# IMPROVING RELIABILITY OF DROP WIRE CONNECTIONS

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## ABSTRACT

*One of the weak links in CATV systems for years has been the 59/U drop connectors when they have been installed outdoors. This can be shown by the analysis of service call records and more recently thousands of radiation reports.*

*This presentation describes new connector concepts that are designed to reducing these problems. These concepts are applied to a new connector which has improved mechanical and electrical parameters with simple installation procedures for all weather conditions.*

*What is the cost of a more reliable system and improved reception to the subscriber?*

*How can the technical trade-offs be converted into dollars? The method of assessing the economics of this new connector are also discussed.*

## INTRODUCTION

The demand for improved performance of subscriber drop "F" connectors is steadily increasing. The CATV Industry is now utilizing the full bandwidth of the system. Frequencies outside the standard TV/FM band are now regularly being used for additional channels in the forward and reverse directions. RF integrity in the mainline hardware and co-axial cables in the past has been greatly improved to overcome egress and ingress problems. The weak link in the present CATV network remains in the drop wire "F" connector, and since this is an equally important connection the requirement to maintain integrity must be met.

This paper deals with improvements to the "F" connector aimed at overcoming this weakness. This paper is divided into the following sections.

1) Historical Background
2) Design Philosophy
3) Improved Connector Assembly
4) Cost Analysis

## HISTORICAL BACKGROUND

One way to evaluate system problems is to maintain records that can assist in the review of past experiences and problems. Our radiation monitoring system has certainly indicated a problem in the connector area.

Figure 1 represents the data tabulated for over 3,000 cleared radiation problems that have been detected by this monitoring procedure. The chart is divided into six sections as follows:

a) <u>Drop Hardware</u>
Consisting of connectors, splices, matching transformers, tap-off devices, and drop cable. Seventy percent of the data reported in this section was due to connectors alone.

b) <u>Feeder Cable</u>
Consisting of connectors, splices, sheath breaks, and other problems that could be encountered on trunk and distribution cables. The problems reported in this section were mostly with connectors and splices.

c) <u>Passive Equipment</u>
Consisting of splitters, multi-taps, wrong value multi-taps, matching transformers and other passive equipment. Problems reported were mixed with no definite trends.

d) <u>Active Equipment</u>
Consisting of amplifiers and mostly reflects problems with levels set too high and loose housing lids.

e) <u>Illegal Hookups</u>
Consisting of illegal extensions to FM/TV sets, or neighbour's sets with 300 ohm lead or other unauthorized connections with unshielded cables.

f) <u>Subscriber's Equipment</u>
Consisting of internal and external antennas that are still hooked up and extensions made with 300 ohm lead or other unshielded cable to move the receiver. Approximately 60% of this section was due to subscribers antennas still hooked up.

The radiation monitoring system has indicated approximately 1,455 connectors requiring repairs. Radiation monitoring equipment has been operating in eleven of Canadian Cablesystems' licensed areas for three years now with one radiation receiver installed per vehicle for each one hundred and fifty kilometers (94 miles) of plant.

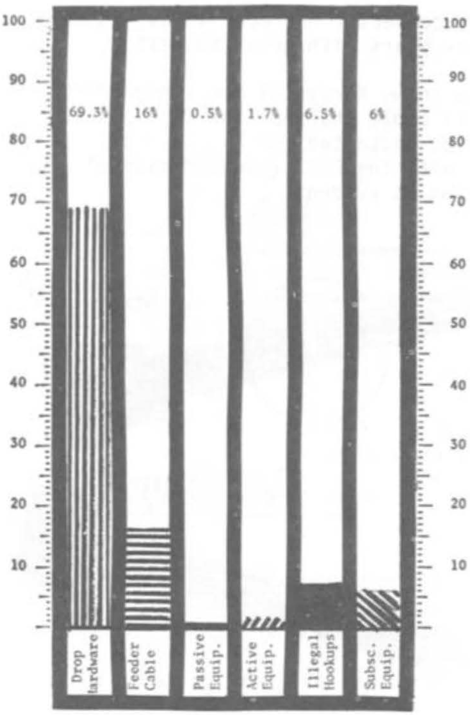


Figure 1
ANALYSIS OF RADIATION MONITORING PROBLEMS

In 1972 the demand for a more effective shielding for drop wire steadily became important to meet the requirements of systems with signals in the midband. The cable selected by Canadian Cablesystems is of the aluminum tape surrounded by braided shield. Specifically the construction is an aluminum-polypropylene-aluminum-laminate tape, 0.0017" thick applied longitudinally with an overlap encasing the polyethelene dielectric with an additional braid with 55% of shielding. See Figure 2.

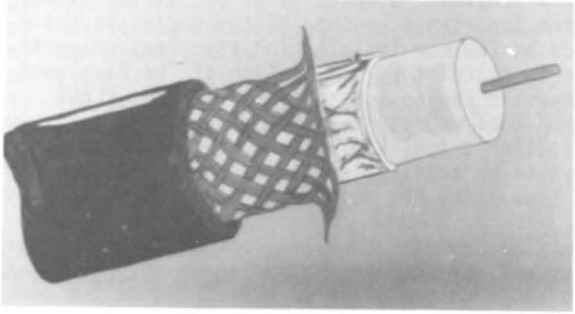

Figure 2
SINGLE BRAID CABLE WITH FOIL

Standard F59 connectors did not make proper connections to the aluminum foil; they caused more radiation and ingress problems than we had experienced with our 95% braided cables. This problem is specifically related to the mandrel forcing the foil back or through oxidized contact materials and not making a proper connection.

A second problem of concern for many years has been that of weatherproofing connections. Weatherproof boots and other methods that have been used for many years have not been very successful. I am sure you have seen corroded connections at your line tap-offs. Totally sealed drop connection in the underground environment has been another problem not yet solved.

In search of a solution to this problem, one must examine the fundamentals.

## DESIGN PHILOSOPHY

Proper operation and reliability of a connector depends to a large extent, on how well it can perform while withstanding specified environmental conditions. The following are some of the most commonly encountered environmental factors to be considered:

a) High and low temperature
b) Thermal shock
c) Mechanical shock and vibration
d) Rapid change in pressure
e) Humidity
f) Bacteriological growth and fungus
g) Presence of corrosive atmosphere (1)
h) Salt spray
i) Dust and sand
j) EMI - electromagnetic interference (2)

Not all of the above factors may be encountered in the same system, but sometimes a combination of several of them may create extremely critical situations. In addition to the environmental factors other requirements must be considered in this design:

a) Compatibility with other fittings and hardware of the system.
b) Easy installation with minimum effort and inexpensive installation tools.
c) Producible at a reasonable and justifiable cost.
d) Exhibit a high reliability level and be readily maintainable.

## IMPROVED CONNECTOR ASSEMBLY

In 1954, Eric Winston of Jerrold Electronics developed a solderless and easy to install connector call the F59 as shown in Figure 3.

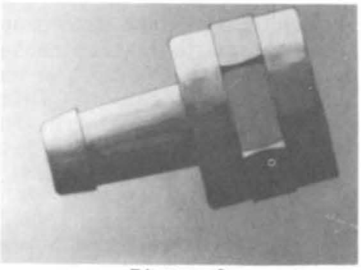

Figure 3
STANDARD CONNECTOR

This connector has been, and is still being used with a great deal of success for RG59/U type braided cables. However, when the foil braided cables came along, the standard "F" connector could not be installed without the foil being pushed back under the braid and jacket as shown in Figure 4.

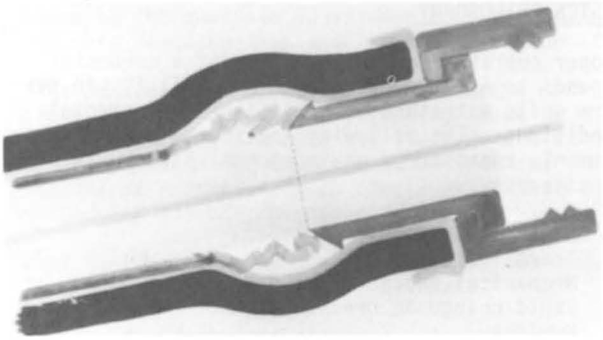

Figure 4
FOIL DISTORTED WITH STANDARD F59

In an attempt to correct this problem, Albert Stirling of Stirling Connectors, Canada, worked with Canadian Cablesystems to improve this problem. A solution was modifications to the standard F59 as shown in Figure 5, that consists mainly of slots in the mandrel and a flare inside the mandrel so that the connector may now slide over the foil and under the braid.

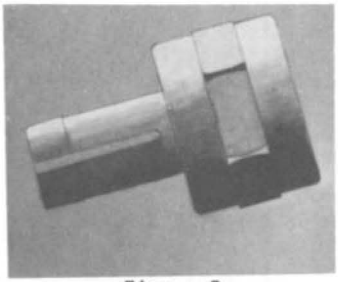

Figure 5
SPLIT MANDREL CONNECTOR

The foil could now be seen inside the connector's swivel nut fitting, assuring a good connection. One additional feature of this modification is that with a standard size crimp ring the mandrel will collapse down onto the foil making a mechanical and electrical connection, ensuring continuity of the shield conductor. The mechanical cable retention is increased by an additional 15 lbs. This improved connector has been in use in cable systems for three years with great success.

Figure 6 shows X-rays of the standard F59 installed on a foil cable that has the foil pushed back and the braids distorted for a couple of inches, contrasted with the F59S (slotted mandrel where no distortion is evident.

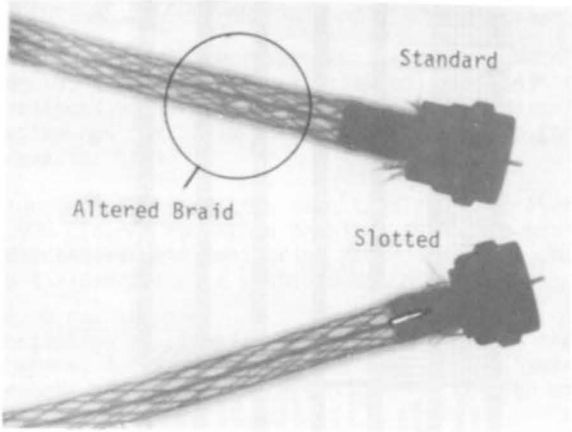


Figure 6
X-RAY COMPARISON OF STANDARD AND SLOTTED F59

The slotted mandrel connector also shows shielding improvement for bonded foil cables through the improved electromechanical connections. However, this does not solve our moisture ingress problem.

The combined efforts of Cablesystems Engineering and Amphenol of Canada Ltd. continued with the activity in attempting to solve the moisture ingress problem through the development of a waterproof F59S connector.

In the preceding section, the design philosophy which should be considered in this development was discussed. Simplicity is identified as having prime importance because of the desire to introduce as few new installation practices or parts. For instance, the installation of the developed connector can be accomplished with the PL602 crimp tool and other standard tools found in your installer's tool kit. The number of parts that have to be handled is still three. This concept of simplicity has maintained an economical design.

The first modification was made to the connector body and the coupling nut as shown in Figure 7-1. Two neoprene seals 3 have been added to the connector. The Hex nut has to be changed to 1/2", to permit an increased shell size necessary to accommodate the addition of the seal inside the coupling nut. The seal is positioned inside the coupling nut 1 and 3 in order to maintain the same grounding contact of the shouldered contact 4 found in the standard F59.

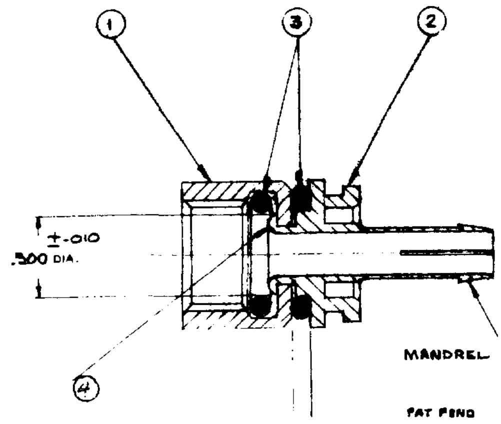


Figure 7
AMPHENOL WATERPROOF F59S

The addition of these seals waterproofed the connector, but they do not guarantee a seal from the body of the connector to the cable.

The next modification included the design of a sealing boot that could be easily installed on the cable and would slip over the body of the connector but would not interfere with the coupling nut. The body of the connector has an additional groove to accommodate the sealing boot shown in Figure 7-2 This design approach allows the boot to remain on the connector during installation and disconnection. Three sealing rings are moulded into the inside surface of the boot so that proper sealing is achieved around the cable jacket. See Figure 8.

Critical properties must be considered in the selection of the material for the sealing parts. They must have:

a) Long-term weather adaptability
b) Non-solubility
c) Resistance to corrosive reagents
d) Non-adhesiveness
e) Flexibility at low temperatures
f) Low co-efficient of friction
g) Stability at high temperature

Neoprene was selected as the material most suited to these requirements.

Figure 8 shows the final version of the waterproof F59S with the sealing boot installed.

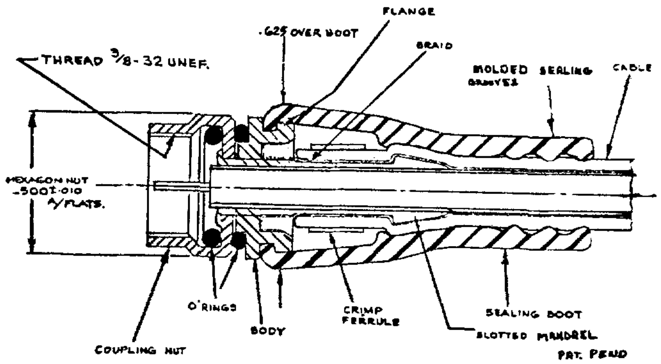


Figure 8
AMPHENOL WPF59S WITH WEATHER BOOT INSTALLED

After finalizing the requirements for the connector, and the basic electromechanical design criteria, a set of performance specifications were formulated. They are as follows:

Specifications for Waterproof F59S Co-Axial Connector

a) Electrical

i) Impedance - 75 ohm nominal.
ii) Voltage rating - 500 volts peak.
iii) Dielectric withstanding voltage - 1500 volts R.M.S.

b) Mechanical

i) Cable affixment - Crimp Ferrule 0.135" wide.
ii) Cable retention - 35 lb. maximum pull test of cable from connector.

c) Environmental

i) Operating temperature range -40°C to 85°C.
ii) Vibration - Mated connectors will withstand vibration to MIL-STD-202 Method 204 (Test Condition D) (20 G. peak) over a frequency range of 10 to 2000Hz. 12 times with connector mounted in the horizontal position and vibration in the vertical mode for a period of 8 hours.
iii) Corrosion - Salt spray test in accordance with MIL-STD-202 Method 101 (Test Condition B) length of test 48 hours exposed to a salt solution concentrate of 5%.
iv) Water Pressure Seal - Mated connectors will withstand a differential water pressure of 5 P.S.I. No electrical degredation after testing.

d) Materials

i) Connector body - Zinc diecast.
ii) Coupling nut - Zinc diecast.
iii) Crimp Ferrule - Brass.
iv) Plating - Cadmium Plate (All metal parts).

v) Sealing boot - Neoprene Per MIL-G-1149B Type 1-Class 1.
vi) O'Rings - Neoprene Per MIL-G-1149B Type 1-Class 1.

Prototype connections have been built to those specifications and have been subjected to and have passed the following tests:

a) Continuity - mating connector coupling nut and center conductor to cable.

b) Dielectric withstanding voltage - 500VDC for 5 seconds mated.

c) Waterproof - tested at 5 lbs. per square inch pressure - 60 days.

d) Physical vibration at -30°C - 20 G. peak 20-2KHz, 8 hours, mated followed by tests a), b), and c).

e) Physical vibration at 50°C - 20 G. peak 20-2KHz, 8 hours mated followed by tests a), b), and c).

f) Accelerated thermal aging at 85°C - 50 hours unmated.

g) Accelerated thermal aging at -55°C - 50 hours unmated followed by tests a), b), and c).

h) Cable retention test - 30 lbs. axial pull force, followed by tests a), b), and c), mated.

i) Salt spray - as Per MIL standard 202, Method 101 (Test Condition B) length of test 48 hours exposed to a salt solution concentrate of 5%.

COST ANALYSIS

In order to compare the costs a model system with 20,000 subscribers will be used. The assumptions in developing this model are as follows:

a) Cost of standard F59 with weather boot--0.20
b) Cost of waterproof F59S--0.50
c) Cost of service calls, overhead including truck, tool and expenses per call--10.85
d) Service calls due to drop problems average 7.5% of subscribers per year with 80% of these calls due to connectors.
e) Assumed service call reduction of 50% is proposed for the waterproofed drop connectors.

Therefore, fixed cost for standard F59 will be:

$$\begin{aligned} FC_S &= 20{,}000 \times (a) \\ &= 20{,}000 \times 0.20 \\ &= \$4{,}000 \end{aligned}$$

Variable cost per year will be:

$$\begin{aligned} VC_1 &= 20{,}000 \times (d) \times (c) \\ &= 20{,}000 \times 0.075 \times 0.80 \times 10.85 \\ &= \$13{,}020 \end{aligned}$$

Proposed waterproof F59S will be:

$$\begin{aligned} FC_P &= 20{,}000 \times (b) \\ &= 20{,}000 \times 0.50 \\ &= \$10{,}000 \end{aligned}$$

Variable cost per year will be:

$$\begin{aligned} VC_2 &= 20{,}000 \times (d) \times C \times 0.50 \\ &= 20{,}000 \times 0.75 \times 0.80 \times 10.85 \times 0.50 \\ &= \$6{,}510 \end{aligned}$$

Figure 9, indicates a breakeven point at the 12th month period and a cost savings in the second year. If some of the assumptions in this model do not agree with your experience, try your own maintenance costs.

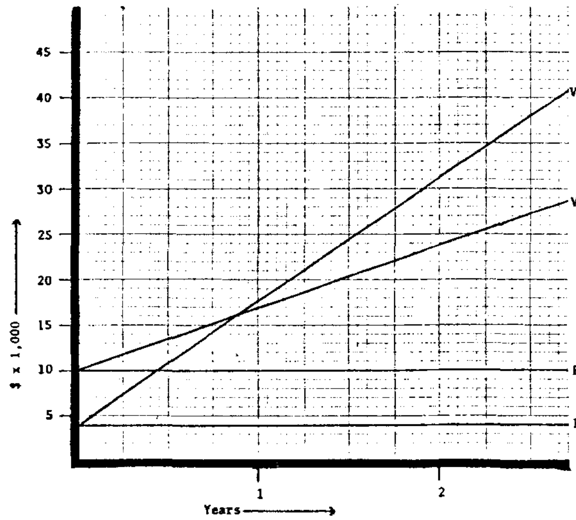


Figure 9

COST COMPARISON

The above calculations have not considered depreciation, tax savings and present value since technical departments do not normally base their evaluations and comparisons on that type of calculation. However, I would like to model another analysis based on present value calculations. The data in developing this model is as follows:

a) The cost of a standard F59 with weater boot--0.20
b) The cost of waterproof F59S--0.50

Therefore, the incremental investment in a 20,000 subscriber system = 0.30 x 20,000 = $6,000

c) Service calls due to drop problems average 7.5% with 80% of these calls related to

connector problems. The assumption that the proposed connector reduced connector related service calls by 50% as a savings of 20,000 x 0.075 x .80 x .50
= 600 calls per year is realized.

d) Cost of service calls, overhead including truck, tools and expenses per call--10.85

Therefore, yearly savings = 600 x 10.85
= \$6,510

e) Tax rate 48%
f) Capital cost allowance 30%
g) Present value return rate 12% = i
h) Life 10 years = N
i) Annuity factor $\frac{1}{i}\left[1 - \frac{1}{(1+i)^N}\right]$
j) Tax shield = tax rate x $\frac{\text{capital cost allowance rate (CCA)}}{\text{CCA + return rate}}$

The net present value (NPV) can be obtained from the following formulae:

NPV = Investment x [1-tax shield] + yearly savings x [1-tax rate] x annuity factor

$$\text{Therefore, NPV} = -6{,}000 \times \left[1 - \frac{0.48 \times 0.30}{0.30 + 0.12}\right] + 6{,}510 \times (1-0.48) \times 5.65 = \$15{,}184.38$$

Therefore, the waterproof connectors after recovering their increased costs provide a net saving of \$15,184.00.

Now, if we wish to determine how many service calls per year we need to breakeven on the incremental cost of investment over a 10 year period; i.e. set the net present value to 0.

NPV = investment x (1-tax shield) + (# service calls saved) x cost of service calls x (1-tax rate) x annuity factor

$$0 = -6{,}000 \times \left[1 - \frac{.48 \times .3}{.3 + .12}\right] + \text{\# service calls} \times 10.85 \times (1 - .48) \times 5.65$$

0 = -3,942 + # service calls x 31.88

Therefore, # service calls = 123

Therefore, if more than 123 or 0.6% of subscribers have service calls due to connector problems then the extra cost of the new connector is covered and a net savings is realized in the 20,000 subscriber model system.

I must point out that the above models do not take into account radiation problems, since the subscribers normally don't call for a service call when their drop wire connector is exceeding FCC/DOC standards and regulations. Radiation problems have not been recorded in our service call analysis; therefore additional expense allowances must be added to the above results for the added costs. Based on data recorded and indicated in Figure 1, this percentage can be quite high in the first couple of years when clearing radiation problems.

I believe that this Cost Analysis helps to indicate that improved drop line connections are required and can be justified.

## SUMMARY

The CATV operators' primary goal is to manage profitable systems with a minimum of downtime. From the data taken to date and with these design concepts, we have demonstrated that predetermined electromechanical design objectives can be achieved in addition to practical and inexpensive goals.

## ACKNOWLEDGEMENTS

The author would like to acknowledge the assistance of A. Stirling of Stirling Connectors, Canada and Jim Stokes and Kam Boutrof of Amphenol Canada Ltd. Appreciation is also extended to my colleagues at Cablesystems Engineering for their contributions in this project.

## REFERENCES

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(2) Winston, Eric, A Study of Aluminum Cable - Connector Interfaces and Their Effect on CATV System RF Ingress.