Quick Disconnect
VS
Threaded Style
RF Interconnect Technology

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Introduction;

The purpose of this report is to give the reader an overview of Quick Disconnect interconnect product technology offered by TRU Corporation and to compare that product to more common threaded style RF interconnect types of the same size. This report will focus on features and benefits of TRU Quick Disconnect RF interconnects as compared to threaded RF connector types. The report will compare such areas as physical line size, power, voltage, configuration options, ease of use, cable options/terminations, safety, reliability, product cost and cost associated with equipment downtime and failure in the end application.

Overview of RF Interconnects:

Threaded Connectors:

In general, RF threaded connectors started out in the 1930's with the early radio and UHF communications equipment that had a frequency of operation up to 300MHz. RF connectors grew, in large part to support the RF technology being developed and used during WWII. Since then, many other RF connectors have been developed over the years, each one type or style attempting to address each new requirement, whether due to physical size, power/electrical performance and/or mechanical/environmental application. The primary grades of RF connectors are Military, Industrial/Commercial and Test/Measurement. Each grade is designed and built to perform to the unique requirements of their particular segment. The Military market usually involves high grade, high price connectors designed to perform in harsh electrical, mechanical and temperature/altitude environments such as corrosion, vibration, thermal shock, and many other conditions. MIL-PRF-39012 is the most commonly cited reference specification that governs RF connectors. Industrial would be a medium grade, medium price RF connector that is designed to meet the published specifications of each companies application needs. Commercial would be a low grade, low price alternative that rarely meets the full range of stated specs but is suitable for less challenging or lower performance applications.

Quick Disconnect:

In the early 90's the semiconductor equipment manufacturers began using **QDS** series connectors on their cable assemblies for quick mating in low power applications. They also used 7-16, C and HN series for higher power RF cable assembly applications. The manufactures were looking for RF cable assemblies with an interconnects that would handle higher power, higher voltage and would have the same coupling style as the **QDS** interface. TRU Corporation developed cable assemblies with **SQS, QRM** and **QDS-UL** interfaces over the next few years that would meet and exceed all the electrical and mechanical requirements of the semiconductor equipment manufcaturers. The **QDS-UL** is an example of TRU Corporation's proprietary customization of a **QDS** originally developed for the US Navy. This resolved the safety problem facing equipment manufacturers in which technicians and operators could easily touch the center contact while the RF power was on. The custom designed quick disconnect connector eliminated this potential and also lead to development of more integrated safety interlock features within quick disconnect interconnects.

Industry Trends of Threaded and Quick Disconnect Interconnects:

Threaded Connectors:

The trend of the RF Microwave threaded designs have changed over the years due to the associated issues that come up with threads such as tooling needed to mate, cross threading, and repeatability/reliability of mating. As the demand in Military, Industrial/Commercial and Test & Measurement applications called for smaller sizes, quicker more reliable mating, no special, expensive tooling, threaded coupling connectors have given way to quick disconnect style coupling. Interfaces such as the MCX, SMB, BMA, SMP, QMA, QN and others were developed and are examples of non-threaded "push-on, blindmate, and quick disconnect interfaces that are widely used in the RF Microwave industry. These interfaces have replaced some of the standard threaded coupling styles and there will be more development of quick disconnect styles going into the future. At the same time as this was occurring, TRU recognized the need and benefit of developing quick disconnect connectors to address the high power, safety, reliability demands of the Semi industry.

Quick Disconnect:

As the Semi equipment manufacturers, have gone higher and higher in power and voltage levels, these quick disconnect products address the mechanical/electrical challenges and have become the established standard across the industry. RF coaxial cable assemblies with TRU Quick Disconnect products have been used over the past decade by Semi manufactures such as Novellus, Lam Research, Applied Materials, AKT, Tokyo Electron and also RF generator and Match suppliers such as Daihen, Advanced Energy, Comdel and MKS/ENI. These products have been so successful that the end product users have requested these products on their equipment. When companies such as Hitachi, Panasonic, Sharp, Samsung, LG and Intel look for an easy, safe and reliable way of making their RF power connections they specify TRU Corporation quick disconnect products because they offer a competitive value and advantage whether it is reliability, downtime, ease of installation as well as power/voltage performance to power the next generation equipment.

Features and Benefits of Quick Disconnect:

This section will highlight the Mechanical and Electrical features that the Quick Disconnect coupling has over the threaded style coupling.

Mechanical:

Interface Line Size comparison:

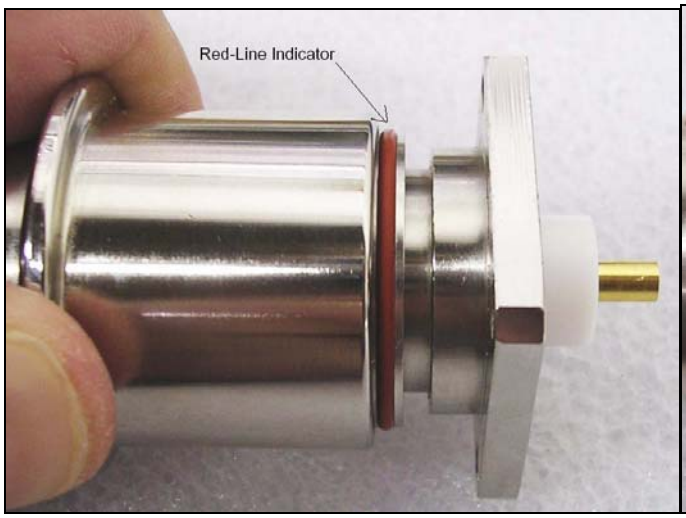
In order to evaluate threaded interfaces versus Quick Disconnect interfaces it is important to compare similar line sizes. The interface chart below, groups the physical/dimensional line size (inner and outer conductor diameters) of these interfaces in order to perform a more accurate comparison of the QRM to HN, QDS to C, and the SQS to 7-16.

Connector Interfaces	Inner Conductor OD (inches)	Outer Conductor ID (inches)
QRM	.124	.546
HN	.132	.430
QDS	.124	.374
C	.124	.374
SQS	.274	.685
7-16	.276	.630

Mating:

Red-line Mating Indicator:

All Quick Disconnect products have a Red-Line visual indicator that indicates to the technician that the RF connection is properly mated and secure. The way this works is male connector plug employs a sleeve, which when slid into the closed position covers a red band and forces the locking balls to seat into a groove on the mating connector. The covering of the red band signifies that the male and female contacts have been fully engaged. The photographs below of the QRM display this feature.



Quick Coupling Mechanism:

Quick coupling mechanism provides a high integrity connection with a fast on/off capability and reliable mating without bayonets, screw threads or tools. These connectors feature a positive locking mechanism employing a spring loaded sleeve on the male that is drawn back to let self contained bearings “click” into grooves on the corresponding female and then slide forward. The result for the user is an obvious true connection between the two, without guessing whether they have mated properly (Red-Line indicator). Also this coupling style has an approximately10 times faster mating cycle compared to threaded coupled interfaces requiring torque wrenches. This equates to less down time during installation and periodic maintenance cycles. Quick Coupling does not require any torque wrenches or special tooling when making RF connections.

Ease of Mating:

Ease of mating of RF connections in Semi fabrication areas has many ergonomic challenges for the installation technicians. Many RF connections in semi applications are difficult to get to and performing this frequent mating and un-mating is not an easy task. Technicians are either lying on the floor or up on a ladder making these connections often with limited line of sight or just be feel. When making threaded style RF connections it is very easy to cross thread or miss mate these interconnects. Having to use tools such as torque wrenches in these tight spots can be very difficult and in some cases not an option. This fact alone puts these connections in jeopardy of not being connected properly and repeatable each and every time. The quick coupling mechanism of the Quick Disconnect line of products gives the technician an easy and safe connection each and every time without the use of bayonets/Threads or assembly tools.

Recessed Center Contacts:

A recessed center contact greatly reduces the chances for electric shock by not allowing the operator to come in contact with the power-carrying conductor. The photographs below of the QRM display this safety feature.

Reverse Polarization:

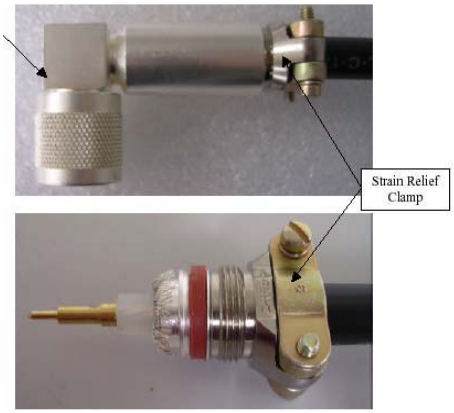
Reverse polarized coaxial connectors utilize a center conductor with reverse polarization (male to female gender) to achieve a non-standard interface. This non-standard interface guarantees correct mating when making multiple mates of the same type interface in the same area. SQS interfaces as shown below displays this feature.

Cable Termination:

TRU cable assemblies are designed for strength, reliability and performance in high power, high voltage Semi manufacturing applications. Optimized electrical, mechanical and environmental performance through the expert selection of materials, construction and attachment design methods. TRU understands Semi Manufacturing applications and the attention to detail that has to be taken to obtain high performance and reliability. TRU's attention to detail from design to final assembly also includes terminating the coax cable into the coax connector. One of the advantages of the TRU Quick disconnect products is the interface can rotate 360 degrees even after mated and still perform. This ability to rotate when mated, reduces torsional stress on the coax cable/connector junction which is typically the weakest link of any cable assembly. In comparison, any amount of rotation or loosening in a threaded interface will immediately sacrifice performance and will lead to failure. Key elements of terminating high power coax cable assembly are as follows:

Impedance matched
Sufficient Voltage overlap.
Robust strain relief.
Proper assembly tooling.
Cleanliness and precise assembly methods.
Environmental Sealing

The photographs below are some examples of design modifications that addressed various application issues that the Semi manufactures have had in the past. The left Photograph is an example of a 1-5/8 EIA Male that has a robust 2-piece strain relief that also is electrically insulated. Middle Photograph is example of a saddle clamp strain relief that better grips the outer jacket. Photograph on the right shows TRU Tie™ type of termination where the outer braid is secured to a braid shim with tie wire, standard crimp style connector designs rely on a properly used crimp tools and the captivation of the outer braid is blind to the assembler.



Mechanical Features Table:

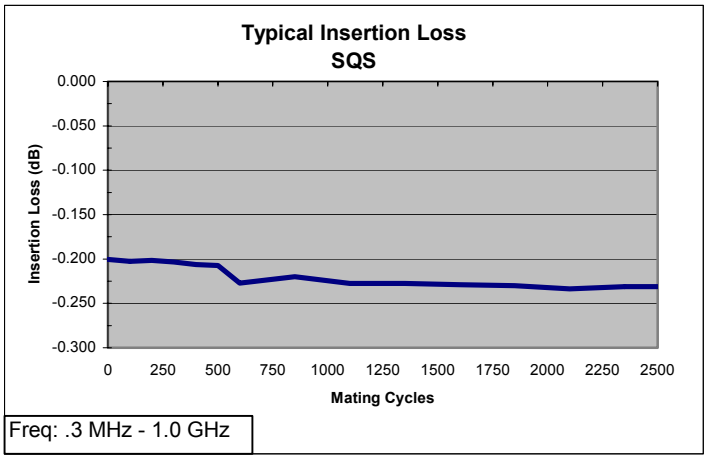
Connector Interfaces	Polarized	Recessed Center Contacts	Red-Line Mating Indicator	Quick Coupling
C	N/A	N/A	N/A	N/A
HN	N/A	N/A	N/A	N/A
7-16	N/A	N/A	N/A	N/A
QDS-UL	A	STD	STD	STD
QRM	A	STD	STD	STD
SQS	A	STD	STD	STD

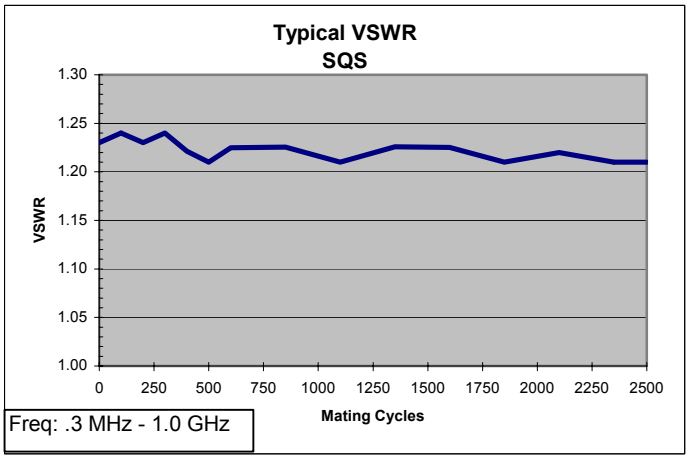
N/A = not available, **A** = available, **STD** = standard

Mating Durability:

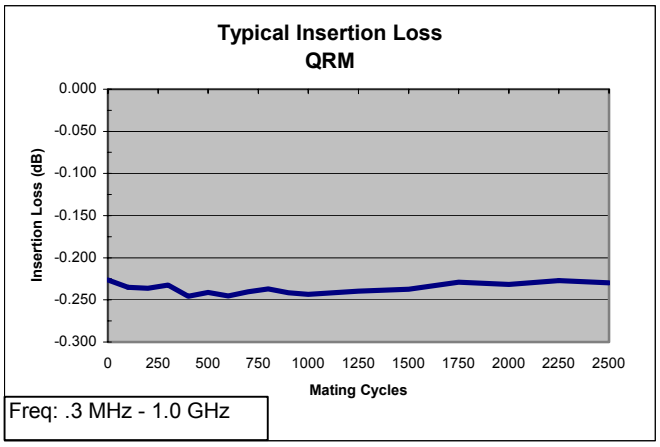
Durability Mating test of TRU Quick Disconnect Products (SQS, QRM, and QDS) over an extended number of mating cycles (2,500) to simulate the lifetime performance of TRU quick disconnect interface(s) has been performed. The test measured and monitored the following parameters: VSWR, Insertion loss and mechanical mating ability from .3MHz to 1GHz frequency range that would cover most if not all semi applications. The test result was TRU Quick Disconnect products will operate without any significant impact to electrical / mechanical performance up to a minimum of 2,500 mating cycles. Most RF coax connectors are per Military standard MIL-C-39012 paragraph 3.15 and are only rated up to 500 mates. See below test results SQS, QRM and QDS. Full test report including other parameters is available upon request to TRU Corporation.

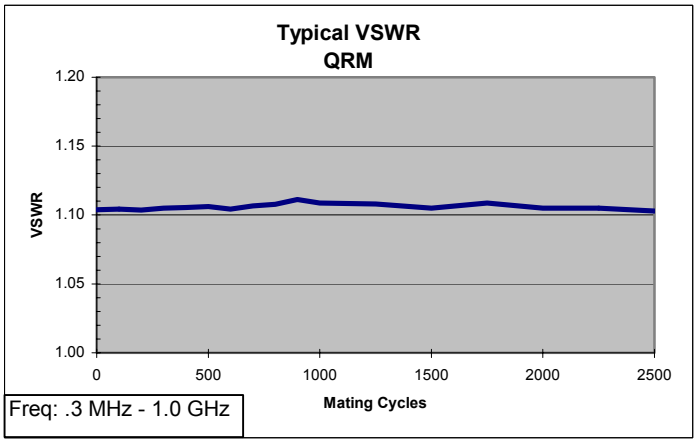
SQS
TEST DATA



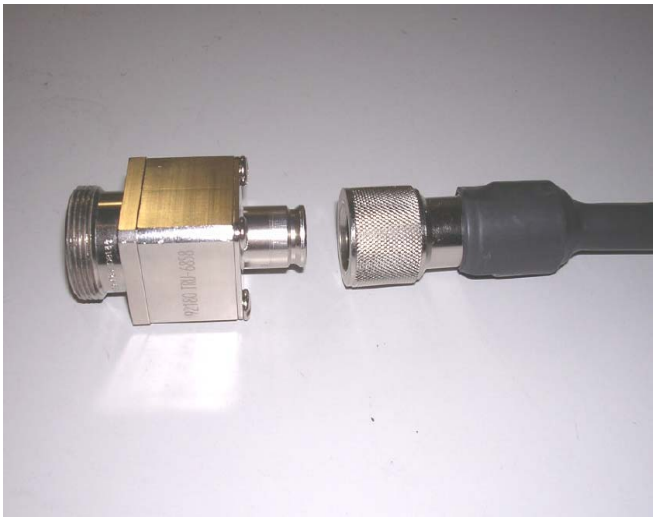


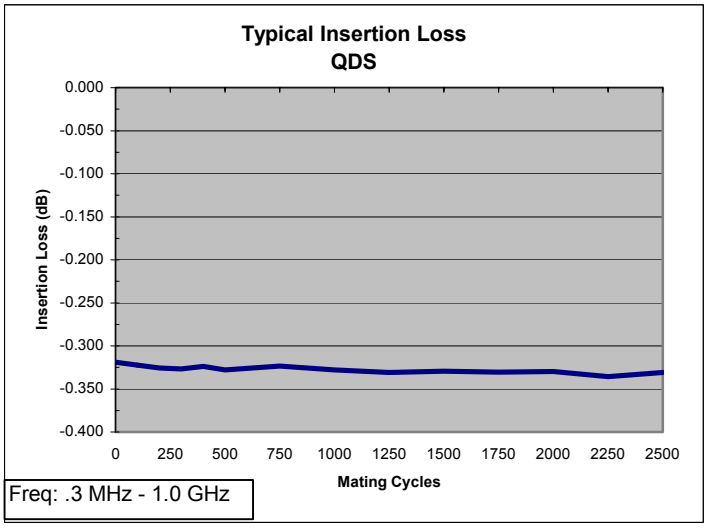
QRM
TEST DATA

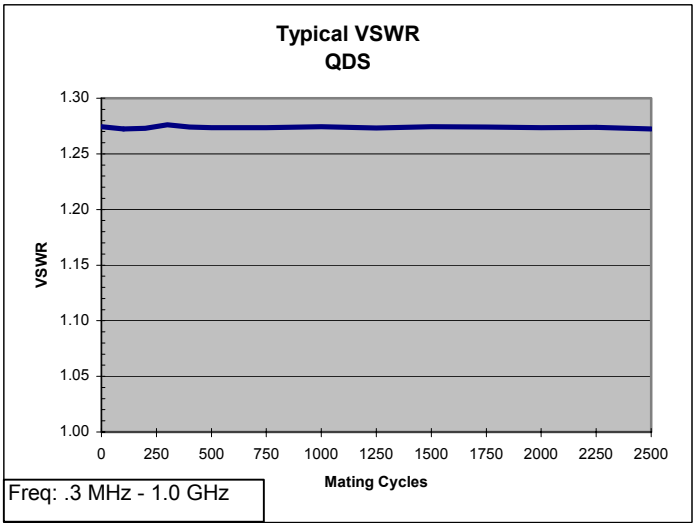




QDS
TEST DATA



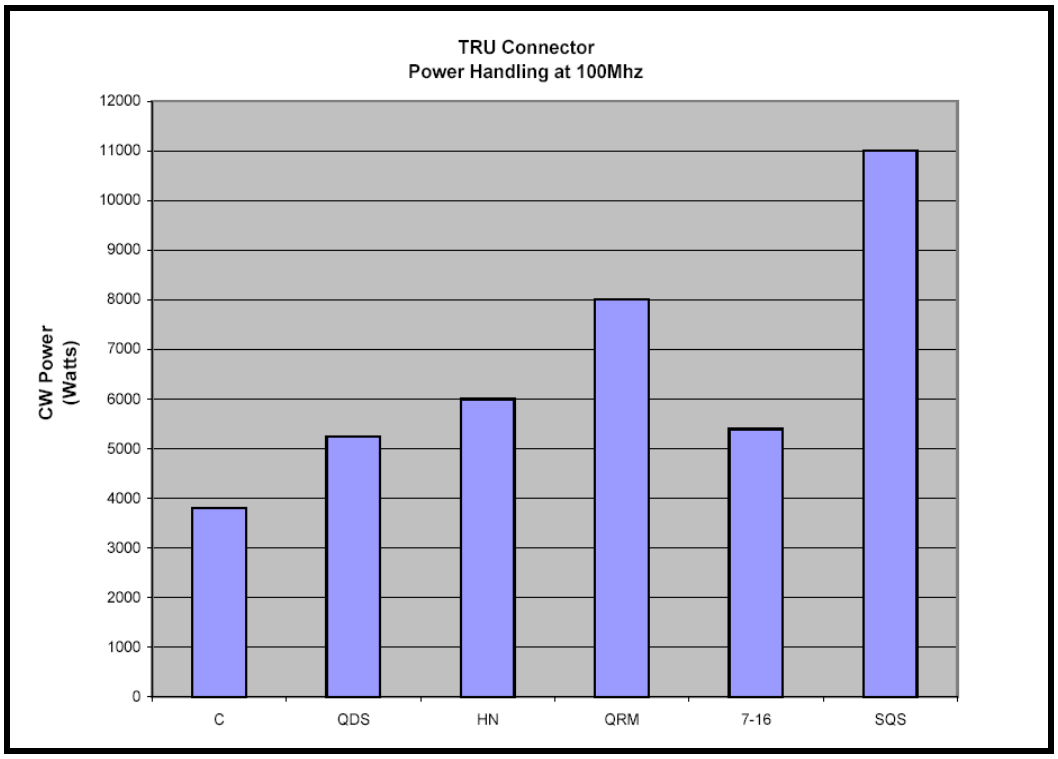




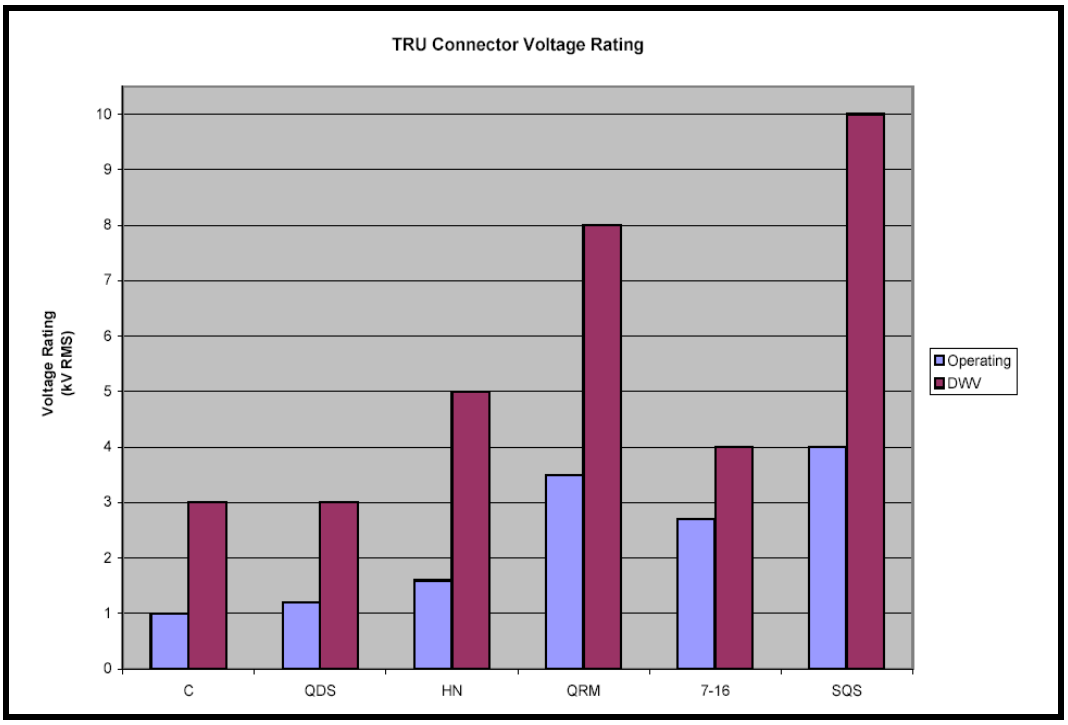
Electrical Comparison:

Power:

Quick Disconnect products will handle higher power and higher voltages levels as compared to the threaded of the same Line size. This is very beneficial to semi manufactures as their power/voltage levels have been rising over past years and will continue to climb.



Voltage:



Reliability:

Cost of Failure (Damage Lost Production):

The cost of failure of an RF cable assembly is substantial and difficult to quantify. In Semi Fabs, failure of an RF cable assembly under high power could damage other very expensive processing equipment; and even more importantly compromise operator safety.

RF Matching Networks
RF Generators
Plasma Chambers
Operator Safety

The Manufacturing down time to make these repairs is lost production time. Between repairing/replacing and production down time the cost can easily reach into the hundreds of thousands of dollars. Making these RF connections in a fast and reliable way is very important to Semi manufactures.

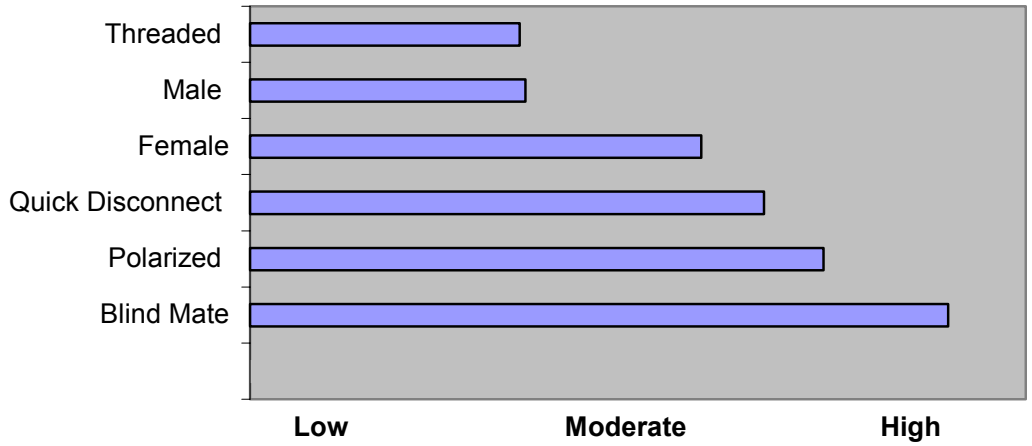
Flexibility / Change Over:

The cost of change over from one type of RF interface to another can also be very costly. When changing any RF interface to another there typically has to be changes to the following;

Test standard calibration tools
Interlock-switching mechanisms
Training of technicians
Over all system documentation/procedures

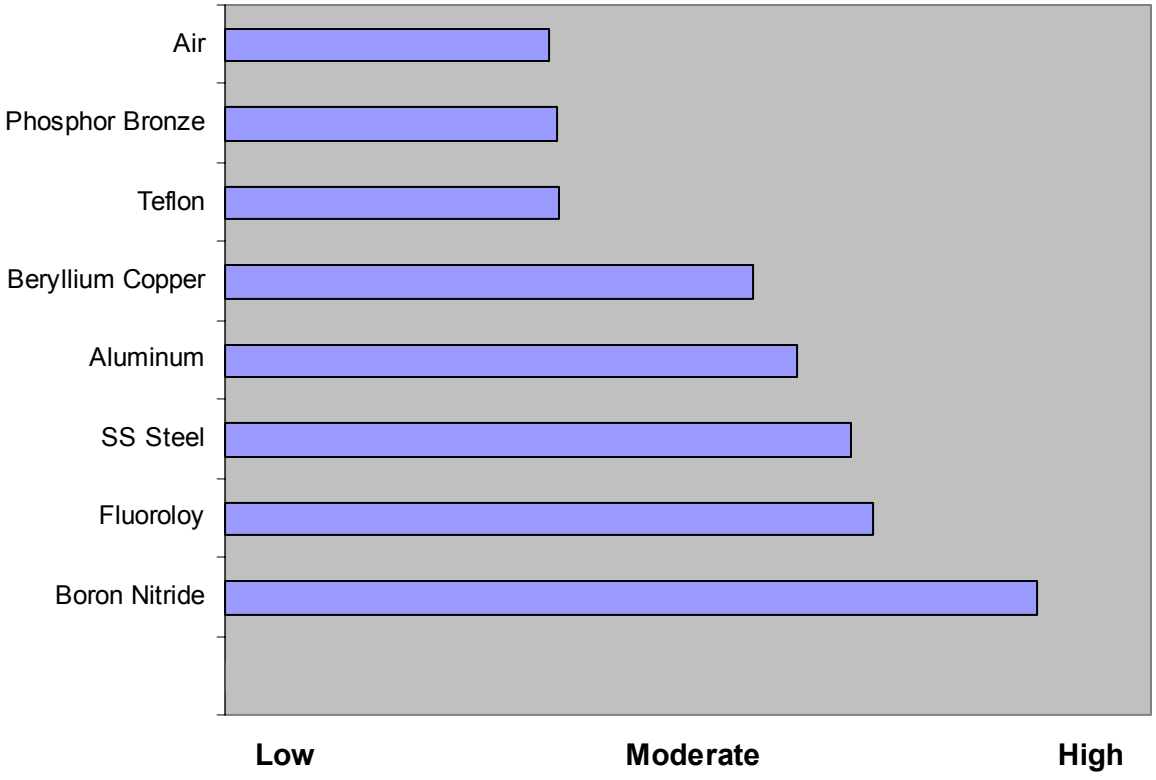
These kinds of changes can also reach into the hundreds of thousands of dollars. Another benefit of using quick disconnect products is the reduction of Periodic maintenance cycles (PM). The quick on off mating cycle (10x faster) of these interfaces reduces this cycle time. Before making any RF interface change these areas must be looked at as part of the decision process.

Connector Interface
Cost Comparison Matrix

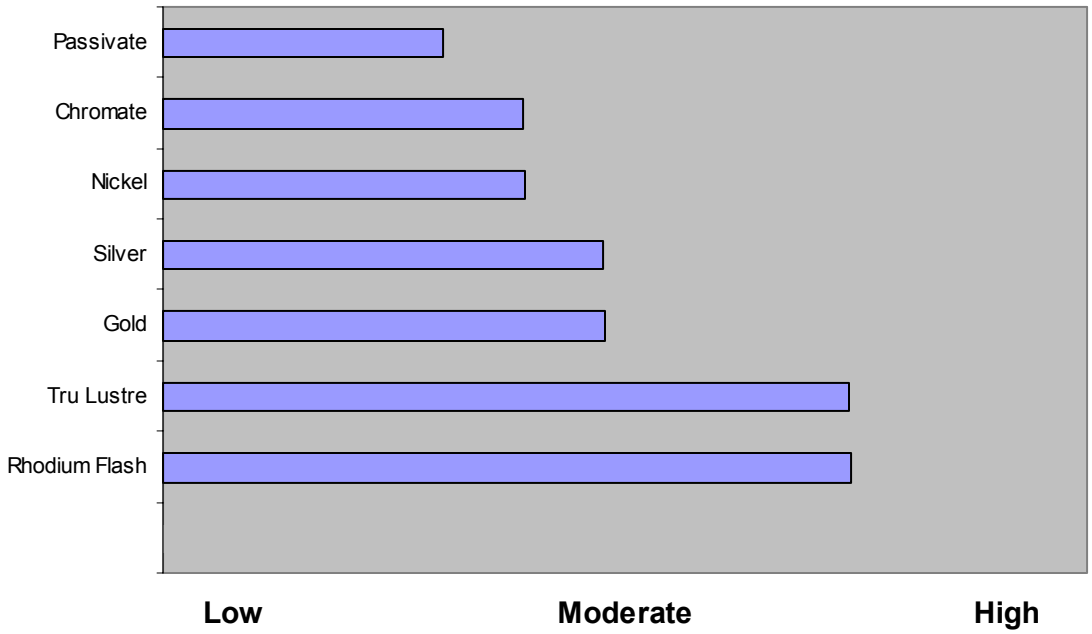


Connector Configuration
Cost Comparison Matrix

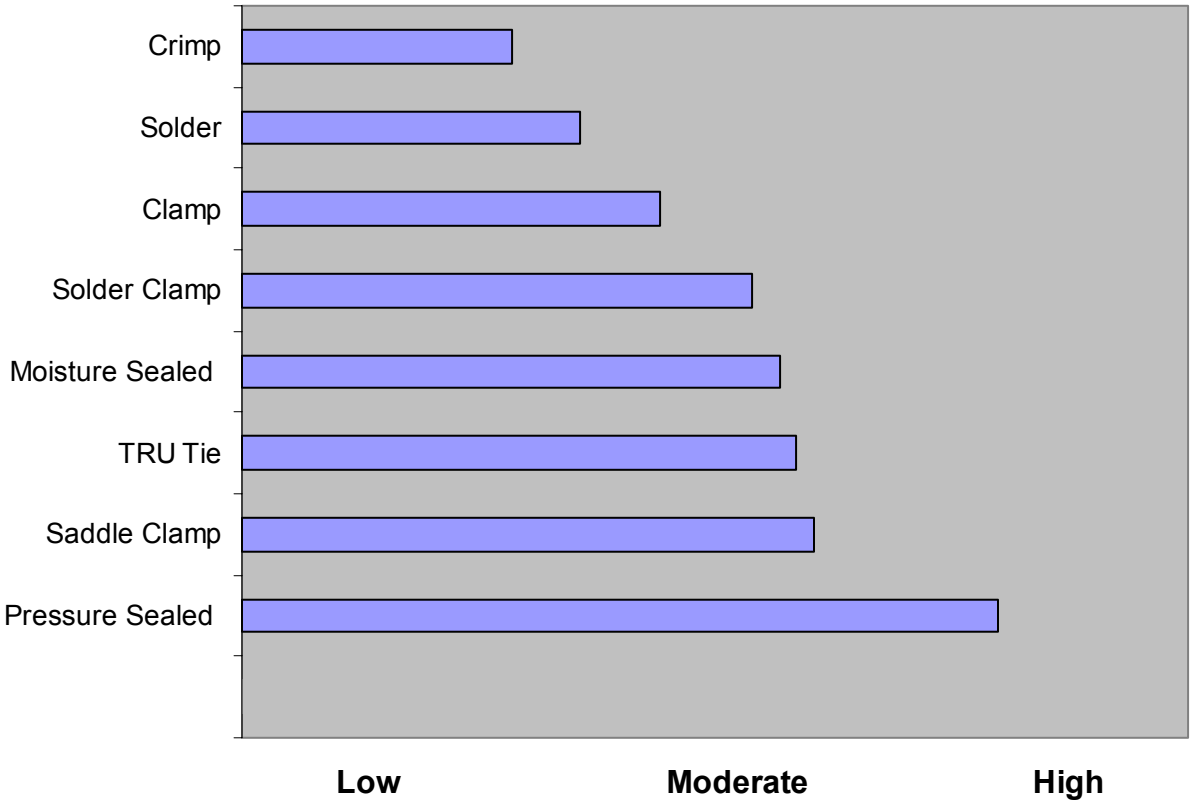
Connector Materials
Cost Comparison Matrix

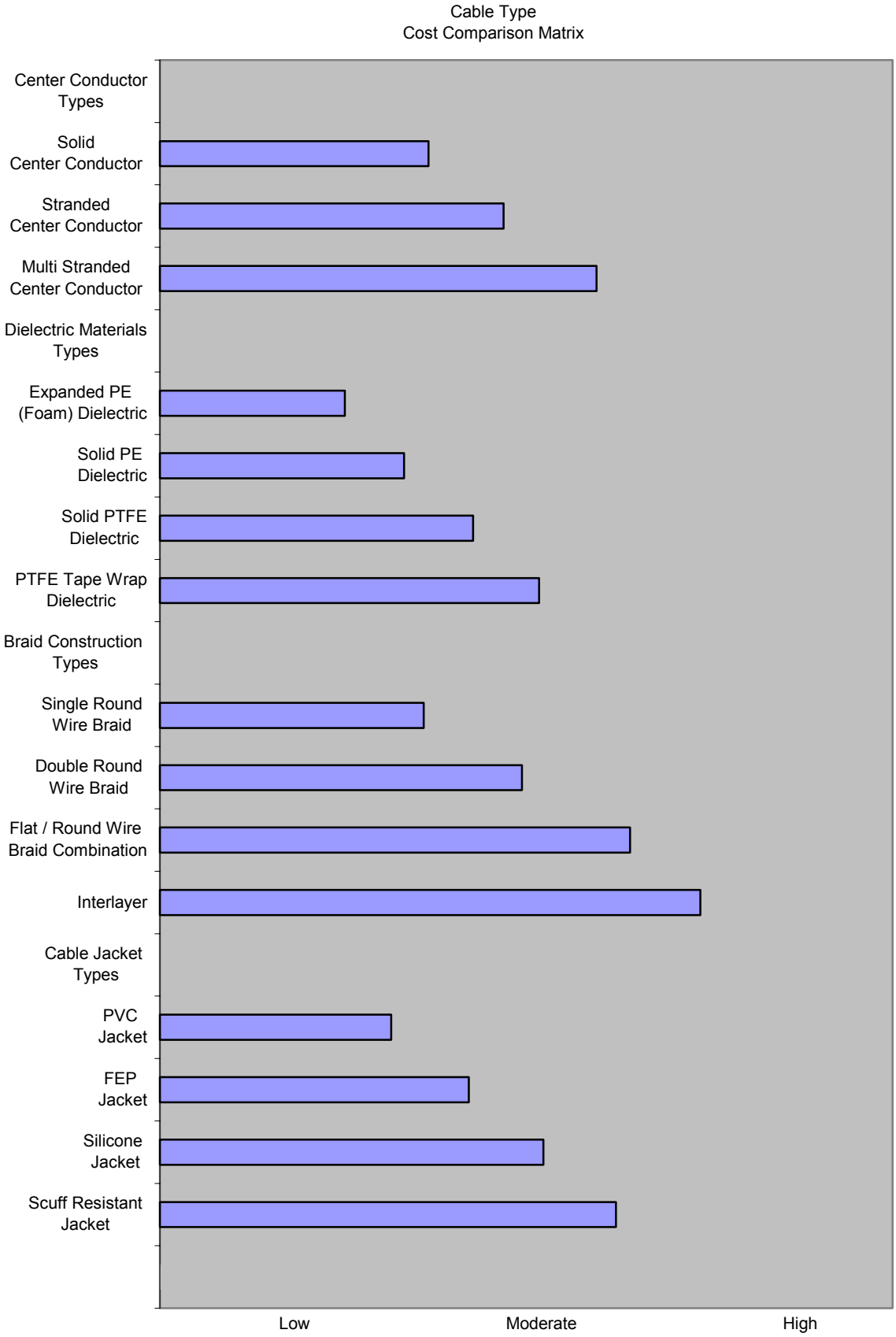


Plating / Finish
Cost Comparison Matrix

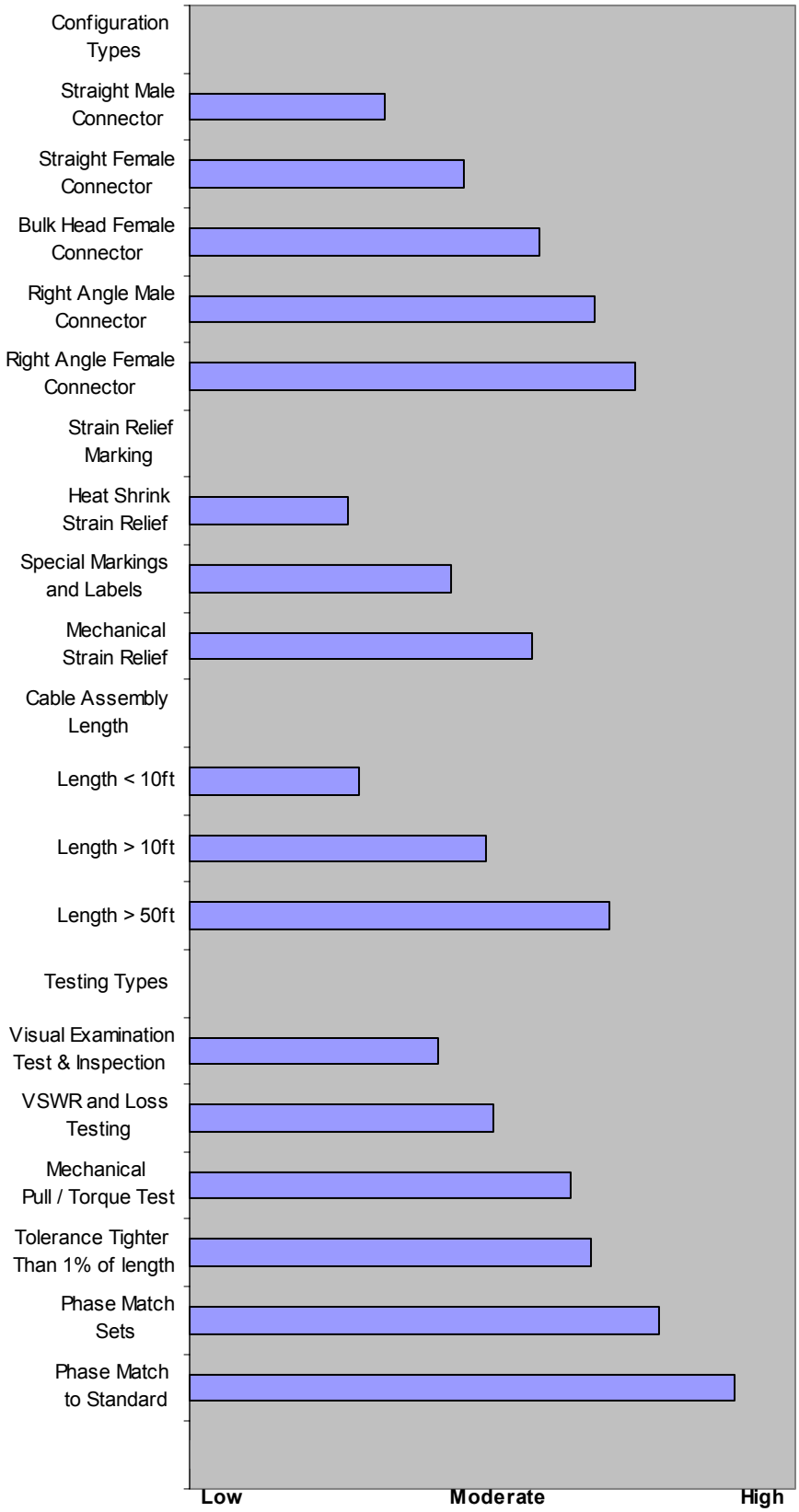


Cable Attachment
Cost Comparison Matrix





Cable Assembly
Cost Comparison Matrix



Summary:

All RF Connectors and Cable Assembly applications involve three very important factors and they are Mechanical, Electrical and Environmental conditions. TRU Corporation manufactures both types of coupling styles, this report demonstrated that TRU Quick disconnect products are the preferred choice for Semi manufactures to address all of those conditions.

Conclusion:

In conclusion the overall value of Quick disconnect interfaces in the Semi Manufacturing applications are far superior to the threaded style coupling of the same line size. When it comes to connector design and cable assembly manufacturing, TRU Corporation is the leader and the standard for all others to follow in the Semi Conductor manufacturing RF interconnects.