A New Type of Very High Reliability Torsion IDC Which Can Accept A Large Range of Wire Gauges

Janos Legrady

Zierick Manufacturing Corporation
Radio Circle, Mount Kisco, New York 10549

ABSTRACT

This paper describes a new type of insulation displacement connector (IDC). The terminal is capable of terminating a wide range of wire gauges with very high reliability and withstanding repeated mating cycles. The following subjects are discussed in this paper:

- The mechanics and some of the limitations of conventional IDCs.
- Design analysis of the new type torsion IDC and practical advantages of the new design.
- IDC beam and wire interaction with emphasis on stranded wire.
- Degrading mechanisms acting on an IDC and how this design addresses those issues.
- Testing

INTRODUCTION

IDCs have become popular as they are highly economical and a cost effective method for performing wire terminations. No wire or cable preparation required. In the case of ribbon cable applications mass termination of multiple wires is accomplished easily and effectively. The design of early or first generation IDCs only allowed for peak application performance over an application range on one or possibly two wire gauges. These designs made a good initial contact but failed to withstand harsh conditions typical in industrial, automotive and appliance applications.

Much research has been done to design an improved IDC, and to analyze the cause of IDC failure. I studied and researched this IDC related work. The results of some of this work were presented on this forum.

Zierick Manufacturing Corporation had a request from a major car manufacturer to replace a two piece separable (6 line) connector on their suspension level control system with a low profile (3/16" high) inexpensive separable printed circuit board mounted connector, which has reliability equivalent to a crimp type terminal. It is needless to say that they were very surprised and very pessimistic when we recommended an IDC. They told us all their previous bad experiences with PCB mounted IDCs and it took some persuasion just to convince them to take our samples and run their own tests on them. Their biggest concern after testing the terminal was how fast we can tool it up.

Some of the design criteria for the torsion IDC:

- It must be a separable connection. At least 10 mating cycles.
- Must stand up well in a harsh operating environment (shock, vibration, high temperature, etc.) just like a good crimp termination.
- Must terminate several wire gauges (stranded and solid).
- Must provide strain relief for the wire.

- Terminal must lend itself for automatic PCB insertion and wire termination.
- Easy and reliable wire termination in the field with a hand tool providing positive wire feed back.

To explain the principal of torsion IDC and demonstrate the superiority of the design we analyze step by step the conventional and the torsion IDC.

CONVENTIONAL

The conventional IDCs consist of two fairly rigid contact beams and a wire slot between them. The conductor slot is smaller than the conductor diameter. When a wire is inserted into the IDC slot, the lead-in chamfer cuts and displaces the wire insulation. As the wire is pushed further down in the slot, there is a deformation of both the conductor and the IDC beam. The conductor will have mostly plastic deformation while the contact beams will have elastic deformation (deflect outward) as shown in figure 1.

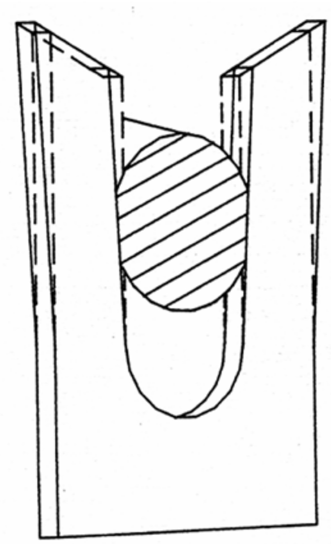

FIG.1 Conventional IDC terminated with solid wire

This deformation is proportional to the ' - normal (contact) force which acts on the conductor and on the contact beam interface. This normal force is very important to establish and maintain a good gastight connection. Several degrading mechanisms work against this gastight connection. The most important are:

- Creep which is the change in deflection or deformation over time with constant force. In the case of IDC termination the wire creep is a significant factor. Also referred to as sizing which is defined as reduction of the wire diameter due to environmental conditions.
- Stress relaxation - which is the reduction in force over time with constant deflection is largely depends of initial stress level and temperature. Stress relaxation in the contact beams will reduce the normal force.
- Movement between conductor and contact which is caused mainly by wire flexing, pulling, and the difference in thermal expansion coefficients of the conductor and the contact material. Those movements are specially degrading in the case of stranded wire because it helps the wire strands to rearrange in a narrower shape with lower energy level. Figure 2 shows a typical wire strand rearrangement of a seven strand wire before and after inserted into a conventional IDC.

All these degrading mechanisms cause normal (contact) force reduction, which depends on the contact spring rate. Figure 3 shows the spring rate of a conventional IDC contact and the force-deformation curve of different wire sizes. The short stiff beams of the conventional IDC have very little deflection. After wire sizing the contact force is largely reduced. Also the stiff contact beams are doing a poor job rearranging the wire strands into the narrowest width shape.

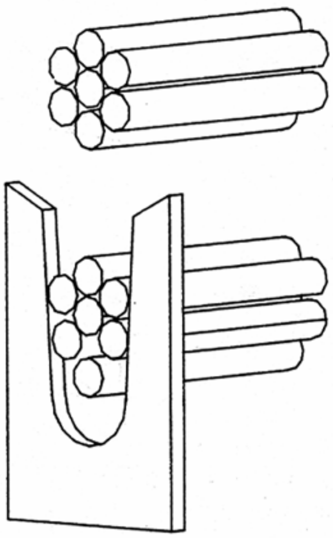

FIG.2 Conventional IDC terminated with stranded wire

TORSION IDC

Figure 4 shows a PCB mounted, high force, high deflection, low stiffness, torsion IDC before and after wire insertion.

The two front contact beams are pushed against each other with a preset force called preload. It is set by forming the top torsion beams into a curved shape (crown). Figure 5 shows a cross section of the curved top torsion beams. Preload also can be set by slightly curving the rear torsion beams and the rear base. With the right preload the minimum contact force, the range of the wire sizes, and even the wire strand rearrangement can be controlled effectively.

When a wire is pushed down against the coined V shaped insulation shear edges, the edges will cut the wire insulation. If

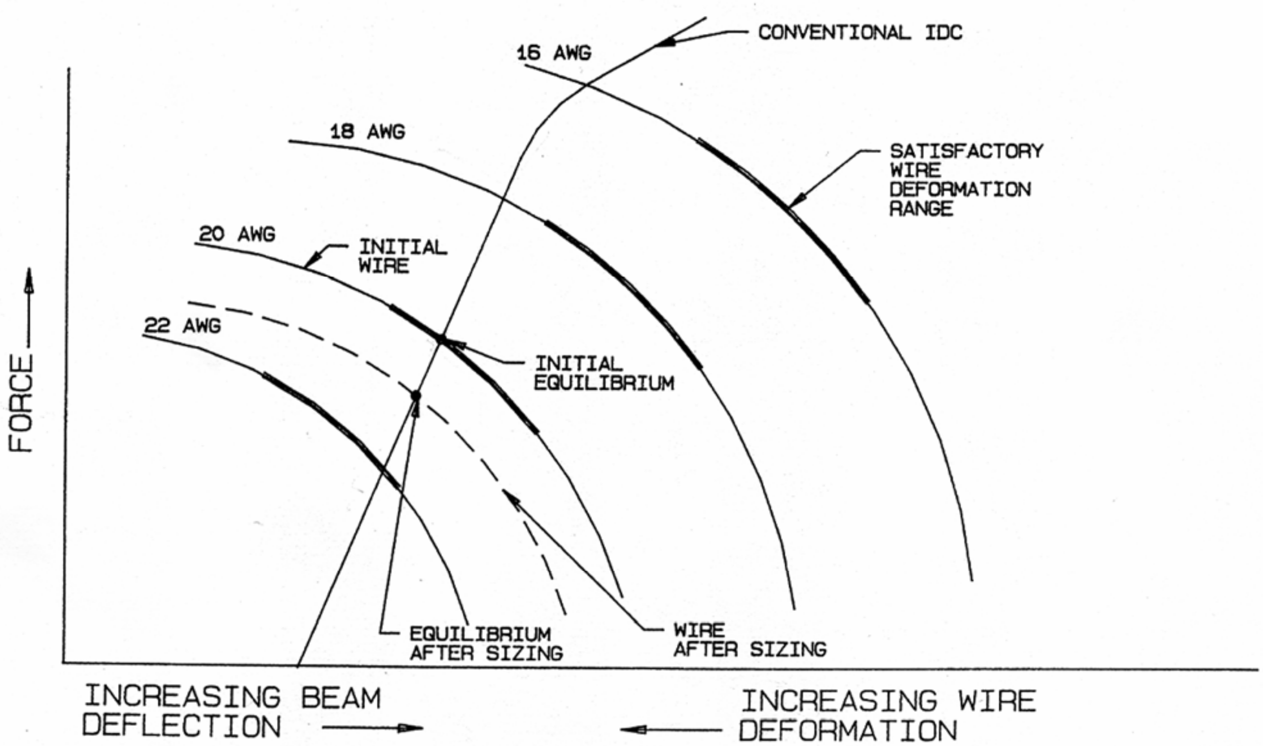

FIG.3 Force-deformation curve of different wire sizes and the spring rate of a conventional IDC contact beam

the wire is pushed further down, the wire termination slot will open up. This slot can open up to a width larger than the wire diameter without taking permanent set, so it can receive the total full diameter of the stranded wire. At this stage the terminal beams are in a maximum force - maximum deflection position exerting high normal forces on the wire.

When the wire is moved further downward in the wire conduit slot, the high normal forces combined with the downward movement of the wire will rearrange the wire strands into their narrowest shape, and in the case of stranded wire, one single line (if the wire strands are not bundled too tight). The front contact beams will close in on the wire strands and keep them under contact pressure. See figure 6.

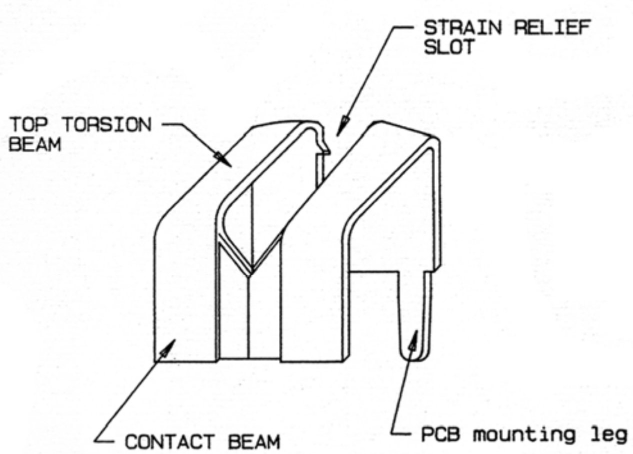

FIG. 4-A Torsion IDC

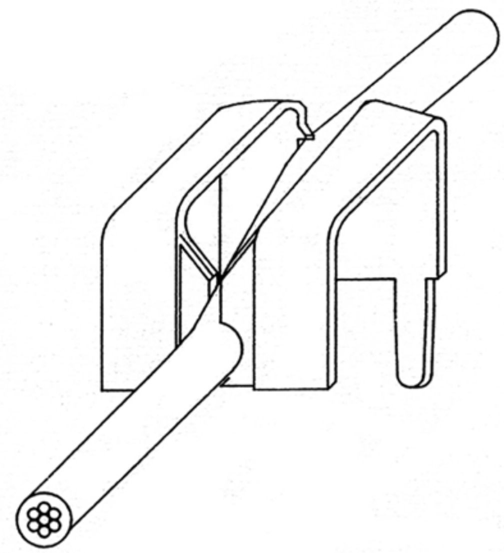

FIG. 4-B The Torsion IDC terminated with stranded wire

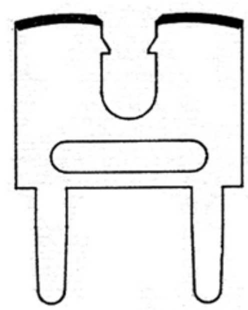

FIG.5 Top torsion beam cross section

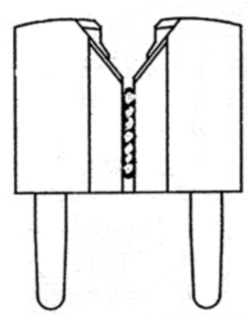

FIG.6 Single line wire strand rearrangement

The ability of the torsion IDC to achieve this large - force, large - deflection characteristic can best be explained by a stress analysis.

When an 'F' force (wire) is applied at the center of the two front contact beams as shown in figure 7, the two front contact beams are under bending load. The top beams are under a combined load of torsion and bending load and the rear beams also under torsion and bending load. The deflection at the wire is the sum of the angular deflection of the beams under torsion load and the beam deflection under bending load. Numerical analysis shows that the deflection from torsion load is much larger than the deflection from bending load.

Figure 8 shows the force - deflection diagram of a conventional IDC, the torsion IDC and the force - deformation curves for different wire sizes. The intersection of curves represents equilibrium points. Since the preload can be set independently (without changing the stiffness of the torsion IDC), the force - deflection curve can be moved up and down so it intersects the maximum different wire sizes at the satisfactory wire deformation range.

In figure 8 the torsion IDC with 0 preload provides acceptable connection for 2 wire sizes only. By increasing the preload to the correct levels, the IDC can terminate five or more wire sizes. One of our terminals can terminate a range from 18 to 26 awg.

Figure 9 shows conductor sizing or change in the width of the rearranged wire strands. There is only a small change in the normal force because of the low stiffness characteristics of the torsion IDC. Even at zero gap there is enough force to maintain a good gastight contact.

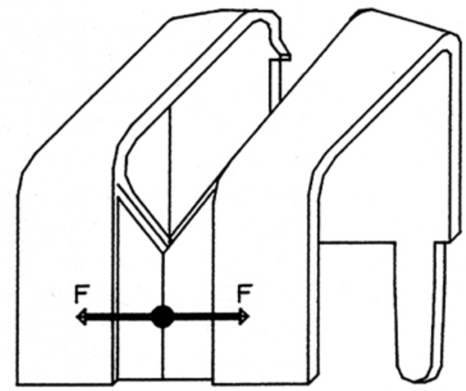

FIG. 7

The contact pressure can be set by the optimum combination of the preload on the two front contact beams and by coining the edges of the contact beams to adjust the contact area.

Figure 10 shows the deflection of the loaded contact beams. Notice the slightly tapered wire conduit slot which is widening at the lower part of the terminal. The angle of the taper can be adjusted by setting the preload correctly. As mentioned before, the preload is not uniform along the length of the wire conduit slot; it is larger near the insulation shear edges.

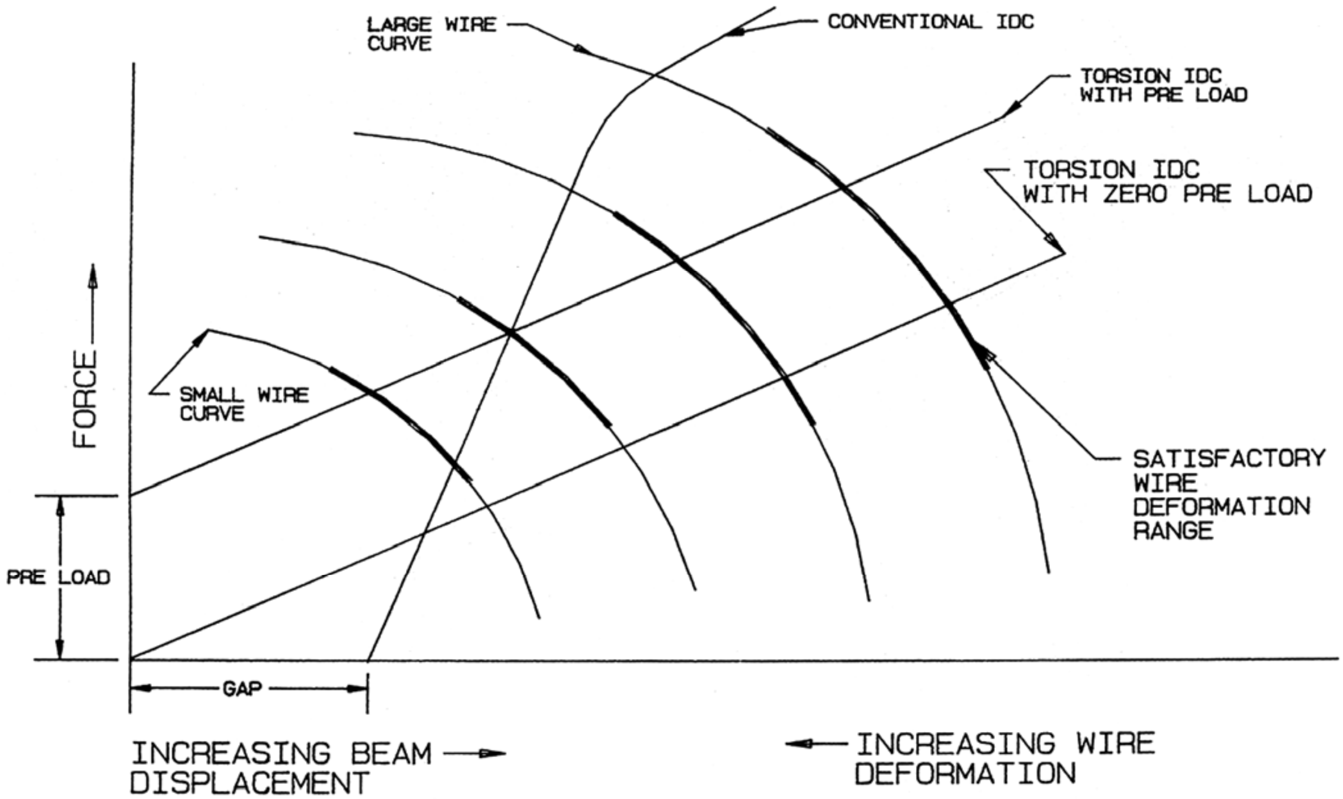

FIG.8 IDC Deformation - Deflection curves

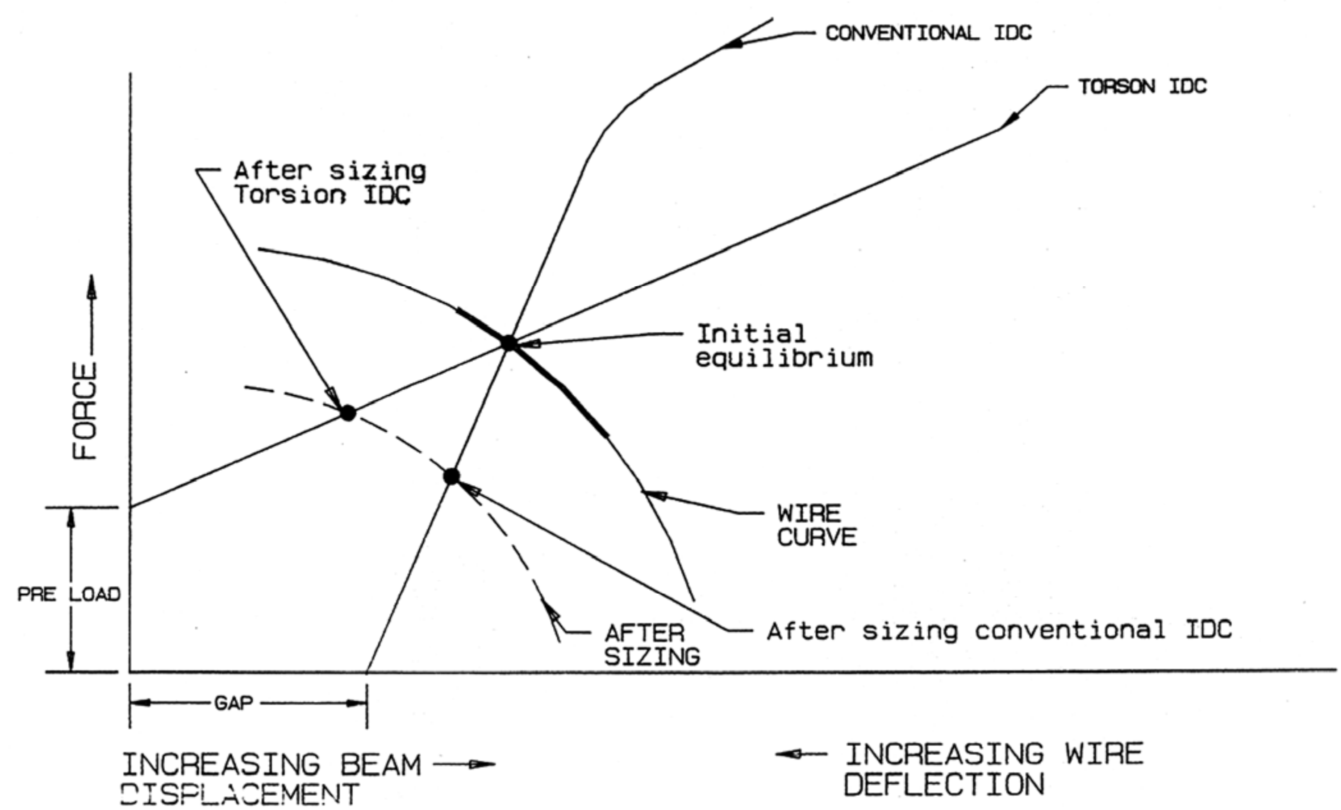

FIG.9 Change of normal force after sizing

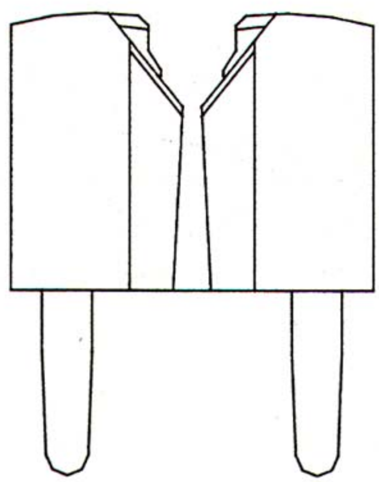

FIG. 10

A slightly tapered wire slot improves the connector's reliability. If there is a wire strand movement from vibration or temperature change, the strands will move to the direction of least resistance, which is downward, where the slot is slightly wider. The lower end of the slot is closed off by the PC board so the wire strands cannot leave the slot. When a wire is inserted into the terminal, the wire insertion force is increased to the maximum while the insulation is cut and the wire opens up the wire slot. From this maximum level, the wire insertion force will rapidly decrease to a minimum while the wire is pushed down in the slot. This gives a snap-in effect. It is critical that when the wire is inserted with a hand tool (field termination) it gives a good feedback. When the operator pushes the hand wire insertion tool with an increasing force, the wire does not move until the force reaches the termination force level. Then the wire just snaps all the way into the slot - no half way wire insertions. On a conventional IDC terminal, the wire insertion effect is just the opposite. It takes an increasingly large force to push the wire all the way down in the wire slot because the wire gets tighter and tighter.

When there is a wire movement from shock, thermal cycling, or vibration, the wire tends to move out from the slot because it moves in the direction of least resistance. This IDC is not sensitive to the relative motion between the wire and the terminal.

The rear slot on the terminal body works well as a wire strain relief by holding the wire firmly in place. Two hooks or dimples prevent the wire from coming out of the strain relief slot. Also this strain relief slot with hooks simplifies the wire insertion during assembly. The wire can be pushed in and seated in the strain relief slot by hand. This will keep a section of the wire lined up with the "V" grove of the insertion tool, which terminates the wire by inserting it into the wire slot.

The terminal is designed for a large range of wire sizes and dozens of mating cycles. A single terminal can accommodate a range from 18 to 26 awg, while the maximum stress in the terminal remains below 70% of yield stress, so no permanent set and very little stress relaxation takes place.

TESTING

Actual force-displacement test proved the result of the conventional stress analysis and finite element analysis.

Cross sections of the termination show wire deformation range 15% - 40% depending on wire sizes. With stranded wire the deformation range 5% - 15%. With seven strand stranded wire most of the time, the wire strands get rearranged into one single line, but not consistently because of other variables. When the wire is removed from the slot, the terminal returns to its original zero gap position without the loss of the preload force between the contact beams, which is sufficient to maintain a good contact.

Contact resistance measurement before and after accelerated aging and temperature shock show less than 9% maximum change in contact resistance.

SUMMARY

We have developed a highly reliable insulation displacement terminal, which accepts a large range of wire sizes. It is capable of enduring many mating/unmating cycles without terminal fatigue. The wire can be mass terminated, or terminated in the field with a hand tool-which provides a good feed back of the wire "snap in." A year of mass production proved that it provides a reliable termination even in the most demanding automotive application.

The torsion IDC is a proprietary product of Zierick Manufacturing Corporation, for which is patent protection is applied for.

REFERENCES

1) Edward Key, "A new Type of Insulation Displacement Terminal Which Can Accept a Large Range of Wire Gauges" ECSG Symposium, November 1983.

2) Robert A. Wandmacher, "Insulation Displacement Connector Reliability" ECSG Symposium, October 1986.

3) William J. Gawer, "Mass Terminating Discrete Wire" ECSG Symposium, October 1979.