

**RELIABILITY OF FIBER OPTIC CABLE SYSTEMS:**

**BURIED FIBER OPTIC CABLE**

**OPTICAL GROUNDWIRE CABLE**

**ALL DIELECTRIC, SELF SUPPORTING CABLE**



**ALCOA FUJIKURA LTD.  
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## EXECUTIVE SUMMARY

The selection of cables and their reliability in fiber optic telecommunications systems has now replaced the initial cost of system installation as the most important consideration of the system design. Cable reliability is directly related to the frequency of cable breaks and failures in the telecommunications system. The measurement used in expressing the reliability of various types of fiber optic cables is: Service Affecting Failures per 1,000 Kilometers per Year.

As measured by the expression of reliability noted above, the aerial fiber optic cables of Alcoa Fujikura Ltd. (AFL) – Optical Groundwire (OP-TW) and All Dielectric Self Supporting (ADSS) cables – have more than 25 times the in-service reliability as compared to buried fiber optic cables. The data presented in this paper is summarized as follows:

<u>Type of Cable</u>	<u>Failure Rate</u>	<u>Reference</u>
Conventional Buried Cables	2.130	Bellcore
AFL Optical Groundwire	0.085	Alcoa Fujikura Ltd
AFL All Dielectric Self Supporting	0.081	Alcoa Fujikura Ltd

Based on the data, the Alcoa Fujikura Ltd. aerial fiber optic cables are expected to provide the longest continuous telecommunications systems service of all the cables studied.

Conventional Buried Cables are significantly more susceptible to human related damage than aerial cables. Eighty percent (80%) of the failures of direct buried cables and sixty-five (65%) of the failures of cables installed in ducts were caused by excavations. With an eight (8) hour average restoration time for buried cables, buried fiber optic systems experience significantly greater lost revenue and greater maintenance costs than Alcoa Fujikura Ltd. aerial cables. Seventy-one percent (71%) of the excavations damaging fiber optic cables were accidentally performed by responsible companies such as Electric & Gas, Water & Sewer, Telephone, and Highway & Road.

Aerial fiber optic cables do not experience failures from these causes. The data presented for Alcoa Fujikura Ltd. aerial cables compared to the Conventional Buried cables displays the superior in-service reliability of its Optical Groundwire and All Dielectric Self Supporting fiber optic cable systems.

## 1.0 Introduction

Since 1985 long distance telecommunications systems have been operating with increasing optical fiber counts with average transmission systems many times greater than the original 140 Mbit / second systems.

At that time the selection criteria for system design was greatly influenced by the economics of the initial installation cost. Now, with the availability of field data, a much greater emphasis is being placed on the reliability of the systems being designed.

This presentation will compare the reliability data obtained in the United States by Bellcore of buried fiber optic systems, and compare that data to the performance data of Alcoa Fujikura Ltd. Optical Groundwire and All Dielectric Self Supporting Cable Systems. No independent source for aerial fiber optic cable reliability data could be obtained. Therefore, Alcoa Fujikura Ltd. will present its own internal data for the reliability of its own aerial cables. Because of differing designs and quality processes in manufacturing, other manufacturers of Optical Groundwire and All Dielectric Self Supporting cables may not achieve the same excellent reliability results as Alcoa Fujikura Ltd. In many telecommunications systems the goal for maximum service affecting failures is 2.50 failures / 1000 kilometers / year.

Now telecommunications systems can select whichever system provides them with the best cost-benefit relationship without impacting the existing infrastructure in use.

The reasons for cable breaks vary according to the type of installation. For example, for buried cables, Excavation is the principal reason for cable breaks.

This presentation will demonstrate the various causes for cable breaks for buried cables, AFL Optical Groundwire, and AFL All Dielectric Self Supporting Cable. This presentation will show the field data for the number of occurrences for these types of cable breaks. This presentation will also show the time for temporary restoration and permanent repair time for conventional buried fiber optic cables.

## 2.0 Source of Data

The data presented from Bellcore and Alcoa Fujikura Ltd. on the cable breaks is for installed cables from 1986 through 1998.

The data for the buried optical cables and the aerial fiber optic cables is based on studies (1) and (2), and the data for the Optical Groundwire and the All Dielectric Self Supporting cable is from the base of installed and in-service optical aerial cables manufactured by Alcoa Fujikura Ltd.

In this presentation, a fault in service is defined as an event that causes:

- Interruption of the operations of the system,
- Requiring restoration of the cable.

### 3.0 Causes of Cable Breaks in Buried Fiber Optic Cables

#### 3.1 Cable Breaks in Direct Buried Cables

<b>Cause</b>	<b>Number of Reports</b>	<b>Percent of Total</b>
Excavation	172	80%
Rodents	11	5
Workmen	5	2
Flood	4	2
Lightning	4	2
Other/Unknown	20	9
<b>TOTAL</b>	<b>216</b>	<b>100%</b>

The data above shows that Excavation (dig-ups) is responsible for 80% of the Direct Buried Cable failures. The failures can occur along public right-of-way such as roadways and utility easements, and private right-of-way such as railroads and pipelines. Note that damage caused by Rodents only accounts for five percent (5%) of the total failures.

#### 3.2 Cable Breaks of Cables Installed in Duct

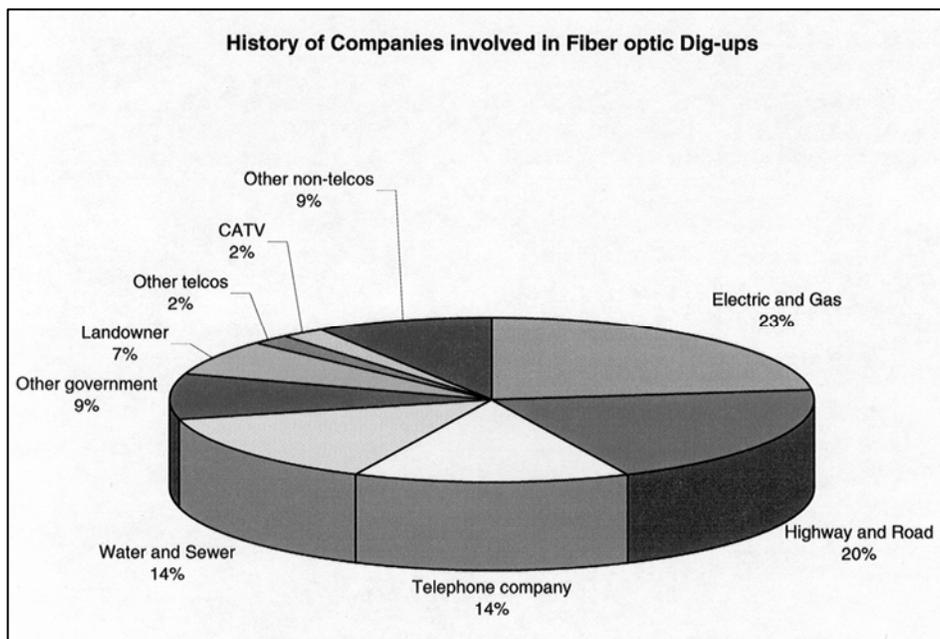
<b>Cause</b>	<b>Number of Reports</b>	<b>Percent of Total</b>
Excavation	84	65%
Workmen	17	13
Rodents	3	2
Steam	2	2
Extreme Temps	4	2
Other/Unknown	20	17
<b>TOTAL</b>	<b>130</b>	<b>100%</b>

### 3.3 Failures of Buried Fiber Optic Cables

#### Excavation (Dig-ups)

An excavation failure is defined as damage to fiber optic cable during an attempt to penetrate the ground. In the majority (86%) of the cases, the excavator involved in the dig-up was not working on behalf of the cable owner, while 14% of the dig-ups were caused by the telephone company or their contractor.

The following graph provided a history of companies involved in fiber optic dig-ups:



Electric & Gas companies were involved in about 23% of the dig-ins, and Highway & Road construction account for about 20% of the dig-ins. Water & Sewer companies were involved in 14% of the dig-ins, and Other Government Agencies or contractors were involved in 9%. Of the remaining 34% of the causes of dig-ins, Landowners accounted for the largest individual share with 7%.

Of the Telephone Company dig-ups studied, 59% occurred after notification was given to the telephone company of the intended excavation!

### Workman Error

Damage considered workman error included failures caused by telephone company personnel during maintenance, installation, and other activities. However, the data did not include procedural errors leading to dig-ins. Damage due to workman error has consistently been responsible for 7% to 8% of the failures reported.

### Rodents

Rodent damage affects buried, intrabuilding and aerial fiber optic cable and includes failures caused by gnawing animals such as rats, mice and gophers.

Frequently damage caused by rodents results in only partial failure of the cable. By contrast, 86% of the reported dig-ins severed every fiber in the cable.

In general, increasing the diameter of the cable or the duct beyond 2.2 inches delays and sometimes eliminates the threat of rodent damage. This can be done by placing rodent guards around an aerial cable or placing sub-surface cable in a large diameter PVC duct.

### Extreme Temperatures

Of the reported failures, two occurred because water froze inside a splice closure. One failure was caused by exhaust of a vehicle melting a nearby fiber cable.

### Floods

Floods cause damage when large quantities of water sever the cable or fibers. Of the six failures reported, five were the results of floods or wash-outs that broke fibers in the cables. One failure was caused by a broken water main in an underground vault.

### Lightning

Of the six events of lightning damage reported, five did not sever all fibers in the cable. Two of the events damaged only protection fibers and caused no loss of service. One failure occurred when lightning struck a tree and traveled down the roots causing damage to the nearby buried cable. The lightning strike flattened the buffer tube as well as the entire cable.

### Other Failures

These failures were caused by accidental damage by linemen, vandalism, intentional cuts during emergency situations, ice, and other unusual failures.

#### 4.0 Service Affecting Failures – Alcoa Fujikura Ltd. Data

##### 4.1 Failures in Optical Groundwire (OP-GW) Cables

By the end of 1998, Alcoa Fujikura Ltd. had installed, and in service, more than 45,000 kilometers of Optical Groundwire cable. The following table shows the cumulative AFL Optical Groundwire experience from 1986 through 1998:

<b>Cause</b>	<b>Number of Reports</b>	<b>Percent of Total</b>
Lightning	11	25%
Installation Defect	8	19
Firearms	7	17
High Winds	6	14
All Other	10	24
<b>TOTAL</b>	<b>42</b>	<b>100%</b>

High intensity Lightning strokes and Installation Defects account for 45% of the failures in Alcoa Fujikura Ltd. OPT-GW cables. Lightning strikes that do not result in damage to the cable or fibers are not reported to AFL. Only optical outages from lightning strikes are reported in the data above.

##### Lightning

Lightning strikes can cause one or more of the outer strand wires to be broken, usually without any damage to the fiber core causing an interruption of service. Normally, these defects are identified during maintenance and repaired using a preformed wire splice. The AFL Optical Groundwire cables are designed and manufactured to be equivalent in mechanical and electrical specifications to standard groundwire cables used by electric utility companies.

##### Installation Defects

Installation defects typically result from departures from the installation recommendations provided by Alcoa Fujikura Ltd. Examples of such defects include improperly grounding the OPT-GW system, and not observing the correct diameter of the wheels (travelers) used when pulling in the cable.

### Firearms

Hunters in remote areas with high powered rifles shooting at birds roosting on the OPT-GW can hit the cable in an attempt to down their prey. A strike from a bullet of a rifle will usually break an outer strand or two of the aluminum clad steel wires, which can be repaired during maintenance. At worst, damage to both the cable and the fibers will result in an unscheduled outage of the fiber system.

### High Winds (Tornadoes & Hurricanes)

Winds at very high velocities can cause towers to bend and fall, with the OPT-GW remaining attached to the top of the tower resulting, in most cases, in an uninterrupted continuation of the fiber optic telecommunications service. Where hurricanes can pack winds of up to 100 miles per hour, it is common for tornadoes to carry winds of up to 300 miles per hour.

#### 4.2 Failures in All Dielectric Self Supporting (ADSS) cables.

By the end of 1998, Alcoa Fujikura Ltd had more than 38,000 kilometers of All Dielectric Self Supporting (ADSS) fiber optic cable installed and in service. The following table shows the cumulative causes of failures with the AFL ADSS cable from 1986 through 1998:

<b>Cause</b>	<b>Number of Reports</b>	<b>Percent of Total</b>
Installation Defects	11	38%
Gunshot	8	28
High Winds	5	17
All Other	5	17
<b>TOTAL</b>	<b>29</b>	<b>100%</b>

### Installation Defects

The Installation Defects resulted from departures from the Installation Recommendations and Procedures provided by Alcoa Fujikura Ltd. The departures include installing the ADSS closer to the electrical conductors than what was recommended, and damaging the cable jacket during the installation of the cable and hardware.

Gunshot

Gunshot penetrating the outer jacket, the aramid yarns, and the inner jacket until reaching the fibers caused 28% of the failures reported. In shotgun tests conducted by AFL, the aramid yarns provided more than sufficient protection to the fiber units by preventing the buckshot from penetrating the inner jacket of the cable.

High Winds

High winds caused by tornadoes accounted for 17% of the outages reported. In these instances the integrity of the structures supporting the cable may have contributed to the failures.

5.0 Calculation of Reliability in Optical Cables

5.1 Reliability of Buried Fiber Optic Cables – Bellcore Data

The calculation of reliability in optical cables is based on the period from 1986 to 1993, utilizing the following formula:

$$E = \frac{N86/M86 + N87/M87 + \dots + N93/M93}{8} \quad (I)$$

8

where E equals the estimation of reliability, N86 is the number of cable faults in 1986, . . . , N93 is the number of cable faults in 1993; M86 is the cumulative cable kilometers installed and in service in 1986, . . . , M93 is the cumulative cable kilometers installed in 1993.

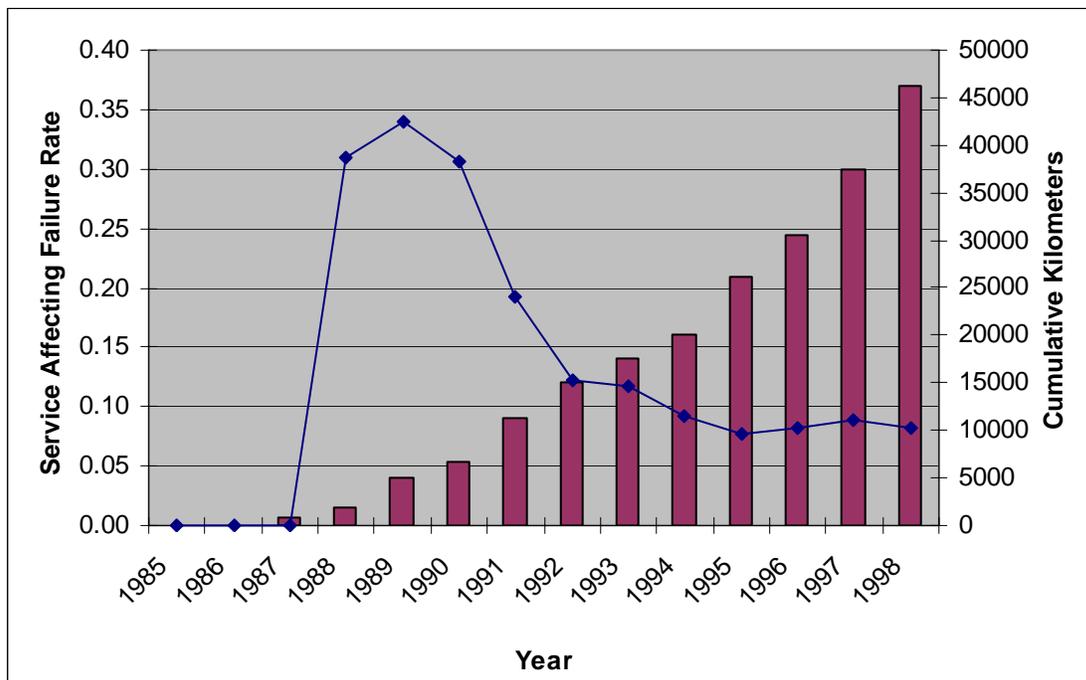
Utilizing formula (I) above, in accordance with the data taken from the articles cited in (1) and (2), conventional buried cables have an in-service reliability of 2.13 failures per 1000 kilometers per year.

## 5.2 Reliability of Optical Groundwire Cables – Alcoa Fujikura Ltd. data.

Alcoa Fujikura Ltd. had more than 45,000 kilometers of Optical Groundwire cable installed worldwide at the end of 1998, with more than 75% market share in the United States.

The in-service reliability experience with AFL's Optical Groundwire cable has resulted in only 0.085 failures per 1000 kilometers per year. This reliability factor is 25 times better than the reliability factor noted in 5.1 above for conventional buried fiber optic cables.

The following figure shows the cumulative reliability data for Alcoa Fujikura Ltd. Optical Groundwire Cable:

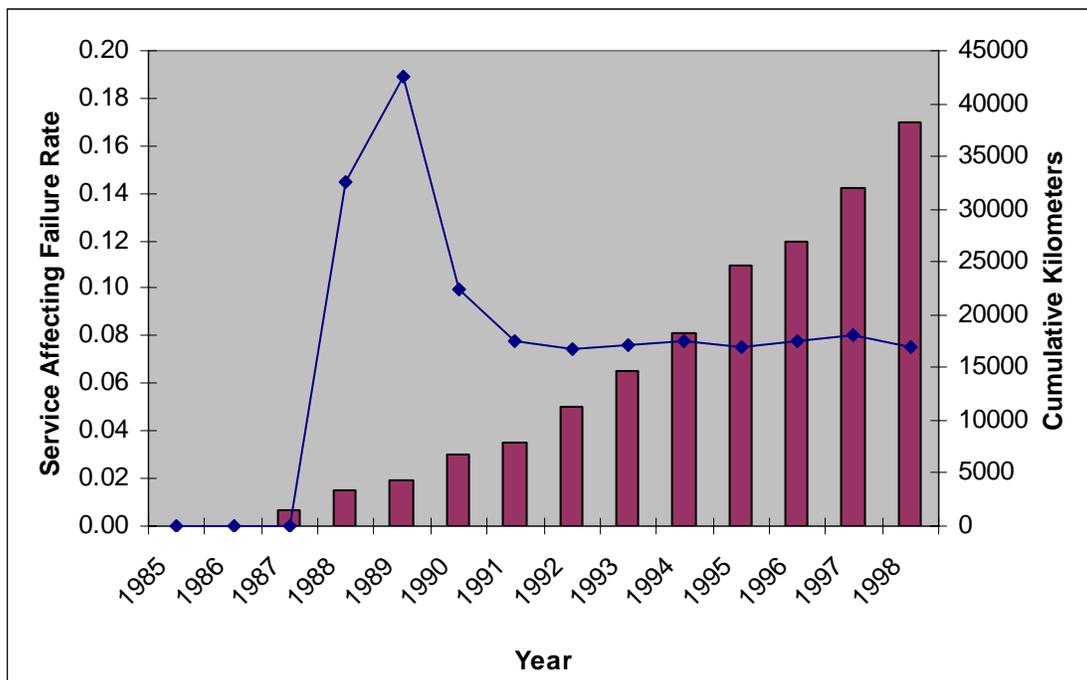


### 5.3 Reliability of All Dielectric Self Supporting Cable – Alcoa Fujikura Ltd. Data

Alcoa Fujikura Ltd. had more than 38,000 kilometers of All Dielectric Self Supporting Cable installed and in service worldwide at the end of 1998.

The in-service reliability experience with AFL's All Dielectric Self Supporting Cable has resulted in only 0.081 failures per 1000 kilometers per year. This reliability factor for ADSS is 26.3 times better than the reliability factor noted in 5.1 for conventional buried fiber optic cables.

The following figure shows the cumulative reliability data for Alcoa Fujikura Ltd. All Dielectric Self Supporting cable:



### 6.0 Repair Time for Conventional Optical Cables

For repair time for optical cables, two measurements are considered:

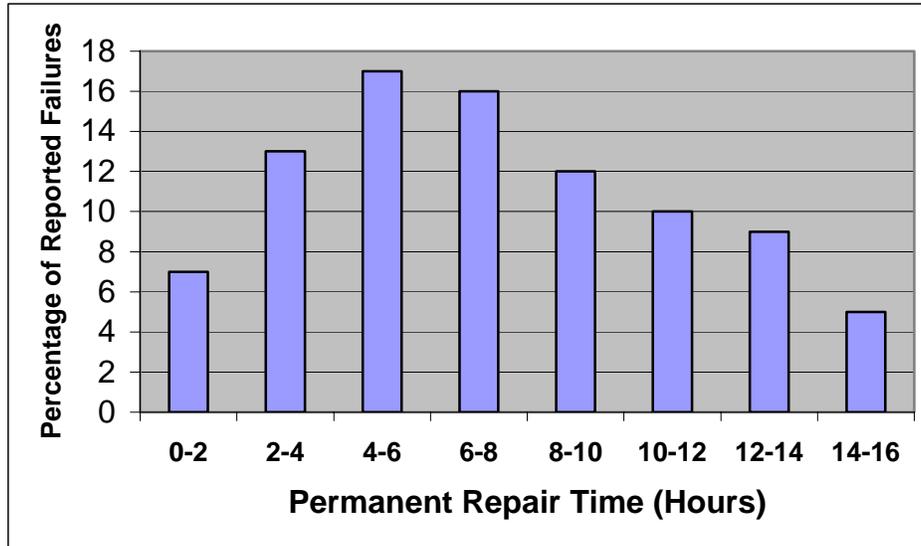
- Time to Permanent Restoration
- Time to Restoration of Service

The permanent repair time includes the time required for the repair personnel to arrive on site, locate the cable fault, make the necessary repairs including resplicing the fibers, and reinstall the cable.

The restoration of service time includes the time necessary to install the emergency cable and the temporary splices. Usually, the time to restoration of service is much less than the permanent repair time.

## 6.1 Permanent Repair Time

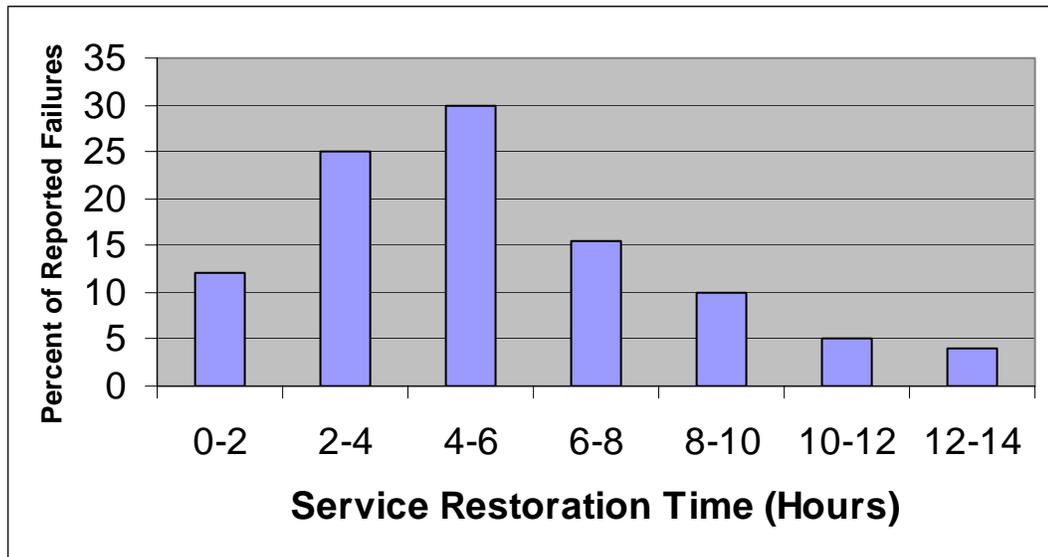
The following histogram shows the permanent repair time, based on the 233 cable faults reported. Of these faults reported, the average repair time was 13.8 hours, and the median repair time was 8.0 hours.



For Alcoa Fujikura Ltd. aerial cable, Time To Restoration of Service on a temporary basis is usually less than two hours using established emergency restoral procedures. Time to Permanent Restoration is somewhat dependent on availability of line outages from the electric utility and the telephone company's timetable for rolling traffic off the fibers in order to splice-in the permanent cable and replace the temporary cable.

## 6.2 Restoration of Service Repair Time

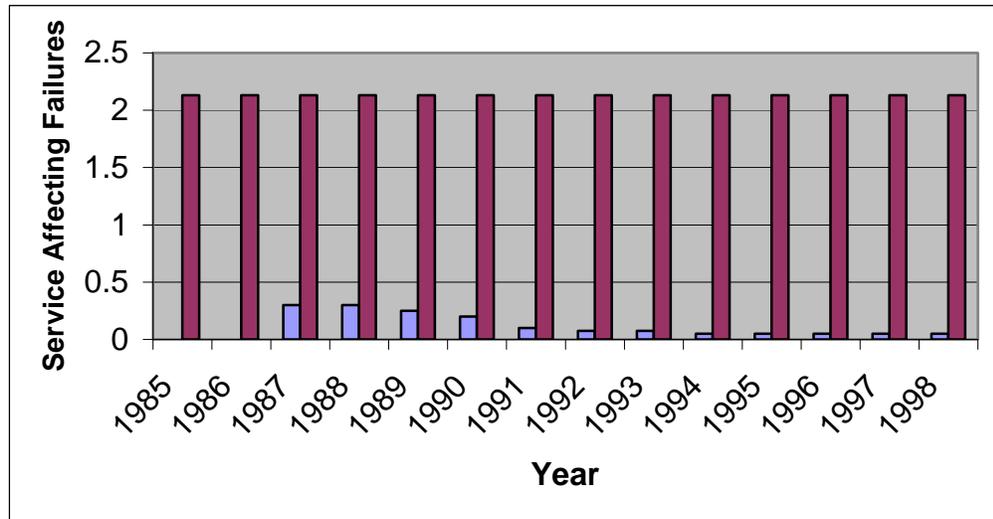
The following is a histogram of the service restoration time for conventional buried fiber optic cables:



## 7.0 Conclusion

According to the data presented on the failures of fiber optic cables, we conclude the following:

- Based on the current experience, Alcoa Fujikura Ltd. aerial fiber optic cables have the lowest service affecting failure rates of the cables studied, and are therefore expected to provide the longest continuous service of any fiber optic cables;



- 80% of the failures of Direct Buried Cables and 65% of the failures of Buried Cables installed in Ducts were caused by excavations – this type of human error has no impact on aerial fiber optic cables;
- The Alcoa Fujikura Ltd. Optical Groundwire and All Dielectric Self Supporting cables have exceptionally low service affecting failure rates as compared to the Buried Fiber Optic Cables;
- With an average of more than 2 service affecting failures per 1000 kilometers per year, and with an 8 hour average restoration time, buried fiber optic cable systems experience significantly greater lost revenues caused by catastrophic failures and greater maintenance costs than what would be experienced with the Alcoa Fujikura Ltd. aerial cable systems.
- The Buried Cable Systems are projected to have a much greater lifetime cost than the Alcoa Fujikura Ltd. aerial systems.

## **Bibliography**

- (1) V.T. Hou, "Update on Interim Results of Fiber Optic System Field Failure Analysis." Proceedings of the National Fiber Optic Engineers Conference (NFOEC), Nashville, Tennessee, April, 1991.
- (2) Samuel V. Lisle, "The History, Prevention and Impact of Fiber Optic Cable Failures," NFOEC, 1993
- (3) Alcoa Fujikura Ltd., Internal data on reliability of Optical Groundwire and All Dielectric Self Supporting fiber optic cables.