Wedge-Connector Technology in Power Utility Applications

J.D. Sprecher
Pacific Gas and Electric

J. Schindler
B. Johnson
G. Menechella
R.S. Timsit*
AMP of Canada Ltd.

ABSTRACT

Results of performance studies of several types of tap connectors under thermal cycling conditions and under harsh-environment conditions are reviewed. Performance attributes of fired wedge-connectors are related to key design characteristics that allow generation of stable electrical contact interfaces. Among these design characteristics are the mechanical stress distribution within the connector and the abrasion of the connector / conductor surfaces that occurs during installation. The effect of surface abrasion on oxide films on the connector surfaces and on the microtopography of the surfaces in contact, is reported. The superior performance of fired wedge-connectors is pointed out.

INTRODUCTION

The increased demand for electricity in many parts of the world in recent years is leading to increased electrical loading of transmission and distribution lines by many utilities. Increased loading raises the average operating temperature of conductor lines, up to 130 °C during times of peak power transmission[1,2], and may expose connectors to temperatures that exceed their designed operating range. At the Pacific Gas and Electric Company (PG&E) it was observed that this temperature increase has led to a noticeable increase in the reported failure rate of tap-connectors in distribution systems[1,2]. Tap-connectors provide an electrical connection between a main power line conductor and a tap conductor. Infrared surveys of PG&E overhead facilities also indicated that hundreds of tap-connectors were running unacceptably hot.

* Correspondence to be addressed to Roland S. Timsit, AMP of Canada Ltd., 20 Esna Park Drive, Markham, Ontario, Canada L3R 1E1.

Concern over this issue prompted PG&E to set up a Connector Task Force (CTF) to evaluate all tap-connector technologies relevant to its overhead primary and secondary distribution systems. After this evaluation, the CTF would make recommendations for a connector system that would provide reliability and safety for the public and for PG&E employees. All evaluations of tap-connectors would be carried out according to accepted testing procedures, and preferably according to test requirements of the American National Standard Institute (ANSI).

Evaluation according to ANSI C119.4[3], requires that a number of the connectors under test are attached to a selected electrical conductor and are then connected in series in a closed loop. An AC electrical current is passed through the loop to raise the temperature of a reference length of conductor to a selected temperature. The current is cycled using recommended current-on and current-off time intervals to induce micro-motion at electrical interfaces in the connectors and hence promote contact degradation. Connectors that overheat during a specified number of joule-heating cycles are deemed to have failed. In reviewing the ANSI evaluation test, a concern was raised by the CTF that the testing procedure calls for use of *new/unused* electrical conductors. This is inconsistent with field conditions wherein connectors are installed on conductors that in general have been exposed already to the environment for many years, possibly even under harsh-environment. With this concern in mind and with the commitment to comply with ANSI's test requirements, the CTF recommended that the tap-connector evaluation program be undertaken using three simultaneously operated test circuits adapted respectively with *new/unused* aluminum conductors (as recommended by ANSI C119.4), with *cleaned* service-aged aluminum conductors obtained from the field, and with *as-received/uncleaned* service-aged aluminum conductors. Connector evaluations using *cleaned* service-aged conductors would be consistent with PG&E's standard installation practice. Evaluations using *as-received/uncleaned* service-aged conductors were recommended for reference purposes only, to determine the effects on electrical connectibility of unusually thick contaminant deposits present on the conductor.

This paper reports and reviews the results of performance evaluations of several types of tap-connectors under thermal cycling conditions, as outlined above. Because the results show that fired wedge-connectors are among the most reliable, their performance under corrosive/harsh-environment conditions is also covered. Finally, the performance attributes of fired wedge-connectors are related to key design characteristics that allow the generation of stable electrical contact interfaces.

THERMAL CYCLING TESTS

Test Procedure

Ten types of tap-connectors were evaluated in the thermal cycling tests. The generic connector designs are illustrated in Figure 1. They include four compression connectors, three bolted connectors, two types of wedge-connectors and one formed-wire connector. The compression devices comprised the following types: the dieless sleeve, the barrel sleeve, the "6" compression and the "H" compression connectors. The dieless sleeve and barrel sleeve connectors were identical except that the former was installed using a dieless crimping tool. The bolted connectors included a 2-bolt parallel-groove, a bolt-driven wedge-connector and a bolt-vise connector. The wedge-connectors included two fired-wedge connectors obtained from two different manufacturers. The formed-wire connector is a simple device that attaches main and tap conductors directly to each other. This type of connector was included in the performance evaluations for the sake of completeness but is otherwise seldom used in power tap applications. Thus, of the ten types of connectors subjected to evaluations, nine represented commonly used devices.

All compression connectors are installed by crimping part of the connector over the conductors. In this investigation, the compression connectors were attached to conductors using the crimping tool and the crimping procedures recommended by the connector manufacturers. Similarly, all bolted devices were installed using recommended procedures inclusive of the recommended torque applied to the securing bolts.

As shown in Figure 1, wedge-connectors consist of a metal wedge located between the main and tap cables situated at opposite ends of a C-shaped metal component. An electrical connection is formed by inserting the wedge between the two cables with sufficient force to cause plastic deformation of the C-member[4]. In the bolt-driven wedge-connector, the wedge is inserted by the driving action of a bolt. On the other hand, fired wedge-connectors are installed using a tool actuated by a powder cartridge[5]. In this work, the wedge-connectors were installed using the appropriate tools in accordance with manufacturers' specifications.

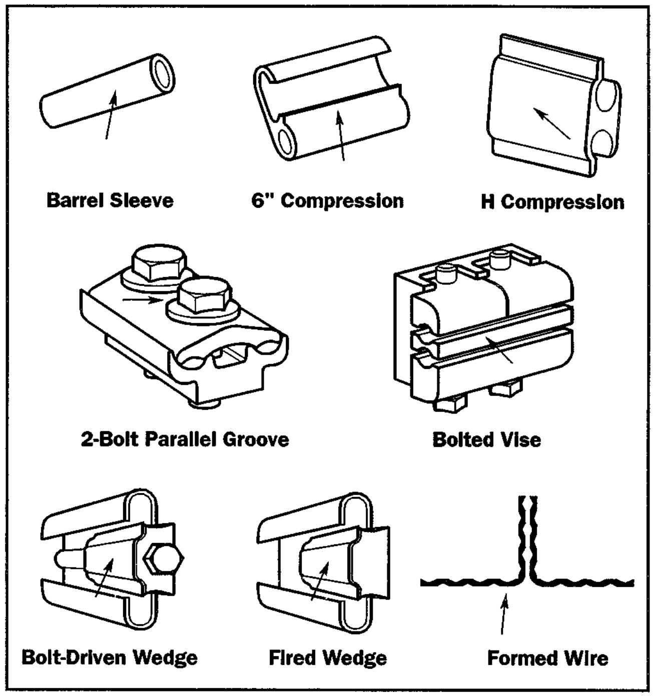

Figure 1. Schematics of tap-connectors evaluated in the present investigation.

For the thermal cycling tests, four connectors of each type were installed for a total of 40 connectors per loop, using 397.5 kcmil AAC conductor. As mentioned earlier, separate loops were prepared using new/unused conductors, cleaned service-aged conductors and as-received/uncleaned service-aged conductors. The test loops were prepared in accordance with ANSI C119.4 test specifications[3], using welded aluminum electrical equalizer plates to allow electrical resistance measurements across a connector after selected thermal cycling intervals. To monitor the temperature excursions during thermal cycling a thermocouple was attached to the center of each connector, as identified by the arrow location in Figure 1. Finally, a 61 cm length of 397.5 kcmil AAC conductor, terminated at each end with an electrical equalizer plate, was connected in series with each test loop to provide a reference temperature during test-cycling. The reference temperature was measured at the mid point of the conductor length. All conductors were wire-brush cleaned before installation except those that were to be tested in the as-received, uncleaned, service-aged condition.

All loops were mechanically supported on wooden racks in an open laboratory environment and were electrically energized using AC. The current was passed through the loops and cycled a maximum of 500 times, with identical current-on and current-off intervals of 90 minutes. Temperature was measured once every three hours at the end of each current-on cycle. For loops that used new/unused conductors, the current was adjusted to raise the temperature of the reference 397.5 kcmil AAC conductor to a level 100°C above the ambient temperature in accordance to ANSI C119.4[3]. A slightly modified procedure was applied to test connectors mounted to service-aged conductors. This modified procedure originated from experimental observations and is discussed in the Results section below.

According to ANSI C119.4, a connector is deemed to fail when any of the following conditions are met[3]:

(1) the connector temperature exceeds the temperature of the control conductor,

(2) the connector temperature is unstable in that the difference at any time between the temperature of the connector and that of the reference conductor exceeds by more than 10°C the average difference measured up to that juncture (following 25th current cycle); this will be identified as *temperature differential failure* (TDF),

(3) the electrical resistance of the connector (measured from the equalizers attached to the conductors) exceeds the average resistance over the connector specimens under test by 5% after 25 current cycles; this will be identified as *resistance stability failure* (RSF).

Results

It was found that an electrical current of approximately 630 A RMS was required to raise the temperature of the new/unused 397.5 kcmil AAC reference conductor 100°C above ambient. In Figure 2 the temperature of each tested connector, measured at the end of the 500th current cycle, is shown for new/unused conductors. Note that the reference conductor temperature was 127.1°C. Two bolted wedge connectors failed by thermal runaway and one bolted wedge device failed by RSF. All four formed-wire connectors failed by thermal runaway. Generally, failure by thermal runaway occurred well in advance of the 500th current cycle. Note that the 2-bolt parallel groove (PG) connectors did not fare well. Two of these devices failed by RSF, the remaining by TDF. Finally, note that the fired wedge-connectors operated at relatively low temperatures, which suggests superior contact resistance in these devices.

In the tests carried out with cleaned service-aged and with as-received, uncleaned, service-aged conductors, several anomalies were recorded. First, to raise the temperature of service-aged conductors by approximately 100°C above ambient a current of approximately 750 A was required, instead of the 633 A found for new/unused conductors. This difference in heating current stems from the different thermal emissivities of the two conductors. The rough and dark surface of as-received/uncleaned service-aged conductors enhances the emissivity of the conductor, thus requiring a larger current to produce a selected temperature rise. In addition, every connector heated by a current of 750 A exceeded the temperature of the service-aged control conductor already within the first current-on cycle. Several of the connectors showed early signs of rapid thermal runaway. This rapid deterioration was probably caused by a thick layer of contaminants, e.g. thick oxide films, on the conductor surfaces, which hindered the formation of electrical interfaces of low contact resistance. In light of these observations, the performance evaluation for these tests was carried out using a modified procedure.

In the modified test procedure, current cycling was initiated using AC of only 50 A. The current was then raised in small steps and again cycled. It was finally set at 633 A and cycled for 129 periods. This procedure did not yield the immediate, 1st cycle failures mentioned earlier for two possible reasons: (a) the relatively slow current ramp-up allowed the formation of electrical interfaces of relatively low resistance through contact softening and metal flow, and (b) use of a current of 633 A yielded equilibrium connector temperatures lower than those obtained earlier at 750 A. In fact, the lower current produced a temperature rise in the reference conductor of less than the 100 °C recommended by ANSI C119.4. The evaluation results for the cleaned, service-aged and as-received/uncleaned, service-aged conductors are shown in Figures 3 and 4, respectively.

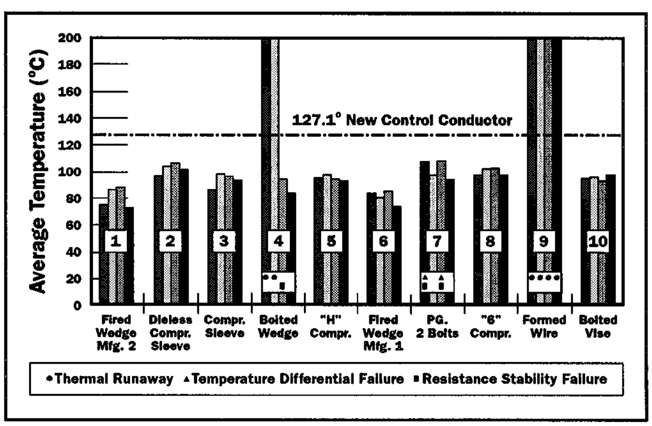

Figure 2. Connector temperature reached after a maximum of 500 current cycles, using *cleaned, new/unused* 397.5 kcmil AAC conductor.

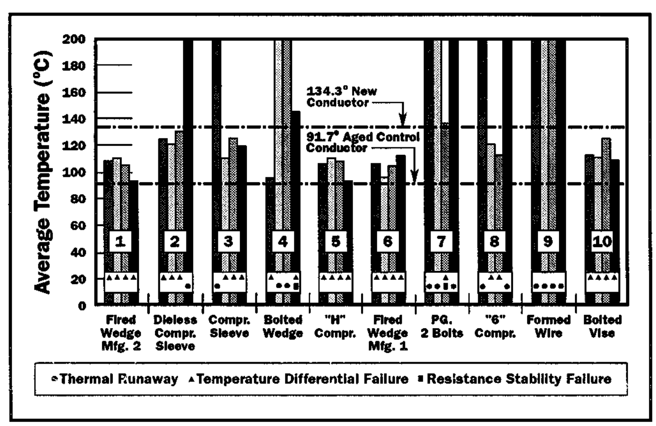

Figure 3. Connector temperature reached after a maximum of 129 current cycles, using *cleaned, service-aged* 397.5 kcmil AAC conductor.

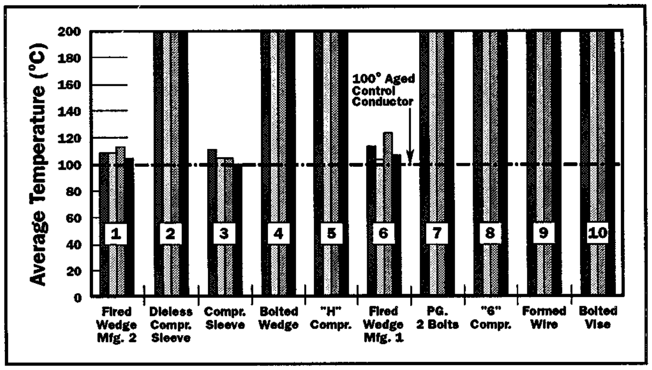

Figure 4. Connector temperature reached after a maximum of 129 current cycles, using *as-received/uncleaned service-aged* 397.5 kcmil AAC conductor.

Note in Figure 3 that the temperature of the reference cleaned service-aged conductor was only 91.7°C, corresponding to a rise of only 64.1 °C above ambient. In this test, a length of new/unused reference conductor was also connected to the test loop, for reference purposes only. Its temperature reached 134.3°C. The temperature of many of the connectors was slightly above 100°C, or only slightly higher than the temperature reached when the connectors were installed on new/unused conductors as shown in Figure 2. Note in Figure 3 that the fired wedge-connectors and the compression ‘‘H’’ connectors performed best, despite observations of TDF failures in all of them. Under conditions where the as-received/uncleaned service-aged conductor was used, the data of Figure 4 show that the reference conductor temperature only rose by 69°C to 100°C. Only the fired wedge-connectors and the compression sleeve device survived the test. All other connectors failed by thermal runaway in a time interval considerably shorter than the time required to complete the 129 current cycles. Because the conductor was uncleaned in this case, it is surmised that this latter test is the most severe of the three tests described in this section and the results therefore provide an excellent indicator of the robustness of the surviving devices.

In summary, fired wedge-connectors perform best overall in all the tests described in this section. Fired wedge-connector technology therefore appears superior to all others evaluated in this study. Although compression ‘‘H’’ connectors performed well in combination with service-aged/cleaned conductors, they did not pass the more severe test using as-received/uncleaned, service-aged conductors. Similarly, the compression sleeve connectors performed well with as-received/uncleaned service-aged conductors but, performed less well with cleaned, service-aged conductors. Overall then, the present evaluation indicates that neither compression ‘‘H’’ nor compression sleeve connector technology ranks as highly as wedge-connector technology.

HARSH-ENVIRONMENT TESTS

The current cycling tests described in the previous section, specifically the tests using service aged conductors, were found effective in ranking connector performance. Although fired wedge-connectors ranked highest, it may be argued that the ultimate reliability test for the connector is an evaluation of its performance in a harsh environment where the device is exposed to current cycling in a corrosive atmosphere. Under these conditions, connector failure would presumably be accelerated through ingress of corrosive contaminants into the connector during interfacial motion induced by current and/or thermal cycling.

The harsh-environment that is easiest to generate in a laboratory, and is generally recognized as severe by electrical utility companies, is a saline fog environment. With this in mind, fired wedge-connectors were subjected to current cycling in a controlled atmosphere containing saline fog.

Performance evaluation was carried out in a corrosion chamber of adequate dimensions to house a test loop consisting of at least six connectors connected in series, and in which a 5% salt fog was introduced. The chamber was calibrated in accordance with ASTM B117-90. Figure 5 shows a block diagram of the test loop layout. The conductors were adapted with welded equalizer plates to allow electrical resistance measurements across a connector following selected thermal cycling intervals. A thermocouple was attached to the center of each connector to monitor temperature during thermal cycling.

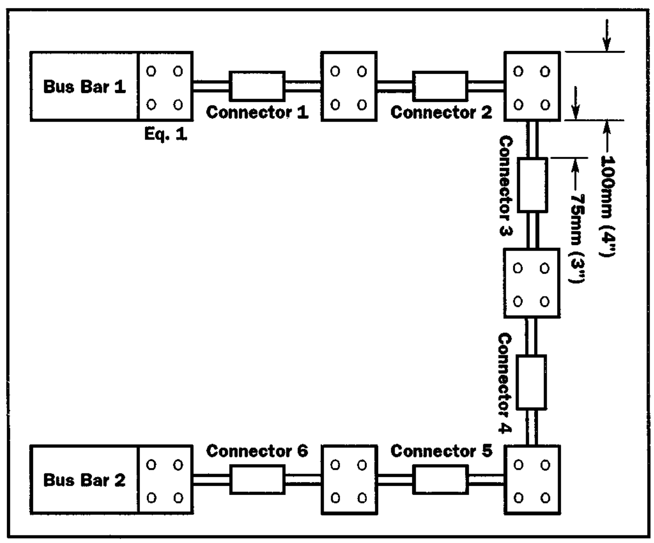

Figure 5. Block diagram of test loop in harsh-environment chamber.

As before, the loop was mechanically supported on wooden racks in the corrosion chamber and was energized with AC. Current was passed through the loop and cycled at least 500 times, with current-on and current-off time intervals of 5 minutes and 55 minutes respectively. Salt fog was sprayed into the chamber at a period of 2 hours. The current cycles were synchronized with the saline fog cycles according to Figure 6. Temperature was measured once at the end of each current-on cycle; resistance was measured at the end of each current-off cycle. The current was adjusted during the first 25 cycles to generate a maximum temperature of 150°C on the hottest connector. Typical excursions of temperature and electrical resistance observed during a test are shown in Figure 7 for fired wedge-connectors and for connectors of other designs.

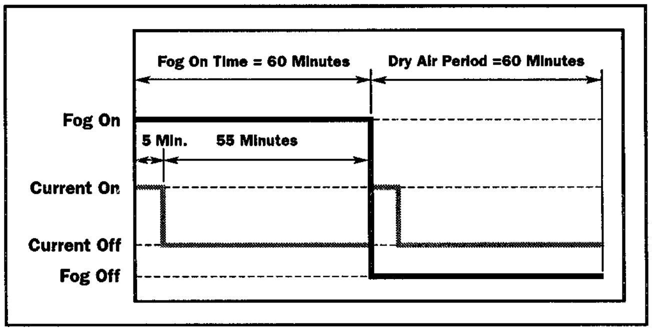

Figure 6. Current and salt fog cycles during harsh-environment testing.

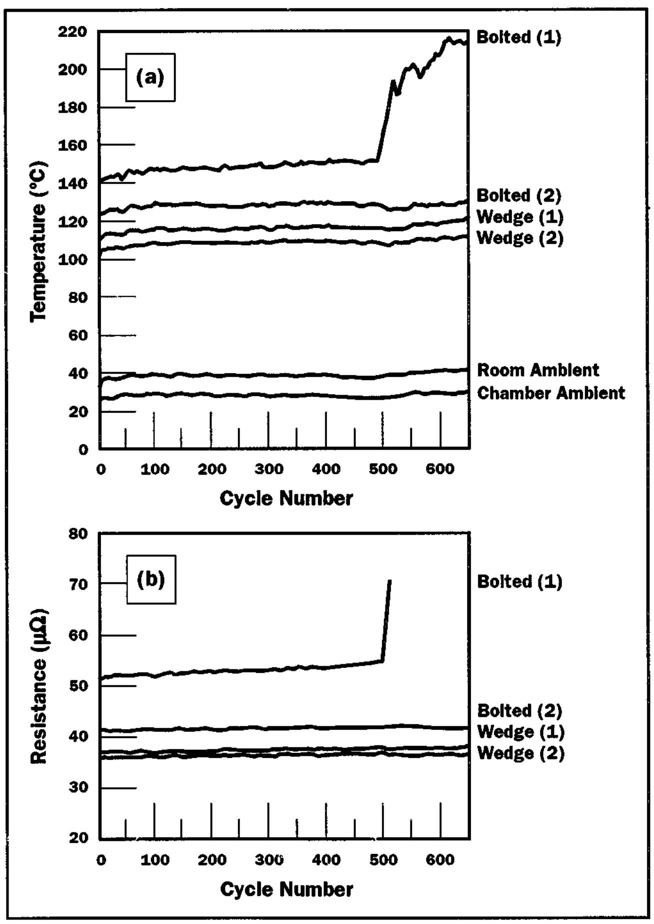

Figure 7. Typical results of harsh-environment testing. (a) peak connector temperature generated during current cycling. (b) corresponding electrical resistance variations.

The curves of Figure 7(a) show the temperature variations in two bolted connectors. Note that one of these connectors failed after approximately 490 cycles. Although the second bolted connector survived for the entire test duration of approximately 650 cycles, it ran at a higher temperature than the fired wedge-connectors. The variations in electrical resistance are shown in Figure 7(b). The resistance of the bolted connectors was found to be noticeably higher than that of the fired wedge-connectors. In contrast with the performance of bolted connectors, and of other types of connectors not shown in Figure 7, none of the fired wedge-connectors ever showed evidence of imminent failure in the test. The data in Figure 7(a) show that the fired wedge-connectors operated at lower temperatures than the bolted connectors. This indicates that the power loss in the bolted connectors was clearly higher.

In summary, fired wedge-connectors have performed well in all of the harsh-environment tests carried out to date. Fired wedge-connector technology thus appears superior also under harsh-environment conditions.

WEDGE-CONNECTOR TECHNOLOGY

General Remarks

In this section, the performance attributes of fired wedge-connectors are related to key design characteristics that allow the generation of stable electrical contact interfaces. Among these characteristics are the mechanical stress distribution within the connector and the abrasion of the connector/conductor surfaces during installation.

In a fired wedge-connector, the wedge and C-member are usually fabricated from strong aluminum alloys, such as AA6061. As described earlier, good mechanical fastness is achieved by inserting the wedge between the two cables with sufficient force to cause plastic deformation of the C-member. This deformation occurs in a direction normal to that of the wedge motion, as the C-member spreads laterally to accommodate the wedge to its full insertion distance. Plastic deformation occurs largely within the flat area located between the two curved ends of the C-member. The deformation path is such that geometrical conformation of the ends of the C-member to the conductors is increased. In addition, a large elastic restoring force is generated within the C-member that holds the conductors in place[4,5]. Details of the mechanical stress distribution within the connector determined from a numerical analysis of the mechanical deformation, and results of measurements of the restoring force, will be presented below. The displacement of the wedge during installation, along with the effect of solid grit particulate present in the lubricant/inhibitor used with the connector, abrades the sliding interfaces formed with the conductors and is responsible for the formation of an electrical interface of high integrity. The effects of this abrasion on oxide films present on the connector surfaces will also be discussed further.

The wedge is installed using a tool of special design[5] actuated by a powder cartridge, as illustrated in Figure 8. Briefly, the tool consists of a breech carrying a cartridge at one end and a sliding steel ram at the other. During connector installation the ram presses against the wide end of the wedge and is actuated by activating the cartridge through tapping the breech end with a hammer[5].

C-body deforms plastically after a displacement of the ends of the C-member of approximately 0.5 mm. The average elastic restoring force following a stretch of 7.6 mm is 21,400 N, with

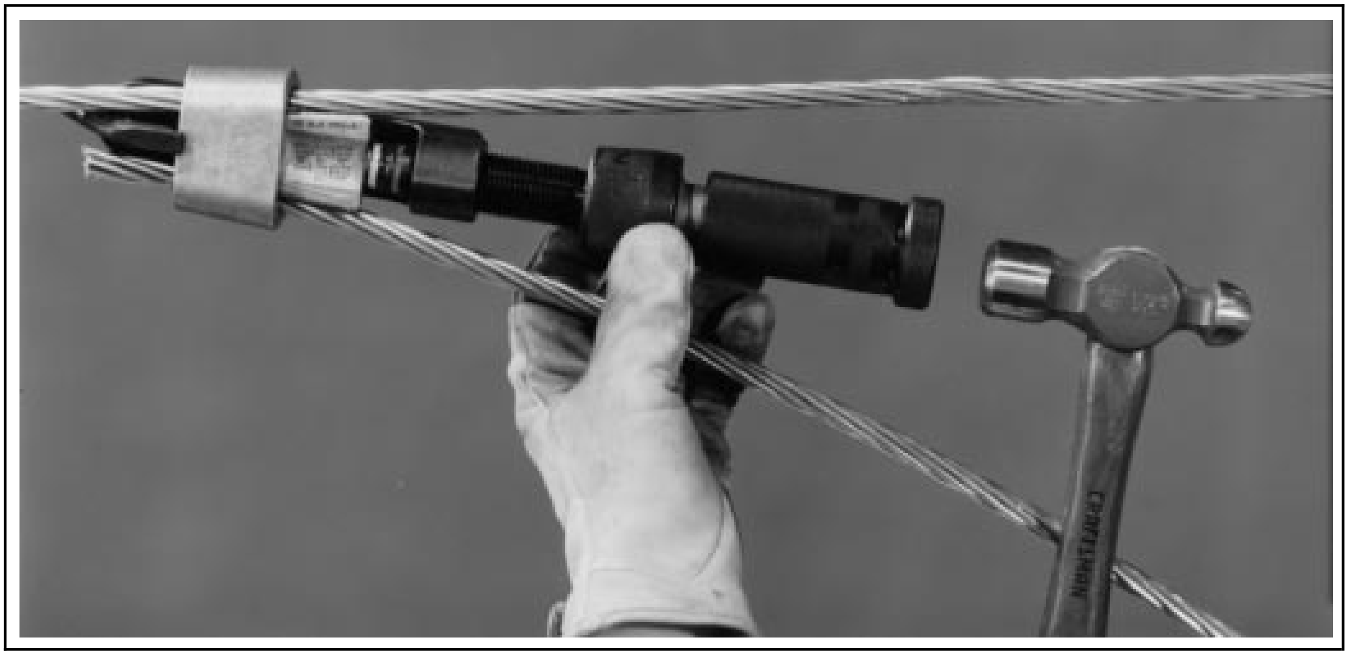

Figure 8. Wedge-connector installation with a cartridge-actuated tool.

an average elastic compliance of 1.9 mm. This compliance value is high. It indicates that the force holding the conductors in place in an assembled connector should remain largely unaffected by small changes in conductor dimensions. Such dimensional changes may arise in practice from conductor creep or because of conductor compaction.

Mechanical Properties

Because the C-member deforms plastically and generates the force that secures the installed wedge and conductors in place, its mechanical properties are vital for a reliable performance of wedge-connectors. The mechanical properties were investigated on a number of “model” connectors. In these connectors, the C-member was made from AA6061 aluminum alloy subjected to a heat treatment different from that applied to commercially available components. The *model C-member* was introduced to protect proprietary alloy information. The conductors consisted of two solid rods of AA6061 aluminum alloys of identical dimensions. The rods were 120 mm in length and 15 mm in diameter. The wedges consisted of the conventional commercially available parts. Wedge dimensions were approximately 89 mm long, with narrow-end and wide-end dimensions of 22 mm and 49 mm, respectively. The surfaces of wedge and C-member were coated with inhibitor prior to wedge insertion.

Two types of measurements were carried out: (1) force versus deformation on unassembled C-members and (2) deformation of C-members in assembled connectors. Force versus deformation curves were obtained on samples of unassembled C-bodies using conventional tensile test instrumentation. The C-body was held in the tensile tester by two cylindrical pins inserted into the curved ends of the C-member. The pins consisted of case-hardened steel and were held in a yoke at inclination angles matching the wedge angles of the connector. Tension was applied via the pins to stretch the C-body. Typical force versus displacement plots are shown in Figure 9. Note that the

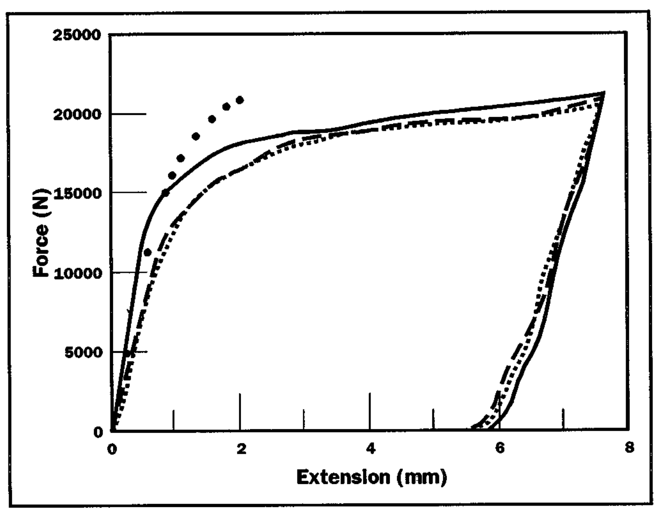

Figure 9. Typical force-displacement curves measured on unassembled C-bodies. Dots represent data calculated by FEA simulation.

The deformation of C-members in assembled connectors was determined by measuring the distance between the curved surfaces at each end and at the center of the C-member, and by comparing these values with the corresponding dimensions before assembly. The average increase in these dimensions was found to be 0.95 mm for the wide end, 0.96 mm for the center section, and 0.96 mm for the narrow end of the C-member. Stresses associated with these displacements within the C-member and on the conductor surfaces were determined through computer modeling[6].

A dedicated three dimensional finite element analysis (FEA) model of a wedge connector assembly was built. It takes advantage of the connector's symmetry about its center plane. This model assembly comprises half of the C-member, one solid aluminum conductor and half of the wedge, as shown in Figure 10. In the calculations, the wedge is displaced vertically until the deflection of the center of the curved ends of the C-body reaches a value of 0.48 mm, i.e. half of the previously described average spread of the C-body of the real model-connectors[6]. The final stress distribution within the connector components is then plotted.

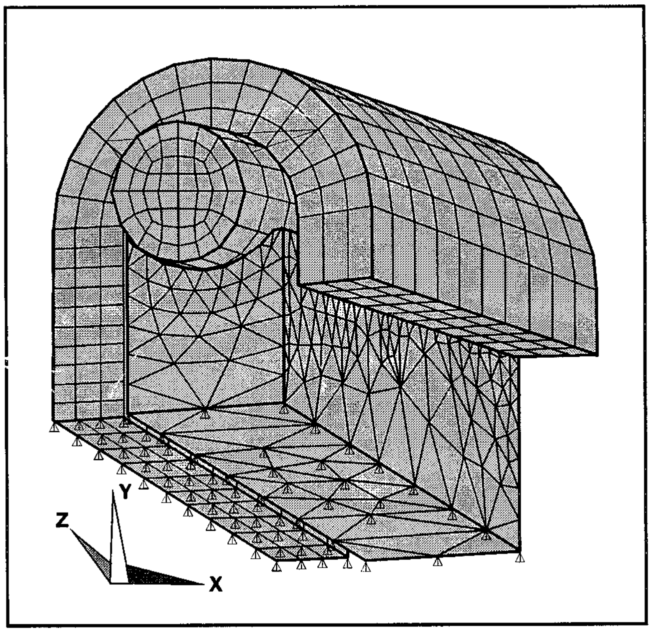

Figure 10. Finite element analysis model assembly.

The FEA model used ANSYS revision 5.1, which relies on a Newton-Raphson solver procedure for nonlinear analysis[7] and 3D contact elements simulating contact interfaces[8]. Results of the analysis, expressed as von Mises stresses, in the surfaces of the C-body are shown in Figures 11 and 12. Note that the stresses in the internal flat surface exceed the yield value of 208 MPa. The stresses generated in the remainder of the C-body are much lower. The total strain in the C-body varies from 0 to approximately $6 \cdot 10^{-3}$. Distributions of normal contact stresses on the conductor surfaces mated to the C-member and wedge are shown in Figures 13 and 14, respectively. Note that the stress distribution on the conductor surfaces is characterized by slight localized peaks near the edges of the connector. The computations show that the contact stresses are well below the yield value for AA6061.[a]

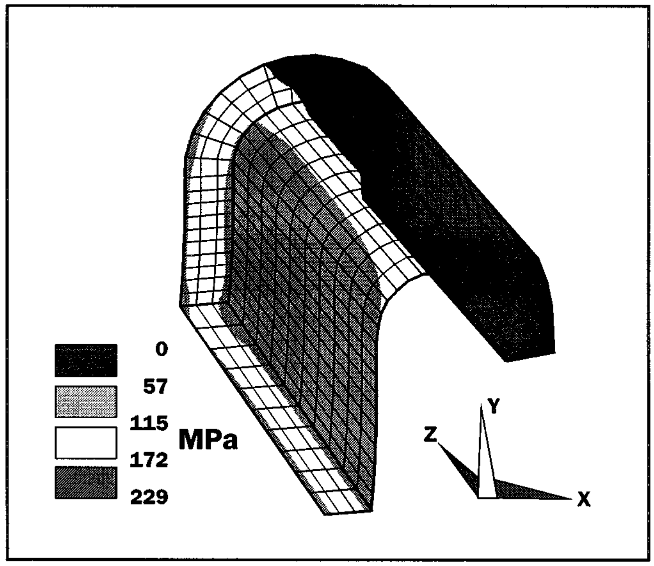

Figure 11. Computed von Mises stress distribution in the internal C-body surface.

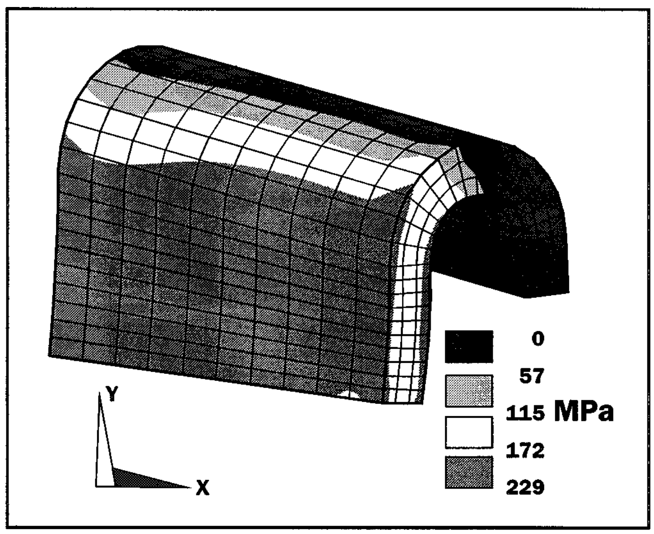

Figure 12. Computed von Mises stress distribution in the external C-body surface.

[a] The accuracy of the calculation can be improved by reducing the dimensions of the FEA elements. A corresponding analysis is currently being carried out. The results presented here are sufficiently accurate to support this conclusion.

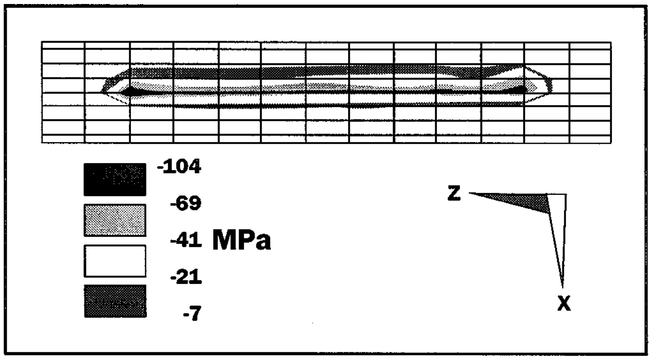

Figure 13. Computed contact stress distribution in the conductor surface mated to the C-member.

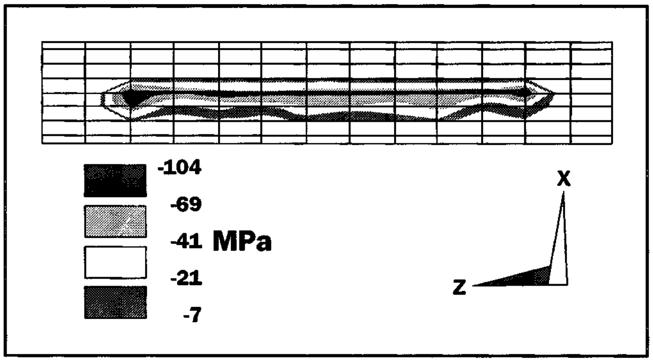

Figure 14. Computed contact stress distribution in the conductor surface mated to the wedge.

The results of the FEA simulation indicate that only the C-body undergoes plastic deformation. Stresses in the region of contact interfaces are well within the elastic range. The total reaction force generated by the C-member, when deflected by 0.48 mm in the Y direction, was calculated as 16,170 N. This compares favorably with the corresponding average force of 14,000 N determined experimentally by the tests described in reference to Figure 9.

The main conclusions drawn from the FEA calculations are that

* only the C-member undergoes plastic deformation,
* this deformation occurs in areas situated away from the interfaces with the conductors,
* the relatively small mechanical stresses generated in the contact interfaces preclude significant conductor creep and probably account in part for the superior performance of fired wedge-connectors during current cycling and harsh-environment tests,
* although the conductors deform only elastically, the total holding force generated by the C-member is high, i.e., of the order of 14,000 N, thus producing a pull-out constraining force of 5,600 N on each conductor for a friction coefficient of 0.2.

Characterization of Connector Contact Surfaces

The results of the FEA presented above indicate that the stresses generated in the contact interfaces are too small to produce plastic deformation of the conductor or connector surfaces. However, these results were obtained under the assumption of geometrically smooth interfaces. In practice, contact between solid bodies in the connector occurs at discrete spots produced by mechanical contact of asperities on the contacting surfaces[9]. Because this produces true contact areas that are much smaller than the nominal contact areas, the normal stresses developed at the asperities in the connector exceed the elastic limit of the mating components.

In interfaces involving aluminum, the contacting surfaces are separated by a layer of Al_2O_3. It was shown previously[10] that electrical contact spots can develop through Al_2O_3 films on aluminum. This requires deformation of the film by compression to cause flow of the underlying metal through narrow fissures generated in the oxide film. The area of electrical contact formed under these conditions is generally small and appreciably smaller than the area of mechanical contact. Different conditions exist during formation of fired wedge-connectors. Here, the electrical interfaces are formed by shearing of rough interfaces sliding relative to each other. The high local stresses at asperities generate conditions favorable to abrasion of oxide and other contaminant films and to dispersal of particulate matter. Thus, the total area of metal-to-metal contact must be expected to be relatively large. Figure 15 supports this conclusion. It shows the wedge surface after installation of a wedge-connector between two aluminum conductors. Note the state of disruption of the surface as indicated by the number of scratches. The area of metal-to-metal contact in the aluminum-aluminum interface from which this surface was taken is increased greatly over that produced by compression alone.

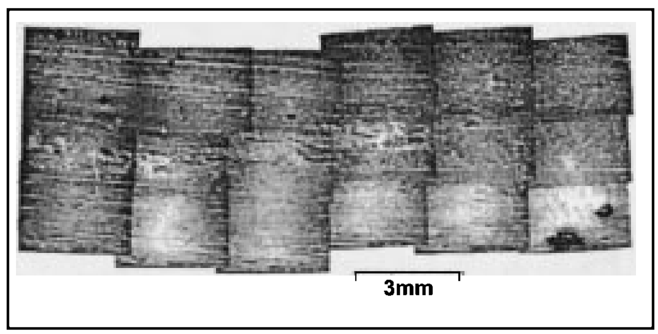

Figure 15. Scanning electron micrograph of a wedge surface after conductor installation. Note the many scratches at the surface indicating disruption of the oxide layer. The micrograph was obtained after the connector had been carefully cut into two parts along a direction parallel to the feed cable, to allow removal of the wedge and conductors. Due to the penetration of the oxide layer, the metal-to-metal contact area in this aluminum-aluminum interface is high.

Figures 16(a) and 16(b) show typical depth profiles obtained by Auger Electron Spectroscopy (AES) of areas on the wedge surface that were, respectively, abraded and unabraded. In the first case contact with the conductor had been established. The profiles were obtained by sputter-etching the areas of interest in vacuum to a selected depth from the exposed surface, carrying out the AES analysis at that depth and then repeating the procedure[6]. Figure 16(a) shows relatively high concentrations of carbon, oxygen and magnesium in the initial surface layer. In particular, note that magnesium accumulates near the surface in a concentration much larger than the bulk concentration. This is consistent with the results of earlier investigations of surface segregation phenomena in Al-Mg alloys[11,12]. The depth profile of Figure 16(a) indicates that the oxide film thickness is approximately 28 nm. In contrast, according to the data of Figure 16(b), the oxide layer of an unabraded area is about 83 nm thick. Recall that this finite thickness stems from exposure of the wedge surface to ambient environmental conditions for several weeks following its removal from the connector. Nevertheless, a comparison between the profiles of Figures 16(a) and 16(b) provides unambiguous evidence of the effectiveness of the oxide-abrading action of wedge motion during connector installation. This abrasion action accounts also in part for the superior electrical properties of fired wedge-connectors.

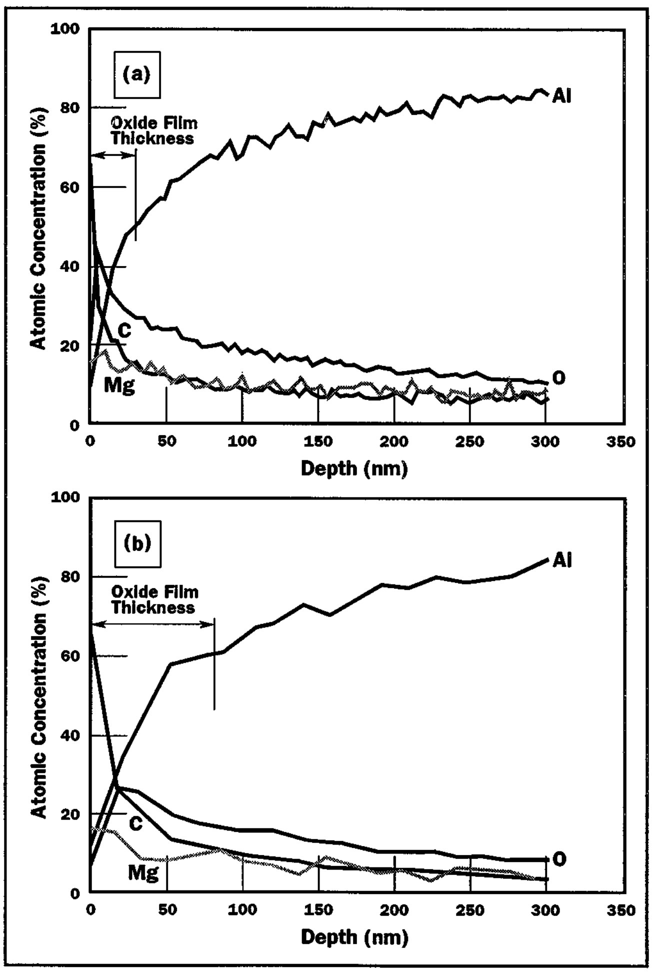

Figure 16. Auger electron spectroscopy depth profiles of (a) an abraded area on the wedge surface, (b) an unabraded area on the wedge surface. For definition of the terms abraded and unabraded used in this context see text.

CONCLUSIONS

Experimental data show that the performance of fired wedge-connectors under current and/or thermal cycling is superior to that of most other types of tap-connectors. Fired wedge-connectors also perform very well under harsh-environment conditions.

Some factors causing the reliable performance of fired wedge-connectors are:

(1) The relatively low average stresses produced at interfaces with the wedge and C-member within the connector. These stresses are sufficiently low to preclude significant conductor creep and therefore minimize loss of clamping force on the conductors.

(2) The relatively large elastic compliance of the C-body. This allows the contact forces to remain nearly constant in case of dimensional changes caused by temperature variations, conductor compaction, etc. Thus, the high degree of elastic compliance contributes significantly to the robustness of the connector.

(3) The abrading action of the wedge. This effect causes localized removal of the oxide films from conductor and connector surfaces during installation and dispersal of particulate matter. The combination of the two effects results in low contact resistance. Low contact resistance promotes the passage of electrical current of approximately equal magnitudes through the wedge and the C-member[6] and thus minimizes joule heating and power dissipation within the connector.

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James D. Sprecher is Principal Electric Engineer in the Distribution Department at Pacific Gas & Electric (PG&E), San Francisco, CA.

Mr. Sprecher received a Bachelor of Science degree in electrical engineering from the University of Wyoming and a Master of Science degree in Engineering Management from Santa Clara University, CA. He has worked at PG&E for 29 years and has held various department head positions in the last 26 years. Mr. Sprecher has served as program manager for many of PG&E's strategic initiative programs.

John J. Schindler was Senior Project Leader at AMP of Canada Ltd. when the work reported here was done.

Barry Johnson is Manager of Product Development at AMP of Canada Ltd.

Mr. Johnson obtained a Bachelor of Science degree in Electrical Engineering from the University of Toronto, and a Master of Business Administration from York University, Toronto, Canada. He joined AMP of Canada Ltd. as a Product Engineer in 1987. His career at AMP has focused largely on the design, development and testing of power and utility connectors.

Gino Menechella is Product Development Engineer at AMP Canada Ltd.

Mr. Menechello graduated in mechanical engeneering from the University of Toronto. He joined the Product Engineering Group of AMP Canada Ltd. in 1989 where he has been involved in design, development and testing of power utility connectors. He is an active participant in several North American standards committees associated with the performance evaluation of power utility electrical connectors.

Roland S. Timsit is Director of Technology, Global Power and Utilities, at AMP Canada Ltd. Dr. Timsit earned a Ph.D. degree in Physics from the University of Toronto. He spent 20 years in Research and Development in the aluminum industry where he focused on modification and control of properties of aluminum surfaces, such as electrical contact resistance, adhesion, brazing and metal-working. He is active in several international scientific and engineering societies.