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Fabrication

1. Welding u-joints to steering shafts:

While it has become obvious over many years that universal joints can be welded to shafts with a high degree of reliability, some procedures are detrimental to the u-joint itself and must be avoided. Plug or rosette welds on universal joints are virtually guaranteed to shorten the life of the bearings from both direct heat and the distortion resulting from the proximity of the welds to the bearings. Even if the bearings are removed first, this distortion will cause enough misalignment to do them in when reinstalling. Likewise, any welding procedure which consumes enough time to discolor the ears of the u-joint should be assumed to have drawn the temper of the bearings. In any case, the cross section of the circumferential weld joint is comfortably larger than that of the tubular shaft, and additional welding in the form of plugs or rosettes will be superfluous. The obvious disadvantage of welding is, of course, that once you've welded the u-joints they cannot be removed without resorting to a torch, saw, or angle grinder. A mechanical connection, on the other hand, carries the great convenience of being removable for inspection or replacement.

The best mechanical connection by far is a spline. Unlike a key, crosspin, or flats, a spline transmits torque uniformly around the circle and gets the most out of a given wall thickness. The closer to "square" its tooth profile, the more effective it is than one with a "pointed" profile. The pointed serration used in the automotive industry has a self-separating action, exerting an expanding force on the outer member much like a wornout screwdriver tries to pry itself out of a screw slot (see figure 56 at right). While serrations have the commercial advantage of being very easy to manufacture, their profile requires pinch-clamping in order to stay tight (as in the rag joint in a stock automobile, for example). For space reasons, most race cars use set screws to retain the u-joints rather than pinch bolts. Automotive serrations retained in this way, particularly in the finer pitches, are prone to loosening from vibration—so check the set screws frequently. A spline of square profile, such as the 201 spline used on all Woodward products, develops an interlocking grip when tightened with a set screw, and is vastly more resistant to loosening than a pointed profile. Its greater depth provides more mechanical engagement, and it will perform reliably even in a rusted or damaged condition.

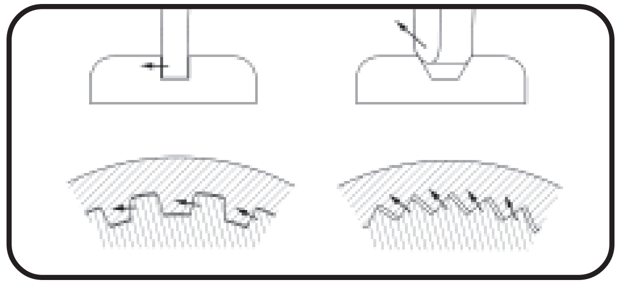

Fig. 56

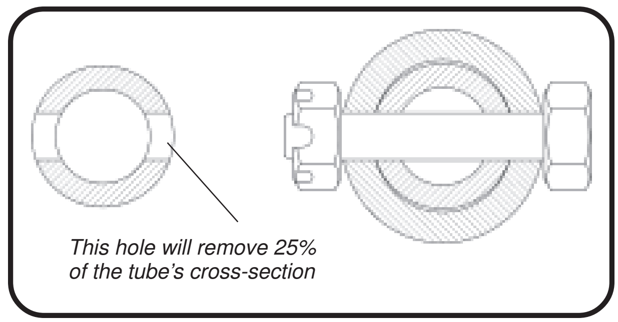

Fig. 57

2. Avoid through-bolts:

Whatever your connection method, **do not use pins or through-bolts.** The effect of a hole through the shaft or tube is the functional equivalent, strengthwise, of sawing it partway through. Additionally, as shown in figure 57, tightening a transverse bolt may squeeze the joint closed in one direction but it will tend to squeeze it *open* in the other. Trying to counteract this effect by installing a second bolt at 90 degrees to the first bolt may create an outward, cosmetic appearance of great strength, but this is an utter illusion. It is the functional equivalent of sawing the shaft the *rest* of the way through.

3. Making your own splined shafts:

Welding splined stubs into the steering tube is no more work than welding u-joints directly to it. However, by confining the welding to the tube, potential heat damage to the u-joint bearings is eliminated. The ST201A weld-in splined stub is intended for 3/4 OD x .120 wall steel tubing. Tubing of this size has the minimum torsional stiffness needed for the steering shaft on full-size race cars; using either a thinner wall or a smaller diameter on a late model stock car can allow enough torsional flex over the length of the shaft to cause the steering to lag.

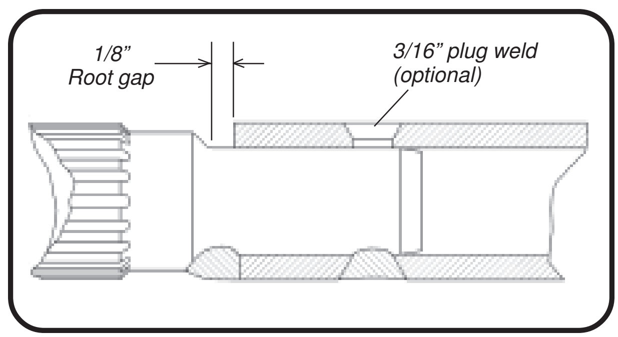

Fig. 58

A full-penetration circumferential weld of the stub to the tube as in figure 58 will transmit steering torque as effectively as the tube itself, and is not difficult. Plug or rosette welds can be added if desired. If so, use two; these should be as directly opposite each other as possible to equalize the inevitable distortion. The pilot of the splined stub is made a few thousandths oversize to ensure a tight fit in the expected ID of a .120 wall tube. File the pilot if necessary until it fits the tube snugly. A heavy driven fit is unnecessary and will restrain the weld joint. **Leave a 1/8" gap at the root of the weld** to ensure penetration. For the circumferential weld, a couple of hot MIG passes (use a rolling fixture if you can) will get the job done before any significant distortion can set in. Although we are obviously not talking about a high-speed rotating assembly here, straightness is still a practical goal. If you prefer TIG welding, excellent results will be obtained using 309 stainless steel filler rod. However, keep in mind that TIG is relatively slow; the slower the welding process, the more your finished job is likely to deviate from straight. Postheat to a faint red and let cool in air (Note: *don't* postheat a u-joint).

4. Phasing/clocking:

Phasing or "clocking" of the universal joints for smooth operation is discussed at some length in *Rack and Pinion Tech* and is especially important when welding u-joints directly to the shaft, since it will be impossible to reposition them once you've done it. Any back-to-back pair should be aligned like the ends of a driveshaft, as in figure 59 at right. Please study it closely; the difference is not obvious unless you are looking for it. The more acute the operating angle, the more critical the phasing. For reference, most stock car steering layouts will tolerate joints 20 degrees out of phase, but 45 degrees out will be noticeable.

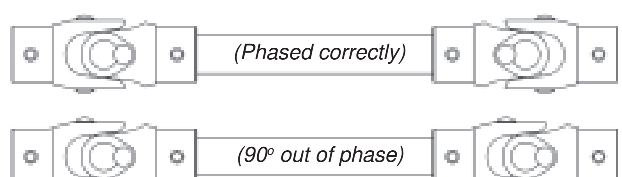

Fig. 59

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5. A word about aluminum shafts:

Aluminum alloys are available with tensile strength ratings equivalent to medium strength steel. The relevant factor in shafting, however, is not ultimate strength, but *stiffness,* which is a completely different property. The measure of stiffness of a material is its elastic modulus, which for steel is three times that for aluminum. *A given stress on an aluminum shaft will cause it to deflect three times as far as a steel shaft* of identical cross-section (put another way, compared to steel it will wind up like a rubber band). This effect can be seen in an aluminum C clamp, which in achieving a given clamping force will spring open three times as far as an equivalent iron or steel clamp. Steering shaft windup is very detrimental to handling, and cannot be avoided with aluminum parts unless they can be made *much larger* than normal (something rather hard to fit into the available space on a race car). It is worth noting that NASCAR does not allow the use of either aluminum shafts or aluminum steering universal joints.

Safety steering column installation

6a. Installing an SCA827B (in the driver's compartment):

Converting the plain shaft in an existing short track car is fairly simple. These cockpit-mounted columns require no actual welding or fabrication to install, other than the bracket or tab where a 3/4" rod end (SB12) normally goes. There are instances of this bracket not extending far enough from the dash bar to stabilize the steering shaft; twelve inches is about the maximum distance the steering wheel disconnect should be from the support bearing. Although its greater stiffness makes the SCA827B an immediate improvement over a 3/4" shaft, it doesn't hurt to evaluate your bracket and extend or brace it if necessary. Figure 60 shows an excellent installation. Note that a tab has been added to the car's existing mounting bracket so that the column can be supported closer to the wheel. The column is correctly installed in the fully extended position. There is enough stroke allowance for the wheel to be adjusted farther away from the driver by just loosening the clamp collars and and repositioning the torque tube.

The SCA827C uses dash bar clamp brackets but is otherwise identical.

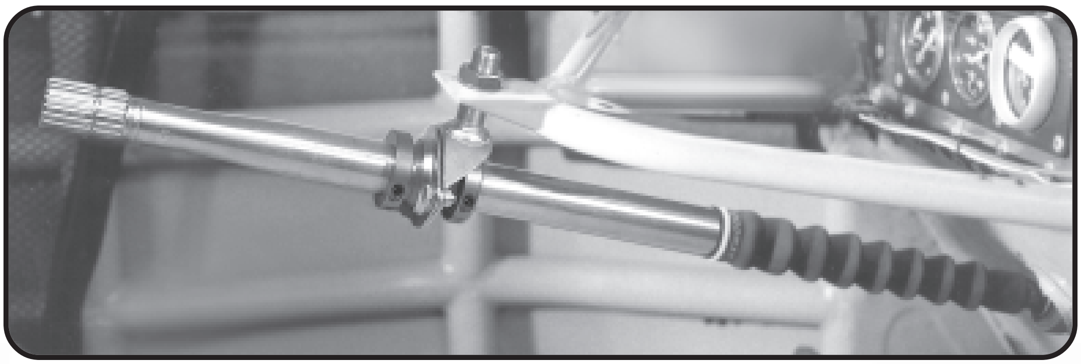

Fig. 60

6b. Bearing location:

In figure 61A a plain 3/4" upper shaft is rigidly supported in TWO BEARINGS, with the intermediate shaft (which connects to the rack or servo) FULL FLOATING, like a driveshaft. At B the SCA827 safety column's self-aligning bearing assembly has directly replaced the rod end nearest the steering wheel, and the unit's extended spline shaft (p/n SL17 or SL20) fits through the other rod end (or firewall flange bearing, as the case may be). This is the preferred installation for a safety steering column.

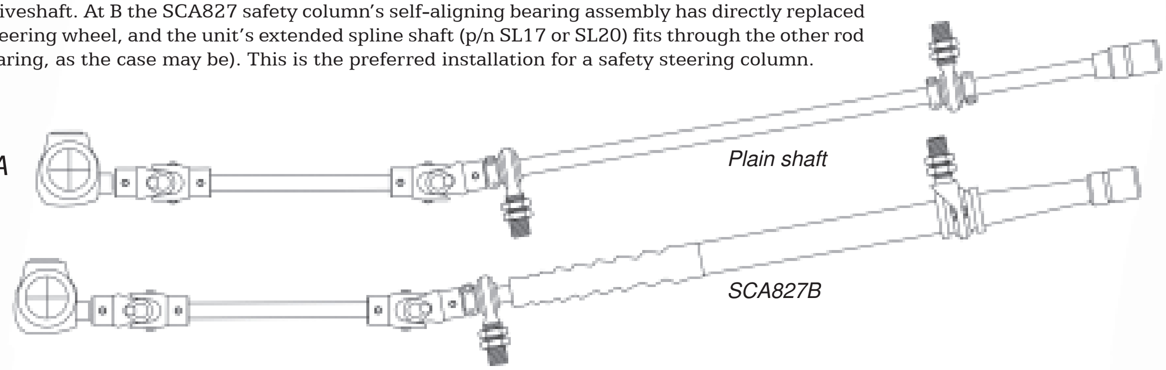

Fig. 61 (1st choice): **TWO bearings on the UPPER shaft**

While the use of the SCA827 provides an obvious improvement in driver safety over the plain shaft, there are some other considerations.This next setup (fig. 62) looks very similar except that each of the two shaft sections run in ONE BEARING. As in figure 61, the self-aligning bearing assembly of the SCA827B replaces the rod end nearest the steering wheel. However, there the similarity ends. This sequence of bearing points could allow a downward displacement of the rack crossmember, in a crash, to pry the steering wheel toward the driver's legs. To minimize this potential movement, all supporting rod ends arranged in this way should be *as close to the ends of their respective shafts as possible.* A full floating lower shaft as in figure 61 could not exert any prying effect.

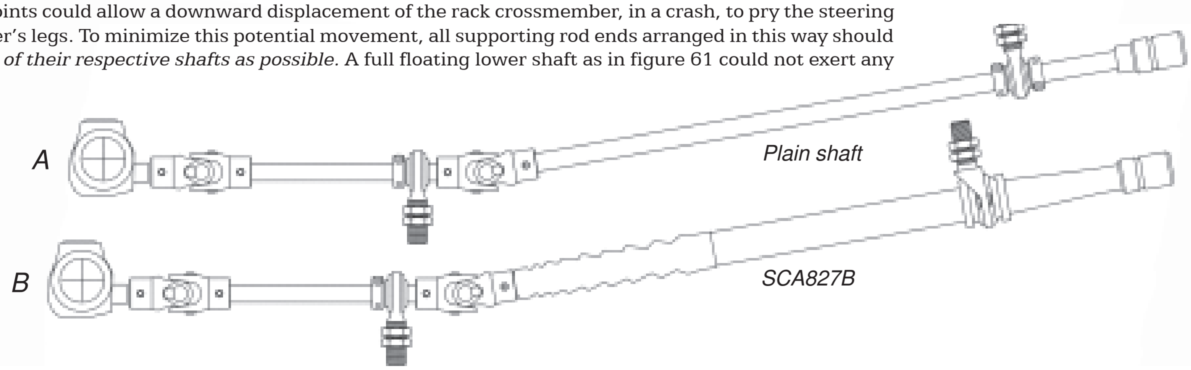

Fig. 62 (2nd choice): **ONE bearing on EACH shaft**

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7a. Installing an SCA500 (in the front or engine bay):

IMPORTANT: In contrast to the SCA827, this model is designed as an intermediate shaft section. It has a reduced diameter over most of its length for header clearance. This diameter is suitable for torsional loading, like a driveshaft. It is NOT intended to act as a bearing surface for the side loads from a steering wheel. We neither make nor approve any adapters to allow installation of a steering wheel on an SCA500, and we specifically recommend against this practice.

The SCA500 is supplied as a basic unit which the fabricator lengthens or shortens to fit the particular space available. With a collapsible section in the engine bay, it is essential that the steering wheel be positively located against movement in or out. With a plain upper shaft, install SCA175 clamp collars on both sides of one support bearing. If your upper shaft is an SCA827 safety steering column, it is already equipped with clamp collars.

The installation shown in figure 63 would allow this car's rack and crossmember to be shoved rearward in a collision for a distance of 9 inches before imparting any thrust to the upper steering shaft. Another benefit is the complete elimination of binding of the steering shaft due to chassis flex and misalignment. In Nextel Cup competition, the SCA500 is sometimes used in tandem with the SCA700/900 upper column, giving a total theoretical crush allowance of 18 inches along the axis of the shaft.

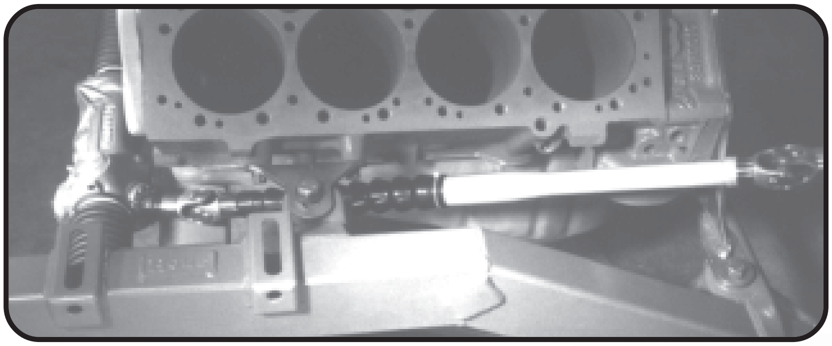


Fig. 63

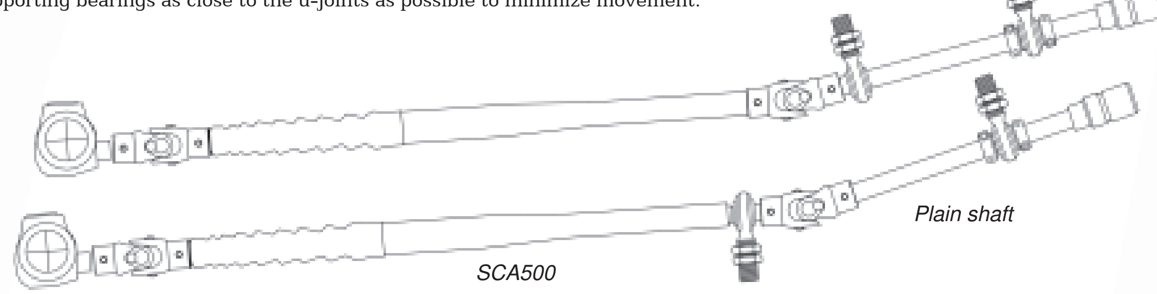
7b. Bearing location:

The setup shown in figure 64A is good for cars whose upper column support bearings are too close together for installation of an 827. The existing upper shaft section is rigidly supported in TWO BEARINGS and the SCA500 section leading to the rack or servo is FULL FLOATING, like a driveshaft. This is the preferred installation. The alternative shown at B, like its counterpart in figure 62, could be subject to some vertical displacement of the steering wheel if the crossmember and rack were to fold under the chassis. If you must use method B, locate the supporting bearings as close to the u-joints as possible to minimize movement.

Fig. 64

A (1st choice):
TWO bearings on the UPPER shaft

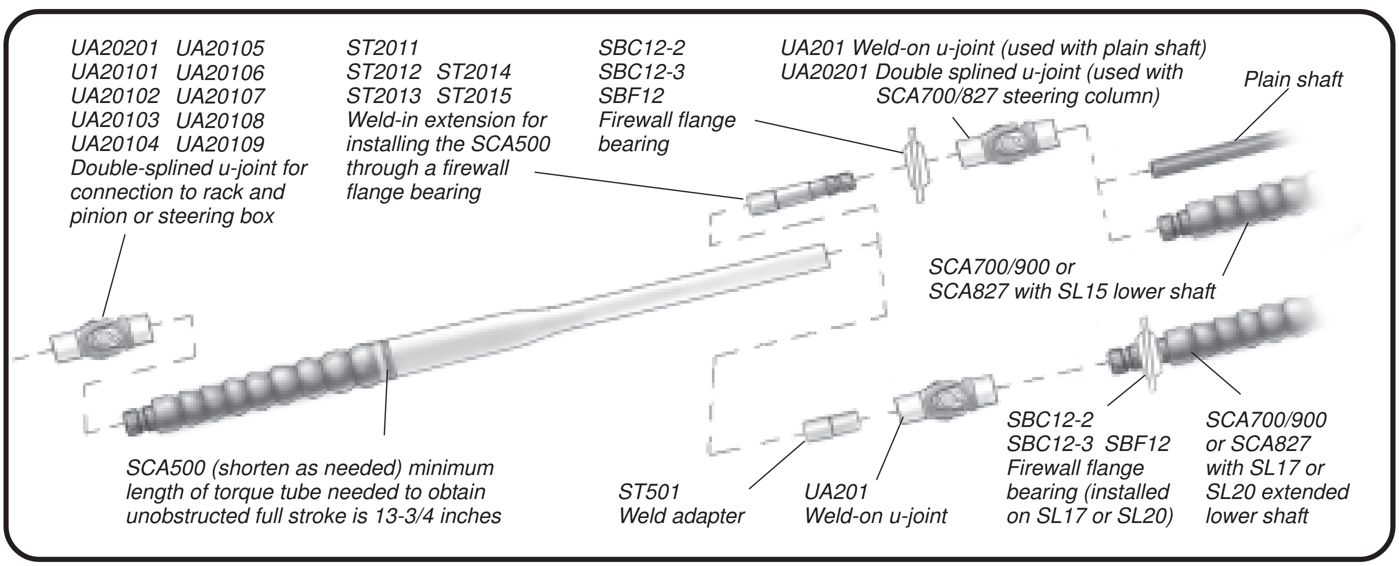
B (2nd choice):
ONE bearing on EACH shaft



8. Connections to the SCA500:

A variety of hardware is available to adapt both ends of the SCA500 as necessary. When sawing off the torque tube, stuff a rag in the end first to exclude chips from the slider, which is packed with grease. Also be careful of grit contamination from grinding operations in the shop.

Fig. 65



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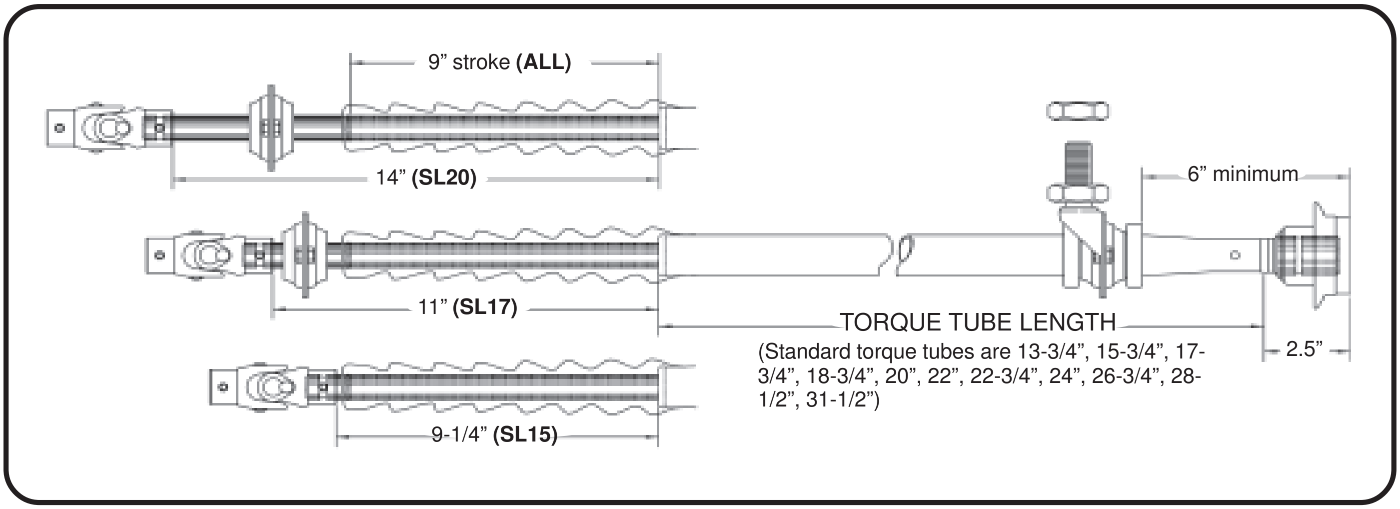
9. How to order a cockpit-mounted safety steering column:

There are two length-variable components whose dimensions you must determine. The *splined lower shaft* (p/n SL15, SL17, or SL20) is common to all models. The other part to be specified on the SCA827 series is the *torque tube*; on the SCA700/900 series, it is the *jacket.* These have no part number other than a length specification. The lengths of the splined shaft and torque tube or jacket are combined to make a unit suitable for the driver's seat position and arm extension, and to connect to a universal joint either inside or outside the cockpit. Note that certain dimensions remain constant regardless of the total built length of the unit, as shown in figs. 66 and 67 below:

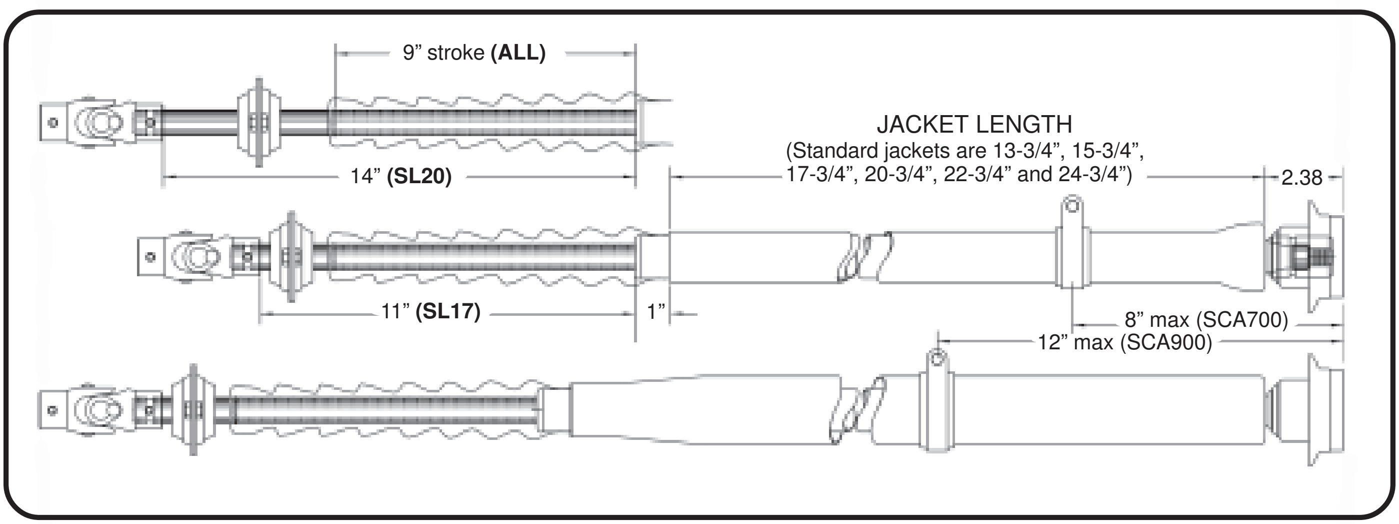
SCA827 Measurements

Fig. 66



SCA700/900 Measurements

Fig. 67



First, determine whether the column must extend through a flange bearing or rod end in the vicinity of the firewall. If so, pick an SL17 or SL20 spline shaft based on how much distance you wish to leave either side of the bearing or rod end. If it will not pass through a bearing and the u-joint is *inside* the firewall, pick the SL15. Note that since 2003 the upper divisions of NASCAR such as Nextel Cup are no longer permitted to locate the u-joint within the cockpit. Applications subject to this restriction are limited to either the SL17 or SL20 splined shaft, since there must be enough shaft (in addition to the 9-inch collapse stroke) to extend through the firewall bearing and connect to a u-joint outside the firewall.

Second, measure the distance from your universal joint to the mounting surface of your steering wheel. Subtract the extended length of your chosen spline shaft from this total (see figures 66 and 67 above). For an **SCA827** column, subtract the 2-1/2 inches occupied by the quick release. The remainder indicates the length specification for your **torque tube.** The part number will include the dimensions of both the torque tube and lower shaft; for example, SCA827B—26-3/4—SL20. For an **SCA700 or 900** column, subtract 2-3/8 inches for the quick release and one inch for the torque tube protrusion. The remainder indicates the length specification for your **jacket.** The part number will include the dimensions of both the jacket and lower shaft; for example, SCA700—24-3/4—SL20.

If you can't obtain your desired overall length closely enough with one of the standard torque tubes, refigure it using a different spline shaft (for example, try an SL20 instead of an SL17). Any of the standard combinations can be built directly from stock.

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Like the splined lower shafts, **torque tubes** and **jackets** are made in a range of nominal lengths. If the car will see an unknown roster of drivers, we suggest that you make the unit slightly longer than your measurement would indicate. While theoretically a steering column is installed fully extended to obtain the maximum possible collapsibility, in actual practice up to two inches is utilized as a ready adjustment for driver comfort. If you install the unit slightly compressed, it can always be pulled toward the driver later, whereas if you install the unit fully extended there will be no adjustment available other than *away* from the driver.

In figure 66, note the six-inch minimum distance from the steering wheel mounting surface to the thrust collar. Be sure this will be obtainable, as the thrust collars can only grip the straight diameter of the tube. They will not hold on the tapered portion. The SDK20 hanger bearing shown in fig. 64 has an offset stud and can be reversed. This will relocate the bearing and thrust collars by about 1-1/4". MB168 adjustable brackets can be used in lieu of the stud-type hanger bearing. **Whenever you reposition an SCA827 column, take care to loosen the flange bolts on the self-aligning ball so that it can freely conform to the new position.** Otherwise you will have a difficult-to-trace bind in the steering.

In figure 67, note the recommended maximum distance from steering wheel to mounting clamp of 8 inches. The SCA700 column exhibits excellent rigidity when supported within this limit. The SCA900 is recommended for installations requiring greater extension from the mount or a particularly long overall length. Except for its larger diameter jacket tube, it is completely identical to the SCA700. Mounting is by pinch clamp around the jacket. Clamps are available in both single-hole and 3-hole versions for the 1-1/2" diameter SCA700 jacket, and a single-hole version for the 2" diameter SCA900. The clamp is sandwiched (with or without spacers for sideways adjustment) between a pair of MB177, MB178, or MB179 clamp brackets extending from the dash bar.

Standard lengths for the popular makes of chassis have been established by the chassis builders, and result from their respective average experience in fitting drivers to their cars. Depending on your seating position you may require something other than the standard column. A custom torque tube costs nothing extra, but can take two weeks to build. Often the original column can be modified sufficiently by changing out the spline shaft. The shaft is retained by a compressible ring. A sharp pull will compress the ring and the spline shaft will snap out like the half-shaft of a front-drive car. It engages two internal spline sections five inches apart, so two sharp pulls are needed to remove it. Reinstall by pushing firmly until the ring compresses and snaps through the first spline. Make absolutely sure to snap it through *both* spline sections.

10a. The steering wheel quick release:

The SCA827 column has an integral disconnect spline and is supplied with either the QRA or QRS quick release per the customer's choice. The QRA model has an aluminum pull ring and, being the lightest, is the most popular. The QRS has a steel pull ring and we recommend it for cars competing under NASCAR sanction. Whether steel or aluminum, all Woodward quick releases meet the SFI 42.1 specification adopted by NASCAR; however, a steel pull ring is required for Nextel Cup competition. Since the possiblity exists that this rule could be extended to other NASCAR-sanctioned events at the discretion of the inspectors, we recommend the QRS for pavement cars in general. The SCA700/900 column uses the model QRSN quick release (a QRS with a special spline adapter with a recessed lock nut) which, per Nextel Cup rules, bolts onto the splined/tapered steering post.

When bolting a steering wheel to the hub, use the appropriate number of washers to obtain correct engagement of the cap screws. The depth of the tapped holes in the hub is 7/16 inch. The button head Torx cap screws are supplied with flat and lock washers which can be used in whatever combination necessary to obtain a minimum of 3/8 thread engagement with a given thickness of steering wheel. As shown in figure 68 at right, *failure to use the correct washer stack, especially on a thin steering wheel, may allow the screws to protrude far enough through the hub to block the release movement.*

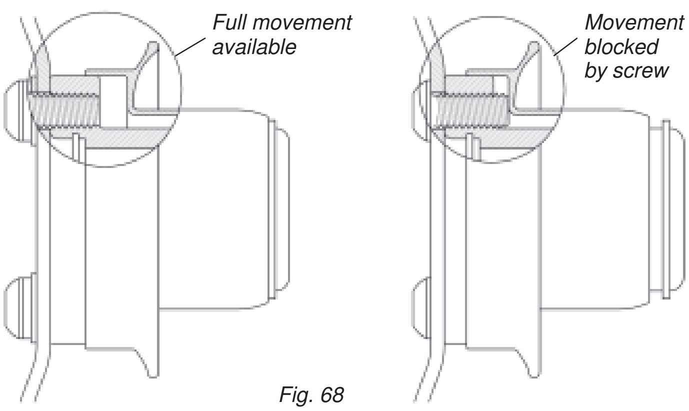

Fig. 68

The hub is provided with three copies of the standard US bolt pattern to allow, where necessary, realignment of the steering wheel with respect to the 20 splines on the adapter. The extra bolt holes also enable reuse of the hub in case of stripped or worn holes. The splined hub is anodized for wear resistance, but is nevertheless aluminum and can be burred or otherwise damaged if not treated with reasonable care. Wipe off any obvious dirt from the shaft spline before you put the wheel on, and let the teeth get aligned and started with as little pressure as possible. The hub will slide onto the spline for a full half inch before you need to actuate the pull ring; it doesn't need to be forced on.

Should you disassemble the unit for cleaning, repack it with a very light grease with minimum solid content such as Aeroshell 14. The spline contact surfaces themselves are normally left dry so as not to attract dirt.

10b. Steering wheel positioning:

Always bolt the steering wheel directly to the quick release hub. If you have to bring the wheel closer to the driver, the best way is to adjust the column outward (provided you allowed an extra inch or two when ordering the column, as described in section 9 above). **Be careful never to pull the lower shaft out of its full engagement with both internal spline bushings.** If it is at the limit, substitute a longer lower shaft (e.g. change out an SL15 for an SL17). **Shim or extend the steering wheel from the hub only as a last resort.** Excessive leverage acting on the quick release unit will bell-mouth the splined bore and ruin the fit in short order. If you have no choice but to extend the wheel, try using a more deeply dished wheel rather than a shim, as there will be less static weight acting to wear out the splines.

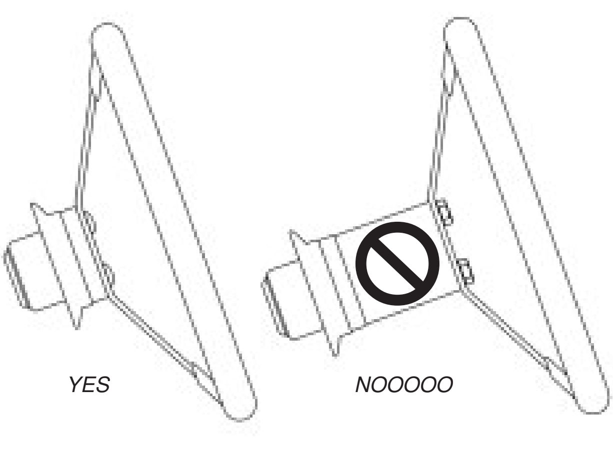

Fig. 69

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11a. Operating principle of the telescoping safety steering column:

There have existed for some time some fairly serious misconceptions regarding the application of collapsible columns in race cars. A major one is the idea that, in a crash, the steering column is intended to telescope upon being struck by the driver. This is by no means the case. To begin with, an essential requirement of mounting any steering wheel is that it specifically *not* be movable in or out through any effort applied by the driver while engaged in steering the car. "Shear pins" which would theoretically hold up under the loads of driving and yet yield under any reasonable impact applied by the driver's chest are a myth. They do not and cannot exist. The assumption that the driver could somehow benefit from striking the steering wheel a heavier blow with his rib cage (or his face!) than he could otherwise apply with his hands, is in any case absurd. The whole point of the elaborate driver restraint systems in use today (multi-point harnesses, HANS and Hutchens devices, helmet tethers, safety seats, full-face helmets, etc.) is to *prevent* driver impact with interior objects, *especially the steering wheel.*

The real function of a telescoping steering column is to accommodate a rearward thrust of the steering shaft resulting from compression of the front end of the chassis. In order for this accommodation to happen effectively, there must be no resistance to the collapsing action within the column—that is, no shear pins, tension clips, shim stock, set screws, dirt, or anything else that would inhibit movement of the telescoping parts. On the other hand, there should be maximum external resistance to movement of the end that the driver holds, usually in the form of clamp collars installed against shaft support bearings. There is no limit to the number of places the shaft can be stopped or made to resist thrust (the more the better, actually) *provided there are no thrust-resisting elements within the telescoping section itself.*

Relying on the operating angle of a universal joint to force a plain shaft to buckle away from the driver is not an acceptable substitute for an adequate telescoping section. Depending on the location of the support bearings, such an arrangement may cause the shaft to simply jacknife and pry the steering wheel into the driver's lap, pinning him into the seat. If the angle is sufficient to pry one of the u-joints apart, you will have a loose shaft waving around. If the u-joint doesn't break apart, it might break off a supporting Heim joint and allow the shaft to move in unpredictable ways. If neither breaks, the steering shaft tubing, which in longer lengths can be fairly flexible in bending, may be forced right up through its support bearings and even around a bend. Debating which of the above conditions is the least dangerous is rather pointless, especially since either an SCA827 or 700/900 column or a telescoping section such as an SCA500 would absorb up to nine inches of the linear component of the wreck in the first place.

The safest possible steering shaft for very high speeds, of course, is one where both upper and lower segments can telescope. Setups like this (an SCA500 in the front bay connected to an SCA700 in the cockpit) have been in use by a few Cup teams since 1997. The drawbacks for short track use of a dual installation are the obvious ones of expense and fabricating time, plus the fact that speeds on a typical half mile are not normally high enough to shorten the front frame of a stock car by eighteen inches. On the other hand, one of the safety advantages of an extremely *light* car is the absorption of collision energy into a "crush zone." A crush zone reduces the likelihood of inertial injuries, such as concussion, *precisely by allowing the car to shorten itself.* At extremes of light weight, therefore, a tandem system may be well worth the extra work.

11b. Sanctioning body regulations regarding safety steering columns:

Sanctioning organizations other than NASCAR have not yet acknowledged the degree to which the safety steering column has been refined specifically for race car applications, especially those incorporating crush zones.

FIA, for example, still has a requirement that a "safety" column be tested by striking it with a bowling-ball-sized pendulum weight obviously intended to simulate a driver's head. Such a test derives from traditional road-vehicle design practice wherein the restraint system for so many years consisted solely of a lap belt and the chassis had no crush zone to attenuate a collision impact. Such an approach assumes that the driver will be flung forward into the steering wheel, which, given current driver-restraint technology, is no longer likely. With current sedan construction, there exists an arguably greater danger that the driver will be struck or pinned in the seat by the wheel. At present, no consideration whatever is given in FIA rules to the principle of telescoping the column from the front to prevent the displacement of the steering shaft toward the driver. If you compete in certain circuits in Europe, therefore, it is possible these rules may actually prevent you from employing a Woodward column, in which case you have our sympathy. However, we are not going to reject common sense and build anything less than what is described in this catalog, for the reasons stated in 11a above.

SCCA "club" rules neither require nor even mention safety steering columns. SCCA "pro" rules merely reference the installation or possible modification of OEM columns (such as removing the parking lock) and describe the common practice of using u-joints with an angled intermediate shaft to induce a Z-shaped deflection. Of course, the detrimental effect on the steering of severely angled joints is an issue in itself, and is discussed elsewhere in the tech section. Although the racing-type safety column is not mentioned, it is certainly not prohibited, nor has any SCCA official ever, to our knowledge, objected to the installation of a Woodward unit.

We must point out that, although the dimensions given in figures 66 and 67 are the *de facto* standard in NASCAR, no other association has yet defined the extent to which a column must collapse in order to qualify as an effective safety device for a race car. We consider the four inches theoretical collapsibility of OEM or aftermarket street rod columns to be inadequate for racing installations. Sometimes for reasons of packaging convenience, especially in sports cars, we are asked to build a column which in our opinion would be too short to telescope far enough to provide any meaningful protection, or would lack mechanical stability. While such compromises may be theoretically permissible by virtue of not being mentioned in any rules, our policy has always been not to manufacture anything not meeting our established minimum dimensions.

Since these components were originally designed for full-size stock cars, it is entirely possible that for some applications these standards may prove unnecessarily stringent. Should a sanctioning body make the engineering decision to adopt *and publish* guidelines specifying a shorter minimum collapsibility, we will offer shorter columns. Pending such an event, our minimum dimensions will remain those published in this catalog. Technical and safety personnel from organizations wishing to develop specifications for this category of equipment are most cordially urged to contact our engineering department.