Shur-Lok

Design Manual

Fasteners for Sandwich Structure

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SANDWICH PANEL FASTENERS

DESIGN MANUAL

PREFACE

Fasteners are as old as history itself. From the time that prehistoric man first used vines and fibers to secure his crude shelters, the science of fastening has steadily evolved until today it ranks in importance with the most sophisticated technical operations. Every advanced vehicle, every complex electronic device is largely, if not wholly, dependent on the integrity of its fasteners. Shur-Lok Corporation, a pioneer and current frontrunner in the design and manufacture of specialty fasteners for industry, dedicates this document to a thorough comprehension of the selection of fasteners for sandwich structures, and to their proper application.

Towards this goal, it is important for the reader to understand the applications and configurations of sandwich composites themselves.

SECTION 1 — INTRODUCTION

WHY USE SANDWICH?

When design requirements demand superior strength-to-weight ratios, sandwich structure is indicated. In addition to its high strength, inherent rigidity and minimum weight, sandwich provides the desirable side benefits of thermal and acoustical insulation.

Sandwich, by its very nature, is generally used as sheeting or flat panel form, applied to open framework as a transverse web to carry shear loading. In other applications, it acts as a support diaphragm. It serves as both a primary and secondary load member. And, it is capable of transmitting extremely high loads when properly attached to the framework.

Other applications take advantage of its favorably low weight-to-area ratio. Typically, these include curtain walls for decoration or the baffling of sound and light. Such applications do not generally consider the inherent load capabilities of the structure.

Initially sandwich was used only in flat panel applications-a logical step away from plywood and other sheet panels. Recent improvements, however, in fabrication techniques and growing industry awareness of sandwich potential have spurred bolder forms. Today these include compound curves, skeletonized sections and many complex shapes previously considered impossible.

SANDWICH STRUCTURE DETAILS

The principal form of sandwich structure is the honeycomb configuration. This consists of top and bottom face sheets attached to an inner core material; the core is made of hexagonal cells having walls perpendicular to the facesheet planes (See Figure 1). Many materials have been used successfully in honeycomb sandwich including aluminum, steel, high-temperature alloys, paper, wood, fiberglass and plastics. In some applications honeycomb cells are filled with a foam-in-place expanding plastic. Other forms of sandwich consist of face sheets bonded to homogeneous cores such as foamed plastics or wood. The variety is limited only by the state of the art and the imagination of the designer.

METHODS FOR JOINING

Regardless of form, the methods for joining the two face skins and inner core into a rigid member are numerous.

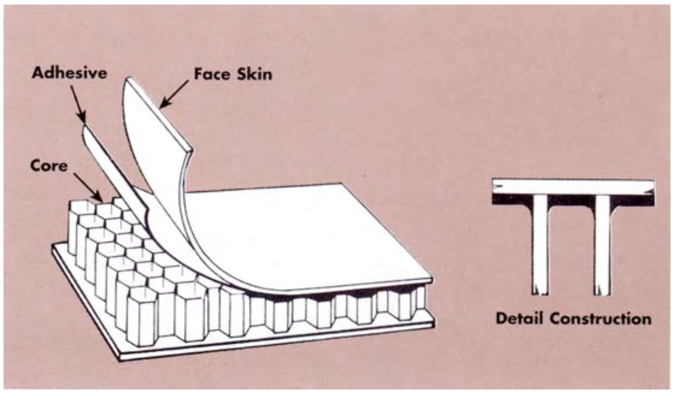


Figure 1 — Typical Honeycomb Panel Construction

By far the most widely used is that of adhesives applied by any of several techniques, and activated chemically or thermally.

1. One method consists of brushing or spraying the adhesive film over one surface, and subsequently mating with the second part precoated with activator.
2. A second approach use prefabricated sheet adhesive. Adhesive, rolled into a thin sheet partially cured to retain form, is stored between temporary non-adhering film, ready for use.
3. Another bonding technique consists of applying the adhesive with rollers to a scrim or grid cloth, which is then cut to size and applied between core and face skins.
4. Still another method simply calls for an even coating of adhesive on the face skin, which is subsequently activated and applied before setup.

In all methods, development of optimum strength depends on proper preparation of face skins and controlled application of adhesive to form optimum fillets between mated ends or faces of the core structure. Such bonding optimization achieves even transmission of loads from face skins to core without bond rupture.

Other forms of sandwich structure which offer excellent high temperature strength performance are composed of all steel honeycomb and face skin. These are most often resistance welded or of brazed construction.

TYPICAL SANDWICH PANEL APPLICATIONS

AIRCRAFT INDUSTRY
- Floor Panels
- Interior Walls
- Food Handling Galley Assemblies
- Wing Control Surfaces
- Passenger Storage Racks
- Thrust Deflector Assemblies

AEROSPACE INDUSTRY
- Capsule Panels
- Ablative Shields for Nose Cones
- Instrumentation Enclosures & Shelves
- Bulkhead Panels
- Space Satellites

ELECTRONICS INDUSTRY
- Electronic Radome Construction
- Large Antenna or Disk Reflectors
- Military Electronic Instrumentation Shelters
- Shipboard Electronic Deck Shelters

TRANSPORTATION INDUSTRY
- Cargo Pallets
- Shipping Containers
- Refrigeration Panels
- Rapid Transit Floor Panels
- Special Automobile Bodies

CONSTRUCTION INDUSTRY
- Architectural Curtain Walls
- Partitions & Divider Panels
- Expandable Hospital Shelters

SECTION II — DESIGN CRITERIA

TRANSMITTING LOADS

Of prime importance to successful utilization of a sandwich structure is the method for transmitting loads into and out of it. By its very nature, sandwich cannot carry concentrated unit loading. Moreover, modern designers cannot resort to the crude and heavy methods of attachment that typified early attempts to fasten sandwich.

Many of these earlier methods tended to nullify the advantages of high strength-to-weight ratios because they used solid sections of fillers or wooden blocks bonded in place within the structure adding undue weight. These were inserted by removing sufficient core volume to develop required strength (See Figure 2).

Fortunately for today's designers, sophisticated means of sandwich attachment have been developed by Shur-Lok Corporation. The balance of this section explores the design criteria for these insert fasteners.

There are two primary load forms to be considered: shear and tension (See Figure 3). In many instances designers encounter combinations of these loads in multiple directions. A study of sandwich will reveal that all primary loading must be carried by the face skins. The cores acts as a stabilizer. Load application must therefore be spread over the greatest possible area since the face skins are relatively thin. Proper selection of the correct fastener, used in sufficient numbers, can achieve the necessary degree of load distribution.

Aside from the primary loads, there is a third, though less critical load. This is torque, and is usually significant only if the insert is a threaded variety (See Figure 3). The torque generally results from assembly methods rather than service loading.

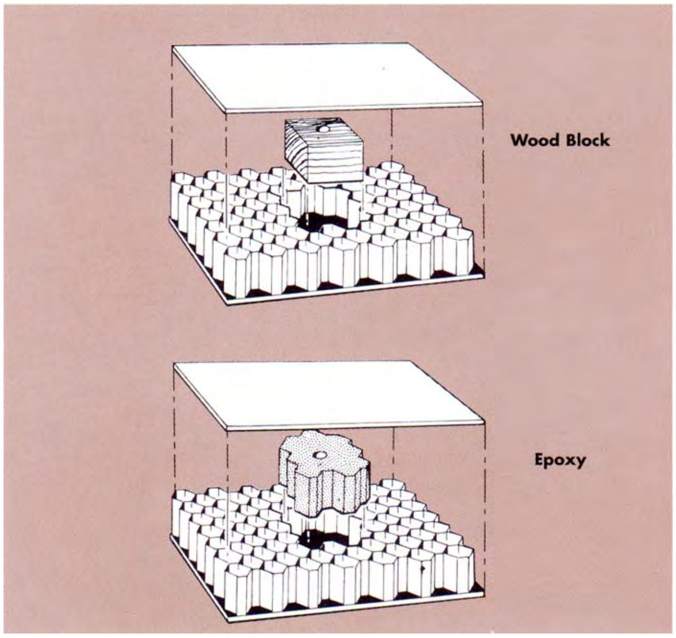


Figure 2 — Solid Section Fillers

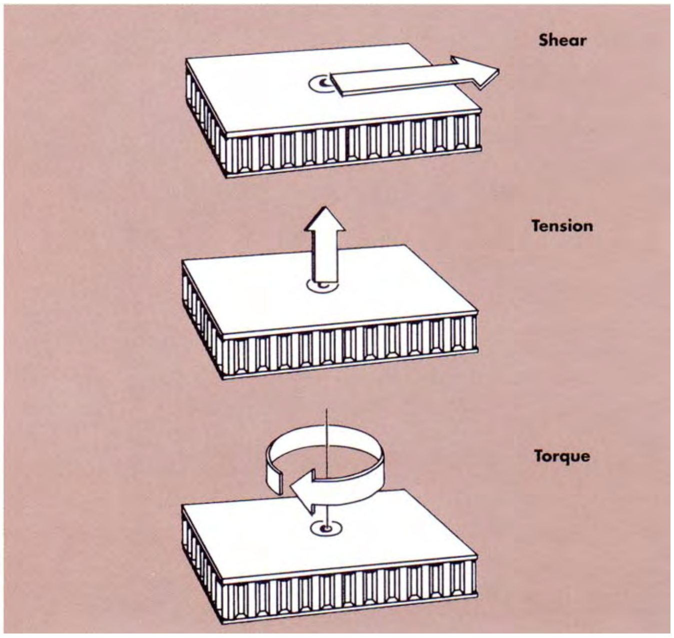


Figure 3 — Typical toad Forms

Basically there are two types of fastener inserts for honeycomb application: the molded-in type and the mechanical type (See Figure 4). The molded-in type should always be used if possible because it offers several distinct advantages. Among these is the ability to bond the insert, core and face skins into one rigid unit with the selected potting medium. Another advantage is that molded-in inserts are not particularly sensitive to manufacturing variations within the sandwich structure. Furthermore, bonded parts necessitate a relatively short learning curve for inexperienced installers.

CONSIDER THE DESIGN PARAMETERS

The first logical step in the selection of a fastener is to determine exactly what is expected of it in the specific application under study. Typically the designer must know the structural arrangements of the joint involved as well as the loads expected. The sandwich construction must similarly be defined. The following two lists typify design parameters which must be considered.

Sandwich (See Figure 5).

1. Overall thickness of panel?
2. Face skin thickness? Rigidized or plain?
3. Type of core?
4. Material of core and face skins?
5. Flat, curved or tapered surface?
6. Fastener molding compound?

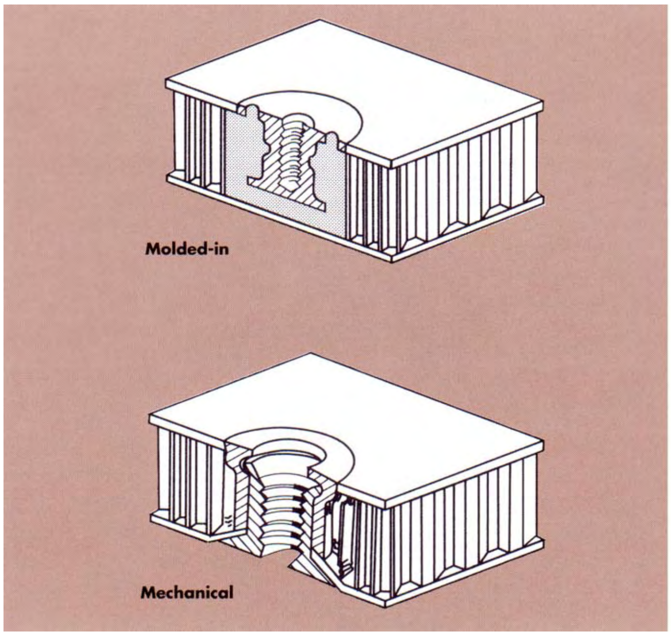


Figure 4 — Fastener Inserts for Honeycomb Applications

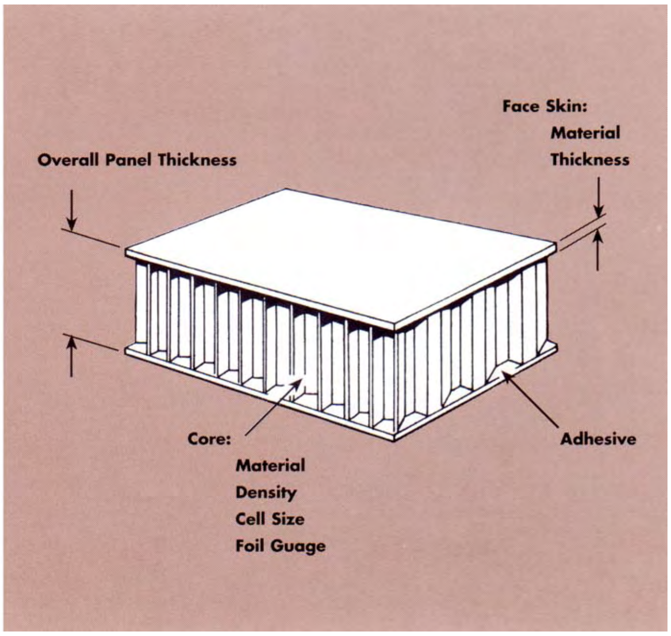


Figure 5 — Sandwich Panel Considerations

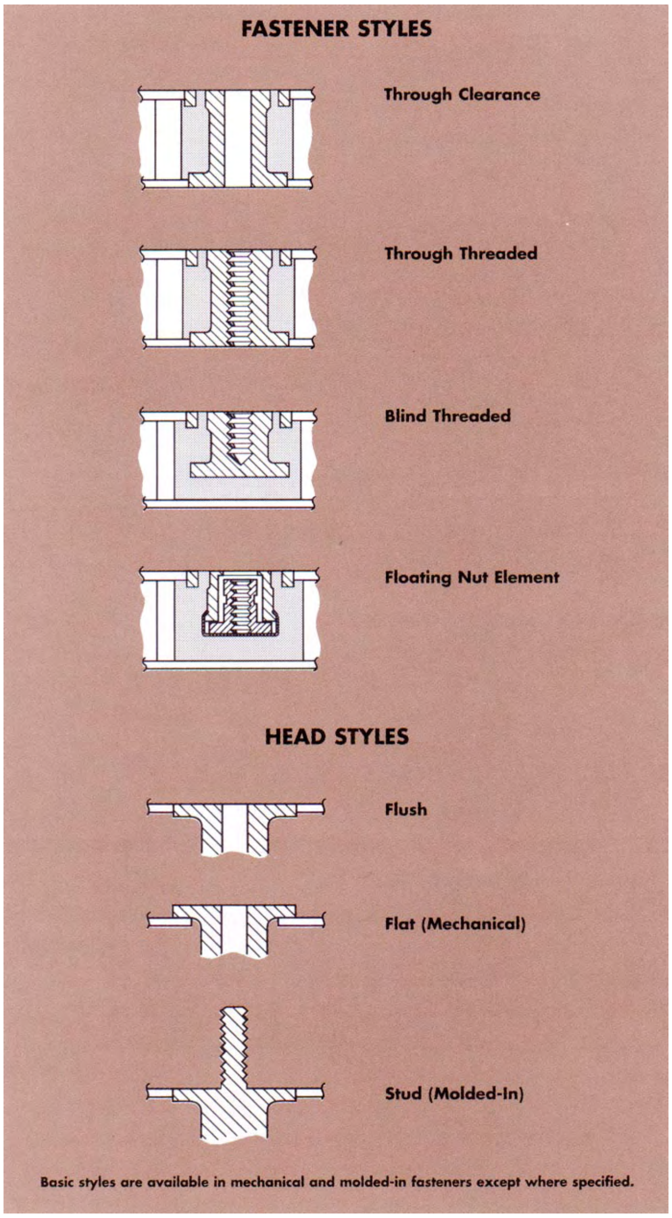


Figure 6 — Fastener Considerations

Fastener (See Figure 6).

1. Size (diameter) of through-mounting member? Bolt or rivet?
2. Is fastener to be through or blind type?
3. Must installation be flush with surface of face skin?
4. Is a facing type or standoff head required on either end? What diameter? How thick?
5. What are torque requirements of threaded type? Is self-locking feature required?
6. What material is required for fastener?
7. Operating temperature of installation?
8. Design load requirements for each fastener?
9. Type of fastener preferred: molded-in or mechanical?
10. Material compatibility of mating fastener?

Naturally some of these questions cannot be readily answered during the first approach to design, but eventually all must be acknowledged before achieving a final fastener design. Typically, as a result of the indeterminate character of some applications, the magnitude and direction of loading are unknown. Specific application testing of the fastener-installed within the sandwich, as opposed to tests on the fastener alone-are therefore often required to prove the design.

Since the facilities required for such combined testing are of a specialized nature, test and sample requirements have become the responsibility of the fastener manufacturer. He has, of necessity, developed the many specialized test techniques peculiar to sandwich structure and associated fasteners, Through natural evolution, the manufacturer has also developed a panoramic image not of just a hardware seller, but of a complete service, running full circle from design recommendations, hardware development, test, installation recommendations, and the furnishing of test samples for full prototype. These are the services Shur-Lok Corporation offers to its customers.

A WORD ABOUT STANDARDIZATION

Aside from the foregoing requirements, the duty of making standardization recommendations has also fallen to the fastener manufacturer.

The best effort for standardization lies in the molded-in blind insert, because little is gained by increasing the insert's length once an optimum ratio of threads-to-bolt size has been established. Thus, while accepted design calls for a minimum of 1.5 diameters of thread engagement, 0.75 diameters is sufficient to develop full bolt and sandwich strength. The additional provision of 0.75 diameters is adequate for bolt overtravel resulting from tolerance buildup. A nominal insert length could be used for most sandwich applications. Obviously, ultra-thin sandwich panels must be treated differently when attempting sandwich insert length standardization.

LOAD ANALYSIS

Sandwich structures consisting of light gage face materials and low density cores cannot be expected to carry any greater load than can be developed between the fastener and the face skins. As mentioned earlier, all loads entering the sandwich panels are carried first through these skins. The core member acts to stabilize and transmit transverse stress across the panel.

The chief design consideration, then, is to keep unit loading compatible with the load capabilities of and through the thin face skins. This generally means maintaining proper load distribution and a relatively low load per fastener by using an adequate number of the proper type and size fasteners.

Regardless of sandwich construction, it is necessary to make an analysis of total load vs. fastener size and quantity. The lighter the sandwich structure, the greater care required in selecting the proper fastener.

TENSION LOADING

An element analysis across any given section of honeycomb in any direction will indicate a structure that is very similar to the "Wagner Beam." The face skins represent the cap strips. The vertical surfaces of cell walls form individual shear panels, with the junctures of the cell wall acting as vertical boundary stiffeners of each small shear panel.

In tension loading of a fastener, the bonding of core to face skin plays a major role. The whole area about the fastener acts as an unsupported diaphragm, with load centered at the fastener. Design should strive to minimize the unsupported diaphragm area and to obtain as much support from the core material as possible. With molded-in inserts this support objective is dependent on the type of potting material. Its ability to fill the core voids reduces the loading per unit area and dependent upon adhesive strength, provides the ultimate in load transfer between skins, core and insert. This support aspect is exhibited by the SL600 Series' ability to provide a completely void-free fill.

With mechanical inserts, strength is derived from a through part which can be secured to both face skins as in the Shur-Lok SL500 Series. This method tends to reduce dependency on the bond between core material and face skin, making the unsupported diaphragm area less critical.

SHEAR LOADING

Design for shear loading must take note of face skin thickness and bearing area. The insert must remain stable and in position in order to develop full bearing load in the face skin. In common single-shear applications, the load develops a relatively high upsetting moment, tending to cause the insert to turn over and lose continuity with the face skin. In the case of molded-in blind type fasteners, a complete distribution of the potting medium around the insert will achieve good stability. In cases of severely high unit loading, it may be necessary to undercut surrounding cells in order to provide a sufficiently large bearing area for stability. The core material plays only a secondary role in single-shear loading; when the continuity between face skin and insert is lost, failure is quite rapid.

SECTION III — APPLICATION METHODS

MOLDED-IN INSERTS

With molded-in inserts, the key to proper design is the selection of a head diameter which provides sufficient bearing area in the face skin for the size of the bolt or screw to be used. The SL600 Series Shur-Tab system of fastening is available in both blind and through types.

For blind types, minimum insert length should provide 1½ diameters of thread engagement. It is not generally necessary to use a different insert length for each application, but certain special considerations may arise which will demand a longer length for thicker panels.

In these instances, however, the insert should not be allowed to touch the inner surface of the bottom skin. A minimum of 0.040 inches clearance is recommended to allow the epoxy to flow under and around the insert. This assures a bond between the inside surface of the bottom skin and the fastener (See Figure 7).

For through types the insert length must be precise to assure flush installation across the overall thickness of the sandwich. To help position the insert accordingly, the Shur-Tab system provides a special adhesive-backed tab. Epoxy is injected through one of the potting holes with a Semco sealant gun, or equivalent, which permits venting through the other hole thus insuring a completely uniform fill (See Figure 8).

INSTALLATION HOLE PREPARATION

When drilling holes in honeycomb panel for blind inserts, it is only necessary to drill deep enough to provide a clear hole having a depth of 0.020 or 0.030 inches beyond the length of the insert. When drilling holes in panel with a homogeneous core such as foam material, it is recommended to drill to the inside surface of the bottom skin for maximum performance. It is not necessary to clean up the inner surface when the core is honeycomb since any roughness or remaining core will actually add materially to the bond efficiency by providing additional adhesion area.

The through type requires a single diameter hole through both face skins. The core may be undercut to provide additional bearing surface or footprint area (See Figure 9).

Incidental to the drilling of installation holes in honey comb is a certain amount of cell opening. These opened cells become filled with epoxy which provides a bond between face skins, cell walls and the insert. Cell size and the number of cells opened during drilling will thus determine the amount of epoxy requires for a given installation.

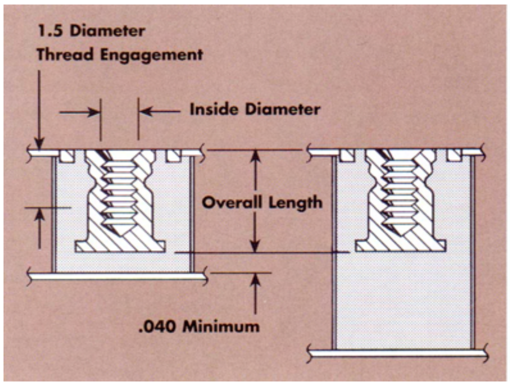


Figure 7 —
Dimension Considerations

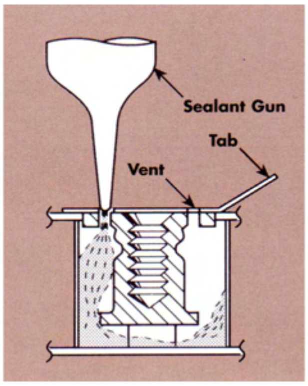


Figure 8 —
Shur-Tab Potting Operation

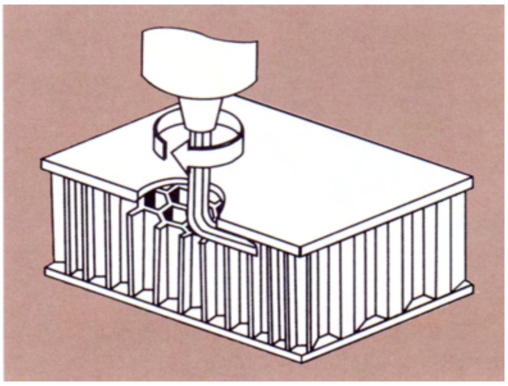


Figure 9 —
Typical Core Undercut for Molded-In Insert

MECHANICAL INSERTS

When loading requirements warrant, a simple mechanical spacer such as the Shur-Lok SM or SN types is recommended (See Figure 10). These spacers require only a thru hole for installation and when flush mounting is required the "D" type head style provides the advantage of automatic dimpling of the face skins during installation.

Mechanical inserts, such as the SL500 Series, attach to both face skins (See Figure 11). Therefore, two sizes of drills or a step drill must be used to provide the installation hole (See Figure 12).

There are two basic head forms on the SL500 type mechanical inserts-the dimpled or flush type, and the flat-head or standoff type. Flat or standoff types require control only of hole size and overall length. The face skin gage, type of material and effects of dimpling must be considered when using the flush type.

When SL500 flush type inserts are used, the face skins in most cases are depressed by the installation of the fastener to provide a flush installation. Most prime fabricators of missile or airframe assemblies have established rules controlling the method of dimpling.

Some companies require predimpling of the skins for all materials. Shur-Lok Corporation recommends that predimpling be used on skins in excess of 0.020 inches. For skins thicker than 0.060 inches, we suggest countersinking.

Certain forms of sandwich facing will require special consideration. For example, most fiberglass skins cannot be dimpled but must be sufficiently thick to be countersunk when flush heads are required. Hot predimpling is usually required for 7075 aluminum alloy and like materials.

EDGE DISTANCE

Insert users frequently inquire about minimum required edge distance for sandwich fastener installation. Best practice is to maintain a minimum of two diameters from the edge based on insert head diameter. In some cases a closer edge distance may be required. The exact allowables should be determined by testing.

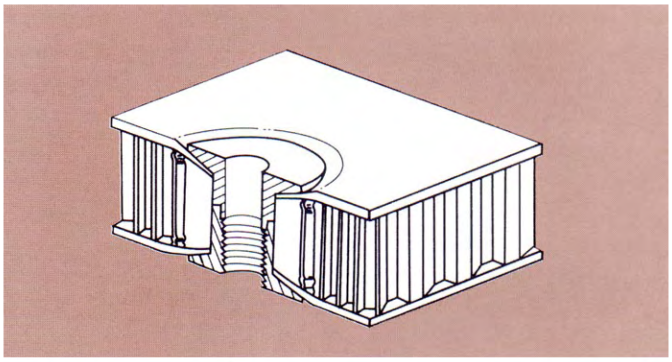


Figure 10 — Simple Mechanical Insert

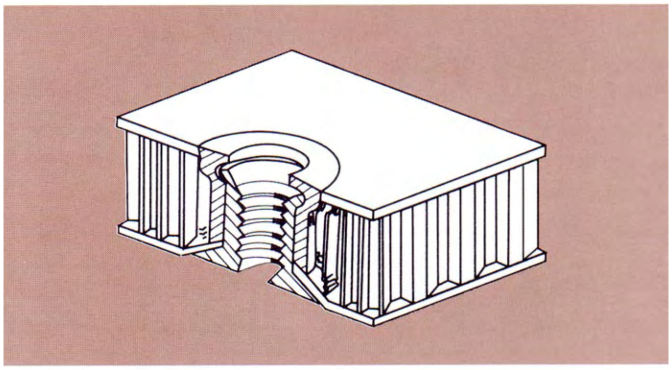


Figure 11 — Shur-Torq Self-Retaining Mechanical Insert

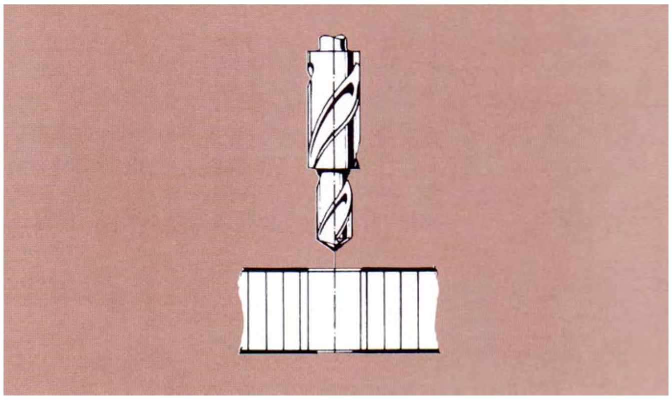


Figure 12 — Step Drill Provides Two Hole Sizes

SECTION IV — MATERIALS

SELECTION OF POTTING COMPOUNDS

Selection of potting compounds can be a puzzling problem. There are many different brands, all claiming desirable features. Densities range from about 40-90 pounds per cubic foot. Density reduction in any compound is achieved through the addition of fillers. Inherent with this addition is some reduction in strength. Also, fillers lead to some stiffening which reduces workability of the compounds.

On the production line, the workability of all such compounds is important. Since most epoxies have potential "pot life" ranging from about 15 minutes to two hours, it is important to production line function that the compound is compatible with a sealant gun and the SL600 Shur-Tab System.

Proper mechanization, using the SL600 System, will help lower installation time per fastener, with resultant cost savings. In this respect, filler use will depend on an analysis of weight requirements vs. economics of the overall application. As more filler is added to reduce density, the more difficult it becomes to mechanize installation. The actual volume of epoxy utilized per insert varies with sandwich thickness, core density and insert size. The epoxy weight for a 3/16 inch diameter insert in a ½ to ¾ inch sandwich will range from 5 to 20 grams.

Epoxies for edge sealing must handle easily when applied with hand tools. They must be sufficiently thixotropic in character to stay in place on vertical surfaces, and spread easily without excessive pull. Other potting compound considerations include adhesive strength, tendency to outgas and shrinkage during cure.

TAILORED COMPOUNDS AVAILABLE

Having been directly involved with these potting compound requirements, Shur-Lok Corporation offers epoxy compounds tailored to meet the specialized needs of sandwich fasteners.

These epoxy systems include:

1. SLE3001 which is a two-part epoxy system designed specifically for use with sealant gun potting. SLE3001 flows readily and can be potted with pressures as low as 20 psi, or with conventional hand syringes. It has excellent adhesive strength. It provides a complete fill free from voids. It also exhibits excellent thixotropic characteristics, yet does not outgas during exothermic stage. Density is 75 lbs. per cubic foot.
2. SLE3002, also a two-part system, which is recommended for the open potting method. Its flow characteristics are such that it will flow through the smallest openings and fill surrounding cells completely. SLE3002 works well in papercore honeycomb with excellent adhesion. Density is 75 lbs. per cubic foot.
3. The third epoxy compound, SLE3003, which can be used for both potting and edge bonding. Being nonsticky, it is easy to spread into position for edge bonding and will develop adequate strength with edge potting only 1/2-cell thick. Edge finish cleanup is held to a minimum. SLE3003 also embodies excellent thixotropic characteristics that eliminate sag on vertical surfaces. Its adhesive quality is good. It resists chipping and spalling to such a degree that standard wood screws can be turned into the mass without cracking the epoxy.

When selecting the material, the following factors must be considered:

1. Strength required
2. Service life of fastener
3. Temperature requirements
4. Corrosive environments
5. Thread lock requirements
6. Magnetic requirements
7. Weight
8. cost

The last factor, cost, is not generally considered an engineering problem, but certainly should be considered in the overall design. Designers are cautioned to avoid overdesigning when a corrosion-resistant alloy is needed. For example, A286 alloy has superior properties of corrosion resistance and strength under elevated temperatures and prolonged exposure. Yet 17-4 PH will frequently do the same job at 20% of the cost. Use the minimum grade that will do the job.

MATERIAL SELECTION

Typical materials used in the manufacture of Shur-Lok sandwich fasteners are:

TABLE 1

Aluminum Alloys	Carbon and Alloy Steels
2024 6061 7075	B1113 C1137 4130
Corrosion-Resistant Steels	**Special Alloys**
17-4 PH 303 A286	Inconel 600 Inconel 625 Inconel 718 Hastelloy C

METHODS OF TESTING

As mentioned earlier in this document, a sandwich panel fastener cannot be tested as an individual unit, but should be evaluated as installed in the applicable sandwich specimen. Experience shows that failure always occurs in the panel, never the fastener. Three basic tests are recommended and shown in the following figures:

Figure 13 Shear test

Figure 14 Flatwise Tension Test

Figure 15 Torque-Out Test

It is important that test procedures be standardized in order to obtain effective design evaluation. Standard test procedures specify the edge distance and location of the fastener within each specimen which will give the ultimate load-carrying capability of a particular fastener in a specific panel. Additional tests may be required which will include the true design parameters in a particular application to determine actual design loads. These could be in the nature of closer edge distances, combination pulls of two or more fasteners, or pulling straps which represent the actual attaching structure. The thickness of the pulling straps, in the case of single shear tests, has a direct effect on the stability of the fastener installation. The span or unsupported diaphragm area within the test ring in a tensile test does not in some cases represent the true loading conditions of the specific application.

In addition to the three basic tests mentioned above, additional special test may be required to completely evaluate the final fastener and panel configuration. These may include fatigue, vibration and shock tests.

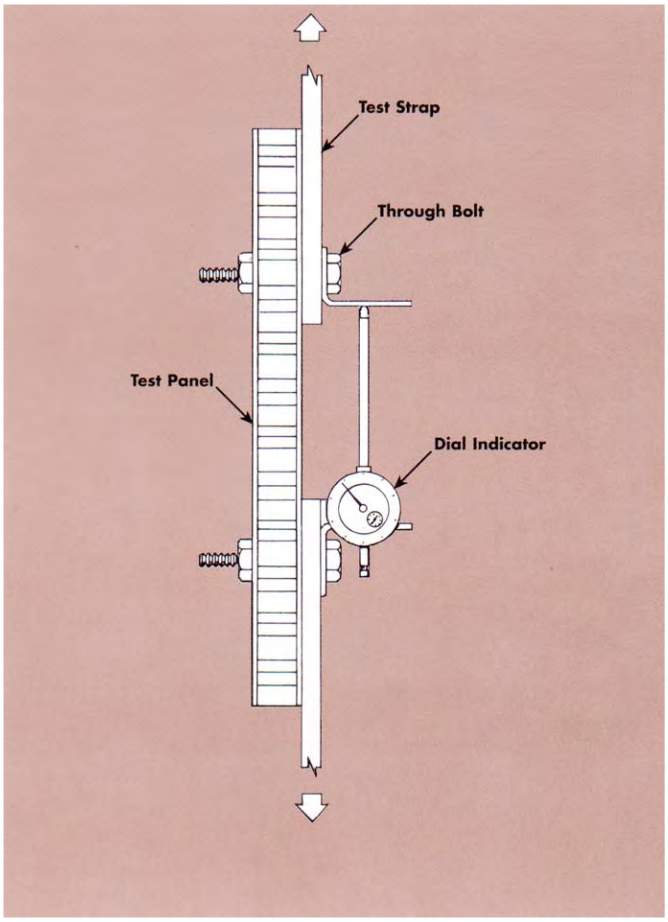


Figure 13 — Shear Test

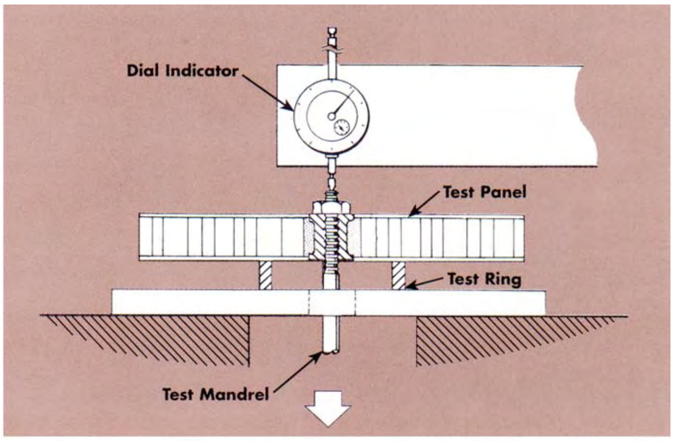


Figure 14 — Flatwise Tension Test

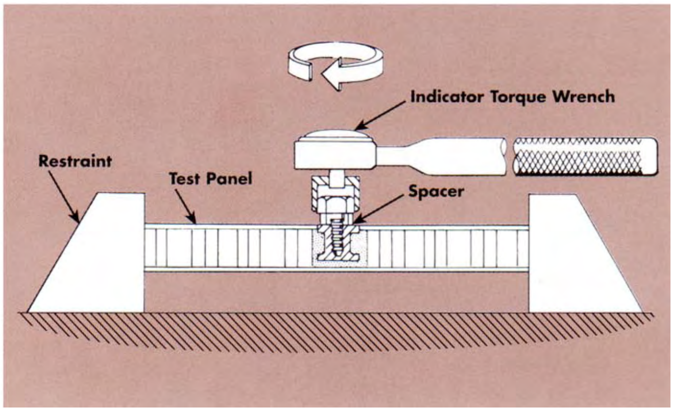


Figure 15 — Torque-Out Test

RECOMMENDED TEST PROCEDURE

1.0 SCOPE

1.1 PURPOSE

The purpose of this document is to establish standardized procedures for the testing and qualification of sandwich fasteners. Unless otherwise specified, all tests are static tests to be conducted at room temperature.

1.2 CLASSIFICATION OF TESTS

The test procedures outlined herein pertain to three specific phases of sandwich fastener testing and apply to the installation of the fastener within the panel. The types of tests covered are:

1. Single Shear
2. Flatwise Tension
3. Torque-Out

2.0 TEST PLAN

2.1 TEST SPECIMEN

2.1.1 Shear Test

The shear test specimen shall be a rectangular section 4.0 inches by 8.0 inches. Two fasteners shall be installed on the centerline, each fastener 2.0 inches from the end. A minimum of three specimens shall be tested. For molded-in fasteners a full cure of the compound shall be obtained prior to testing.

2.1.2 Tension Test

The tension test specimen shall be a 4.0 inch square section. The fastener shall be installed in the center of the specimen. A minimum of three specimens shall be tested. For molded-in fasteners a full cure of the compound shall be obtained prior to testing.

2.1.3 Torque Test

The torque test specimen shall be a 4.0 inch square section. The fastener shall be installed in the center of the specimen. A minimum of three specimens shall be tested. For molded-in fasteners a full cure of the compound shall be obtained prior to testing.

2.1.4 Installed Weights

The installed weight of each specimen shall be obtained by weighing the blank specimen, weighing the specimen after installation holes are drilled and weighing the specimen after the installation is complete. The weights of the fasteners shall also be included.

2.2 TEST SETUP

2.2.1 Single Shear Test

The shear test shall be conducted using two steel straps 6.0 inches by 1.0 inch by .125 inch. The bolt used shall be the same strength as the bolt used in the specific application. The bolt shall be torqued to the value specified for the actual installation. The specimen with straps attached shall be mounted in self-aligning jaws of the tensile machine. Care shall be taken to assure that the direction of loading passes directly through the centerline of each fastener. A dial indicator or automatic recorder shall be utilized to measure deflection. If a dial indicator is used, it shall be mounted as close as possible to the pull straps to minimize error due to cocking of the insert. See Figure 9.

2.2.2 Flatwise Tension Test

The flatwise tension test shall be conducted with the specimen supported in a box frame fixture by a 2.5 inch diameter steel ring with an 0.250 inch thick wall. The fastener shall be centered in the middle of the ring. The bolt or mandrel used shall be of sufficient strength to fail the specimen. Care shall be taken to assure that the direction of loading is perpendicular to the surface of the specimen. A dial indicator or automatic recorder shall be used to measure deflection. See Figure 10.

2.2.3 Torque-Out Test

The torque-out test shall be conducted with the specimen rigidly held in a vise or restraining fixture. The bolt used shall be of sufficient strength to achieve the required torque-out load. Unless otherwise specified, the minimum strength shall be 200,000 psi. A spacer with an O.D. of less than the diameter of the fastener head shall be used under the bolt head to prevent axial loading on the installation. The torque wrench shall have a maximum indicating dial so an accurate reading at the point of failure can be obtained. See Figure 11.

2.3 TEST PROCEDURE

2.3.1 Rate of Loading

The rate of loading for the shear and flatwise tension tests shall be 700-1200 lbs. per minute. The rate of loading for the torque-out test shall be approximately one revolution every five seconds applied at a steady rate.

2.3.2 Test Data

Test data shall be recorded in the form of a test log sheet. If a dial indicator is used to determine deflection, the witness to the test shall take readings to allow the operator to maintain a constant rate of loading. Notes shall be placed on the log sheets concerning all incidents of tests such as temporary yielding, slippage of the test setup or any other observation deemed pertinent to evaluating the installation.

3.0 TEST REPORT

As a minimum the test report shall include the following information.

3.1 SANDWICH CONSTRUCTION

A complete description of the sandwich construction shall be given. This shall include:

a. Face skin material and thickness
b. Complete core description
c. Bonding material
d. Core and panel manufacturer (if required)

3.2 FASTENER IDENTIFICATION

The fastener used shall be identified by complete part number. If the fastener is a modification of a standard part, a complete description of the change or a drawing of the part shall be included in the test report.

3.3 INSTALLATION DATA

3.3.1 Installation Procedure

A complete description of the installation procedure shall be given. This shall include installation hole sizes, depth of hole if applicable, and amount of undercut if applicable. The installed weight of each specimen shall be recorded.

3.3.2 Potting Compound

Identification of the potting compound used for molded-in fasteners shall include the manufacturer's designation of both the resin and the catalyst. Mixing procedure, method of potting and curing time and temperature shall be specified.

3.3.3 Installation Tools

The installation tool and method of installation for mechanical fasteners including the installation pressure or line pressure for pneumatic tools shall be specified.

3.4 TEST PROCEDURE

The test setup and procedure followed shall be fully described utilizing illustrations or photographs as necessary. The test conditions shall specify test temperature and humidity, if applicable. A graphic plot of load vs deflection shall be included for all shear and flatwise tension tests.

3.5 FAILURE

A complete description of the type failure shall be given. Failure analysis shall include all pertinent observations leading up to the failure. Photographs shall be included when required for clarification of the mode of failure and resultant destruction of the panel.

3.6 CONCLUSIONS AND RECOMMENDATIONS

The conclusion shall be an objective analysis of the type fastener and its utilization in the particular sandwich panel. A discussion of the application shall include recommendations for improving the design whether it be a modification of the fastener, the sandwich panel or method of installation.

SECTION VI — TEST RESULTS

SCOPE

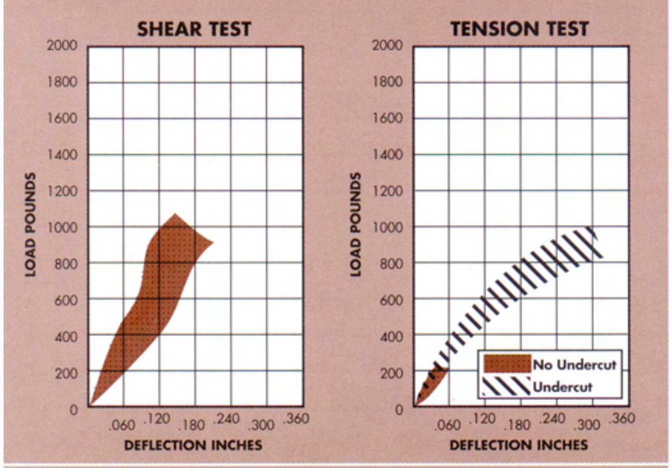
The following graphs and tables depict actual test results obtained with various sandwich fasteners installed in different types of panel. This data is intended to provide the engineer with comparative loads when different type fasteners are installed in the same panel. It also illustrates that, as explained in the foregoing sections of this manual, the selection of the type fastener is dependent upon the design parameters and specific application.

The graphs illustrate the difference in loading curves between molded-in fasteners installed with and without an undercut and mechanical fasteners. These loading curves are the result of three test specimens for each condition of panel variation, type of insert, undercut vs no undercut and potting compound. The advantage of the undercut in the molded-in fastener is obvious. However, it must be realized that the greater load-carrying capabilities are achieved at the expense of an increase in weight. But in most cases the strength-to-weight ratio of the undercut installation is still more attractive than without an undercut. It is emphasized that the ultimate fastener selection must be made by the designer and that the information provided in this section is to serve as an aid in making his selection an engineering decision rather than simply guesswork. The higher load values which are obtained with the mechanical fastener are attributed to the greater stability provided by this type of part.

PANEL A DESCRIPTION

BMS4-13, Type 1, Grade 5
Skins: AL ALY 7075-T6, .016 top, .010 bottom
Overall Thickness: .400
Potting Compound: SLE3001
Core: PVC foam 4.1 lb. density

Panel: A/ Fastener: SL602-3-400S

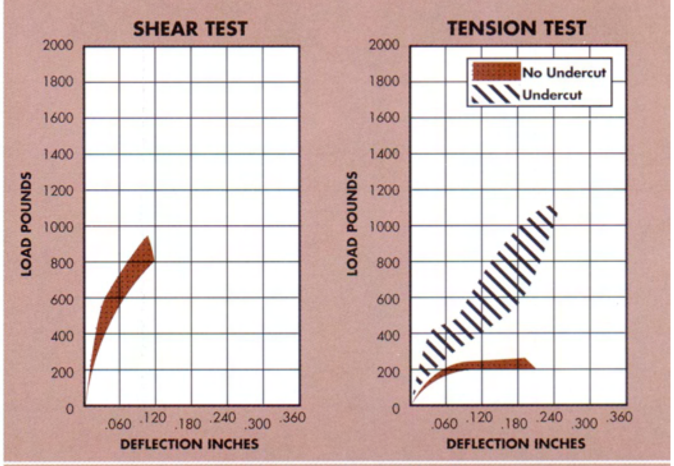


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
822 lbs.	207 lbs.	900 lbs.	80 in. lbs.
1000 lbs.	225 lbs.	900 lbs.	85 in. lbs.
882 lbs.	215 lbs.	810 lbs.	70 in. lbs.

Installed Weights: No Undercut 5.05 gr., Undercut 7.26 gr.

Panel: A/ Fastener: SL602-3-400A

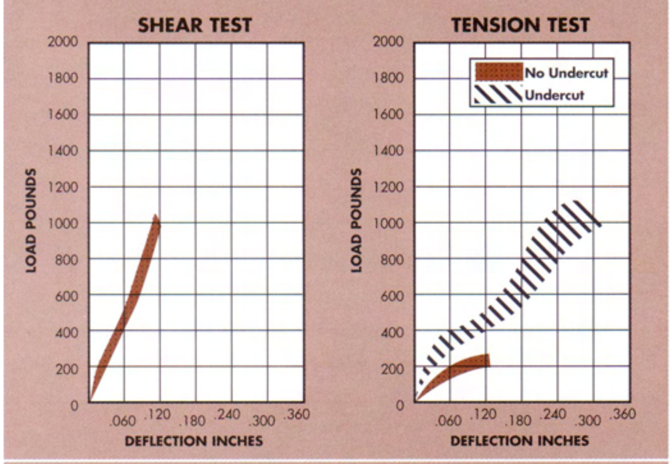


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
830 lbs.	215 lbs.	1105 lbs.	95 in. lbs.
788 lbs.	208 lbs.	917 lbs.	110 in. lbs.
800 lbs.	175 lbs.	625 lbs.	90 in. lbs.

Installed Weights: No Undercut 2.03 gr., Undercut 6.53 gr.

Panel: A/ Fastener: SL602-4-400S

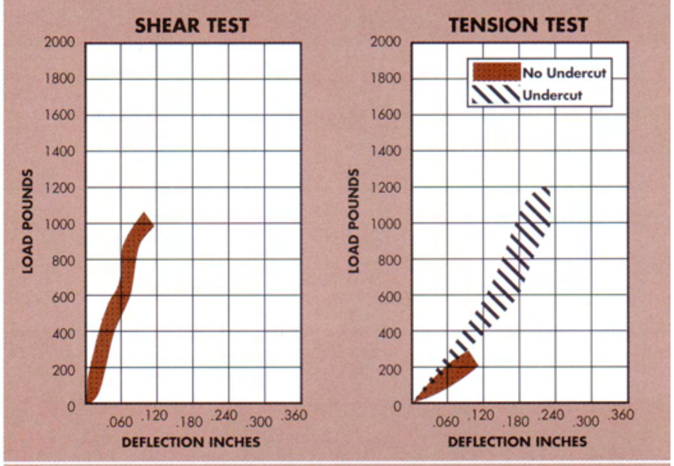


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
985 lbs.	185 lbs.	925 lbs.	160 in. lbs.
995 lbs.	170 lbs.	1035 lbs.	140 in. lbs.
1017 lbs.	235 lbs.	923 lbs.	140 in. lbs.

Installed Weights: No Undercut 7.25 gr., Undercut 14.4 gr.

Panel: A/ Fastener: SL602-4-400A

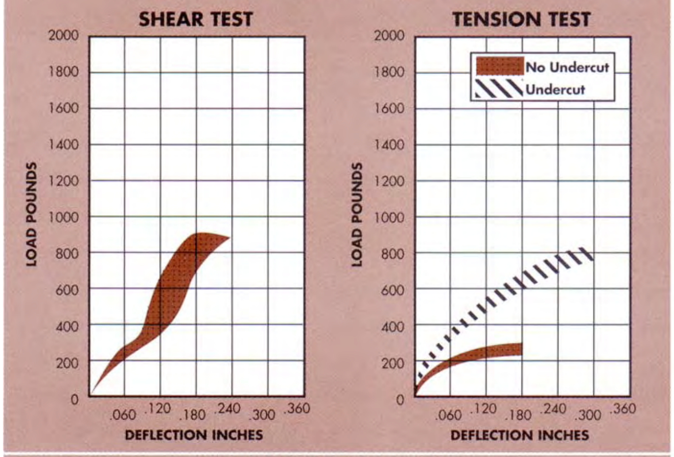


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
850 lbs.	210 lbs.	—	90 in. lbs.
925 lbs.	200 lbs.	1205 lbs.	120 in. lbs.
750 lbs.	200 lbs.	987 lbs.	70 in. lbs.

Installed Weights: No Undercut 2.07 gr., Undercut 6.22 gr.

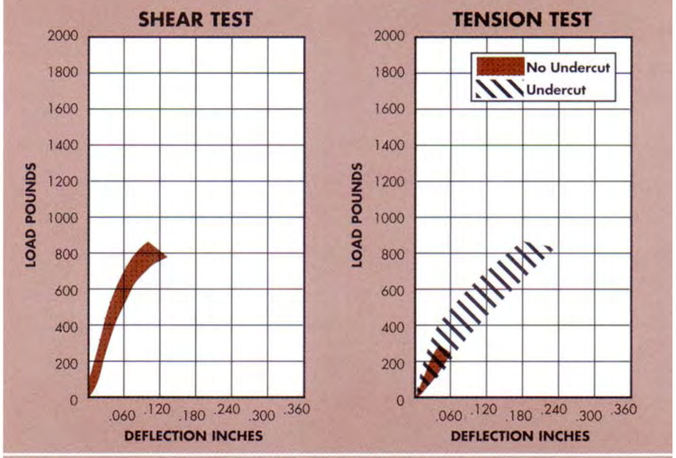
Panel: A/ Fastener: SL607-3-6S



ULTIMATE LOADS AT FAILURE			
Shear	Tension		Torque
	No Undercut	Undercut	
850 lbs.	250 lbs.	600 lbs.	100 in. lbs.
750 lbs.	240 lbs.	722 lbs.	75 in. lbs.
842 lbs.	250 lbs.	795 lbs.	90 in. lbs.

Installed Weights: No Undercut 2.25 gr., Undercut 5.40 gr.

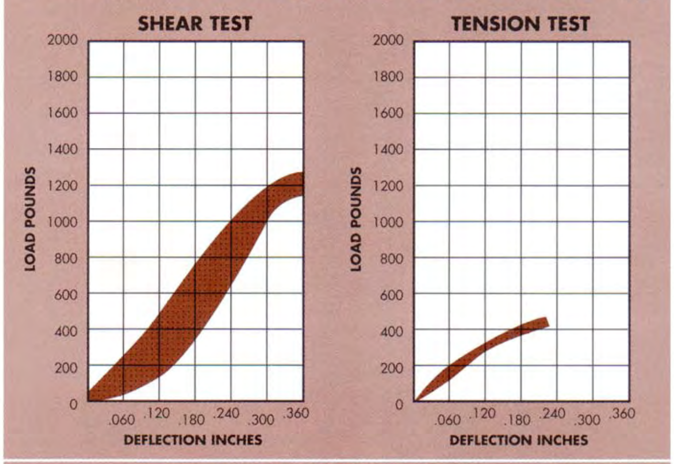
Panel: A/ Fastener: SL607-4-6S



ULTIMATE LOADS AT FAILURE			
Shear	Tension		Torque
	No Undercut	Undercut	
700 lbs.	246 lbs.	560 lbs.	70 in. lbs.
800 lbs.	200 lbs.	825 lbs.	55 in. lbs.
835 lbs.	230 lbs.	775 lbs.	60 in. lbs.

Installed Weights: No Undercut 3.34 gr., Undercut 7.58 gr.

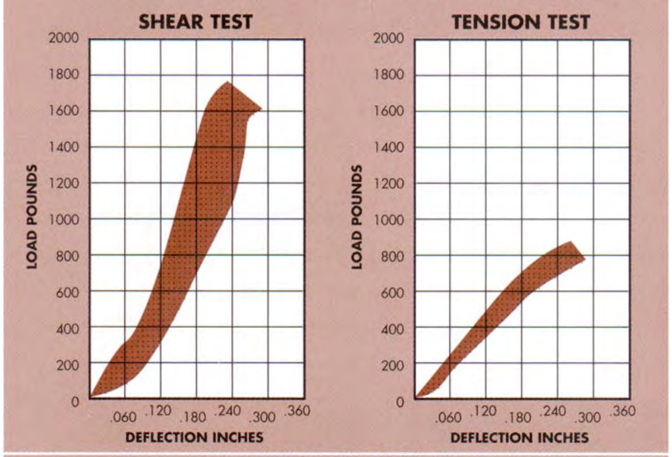
Panel: A/ Fastener: SLS512-3-16-400, SLP514-3-16-400



ULTIMATE LOADS AT FAILURE	
Shear	Tension
1250 lbs.	400 lbs.
1212 lbs.	385 lbs.
1162 lbs.	423 lbs.

Installed Weights: 3.36 gr.

Panel: A/ Fastener: SLS512-4-16-400, SLP514-4-16-400

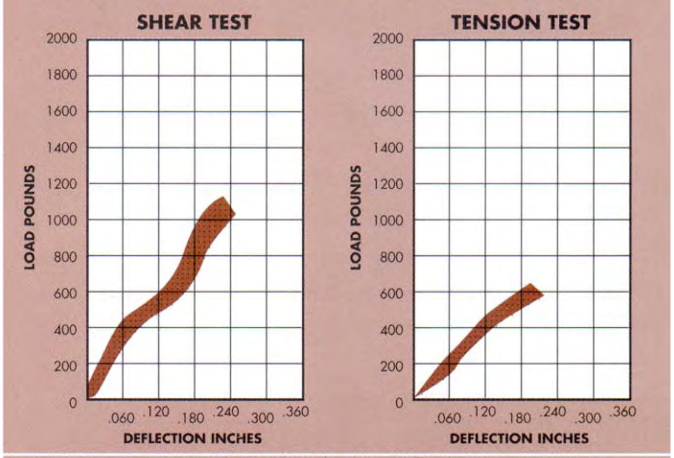


ULTIMATE LOADS AT FAILURE

Shear	Tension
1647 lbs.	786 lbs.
1462 lbs.	750 lbs.
1350 lbs.	800 lbs.

Installed Weights: 6.70 gr.

Panel: A/ Fastener: SLS521-3-16-400, SLP521-3-16-400



ULTIMATE LOADS AT FAILURE

Shear	Tension
837 lbs.	588 lbs.
1037 lbs.	585 lbs.
881 lbs.	500 lbs.

Installed Weights: 1.55 gr.

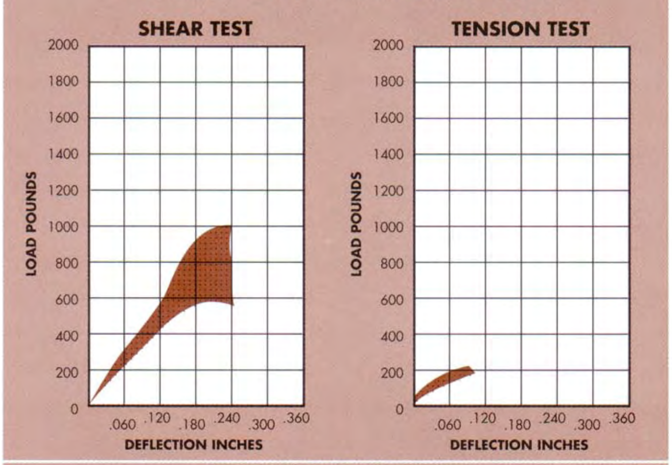
PANEL B DESCRIPTION

BMS4-13, Type 3, Grade 2
Skins: TITANIUM CP-70, .010 top,
.005 bottom

Overall Thickness: .400
Potting Compound: SLE3001

Core: PVC foam 5.7 lb. density

Panel: B/ Fastener: SL602-3-400S

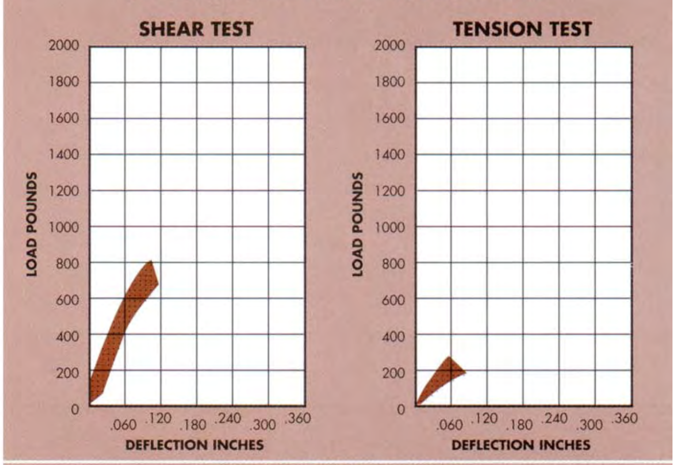


ULTIMATE LOADS AT FAILURE

Shear	Tension	Torque
537 lbs.	162 lbs.	90 in. lbs.
940 lbs.	165 lbs.	110 in. lbs.
537 lbs.	175 lbs.	95 in. lbs.

Installed Weights: No Undercut 5.05 gr., Undercut 7.26 gr.

Panel: B/ Fastener: SL602-3-400A

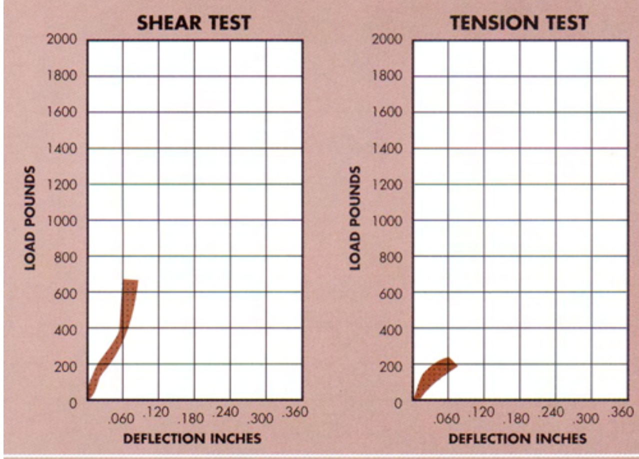


ULTIMATE LOADS AT FAILURE

Shear	Tension
732 lbs.	185 lbs.
538 lbs.	131 lbs.
612 lbs.	180 lbs.

Installed Weights: 5.28 gr.

Panel: B/ Fastener: SL602-4-400S

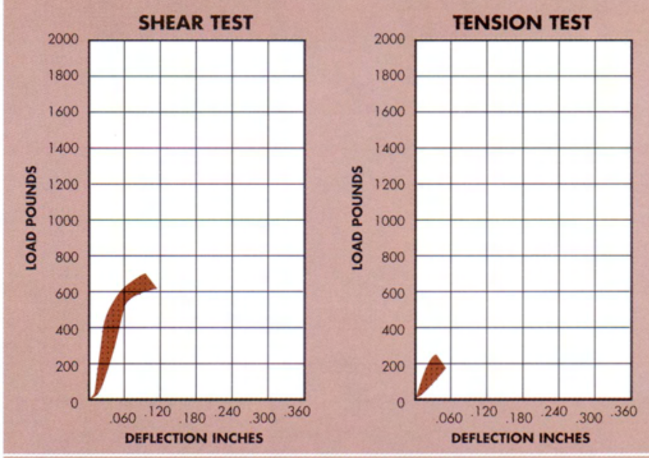


ULTIMATE LOADS AT FAILURE

Shear	Tension
560 lbs. 650 lbs. 657 lbs.	157 lbs. 185 lbs. 167 lbs.

Installed Weights: 7.25 gr.

Panel: B/ Fastener: SL602-4-400A

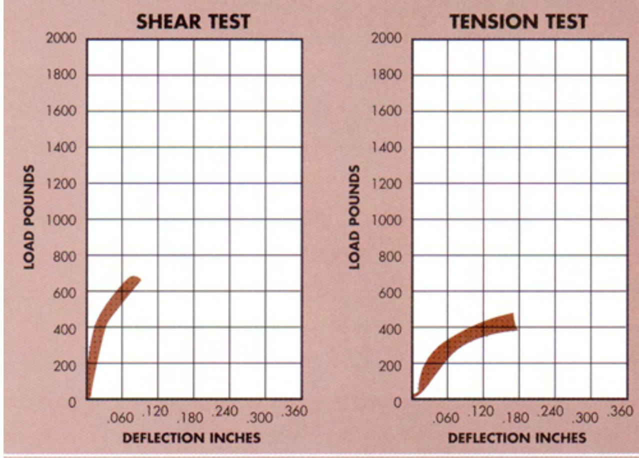


ULTIMATE LOADS AT FAILURE

Shear	Tension	Torque
650 lbs. 637 lbs. 450 lbs.	127 lbs. 150 lbs. —	75 in. lbs. 100 in. lbs. 60 in. lbs.

Installed Weights: 2.68 gr.

Panel: B/ Fastener: SL607-3-6S

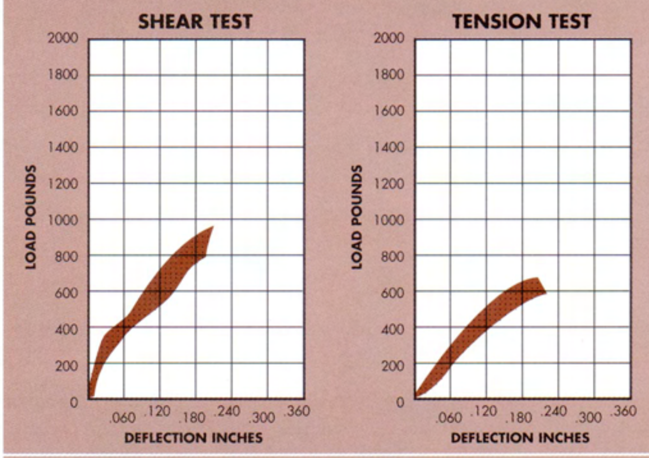


ULTIMATE LOADS AT FAILURE

Shear	Tension	Torque
325 lbs. 587 lbs. 650 lbs.	400 lbs. 260 lbs. 200 lbs.	75 in. lbs. 75 in. lbs. 75 in. lbs.

Installed Weights: No Undercut 2.25 gr., Undercut 5.40 gr.

Panel: B/ Fastener: SL607-4-6S

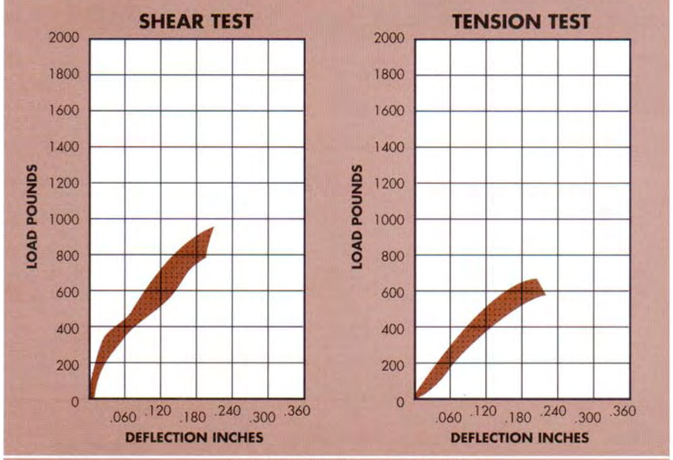


ULTIMATE LOADS AT FAILURE

Shear	Tension	Torque
605 lbs. 565 lbs. 550 lbs.	225 lbs. 182 lbs. 197 lbs.	90 in. lbs. 95 in. lbs. 70 in. lbs.

Installed Weights: No Undercut 3.34 gr., Undercut 7.58 gr.

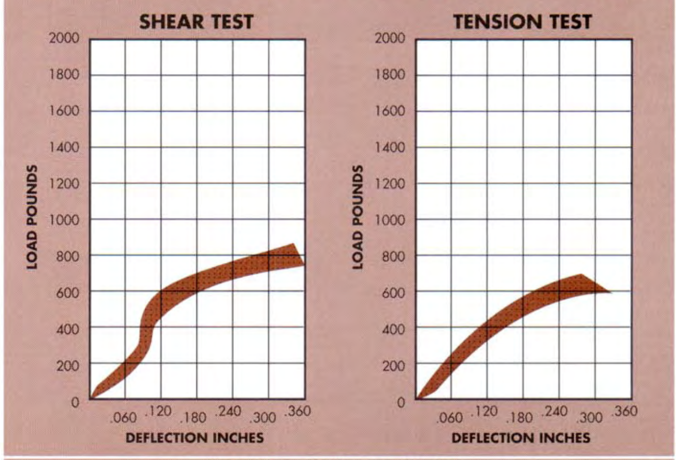
Panel: B/ Fastener: SLS512-3-16-400, SLP514-3-16-400



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
760 lbs. 765 lbs. 910 lbs.	590 lbs. 627 lbs. 712 lbs.

Installed Weights: 3.38 gr.

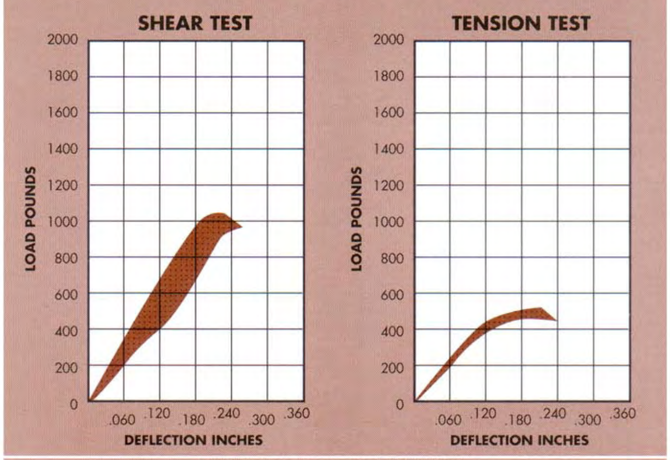
Panel: B/ Fastener: SLS512-4-16-400, SLP514-4-16-400



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
705 lbs. 740 lbs. 780 lbs.	507 lbs. 655 lbs. 550 lbs.

Installed Weights: 6.70 gr.

Panel: B/ Fastener: SLS521-3-16-400, SLP525-3-16-400



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
900.0 lbs. 957.5 lbs. 777.5 lbs.	475 lbs. 450 lbs. 450 lbs.

Installed Weights: 1.55 gr.

PANEL C DESCRIPTION

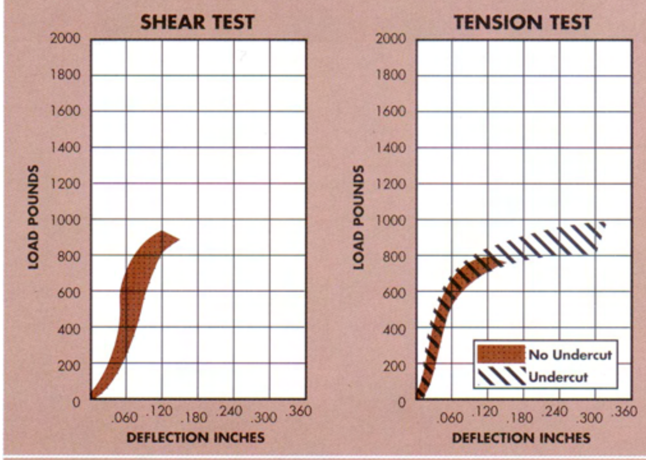
Skins: AL ALY 2024-T3, .016 top, .016 bottom

Core: HONEYCOMB, AL ALY 5052, $^1/_4$ X .002

Overall Thickness: .500

Potting Compound: SLE3001

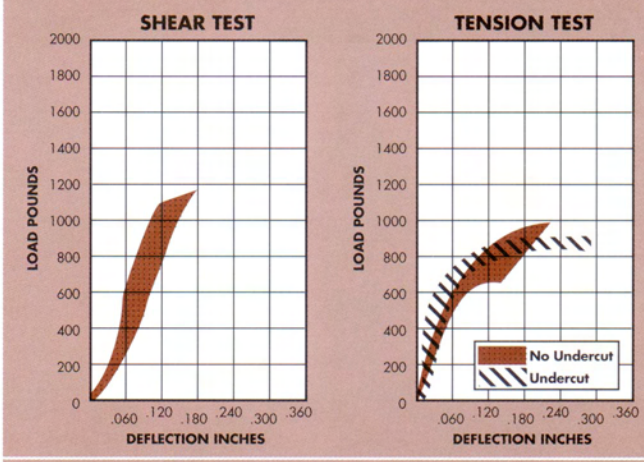
Panel: C/ Fastener: SL601-3-3S



ULTIMATE LOADS AT FAILURE			
Shear	Tension		Torque
	No Undercut	Undercut	
797 lbs.	800 lbs.	750 lbs.	85 in. lbs.
805 lbs.	655 lbs.	930 lbs.	85 in. lbs.
805 lbs.	710 lbs.	900 lbs.	85 in. lbs.

Installed Weights: No Undercut 7.79 gr., Undercut 15.13 gr.

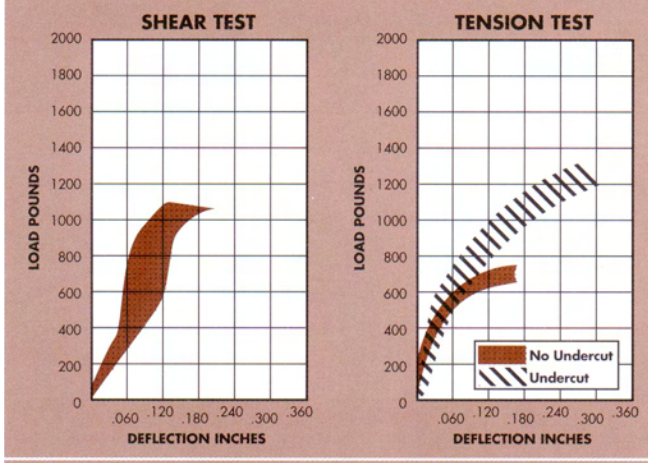
Panel: C/ Fastener: SL601-3-3A



ULTIMATE LOADS AT FAILURE			
Shear	Tension		Torque
	No Undercut	Undercut	
700 lbs.	662 lbs.	845 lbs.	100 in. lbs.
1125 lbs.	737 lbs.	860 lbs.	90 in. lbs.
1013 lbs.	925 lbs.	860 lbs.	90 in. lbs.

Installed Weights: No Undercut 5.42 gr., Undercut 10.89 gr.

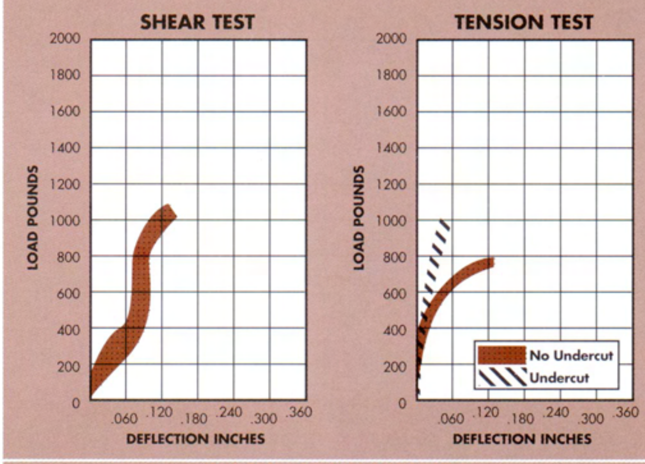
Panel: C/ Fastener: SL602-3-500S



ULTIMATE LOADS AT FAILURE			
Shear	Tension		Torque
	No Undercut	Undercut	
1095 lbs.	657 lbs.	1155 lbs.	85 in. lbs.
1085 lbs.	730 lbs.	1250 lbs.	75 in. lbs.
1195 lbs.	725 lbs.	1170 lbs.	80 in. lbs.

Installed Weights: No Undercut 8.87 gr., Undercut 13.77 gr.

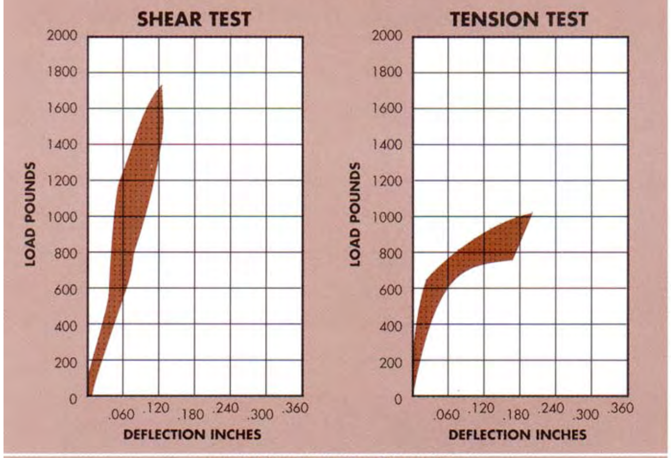
Panel: C/ Fastener: SL602-3-500A



ULTIMATE LOADS AT FAILURE			
Shear	Tension		Torque
	No Undercut	Undercut	
794 lbs.	612 lbs.	900.0 lbs.	85 in. lbs.
940 lbs.	762 lbs.	1002.0 lbs.	85 in. lbs.
1000 lbs.	550 lbs.	1037.5 lbs.	90 in. lbs.

Installed Weights: No Undercut 4.65 gr., Undercut 12.03 gr.

Panel: C/ Fastener: SL602-4-500S

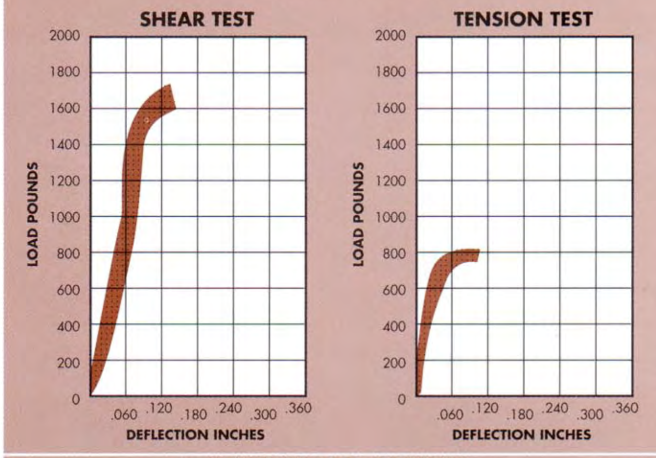


ULTIMATE LOADS AT FAILURE

Shear	Tension	Torque
1558 lbs.	800 lbs.	150 in. lbs.
1330 lbs.	730 lbs.	150 in. lbs.
1720 lbs.	960 lbs.	150 in. lbs.

Installed Weights: 11.56 gr.

Panel: C/ Fastener: SL602-4-500A

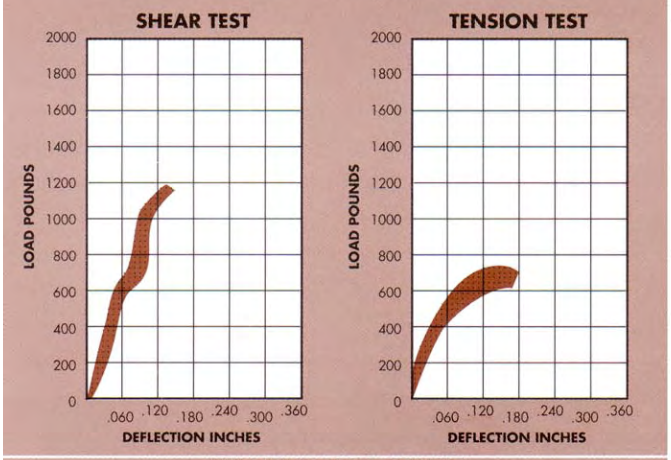


ULTIMATE LOADS AT FAILURE

Shear	Tension	Torque
1550 lbs.	762 lbs.	270 in. lbs.
1607 lbs.	758 lbs.	270 in. lbs.
1660 lbs.	700 lbs.	225 in. lbs.

Installed Weights: 7.20 gr.

Panel: C/ Fastener: SL603-3-500S

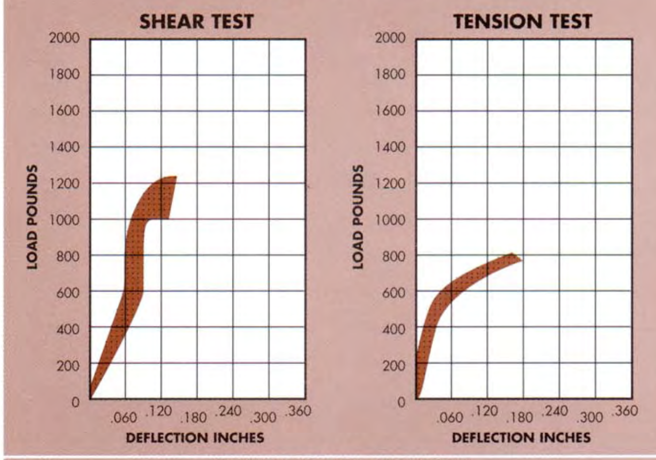


ULTIMATE LOADS AT FAILURE

Shear	Tension
1168 lbs.	710 lbs.
1135 lbs.	710 lbs.
1315 lbs.	637 lbs.

Installed Weights: 8.67 gr.

Panel: C/ Fastener: SL603-3-500A

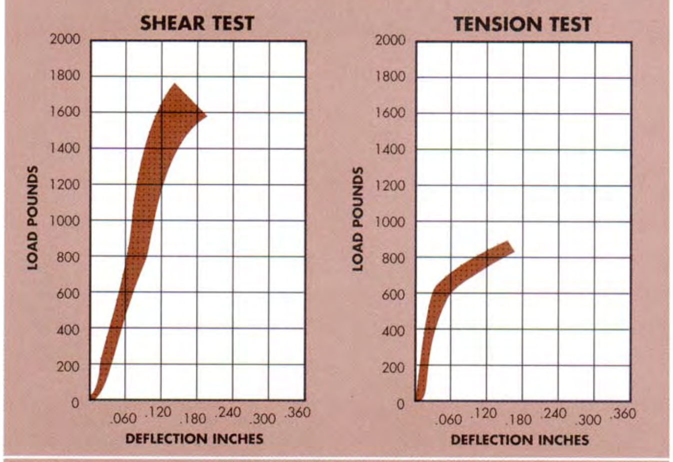


ULTIMATE LOADS AT FAILURE

Shear	Tension
1200 lbs.	775 lbs.
1225 lbs.	665 lbs.
1080 lbs.	787 lbs.

Installed Weights: 5.35 gr.

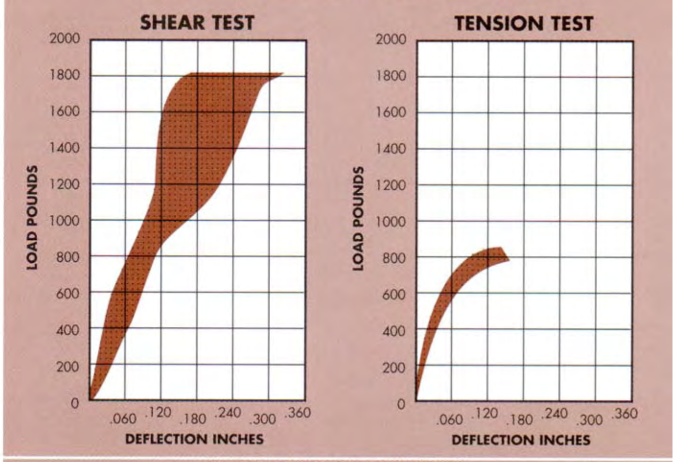
Panel: C/ Fastener: SL603-4-500S



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
1730 lbs. 1490 lbs. 1550 lbs.	842 lbs. 920 lbs. 795 lbs.

Installed Weights: 10.61 gr.

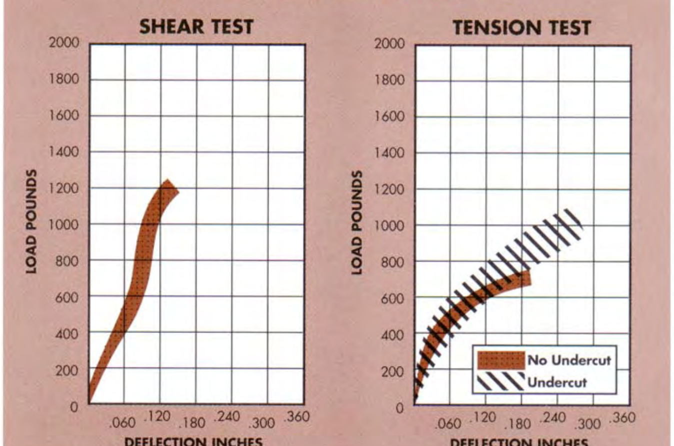
Panel: C/ Fastener: SL603-4-500A



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
1715 lbs. 1785 lbs. 1710 lbs.	738 lbs. 861 lbs. 750 lbs.

Installed Weights: 5.84 gr.

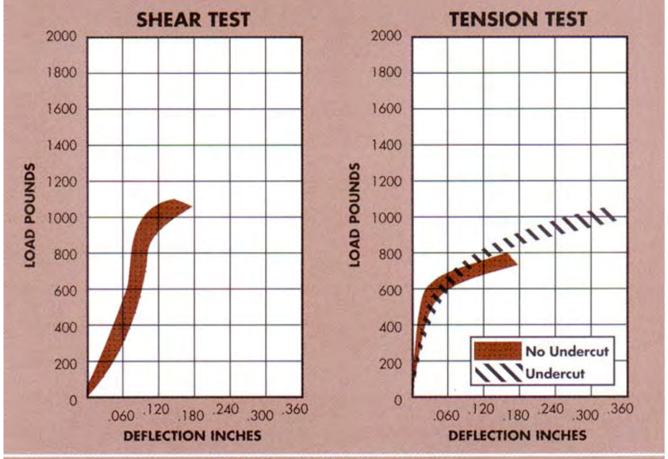
Panel: C/ Fastener: SL607-3-8S



ULTIMATE LOADS AT FAILURE			
Shear	**Tension**		**Torque**
	No Undercut	**Undercut**	
1077 lbs. 1155 lbs. 1175 lbs.	655 lbs. 570 lbs. 690 lbs.	990 lbs. 510 lbs. 1017 lbs.	75 in. lbs. 75 in. lbs. 75 in. lbs.

Installed Weights: No Undercut 5.41 gr., Undercut 11.14 gr.

Panel: C/ Fastener: SL607-4-8S

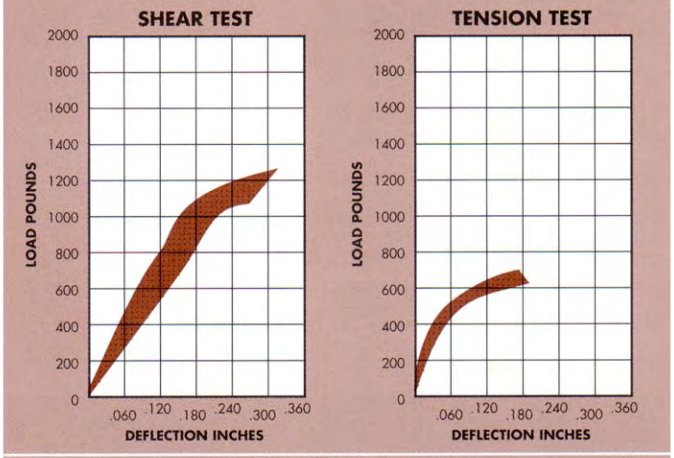


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
975 lbs.	672 lbs.	900 lbs.	150 in. lbs.
905 lbs.	770 lbs.	965 lbs.	125 in. lbs.
1143 lbs.	740 lbs.	925 lbs.	150 in. lbs.

Installed Weights: No Undercut 5.99 gr., Undercut 11.50 gr.

Panel: C/ Fastener: SLS521-3-16-500, SLP541-3-16-500

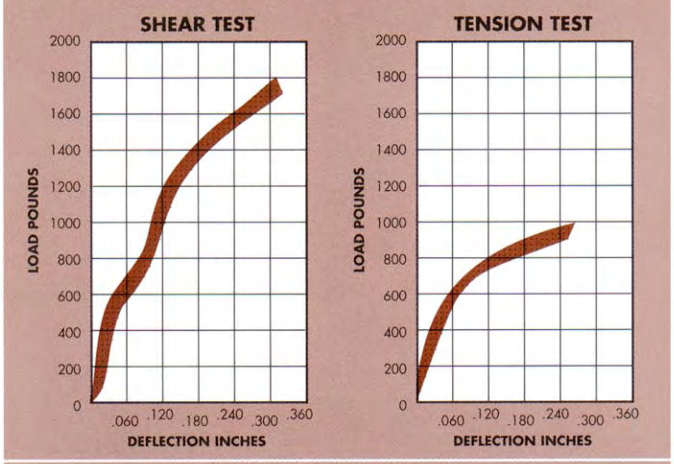


ULTIMATE LOADS AT FAILURE

Shear	Tension	Torque
1225 lbs.	610 lbs.	135 in. lbs.
1035 lbs.	607 lbs.	140 in. lbs.
1220 lbs.	480 lbs.	120 in. lbs.

Installed Weights: 2.79 gr.

Panel: C/ Fastener: SLS521-4-16-500, SLP541-4-16-500



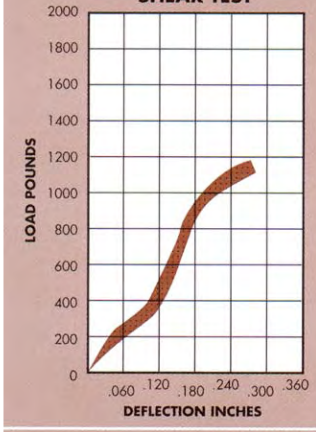
ULTIMATE LOADS AT FAILURE

Shear	Tension	Torque
1775 lbs.	905 lbs.	150 in. lbs.
1365 lbs.	800 lbs.	300 in. lbs.
1715 lbs.	870 lbs.	220 in. lbs.

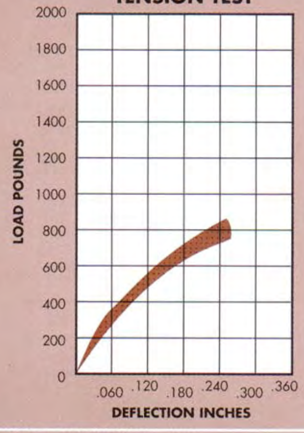
Installed Weights: 6.94 gr.

Panel: C/ Fastener: SLS512-3-16-500, SLP514-3-16-500

SHEAR TEST



TENSION TEST



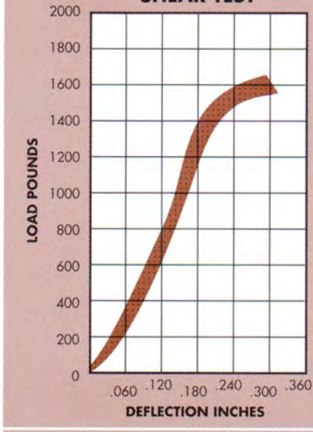
ULTIMATE LOADS AT FAILURE

Shear	Tension
1012 lbs.	643 lbs.
1050 lbs.	645 lbs.
1025 lbs.	782 lbs.

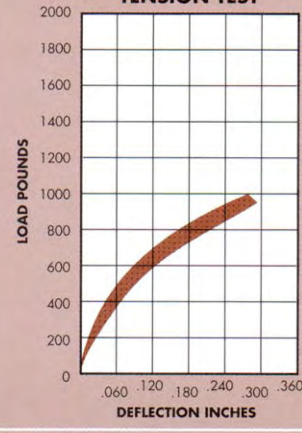
Installed Weights: 4.87 gr.

Panel: C/ Fastener: SLS512-4-16-500, SLP514-4-16-500

SHEAR TEST



TENSION TEST



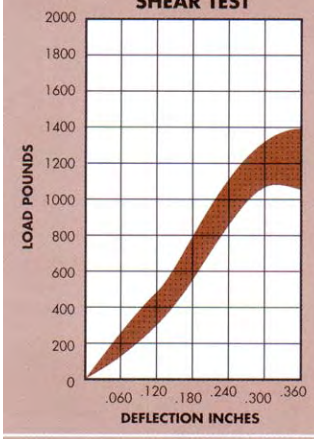
ULTIMATE LOADS AT FAILURE

Shear	Tension
1375 lbs.	817 lbs.
1475 lbs.	862 lbs.
1500 lbs.	837 lbs.

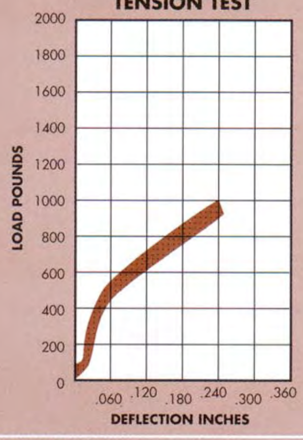
Installed Weights: 9.34 gr.

Panel: C/ Fastener: SLS521-3-16-500, SLP525-3-16-500

SHEAR TEST



TENSION TEST



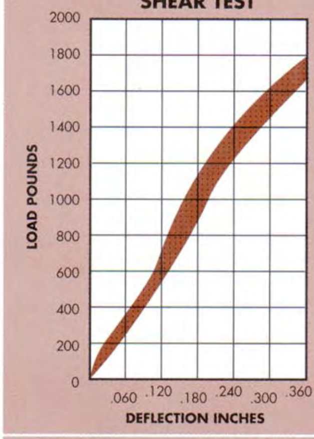
ULTIMATE LOADS AT FAILURE

Shear	Tension
1390 lbs.	815 lbs.
1355 lbs.	912 lbs.
1015 lbs.	912 lbs.

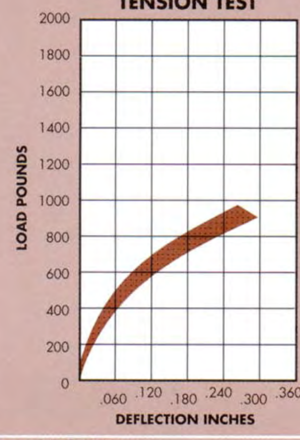
Installed Weights: 1.91 gr.

Panel: C/ Fastener: SLS521-4-16-500, SLP525-3-16-500

SHEAR TEST



TENSION TEST



ULTIMATE LOADS AT FAILURE

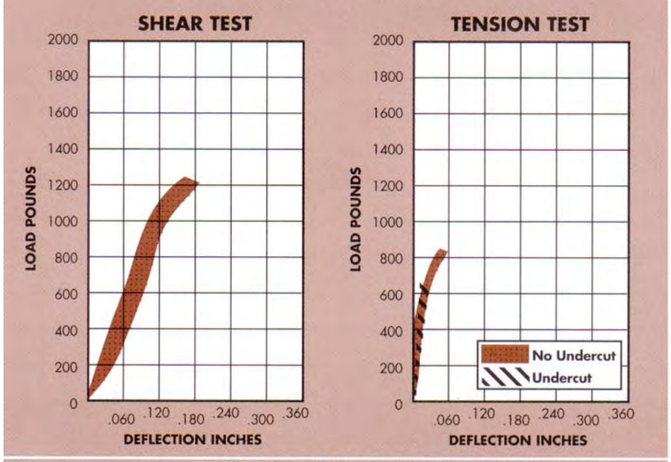
Shear	Tension
1655 lbs.	815 lbs.
1605 lbs.	937 lbs.
1245 lbs.	775 lbs.

Installed Weights: 2.90 gr.

PANEL D DESCRIPTION

GELAC 10N5052
Skins: AL ALY 7075-T6, .020 top, .010 bottom
Core: HONEYCOMB, AL ALY 5052, 1/8 X .001
Overall Thickness: .690
Potting Compound: SLE3001

Panel: D/ Fastener: SL601-3-3S

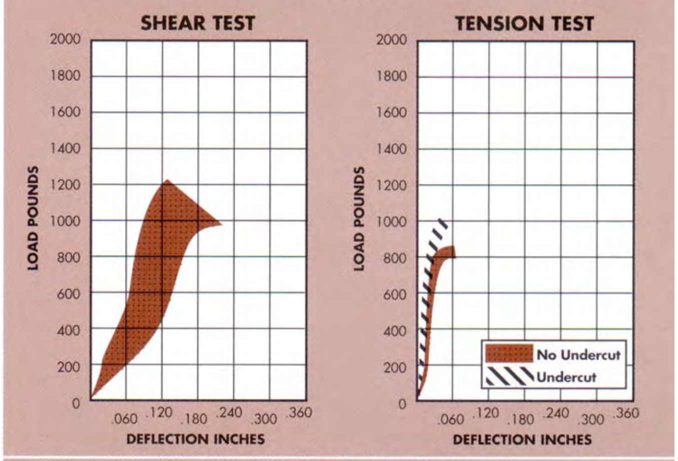


Shear	Tension		Torque
	No Undercut	Undercut	
1173 lbs.	652 lbs.	675 lbs.	80 in. lbs.
1205 lbs.	800 lbs.	680 lbs.	85 in. lbs.
1150 lbs.	760 lbs.	525 lbs.	90 in. lbs.

ULTIMATE LOADS AT FAILURE

Installed Weights: No Undercut 6.89 gr., Undercut 14.93 gr.

Panel: D/ Fastener: SL601-3-3A

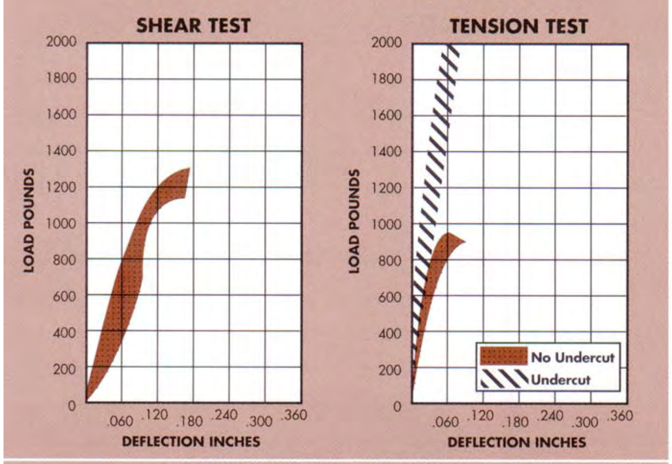


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
915 lbs.	775 lbs.	760 lbs.	80 in. lbs.
1170 lbs.	782 lbs.	975 lbs.	80 in. lbs.
937 lbs.	800 lbs.	950 lbs.	

Installed Weights: No Undercut 5.19 gr., Undercut 13.11 gr.

Panel: D/ Fastener: SL602-3-690S

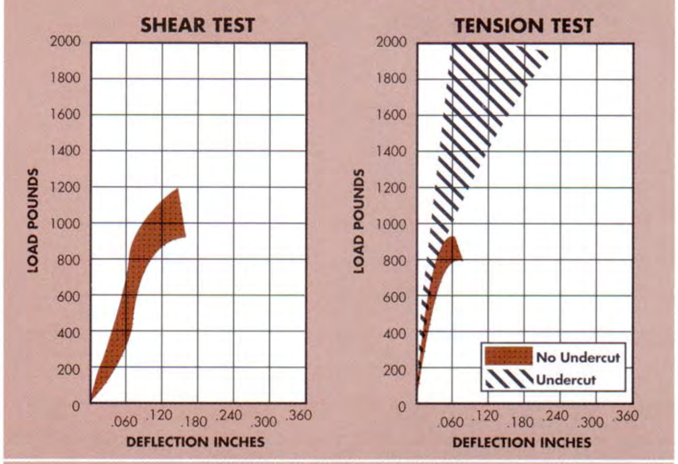


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
1065 lbs.	805 lbs.	1580 lbs.	150 in. lbs.
1125 lbs.	805 lbs.	2155 lbs.	145 in. lbs.
1205 lbs.	817 lbs.	2540 lbs.	145 in. lbs.

Installed Weights: No Undercut 9.18 gr., Undercut 52.11 gr.

Panel: D/ Fastener: SL602-3-690A

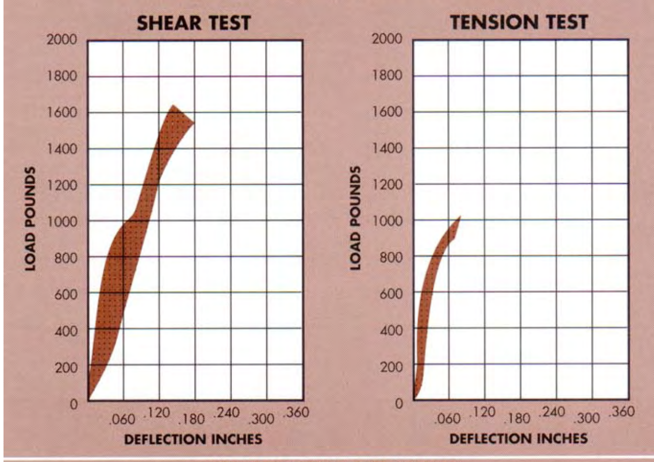


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
1000 lbs.	790 lbs.	2505 lbs.	130 in. lbs.
1082 lbs.	837 lbs.	1915 lbs.	135 in. lbs.
800 lbs.	845 lbs.	2985 lbs.	130 in. lbs.

Installed Weights: No Undercut 5.17 gr., Undercut 35.66 gr.

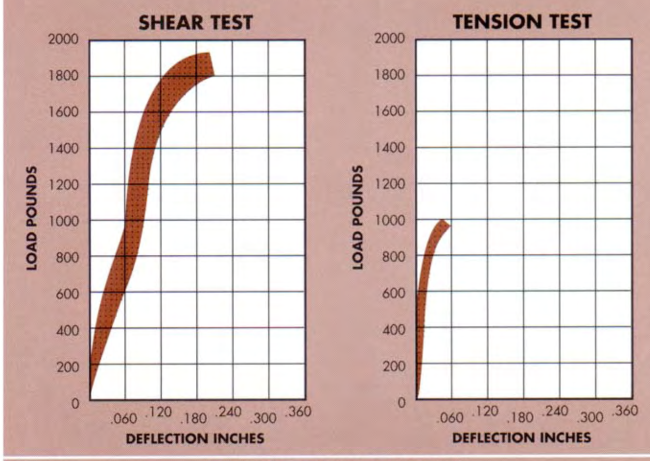
Panel: D/ Fastener: SL602-4-690S



ULTIMATE LOADS AT FAILURE		
Shear	**Tension**	**Torque**
1422 lbs. 1435 lbs. 1588 lbs.	957 lbs. 822 lbs. 875 lbs.	300 in. lbs. 300 in. lbs. 300 in. lbs.

Installed Weights: 13.22 gr.

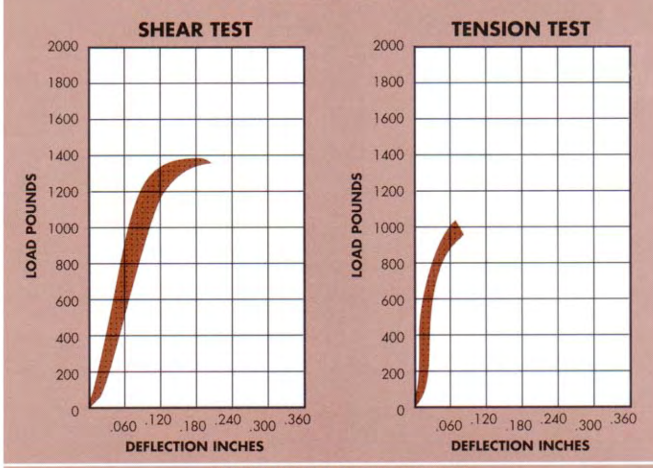
Panel: D/ Fastener: SL602-4-690A



ULTIMATE LOADS AT FAILURE		
Shear	**Tension**	**Torque**
1667 lbs. 1825 lbs. 1820 lbs.	915 lbs. 950 lbs. 850 lbs.	300 in. lbs. 300 in. lbs. 300 in. lbs.

Installed Weights: 7.17 gr.

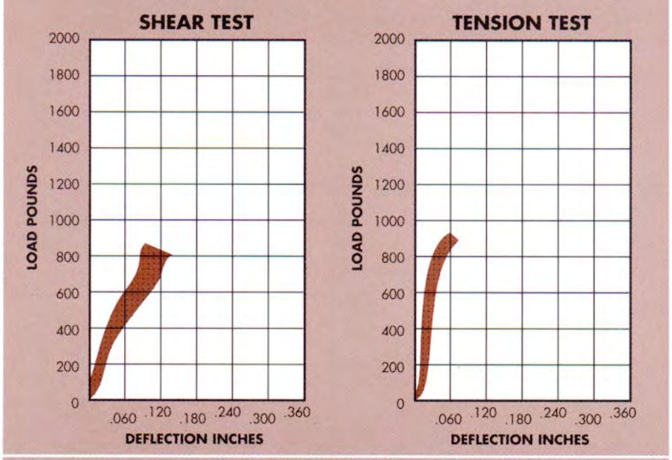
Panel: D/ Fastener: SL603-3-690S



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
1250 lbs. 1295 lbs. 1335 lbs.	825 lbs. 912 lbs. 817 lbs.

Installed Weights: 11.45 gr.

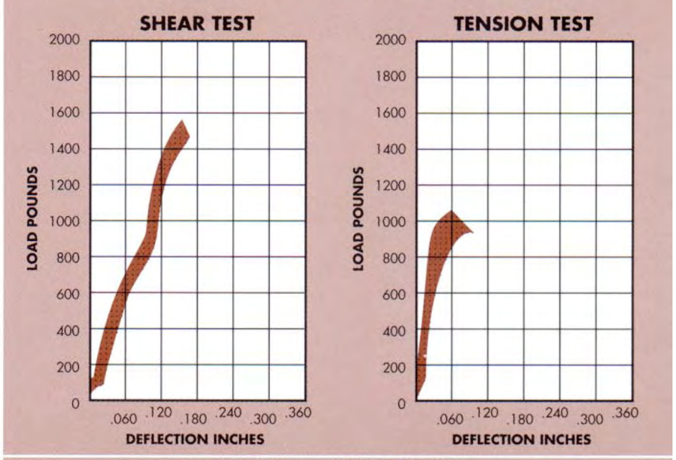
Panel: D/ Fastener: SL603-3-690A



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
1045 lbs. 1082 lbs. 1077 lbs.	810 lbs. 805 lbs. 757 lbs.

Installed Weights: 6.14 gr.

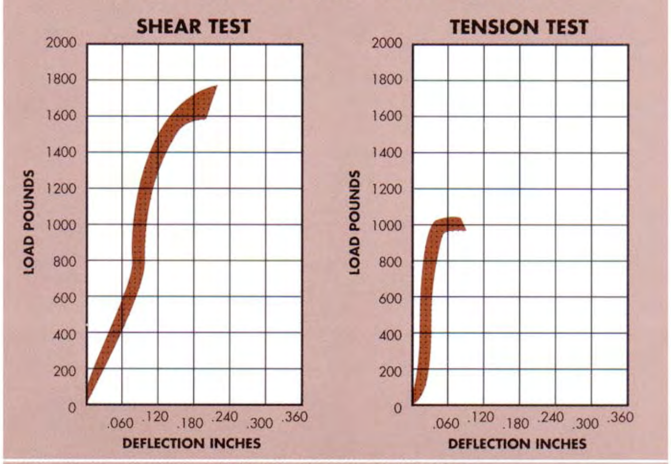
Panel: D/ Fastener: SL603-4-690S



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
1385 lbs. 1502 lbs. 1505 lbs.	850 lbs. 952 lbs. 952 lbs.

Installed Weights: 10.40 gr.

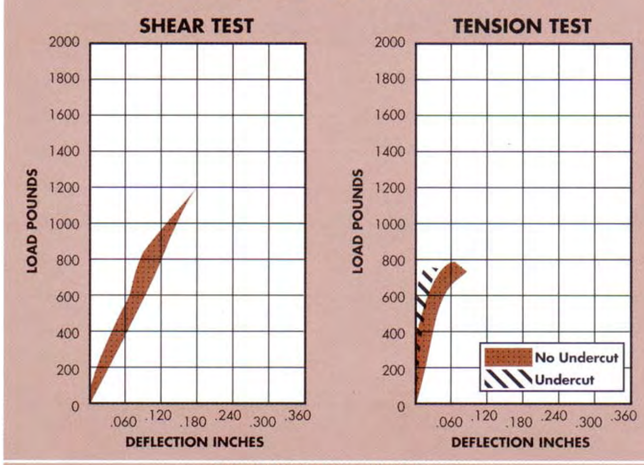
Panel: D/ Fastener: SL603-4-690A



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
1428 lbs. 1717 lbs. 1655 lbs.	950 lbs. 960 lbs. 817 lbs.

Installed Weights: 6.05 gr.

Panel: D/ Fastener: SL607-3-8S

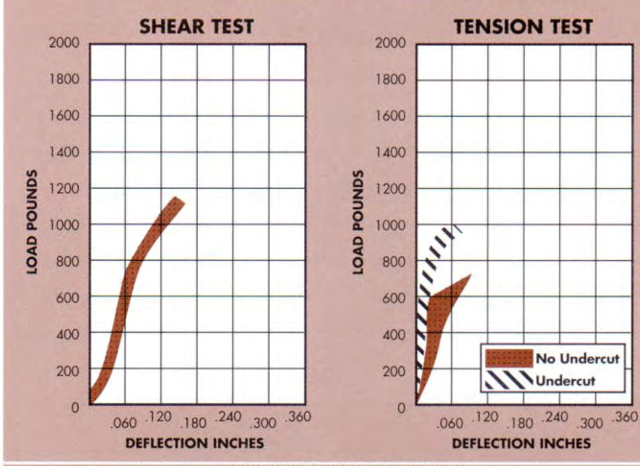


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
845 lbs.	750 lbs.	700 lbs.	75 in. lbs.
845 lbs.	550 lbs.	731 lbs.	75 in. lbs.
1165 lbs.	605 lbs.	675 lbs.	75 in. lbs.

Installed Weights: No Undercut 5.56 gr., Undercut 11.85 gr.

Panel: D/ Fastener: SL607-4-8S

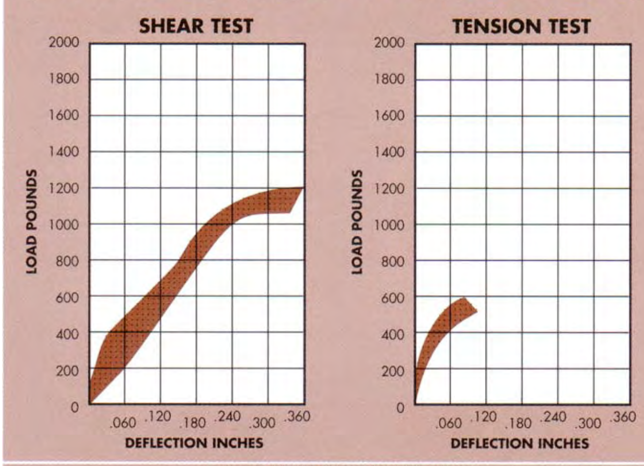


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
1062 lbs.	745 lbs.	655 lbs.	125 in. lbs.
880 lbs.	350 lbs.	750 lbs.	140 in. lbs.
1050 lbs.	600 lbs.	969 lbs.	150 in. lbs.

Installed Weights: No Undercut 5.93 gr., Undercut 14.06 gr.

Panel: D/ Fastener: SLS521-3-10-690, SLP541-3-20-690

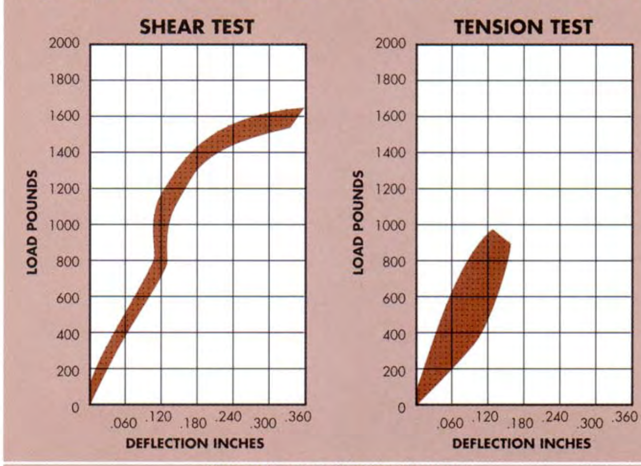


ULTIMATE LOADS AT FAILURE

Shear	Tension	Torque
1250 lbs.	460 lbs.	170 in. lbs.
1062 lbs.	540 lbs.	140 in. lbs.
1085 lbs.	568 lbs.	185 in. lbs.

Installed Weights: 3.75 gr.

Panel: D/ Fastener: SLS521-4-10-690, SLP541-4-20-690

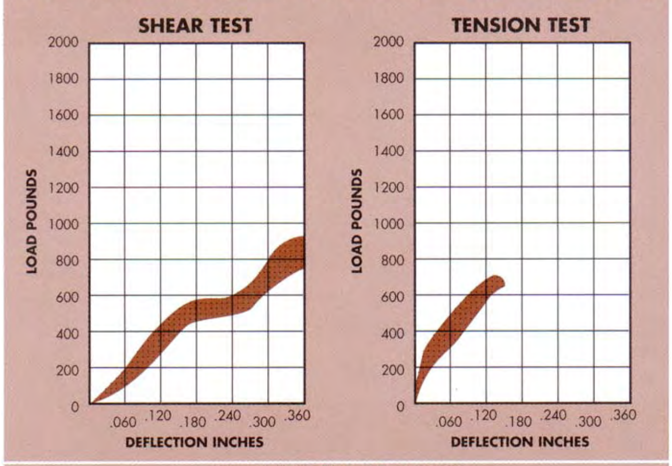


ULTIMATE LOADS AT FAILURE

Shear	Tension	Torque
1455 lbs.	473 lbs.	270 in. lbs.
1325 lbs.	865 lbs.	240 in. lbs.
1592 lbs.	915 lbs.	290 in. lbs.

Installed Weights: 6.70 gr.

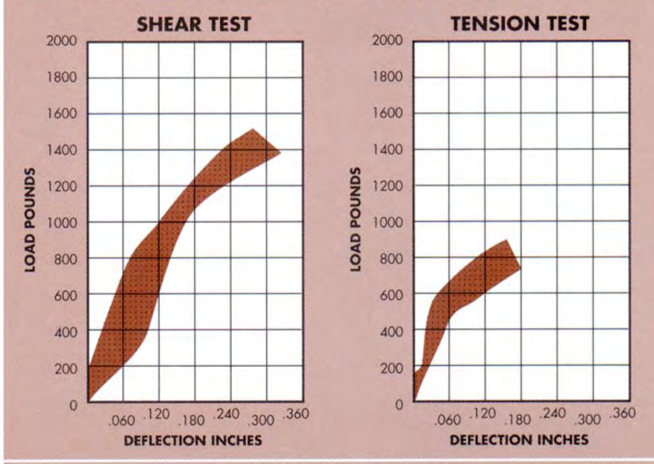
Panel: D/ Fastener: SLS512-3-10-690, SLP514-3-20-690



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
627 lbs. 857 lbs. 730 lbs.	625 lbs. 355 lbs. 673 lbs.

Installed Weights: 5.17 gr.

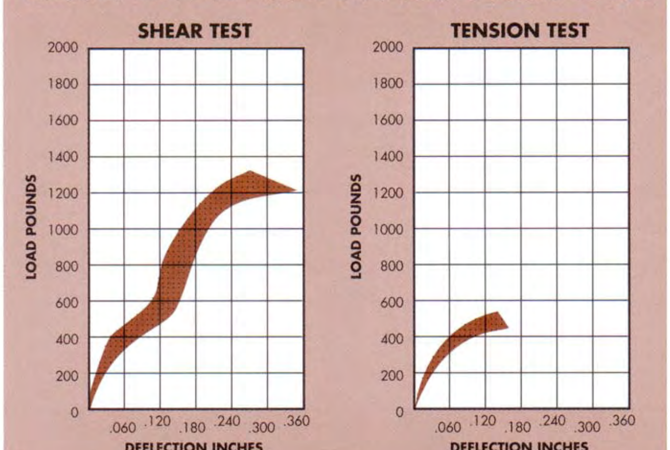
Panel: D/ Fastener: SLS512-4-10-690, SLP514-4-20-690



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
1185 lbs. 1417 lbs. 1180 lbs.	855 lbs. 672 lbs. 755 lbs.

Installed Weights: 14.08 gr.

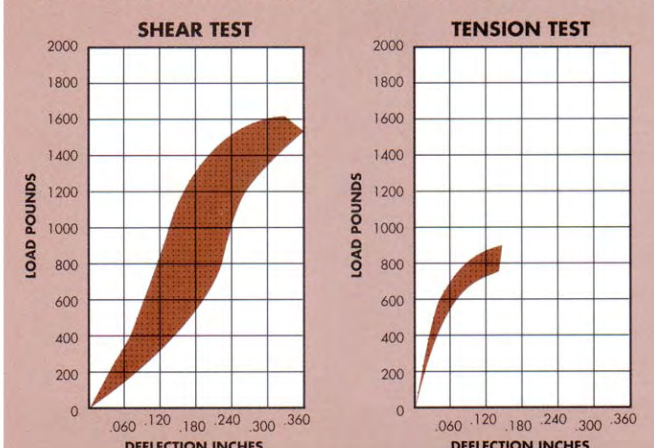
Panel: D/ Fastener: SLS521-3-10-690, SLP525-3-20-690



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
1270 lbs. 1255 lbs. 1215 lbs.	455 lbs. 415 lbs. 417 lbs.

Installed Weights: 2.85 gr.

Panel: D/ Fastener: SLS521-4-10-690, SLP525-4-20-690



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
1500 lbs. 1489 lbs. 1550 lbs.	762 lbs. 840 lbs. 780 lbs.

Installed Weights: 4.65 gr.

PANEL E DESCRIPTION

Skins: STRATOGLAS 7005-ESAO, .030 top,.020 bottom

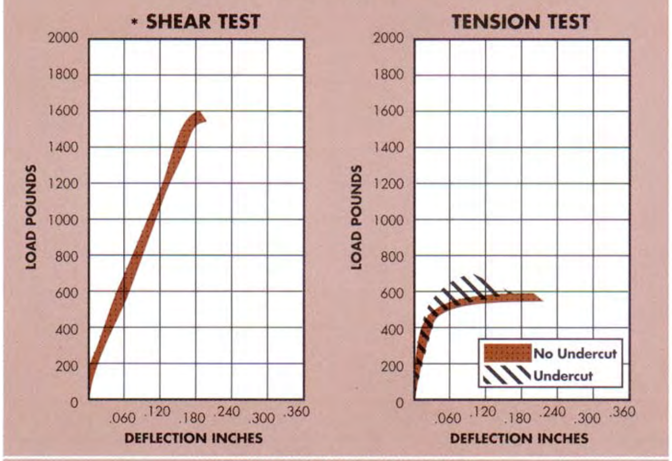
Core: HEXEL PHENOLIC HONEYCOMB 25% Impregnated paper, 60 lb. wt., ⅛ lb. density

Overall Thickness: .562

Potting Compound: EPOCAST 8623A/B, Type 3

*Indicates test panels using SLE3001 potting compound

Panel: E/ Fastener: SL601-3-3S

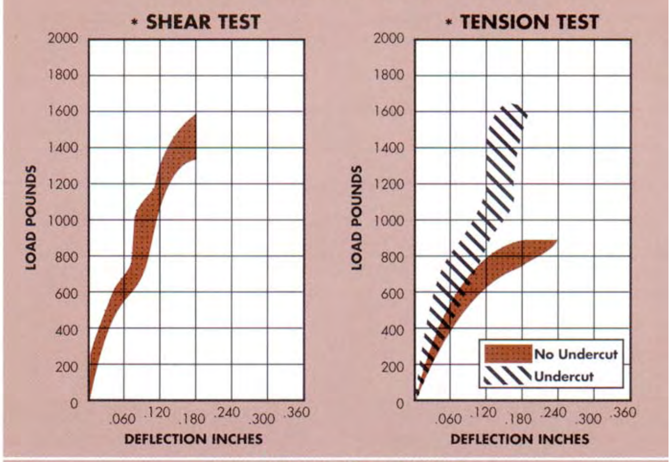


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
1565 lbs.	448 lbs.	605 lbs.	95 in. lbs.
1481 lbs.	585 lbs.	545 lbs.	100 in. lbs.
1128 lbs.	415 lbs.	563 lbs.	85 in. lbs.

Installed Weights: No Undercut 8.50 gr., Undercut 12.05 gr.

Panel: E/ Fastener: SL602-3-562A

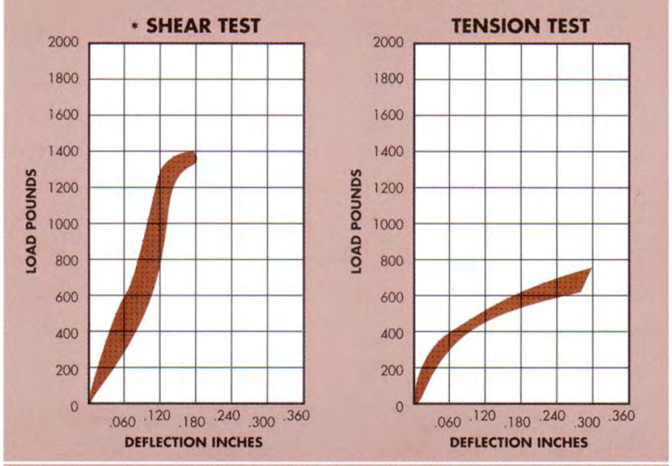


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
1312 lbs.	815 lbs.	1088 lbs.	105 in. lbs.
1476 lbs.	925 lbs.	1682 lbs.	115 in. lbs.
1520 lbs.	925 lbs.	1612 lbs.	90 in. lbs.

Installed Weights: No Undercut 8.13 gr., Undercut 14.83 gr.

Panel: E/ Fastener: SL603-3-562A

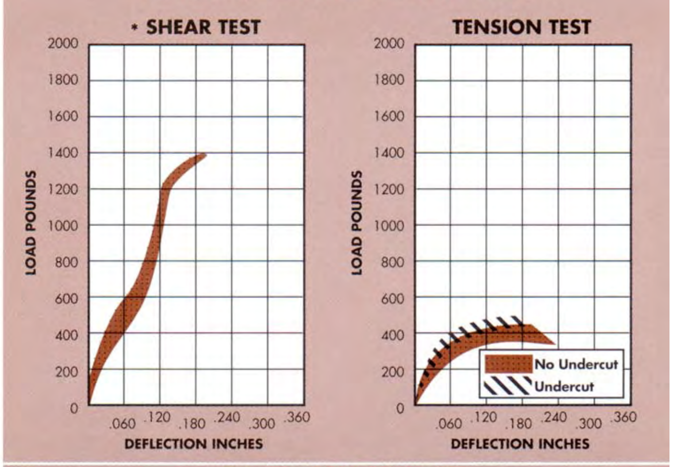


ULTIMATE LOADS AT FAILURE

Shear	Tension
1210 lbs.	750 lbs.
1110 lbs.	702 lbs.
1340 lbs.	635 lbs.

Installed Weights: 4.93 gr.

Panel: E/ Fastener: SL607-3-8S

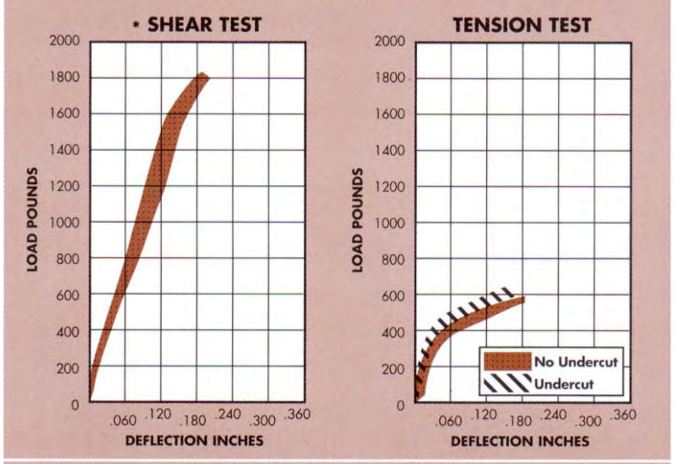


ULTIMATE LOADS AT FAILURE

Shear	Tension		Torque
	No Undercut	Undercut	
1362 lbs.	425 lbs.	427 lbs.	90 in. lbs.
1285 lbs.	350 lbs.	447 lbs.	95 in. lbs.
1083 lbs.	310 lbs.	415 lbs.	105 in. lbs.

Installed Weights: No Undercut 5.82 gr., Undercut 11.18 gr.

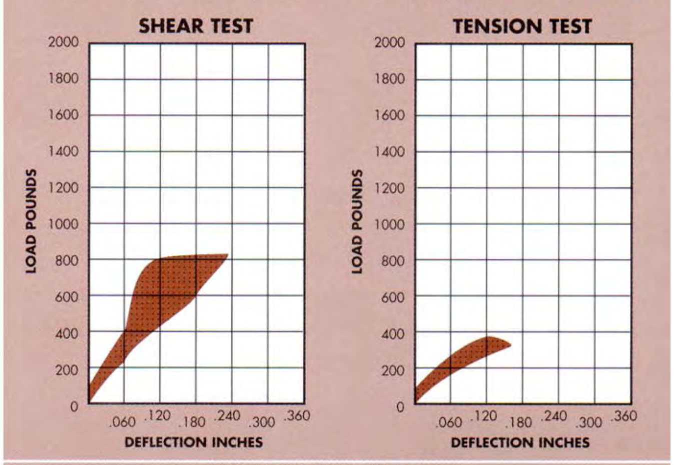
Panel: E/ Fastener: SL607-4-8S



ULTIMATE LOADS AT FAILURE			
Shear	Tension		Torque
	No Undercut	Undercut	
1830 lbs.	492 lbs.	562 lbs.	140 in. lbs.
1417 lbs.	485 lbs.	545 lbs.	120 in. lbs.
1735 lbs.	427 lbs.	522 lbs.	105 in. lbs.

Installed Weights: No Undercut 6.60 gr., Undercut 11.13 gr.

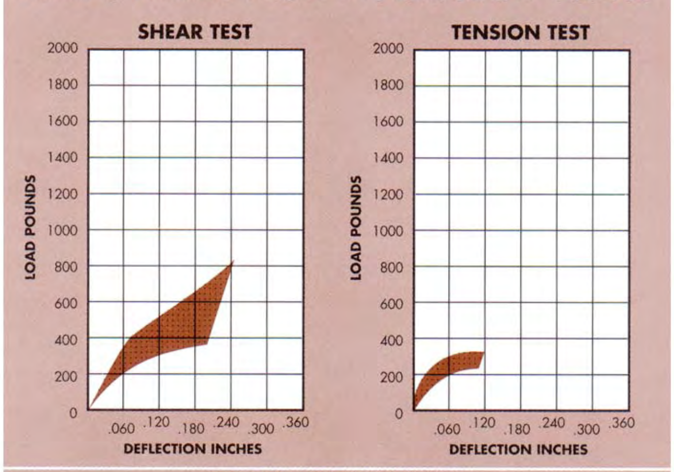
Panel: E/ Fastener: SLS521-3-10-562, SLP541-3-20-562



ULTIMATE LOADS AT FAILURE		
Shear	Tension	Torque
740 lbs.	330 lbs.	60 in. lbs.
807 lbs.	295 lbs.	70 in. lbs.
650 lbs.	278 lbs.	55 in. lbs.

Installed Weights: 3.80 gr.

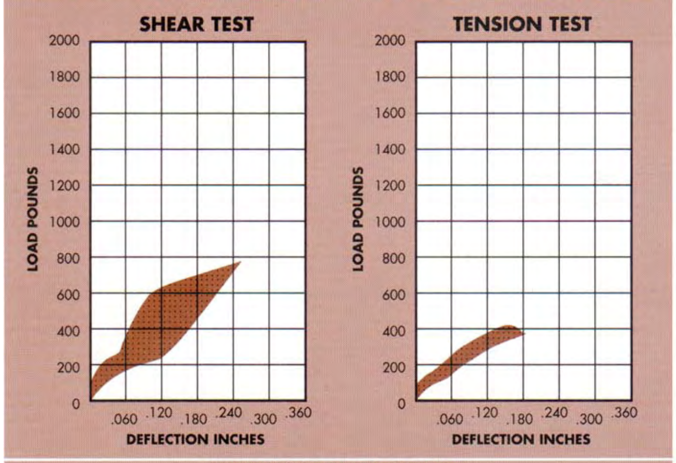
Panel: E/ Fastener: SLS521-4-10-562, SLP541-4-20-562



ULTIMATE LOADS AT FAILURE		
Shear	Tension	Torque
337 lbs.	307 lbs.	75 in. lbs.
785 lbs.	258 lbs.	80 in. lbs.
755 lbs.	225 lbs.	95 in. lbs.

Installed Weights: 6.78 gr.

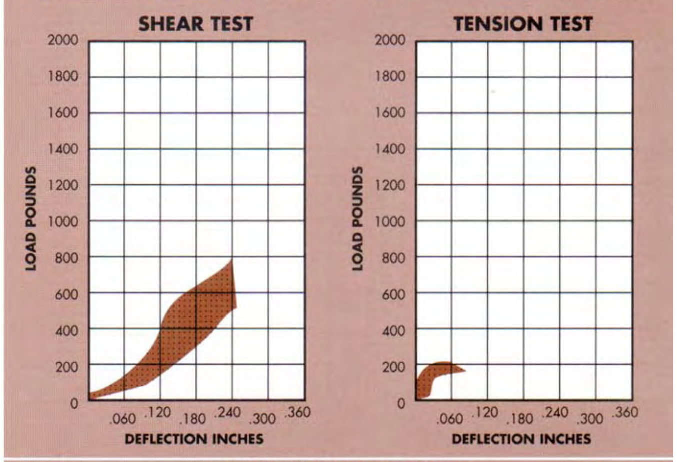
Panel: E/ Fastener: SLS512-3-10-562, SLP514-3-20-562



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
605 lbs.	375 lbs.
640 lbs.	383 lbs.
695 lbs.	345 lbs.

Installed Weights: 5.83 gr.

Panel: E/ Fastener: SLS521-3-10-562, SLP525-3-20-562



ULTIMATE LOADS AT FAILURE	
Shear	**Tension**
745 lbs.	162 lbs.
587 lbs.	165 lbs.
537 lbs.	95 lbs.

Installed Weights: 2.23 gr.

CONCLUSIONS

TOTAL ENVIRONMENT — Many individual factors have been discussed in this Design Manual. It is important for each of these items to be measured in relation to the total environment of fastener, sandwich structure and end use.

To aid design engineers in applying these factors to their specific requirements, Shur-Lok Corporation offers two outstanding services, complete testing facilities and engineering consultation.

IN-PLANT TESTING — To insure the validity of each step in the design process, Shur-Lok maintains complete testing facilities staffed by qualified fastener specialists. With this in-plant capability, Shur-Lok has documented a wide range of test data beyond the examples presented in this manual. The test data is readily available to designers.

This in-depth approach to problem solving has been greatly appreciated by designers. It has been a major factor in Shur-Lok's growth to pre-eminence in the field of sandwich panel fasteners.

EXPERT CONSULTATION — Our highly skilled engineering staff is available at all times to help in exploring each facet of a design problem. As pioneers in the development of fasteners for sandwich structure, Shur-Lok has developed an impressive record of successful solutions to complex problems. We welcome the opportunity to be of service, whatever the challenge.

ADDITIONAL TEST DATA — Numerous tests have been conducted since the original publication of the Design Manual. Be sure to contact our engineering staff for information about testing with sandwich panel material or potting compounds not included in this publication.

POTTING COMPOUNDS — For expert assistance concerning the aerospace industry's most advanced potting compounds you may also wish to contact:

Fiber-Resin Corporation
a subsidiary of H.B. Fuller Company
20701 Nordhoff Street
Chatsworth, CA 91311
TEL: 1-800-624-9487
FAX: 818/709-0399