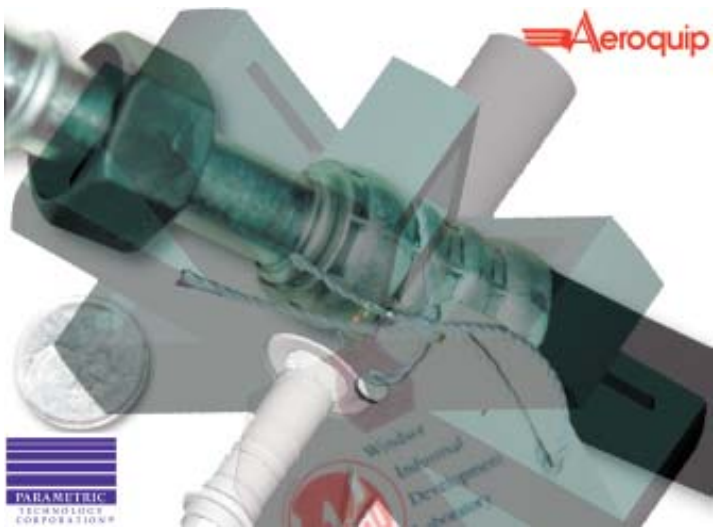
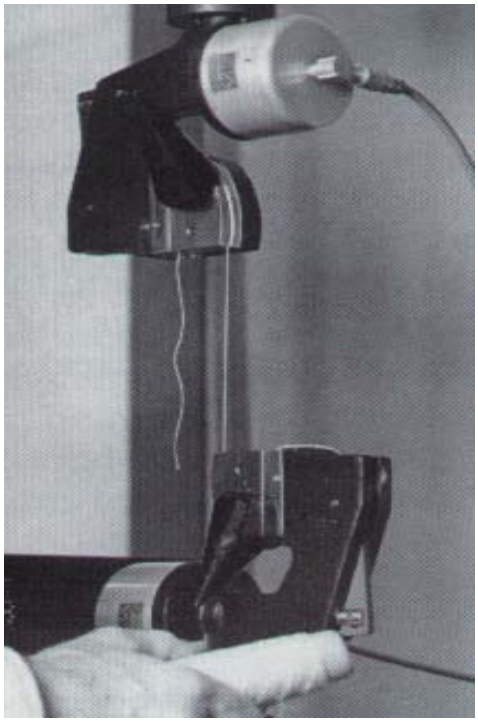
Composite Hose Crimping Analysis

The analysis of rubber components is fully non-linear. Rubber deforms significantly under load or straining. Its reaction to deformation is non-linear, and it is often used in contact. The analysis reaches a higher level of difficulty, when dealing with the crimping of composite hoses. This can be explained by the presence of numerous contact bodies (deforming nipple, socket, and rubber, and rigid dies). Orthotropy of the reinforcing texture and the speed of crimping (strain sensitivity) add complications, besides the definition of leakage, the interaction fluid-crimp assembly, spring-back, and so on.



CAD Representation of Hose Crimping Operation

Aeroquip – now part of the Eaton Group- requested WIDL to develop a computer model that would simulates leakage of refrigerants, off crimped (composite) hoses. The goal was to predict optimal crimping of multi-layered hoses, and avoid the "hit and miss" testing of prototypes. A case study focused on a hose made of two layers of isobutyl rubber, and a middle polyester fabric. The hose stretched on a nipple, and an outer socket was crimped to various degrees, for testing. Occasionally, high crimps collapse nipples, as assemblies get discarded. Besides, durability testing of each assembly used to take weeks to complete.

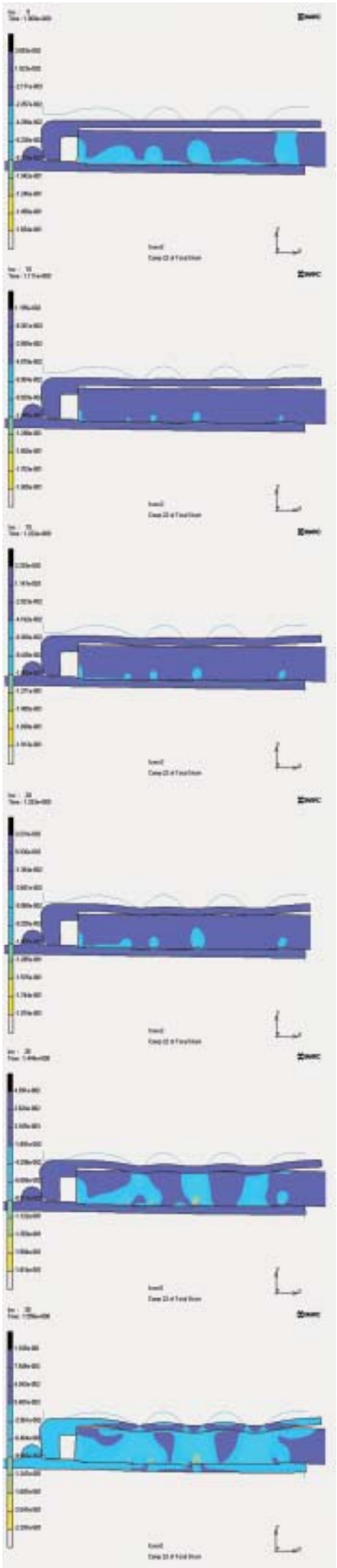


Testing Yarn in Tension at WIDL

Initially, rubber samples were molded at WIDL, then conditioned and tested to fit strain energy density functions. Bars of alloys making nipple and socket, received from the *Aluminum Association* in England and French *Pichnet*, were tested to elastic-plastic straining. The yarn, basis to the fabric, was pulled under quasi-static conditions. Mechanical properties of the bundle were based on characteristics of the fiber and rubber matrix, in a code internal to WIDL. Bundle properties were "injected" in non-linear orthotropic models (including large deformations, contact, hyper-elastic and plastic materials behaviors). The Marc™ non-linear software – now, product of *MacNeil Schwendler Corp.*- was used, then, for the analyses (refer to http://www.mscsoftware.com for information on the code).

Following computer simulation, a "Design Of Experiments" (or DOEs) was run at *Aeroquip*. Hose assemblies sealed at 23% crimp. The onset of leakage agreed with charts showing "flow rates with compressions" considering isobutyl ring gaskets air-pressure leak tests at WIDL. These were "trapped" between aluminum mates under a load frame, to mimic the finish of surfaces of nipple and socket.

Since, other rubber-fabrics composites projects at WIDL looked at diaphragms, duckbill check valves, tires, for various companies, and bridge joints for the *Ministry of Transport of Ontario*.



Virtual Crimping of Three-layers Hose