KEMBLA

OVERHEAD CONDUCTORS IN AUSTRALIA

METAL MANUFACTURES LIMITED
TECHNICAL REPORT

Metal
Manufactures
Limited
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TECHNICAL DEPARTMENT

SUMMARY:

A short commentary is provided of the development of overhead conductors in Australia since 1923. The Australian Standards are listed and compared with their overseas counterparts, and operating problems peculiar to Australia are mentioned.

The developments in the use of aluminium alloys are traced, together with more recent work on sags, tensions and creep.

The current position in Australia relating to probabilistic designs based on statistical information of conductor properties is outlined.

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1.0 HISTORY

The high voltage transmission of electric power in Australia, as elsewhere in the world, initially used stranded copper conductors. It was soon recognised that the superior strength-to-weight ratio of steel reinforced aluminium conductors provided a more economical solution for the transmission of power over long distances. The first such conductors manufactured in Australia were made at Port Kembla in 1923 (Reference 1)

The rapid expansion of the high-voltage electricity grids in the years following the Second World War was carried out almost exclusively using steel reinforced aluminium conductors (ACSR). The high tensile steel core wires were galvanised to prevent corrosion, and were further protected with a temperature -and weather-resistant grease before the aluminium wires were laid up. The aluminium was a high purity, electrical conductor grade material, now designated as alloy 1350.

Copper is now used only to a very limited extent, usually under very special circumstances. Its well known resistance to atmospheric corrosion is exploited in industrial-marine environment such as Port Kembla, where a transmission line passing through the BHP Steelworks, originally erected in copper in 1938 and unaffected by the environment, was upgraded to 37/.103" copper strand in 1968. In Darwin a line planned to operate at up to 120°C was constructed in 1974, using 7/3.93 mm hard drawn silver-bearing copper, and successfully withstood the devastating cyclone later the same year.

1.1 Alloy Development

In many overseas countries, the traditional use of ACSR for high voltage transmission lines has been coming under increasing pressure from all aluminium alloy conductors (AAAC). The aluminium alloys used in these conductors have improved tensile strengths making it possible to eliminate the steel reinforcing wires. For example, in France, AAAC has been well established for many years and now occupies some 90% of the total requirement for transmission conductors. In the United Kingdom many of the HV lines are now strung with AAAC and a number of the smaller regional authorities have changed over completely to AAAC from ACSR and AAC types. In USA, Canada, Sweden and South America the use of all aluminium alloy conductors is increasing. A recent French paper presented at the CIGRE Conference in Rio de Janeiro cited their use in more than sixty countries(2).

The history of manufacture of all aluminium alloy conductors in Australia dates back to 1954 when the first conductor was produced following enquiries for a 7-strand cable. In 1959 the first multi-strand contract for fourteen miles of 91/0.161" AAAC, was let by the Snowy Mountains Hydro-Electric Authority.

Since that time a number of distribution authorities have used considerable quantities of AAAC, mainly for long coastal river crossings where the high strength and low weight coupled with improved corrosion resistance were major factors influencing conductor choice. All aluminium alloy conductor has also been specified for lines subjected to salt spray conditions where ACSR had suffered severe corrosion. More recently large contracts for the supply of 61-strand AAAC were let for 1800 km of conductor for 275 kV lines, and 316 km of a similar alloy 19-strand conductor for 66 kV lines in Queensland.

Initially the aluminium alloy used exclusively was of the magnesium-silicon type and an extensive heat treatment procedure was required in order to develop its full strength in the finished wire. In 1982 a manufacturing method was developed for the alloy, designated as 6201, simplifying the heat treatment operation to a low temperature (approx. 160°C) precipitation treatment on the drawn wire.

More recently another aluminium alloy, designated as 1120, has been developed which develops its strength solely by cold reduction. It consists of electrical grade aluminium containing small additions, including copper and magnesium.

The important chemical, mechanical, electrical and physical properties of the three aluminium alloys are listed below in Table 1. the values shown are for individual wires and are not necessarily the properties of conductors manufactured from these wires.

TABLE 1 TYPICAL PROPERTIES OF ALUMINIUM ALLOYS USED IN OVERHEAD CONDUCTORS

PROPERTY	UNIT	1350	1120	6201
Composition - Aluminium	%	99.50 Min.	99.20 Min.	Rem.
- Silicon	%			0.6
- Magnesium	%		0.06	0.7
- Copper	%		0.2	
Ultimate tensile strength	GPa	0.170	0.240	0.315
Conductivity	%IACS	61.0	58.8	52.6
Volume resistivity	microhm.m	0.0283	0.0293	0.0328
Mass resistivity	ohm.g/m^2	0.0763	0.0791	0.0886
Density	g/cm^3	2.7	2.7	2.7
Temperature coeff. of resistance	per °C	0.00403	0.0039	0.0036
Coeff. of thermal expansion	per °C	23×10^{-6}	23×10^{-6}	23×10^{-6}
Modulus of Elasticity	GPa	68	68	68
Strength/mass ratio	-	63	89	117

3.0 AUSTRALIAN AND OVERSEAS SPECIFICATIONS

Australian Standards for overhead conductors are prepared by SAA committees containing representatives of major electrical authorities and conductor manufacturers. These standards reflect the current usage of conductors in Australia. The recent interest shown in conductors manufactured from 1120 aluminium alloy wires has resulted in the preparation of a new standard AS 1531-Part 3 to cover the properties of this new range of conductors.

Whilst it is recognised that conductor produced for use in Australia under Australian conditions should be manufactured to comply with the appropriate Australian Standards, there are a number of related overseas specifications which apply to all types of aluminium conductors for overhead lines. For each particular conductor type, the relevant Australian Standard is shown together with the appropriate nearest equivalent British, French, American and Swedish specification.

TABLE 2 AUSTRALIAN AND OVERSEAS SPECIFICATIONS FOR ALUMINIUM CONDUCTORS

Conductor Type	Australian	British	French	American	Swedish
AAC	AS 1531 Pt1	BS 215 Pt1		ASTM B231	SS 424 08 02
AAAC/6201	AS 1531 Pt2	BS 3242	NF C34-125	ASTM B399	SS 424 08 12
AAAC/1120	AS 1531 Pt3				SS 424 08 14
ACSR/GZ	AS 1220 Pt1	BS 215 Pt2	NF C34-120	ASTM B232	SS 424 08 14
ACSR/AZ	AS 1220 Pt2			ASTM B232	
ACSR/AC	AS 1220 Pt3			ASTM B549	
ACAR				ASTM B524	
AACSR/GZ			NF C34-125		

A new Australian Standard is in course of preparation, to replace AS 1220, and to provide for other alternative conductor constructions currently being specified. These alternatives include aluminium alloys 6201 and 1120, reinforced with galvanised, aluminised or aluminium-clad steels.

4.0 AUSTRALIAN OPERATING CONDITIONS

The operating conditions of transmission lines in Australia vary widely, from ice prone areas in Tasmania and the Snowy Mountains of the mainland to the cyclone areas in the tropical north. Wide temperature variations from day to night are often encountered inland, and some lines on the coastal fringe must operate under very corrosive conditions. Most transmission lines are located in this coastal fringe of the continent, where the majority of the population is concentrated.

A very severe corrosive environment is encountered in some coastal areas of Western Australia, where there is an adverse combination of high ambient daytime and low night-time temperatures, strong on-shore winds salt-laden due to the heavy surf, and low rainfall. The transmission lines running along the coast are thus subjected to severe corrosion by a build-up of concentrated sea-salt deposits which are moist at night-time. Conductor corrosion effects may be minimised by avoiding the use of steel reinforcing when possible, and by greasing even all aluminium alloy conductors to reduce the risks of internal crevice and fretting corrosion.

In other areas more densely populated or of natural beauty, the impact of the conductors on the local environment may be reduced slightly by providing a non-specular finish on the outer aluminium layer. This dull surface finish is achieved in the factory by a final grit-blasting operation.

5.0 SAGS, TENSIONS AND CREEP

Attention has become focussed on the effect of creep extension on sags by the development of the 1120 aluminium alloy, by the introduction of conductors of novel construction, and by the special conditions of Australian geography. Transmission lines in Australia are long and rural by comparison with the densely populated industrial nations of the world. This allows greater freedom in the placement of support structures with the result that cost savings for structures can be significant in reducing the total cost of the line. If the expected creep of the conductor can be fully characterised before it is strung, considerable savings can be made by optimising the height of each of the many towers on long lines.

Laboratory creep tests have been performed using methods developed from those published by CIGRE Study Committee 22. The tests are conducted at constant temperature and load for three months, with tests at three levels of load being made on each conductor.

Some surprising results have been obtained: for example the predicted ten year creep of a large conventional ACSR conductor extrapolated from test was found to be only half that predicted by data given in the CIGRE publication(3), although results on other sizes of ACSR conductor have shown good agreement with these standard values.

On testing a novel AACSR/AC/1120 construction, that is aluminium 1120 alloy wires over a stranded aluminium clad steel wire core, it was found that the creep was slightly less than an ACSR/GZ of similar construction. This result gave the line designers confidence to use traditional design factors derived from experience with ACSR. On the same transmission line, the creep of a conductor of similar construction but with a non standard combination of alloy and steel wires was also measured. This special high strength conductor, used for a river crossing was found to need a more generous creep allowance than was expected, based on earlier tests.

Tests on homogeneous 1120 aluminium conductors have shown lower creep rates than ACSR when compared at a constant proportion of the breaking load. This surprising result has been confirmed in tests on four different aluminium 1120 alloy conductors. Tests are now being extended to allow comparison with homogeneous conductors of 1350 and 6201 alloys.

Outdoor creep tests on a realistic test span have been performed on 1120 aluminium conductors by one of the Electricity Authorities, with results broadly in agreement with the laboratory tests. These outdoor tests, which are exposed to the weather, have confirmed the low creep behaviour of 1120 aluminium alloy.

6. DESIGN SAFETY FACTORS - PROBABILISTIC DESIGN

Stochastic approaches to line design are receiving increasing attention worldwide, as is shown by a number of recent publications on the subject (4,5). Manufacturers in Australia are developing a computer database of conductor properties which will be capable of generating the statistical information used for probabilistic designs. The database is currently being used to examine the validity of methods given in Standards for calculating complete conductor properties from individual wire tests. Interestingly, the results of work to date have shown very clearly that most drums of conductor have properties substantially better then the minimum values required by Australian Standards. This arises because the Standards require that each individual wire tested meets minimum requirements. In order to meet this, manufacturers must produce wire whose average properties exceed these minimum values. The increment of properties gives users of conductor an added safety margin of strength, often as much as 10% of the nominal breaking load, and a lower than nominal resistance.

BJR:AJG:CW

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3. Permanent Elongation of Conductors. Predictor equations and evaluation methods. Electra No.75 p63-98.

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