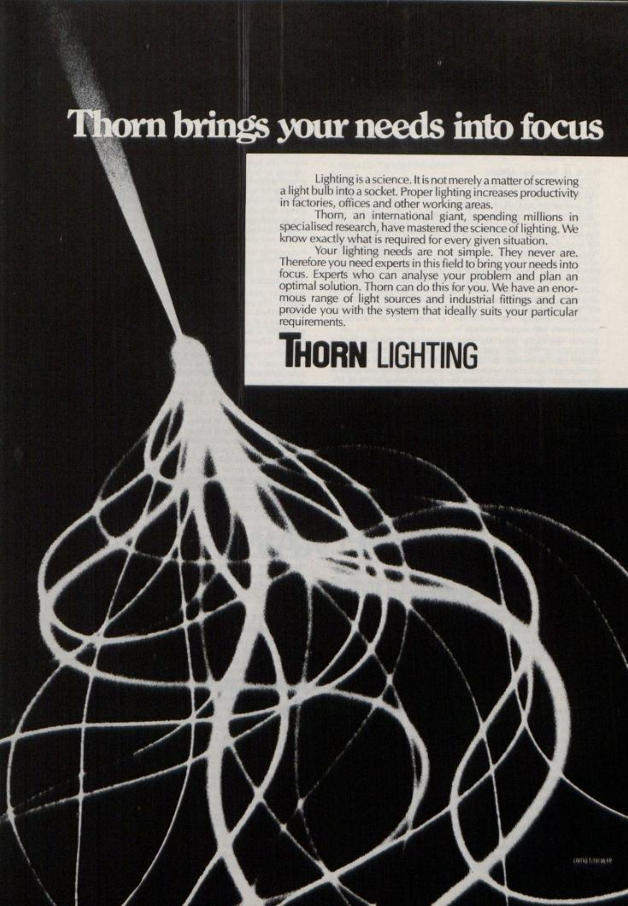
Failure rate. London Electricity Board has 1 transformer failure every 700 transformer years (0,14% pa). (12 years old Data). Virtually all cable connected and not subjected to Highveld storm conditions. Experience in Durban June 1979 and March 1980 0,3% pa, i.e. 19 failures out of 5 124 transformers, 13 of which were 50 kVA or less. In 15 of the failures the fault was in the high voltage winding. In two cases the tanks burst.

It is interesting to note that while the hermetically sealed transformer becomes the natural preferred solution to the lower size range of transformer, the Authors indicate that there is a cautious attitude in recommending the use of hermetically sealed transformers both in Europe and R.S.A. because of insufficient experience having been gained in all respects. Would the Authors care to enlarge on the reason for this cautious attitude? Have they any records of transformer tanks bursting, welded seams splitting or gaskets blowing out under transformer fault conditions? Are the Authors aware of any special electrical protection or precautions that should be taken when using sealed transformers? Would an explosion vent or excess pressure release valve be considered a disadvantage?

The Durban Corporation Electricity Department has had the experience of a hermetically sealed transformer exploding, setting fire to adjacent equipment and causing structural damage to the brick substation building in which it was housed. (The building was later demolished). There is little doubt that had operating personnel been present when this had occurred they would have been severely or fatally injured. Have the designers given consideration to these possibilities?

It would be interesting to know whether any of the members present have had similar experiences or have given consideration to the explosion hazard of sealed transformers.

It is surprising that the Authors have not found a single case where gas and oil actuated relays have had any protective value (according to available records over a 10-year period). From our own experience I.


Thorn brings your needs into focus
Lighting is a science. It is not merely a matter of screwing a light bulb into a socket. Proper lighting increases productivity in factories, offices and other working areas.
Thorn, an international giant, spending millions in specialised research, have mastered the science of lighting. We know exactly what is required for every given situation.
Your lighting needs are not simple. They never are. Therefore you need experts in this field to bring your needs into focus. Experts who can analyse your problem and plan an optimal solution. Thorn can do this for you. We have an enormous range of light sources and industrial fittings and can provide you with the system that ideally suits your particular requirements.
THORN LIGHTING

would however agree that their value in detecting incipient faults in distribution transformers is limited but several instances of Buchholz relay operation or incipient faults in 33/6,6 kV 15 MVA transformers have occurred. It has been the experience in Durban that these relays certainly reduce the amount of damage because they are extremely fast and in fact, depending on where the fault has occurred, frequently beat the over-current protection.

The gas-operated relay has also proved invaluable in giving early warning of low oil level leaks from the transformer. The alarm is given when the oil level falls below the level of the gas actuated relay.

I firmly believe that the gas and oil actuated relay still has a place in the protection of transformers and would be pleased to hear the comments of other members.

Mr. S. H. Salomons: Affiliate

Mr. Potgieter raised the matter of Transformers with copper windings which have a life expectancy of 20-30 years, and could be financed over a 20 year period, and asked the question what the life expectancy of a transformer with aluminium windings would be. Transformers with aluminium windings have been in use in the USA extensively since the war and they have also been used at least for some ten years in Europe and have proved to be as reliable as transformers with copper windings. What determines the life of a transformer is the rate of ageing of the insulation materials used. Coupled thereto is the way in which the transformer has been maintained. If in a free breathing transformer the silica gel in the dehydrated breather is not regularly maintained, this would shorten the life span of the transformer. The conductor material used for the winding, be it aluminium or copper, has nothing to do with the life expectancy and we are convinced that transformers with aluminium windings will serve you as long and as reliable as transformers with copper windings.

Another interesting point Mr. Potgieter raised, is the fact that in Verwoerdburg they are making use of the overload capacity of transformers; escpecially during winter peak periods they have been overloading transformers by about 35%, and he asked our comments to this practice. I would like to leave the reply to this question to Mr. Sollergren who has served on the IEC Committee that has drawn up the "Guide to the loading of transformers", and therefore is quite an expert on these matters.

Also Mr. de Wet raised this matter.

With regard to price comparison between a transformer fitted with a conservator versus a sealed unit, I would say that for a true comparison various factors have to be taken into consideration and the comparison cannot simply be based on ex factory prices. To my mind you have to take into consideration the savings resulting from the lesser degree of maintenance in the case of sealed transformers. In the case of a free breathing transformer with a dehydrating breather, maintenance must be pretty expensive in that at regular intervals, be it three months or half-yearly, the silica gel breather has to be checked. It would definitely be wrong to wait until the silica gel breather has completely turned pink. If this cost is taken into consideration there should be a definite advantage towards the use of sealed units escpecially for smaller sizes.

With regard to surge arrester positioning, ESCOM have changed their standard specification such that on all distribution transformers mounting brackets are fitted directly below the HV terminals such that a surge arrester can be fitted directly in line with the terminals and connected thereto. You get the best form of protection if the surge arrester is situated as close as possible and directly connected to the HV bushings. Mr. Potgieter made the point that due to the surge current once could expect a greater number of transformer outages as compared with the case where surge arresters would be positioned before the fuse. I am not convinced that he is right there. However, surely this would be a matter of selecting the correct fuse ratings, and anyway, it has been proved that connecting the surge arresters directly to the transformer terminals definitely gives the best protection to the transformer which should be quite an advantage with our high incidence of lightning. There may be certain disadvantages associated herewith but would not these be more than out-weighed by the advantages?

Mr. de Wet, and also Mr. van Alphen, raised the matter of standardisation. I would like to make some comments to what Mr. van Alphen has said about loss evaluation for the larger transformers. We have probably been rather pragmatic in our approach and I am in full agreement with the view-points expressed by Mr. van Alphen. In practice, as manufacturers, we find that most municipalities seldom buy transformers in excess of 800 kVA in rating. When it comes to the larger sizes these are normally required by industry, mines, etc. and we have found that a large proportion of these customers do not adhere to the SABS Specification as regards losses and impedances. They often require units to be working in parallel with existing units. They have their own ideas about a lot of details and since they normally take the life time of the transformer over a limited period (especially in the case of mines) they do not care about loss evaluation. As manufacturers, we have to live with these market requirements and that is one of the reasons whey we have taken a rather pragmatic attitude with regard to these larger distribution transformers. While we really strive for the ultimate in standardisation for the small distribution transformer, we are more or less forced to fall in line with the requirements of various customers for the larger sizes, much to our regret. We would strongly prefer all customers to stick strictly to the SABS Specification as regards their requirements and in our opinion it is somewhat short-sighted of some of our customers to insist on deviating therefrom. We are strong supporters of standardisation because we belief that ultimately this is in everyone's interest. We would definitely not advocate the use of high loss transformers in such cases. In fact, because of the high degree of standardisation that we have introduced in our factory, the high loss unit may end up by costing more than a low loss transformer.

With regard to the sealing of transformers, in our opinion sealing by welding is the best to get a maintenance free transformer. SABS 780 leaves the option open whether a transformer should be sealed by welding or bolting. In our mind, a bolted cover does not give you a proper permanent seal and it should be remembered that a defective seal is to be considered worse than free breathing with regard to the ingress of moisture. There are certain disadvantages and there could be certain dangers in sealing a transformer by welding, as Mr. van Alphen has pointed out. In our opinion, however, the disadvantages are outweighed by the advantages. There is no doubt that welding gives you a perfect seal and should give the user a maintenance free transformer.

I personally question the use of an oil level indicator as required by SABS 780 on a sealed unit. Part of the oil level indicator gasket would be above oil level and could deteriorate in which event the sealing would become ineffective.

As far as expansion space is concerned, we fully agree with Mr. van Alphen. The point we wanted to bring home is standardisation. In our opinion there is no need to have different requirements with regard to the volume of expansion space. We would prefer to see one specific requirement in this regard, and we feel there is no good technical reason to have different volumes of expansion space for different voltages.

Mr. Palser raised the matter of the relative cost difference between transformers with copper as compared with aluminium windings. His view-point is that he would only buy a transformer with aluminium windings if at least there was a price difference. It is virtually impossible to give a definite figure with regard to the relative cost difference. Even if at a tender opening it is found that the price of transformers with copper and aluminium windings are very close, you may find that when it comes to the payment of the Contract Price Adjustment, there is quite a price difference. The price of copper has been fluctuating wildly in the past and in fact has recently made quite a jump in that it went up from R1 700 per ton to a price of over R2 400 in a very short period of time. The price dropped again after the peak was reached but if your CPA indices happened to fall in the period that the copper price was high you may find yourself in a situation where the ultimate price you are paying for the transformer is considerably affected by this. You may argue that the same could happen to aluminium. However, the past has shown that aluminium is much more stable in price and has never fluctuated as copper has been doing. I fully agree that transformer reliability is extremely important but we are pleased to state that world wide experience to date has proved transformers with aluminium windings to be as reliable as transformers with copper windings. Especially the elimination of axial short circuit forces to my mind greatly contribute to making the aluminium winding transformer a very reliable and safe transformer. There are more technical arguments in favour of aluminium but unfortunately my time has run out and I cannot go into any further details now.

Thank you.

Dr. R. Anderson: CSIR

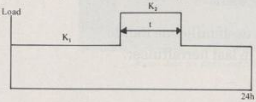
Mr. President I would just like to make a few points on the paper by Mr. Salomons to tell you a little bit more of the tast force on lighting protection of distribution lines, distribution systems which is conducted by Escom under the high voltage co-ordinating committee of the CSIR, and on which you have a representative member from the AMEU. This information should find its way into your membership. This committee does look at the problems of lighting protection of distribution systems, including distribution transformers. And some of the recommendations are being putting to effect voluntary, by Escom for example and you heard Mr. Salomons mentioned the question of fitting directly on the transformer thermals. Escom I believe have used a 20 A fuse rating very successfully, obviously one cannot protect these combinations with less than 20 A because the fuse will blow. Attention is also being given to the specification of surge arrestors as we know the fuse rate of some of these arrestors has been as high as 45% per annum, which is extremely high and costly considering the expense of replacing them. The first move towards arresting this has been to propose the increased thermal rating which is getting into the South African specification and also into the IEC's specification in due course. But the task force is not really satisfied that these arrestors will operate on multiple lighting conditions and has been given attention to making a test read to be able to test the arrestors under multiple surge conditions. This equipment has been developed by the SABS. Hopefully one might have a test for it by the end of this year. Under these conditions one will be able to test the local manufacturers' arrestors to see if they can in fact withstand a multiple stroke of lightning. One other thing I should mention and that is the experimental work being done by Dr. Eriksson. In a joint programme with Escom on 11 kV line outside Pretoria, 10 km lengths, which has been measuring the surges due to lightning either directly strokes to the line or induce strokes and we will be reporting on this during the coming year. I am sure this will assist us very greatly in formulating optimal protection for 11 kV distribution systems. I believe this coming season will see a move towards fitting arrestors to the 11 kV line and making measurements on the effect of lightning on these arrestors directly. I thought you would be interested Mr. President in having these information. Thank you.

Mr. B. Sollergren: Affiliate

1. **OVERLOADING**

The problem of overloading transformers in winter time according to the questions but by Messrs de Wet and Potgieter, I wish to make comments based on the loading guide for oil-immersed transformers (IEC Publication 354).

According to this guide the daily variable load is schematically divided up in two parts as illustrated by the simplified diagram:



K_1 = Initial load power as a fraction of rated power

K_2 = Permissible load power as a fraction of rated power, duration t hours

For two typical or maybe rather high values of the initial load, 70% and 80% of rated power, thus $K_1 = 0{,}7$ and 0,8 the following K_2-values are obtained. Two different ambient temperatures have been assumed, 10°C and 20°C, representing maybe the typical winter temperature range for South African climatic conditions. The selected overload periods are 4 and 6 hours.

	$K_1 = 0{,}7$ 10/20°C	$K_1 = 0{,}8$ 10/20°C
t = 4 h	K_2 = 1,36/1,27	K_2 = 1,33/1,24
t = 6 h	= 1,27/1,18	= 1,25/1,16

Because of the nature of the overloading problem the K_2-values should not be considered to be so precise. Depending on the actual conditions, characterized by the three variables temperature, time of overload and initial load, rounding off the K_2-values is suitable and entirely permissible. A practical rule of thumb could for instance be expressed as follows: For an ambient temperature not exceeding 10°C a 40% overload is permissible up to 4 hours provided the initial (previous) load has as on average been lower than 80%.

2. **SEALED TRANSFORMERS**

Although we have written in the paper that a 25% expansion space ought to be chosen generally, our main point was not to differentiate between voltages up to 12 kV and higher. The test results mentioned by Mr. van Alphen support definitely the conclusion that 20% expansion space should be possible to accept generally. We have also made similar experiments and can confirm the results. Our only reason for proposing 25% expansion space independent of voltage data was the standardisation aspect — it is not practical to design the tanks to individual customer specifications with regard to the expansion space.

Our cautious attitude to recommend a limit of 500 kVA for sealed transformers was mainly based on practical considerations and again standardisation aspects. For larger sizes than 500 kVA maintenance viewpoints are probably not so decisive as for smaller units, and therefore conservator transformers seem to be the preferred solution, and by experience it is a good oil preservation system.

Mr. Fraser mentioned a case of explosion on a sealed transformer. Without knowing the actual circumstances and how the transformer was protected, it is unfortunately not possible to comment on a case like this, but it ought in our judgement to be of an exceptional nature.

It may further be of interest to mention that we have — although not in South Africa — experience of sealed transformers up to the largest sizes of high voltage transformers. Especially in USA this system is preferred and specified by many Utilities.

Speaking finally on behalf of both authors, we are most satisfied that the new technology of distribution transformers for South Africa has had a good reception. It may therefore be of interest to mention that the same basic technology is definitely not limited to distribution transformers. Work is in progress to employ the same design principles in the smaller power transformer range up to ratings of above 10 MVA.

are now doing installations in the various systems available to us locally and then these systems would be viewed by the likely tenderers for the first contract of Soweto which is 5 000 houses. Our experience Mr. Chairman, is that there is a considerable labour saving with the new systems and is also a saving in material. That is in spite of the fact that we have to use adaptors to fit into the socket-outlet boxes and switch boxes. The reason being that SABS 1085 has tied us down to a certain extent, but I believe work is in progress to al leviate the stringent conditions and also to permit square knock outs that these new wiring systems could be fitted easily and expeditiously. Mr.Chairman the results of Soweto are not known to me yet, I will only know this on Friday when we check them over labour time, taken to do each individual system, but I can assure you even if these labour times do not show considerable saving, with mass production at the rate that is envisaged for Soweto, which is 200 houses a day, we see this up to the end of the year, starting July and perhaps for the next 2 years. We heard over the radio 1982 being the completion date not only for house wiring but also for reticulation, then with mass production these new systems will show a labour saving and an economic saving for the country. It is in the national interest, because not only do these systems save labour and cost perhaps to the individual using it, but there is also a great saving in material. We produce PVC locally, cheaply, we can easily outphase the old traditional systems of wiring houses.

Thank you Mr. Chairman.

Mr. K. G. Robson: East London

Mr. President may I thank Mr. Lap for his remarks this morning, but may I perhaps indulge the electrical contractors on this issue. We have been operating in East London officially on the new code of practice since the beginning of the year and there are one or two other municipalities in the Cape Province also officially operating on the new code. And we have had a number of specifications or contracts or tenders out for reasonable quantities of houses and our specification has made provision for the new wiring systems and not in a single case have we had an offer. We have been hearing for years here at the AMEU conventions, and technical meetings that we have perhaps been dragging our heels and I don't believe that this is the case. One has a suspicion that we are still living in the times of tenders, that are based on the system of what the market will bear. I think one of the weaknesses from the manufacturers' point of view, is that the accessories or the means of adaption of the new systems havn't kept pace with the actual cable systems. And in fact I have not yet seen a set of accessories to use with the new cables. Now it may be that the distributing system is wrong. It would appear to me that there is no desire on the part of electrical contractors to use the new systems.

I could be wrong in this and one hesitates to write a specification that provides only for the new system. It is difficult to decide at this state whether there is much difference in fact between the PVC conduit system and the new wiring system. I am disappointed that we in East London and at any rate have not been able to prove to ourselves that there is a cost saving with the two systems.

And may I make an appeal to manufacturers or their distributors to make sure that the contractors themselves are aware of what is on offer and then perhaps ask the electrical contractors' association to make sure that their members also are urged to do some experimenting with them at least with the pricing of the new systems. But in our case if I may repeat, have not received a single tender offering the new systems.

Thank you Mr. President.

Mr. Wessel Barnard: Johannesburg

Mr. Questionmaster I think the problem is much wider than we realise and its been certainly over-simplified by Mr. Lap.

We in Johannesburg at this stage will be responsible for testing wiring installations in Soweto. Now our inspectors work on the basis that they have to test an installation to comply with regulations or a code of practice. We do not and we cannot allow then discression in testing and passing an installation. So as we stand at this stage and at this moment, they would not be in a position to pass any installation wired in accordance with what we call the new innovative systems. A report I have from my staff is that no innovative wiring system has as yet been approved by the Approvals Committee. To these systems have been given provisional clearance subject to them getting certain components, passed and accepted by the Bureau of Standards. It is entirely impossible for us to work on an ad hoc basis. What we need is an official approval by the Approvals Committee, which does not comprise only of AMEU members. It comprises people from the industry, electrical contractors from everybody involved. I don't know if the NBRI are perhaps represented on that, but I would suggest that they should serve on that committee. And what we want them to do is to get together and say this system is suitable for use anywhere. As far as I am concerned I cannot differentiate between Johannesburg and Soweto. In fact Soweto is part of Johannesburg. And I want a directive which tells me that there are systems which have been approved by the Approvals Committee for use in domestic installations. Thank you.

Mr. P. J. Botes: President

Ladies and gentlemen as Chairman of the New Commodities Committee we have had great difficulties in assessing these new commodities. They do have at times before, just the cables alone, the terminations alone, the boxes by themselves and they all want to have approval. And in the case where we have a complete wiring system before us, it is difficult to assess what it will look like in a building. You have a lot of wires, you have a lot of plugs and you have a lot of terminations. And now you must think whether this is suitable. How can you assess it? However, we have great assistance from SABS on this matter guiding us on quality of products and what should be approved. The exact same thing may be manufactured in South Africa that the cables, the PVC are not of the same quality as those that were imported, but we feel more or less that one should have pilot plants done by the NBRI, that is how I feel about it. Whereafter these systems can be assessed and approved. I think that is the only practical way. But for us to approve this type of system before and the trouble is most of these systems are only systems manufactured overseas, which people intend to manufacture in South Africa, but they haven't got a sample for the South African product. It is so difficult we don't know what to do in this respect. Now I would like guidance from you people, but I think one should have, through the NBRI to have pilot plants where these things are installed that way and where we can assess them afterwards and then approve. Thank you.

Mnr. Jan Loubser: Benoni

Mnr. die Voorsitter eerstens dink ek moet ons net mnr. Barnard reghelp. Dit is nie die "Approvals Committee" nie, dit is nie die goedkeuringskomitee nie, dit is 'n "Aanbevelingskomitee". Ons maak slegs aanbevelings. Die gebruikers wat uself is, kan besluit of u die goed wil aanvaar of nie aanvaar nie.

Tweedens wil ek net dit noem dat u moet onthou ons plig was eintlik die opstel en wysiging van die bedradingskode. Dit is gedoen, dit is deur die meeste van ons aanvaar vanaf die 1ste Januarie, wat nie baie lank gelede is nie. Wat eintlik beteken dat tot op daardie datum kon die nuwe bedradingsmetodes nie gebruik gewees het nie. Maar daarna kan dit wel vryelik gebruik word. Daar is 'n verdere probleem en dit is dat ons hier vandag bymekaar is, is eintlik almal voorsieners van elektrisiteit aan huise. Dit is net toevallig dat ons Rade dalk betrokke raak in behuisingskemas wanneer ons vereistes kan stel soos nuwe bedradingsmetodes. Maar in werklikheid is dit nou nie meer ons werk nie. Dit is nou die elektriese kontrakteurs se werk om te sorg dat hierdie nuwe bedradingsmetodes uitgevoer word. Daar is 'n verdere vraag en weet u wat ook na die nuus geluister het, het nou die dag gehoor dat daar 'n nuwe metode van TV-stel in Suid-Afrika uitgevind is. Daar gaan bv. 300 minder onderdele in hierdie stel wees. Maar die persoon het gesê die stel sal nie goedkoper wees nie. Dit het my laat wonder. Gaan hierdie nuwe bedradingstelsels werklik vir die verbruiker goedkoper uitwerk of gaan dit net meer geld in iemand anders se sak wees? Dankie mnr. die Voorsitter.

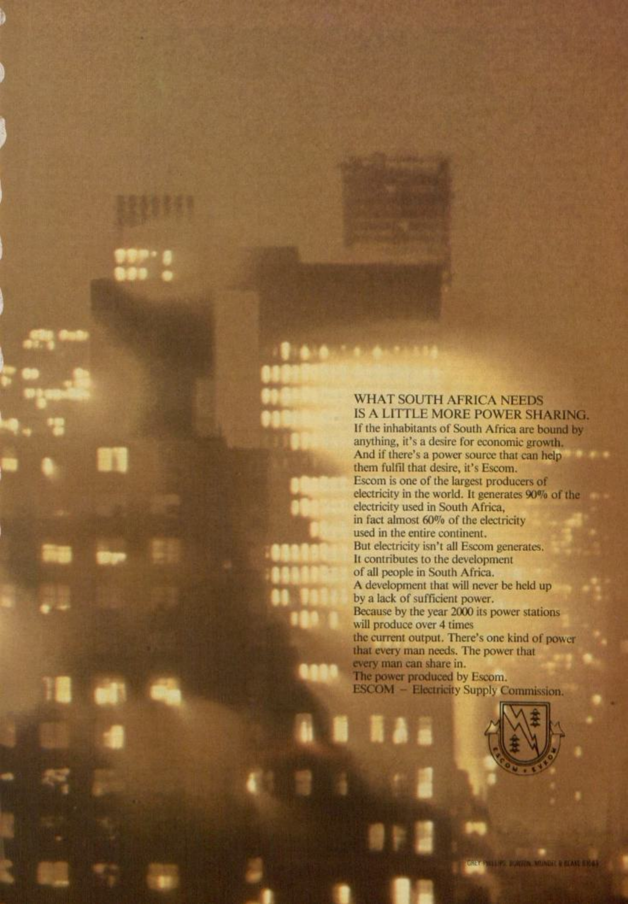
Mr. L. Clarr: ESCOM

Gentlemen we have contractors putting in wiring in houses on farms but, basically farming supplies. Now we have approved certain of these wiring systems for our Rand and OFS Region and I just want to point out the problem that arises with the systems. The systems themselves worked well, there are a few problems here and there where we have for example in pre-fabs demanded tubing down to the fittings so that the fitting does not fall into the cavity. The real basic problem is that the wiring systems are developed in Johannesburg, the price is much cheaper than can be done by local contractors and the local contractors are therefore very wary having the work taken away from them and given to factories and people from Johannesburg and this is the major problem in that the farmers, basically farming supplies, are really told Escom doesn't approve of this. That is the idea that gets around and then they say check with Escom. Now if these people do not check with Escom and find that we do agree with it, then the contractor gets the job. Thank you.

Mr. G. Welch: Chief Inspector of Factories

Mr. President for a Mechanical Engineer to speak to electricals of cost could be considered to be sacrilege but listening to the arguments about the innovative wiring systems, I cannot help but think that the peculiar bird that runs around in ever decreasing circles until it eventually disappears.

Mr. President then in the first place the question of costs. The new systems are cheaper. Don't ask me to prove it to you, but the Germans are cost conscious people and they have been using some of these systems since the war and they have been using it to rebuild their bombarded cities and they did it in order to do it cheaply and quickly. So obviously because they wanted to do it, they did it. I think there is reluctance in S.A. by contractors, local authorities to really give these systems a go. If there was more enthusiasm for it, the systems will be produced and they will eventually be cheaper. As far as the approval of these systems are concerned, every supplier can approve the system in his own supply area, it does not require the approval of the Recommendations Committee as Mr. Loubser has pointed out. He is quite correct in that respect.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IS A LITTLE MORE POWER SHARING.
If the inhabitants of South Africa are bound by anything, it's a desire for economic growth. And if there's a power source that can help them fulfil that desire, it's Escom. Escom is one of the largest producers of electricity in the world. It generates 90% of the electricity used in South Africa, in fact almost 60% of the electricity used in the entire continent. But electricity isn't all Escom generates. It contributes to the development of all people in South Africa. A development that will never be held up by a lack of sufficient power. Because by the year 2000 its power stations will produce over 4 times the current output. There's one kind of power that every man needs. The power that every man can share in. The power produced by Escom.
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The reason why the reluctance on the side of local authorities, I can only assume is because they do not want at this stage to change their by-laws. They are tied up in a tangle of legalities which they themselves are reluctant to untie. I know that I shall call forth a torrent of abuse on my head. As for the Recommendations Committee of the AMEU I am very disappointed to hear your remarks Mr. President. I think as responsible engineers it is possible to visualise what the system is going to look like by looking at its components. We are at a point in time where we require to introduce the systems on a large scale. I am not a politician and I don't hold with politics, but you know while we are fiddling with this, there is a certain amount of banning going on. You will have to accept these responsibilities without waiting for someone else. You must get on with the job. Thank you Mr. President.

Mr. H. Barnard: Affiliate

Mr. Question master, you are on a very thin ice problem here at the moment and I would like to say a few things from the contractors' side, although we are not house wiring contractors, I can see the problem why these systems are not just installed in every house wherever contractors work.

Now firstly there is a question of staff to install these things. You will find that a contractor that will tender on a job like that, will use existing methods that are well known by all his personal staff. Should they use any other method and having to deliver 200 houses per day, will have a situation where you will have most probably 600/1 000 of his labour staff that has got to be trained to do these new systems and when you have a contract like that there is normally a stiff penalty clause at the end so that he won't have too much time to train his staff.

The other problem arises, is who is going to train the staff? Will the manufacturer come out and show these people? As you will know most of those contracts in Soweto will be done by black electricians, which will require quite a bit of training to learn the new methods.

The other thing is the existing systems have been proved. You had a really nice day yesterday trying to convince municipal electrical engineers to make use of XLPE. Now how much more trouble are you going to have in convincing the contractor that this new method is better than the old. He has got to look after that system for six months before he gets his last 10% of the contract's monies and in a black township where mechanical things are of very important nature.

The third item arises which I would like to mention, is the availability of equipment. Once again the penalty clause comes in. You have 200 houses to deliver a day and you can't have a 600/1 000 chaps standing around waiting for individual parts. On a system you have to have the complete system. Material has got to be on site. You can have no delays on this. Further I feel it is up to the particular consultant or engineer, specifying the tender or writing the specification for this particular job to specify exactly what he wants. It is not for the contractor to leave alternatives or design an offer for alternative schemes. It is a really competitive game, you really got to know what you want to do and if each one is going to come with his own specification or alternative to the specification, you are going to find yourself in very deep waters. Firstly you won't be competitive and secondly you will get all funny looking installations.

Mnr. die Vraesteller, dan is daar net een of twee punte vir my eie nuuskierigheid. Watter sisteme, en word die stelsels gekoördineer, wat gebruik word in nuwe swart dorpsgebiede, want dit is tog 'n baie belangrike item. U weet dit is nie een konsultant of een elektrotegniese ingenieur wat al hierdie goed gaan ontwerp en spesifikasies gaan aanvra nie. Soos uself weet, die VMEO het al baie werk gedoen in hierdie rigting.

Watter stelsel gaan gebruik word vir al hierdie verskillende dorpe — eerstens. Tweedens, die konsultante wat aangestel is vir hierdie tipe werk, gebruik hulle die riglyne wat daargestel is deur die VMEO en SABS of het elkeen maar sy eie sisteem wat hy volgens werk?

'n Laaste vraag. Gaan relê geïnstalleer word in hierdie plekke of gaan dit nie geïnstalleer word nie? Dankie meneer die Vraesteller.

Mnr. A. Lap: WNNR

Mnr. die Voorsitter, ek sal van onderaf begin met mnr. Barnard. Hy het 'n paar vrae gestel wat blykbaar meestal na Soweto gerig is en daar het ek voorheen genoem dat ons daar 'n paar huise tans bedraad met die verskillende stelsels. Ook die spesifikasies van die werk laat toe vir vier verskillende stelsels met vier verskillende hoeveelheidslyste. Daarbenewens moet ek ook byvoeg dat daar ook toegelaat word vir gemengde stelsels maar in daardie geval sal die tenderaar self sy hoeveelheidslys moet opstel. Nou watter een gaan aanvaar word, die tender sluit die 26ste Mei, kan ek vir u op hierdie stadium nie sê nie, maar die tender is vir 5 000 huise en dit word as 'n voorbeeld gebruik vir die res van die 70 000 of meer wat nog bedraad moet word in Soweto en ook vir die res van die land. Indien dit uitkom dat sekere stelsels meer billiker as ander is, sal daar voorkeur aan gegee word, want dit is logies hoe meer huise ons kan bedraad vir dieselfde geld, hoe beter sal dit wees vir ons almal.

Dan was die kwessie van die koördinasie wat ek nou genoem het, hoe dit gedoen gaan word. En dan aardlekkasie relês, nou soos u weet dat dit mandateer is en op hierdie stadium is daar niks verder te sê nie. Alle huise volgens die kode moet daarmee voorsien word.

Mr. Robson, East London thank you for your little talk and also the question you mentioned that the problem lies in accessories, I know that you and Mr. Beck did try it out and I am disappointed that you did not get any tenderers. Perhaps at a later stage when we are busy with a standardisation of specifications which allow for all the particular systems which we will send to everybody concerned as a guide but perhaps then you may find some tenderers. Mr. Barnard you talked about over-simplification of the system now. Agreed. We have a problem — accessories. Mr. Robson also mentioned it. But there are ways of overcoming it if the local authority or the contractors are prepared to use their initiative. Mr. Loubser put it veryd clearly, you have the permission of the code to try everything yourself. You do not have to wait for approval from any committee.

Dankie mnr. Loubser vir u bydrae. U het dit baie duidelik gestel en die vrees wat u het van die TV-stel, is seker by ons almal, dit is waarom ons nou die paar huise bedraad om te sien wat die werklike tyd is. Ek het self ondervinding waar hulle een huis bedraad het in een van die myne naby en dit was moontlik om die hele stelsel in te sit in ses ure, terwyl dit soos u weet, drie dae neem met normale professionele stelsels. Die materiaal was ongelukkig bietjie duurder, maar die spoed is daar. Dit kan gedoen word.

Mnr. Weich ook baie. I appreciate your help in this matter and I know we are going to get more help form you when we hope certain amendments will be made to the Act, the Wiremen's Act, and perhaps the 1958 Act to make it possible for us to use semi-skilled labour to put up these systems, providing there is no connections made and no actual wiring done. Thank you very much.

I know everybody is aware of the various systems available, but in case there are some who have not seen some of the European systems, outside here in the porch I have just put a board showing all the various systems available or known to us plus two examples of multi-core cable which was made in this country and which is on sale now. This particular type is for under-surface, in other words for plastered walls. The same system is also used for surface work in which case the web is omitted. I thank you Mr. Chairman.

Mr. P. J. Botes: President

To sit on this Committee you will note what the problems are. May I just mention that there used to be a man from the Dept. of Labour at that time on this committee. We have not had one for some year now. I would like Mr. Weich to reconsider to let us have one of his men on this committee. Thank you Mr. Weich.

Mr. John Morrison: Affiliate

I am speaking as a member of the Recommendations Committee for new products on which I sit as representative of industry. I know that I speak on behalf of some of the manufacturers of these systems whereby they tend to sit on the fence until someone has made up his mind. I know that this is a negative thing, but when you are spending money on tools and they may cost you R20 000 and you need five or six of them, it is a lot of money to spend on the assumption that a system is going to be accepted. I fully support Mr. Weich, but there are a lot of difficulties, for example the committee do feel that we should use our standard SABS boxes, which in effect means that the system might have been used in Germany using a circular box, has now got to be adapted to use onto our standard four box or whatever they may be here. So I would suggest that maybe through Mr. Lap or through our own association where, we are really trying and get moving and to get off the ground. Thank you gentlemen.

Mr. P. J. Botes: President

Ladies and gentlemen, I trust that all of you know about the existence of SATEPSA called SATEKG in Afrikaans.

Introduction

SATEPSA (STAEKG(stands for the SA Telecommunications and Power Supply Authority. Its members consist mainly of government departments and organizations in the public sector. The Chairman is a senior member of the SADF. SATEPSA is vested with very wide ranging powers in the event of a state of emergency being declared, but seeks to stimulate and co-ordinate the preparation of contingency plans in order to minimize the disruption of essential services in the event of an emergency situation of any kind.

Objectives

Tot formulate policies, co-ordinate planning, document resources and prepare contingency plans relating to:

(a) Procedures and lines of communication.

(b) Telecommunication facilities.

(c) Standby power supplies for telecommunication facilities.

(d) Supply of power in emergencies.

Tasks which concern the AMEU

(a) Establish categories of consumers.

(b) Establish criteria for determining priorities of consumers.

A view of the large audience.

(c) Establish criteria for relating priority to duration of supply interruption.

(d) Evaluate all consumers in each area of supply.

(e) Establish district, regional and national priority rankings.

(f) Identify consumers with high priority and inadequate security of supply.

(g) Consumer liaison and education.

(h) Establish unambiguous procedures for the initiation, maintenance and cancellation of load shedding in accordance with priorities in force.

(i) Co-ordinate the adoption of standards for and the provision and use of mobile standby power supplies.

(j) Initiate and extend mutual assistance agreements.

(k) Extend mutual standby agreements with Escom to cover contingencies other than the loss of plant and to provide for proper recovery of costs and waiving of penalty clauses.

(l) Establish procedures to ensure continued supply of fuels in an emergency.

In the Rand and O.F.S. area of supply all consumers have received a letter from the ESC regarding Emergency Power Plan Data Collection. It reads thus:

The South African Telecommunication and Power Supply Authority, which was formed in 1976 under the chairmanship of a member of the South African Defence Force. The aim of the body is, inter alia, to co-ordinate electrical power supplies in such a way so as to provide for the requirements of essential services during an emergency, i.e. when there is a complete loss or limited availability of electrical power for up to 48 hours. Senior representatives of the Department of Posts and Telecommunications, Escom, the various arms of the South African Defence Force, the South African Police and other state departments and semi-state departments/ institutions serve on this body.

SATEPSA functions at national level and is assisted by regional sub-committees and local work groups in the execution of its task. To provide for the requirements which may arise, it is necessary that plans concerning telecommunication and electrical power supply for contingencies be drawn up before an emergency.

To perform this planning, information concerning electrical power supply needs is required. The collection of this date is presently the main activity of the SATEPSA sub-committee concerned with power supply. Once the data has been gathered, it will be processed and a priority list of consumers who will then receive essential services during emergencies will be compiled.

The collection of this data is a very large undertaking as information has to be collected from all power consumers in the Republic of South Africa. In order to make the task more manageable, it was decided to limit the amount of collected data for processing by working on the basis of exception. With this in mind, all large consumers of electricity have been informed that they are not on the priority list for receiving electrical power during any emergency. Data need then only be collected from those consumers who submit applications for inclusion on such a priority list.

I must appeal to you to give your co-operation as far as possible. There seems to be mixed feelings on this matter and it is only with our co-operation that the whole plan can be guided onto a practical path. You must please respond to this letter as requested as soon as possible.

Mr. Walter will also like to say a few words on this matter.

Mr. M. Walter: ESCOM

Mr. President, gentlemen SATEPSA is as you have heard from the President an organization set up by and at Government's level. Escom being the major supplier of electricity throughout the country has been involved right from the commencement or the setting up of SATEPSA and there have been many things over many months some 3/4 years now in working out how power provisioning under emergency conditions can be best put into effect. As a result of deliberations that have been carried out, sample questionnaires have been tried on a number of larger consumers of Escom, a computer programme has been developed and in fact has been tested out on sample data, which will give under certain categories of emergency and certain situations of power requirements, first of all obviously to insure the safety of life and limb.

Now I don't want to say too much about this, Mr. President, but I must appeal to all members of your organization to take this matter very seriously. Murphy's eleventh law states that what has not been planned for is bound to happen and really all we're asking here, is that we should plan for virtually every possible contingency. Again one doesn't want to say too much in a public hall of this nature, but I believe we must realise gentlemen, the time is running out. We can't go on living in the hopes that it won't happen to us. Some years ago we did suffer in quite a few areas of the country attempted sabotage, and it was a very amateurish attempt if I may say so. For example on certain power line structures, the compression legs were blown up and not the tension legs. In line suspension structures were damaged and not strain structures, and particularly not angle strain structures. Gentlemen I don't believe we are dealing any more, and this is been confirmed by very senior officials of the various State Departments concerned with security and defence, we are not dealing with amateurs any more. We can have a major emergency effecting power supplies, either isolated, in various parts of the country or even nation wide. I believe that also as part of our total civil emergency we have in various parts of the country at various times suffered from floods, from earth quakes, from snow storms and this is all part of the same emergency planning that we believe that responsible electrical engineers have, we have a professional responsibility to plan adequately for these contingencies. As I mentioned in terms of Murphy's eleventh law if we do plan, it probably won't happen. So Mr. President, I would ask that you and your members give this matter very serious thought. It is not an easy questionnaire that you will be asked to complete, if you return that reply card and I believe that all, I think they call them regions, regional committees of the SATEPSA have sent out but SATEPSA needs this information if they are going to do a proper job, if in fact somebody says the paw-paw does really hit the fan at any time and I believe that if you have problems incidentally, filling in this questionnaire, please contact the Local Chairman or his assistant on the regional sub-committees, power provisioning sub-committees of SATEPSA, you will be able to contact them and if you don't know them, you can always contact through the local Escom Regional or area office, as in most cases the Chairman of the Power Provisioning Sub-committee is the Head of the operations or distribution in that particular area. Thank you, Mr. President.

AMEU CODE OF PRACTICE FOR THE APPLICATION OF MULTIPLE EARTHING TO LOW VOLTAGE DISTRIBUTION SYSTEMS

Introduction

Multiple earthing systems were first established in Europe in 1940 as a means of overcoming the increasing difficulty of obtaining efficient earths for LV distribution networks and consumers' premises. This was consequent on the deterioration and loss of what hitherto were acceptable and reliable earths viz. underground metallic water mains and buried electrodes.

The principle of allowing consumers to connect their earthing lead to the neutral was legally accepted several years later and in Britain the Electric Lighting (Clauses) Act 1899 was amended by the introduction of two Act, vix. the Multiple Earthing Approval Act 1974 and the Protective Multiple Earthing Approval Avt. 1974.

The former provided legislation which applied to supply authorities in Britain and the latter applied to consumers.

These Acts permitted consumers' premises and street-mounted distribution equipment to be earthed to the supplier's neutral, subject to compliance with certain conditions.

Under "broken-neutral" conditions, the Protective Multiple Earthing (P.M.E.) System can give rise to certain hazards which are avoided in the Multiple Earthed Neutral (M.E.N.) System.

This Code of Practice describes the various methods of applying multiple earthing to low voltage distribution systems.

1. This Code of Practice deals with the design and installation requirements of a multiple earthed neutral distribution system. This code applies to new installations, but can also be applied to modifying existing installations. SCOPE

2. Three systems are specified in this Code: TYPES

   (a) Multiple Earthed Neutral (M.E.N.)
   (b) Protective Multiple Earthing (P.M.E.)
   (c) Protective Neutral Bonding (P.N.B.)

3. **Description of Systems** M.E.N.

   3.1 **M.E.N. System** (Refer Fig. 1)

   A system in which the neutral is earthed

   (a) At or near the star point of the transformer
   (b) At other points on an LV distributor
   (c) At the remote end of every distributor

   All service connections have an insulated neutral and a separate earth conductor. The consumer's earthing lead is connected to the supplier's earth terminal at the consumer's supply point on his premises.

   The neutral and earth conductor are solidly connected at the tee-off point on the distributor.

   3.2 **P.M.E. System** (Refer Fig. 2) P.M.E.

   A system in which the neutral is earthed

   (a) At or near the star point of the transformer
   (b) At other points on an LV distributor
   (c) At the remote end of every distributor

   Service connections comprise a neutral and live conductor. The consumer's earthing lead is connected to the supplier's neutral at the consumer's supply point on his premises.

   3.3 **P.N.B. Systems** (See Fig. 5) P.N.B.

   A system in which

   (a) Only one consumer is fed from a transformer supplied by an overhead line without an earth continuity conductor.

   (b) The neutral is not earthed at the star point of the transformer

   (c) The neutral is earthed at a single point on the consumer's service connection, at least 6 m from the transformer star point.

4. **Basic Differences between M.E.N. and P.M.E. Systems**

   The following advantages and disadvantages of the M.E.N. and P.M.E. systems are given as a guide in the choice of system to be adopted.

   4.1 **Method of Earthing Neutral**

   The basic difference in the M.E.N. and P.M.E. systems lies in the method of connecting the consumer's earthing lead at the supply point on his premises, viz.: BASIC DIFFERENCES M.E.N./P.M.E.

   M.E.N. System: Earthing lead is connected to the supplier's earth terminal

   P.M.E. System: Earthing lead is connected to the neutral

   4.2 **Safety of Operation**

   4.2.1 **Broken-neutral Condition: P.M.E. System**

   A break in the neutral of a P.M.E. service connection can give rise to a hazardous situation because BROKEN NEUTRAL

   (a) A broken neutral results in a loss of an earth connection to the consumer's premises;
   (b) If load is connected on the consumer's premises, voltage gradients can occur between the premises and the supplier's transformer which may be hazardous to public safety.
   (c) Loss of a supplier's neutral will not cause an earth leakage device to operate.

4.2.2 **Broken-neutral Condition: M.E.N. System**

A break in the neutral of an M.E.N. service connection would not be hazardous to the consumer or public safety.

4.2.3 **Earthed-neutral Condition on Consumer's Premises**

EARTHED NEUTRAL ON CONSUMER'S WIRING

The inadvertent earthing of a neutral in the wiring installation of a consumer's premises can have a desensitizing effect on certain types of earth leakage devices currently in use. In the P.M.E. system the desensitizing effect is more pronounced than in the M.E.N. system because of the "short-circuited turn" effect of the neutral earth fault and the neutral-to-earth bond.

4.3 **Cost**

COST

The M.E.N. system is more costly than the P.M.E. system to the extent that an additional conductor must be provided with each service connection.

5. **Technical Requirements for Distribution Systems and Service Connections**

5.1 **Distribution Systems**

DISTRIBUTION SYSTEMS

M.E.N. and P.M.E. Systems (Refer Figs. 3, 4A, 4B, 6A, 6B & 7)

Distribution equipment associated with transformer substations that are either ground mounted or pole mounted and fed by underground cable or overhead line, with or without earth continuity conductor, should be installed, connected and earthed in accordance with the following requirements:

(a) Metal tanks of transformers, switchgear and all metal work supporting or enclosing HV apparatus shall be connected direct to an earth electrode hereinafter referred to as an HV earth electrode.

(b) Where the resistance to earth of an HV earth electrode is 1 ohm or less, it is permissible to earth the LV neutral at the HV earth electrode position.

(c) Where the resistance to earth of an HV earth electrode exceeds 1 ohm, the LV neutral shall be earthed at a minimum distance of 6 m from the HV earth electrode.

(d) The cross-sectional area of the neutral and of all LV distributors must not be less than that of a phase conductor.

(e) The neutral of underground and overhead LV distributors shall be earthed at remote ends.

(f) Where the overall resistance to earth of the neutral of an LV distributor exceeds 10 ohms, the neutral shall be earthed at intermediate positions to reduce its resistance to earth to below this limit.

(g) No circuit breakers, isolators, fuses, switches, or removable links shall be installed in the neutral between the transformer star point and the remote end of any LV distributor or service connection.

(h) All metallic sheathing and armouring of cables and all metal work supporting or enclosing LV distributors shall be connected to the neutral.

(i) Where a separate neutral earth (S.N.E.) cable is part of an M.E.N. or P.M.E. system, the armouring and/or metallic sheath and any earth continuity conductor shall be bonded to the neutral at both ends of the cable.

(j) Multiple earthing may be carried out by connecting the neutral to other supply neutrals, earth electrodes, cable sheaths and armouring and these connections used to obtain the required overall earthing resistance value not to exceed 10 ohms.

(k) To ensure the integrity of the neutral, it is recommended that all connections and joints on or to overhead line conductors be made by compression fittings or, alternatively double bolted connectors.

(l) M.E.N. or P.M.E. may be applied to any single LV distributor without alteration to other LV distributors supplied from the same transformer.

5.2 **Protective Neutral Bonding P.N.B. System**

In this system the neutral is not connected to earth at the transformer position, but only at one position, viz. adjacent to the consumer's installation. Since the neutral is earthed at one point only, the question of multiple earthing does not arise and there is, therefore, no necessity to meet the M.E.N/P.M.E. technical requirements.

5.3 **Service Connections**

SERVICE CONNECTIONS

5.3.1 **M.E.N. System** (Refer Figs. 3, 4A & 6A)

The following conditions apply to consumers' service connections as well as service connections to traffic signals, road signs, street lighting and other power-consuming equipment installed in public thoroughfares:

(a) A single phase service connection comprises a live, a neutral and an earth continuity conductor (E.C.C.)

(b) A polyphase service connection comprises two or three phase conductors, a neutral and an E.C.C.

(c) The neutral and earth conductor are solidly connected at the tee-off point on the LV distributor.

(d) In a consumer's service connection, the earthing lead is connected to the E.C.C. of his service connection at the supply point on his premises.

(e) In a service connection to traffic signals, street lights and other power-consuming equipment installed in public thoroughfares, such equipment is earthed to the E.C.C. of the service connection.

5.3.2 **P.M.E. System** (Refer Figs. 4B & 6B)

P.M.E.

The following conditions apply to consumers' service connections only:

(a) A single phase service connection comprises a live conductor and a neutral.

(b) A polyphase service connection comprises two or three phase conductors and a neutral.


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(c) The consumer's earthing lead is connected to the neutral of the consumer's service connection at the supply point on his premises.

(d) A label must be attached at the service supply point on his premises indicating that the installation is part of a P.M.E. system.

NOTE It is not recommended that the P.M.E. system be applied to supply traffic signals, street signs or other power-consuming equipment installed in public thoroughfares because the P.M.E. system is inherently unsafe under "broken-neutral" conditions.

6. **Appendices**

6.1 **Appendix A***

Size and type of contuctors for earthing HV equipment and LV multiple earthing connections.

6.2 **Appendix B***

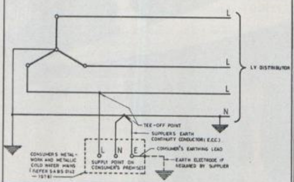
Recommendations on the practical installation of earth electrodes.

* Not yet available.

W. BARNARD
CHAIRMAN
EARTHING SUBCOMMITTEE
1.5.1980

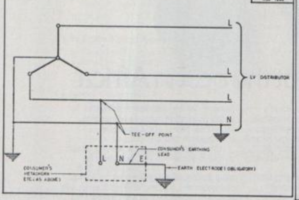
MULTIPLE EARTHED NEUTRAL (M.E.N.) SYSTEM

FIG.1
MAY 1980
JCC-ED



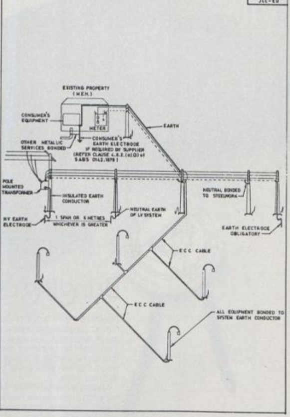
PROTECTIVE MULTIPLE EARTHING (P.M.E.) SYSTEM

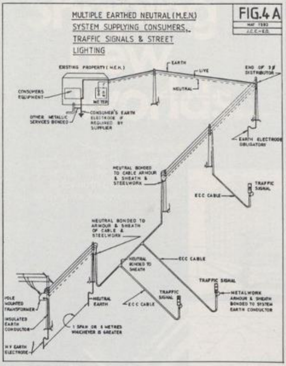
FIG.2
MAY 1980



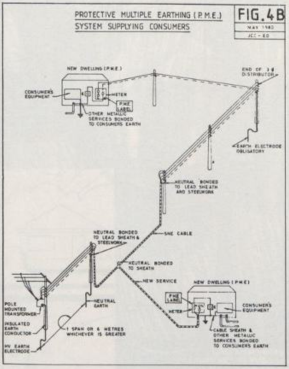
MAIN SYSTEM SUPPLYING CONSUMERS AND STREET LIGHTING

FIG.3
MAY 1980
JCC-ED





MULTIPLE EARTHED NEUTRAL (M.E.N.) SYSTEM SUPPLYING CONSUMERS, TRAFFIC SIGNALS & STREET LIGHTING
FIG.4A
MAY 1980
J.C.C.-E.D.
EXISTING PROPERTY (M.E.N.)
EARTH
LIVE
NEUTRAL
END OF 3Ø DISTRIBUTOR
CONSUMERS EQUIPMENT
METER
OTHER METALLIC SERVICES BONDED
CONSUMER'S EARTH ELECTRODE IF REQUIRED BY SUPPLIER
EARTH ELECTRODE OBLIGATORY
NEUTRAL BONDED TO CABLE ARMOUR & SHEATH & STEELWORK
TRAFFIC SIGNAL
ECC CABLE
NEUTRAL BONDED TO ARMOUR & SHEATH OF CABLE & STEELWORK
NEUTRAL BONDED TO SHEATH
ECC CABLE
TRAFFIC SIGNAL
METALWORK ARMOUR & SHEATH BONDED TO SYSTEM EARTH CONDUCTOR
POLE MOUNTED TRANSFORMER
NEUTRAL EARTH
TRAFFIC SIGNAL
ECC CABLE
INSULATED EARTH CONDUCTOR
1 SPAN OR 6 METRES WHICHEVER IS GREATER
H V EARTH ELECTRODE



PROTECTIVE MULTIPLE EARTHING (P.M.E.) SYSTEM SUPPLYING CONSUMERS
FIG.4B
MAY 1980
J.C.C.-E.D.
NEW DWELLING (P.M.E.)
END OF 3Ø DISTRIBUTOR
CONSUMERS EQUIPMENT
METER
PME LABEL
OTHER METALLIC SERVICES BONDED TO CONSUMERS EARTH
EARTH ELECTRODE OBLIGATORY
NEUTRAL BONDED TO LEAD SHEATH AND STEELWORK
SNE CABLE
NEUTRAL BONDED TO LEAD SHEATH & STEELWORK
NEUTRAL BONDED TO SHEATH
NEW SERVICE
NEW DWELLING (P.M.E.)
PME LABEL
METER
CONSUMER'S EQUIPMENT
POLE MOUNTED TRANSFORMER
NEUTRAL EARTH
INSULATED EARTH CONDUCTOR
1 SPAN OR 6 METRES WHICHEVER IS GREATER
HV EARTH ELECTRODE
CABLE SHEATH & OTHER METALLIC SERVICES BONDED TO CONSUMERS EARTH

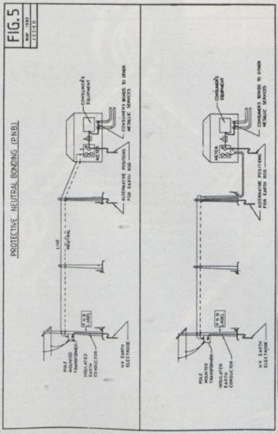
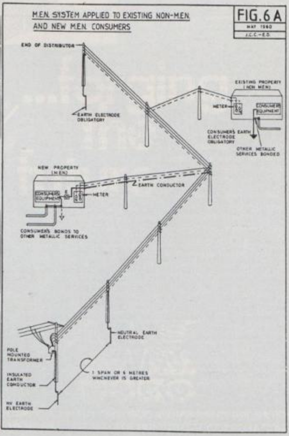
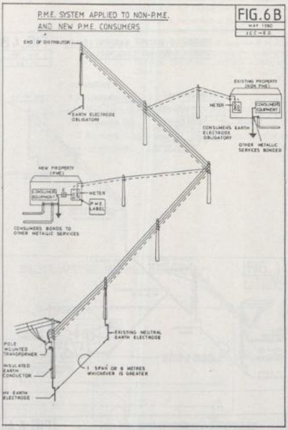
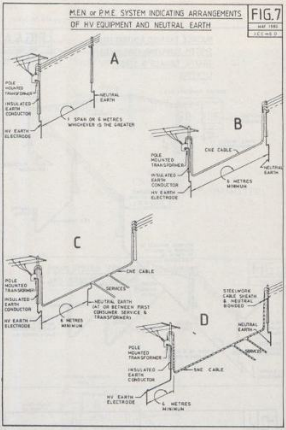


FIG.5
MAY 1980
J.C.C.E.D.
PROTECTIVE NEUTRAL BONDING (P.N.B.)
CONSUMER'S EQUIPMENT
CONSUMERS BONDS TO OTHER METALLIC SERVICES
METER
ALTERNATIVE POSITIONS FOR EARTH ROD
LIVE
NEUTRAL
P.N.B. LABEL
POLE MOUNTED TRANSFORMER
INSULATED EARTH CONDUCTOR
HV EARTH ELECTRODE



M.E.N. SYSTEM APPLIED TO EXISTING NON-M.E.N. AND NEW M.E.N. CONSUMERS
FIG.6A
MAY 1980
J.C.C.-E.D.
END OF DISTRIBUTOR
EXISTING PROPERTY (NON MEN)
METER
CONSUMERS EQUIPMENT
EARTH ELECTRODE OBLIGATORY
CONSUMERS EARTH ELECTRODE OBLIGATORY
OTHER METALLIC SERVICES BONDED
NEW PROPERTY (M.E.N.)
EARTH CONDUCTOR
CONSUMERS EQUIPMENT
METER
CONSUMER'S BONDS TO OTHER METALLIC SERVICES
NEUTRAL EARTH ELECTRODE
POLE MOUNTED TRANSFORMER
1 SPAN OR 6 METRES WHICHEVER IS GREATER
INSULATED EARTH CONDUCTOR
HV EARTH ELECTRODE





Mr. W. Barnard: Johannesburg

The subject that we are discussing here, which is basically two earthing systems, there are wires in both systems but most of us don't understand and the whole object of this exercise has been to explain the basis of these two systems. Basically there are two systems, which is a M.E.N. system and a P.M.E. system.

We don't want to get involved with the campus from the Cape about the use of CNE cables. We don't want to get involved with Transvaal, the Verligte Transvalers, with their refusal to use earth rods and we certainly don't want to make the people from Kakamas cross because we won't allow them to use Cross-linked plastic water pipes for earthing systems. So all the technique and the technical matter of systems we have left out and we have looked at the basic philosophy. We have tried to give you pro's and cons but in the end it will be your decision what system you use. We have said here that the M.E.N. system has got certain very substantial advantages. Firstly it is a safer system under broken neutral conditions. The second thing where it also has a big advantage is, it doesn't desensitise earth leakage relays to the same extent as PME system can be desensitised. As I see it, the only advantage on the PME system is a very slight cost saving. I think it is a saving that is not worthwhile when you take into account the risks that you can run with spurious voltages and leakage currents underbroken neutral conditions. We have purposely left the annexures because we don't want to have a full scale debate today about this, but I think that the annexures or appendixes will be a vital part of this document, because it will list and this will be facts, it won't be opinion, sizes and types of conductors that can be used, which you can select from. There will be recommendations on the use of installation of earth electrodes and finally, we will also list the minimum size that can be used for the consumer,s bond between the earth terminal and other metal services like water pipes and other metal structures. The intention is that we would ask you to accept this as a draft code and for us to give it a trial period of 12 months. The SABS has already indicated that, on our saying that this is acceptable. They are prepared to publish this as a Code of Practice without alteration.

I have also discussed it with the Chief Inspector, Mr. Weich and he is very happy that we should make at least some progress in coming to some decision as to how we are going to deal with this subject, which have quite tremendous problems all over the country now for a number of years. Thank you Mr. Chairman.

Mr. J. C. von Alphen: SABS

Mr. Chairman I agree with the idea that Mr. Barnard has put forward here. We have been battling as you all know for more than a year because the field was not sufficiently sifted out, essentials from non-essentials and I think Mr. Barnard's first approach here is very good and should carry on to further discussions.

Now also at the level of the S.A. Institute of Electrical Engineers and the Chairman of the Power Group have also been discussing this and from a return of questionnaires we found that there is quite an interest from various regions in either workshop or a symposium on PME or MEN and we have decided in our power group to convene a symposium, not a workshop but a proper symposium, where the various speakers from regions should answer matters of proper document, lecture, probably next year, say about 2 months before the next AMEU meeting and I think then the results of the symposium could then be reported back to the AMEU for further action. Thank you Mr. President.

Mr. H. Barnard: Affiliate

Mr. Chairman to me there is just one point that does bother me with all these codes of practice and standardisation and so on, and that is that you have given two systems to choose from. Why can't they just sort this one out to one system and everybody uses that and that is the end of it.

You have various municipalities applying the two systems, maybe two towns are using the one system and the other two towns not and that is also going to cause various problems once again. Thank you.

Mr. W. Barnard: Johannesburg

Mr. Question Master I think we have put forward two alternatives, mainly because members feel they don't want to do the design work. Hopefully the majority will implement any system, but you get certain cases where there are problems. You get other cases again where the cost is appreciable. If you have very long services for instance, this could be a factor and I am hoping that in general we will adopt one system, but I do not believe we have got to be dogmatic about it and try and say to our members you shall do this and you shall do that. I think it must be left to their discretion. The PME system is certainly the inferior system, but if it is used carefully in accordance with the technical re-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quirements that we have listed, there is no reason why you should not use it.

Thank you.

Mr. E. de C. Pretorius: Potchefstroom

Mr. Questionmaster I have one question, cables leading to traffic signals and cables to streetlights. The ECC cable, is it a proper ECC cable? I'll tell you why I am asking this question, if you refer to figure 1, the abbreviation ECC refers to earth continuity conductor. But to my mind ECC cables is something special, that is a cable with copper conductors in its armouring. Thank you.

Mnr. W. Barnard: Johannesburg

Mnr. die Vraesteller, ek weet nie of ek heeltemal die probleem raaksien nie, maar dit blyk vir my of die aardgeleier, of hy in die kabel is of los is, maak nie verskil nie, maar in altwee gevalle verwys ons na dieselfde aardgeleier. Dit is heeltemal oorgelaat aan die ingenieur se diskressie. Ekself sal nie baie gou die pantsering gebruik vir aard nie, maar as mnr. Pretorius dit wil gebruik, dan kan hy dit gebruik. In die byvoegsels sal dit meer duidelik gemaak word wat die alternatiewe is.

SABS ARMATUUR SPESIFIKASIES

Die implementering van die nuwe SABS 1277, 1278 en 1279/1980 armatuur spesifikasies vir straatverligting en vloedverligting.

SABS LUMINAIRE SPECIFICATIONS

The implementation of the new SABS 1277, 1278 and 1279/1980 luminaire specifications for streetlighing, interior lighting and floodlighting.

Mr. J. Morrison: Question Master

Ladies and gentlemen Mr. Jan Smit was due to lead this discussion. He has had an operation and is now home-recovering and we all wish him very well and Mr. Steyn will take that message back with him. Can I ask Mr. Steyn to substitute for him?

Mnr. H. J. Steyn: SABS

Daar is 'n paar dinge wat ons onder u aandag wil bring, maar om my in staat te stel om dit duidelik te doen, moet ek eers 'n kort historiese oorsig van die projek oor straatverligtingsarmature gee. Dié spesifikasie is oorspronklik deur die VMEO aangevra en daarna is daar jaar na jaar deur die VMEO druk op die SABS uitgeoefen vir die spesifikasie. Die opstel van die spesifikasie het lank geduur, maar daar was goeie redes daarvoor en ek wil dit kortliks aan u verduidelik. Die spesifikasie vir straatligarmature en die spesifikasie vir binne-armature vir fluoresseerlampe is op dieselfde tyd aangevra. Daar is toe besluit om eers die spesifikasie vir binne-armature klaar te maak, ondervinding daarmee op te doen en om daarna die spesifikasie vir straatligarmature aan te pak. Die spesifikasie vir binne-armature, SABS 1119, is toe in 1976 gepubliseer. Die projek vir straatligarmature word daarna om twee redes vertraag:

Eerstens word SABS 1119 nie aanvaar nie en ons kon dus nie vinnig genoeg ondervinding opdoen nie. (SABS 1119 het selfs nou nog maar net ongeveer 5% aanname, of u dit nou wil glo of nie.)

Tweedens het dit met die klein bietjie ondervinding wat ons wel opgedoen het, vir ons baie duidelik geword dat daar eers 'n spesifikasie vir die ballaste vir ontladingslampe sal moet wees voordat 'n spesifikasie vir die armature opgestel sou kon word. 'n Spesifikasie vir ballaste vir ontladingslampe, SABS 1266, is toe in 1979 gepubliseer en nou is die spesifikasie vir straatligarmature ook uiteindelik gepubliseer.

Omdat daar so 'n noue verwantskap tussen straatligarmature en twee ander tipes armature, waarin ontladingslampe ook gebruik word, nl. binne-armature en vloedligarmature is, het die Komitee op aanbeveling van die SABS besluit om terselfdertyd ook sommer spesifikasies vir lg. twee tipes op te stel. Deur dit te doen, is daar geweldig baie tyd bespaar en dit is daarom dat daar nou drie spesifikasies in een omslag gepubliseer word, nl.:

SABS 1277 vir Straatverligtingsarmature
SABS 1278 vir binne-armature en
SABS 1279 vir vloedligarmature

Al die nodige spesifikasies is dus nou gepubliseer en ons is seker daarvan dat ons nie in hierdie geval dieselfde probleme gaan ondervind as wat ons in die geval van ballaste vir fluoresseerlampe ondervind het nie, waar ons veral hitteprobleme gehad het. In daardie geval het ons in die oorgrote meerderheid gevalle gevind dat dit nie die ballas se skuld was dat dit uitgebrand het nie, maar wel dié van die armatuur. Omdat daar nie 'n spesifikasie vir die armatuur self bestaan het nie, kon ons niks daaraan doen nie, maar vandat die spesifikasie vir binne-armature gepubliseer is, het ons nog nooit soortgelyke probleme ondervind waar die armatuur die SABS-merk dra nie. En dit is 'n bekvol. In hierdie geval van armature vir ontladingslampe het ons nog 'n verdere veiligheidsfaktor deurdat ons 'n minimum van klas B-isolasiemateriaal vereis vir die beheerapparaat, maar nogtans 'n temperatuurstyging van net 65°C to 40°C toelaat. Dit is werklik 'n groot toegewing van fabrikante om toe te stem om aan sulke streng verhittingsvereistes te voldoen. (Terloops kan ek noem dat ook in die geval van die spesifikasie SABS 890 vir ballaste vir fluoresseerlampe, die verhittingsvereistes verhoog is en dat ons ook in hierdie geval dieselfde loofwaardige samewerking van fabrikante ondervind het.)

Daar kom nou egter 'n paar verskynsels voor wat mnr. Smit in die besonder en die SABS in die algemeen hinder:

Eerstens vind ons oms dat 'n spesifikasie aangevra word en dat daar druk op die SABS uitgeoefen word om dit te voltooi, maar dat niemand gebruik daarvan maak wanneer dit voltooi is nie. SABS 1119 is byvoorbeeld in 1976 al gepubliseer en het selfs nou nog nie eers 5% aanname nie! 'n Ander baie goeie voorbeeld wat niks met hierdie vereniging te doen het nie, maar wat my stelling pragtig illustreer, is die geval van ons spesifikasie vir spieëls. Dié ding was so dringend dat ek van my topbestuur opdrag gekry het om dit as prioriteit nr. 1 te beskou en nou, nadat dit gepubliseer is, sê 'n vervaardiger, wat ook die aanvraer was (en dit moet ek seker nou terloops sê), dat **as** ons hom betaal, hy aansoek om die SABS-merk sal doen. Ek moet u miskien daarop wys dat die onkoste verbonde aan 'n enkele spesifikasie-komiteevergadering R4 000 beloop . . .!

Mnr. Smit het my daarom versoek om 'n beroep op die VMEO te doen om toe te sien dat al u lede aandring op die SABS-merk op beheerapparaat sowel as op armature. Mnr. Smit het gesê dat ek vir u moet sê, dat as u dit nie doen nie, ons sal weet wat om met toekomstige aansoeke van die VMEO te doen, want ons moet ook ons prioriteite in die regte volgorde kry. Hy het alreeds met mnre. Eugene Pretorius en Jules von Ahlften geskakel en het my versoek dat ek dié twee here bedank vir die ondersteuning wat hulle tot dusver aan die dag gelê het.

Die tweede verskynsel wat ek moet noem, is die volgende: Op komiteevergaderings het dit duidelik geword dat sekere fabrikante die indruk skep dat die SABS-merkgelded die pryse van produkte opstoot en dat hierdie indruk nou by verbruikers posgevat het. Daar word bv. op komiteevergaderings deur verbruikers gevra wat die inslag van die SABS-merk op die prys van sekere produkte gaan wees en selfs op die afgelope SANKV-kongres is die vraag ook gestel. Ons is deur 'n verbruiker ingeroep in die geval van 'n fabrikant wat twee oënskynlike identiese armature aanbied, een mét die SABS-merk en een sónder die merk. Die een met die merk kos R24 en die een sonder die merk kos R21 en die fabrikant vertel aan die verbruiker dat die twee identies is, maar dat die een met die merk duurder is, omdat hy merkgelde daarop moet betaal. Toe ons die saak ondersoek, blyk dit dat die twee armature **nie** identies was nie, want die R21 een het nie 'n hittesink in soos die ander een nie. Die goedkoper armatuur sou dus nooit 'n kans gestaan het om die spesifikasie deur te kom nie en 'n mens kan skaars glo dat 'n vervaardiger so oneties kan optree deur verbruikers onder die indruk te probeer bring dat die twee armature identies is.

Om hierdie bewerings dat die SABS-merk die prys van produkte aansienlik beïnvloed te weerlê, het mnr. Smit my gevra om 'n paar voorbeelde te noem van merkgelde op verskillende produkte. Ek gaan net voorbeelde in die verligtingsveld aan u noem, omdat ek my nie buite my gebied wil waag nie, maar ek weet dat mnr. Smit nog ander voorbeelde aan u sou genoem het. (Ek vermoed dat hy veral die voorbeeld van die belaglik lae merkgelde in die geval van sekere elektriese kabels aan u sou wou genoem het.)

Kom ons beskou egter eers 'n produk wat ons almal ken: gewone gloeilampe. Op tot 'n drywing van 100W, betaal 'n fabrikant aan die S.A. Buro vir Standaarde gelde van 52 sent op elke — **1 000** gloeilampe wat hy met die SABS-merk op vervaardig. Deesdae kos een gloeilamp van 60W drywing in die winkel ± 52 sent. Die verbruiker sou dus ongeveer 'n halwe sent betaal vir elke **tien** lampe wat hy koop vir die versekering dat die lamp minstens aan 'n spesifikasie voldoen! U moet maar self besluit of hierdie beinvloeding van die prys van die produk buitensporig is of nie. Die inslag op die laagste prys waarvoor die fabrikant sy lampe verkoop, is ongeveer 0,18 persent! (Minder as 1 sent op R5!)

Kom ek noem nog 'n voorbeeld van 'n produk wat u almal ken. Die geval van ballaste vir fluoresseerlampe: Die fabrikant betaal merkgelde van 85 sent vir elke **100** 40-watt ballaste wat hy verkoop. Dit is minder as 1 sent per ballas en weereens minder as 1 sent of R5!

So kan ons voortgaan met voorbeelde en ek kan maar net aan u noem dat in my afdeling die hoogste inslag wat SABS-merkgelde op die prys van 'n produk kan hê, ongeveer 0,75% is. Dit is in die geval van sekere ballaste vir kwik- en natriumdamplampe waar die omset in die land nie baie groot is nie. Ek moet onder u aandag bring dat dit vir die S.A. Buro vir Standaarde ongeveer R25 000 per jaar kos om die merkskema vir hierdie produk aan die gang te hou en dat dit dus per enkele item meer sal kos indien die omset laag is. Indien die inslag van die merkgelde op die fabrieksprys van 'n sekere produk, waarvoor 'n standaardspesifikasie oorweeg word, te hoog is, sal my Raad nie toestem dat so 'n spesifikasie opgestel word nie.

Kom ons gaan nou terug na die voorbeeld van die twee sogenaamde identiese armature, waar die een met die merk R24 gekos het en die een sonder die merk R21, dit is 'n verskil van R3, en ons probeer vasstel wat die verskil in prys na regte behoort te gewees het, indien die armature werklik identies was.

Gestel die lamp, die ballas, die kapasitor en die armatuur self het almal die SABS-merk op gehad dan sou u, wat merkgelde aanbetref, maksimaal die volgende gelde ekstra moes betaal het:

- 1 sent vir die ballas
- 1 sent vir die kapasitor
- ½ sent vir die lamp
- 6 sent vir die armatuur self

Dit is dus 'n totaal van 8½ sent verskil! Wat ook al die verskil is wanneer die armatuur by u aankom, behoort dit heelwat minder as R3 te wees!

Mnr. Smit het my gevra om 'n uitnodiging aan u te rig dat enigiemand wat twyfel het in verband met merkgelde, enige tyd met hom in verbinding kan tree. Hy sal vir u die ware feite gee. Hy beskou dit as só belangrik dat hy te eniger tyd, tyd in verband daarmee sal afstaan.

Mr. John Grundy: Affiliate

Mr. President, Quiz Masters, Mr. Steyn, gentlemen, I am only speaking on behalf of my own Company, I am not referring to any other company whatsoever. Overall we fully support the SABS regard to the specifications that Mr. Steyn has mentioned. We were invited to join in the committee drawing up this specification, so really had our say and having in effect co-operated, put our names to it, then as a company we agree with it. Mr. Steyn mentioned the question of the specification and the costs. I would say, as far as we are concerned, as part of an international group, since we have the manufacturing in the Republic of South Africa, we naturally have to manufacture road lighting luminaires, flood lights and others really to fit in with international specifications, because the other companies in the group occasionally call on us for components, called upon us for luminaires and we in turn also call on them. So we might say we have been manufacturing to international standards, to British standards and whatever particular standard has been required. Mr. Steyn mentioned this question of costs. We ourselves have a very happy relationship with the Bureau and we think basically that the costs are quite fair and quite logical for the time is involved in testing particular luminaires. Quality control must of course come into your activities in all respects and I am going to raise with the Bureau this question of how they are going to handle the quality control by the manufacturer. I think in future it will be to the advantage of the municipalities in so much as they can refer to a particular SABS specification instead of inflicting on the manufacturer the old specification with very often 3 or 4 pages of sort of questionnaire to be filled in. The yellownes index, The tests, The heat and The right output and so on of the particular luminaires. Therefore in future all that is necessary for the municipality to do is simply by saying we require these luminaires to a particular specification of the Bureau. Now on this question of cost of testing. I looked at a particular municipality's tender invitations for 12 months just recently and it ran 80, 125, 250, 400 W mercury vapour lamps, 55 W, 90 W, 135 W, 180 W low pressure sodium and then it went on into high pressure sodium of 70 W, 250 W and 400 W cut-off and semi-cut off, now surely a municipality is not going to spend a whole year purchasing the whole range of those luminaires, because as far as the manufacturers are concerned, 22 definite luminaires carry the SABS mark is really quite against the economics and what we would do, would be to select what we regard as the popular luminaires, streetlighting luminaires, flood lights apply to the Bureau for the mark and look at the market, it is going to cost us a R1 000 to carry the Bureau mark on one particular luminaire, then if we are going to sell a 1 000, that is R1 per luminaire, that is going to go on plus also of course what you might regard as the Bureau royalty fee of 5 or 6c for putting on the mark on the luminaire. We would be quite willing to pay this figure on the invoices. It is not our intention to make a profit as Mr. Steyn suggested of putting a certain luminaire with the Bureau mark and one without the Bureau mark and saying that is R2 and R3 difference, it could not in our form of business of flood lights, road lights and luminaires continue to run your factory in this method.

Now I don't think this is really one for Mr. Steyn, but in "Vector" for April, on page 50, there is an article, who the author is, I don't know, but it refers to SABS accredited or certificated laboratories, rather suspect this is one for Mr. Middlecote, but it would seem that according to the list that the SABS chases the hope of soon being able to accredit testing laboratories in South Africa. We have, I should think for the last 5 or 6 years, been questioning whether the Bureau would certificate or accredit commercial writing laboratories in the Republic and the answer has always been no. This is completely impossible. That I find rather contradictory to this article which happens to be in "Vector". We will naturally take this up with the SABS and see what sort of an answer we get. Thank you Mr. President.

Mr. W. Barnard: Johannesburg

The three new specifications are welcome additions to the SABS list. They deserve to be supported and implemented as soon as each Authority can practically do so. It is recommended that each authority carefully monitor equipment supplied under these specifications in order to ascertain if and what modifications may become necessary in the future.

There is one problem which is immediate with the floodlight specification in that the light distribution data is presented on the basis of vertical polar axis of angular measurements. This is non-standard with other international data and therefore direct comparison of isocandela diagrams submitted by local and overseas manufacturers, is not possible. In addition some local manufacturers photometer their floodlights on a horizontal polar axis and their data is therefore not compatible with that from the SABS. It is recommended that all SABS isocandela diagrams be made available on a horizontal polar axis basis only, otherwise Authorities cannot insist that supplies must utilise SABS photometric data.

DIE PUNT VAN VOORSIENING

Waar is die algemene aanvaarbare posisie van die "punt van voorsiening" waar die wettige standaardspanning gehandhaaf moet word? Is dit by die grens van die erf of by die meterposisie?

Samehangend hiermee behoort die munisipaliteit die dienskabel slegs tot die erf-grens te bring of al die pad na die perseel wat voorsien word?

Is daar 'n behoefte of andersins vir isolators in mini-subs?

Behoort munisipaliteite dit te oorweeg om 'n beperking te plaas op die toevoer aan verbruikers in plaas van die huidige onbeperkte toevoer wat beskikbaar gestel kan word?

THE POINT OF SUPPLY

Where is the generally agreed position of the "point of supply" at which the legal voltage standard has to be maintained? Is it the boundary of the erf or at the meter position?

Following the above should the municipality take its service cable only to the boundary of the erf or all the way to the premises to be supplied?

Is there a need or otherwise for isolators in mini-subs?

Should municipalities consider limiting the supply given to consumers instead of as at present giving an unlimited supply?

Mr. K. J. Murphy: Somerset West

Many undertakings including ESCOM make use of H.V. rings in which mini-substations cannot be isolated individually.

The mini-substations are frequently not provided with an isolator for the L.V. compartment in which an electrician may be tempted to, for example, repair a hot connection live.

The prospective symetrical fault current on a 315 kVA mini-sub busbars is of the order of 7,5 k.a.

If one considers the confided space available in the metal enclosed L.V. compartment, the hazards become apparent.

Even where H.V. isolation is available at the mini-subs, an electrician may be reluctant to make use of it.

Is it not desireable that an isolater for the L.V. side be provided in the L.V. compartment of all mini-substations

What is the experience of delegates and where do we stand in the event of a serious accident?

POINT OF SUPPLY AND CONSUMERS TERMINALS

The Electricity Act (Act No. 40 of 1958 Reg. 24) stipulates that in the absence of any agreement to the contrary, the pressure at which electricity is supplied, shall not differ by more than 5% for a longer period than 10 consecutive minutes. The point at which the standard pressure is to be maintained being the consumer terminals.

It's common knowledge that the percentage variation of the standard voltage is to be changed.

(a) In view of the different points at which a consumer's terminals may be situated, has the time not come to define this point as being the erf boundary in the case of domestic consumers?

(b) Could someone clarify the situation with regard to the new proposed standard electricity supply pressures and the proposed deviation percentage?

Mr. W. Barnard: Johannesburg

Mr. Questionmaster, I can perhaps answer a few of those questions. If I can refer to the voltage questions first. The IEC have in fact taken a final decision as to what the voltages should be and because throughout the world there are such tremendous diversions, what they are laying down at this state, that the direction in which we should move, is the voltage which is as far as my memomy serves me right, 230 volts plus or minus 10%, but they are not even saying that that is to be achieved immediately, because there are many people who can't achieve it, but I have said that that is the direction in which we should move.

If I can refer to the other matters as far as we in Johannesburg are concerned, we take the point of supply as the point where the voltage will be measured and that should be at the point of metering, but where you have metering in common cubicles on the pavement, we accept that it is the point where the consumer can operate the switch to isolate the supply, in other words, either the isolator or at the meter. If I can just briefly refer to the other point about the isolators in the low voltage sections of the mini-subs. We are in fact going through all your mini-subs. We have today got many or running into thousands, and putting in isolators, becaus we have found it is absolutely essential. We are no longer allowing people to change fuses while the mini-sub is alive and on load and in fact we have had a number of accidents where people got burnt. We even had a case where we had a fire and the whole mini-sub burnt out and so we are going around. It is difficult in some of the mini-subs, because there is not a lot of room, but we are putting on-load isolators on the low voltage side.

Mr. J. Loubser: Benoni

Mnr. die Voorsitter, ek het gehoop mnr. Dawson gaan daarop antwoord. Maar u weet die Nasionale Bounavorsingsinstituut is besig met 'n projek om dienste aan huiseienaars, die voorsiening van dienste aan huiseienaars te ondersoek. In die komitee waarop uself, ekself en mnr. Dawson dien, het ons 'n besluit geneem dat die punt van aansluiting is op die erfgrens. Die metode van kragvoorsiening wat ons daar toepas, is ook baie beter op die erfgrens. So, ons het gevoel die spanning wat ons moet verklaar, moet op die erfgrens verklaar word. Baie dankie.

Mr. J. Dawson: Uitenhage

Mr. Questionmaster, Mr. Loubser is not quite right with what we are going to do at that meeting if I could read back the minutes, it reads as follows: "It was confirmed that the point of supply to the householder is defined as to that point where the consumer's main meets the supply main and to be on the boundary and irrespective of where the meter is situated and the voltage at that point would also be a declared voltage of supply", and we went on further to say "it is recommended that a statutory plus or minus 5% be at the point of supply and that this be the maximum deviation, bearing in mind that the voltage drop should be based on this, irrespective of the allowance of the IEC of plus or minus 10% on the overall voltage that a consumer could take supply". In other words, if you design your reticulation system, it should be based on a plus or minus 5% voltage deviation, but you would allow to supply the consumer at anywhere within that the total range of plus or minus 10% of 230 volts. I don't know if I have made that point quite clear. Thank you.

Mr. E. de C. Pretorius: Potchefstroom

Mnr. die Vraesteller, ek wil mnr. Barnard net 'n paar vrae vra. Ek stel baie belang in die feit dat hulle nou al hulle mini-subsentrales met isoleerskakelaars gaan toerus, maar ek wil hoor of hy konsekwent is en dat hy ook skeidingskakelaars in al sy distribusiekaste gaan aanbring? Dankie.

Mr. K. Murphy: Somerset West

Mr. Quizmaster, I am very interested to know what Johannesburg is doing and Mr. Dawson has clarified the other point. It is really for general information and to hear how the other members feel about this question of making the erf boundary the point of supply. You know as the Act reads, at the moment the terminals and the standard voltages will have to be clarified, I think we have to know a little more clearly what is being spoken of as it is open to various interpretations.

Mnr. die Vraesteller, ek het met u bespreek die moontlikheid, net om hier vir u te noem, dat een van ons lede, te wete die man op Malmesbury, ene mnr. Williams, het 'n patent uitgeneem op 'n stukkie toerusting om te verhoed dat lere omslaan as hulle teen pale opgerig word, dit is nou nie 'n advertensie nie, hy het net gevra dat terwyl ons in die Kaap almal baie in ons skik is dat hy die patent gekry het vir hierdie ding, as u dalk belangstel in so 'n apparaat indien u dalk nog leere teen pale gebruik, dat u hom miskien maar kontak en meer inligting van hom verkry. Dis ene mnr. Williams van Malmesbury. Dit is interessant om te sien. Dankie.

D. C. Palser: Cape Town

Should Municipalities Limit the Supply Given to Consumers?

It has been the practice in the past, when costs were relatively low, to give every consumer an unlimited supply, provided of course he was prepared to pay for it.

In today's inflationary world, though, perhaps the time has arrived when consideration should now be given to limiting supplies to consumers, either directly by means of load control, or indirectly by means of tariff inducements.

In South Africa at present we are still fortunate in not yet having an energy shortage — our problem really is one of capital shortage and our access to foreign exhange to pay for plant and equipment. Accordingly, there is as yet no real necessity to limit energy consumption but rather to make more effective utilization of increasingly expensive capital plant.

As a consequence there is an awakening interest in load management systems to ensure that the best possible utilization is made of generation, transmission and distribution plant.

As mentioned, control can be either direct or indirect. Direct means of control involve the reshaping of the load curve to reduce the maximum demand, either by cutting it at peak times or by shifting it to off-peak valley periods. A system employed extensively in South Africa to shift load from on-peak to off-peak periods is ripple control. In Cape Town we have employed pumped-storage to achieve a similar effect. In emergencies, both these energy storage systems can be used to dump load.

Coming now to indirect means of control, we have the obvious system that is extensively used in this country and that is the circuit breaker tariff. Another indirect method not extensively employed here yet, is time-of-day or multiple tariff metering whereby the consumer is induced to move his demand from on-peak to off-peak periods.

There is no doubt that we are all going to have to employ more sophisticated means in the future to make more effective and economic use of our limited and expensive capital resources.

It would be interesting to have members' views on this subject.

D. Fraser: Durban

Section 30(1) of the Electricity Act of 1958 obliges a licencee to supply electricity "to every applicant who is in a position to make satisfactory arrangements for payment therefore". While this condition may not apply to a Local Authority supplying electricity within its own Municipal boundaries, it seem to me that the spirit of the Act is that there should be no restriction on the provision of the supply to the consumer. It does not follow that the consumer should not be required or encouraged to utilise the supply available in the most economical fashion from the supplier's point of view through load control on water heaters, etc., and tariff incentives which favour a voluntary limitation of maximum demand. In respect of domestic consumers, limitation of individual maximum demands will only benefit the Supplier to the extent that the domestic peak load co-incides with the system peak.

The use of load limitors for sub-economic and non-European areas has been considered and adopted in some areas. Their use in such situations must be viewed with caution as sooner or later the persons living in such properties will aspire to the greater use of electricity. I think the large scale application of load limitors should be discouraged and that these areas should be designed initially for a lower value of after diversity maximum demand, without restriction on the use of electricity, and provision made in the design for future reinforcement.

Mr. J. Mackay: Cape Provincial Administration

For many years I have been very worried as a consumer and working with a lot of other consumers that somebody one day will change the tariff just when I worked out how nicely I am going to use that tariff. And this frequently happens. It happened in Mr. Palser's area not so long ago. When I was a bit younger, everybody was encouraged to use as much electricity as possible — the tariff was related that way. There were various ways of buying apparatus, like stoves and hot water cylinders and dish washers and so on through the municipality. You could do this and that was fine. The minute this became a little bit uneconomic, as far as the municipality was concerned, and everybody started using this low tariff, then the tariff was changed and the tariff went from half a cent a unit over a certain amount and it is now something like 3,2c a unit. It seems that we are not going to have a maximum demand tariff anymore but perhaps we are going to have a straight unit tariff or block tariff or something like that for the whole system to be uprooted, everybody will start again. So it is very dangerous to start talking about limiting things with regard to tariffs. So I would rather say we should encourage people to be more efficient in the use of electricity, by all means discourage waste and encourage the use of an efficient energy and in that way when we are talking about load limiters I want to tell about a coloured township I visited, where the coloured electrician who is in charge of the coloured township, it is a coloured municipality, himself decided that they should have 25 A load limiters in every house. And he himself is running his house, that is a fridge, a stove, a hot water cylinder and his wife uses a dishwasher, on a 25 Amp load limiter. He has suggested that that should be done with all other houses and incidentally that township is on the sub-economic level, is designed on a 3 kVA of maximum demand and on the economic side on a 5 kVA. Now it is quite possible to get an efficient use of electricity by that method and watch out for tariff changes. If the tariff changes too much on the one way, people will go to another form energy usage and then you have to change your tariff again. Thank you, Mr. Chairman.

Mr. W. Barnard: Johannesburg

I wonder if the members of the Electricity Control Board will raise their hands at this stage, because I find myself in a complete state of shock at what Mr. McKay has said there. Certainly in the Transvaal, and I think I can speak with great authority as far as Escom is concerned, we structure our tariffs on two criteria. One is to recover our demand related costs and one is to recover our energy costs and also we have to add a little bit to cover our own internal costs, but basically that is the structure of the tariff. And you might vary it from time to time as we have done, where we give special rebates, because people are costing us less to supply them, for instance if they will take their load at night when our plant is standing idle, we will give them a discount. But the basic structure I think is commonly accepted not only in South Africa, but everywhere in the world. And if you work on that basis, I don't think that you can be caught out as Mr. McKay apparently was. Where he organises his whole living in order to fit in with a particular structure and then on a very arbitrary basis apparently Mr. Palser completely turns the whole tariff upside down as far as he was concerned. Perhaps he has not examined the tariffs or the intent of the tariffs sufficiently, because even in a block tariff, for domestic consumers, it is structured in such a way that you have different steps in order to recover again these two costs of your demand-related, energy-related and I cannot see that any tariff can be structured in any other way. Thank you.

Mnr. J. Loubser: Benoni

Mnr. die Vraesteller, ek wil net interessantheidshalwe 'n voorbeeld noem van wat hulle in Sidney in Australië doen met elektrisiteitstariewe. Daar het hulle rimpelbeheerstelsels toegepas op elke huis. Elke huis het slegs een meter, maar die verbruiker gaan met die voorsiener 'n ooreenkoms aan en ek noem hierdie nou net as 'n voorbeeld, my syfers is nie korrek nie, maar as hy 24 uur op 'n dag krag wil hê in sy huis, dan betaal hy so iets soos 4c per eenheid vir die krag. As hy bereid is om met 22 uur per dag klaar te kom, dan betal hy 'n halfsent minder, sê so iets soos drie en 'n half sent per eenheid. As hy bereid is om met 'n minimum van sê 18 uur op 'n dag klaar te kom, dan betaal hy iets soos twee en 'n half sent per eenheid. Dankie.

Mnr. E. de C. Pretorius: Potchefstroom

Mnr. die Vraesteller, net baie kort in verband met vraag 13.3 wil ek net noem ons ondervinding in Potchefstroom, waar ons nou die afgelope drie jaar stroombrekertarief vir kleiner verbruikers het, dat die las op individuele transformatorstasies het omtrent 10% verminder. Alhoewel ons totale las geen verskil gewys het nie. Dankie.

Mnr. K. Murphy: Somerset-Wes

Mnr. die Vraesteller, net om aan te sluit by wat mnr. Palser daar genoem het, u weet ons is besig om nuwe bedradingstelsels te ondersoek ten einde koste te besnoei. Nogtans gaan ons voort en ons sê man, as jy 70 A wil hê, dan kan jy dit kry. U weet dit is 'n feit. Dit is genoem hier deur ander sprekers dat 'n huis, ek dink mnr. McKay het dit genoem, kan weliswaar met 'n beperkte toevoer baie goed klaarkom. In Somerset-Wes het ons ook 'n stroombrekertarief, ek wil dit nie aan u verkoop nie. 'n Jaar of wat gelede toe die brandstofkrisis op sy hoogtepunt was en ons nie gewoond was om 50c 'n liter te betaal nie, het ons gedink aan allerhande maniere om krag te bespaar en om Maksimum aanvraag te beperk tot 'n minimum, maar nou sê ons hier dat 'n man kan kry soveel as wat hy wil hê, solank as hy gewillig is om daarvoor te betaal. En ons beplan ons netwerke daarvolgens. Ek dink ons moet darem weer 'n keer daaraan dink, want die gewone huishouding kan met gemak op 45 A deurkom en dit is nie te veel moeite vir 'n huisvrou om so af en toe 'n stroombreker weer terug te sit as dit uitgeklink het nie. Baie dankie.

Mr. D. C. Palser: Cape Town

Mr. Quizmaster I think the subject has been adequately covered, but I must put the record straight. Mr. McKay has got me into a lot of trouble. Mr. Barnard has been at me again, but to put the record straight, we did not turn the tariffs upside down in Cape Town, and if they were, it was before my time. I will go along with what Mr. Barnard has said. — Thank you.

MINIATUUR-SUBSTASIES VERVAARDING VOLGENS SABS 1029 EN 1030

Met die vinnige toename in die gebruik van miniatuur-substasies, het verskeie vervaardigers op die mark verskyn en die probleem ontstaan nou dat die transformator-hokafmetings nie presies ooreenstem nie en die transformators dus nie uitruilbaar is nie. Dit beteken dat die munisipaliteit aansienlike kapitaal in spaar transformators vir elke tipe van vervaardiging moet belê.

Hoe benader ander munisipaliteite hierdie probleem van spaar transformators vir mini-subs?

Behoort die SABS-spesifikasie nie verder gewysig te word om die afmetings van transformators te standardiseer nie sodat een transformator met alle vervaardigings uitruilbaar sal wees nie?

Behoort die vermoë van mini-subs nie tot 500 kVA uitgebrei te word nie?

MINI-SUBSTATIONS MANUFACTURED TO SABS 1029 AND 1030

With the rapid increase in the use of mini-substations various makes have come onto the market and the problem arises that the transformer cubicles are not exactly alike for each make and transformers are not interchangeable. This requires the municipality to hold a spare transformer for each sixe and make at considerable investment in spare equipment.

How do other municipalities deal with this problem of spare transformers' for mini-subs?

Should the SABS Specification not be further amended to standardise the dimensions of transformer cubicles so that one spare would serve all makes?

Should the rating of mini-subs not be extended to say 500 kVA?

Mr. C. Adams: Port Elizabeth

Mr. Questionmaster, basically I was looking for information when I sent this question in, because it did occur to us, those of us who use mini-subs may be building a problem for ourselves. Where you use conventional brick substations, you can use one spare transformer for a number of substations. But when you start to use mini-subs, and you buy it from 2 or 3 different manufacturers, you have a problem that you don't have a spare transformer which will fit in your mini-sub. And we felt that the SABS should give some attention to this and possibly include dimensional specifications as well, so that one spare transformer will fit any make of mini-sub. To compound the problem we have recently been informed by one manufacturer that the older mini-subs and the newer mini-subs are not the same and the transformers are not interchangeable. So we do feel it is time the SABS give some attention to this and I wondered how other members felt about it. Thank you.

Mr. K. Robson: East London

Mr. Adams did state, Mr. Quizmaster, that he was looking for perhaps some information on experience and if I may perhaps give a few details. I agree with Mr. van Alphen and his comments and if I may take a batch of about a 100 mini-substations, we in fact have three spare transformers which will cover that complete number of 100 quite adequately. We never had to use one at all. A really don't believe that it is necessary to have such a standardised design. I don't believe it is essential. With regard to 500 kVA miniature substations, I experience trends to indicate that if you are up round about 500 kVA, it's much better to use a conventional substation. We have one 500 kVA substation in use. We think we have temperature problems with that one. We have had it for a number of years and we would say that being on 315 kVA, it doesn't seem to be the case to be made out for any other type. But it would appear that it's not really a problem with regard to breakdown of transformers, if it does happen. Thank you.

KITSTIPE WATERVERWARMERS

Die invloed op die laskromme met die installering van 'n groot aantal kitstipe waterverwarmers in 'n elektriese installasie teenoor die installasie van die normale tipe opgaar waterverwarmer plus sonverhitters.

INSTANT TYPE WATERHEATERS

The influence on the load curve with the installation of a large number of instant type waterheaters in an electrical installation as opposed to the installation of the normal type storage waterheaters plus solar heaters.

Mr. D. van der Merwe: Witbank

Mr. President, the subject is instant water heaters and the object is to discuss the influence of its use regarding load curves and a few other points.

Mnr. die President, ek sal graag 'n paar woorde wou byvoeg tesame met die kurwe a.g.v. hierdie las. Ek het hier gelys wat die effek of die invloed sal wees wanneer een huis so toegerus is teenoor 'n groep huise. Ek het verder die vraag, wat sal die invloed wees op die benettingstel-


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sel, as ons dink aan laste van 12 kW en miskien meer per eenheid. Sal dit nodig wees om 'n drie-fasige aansluiting vir hierdie doel te maak? Ek sou graag wou weet hoe dit huidige benettingstelsels sal beïnvloed? Ek dink veral aan benettingstelsels wat al redelik uitgedien is, sal dit daartoe meebring dat 'n mens versterkings teen hoër kostes sal moet aanbring? Dan sou ek graag wou weet van sekere van die lede of hulle die ondervinding het dat daar wel 'n besparing in energie is met die gebruik van hierdie eenhede? Dan ie daar ook die kwessie van hoe vergelyk die kapitale-installasiekoste met die konvensionele stelsels, in ag geneem miskien besparing van waterpype? Verder het ek ook gelys, wat word van bestaande rimpelbeheerstelsels as so 'n gebruik sou toeneem op 'n grootskaal en wat word dan van die koste van rimpelbeheerstelsels wat reeds aangegaan is, veral op bestaande stelsels?

Dan is hier 'n ander vraag wat bietjie pla. Ons het nou juis 'n gesprek gehad t.o.v. stroombrekertariewe. Ek wonder nou as ons hierdie kitsverwarmers insit van 12 kW en meer of selfs 8 kW en meer, hoe gaan dit 'n stroombrekertarief beïnvloed?

Dan is daar die verdere feit dat wanneer ons kitsverwarmers geïnstalleer het, en ons het 'n kragonderbreking, dan is dit so dat daar 'n voordeel sou wees, dat wanneer die krag gerestoreer word, daar nie 'n skielike aanvraag op die stelsel is nie. Maar daarteenoor moet 'n mens seker ook opweeg die nadeel wat dit sou hê op die verbruikers self wat tydens 'n kragonderbreking met kitsverwarmers geen warmwater het nie. Dan sou ek net ook die vraag wou vra. Is die maandelikse besparing van water 'n faktor, want dit is een van die dinge wat uitgelig is met die gebruik van hierdie eenhede. Soos die vraag ook tereg gestel was, hoe verander die puntjie as jy die eenhede of konvensionele eenhede gebruik tesame met 'n sonverhitter? Mnr. die Vraesteller, soos u weet by die Hoëveldse tak was hierdie saak bespreek en ek het inderdaad eintlik onderneem om sekere gegewens beskikbaar te stel op proewe wat ons nou in Witbank doen, waar o s drie of vier woonstelblokke het en waar daar verskillende tipes van warmwaterverhitters geïnstalleer gaan word en reeds tot 'n mate gedoen is, o.a. ook 'n verhittingstelsel, 'n gemeenskaplike verhittingstelsel, waar 'n woonstelkompleks van ongeveer 16 wooneenhede deur een sentrale verhittingstelsel verhit word. Hierdie navorsing word inderdaad gedoen saam met die Bounavorsingsinstituut en ook in samewerking met Evkom, aan wie die woonsteleenhede inderdaad behoort. Ongelukkig op hierdie stadium is dit nog nie moontlik om u enige inligting te gee t.o.v. maksimum aanvraag nie, weens die feit dat hierdie eenhede maar nou onlangs eers bewoon is. Ons sien daarna uit om al hierdie instrumentasie binne die bestek van die volgende 3 of 4 maande geïnstalleer te hê wanneer ons moontlik 'n bietjie meer lig op hierdie onderwerp sal kry. Maar in die tussentyd is ons tog angstig om te weet of daar nie van die lede is wat op sommige van die vrae 'n toeligting kan maak nie? Baie dankie.

Mr. D. C. Palser: Cape Town

The problem with instant type water heaters, with their inherently high ratings, is not so much a question of their influence upon the system load curve as upon the overloading of individual installations, sub-mains and service connections.

To permit the installation of these units, domestic consumers in Cape Town are required to install load limiting relays operating in conjunction with the stove circuits. Where the rated load of the water heater exceeds 4 kW special written application is required from the consumer. Each such application is then considered on its merits taking into account the conditions existing on the distribution system.

As far as the influence of these units on the system load curve is concerned, this should be of little consequence when considering a large group of similar consumers because of diversity. Clearly to heat a given quantity of water, a 4 kW unit will only need to be on-circuit for half the time of, say, a 2 kW unit. Because of diversity, therefore, the sharp, short peaks of the larger units will not be felt on the overall system and there should accordingly be little difference in the magnitude or shape of the system load curve.

The use of solar heaters with conventional electric water heaters, however, is another matter altogether. With solar heaters the greatest reduction in maximum demand is clearly in the summer months with little reduction in the winter months. There will accordingly be an increase in summer load factors with little or no change in winter load factors. On an annual basis, however, there will clearly be a reduction in load factor. As a consequence the electricity undertaking's overhead costs will have to be spread over a proportionately smaller number of units sold with an attendant increase in the cost of supply.

As far as the distribution system is concerned, there will be no saving since the design must be based on the maximum demand in winter when there is no solar reinforcement.

Mr. J. McKay: Cape Provincial Administration

Sorry to be fighting with Mr. Palser again. We have an installation at one of our coastal hostels which was put in last year in August. Since we put in the solar system, we've been able to reduce the quantity of elements to 18 and in fact we are running 18 at the moment and we are getting about 240 units through the meters and we are getting 248 units from the sun, now that is down in the Cape with a bad angle, call it the worst position we could get in, its right at the coast where we get the mist and the cold weather.

We estimated that even in the middle of winter, when it is overcast, that we are going to get at least 40%. In the summer months, we have got right up to over 80% from the sun, we have been down to 88 units a day for the hostel instead of the normal of previous years of somewhere round about 500. So I think its a question of design as Mr. Palser said. One must be aware of the fact that you can get a lot of energy from the sun and design on this basis. If you want to put in a sun energy system which is run by the sun, in addition to your normal electricity system, then its bad economics and its a bad policy. You should accept the fact that there will be times when there is no sun and you may be a little bit inconvenienced, but you are going to get your money in another way. So you can reduce your electricity usage by a large quantity, but it won't affect the load curve to any real extent, because it is a very high capital intensive system and I think it will be self-controlling. Thank you, Mr. Chairman.

Mnr. A. Fortmann: Boksburg

Mnr. die President, ek wil aanbeveel dat hierdie item vir 'n jaar oorgehou word en by die volgende jaar se konvensie in Durban bespreek word. Aangesien ons nie 'n ledeforum daar het nie, kan dit dan 'n item op die agenda gemaak word. Teen daardie tyd sal mnr. Van der Merwe seker volle besonderhede hê. Dankie, mnr. die President.

Mr. D. H. Frazer: Durban

An instant type water heater will have a considerably larger kilowatt rating than a storage type. Using figures (*) extracted from the Department of Planning and the Environment report on "Energy Utilisation in South Africa" (1978) if one used an instant type water heater to half fill a bath (50ℓ) the following element ratings would be needed to complete the task in the times shown.

3 mins — 24 kW (109 amps at 220 V)
4 mins — 18 kW
5 mins — 15 kW

The effects of this would be:

1. The sizes of element needed become a little impractical particularly in higher class housing.
2. Both the Maximum Demand from a single house and the ADMD are likely to be higher than with storage water heaters. In fact the local reticulation could require re-inforcing to cope with a large number of these being used at peak times.
3. Energy consumption would be somewhat less due to reduction of losses, thus, in tariffs not based on maximum demand (block type, etc.), income to the supply authority would be reduced.

The effects of solar heaters used with storage water heaters have been the subject of much previous discussion. The figures used by the salesmen to justify solar heaters, are often exaggerated and much of the saving they claim is due to the losses being reduced by adequate lagging. (There is a case for some standard to be produced in respect of the insulating of hot water systems to save energy). In any case the reduction of income to the supply authority is not compensated for by an equivalent reduction in maximum demand and will result in an overall deficit in tariffs based only on energy consumption.

* ½ full bath 48ℓ (say 50)
Temperature 40°
Say cold water temp. = 20°C
Say hot water temp. = 70°C

$$\text{Hot water required @ } 70°C = 20\,\ell \quad \left(50 \times \frac{40-20}{70-20}\right)$$

0,21 MJ required to heat 1ℓ 50°C

$$\text{therefore: Bath requires } \frac{0{,}21 \times 20}{3{,}6} = 1{,}17 \text{ kWh } (3{,}6 \text{ MJ} = 1 \text{ kWh}) \quad \text{say } 1{,}2 \text{ kWh}$$

$$\text{To fill a bath in 3 mins requires } \frac{1{,}2 \times 60}{3} = 24 \text{ kW}$$

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  say 1,2 kwh
  To fill a bath in 3 mins requires $\frac{1,2 \times 60}{3}$ = 24 kw

(NOTE: 109 amps = 35 mm^2 cable)

TUIS-SWEISMASJIENE

Die bewering word gemaak dat tuis-sweismasjiene en B.B.-senders wat vanaf 'n ampere sok bedryf word, geen steurnis veroorsaak op die huisbedrading en T.V.-ontvangs nie. Wat is die ondervinding van lede in hierdie verband?

HOME WELDERS

It is claimed that modern home welders operating from 15 amp socket outlets cause no interference to the housing wiring or T.V. reception. Also home based C.B. transmitters do not cause T.V. interference. What has the experience of members been in this connection?

Mr. D. Haigh-Smith: Queenstown

Mr Chairman, Mr. Quizmaster, the question reads that it is claimed home welders operating from a 15 amp socket outlet, causes no interference to the house wiring or T.V. reception.

In common probably with many or several municipal electrical engineers for some two years I operated a television transposer directing the signal into Queenstown. SABC said it couldn't be done, but we did it. Anyway I was there for the recipient and all complaints regarding the poor or interference television signal. Specially when the signal was changed from VHF signal to a UHF signal. I personally conducted several tests, in and around my own home with a home welder and apart from the usual flickering of lights at night, when the home welder was used, I found no interference with my television signal. Several members of my staff conducted similar tests at my instigation with similar results. Several complaints of interference with T.V. reception by home welders proved to be faulty television sets only. So my experience, Mr. Quizmaster, is that the ordinary home welder does not cause interference on the television sets, but I will be interested to hear the experience of other members or engineers in that connection. Thank you.

Mr. Quizmaster, CB radio's do cause TV interference, mainly with sound reception on TV receivers and on hi-fi equipment. Especially when the CB transmitter is used in proximity. I found a limited interference with TV picture curves when a wide band masthead amplifier is used, but in general I cannot say that I have found very much interference on the TV sets. When a TV set is properly installed and the antenna properly installed, and the home-based CB transmitter aerial not installed in the immediate vicinity of the TV aerial, there is very little problems. What has happened is that CB users with the newer model motor cars with an electronic controller windscreen wipers and window control, find when they operate their CB in the radio, the windows go up and down or the windscreen wipers work. That has happened I believe, in a number of cases and I believe its most distressing, but it was cured by altering the electronic control. That is all I have, Mr. Quizmaster, on this and I will be interested to hear the comments of the delegates. Thank you.

Mr. W. Barnard: Johannesburg

Mr. Questionmaster, I am afraid I find myself on the horns of a dilemma. My councillor, clr. Wouter du Toit, has come all this way with a sound purpose of trying to solve these TV problems. Unfortunately I haven't got a lot of comfort to offer him this afternoon.

I am convinced that these good buddies, as they are referred to, are at the bottom of this and I can only think of one sort of immediate solution and that is to ban them from the CB band. Unfortunately with other problems, when I saw the list of questions on this questionnaire, I appeal to some of my staff to do some in-depth research. This is something like the in-depth research we asked Jan Loubser to do in Australia, but with the ladies present, I better not tell you this. I said to him over lunch I was most surprised to hear him even admitting to having been in Australia. Because we sent him down to King's cost to do an in-depth researching to the street women there. My colleagues in my department tell me that home welders would and can and do cause interference. Both the mains, and well that of course, is if you've got a home welder, I don't know if my councillor has got a home welder, but is one of these jack of all trades, perhaps he has one. But it can be caused over the mains directly or through an area of pick-up. Attenuation though would confine this to his immediate locality, which means its probably one of his friends whose interfering with his TV.

I got a few notes here which are a little bit complexed, but you might understand them.

I am told that the CB band with about 20 MHz and TV is on 200 MHz, but presumably most of the good buddies use CB transmitters and they therefore emit harmonics which are picked up by the TV set and cause interference on their TV reception.

The final comment I have here from my very good colleagues in Johannesburg are hardly the concern of the AMEU. Thank you.

Mrs. S. Clives: Affiliate

Interference on the earth leakage circuit breaker through supply disturbance. Unfortunately we have never been able to prove this or given any substantial evidence. However we followed this up a little and recent tests carried out with one popular type of welding set, showed that no nuisance of tripping occurred at all at its maximum setting of 160 amps on the secondary when connected via a 50 mA shock hazard protective device with a sensitivity of 20 mA. This was rather surprising because it tended to deny all the claims that we have had over the last two or three years, but this device indeed created nuisance tripping. I would very much like to hear of any other opinions.

The SABS Standard on home welding sets is pretty wide open and I wondered whether this is the area where one could improve the situation by bringing in some mandatory control on wave form and harmonic patterns so that these troubles, if they exist, could be eliminated.

I am told that a lot of people make their own sets and these must of course be much worse.

A separate issue that interests me from the supply point of view on the home welding set, is the power factor situation. Because when we did our run of tests, we couldn't help but notice how low power factors were. If these things got more than wide-spread use I wonder whether the supply engineer would have a terrific kVA problem. I wonder if somebody could comment on this? Thank you.

Mnr. R. de Lange: Oos-Londen

Mnr. die President, ek is nou 'n gewone leek. I don't belong to this elite section of engineers, just an ordinary councillor as my few colleagues here at this congress. But, Mr. President, I am rather surprised to hear Mr. Barnard say that we should ban CB, wragtag julle Transvalers, julle is 'n beneukte spul. Julle verban, julle verkrimp, julle wis alles uit wat goed is.

Mr. President may I say I am very pleased to hear that my worried colleague, Wouter du Toit has also got a CB. Seriously I can only say we don't have any problems with CB, I don't think so. ... from Queenstown we got into the Transvaal, we got clear air down there. Met julle stowwerige lug daarbo kan julle enige ding verwag.

Mr. President, I don't want you all to get the impression that CB doesn't serve a purpose. I know of cases where CB has saved the lives of many people. I know of cases where CB has helped people in serious trouble. So, Mr. President, you clever electrical engineers, you should help us poor laymen to solve this problem. If you come to Queenstown or come to East London, we will help you to do it, but please don't just knock this down. Thank you.

Mr. K. Robson: East London

Mr. President, we seem to be in the interlude of levity here and I think that it is about time we have some levity. Clr. Robby de Lange, the only reason he has a CB radio, and perhaps I can tell you why he has got a CB radio. Those of you who might have driven in a car with Robby de Lange on the national road, perhaps at a 150 km an hour, will realise just what particular use he puts his CB radio to. And he tells me its the most sufficient system of making sure that you know exactly where the provincial traffic cops are. But also if I may just talk something that has absolutely nothing to do whatever with the AMEU. I was interested in the story about Jan Loubser and his activities in London. Perhaps he might give here a few more details than Mr. Barnard actually gave us. (Verderaan net grappe).

U.V. UITSTALLING VAN KWIKDAMP EN METAALDAMPLAMPE

Indien die buitenste glasomhulsel breek en hierdie lampe aanhou brand, kan die U.V. uitstraling onder sekere omstandighede gesondheidsgevare inhou. Watter teenmaatreëls word deur gebruikers beoog om dit te verhoed?

U.V. RADIATION OF MERCURY VAPOUR AND METAL HALIDE LAMPS

In the event of the outer envelope being broken and these lamps continue to operate, U.V. radiation is emitted and under certain conditions extended human exposure can cause injury. What protective measures are intended by users?

Mr. J. T. Grundy: Affiliate

This particular question I put down to the Forum purely really as a note of warning. The Americans have discovered ultra violet lights and I can go back many years when mercury vapour lamps first started in 1932/33. The cords of the mercury vapour in effect emit ultra violet light over a pretty wide wave band. So buy an ordinary mercury vapour lamp and you got a lamp that is suitable to give you a tan. The Americans have discovered that these lamps get broken and in rather particular American fashion as from the end of March 1980 every lamp manufacturer of ultra vapour lamps has to put with the lamp a warning as to this effect. If the outer envelope gets broken, you get ultra violet radiation, which I will agree has certain dangers. But the Americans of course have gone a stage further and as from September 1981 it will be the law in the United States that if the outer envelope gets broken, then the lamp must switch itself off in 50? 15? minutes. Technically, I don't make lamps today, but technically there is no particular problem in doing this at all. It is very likely that Europe tends to follow the United States in some ways. It is very likely that this legislation will appear in the United States.

So far as the Republic is concerned I would personally see no difficulty if the Chief Factory Inspector or the AMEU said, look we better come into line with this and we want a range of mercury vapour lamps that switch themselves off if the outer envelope gets broken.

Thank you, Mr. President.

Mr. H. Steyn: SABS

Mr. Questionmaster its true that those lamps are very dangerous. I can talk out of personal experience, but maybe I can tell some more. At the Bureau of Standards we sometimes need an ultra violet source as Mr. Grundy said. And then what we do, is we take a 400 watt mercury vapour lamp, we remove the glass cover and we've got that source. In this particular instance I was working very close to the arc tube for about say 10 minutes, and I got severely burnt. But I don't know whether you get many complaints from burning from ultra violet burns from mercury vapour lamps. Usually they are used in high bay luminaires which is fairly high above the ground and at those dangerous wave lengths the ultra violet radiation is to scatter very quickly. Maybe it will be interesting to hear from other members whether they got complaints from ultra violet burns. Thank you, Mr. Questionmaster.

Mr. W. Barnard: Johannesburg

Mr. Questionmaster, just like Mr. Palser and I always have cross purposes so Johannesburg's lighting engineer, Mr. Yates and Mr. Grundy are always on different wave lengths, in fact it reminds me of a story I was told about two chaps in a pub. And one says to the other one, you know I come from Lichtenburg and the other one says: Oh that's interesting, I come from Kakamas. So the first one said: I am a very prominent citizen of Lichtenburg, you know. And the other one said: You know I am very prominent in Kakamas. Now this is mainly because there are not a lot of councillors present here and its only the councillors of the executive council here today. So the first one says: I am the Mayor of Lichtenburg and the other one says: What a coincidence, you know, I am the Mayor of Kakamas. He said as a matter of fact in Lichtenburg they call me the light of Lichtenburg and the other one said: I give up you win.

Now, Mr. Yates tells me that this problem of Mr. Grundy's is no problem. And I can only agree with him. In our experience we have never had the outer glass break without a lamp breaking. Because invariably the most vulnerable part of the whole luminaire is the lamp, which is the hottest part. And if moisture gets in, the lamp will break before the outer glassware will break. I would like to just read the comments which he gave me. He said this is not a problem which has given any cause for anxiety to Mr. Grundy in Johannesburg as far as streetlighting is concerned. He says in fact in our experience this has never happened. Because breakage is usually caused by rain on the bare lamp or vandalism and if you take a shot gun and have a shot at one of these lamps, you don't break only the outer glassware.

With streetlighting human exposure is usually only for a very limited time and there is not much danger due to radiation. The problem is likely to be more acute in industrial areas, for example sport fields, but if enclosed luminaires are used with glass, the radiation will be absorbed by this glass until the lamp can be replaced. The possibility of lamp damage is also very low in these areas. Thank you.

Mr. D. H. Fraser: Durban

Mr. Questionmaster, medical practitioners who have been approached, cannot say what an injurious dose of radiation is.

Outer broken envelopes are rarely encountered (2 lamps in 15 years).

No outer envelope has ever broken whilst lamp is being replaced by staff. Staff have been instructed that they should in any event not stare at an ARC tube as the U.V. radiation could be injurious to their eyes.

Most street light bowls (Makrolon Acrylic Types) inhibit U.V. radiation transmission to a certain extent ("Fluorescent paints are not affected by U.V. lamps enclosed in acrylic bowls).

The amount of visible light given off from a rare ARC tube is minimal and I consider that the public would soon complain about poor lighting with the result that the lamp would soon be replaced.

Members of the public don't normally stand under lamp posts staring at bare ARC tubes.

TRANSFORMATOR GERAASPEIL

Die probleme verbonde aan distribusie transformators geraaspeil in digbewoonde gebiede en die moontlike oplossings.

TRANSFORMER NOISE LEVEL

The problems associated with distribution transformer noise levels in densely populated areas and possible solutions.

Mnr. C. Vosloo: Kimberley:

Mnr. die Vraesteller, ons het onlangs in Kimberley die probleem gekry dat een van die verbruikers wat in 'n woonstel bo-op 'n substasie bly, dat die geraas van die transformator baie hinderlik is. Ons het ondersoek ingestel dat hierdie transformator se geraas en die vibrasie niks meer is as dié van ander soortgelyke transformators nie, maar dat daar ook heelwat van hierdie probleme is. Party van die woonsteleienaars het die probleem self opgelos deur die inwoners redelik kort te vat en te sê as hulle nie van die woonstel hou nie, moet hulle maar liewer padgee.

Daar was by verskeie geboue in meerdere en mindere mate die probleem. Ons het ook gevind dat al hierdie transformators op fondamente gebou is wat integrale deel van die gebou se struktuur is. Nou, ons eerste probleem is, wat moet mens maak in die omstandighede? Ons het een transformator opgelig ongeveer op 12" kurkpakstukke geplaas, die resultaat was 'n verbetering, maar nog nie goed genoeg nie. As gevolg van die feit dat sulke instrumente redelik duur is en dat jy baie van die verbruikers ongerief aandoen as jy die transformator afsit vir lang tydperke en omdat sulke geraas net enkele verbruikers affekteer en nie groot prioriteit geniet nie, het ons nog nie ver gevorder met eksperimente nie.

Die eerste vraag wat ek graag wil vra, is of die lede hier kan sê of 'n aanbeveling kan maak wat ons kan doen by bestaande installasies. Die tweede is dat ons by die nuwe geboue van die argitekte aanraai om voorsorgmaatreëls te tref waar die substasies wel baie na of deel moet vorm van die gebou. Ek het op hierdie stadium nog nie 'n goeie oplossing gekry nie en dit oorgelaat aan hulle. Kan een van die lede sê watter werklike aanbevelings ons kan doen aan die argitekte om waar die substasies nie ver van die gebou geplaas kan word nie, wat hulle moet doen met die oprigting van die gebou?

'n Derde probleem is, wat is die voorsieningsowerheid se wettige en ook morele verpligting om hierdie probleem op te los? Is dit nie die probleem van die eienaar van die gebou self nie? As ons duidelikheid het oor die vraag, dan kan mens bepaal of die oplossing daarvan 'n prioriteit is of nie. Baie dankie.

Mr. D. C. Palser: Cape Town

In Cape Town we have had very few complaints about noise eminating from distribution transformers. Wherever possible outdoor transformers are sited on public open spaces, away from residential erven. Transformers located inside buildings generally do not give rise to any problems. There is, however, one case on record involving a substation in a block of flats where undue noise was reported in one of the flats on the third floor, some considerable distance away from the transformer. After exhaustive tests the problem was finally eliminated by placing the transformer on a layer of anti-vibration material. The material used was a bonded cork material, known as Tico. An alternative material that has also successfully been used, is three layers of ordinary roofing malthoid, more specifically Bitroid type 60 to SABS 298.

Mr. W. Barmard: Johannesburg

Mr. Chairman, I apologise for coming up every time, but I have so many extras in Johannesburg that I don't know when to stop.

Mr. Chairman obviously the best solution to noise is to provide for it before you build your substation or your enclosure. Because in the design of a transformer the manufacturer has virtually reached an optimum position if you relate noise to cost. If you want to reduce the cost further on the manufacturer's side, it will mean a very substantial increase in the cost of transformers. And therefore we feel the solution does not lie in specifying a low noise level from the transformer manufacturer, but rather to provide for it in planning the substation or enclosure for your transformers.

I think the best is if I just read this. It says the need to locate transformer stations in residential areas to economically provide for growing loads, increasing public's objection to noise and the restrictive legislation combine to make transformer noise a problem. A great deal of work has been done on the solution of it, which has shown that one must anticipate the problem in the planning stage, so that the cheapest and most effective solution can be allowed for in the design. Most manufacturers have done all they can in design and manufacture to give us standard products with an optimum noise level and this is very expensive to improve. The simplest and cheapest and surest continuation measures, provided they have been allowed for, is vibration supports and total enclosure of the tank inside the building made of heavy materials. In fact what we have done on an occasion, we have put cavity walls and we put mine sand in the cavity.

Mr. Questionmaster, the transformer of course, is either forced-cooled by radiators contained in the building and then to the outside by continuation ducts or by national circulation radiators, located outside the building and this principle that I have just mentioned, we have successfully employed right in the centre of Johannesburg for many years. Thank you.

NOODKRAGOPWEKKERS

Wat is die munisipale behoeftes vir die voorsiening van noodkragopwekkers?

EMERGENCY POWER GENERATORS

What are the municipal needs for the provision of emergency power generators?

Mnr. M. W. Odendaal: Alberton

Die voorsiening van noodkragopwekkers. Hulle sê nie watter soort noodkragopwekkers nie. Hulle sê nie of dit "manual"-noodkragopwekkers is nie. Mnr. die Vraesteller, ons op Alberton het 'n baie flinke en ywerige hoof van Burgerlike Beskerming en dit is die Stadklerk. Hy het nou al die probleem aan my gestel wanneer hy sy noodbeplanning doen, dan vra hy hoe gaan ons kos aan die mense voorsien as die krag daarmee heen is? Ons het sulke goed soos bakhuise wat brood aan mense voorsien. Ons het slaghuise wat moet vleis voorsien. Ons het kettingwinkels wat die algemene kruideniersware voorsien en watter plan gaan jy nou hier maak? Op sy aandrang is daar toe vraestelle uitgestuur na al die verskillende instansies op Alberton en uiteindelik toe ons die vraestelle teruggekry het, toe kom dit eintlik daarop neer dat in geval van 'n noodgeval, dat die Stadsraad nou aan hulle noodkrag moet voorsien.

Mnr. die Vraesteller, vanoggend het die President ons ook hier attent gemaak op die Suid-Afrikaanse telekommunikasie en elektrise kragvoorsieningsgesag en in Engels SATEPSA en dit is in die lewe geroep om doeltreffende optrede en koördinasie van al die instellings wat krag voorsien, te verseker. Nou het ons dan ook 'n woordvoerder van Evkom hier gehad wat ons meegedeel het dat daar een van die dae ook 'n vraestel gaan uitgestuur word aan groot voorsieners van krag. Nou dit het my nou skielik te binne geskiet dat as ons wat krag voorsien, in ons eie dorpsgebied die versoeke kry van ons kliënte, as ek dit so mag noem, om noodkrag aan hulle te voorsien, kan ons dan nie ook aanspraak maak dat Evkom op een of ander wyse noodkrag aan ons kan voorsien nie. Dit is gemeld dat indien sabotasie kan plaasvind, dit op 'n baie gesofistikeerde basis kan plaasvind, m.a.w. ons kan dan aanneem dat daardie invoerpunte van ons tot niet sal wees. Nou het ek al gelees dat in Amerika in gebiede wat onderhewig is aan orkane, dat wanneer so 'n orkaan deur 'n gebied trek, dan bly daar niks oor nie en dat daardie privaat voorsieningsinstansies wat daar is, het dan sulke mobiele kragvoorsieners selfs aan die orde, ek praat onder valse indrukke, maar ek verbeel my dit gaan tot by 20 mW, sleep hulle die goed daar rond en voorsien krag aan die hele wêreld daar.

Ek weet nie, mnr. die Vraesteller, ek los die gedagte in die midde daarso. En om terug te kom na miskien die werklike probleem. The question arises to whom a local authority must supply power during a case of emergency and consequent interruption which could be at the main Escom supply point. In the first instance, this will depend on the capacity of generators available and whether stationary or mobile. Now in the case of Johannesburg, they've got their load shedding generators of 30 mW, now that is also an idea Mr. Quizmaster, which may be considered by local authorities of also acquiring some load shedding equipment and this can be used in an emergency. But the normal local authority usually only has a set of maybe a couple of sets of the order of say 50 kVA, 200 kVA and that is hardly sufficient to supply any consumer during a total black-out and it is my contention that charity begins at home with the result that any such available generations will only be used to supply the needs of the local authority itself, such as power to its workshops and also maybe to emergency housing. I would be very pleased if my colleagues could give me some more ideas to inform my Town Clerk. Thank you, Mr. Quizmaster.

Mnr. P. J. Botes: President

Ek dink dit is 'n baie belangrike vraag daardie, maar ek dink dit is 'n kwessie dat die Plaaslike Bestuur sal moet besluit hoe ver hy daaromtrent sal gaan. Ek kan net noem, 'n baie belangrike aspek is natuurlik dat noodvoorsiening gedoen moet word aan riool- en waterpompinstallasies. Daar moet ons definitief dink aan noodkraginstallasies. Ek weet nie of baie van u dit het nie. Ek dink daar is dit meer 'n geval dat dit permanent geïnstalleer moet word. Dit is wat ek van plan is vir Roodepoort. Daar is bv. een rioolpompstasie wat net 'n halfuur kan loop sonder krag, dan is daar groot probleme. Dit is 'n absolute noodsaaklike diens in daardie opsig. Maar sover dit privaat verbruikers betref, ek weet nie, 'n deel van SATEPSA sal dan in werking kom. Maar as hulle dan glad geen krag kan voorsien nie, dan weet ek nie, maar daar moet besluit word wat dan gedoen gaan word. Dit moet miskien besluit word op die vlak van SATEPSA, ek weet nie. Ek weet nie of mnr. Walter iets in die verband wil sê nie.

Mr. W. Walter: ESCOM

Mr. Questionmaster, I can't really answer the problem from SATEPSA's point of view. As I understand SATEPSA's function is to set with the assistance of the user, priorities throughout the Republic for power under emergency conditions. And therefore the question of whether a bakery gets, is classed as a top priority consumer, in the event of total loss of major loss of generation or transmission capacity, I honestly don't know what the answer is to that. But I would like to and certainly in Escom we consider this in our reticulation areas, with a point of view of what is the longest outing that you are likely to be faced with as far as a local supply interruption is concerned. And what steps have been taken to be able to put in if necessary running 11 or 33 kV cables along the pavement, along the gutters, running temporary overhead lines. Escom for example has developed a number of emergency transmission line structures which do not require standard foundations, they cannot in all cases take the full conductor loading, wind and weight loading, but there are temporary structures available, which will enable us in comparatively short time. I am talking in terms of 24, 30 odd hours to restore virtually any transmission line providing of course that you don't lose many miles or many kilometres of such line. But I believe that there are steps that each local authority can take to be self-sufficient to restore supplies on a limited basis to those essential consumers, such as bakeries, fruit dispensing organisations. So I believe that the answer is primarily in the local authorities' own planning as what temporary supplies, by means of temporary overhead or cable runs, they can give rather than looking for SATEPSA or Escom to be able to answer the question of who is the priority, whether the bakery gets the supply or the butcher gets the supply. Thank you, Mr. Quizmaster.

Mr. K. Murphy: Somerset-Wes

Mnr. die Voorsitter, u weet Somerset-Wes is geleë aan die hange van die Helderberg en die Hottentotsholland, so ons water moet gepomp word. Ons het om dié rede 'n 150 kVA of ja kW-noodkragopwekker, 'n mobiele eenheid, wat kan beweeg word na die verskillende pompstasies in 'n noodsituasie. Maar ek dink my vrou het die regte ding, wat die algemene verbruiker betref, en dit is gedagtig aan Murphy se wette, het sy altyd 'n pak kerse en haar gasstofie gereed. Dankie.

Mr. D. C. Palser: Cape Town

Municipalities are becoming increasingly dependent upon Escom for their generation needs. Even the larger municipalities, such as Johannesburg, Pretoria, Cape Town and Port Elizabeth, that have their own power stations, are also now more reliant than ever on Escom.

But as we are all only too well aware, the Escom supply is prone to failure at times! To cover such situations, Cape Town, some eight years ago, installed a 40 MW gas turbine for peak lopping and emergency usage and has now on order a further unit of 50 MW. The cost of this unit, as a matter of interest, was a most reasonable R110 per kilowatt.

It is probably economic and acceptable to cover about 20% of your system maximum demand by means of emergency standby plant. This is certainly the case for the larger municipalities, but maybe difficult to justify in the case of the smaller municipalities.

With 20% cover at R110 per kW and assuming a life of around 20 years at current interest rates, this represents an incremental cost of around R2,50 per kilowatt annually. Assuming an average admd of around 3 kVA per consumer, this represents an extra cost of about R7,50 per annum per consumer. On an average domestic consumer's bill of, say, R250 per annum, this represents an increase in cost of about 3% on his electricity bill. This surely is a price most consumers would willingly pay for the additional security it would afford them. It may be looked upon as a form of insurance.

Mr. W. Barnard: Johannesburg

Mnr. die Vraesteller, ek is bly om te sien dat ek en mnr. Palser nou weer hier heeltemal teenstrydig is. I was getting worried about this on too many things. But in the first instance I would like to solve Mr. Odendaal's problem. I think his solution is to fire the Town Clerk. But speaking quite seriously, first of all I would like to explain to you the purpose of Johannesburg's gas turbines. It is basically there to replace loss of our generating capacity. Now we have at present time, got 180 mW of gas turbine plant. Already today our import from Escom is of the order of 250 mW, so should we have to lose our Escom supply, we could not replace it with gas turbines. Primarily the purpose is this that if you lose a boiler or more than one boiler and the boiler is going to be off for a couple of hours, you can at very short notice replace that loss of capacity with these gas turbines. One must appreciate the fact that we could not at a moment's notice, increase our imports from Escom by something like 200 mW. They have not provided for it, its not their function and its not the intention to provide these emergency supplies.

Mr. Odendaal is entirely incorrect when he talks about peak lobbing plant. Peak lobbing is a fringe benefit that we get on this plant in order to pay for it, but primarily it's there as emergency plant in case of the loss of capacity. Now my contention is this, that where you get local authorities that have got no generator facilities, there is no capacity that they could lose and quite candidly I cannot see the justification for any of them putting in any emergency generating power. In Johannesburg we will allow certain consumers to put in their own generating plant and I think as we all are aware, if this plant exceeds 600 kVA, they have got to get the approval from the Electricity Control Board. Below 600 they can put it in without any authority. We laid down some very stringent requirements, mainly from a safety angle that will not become paralleled with our own system, I certainly would not allow them to use emergency generating plant for peak lobbing purposes, because from that we would suffer a considerable loss of income. We expect to get our income from diversity between consumers. But quite candidly, if you are talking about SATEPSA, we are talking about a national emergency. We are talking about a state of real emergencies throughout the country and surely we are not going to talk about maintaining supplies for bakeries. I will say the main supply that we are going to maintain, and I say this in committee, is probably to armscor, and the hospitals but in Johannesburg the hospitals have all got their own emergency generating plant, because we have agreed to it. It is essential that they have a guaranteed emergency supply. But no way can I accept that it is the local authority's responsibility to ensure that a consumer will have a supply under emergencies, even if they haven't got a generating facility available.

INSPEKSIEGELDE

Behoort plaaslike owerhede nie inspeksiegelde te hef vir alle toetse wat uitgevoer moet word van 'n elektriese installasie nie?

Mnr. J. E. Heÿdenrych: Middelburg, Tvl.

Mnr. die Vraesteller, hierdie is eintlik 'n finansiële vraag. Want dit is tog 'n beginsel wat elke voorsiener baie nou raak. Die Staat plaas d.m.v. artikel 19 van die Wet op Elektrotegniese Draadwerkers en Aannemers 'n verpligting op die voorsieners van elektriese krag om alle draadwerke binne daardie voorsieningsgebied te laat ondersoek, te toets en goed te keur voordat sodanige draadwerk met die voorsiener se toevoer verbind mag word. Die Wet bepaal dan verder dat niemand behalwe die houer van 'n Registrasiesertifikaat draadwerk mag doen nie, en die woordomskrywing van draadwerk sluit in die toets van enige kabel, geleidraad ensovoorts. Dit beteken dus dat die persoon wat die voorsiener vir die doel nomineer, om draadwerk te ondersoek, in besit moet wees van 'n bedradingsertifikaat. Die koste van die instandhouding van so 'n inspektoraat vir 'n plaaslike owerheid is aansienlik as mens al die bykomstige uitgawe daaraan verbonde in ag neem, soos die salaris, kantoorhuisvesting, administrasie, toetsapparaat ensovoorts. Konserwatief bereken, skat ek dit op minstens R15 000 per inspekteur per jaar. In meeste gevalle in plaaslike owerhede en ander elektrisiteitsvoorsieners, word hierdie koste gefinansier uit die inkomste wat van die verkoop van elektrisiteit verkry word. Hierdie beginsel kom daarop neer dat die algemene verbruikers betaal vir 'n diens wat eintlik nie by hulle tuishoort nie, omdat dit net op nuwe aansluitings en toevoegings tot aansluitings betrekking het. Indien die beginsel dan toegepas sou word dat die instansie wat die diens gebruik, daarvoor moet betaal, dan behoort 'n stelsel van inspeksiefooi gehef te word soortgelyk aan bouplanfooie t.o.v. siviele werke gehef word. Ongelukkig bepaal artikel 17.8 van die Transvaalse Standaardelektrisiteitsverordeninge wat geen heffing gemaak mag word vir die eerste inspeksie en selfs die daaropvolgende inspeksies nie. Die vraag ontstaan dus nou, mnr. die Vraesteller, of die tyd nie ryp is dat dit gebiedend noodsaaklik is dat ons op hierdie stadium moet besluit dat alle toetse wat ingevolge die Wet op Draadwerkers uitgevoer moet word, van die persoon verhaal moet word ten behoewe van wie die toetse uitgevoer moet word. En indien dit dan so is, indien hierdie vergadering dit so bevind, dan moet hierdie Vereniging die nodige stappe doen om aan hierdie beginsel uitvoering te gee.

Dankie, mnr. die Vraesteller.

Mr. C. Adams: Port Elizabeth

Mr. Questionmaster, I must agree entirely with Mr. Heÿdenrych. My own feelings are exactly the same, that the person that requires the service should pay for it. It might be of interest to the meeting that we have been charging these in P.E. for about a year. We were lucky we had our own by-laws and we could write this in and the fees have been approved by Province. Thank you.

INSPECTION FEES

Should local authorities not charge an inspection fee for all the tests to be carried out on an electrical installation?

Mr. J. McKay: Cape Provincial Administration

Mr. Quizmaster, I think it should be realised that the cost of the inspector is paid for by the consumer in any case. Whether its been by little bits and pieces of R5 here and R10 there or R1 000 per inspection or whether it has come out of tariff, it makes no difference. The fact of Mr. Adams' statement that a person, who wants the service, should pay for it, I think reflects against the municipality. Because he is the one who wants it, the consumer doesn't want it. He can get the service, he can get the person who installs it and tests it, but the municipalities should pay for it themselves and every inspection, not just the first one of subsequent ones. Thank you.

Mr. K. Robson: East London

Mr. Questionmaster, Mr. McKay is not correct actually. Because there are many consumers that request an inspection of the installation. And we find increasingly so now with older houses. But in East London it has become the practice for an inspection report before any sale. And we charge for that. So perhaps one can argue about whether there are certain obligatory inspections and for the first installation is the responsibility of the supplier. But for any requested inspection I think it is quite correct that the consumer should pay for it. Thank you.

Mnr. P. J. Botes: President

Ek sien die voorsiening van 'n inspektoraat vir die veiligheid van die publiek. En die koste verbonde om 'n klomp inspekteurs daar te stel, is in vergelyking met die totale inkomste wat ons vandag het in 'n elektrisiteitsrekening, absoluut minimaal. Dit is geen noemenswaardige inkomste sover dit my aanbetref nie. Dit is 'n diens wat jy aan die publiek lewer. Ek moedig die publiek aan om 'n inspeksie aan te vra, as hulle voel dit is onveilig, of as hulle bykomstige bedradingswerke wil doen. En ek verskaf dit geheel en al gratis. En ek is trots daarop en ek dink dit behoort die uitgangspunt te wees en nie altyd te vra vir 'n bykomende inkomste nie. Dankie.

Mr. C. Adams: Port Elizabeth

Mr. Questionmaster, I just want to correct one aspect where Mr.

McKay was not quite correct. The person who inspects the installation must be in the employ of the supplier. We did look at the question of authorising contractors to do inspections, but there are legal problems and we cannot do it. So we felt that supply authorities are obliged by law to do this testing and this was not fair to the bulk of consumers who don't require the tests and perhaps to pay the costs. So the municipalities are obliged to do this themselves and that is why we charge the fee. Thank you.

Mnr. Heÿdenrych: Middelburg, Tvl.

Mnr. die Vraesteller, net voordat ek kommentaar lewer, wil ek net 'n vraag vra aan die owerhede wat wel fooie het, wat is die orde van die fooie? M.a.w., wat is die bedrag wat hulle het vir 'n inspeksie? En dan wil ek net met u, mnr. die President, verskil in verband met die beginsel dat wanneer die veiligheid ter sprake is, u nie fooie moet hef nie. U sal vind in u eie onderneming dat u wel motorkarre toets vir veiligheid en u vra wel 'n fooi daarvoor. Dankie mnr. die President.

Mnr. P. J. Botes: President

U weet elektrisiteit is gevaarlik en deur 'n fooi te vra, die oomblik wanneer jy 'n fooi vra, dan wil niemand daarvan gebruik maak nie. En daarom vra ek nie 'n fooi nie. Nou maak die mense gebruik van daardie dienste en ek dink dit is 'n noodsaaklike diens wat ek lewer. Dankie.

REGISTRASIE VAN ELEKTROTEGNIESE AANNEMERS

Bestaan daar 'n behoefte aan 'n eenmalige registrasie van Elektrotegniese Aannemers op 'n nasionale vlak, soortgelyk aan die Britse Stelsel vir die aannemersbedryf teenoor die jaarlikse registrasie deur individuele voorsieningsowerhede ingevolge bestaande Suid-Afrikaanse Wetgewing?

REGISTRATION OF ELECTRICAL CONTRACTORS

Is there a need for a once only registration of Electrical Contractors on a national level similar to the British System for the electrical contracting industry as opposed to the annual registration by individual supply authorities, in terms of present legislation in South Africa?

Mnr. E. de C. Pretorius: Potchefstroom

Mnr. die Vraesteller, dit is jammer dat daar geen verteenwoordiger van die EKV hier teenwoordig is om oor die saak te praat nie. Die suggestie wat hier gemaak word, ek dink dit is 'n goeie suggestie, maar wat my betref, is dit die tweede beste suggestie. Ek kom net tot by die beste een, myns insiens. Mnr. die Voorsitter, myns insiens dien dit absoluut geen doel om 'n elektrotegniese aannemer te registreer nie. Ek dink die registrasie van elektrotegniese aannemers behoort heeltemal geskrap te word. Dit is heeltemal voldoende as, ek sê nie dat die werk moet gedoen word deur 'n ongelisensieerde draadwerker nie, dit moet altyd nog gedoen word deur 'n gelisensieerde draadwerker as daar enige draadwerk gedoen word. Maar hoekom moet daardie persoon geregistreer word as draadwerker? Ek het nou 'n klip in die bos gegooi en ek sal graag wil weet hoe die ander mense daaroor voel. Dankie.

Mnr. G. Weich: Hoofinspekteur Fabrieke

Ek wil net een moontlike misverstand uit die weg ruim. Amptelik is daar natuurlik niks daaraan dat die Wet gestaak sal word nie. That is wishful thinking. Elkeen van ons het ons eie versugtinge wat die Wet betref, maar alvorens die Wiehahn-kommissie waarvoor ons al etlike jare wag om sy verslag uit te bring, nie sy verslag uitbring nie, sal ons nie weet van hulle besluit nie. Ons weet dat verskeie voorstelle aan hulle gemaak is i.v.m. die Wet. Ek weet ook, ek het dit nie gesien nie, maar ek kan raai dat daar teenstrydige aanbevelings gemaak is, bloot om die feit dat daar gevestigde belange by is. Maar ons sal moet wag en sien wat hulle oor die saak sê. Nadat hulle hulle sê gesê het, sal ons moet hoor wat die Regering te sê het oor die saak. Derhalwe kan ons nie noual spekuleer of die Wet gewysig gaan word, aldan nie. Oor die registrasie van kontrakteurs kan ek nie heeltemal saamstem dat daarmee weggedoen kan word nie. Kan ek dit liewers so stel, ek glo nie dat 'n mens die beheer oor draadwerk heeltemal kan omverwerp nie. En as jy wil beheer uitoefen oor draadwerk wat gedoen word, dan moet jy weet wie dit doen en waar dit gedoen word. En om dit te weet, moet jy weet wie jou kontrakteurs is. Derhalwe kom jy terug by een of ander vorm van registrasie. So 'n registrasie na alles is tog net 'n kontrakteur wat hom kom aanmeld en sê: ek kom werk in jou fabriek, mag ek dit asseblief doen? En jy sê vir hom: ja. M.a.w., jy weet hy werk in jou afdeling. Jy weet ook dat as hy werk doen wat hy nie moes gedoen het nie, dat jy volgende keer as hy kom vra, dit kan weerhou. Dus, ek glo nie mens kan so maklik sê dat jy gaan wegdoen met die registrasie nie, as jy nog beheer oor draadwerk wil behou. Kom ons gestel dat ons die stadium sal bereik waar ons moontlik nie meer met die Wet op Elektrotegniese Draadwerkers en Aannemers te doen het nie. Ons werk maar net, ons sê as dit sou gebeur, dan vrees ek kan ons nie summier die beheer oor draadwerk los nie. Dit sal 'n te rewolusionêre stap wees. Ons is al gewoond daaraan dat dit beheer word, maar natuurlik, ons moet dit op redelike perke beheer. Soos dit nou bestaan, is dit prakties onmoontlik om uit te voer. Daar word verwag van die voorsiener van krag om elke stukkie draadwerk wat gedoen word, te inspekteer. Ons weet almal dit is fisies onmoontlik. Ons weet dat die Wet elke dag in dié opsig gebreek word en ons maak ons oë toe daarvoor. As ons sou aandring dat dit wel moet gedoen word, sal dit chaos veroorsaak. Om kontrole heeltemal op hierdie stadium te los, is ondenkbaar. Daarom kom ons maar weer terug na 'n mate van registrasie van kontrakteurs. Nou word daar gepraat van 'n eenmalige registrasie. Dit is so dat die Wet op die oomblik vereis dat dit elke jaar gedoen moet word. Dit is natuurlik ingeskryf destyds toe die Wet gewysig is, ek weet nie op aandrang van wie nie. Dit het 'n voordeel daarin dat elke jaar of op gereelde tussenposes registrasie hersien word, dat jy dit kan weerhou vir wie jy dit nie wil gee nie, mits daar goeie redes daarvoor is. Aan die anderkant weerhou dit nie 'n voorsiener om 'n kontrakteur outomaties sy registrasie te hernu nie. Die gedagte wat hulle in Engeland het, het niks te doen met statutêre registrasie nie. Dit is 'n vereniging van kontrakteurs, verbruikers en ander mense wat bymekaar gekom het en besluit het sekere kontrakteurs wat voldoen aan sekere vereistes, dat hulle geregistreer moet word en op 'n lys plaas, sodat die publiek kan sien na wie hulle kan gaan om goeie werk gedoen te kry. Met die gevolg dat in Engeland is daar ook 'n vereniging van elektrotegniese kontrakteurs, maar almal van hulle is nie noodwendig geregistreer by hierdie besondere Raad nie. Maar om eenmalige registrasie te hê, dink ek nie sal heeltemal werk nie.

Mnr. B. Boshoff: Vanderbijlpark

Mnr. die Vraesteller, ek wil tot 'n baie groot mate met mnr. Pretorius saamstem. U weet voor 1964 moes draadwerk gedoen gewees het deur 'n persoon met 'n lisensie, maar dit was nie nodig dat hy registreer as kontrakteur nie. Nou as ek Vanderbijlpark as voorbeeld neem, en ek dink dit geld vir baie myndorpe en industriële plekke, het jy talle mense gekry wat klein werkies wil laat doen, en het 'n vriend van hom met 'n draadwerkerslisensie in die hande gekry, het gekom en die vorms ingevul, hy het die werk heeltemal wettig gedoen en laat toets. Noudat hy moet laat registreer as kontrakteur, kan daardie man nie as kontrakteur registreer nie, hy kry moeilikheid met sy werkgewer, want hy het dit in sy privaattyd gedoen en daar is 'n klomp ander probleme. Ek is definitief nie oortuig dat daardie werk nie nog gedoen word nie. Die enigste verskil is dat ons nie nou daarvan weet nie. Die ander aspek is die beheer wat ons werklik oor kontrakteurs het, is werklik minimaal. Ek het 'n kontrakteur se lisensie geskors en twee dae daarna werk hy met sy hele personeel vir 'n ander kontrakteur. Ek het een by die polisie aangekla en hy het absoluut geen notisie daarvan geneem nie. So ek weet nie of ons nie moet teruggaan na wat ons gehad het voor 1964. Dankie.

Mr. D. H. Fraser: Durban

Comparison between the British and SA systems of registration of electrical contractors, is difficult because of differing legal requirements. There is no licencing of electrical wiremen in Britain and registration with the National Inspection Council for Electrical Installation Contracting (NICEIC) is on a voluntary basis, but admission is subject to passing strict tests of competence as an electrical contractor. The Supply Authority does not conduct in-depth inspection and testing of the work of the contractor who has to accept full responsibility for compliance with the wiring regulations. Persons carrying out wiring work, do not have to be licenced or be registered with the National Inspection Council.

With the present legislation in SA ofcourse it would not be possible to copy the British system. In my view it would be dangerous to drop the SA system of licensing all individuals carrying out wiring work.

Regarding the question of annual registration of Contractors with the Supplier in whose area work is undertaken, it is appreciated that this can be onerous for Contractors working in several different areas. It is however necessary in my opinion for a supplier to be aware of all the Contractors undertaking wiring work in his area so that the correct procedures can be followed to ensure co-ordination of inspection, testing and connection of the installation. The Supplier must be able to communicate with the contractor to make appointments, discuss queries etc. It is difficult to see how the present system of registration can be dispersed with, but I do believe that Suppliers must make it as easy as possible for Contractors to register and that the registration fees should surely cover costs of administration. The most satisfactory solution would probably be to incorporate the procedure and fees for registration in the relevent legislation.

ONBALANS IN MEERFASIGE MOTORSTROOMBANE

Glyringmotors beveilig met termiese relais is sensitief teenoor enkelfase en onbalans in die stroombane en skakel uit na 5 tot 10 minute. Die variasie in die fasespanning is gering.

Het lede soortgelyke probleme ondervind en watter oplossing kan aanbeveel word, sonder om die uitklinkfasiliteit van die relais te oorbrug?

UNBALANCE IN POLY-PHASE MOTOR LINE CURRENTS

Slipring motors protected by thermal relays are sensitive to single phasing and unbalanced line currents and the machines are tripped after 5 to 10 minutes running. The phase voltages only vary slightly.

Have members experienced similar problems and can they suggest a possible cure other than overriding the tripping feature of the relay?

Mr. K. H. D. McMillan: Umtata

Mr. Questionmaster, this has arisen since we got new pumps for our waterworks and we have found, although the pumps are identical, both of them had these imbalanced currents which caused nuisance tripping of the thermo relays. I think the reason for it is probably because you are on the end of a very very long transmission line, and we get negative phase sequence effects coming to it. As a matter of fact, as soon as our local hydro-generation has come in, because we are having this re-occurring and I'll be interested to see whether our problems seem to be solved. I'll be interested to know whether other consumers have had this trouble on their systems. Thank you.

Mr. Jules von Ahlften: Questionmaster

Thank you, Mr. McMillan. Gentlemen, that brings us to the end of this Members' Forum and I would like to thank you all for your valuable contributions.

Mr. John Morrison: Questionmaster

Thank you, gentlemen, for your support and contributions.

Mr. P. J. Botes: President

May I thank you also for your contributions and for the fact that all the questions were put. Please show your appreciation in the usual manner to the good leadership of our two Questionmasters, Mr. John Morrison and Mr. Jules von Ahlften.

DANKBETUIGING EN AFSLUITING:
VOTE OF THANKS AND CLOSURE :

Mnr. P. J. Botes: President

Mev. Odendaal, ons is bly dat u en die dames weer by ons aangesluit het. Dit is vir my 'n voorreg om nou net gou die bedankings te doen en dan die afsluiting te doen.

Die daarstelling van 'n vergadering van hierdie aard verg baie harde werk. Wanneer mens aan die einde van so 'n sessie kom en jy moet dankie sê, is dit met weemoed. Weemoed omdat jy moet afskeid neem van 'n span. 'n Span wat alles wat hier plaasgevind het, tot die fynste detail georganiseer en beheer hét. Diegene wat noual aan die spits gestaan het met reëlings van so 'n byeenkoms, sal met my saamstem dat die mense van Welkom wonders verrig het. Gesien ook in die lig dat mnr. Johan Botha nog nie 'n VMEO-vergadering of -konvensie bygewoon het nie, het hy homself goed van sy taak gekwyt en as 'n teken van ons waardering, wil ek net graag aan hom 'n das oorhandig.

Ek wil ook graag Johan vra om ons dank oor te dra aan sy personeel. Hulle het baie hard gewerk vir hierdie vergadering.

Ons dank nogmaals aan die Burgemeester en Raadslede van Welkom vir die uitnodiging en die gasvryheid wat ons geniet het. Die braai sal ons baie lank onthou.

Aan die Burgemeestersvrou ons besondere dank dat sy die dames getrakteer het en vir al die reëlings. Baie dankie, Mevrou. Ons waardeer dit.

Aan die Stadsklerk, mnr. Van Zyl, ons dank vir sy hulp en bystand met die organisasie.

Aan die Hoofde van Departemente vir hulle samewerking.

Mnr. Steyn van die Parke en sy personeel vir die versiering van die saal en die hulp by die braai. Baie dankie, mnr. Steyn.

Ook aan die Stadsingenieur en sy personeel vir hulle groot bydrae met die regmaak van die sale.

Ook met groot waardering, ons dank aan die volgende persone en instansies:

Vir die blommerangskikkings, mevroue Smit en Gouws, baie dankie. Dit was mooi gewees.

Mev. Louis Smith wat die lêers en inligtingskantoor behartig het. Baie dankie, Mevrou.

Mnr. Rossouw, hul-sekretaris en mnr. Kruger. Baie dankie vir die stille werke. Baie dankie vir die baie harde werk.

Mnre. Snyman en Van der Merwe, die klank-operateurs, dit lyk vir my hulle het nie baie probleme gehad nie. Hulle sit nou nog daar lekker en ontspan. Baie dankie vir die werk, nietemin.

Aan Alwyn Rohrs, Skakelbeampte en mej. Tersia Swanepoel, baie dankie vir alles wat hulle behartig het vir ons.

The following affiliates for their sponsorships:

Messrs. Hubert Davies Electrical Engineering for the convention folders. Thank you very much for the quality folders.

Messrs. ASEA Electric Company and Messrs. Brown Boveri for the excellent lunches provided these two days.

Once again I wish to express my sincere appreciation towards the speakers who delivered such high standard papers, Messrs. Forsyth, Fortmann, Salomons and Sollergren. Thank you very much.

To Messrs. John Morrison and Jules von Ahlften, thank you once again for the leadership at the Members' Forum. All the questions are dealth with and this is the first time this has ever happened. Thank you very much. Also to the discussion leaders and all of you who have made invaluable contributions and a special word of thanks to Messrs. Prins and Bowen, coming to this Technical Meeting to say a few words. Thank you very much. We appreciated it.

My thanks to the President Elect, Mr. Dennis Fraser, for his support and will he kindly give his wife good wishes for a speedy recovery.

My dank ook aan lede van die WNNR, SABS, Departement van Mannekrag en Benutting, mnr. Weich, baie dankie vir u bydrae.

Ook aan die Evkom-personeel, in besonder mnr. Walter en ook sy goedgunstige vergunning dat mnr. Bowen ons kon toespreek. Baie dankie.

Laaste maar nie die minste nie, aan Bennie van der Walt, ons Sekretaris. Baie dankie vir nog 'n vergadering welgedaan. Baie dankie Bennie.

Ten laaste vra ek dan my vrou, Urtney, om na vore te kom en 'n ruiker te oorhandig aan die Burgemeestersvrou, aan mev. Botha en aan mev. Louise Smit. Urt, kom na vore asseblief.

Ek vra nou mev. Louise Smit om 'n ruiker te oorhandig aan mev. Botes.

Dames en here, dit is my bede dat u 'n veilige reis terug sal hê en ons sien u volgende jaar in Durban. Ek verstaan Dennis Fraser het 'n paar woorde.

Mr. D. H. Fraser: Durban

Madam Mayoress, Mr. President, ladies and gentlemen, I am sure that I speak for all that are present here this afternoon, when I say that it is with a sence of regret that this 8th Technical Meeting has come to a close. That has been the most rewarding two days from all points of view. The technical contents of the papers and the contributions to the discussion of these have been of a very high standard and when published, will form a valuable reference for all municipal electrical engineers. Equally valuable has been the social content of the programme. The opportunities which these meetings provide for informal exchange of views and fellowships, are invaluable.

In short this has been the most successful technical meeting. Credit for this must undoubtedly go to our President, who has obviously devoted a great deal of time and talent in preparation of the programme, choice of speakers and many other details that have to be taken into account. He has handled the meeting with courtesy and tact, while still keeping us all under firm control, thereby ensuring that we kept to schedule. Mr. President, please accept our sincere congratulations on a job well done and our thanks for the efforts you have put into this function on our behalf. Thank you.

Ladies and gentlemen, forgive me if I take this opportunity to get in a quick commercial. Our Secretary has quoted me a much more economical rate than SATV. My announcement concerns the 1981 Convention in Durban. The dates have been fixed. Will you make a note of these to ensure that you don't allow any other business to interfere with the pleasure which I hope that you will have in visiting our fair city? The convention will take place in the Elangeni Hotel from Monday, 4th to Wednesday 6th of May 1981. We have made a block booking at the hotel and hope that as many as possible will stay at the conference venue. This does so much to generate the right spirit of fellowship which contributes to the success of any convention. Please therefore ensure that you make your reservation at the Elangeni without delay. Indicating that you are an AMEU delegate. We do look forward to seeing you in Durban and will do our best to ensure that your visit is worthwhile. I suggest that you make it really worthwhile by taking the weekend before the meeting to relax and get into the mood and staying on for a few days to recouperate after the event.

Mr. President, once again I want to compliment you on the success of this technical meeting and extend to you and Urtney our very good wishes for your remaining year in office.

Mnr. P. J. Botes: President

Thank you, Dennis, for your kind words.

Hiermee dan verklaar ek die 8ste Tegniese Vergadering van die VMEO as afgesluit.

I declare this 8th Technical Meeting of the AMEU closed.

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Administrasieraad, Wes-Rand.
Alberton, Tvl.
Aliwal North, CP.

B

Barberton, Tvl.
Benoni, Tvl.
Bloemfontein, OVS.
Brakpan, Tvl.
Burgersdorp, KP.
Beaufort-Wes, KP.
Bethal, Tvl.
Boksburg, Tvl.
Bredasdorp, KP.
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Bethlehem, OVS.
Bothaville, OVS.
Brits, Tvl.

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Carolina, Tvl.
Carletonville, Tvl.
Cathcart.
Ceres, KP.
Carnarvon, KP.
Cradock, KP.
Clocolan.

D

De Aar, KP.
Duiwelskloof, Tvl.
Delmas, Tvl.
Dundee, Natal.
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East London, CP.
Ermelo, Tvl.
Evander, Tvl.
Edenvale, Tvl.
Eshowe, Natal.
Empangeni, Natal.
Escourt, Natal.

F

Fochville, Tvl.
Fort Beaufort, CP.

G

George, CP.
Gobabis, SWA.
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Germiston, Tvl.
Gordonsbay, CP.
Greytown, Natal.
Glencoe, Natal.
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H

Heidelberg, Tvl.
Henneman, OVS.
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Johannesburg.
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K

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Kenhardt, KP.
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Kokstad, Oos-Griekwaland.
Kroonstad, OVS.
Keetmanshoop, SWA.
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Komgha, CP.
Krugersdorp, Tvl.
Kempton Park, Tvl.
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Knysna, KP.
Koppies, OVS.
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Lydenburg, Tvl.
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M

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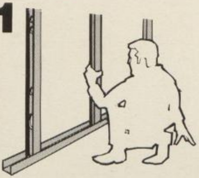
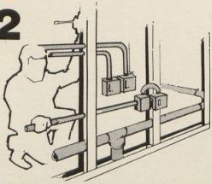
1



1. Once the carpenter (or drywall erector) has erected the framework...

2



2. The abundance of working space and the elimination of chasing make the plumber and electrician's task a joy. Its convenient and time saving, so...

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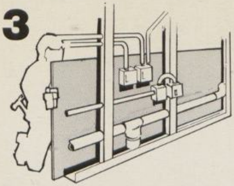
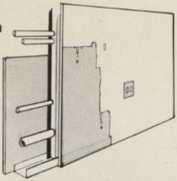


3. With the pipes and conduiting in place, the drywall erection team apply the Rhinoboard cladding to the framework,

4



4. Leaving the electrician and plumber to provide the finishing touchers in the form of plugs and cover plates before the painter decorates the finished wall.

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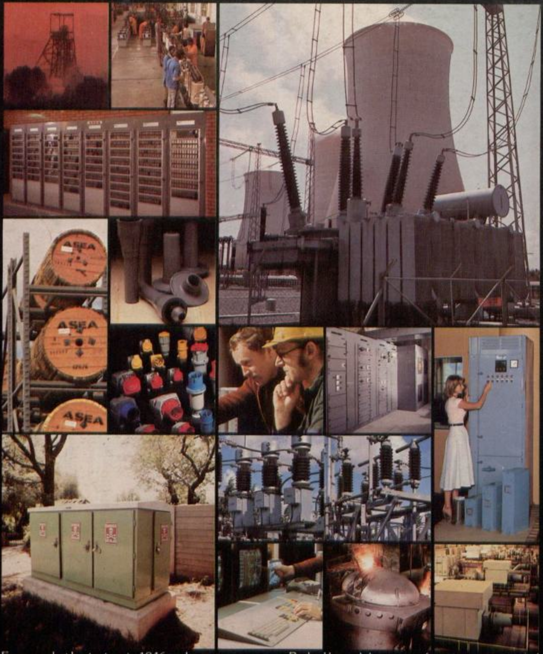
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