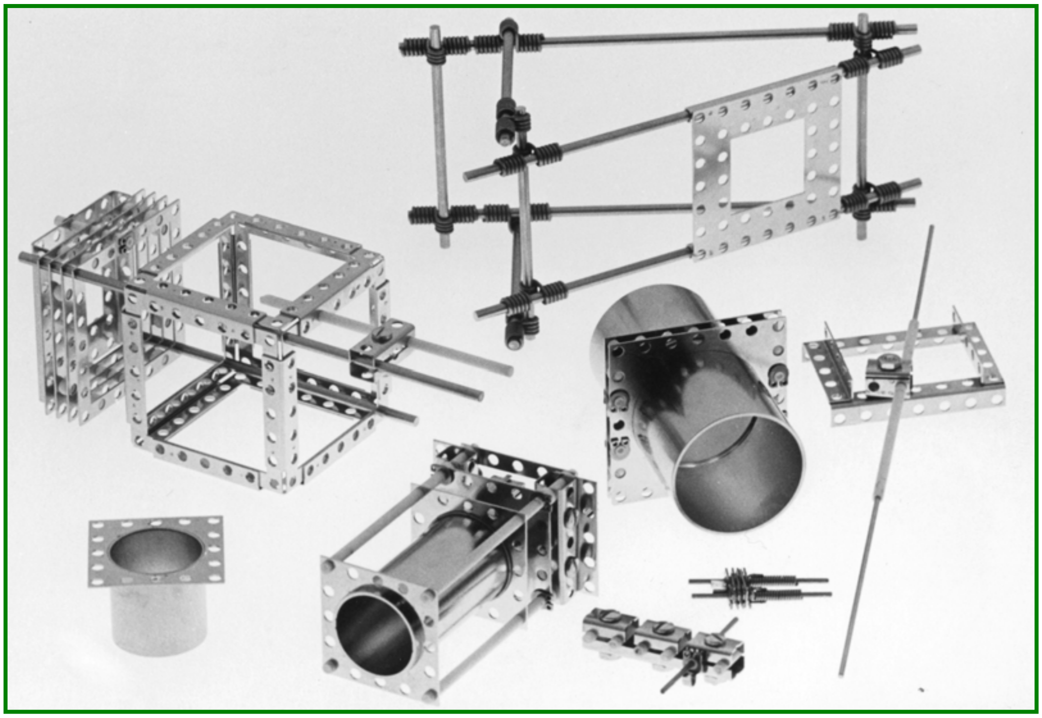
eV Parts®

GENERAL INFORMATION
and
CONSTRUCTION TECHNIQUES



Excellence in Electron and Ion Optics

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WARRANTY

eV Parts® are manufactured from the finest quality materials using the highest standards of workmanship. Any part found defective will be replaced free of charge at the customer's plant (or the purchase price refunded at the discretion of the manufacturer) for a period of one year from the date of purchase. Since Kimball Physics, Inc. cannot control the manner in which parts are used, no other warranty is expressed or implied. In no case shall KPI be liable for consequential or special damages.

NOTE:
All prices, quantities, design specifications dimensions, and materials are subject to change without notice.

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eV Parts®

1 eV Parts® NUMBERING SYSTEM AND ABBREVIATIONS

Parts are numbered according to the system shown in the table below. The first group of letters represents the material used to make the part (normally only one material is used). When the material is a pure element or simple compound, its chemical symbol is given; otherwise a simple abbreviation of its common name is used. The second set of letters indicates the general type/class of part. The next letter designates the Series (usually B or C). The last group varies according to part type, providing more specific information.

Each Series of parts are manufactured according to standard dimensions in terms of a scaling factor “a”. The use of the scaling factor permits most parts to be grouped into one of four different series, A, B, C, or D, according to the size of "a".

These sizes are:

Series	A: a =	0.025 inch (0.63 mm)
	B: a =	0.050 inch (1.27 mm)
	C: a =	0.100 inch (2.54 mm)
	D: a =	0.200 inch (5.08 mm)

Note: At present only part series B and C are being manufactured in commercial quantities.

XX-YY-WZZZ/ZZZ

XX = MATERIAL

Al2O3	Alumina (99% Purity, Vitreous)
Cu	Copper (OFHC)
Mo	Molybdenum
SS	Stainless Steel (304 or 316)
Ta	Tantalum (High Purity)
W	Tungsten (High Purity)

YY = CLASS

BA	Ball
BR	Bracket
CS	Compression Spring
CPA	Clamp Plate Assembly
CY	Cylinder
EC	Element Clamp
ECA	Element Clamp Assembly
IP	Insulator Protector
KG	Knitted Grid
LC	Lock Clamp
LR	Lock Ring
MN	Machine Nut
MS	Machine Screw
PL	Plate
RO	Rod
RP	Round Plate
SC	Screw Clamp
SCA	Screw Clamp Assembly
SH	Sheet
SP	Spacer
TN	Triple Nut
TR	Threaded Rod
TU	Tubing
WI	Wire
WN	Wirenut
WR	Wire Ring
WW	Wound Wire
XT	Split Tubing

W = SIZE, SERIES B or SERIES C

SERIES B – 1/16” series
SERIES C – 1/8” series

	B	C	B	C
DIMENSION:	In millimeters		In inches	
Material Thickness	0.305	0.635	0.012	0.025
Mounting Hole Spacing	3.810	7.620	0.150	0.300
Mounting Hole Diameter	1.5875	3.175	0.0625	0.125
Hole Center to Edge	1.270	2.540	0.050	0.100
Alumina Tubing Diameter	1.575	3.150	0.062	0.124

ALUMINA TUBING AVAILABLE IN D SERIES: 0.25” OD., solid rod, single bore- 0.128” ID (fits C size inside), double, or four bore

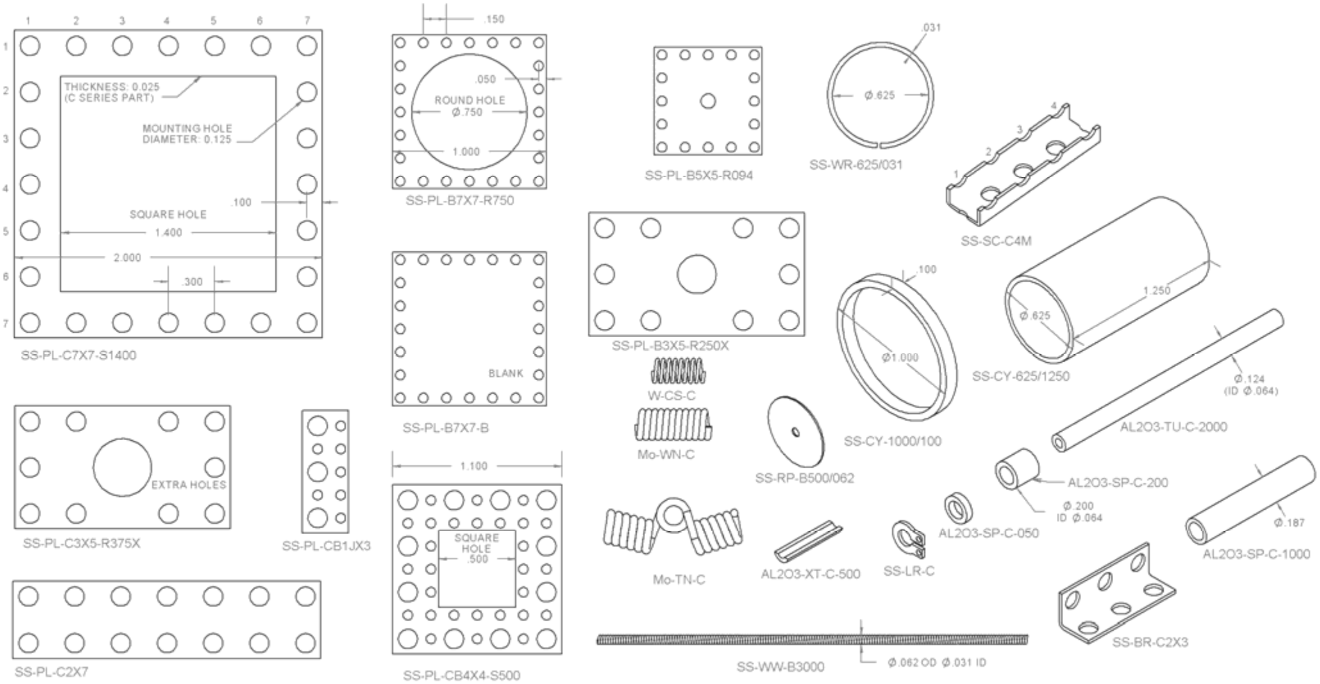
ZZZ = SPECIAL DIMENSIONS

Conventions Vary With Part Class. See drawings.

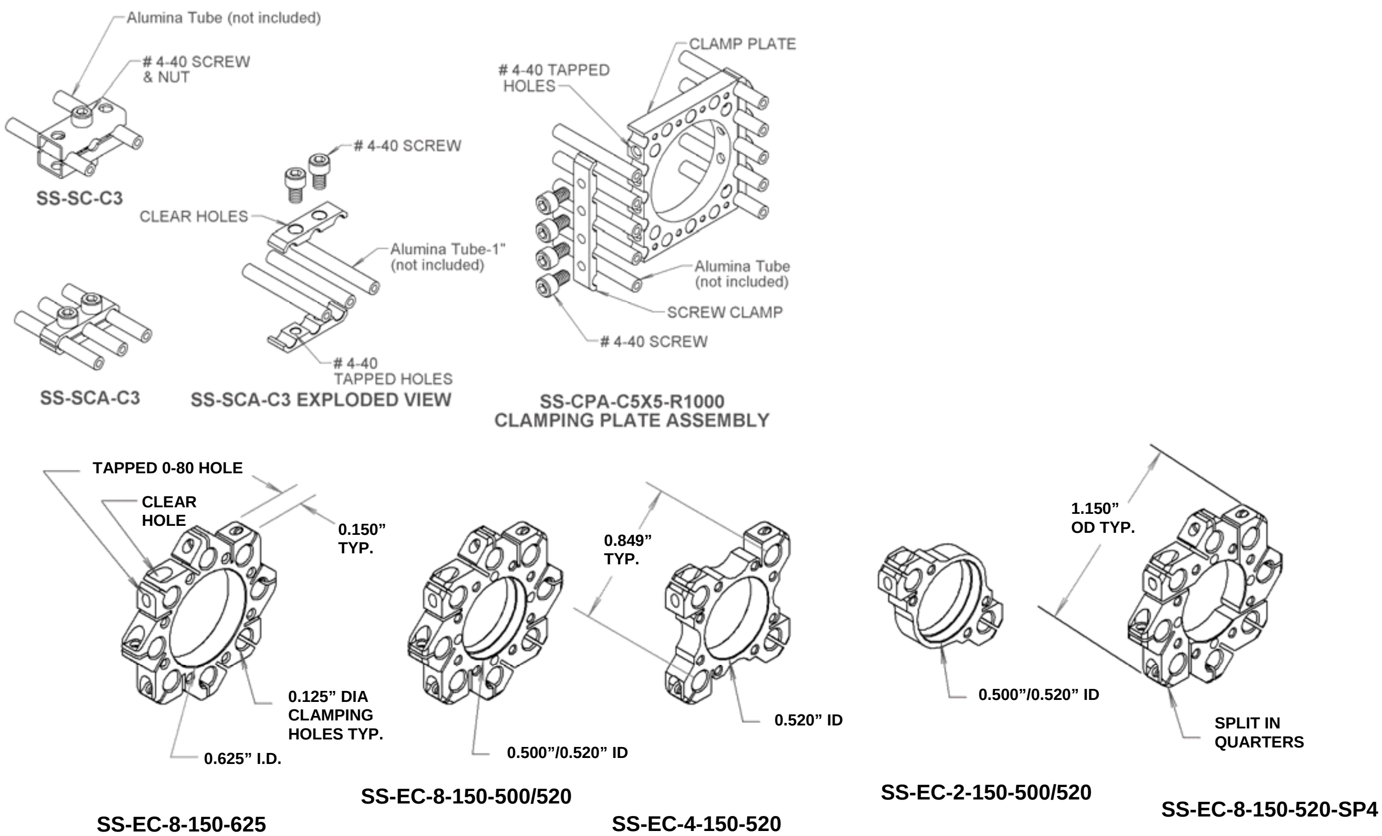
Ex. SS-PL-C7X7-S1400 is a Stainless Steel Plate of the C series with 7 holes by 7 holes and a 1.400 inch square center hole.

Visit www.kimballphysics.com for individual parts details.

Typical Standard Part Types, showing part numbering and dimensions in inches



New parts: Screw clamps, Clamping plates, and Element clamps



2 GENERAL INFORMATION ON eV Parts®

2.1 INTRODUCTION

eV Parts are a group of several hundred standard parts made from high temperature metals and high purity insulators. Intended for use in all phases of high vacuum technology, these modular, easy to assemble parts are particularly useful in ultra-high vacuum environments, and in experiments involving beams (or fluxes) of charged or neutral particles. The parts provide significant benefit in the areas of teaching, research, and manufacturing.

eV Parts have been in use for several decades, and have considerably shortened construction times and lowered costs wherever applied, including many laboratories. The designs have been extensively tested prior to being brought onto the commercial market by Kimball Physics, Inc.

eV Parts have been used to construct many different types of apparatus which include the following: electron guns, ion sources, ionization chambers, Knudsen cells, evaporators, thin film and sputtering apparatus, electron monochrometers, Auger spectrometers, LEED equipment, electron multipliers, collision chambers, flash desorption apparatus, vacuum gauges, and manipulators. The parts have assisted in building mass spectrometers of several types including quadrupole, rf and magnetic sector. In teaching laboratories, the parts have been used to set up experiments relating to basic electron physics and to construct simple scanning electron microscopes.

The parts are well suited to all low-energy electrostatic electron and ion optical problems. In addition, they are well adapted to experiments involving large diameter beam intersections, scattering and cross section measurements.

2.2 eV Parts DESIGN

The design is based on the idea that most high vacuum apparatus can be constructed out of standardized parts, in a manner similar to that used in the construction of electronic apparatus (using standard resistors, capacitors, switches, etc.). Because standardization greatly reduces the drafting, machine shop, and technician time required to set up an experiment, costs can be greatly reduced.

The design philosophy is to construct all complicated shapes with metal and to use simple insulator parts. This philosophy has been followed for three reasons: 1) The high availability of metal working tools and raw metal stocks facilitates making special shapes or reworking existing shapes in metal. 2) It generally costs more to make high quality insulator parts than to make similar shapes out of metal. 3) Keeping ceramic parts simple and small makes it easier to protect them from the contamination and charge-up effects which often result from particle bombardment. Holding down the amount of exposed insulator surface reduces the stray fields generated when such charge-up occurs.

Each part has been designed with the highest possible symmetry consistent with its basic function. This was done to permit fitting parts together in the maximum number of ways. For the same reason, the parts were designed with simple shapes. It is usually easier to build a complex structure from many simple parts (of only a few part types), than to build that same structure from more sophisticated shapes (which would have to be stocked in many more types).

Parts are numbered according to the system explained in Section1. The first symbol, a group of letters, represents the material used to make the part (normally only one material is used). When the material is a pure element or simple compound, its chemical symbol is given; otherwise a simple abbreviation of its common name is used. The second symbol, a pair of letters, indicates the general type of part. The next letter designates the Series (usually B or C). The Series sizing is based on a scaling factor “a”.

2.3 GENERAL PART TYPES

The basic parts in the eV system are flat plate parts (PL parts); several examples of which are shown in Figure 2-1. Some simple assemblies are shown in Figures 2-2 through 2-8.

Around the edge of nearly every plate part is punched a group of small holes 1.25a in diameter, where “a” is the Series scaling factor. These holes are intended for mounting; center to center spacing is 3a. Outside borders of the plate parts (along with most other straight edges) are designed to be either “a” or “2a” away from the nearest mounting hole centers. When plates are bent to a right angle they are bent exactly between two rows of mounting holes (1.5a from the nearest hole centers). The 3a spacing was chosen to allow plates to be mounted side by side in the same plane and still maintain a gap (“a” wide) between them for electrical isolation. This spacing also allows plates to be mounted at right angles without jamming at the corner.

Plate parts are manufactured by a combination of punching, machine work, and chemical milling techniques. Dimensions are closely held to a ±0.001 inch tolerance where possible.

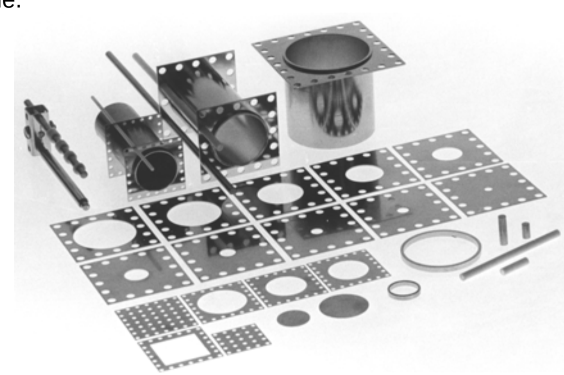


Figure 2-1 Representative sampling of plate, cylinder, and rod parts. Plate parts are made using special high tolerance jig-bored tooling. Several hundred types are available.

Most of the plate parts have a square or round hole in the center. The hole is intended either for use directly as an aperture or for mounting cylinder parts.

Cylinder parts (CY parts) are precision cut lengths of seamless metal tubing. They are most useful in making electrostatic lenses (according to the designs found in many electron optics texts); but they may also be used in constructing housings shields, and the like. Approximately two dozen types are available.

Round plate parts (RP parts) are provided in a variety of sizes for closing the ends of the cylinder parts. Some sizes are provided with a 1.25a diameter hole in the center.

Plates which have been bent in the standard manner are called bracket parts (BR parts) and are made in a variety of configurations. Bracket parts are useful in joining plates at right angles, in reinforcing plates to make stronger structures, and in mounting experiments. They are also the basis for several types of clamps.

Screw clamp parts (SC parts) are clamps made out of plate material. Used for attaching and holding rods, split tubes, tubes and plates together, these clamps operate by pinching one or more rods between a pair of clamps. Each clamp consists of a double bracket cut through its mounting holes. Pressure is provided by a simple nut and screw.

Screw clamp assemblies (SCA) and clamping plate assemblies (CPA) are used for heavier loads. These consist of machined, tapped/clear hole clamping bar pairs, or bars and plates held together by screws.

Metal strips with holes punched in the standard pattern are available for making up plates, brackets, and clamps.

The standard thickness of all plate, bracket, and clamp parts is 0.25a. This is thick enough to make the parts quite rigid, but thin enough to permit the user to cut, punch and bend the parts with readily available tools. The plates are also thick enough to prevent warping at high temperatures but thin enough to have a low thermal mass. If structures are properly designed, the parts are rugged enough for use in space applications.

Material for all plate, bracket, and cylinder parts is stainless steel type 304 or 316. In addition to being non-magnetic and a good vacuum material, these types of stainless steel spotweld easily and are already present in nearly all UHV systems. Parts made from other materials such as tantalum, copper, or gold-plated stainless are available, but normally must be made up on special order.

All stainless steel plates and bracket parts are annealed to a half-hard condition. Half-hard results in adequate strength and good machinability while still permitting plates to be bent without fracture.

Several techniques are available for attaching plates together and for insulating them from one another. The two most useful techniques are: 1) to thread the plates together by passing precision-ground high purity alumina rods through the mounting holes, using alumina spacers to hold the plates apart, and 2) to set precision alumina balls (spherical diameter 1.875a) into the holes and to load the resulting assembly in compression.

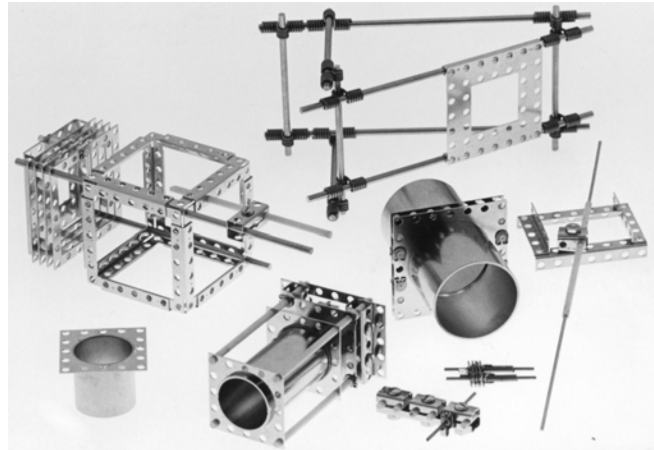


Figure 2-2 Simple assemblies built using only eV Parts. The number of possible assemblies is unlimited.

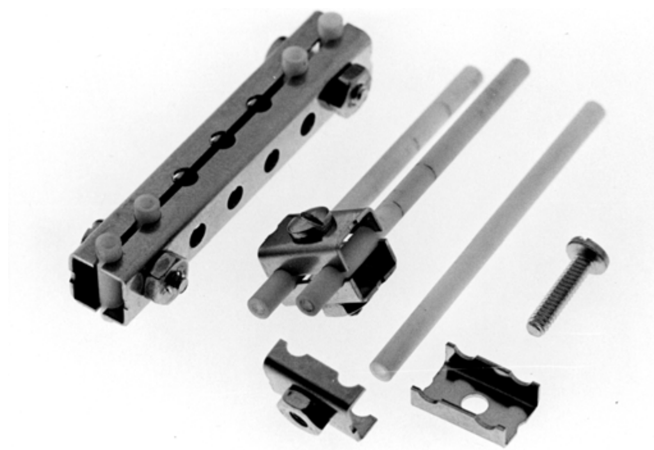


Figure 2-3 Use of screw clamp parts to hold Al_2O_3 tubes. If the screw threads are machined off just down behind the screw head, and an Al_2O_3 spacer inserted, the two clamp halves may be insulated from each other.

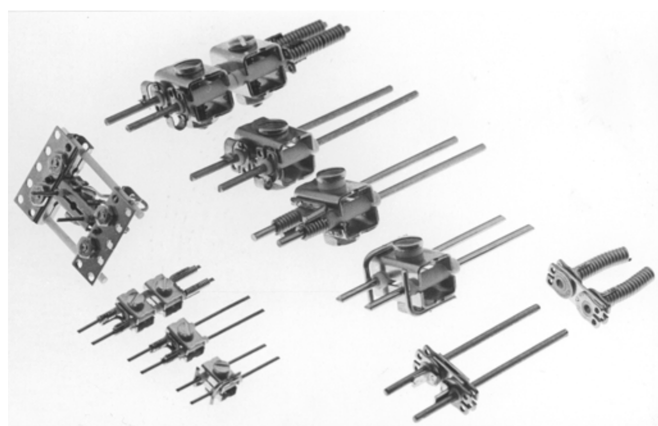


Figure 2-4 Methods of making filament mounts and plug-in assemblies based on screw clamps; both Series B and C are shown.

For threading parts a variety of lengths and sizes of ceramic rod (RO parts), along with alumina spacers (SP parts) of standard lengths of 0.5a, a, 1.5a, and 2a are available.

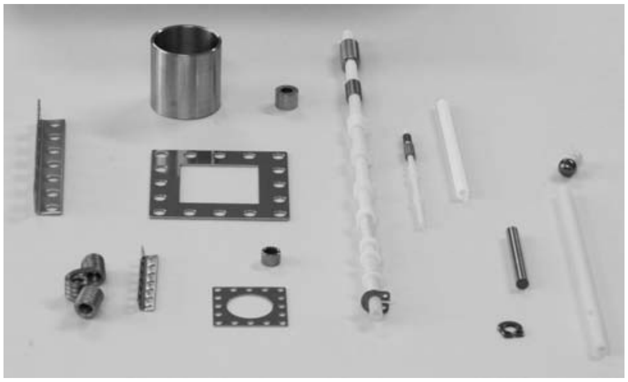


Figure 2-5 Brackets, cylinders, plates, triplenuts, rods, spacers, compression springs, wire nuts, balls, and lock rings.

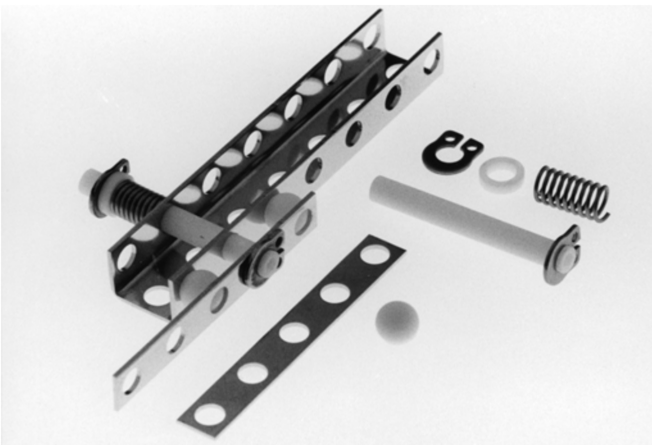


Figure 2-6 Simple structure using lock rings, balls, and a compression spring to mount a plate.

Several different methods may be used to secure the rod ends. Horseshoe shaped stainless steel lock rings (LR parts) clamp onto any rod at any position desired without need of a groove. The lock rings have the advantages of being easy to apply with a lock ring tool, of providing a very strong clamping action, and of requiring a minimal amount of axial space along the rod. Also, the lock rings may be spotwelded directly. However they have two disadvantages. Firstly, they lose their strength gradually at high temperatures with a serious loss of strength at temperatures of 500^o to 600^{o}C (this is the lowest temperature limit of any of the eV Parts). Secondly, because a special high-temperature, spring-grade stainless steel is used to make the lock rings (not stainless steel type 304), the rings are mildly magnetic. This residual magnetism is normally too low to cause any difficulties except when working with electrons at very low energies.

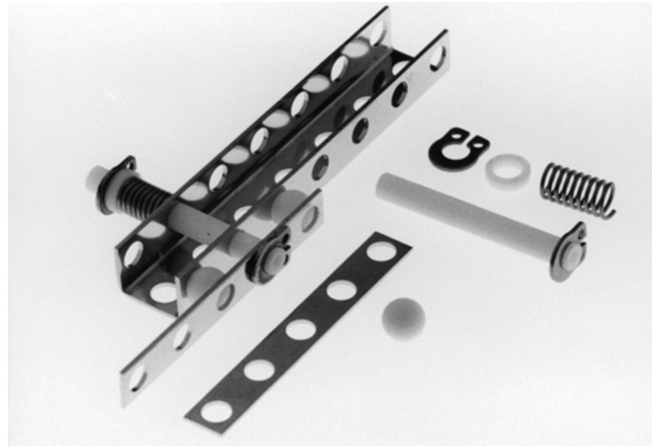


Figure 2-7 Use of lock rings and wound wire stock to make ultra-high vacuum plug-in connectors. Friction is controlled by the amount of kink given to the wound wire.

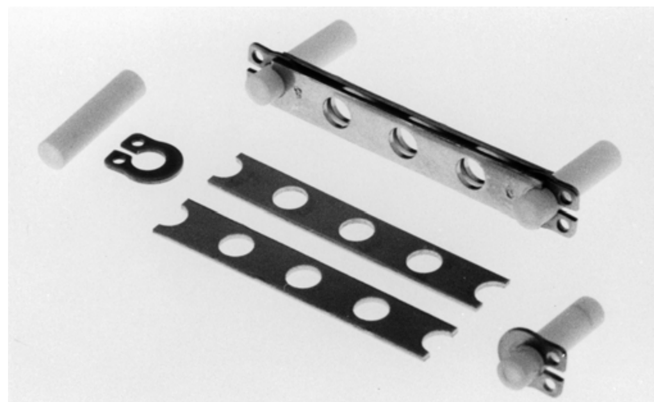


Figure 2-8 Exploded view of one of many techniques for spotwelding lock rings to plates.

An alternative method to secure the rod ends is to use the screw clamps (SC parts) previously mentioned. Some types can hold several rods at once. Screw clamps are non-magnetic and hold firmly even at temperatures up to 1000ºC; however, they are more bulky than the lock rings and the screws may freeze to the nuts after high temperature operation in UHV. Screw clamps may be used to fabricate very rugged filament mounts as shown in Figures 2-9 and 10. They may be spotwelded to either plates or brackets. By use of an alumina spacer and a special screw, the two halves of the clamp may be insulated electrically from one another.

Another method of securing the rods, especially suited to small diameter rods, is to fuse the end of the rod into a small ball using a high temperature (greater than 2000ºC) torch. Normally this can only be done on one end of a rod: if both ends are fused, the structure cannot be disassembled later.

As a final means of securing rods, wirenuts (WN parts) have been made available. These wirenuts consist of closely wound coils which barely slip over the ceramic rods and have been given a kink to insure a bakeout proof friction fit. (The kink must be supplied by the user according to the amount of friction desired.) Wirenuts may be made from either stainless steel type 304 or from molybdenum, but since high temperature operation is often desired, the wirenuts normally furnished are molybdenum.

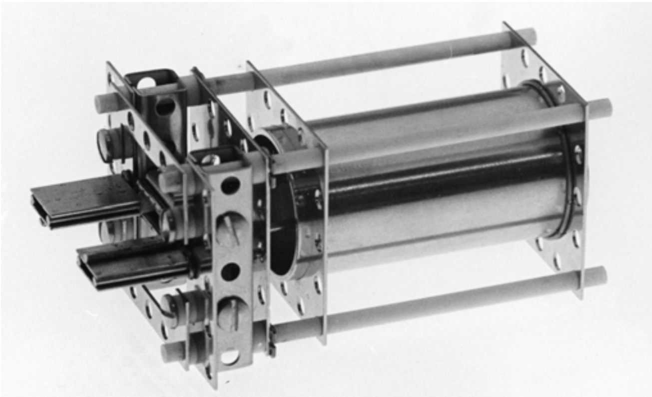


Figure 2-9 One method of constructing a filament mount which can be plugged in from the rear side of an assembly. Note the use of screw clamps with the machine nuts spotwelded to the inside of the channels.

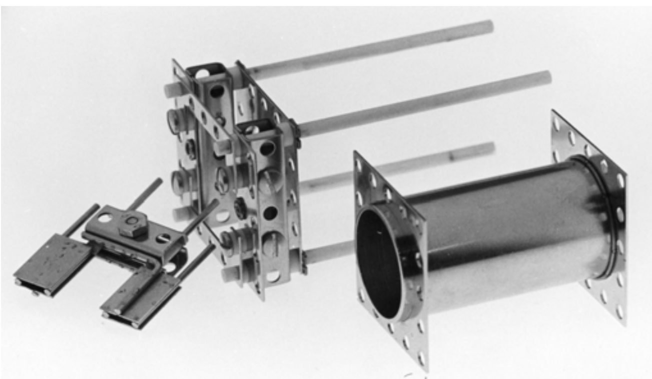


Figure 2-10 Assembly of Fig. 2-9 with filament mount unplugged (filament would be spotwelded between the two center posts) and cylinder removed. Note the use of wire rings to spotweld the cylinder to it's two end plates**.**

As an aid to running electrical wiring through a structure, alumina tubing parts (TU and XTU parts) have been provided which have the same outside diameter as the rods. The inside diameter of each tubing size is just big enough to clear the outside diameter of the next smaller size. Thus, parts can be nested according to the ingenuity of the user. The shorter tube parts are also useful in making high vacuum plug-in connectors, and rigid filament mounts (along with the clamps), and as bushings to insulate mounting holes. The tubing may also be used to pass threaded rods through a structure and then to load the structure in compression using machine nuts (MN parts). The use of threaded rods, however, is not as convenient as the other techniques described.

The ceramic rods have a thermal expansion rate which differs from that of the stack of metal plates and ceramic spacers. Hence small compression springs (CS parts) have been provided which fit precisely over the rods (or tubes) to take up the differential expansion. The springs are made of tungsten, and thus retain their spring properties at high temperatures. These springs are also useful in making quick-change filament holders and other types of snap-together assemblies.

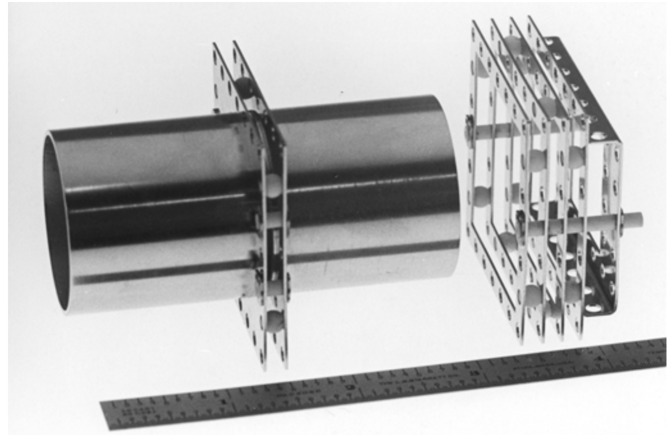


Figure 2-11 Simple structures insulated and spaced using Al2O3 balls. Balls provide more accurate alignment than a stack of spacers and tubes.

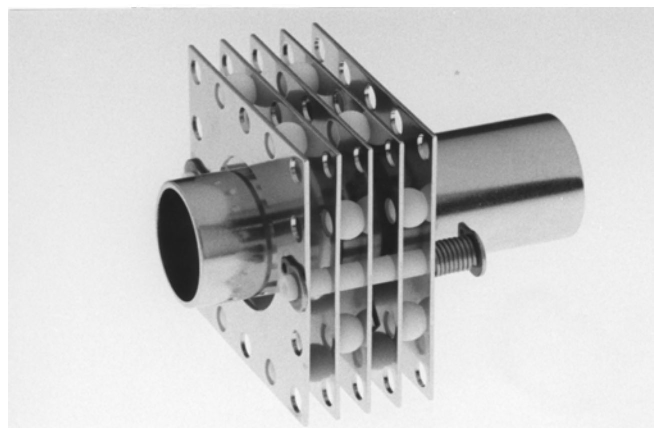


Figure 2-12 Three electrode ion einzel lens mounted using Al2O3 balls and C5x5 plates.

To protect the ceramic spacers from contamination, and to avoid charge-up by stray particles, a group of insulator protector parts (IP parts) has been provided. These protector parts are small cups of diameter 2.5a, with a 1.25a hole in the bottom. The insulator protectors slip over the individual insulators and are held in place by the rods. Because the outside diameter 2.5a is equal to the mounting hole diameter for the next larger size, the protectors may be used to reduce a single hole in a large hole plate to the next smaller size.

The plates may also be positioned using spherical ceramic balls (BA parts). Balls allow closer hole alignment than rods, and generate structures which are inherently resistant to twisting. Balls have the disadvantages, however, of being considerably more expensive, harder to assemble, and less flexible with regard to plate spacing.

The choice between assembling structures using balls or rods, and the choice of means to secure rod ends when rods are used, generally depends on the application. It is often desirable to mix techniques as shown in Figures 2-11 and 12.

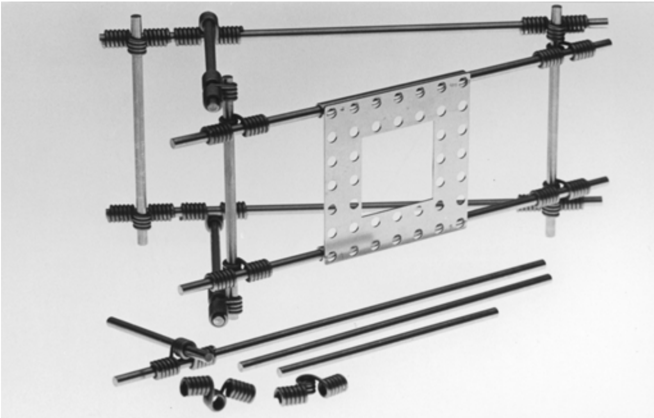


Figure 2-13 Simple mounting frame constructed from Series C stainless steel rods, plate, and molybdenum triplenuts. Straightening out a triplenut to line up the first and third coils locks both rods simultaneously.

Many other parts are available to assist in a variety of construction problems. Metal rods with the same diameter as the ceramic rod, are furnished in several different lengths. These may be used in many ways but are mainly intended for mounting large structures. Metal spacers (SP parts) with outside diameters of 1.875a and inside diameters of 1.27a have also been provided. These are essentially short tubes which slip over either the ceramic or metal rods, and are intended as an additional way of spacing metal plates. Rigid structures can be made by alternating metal and ceramic spacers on one or more ceramic rods. Since metal spacers are less costly than ceramic spacers, it is frequently desirable to use a long metal spacer in series with a small ceramic spacer to provide wide insulated gaps between plates.

As a convenient means of joining long metal rods at right angles special three coil wirenuts (TN parts) have been produced. The axes of two of the three coils make an angle of about 15 degrees while the third lies between the other two, off to one side, and has its axis perpendicular to the plane containing the other two. To use triplenuts, a rod is first passed through the shorter third coil, then a second rod is passed through the two longer coils (15 degree angle). Pulling the two longer coils into line locks the second rod by friction, and simultaneously reduces the turns diameter on the third coil. This reduction locks the first rod (see Figure 2-13). Ceramic rods may also be locked together using the triple nuts; however, it is usually necessary to readjust the nut to make a tight fit. Ceramic rods furnished are 0.001 to 0.002 inch smaller in diameter than the metal rods, because it is frequently necessary to slide a ceramic rod through a long stack of metal plate electrodes. Without the extra clearance such sliding is not possible.

As an aid to joining cylinders to plates, stainless steel wire ring parts (WR parts) are available in several sizes. These should be spotwelded first to the plate (with the cylinder in position), and then to the cylinder. Frequently the cylinders fit so well that the rings are not needed.

2.4 RAW STOCK MATERIALS

Several different kinds of raw stock material are available. These include sheet metal stock of the same thickness as used in making plates, material for making grids, and several kinds of wire. Tungsten wire of several diameters is included for making filaments (and small springs). Molybdenum wire is included, mainly for making up special wire nuts, but also for high temperature wiring. Tantalum wire is provided for use as filament mounting posts and other applications where a high temperature spot weld is required between tungsten and another metal.

For general purpose wiring, hooks, and low temperature wire nuts, stainless steel 304 wire has been provided in several of the most useful diameters. Stainless 304 wound wire stock is also provided; this may be used for making low current electrical connectors.

2.5 ADDITIONAL PARTS

Virtually every low energy particle optics structure can be constructed using eV Parts. However, it should be emphasized that the parts are not a complete set in the sense that every structure can be constructed out of standard parts alone. Special parts are frequently required; these may be made up in a machine shop, purchased outside, or obtained through Kimball Physics. Note that eV Parts are compatible with other types of electron gun parts (such as those used in the cathode-ray tube industry). Flexibility is never lost using standard parts; but considerable time and money can be saved when they are applicable. New users often tend to underestimate what can be done, and revert to a machine shop too soon.

Neither the design nor the number of parts in the eV system are fixed. New parts are continuously being added. The condition for adding new parts is simply that they be useful in building high vacuum apparatus.

High quality research apparatus based on the eV design is just beginning to become available. This is an interesting development since researchers should now be able to modify or add to purchased apparatus with minimum effort. In addition, as more laboratories publish apparatus designs based on standard parts, it should be possible for other laboratories (with the same parts already in house) to duplicate experiments, check results, and build similar apparatus to meet needs of their own. Because the parts have standard dimensions, a simple photograph of a piece of apparatus is often sufficient to disclose most of the design details.

3 eV Parts® CONSTRUCTION TECHNIQUES

The following construction hints have been accumulated over a period of time through the experience of many different people. Some of the suggestions are very elementary, and are included for use by students and others not experienced in high vacuum construction techniques. Most persons using eV Parts for the first time will find it worthwhile to read through the techniques.

(1) General Neatness

It is wise to build structures carefully and neatly. Neatly constructed apparatus often work, sloppily built apparatus rarely do.

(2) Design Optics in Advance

It is usually unwise to attempt to design electrostatic optics for charged particles by trial and error. Unless the experimenter is very familiar with the properties of fields, such designs turn out to be mostly errors. The best method is to copy another design which is already proven. Extensive literature is available for this purpose. When this is not possible, a careful analysis is usually required. Because the parts go together so easily there is a tendency to skip not only the mechanical design (which is often justified) but the optical design as well. The resulting structure, even though it goes together quickly, does not work.

(3) Frequently Used Tools

Relatively few tools and shop facilities are needed when working with eV Parts. Small pliers, screwdrivers, tweezers, a good micrometer (a micrometer caliper is better for a few dollars more), a set of small files, and a jeweler's saw are needed. A pair of Starrett wire cutters (No. 1 - $5^{1}/_{2}$ in.) are useful for cutting stainless wire and rod with minimum burr. A diamond scribe is useful in cutting long lengths of small diameter ceramic rod. Access to a spotwelder is virtually mandatory in building complicated structures, but almost any of the commercially available units is satisfactory. A weld energy capacity up to 40 watt-seconds is usually sufficient, but it is desirable to have larger energies available. Typical tools are shown in Figure 3-1 and 2.

(4) Sheet Metal Tools

The utility of standard parts can be greatly increased by setting up precision sheet metal tooling to cut, punch, and bend the parts. Many laboratories are already equipped with such tooling; for those which are not, tooling may be made up by taking standard sheet metal tools and adding micrometer adjustments. The most difficult tool to set up is a micrometer control brake for making precision bends. Unfortunately the commercially available brakes are generally not intended for very fine work, thus substantial rebuilding is required; micrometers must be added to control both the position of the plate being bent and the bending edge. See Figure 3-3 and 4 on the following page.

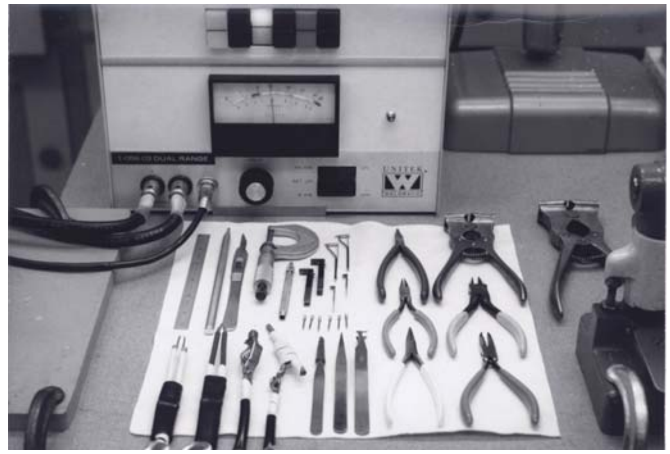


Figure 3-1 Spotwelder and small hand tools useful in fabricating assemblies**.**

Figure 3-2 Micrometer controlled sheet metal tools. Clockwise from the spotwelder: micrometer controlled punch, micrometer controlled brake, small drill press, micrometer controlled shear.

Convenient sheet metal tools to start from are those made by Di-Acro (Lake City, MN 55041). A good beginning is a Di-Acro Shear Number 1, a Box Finger Brake Number 1, and a standard Single Station Punch Press Number 1. Note that the standard punch and die set clearances are far too large for precision sheet metal working; sets should be ordered with 0.001 inch clearance for working thin metal stock. Punches should be ordered without the centering point or the twin shear.

(5) Jigs for Cutting Plates

A surprising amount of part cutting and forming can be done with just a simple shear that is not equipped with micrometers. This is accomplished by making jigs out of standard parts for use in cutting other parts. A jig for cutting parts the standard distance from any pair of mounting holes can be made by mounting jig pins along the edge of one of the larger plate parts. (The jig pins may be short lengths of stainless rod.) The completed jig is used as follows: The pins are placed into mounting holes on the part to be cut, stacked jig and part are placed on the bed of the shear (with the jigging edge moved up to touch the down coming shear blade), then the cut is made. Be careful not to cut fingers, or destroy the jig. In designing the jig, it is convenient to make the pins removable.

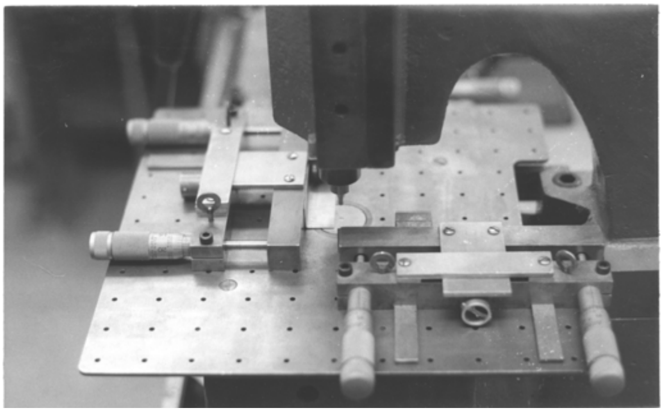


Figure 3-3 Method of using micrometer positioners to do precision punching on a single punch press.

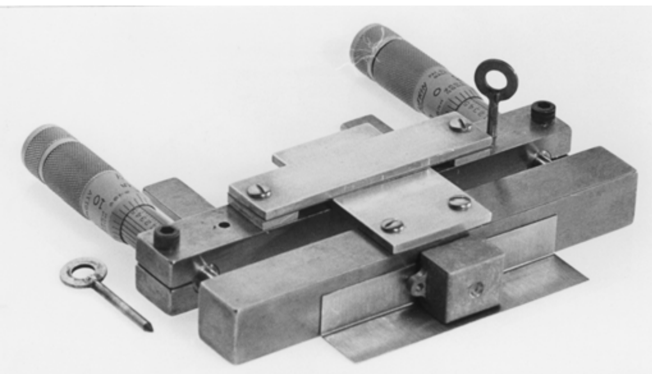


Figure 3-4 Micrometer positioner for use in shears and punch presses. By making the spacing between micrometer heads exactly five inches, it is possible to accurately dial in tangents of angles (up to several degrees). The jigging edge at the bottom right is a piece of thin stainless sheet stock bent to 90º and held in place by a magnet. The positioner can be accurately zeroed by starting with a jigging edge which is oversized, setting the micrometers to zero, and operating a shear once to cut off the excess.

(6) Ruggedness of Structures

Persons building structures out of eV Parts for the first time frequently do not make the structures rugged enough. Simply threading plates and spacers together on ceramic rods does not result in a rigid structure. A simple stack of plates and spacers will twist unless constrained (a stack of plates and spheres does not have this problem). One method of making a structure rigid with respect to twisting is to mount cylinder parts by spotwelding plates at each end rather than by using a single mounting plate in the middle. (This technique also reduces the number of Al2O3-SP parts required and thus reduces cost.) Alternatively, it may be desirable to include a rigid box spotwelded out of plates and brackets, plates spotwelded to metal rods, an external mounting bracket which holds both ends, or to use some other technique. Good rigidity does not mean it is necessary to give up the ability for complete disassembly; it does require thoughtful design. Rigidity and alignment are the responsibility of the individual experimenter.

(7) Spotwelding to Lock Rings

A major convenience in using lock rings is that it is possible to spotweld to them. Metal rods or wire can be easily supported and individually insulated by welding them to lock rings stacked on a single ceramic tube. The lock rings may also be spotwelded directly to metal plates. However, several precautions should be observed. The lock ring works essentially as a strong low-compliance spring; when locked on a rod, the metal far from the rod is in compression while the metal just adjacent to the rod is in tension. When a lock ring fails, it is invariably the material in tension which yields and takes a permanent strain. Thus, when spotwelding to the ring, it is imperative not to spot-weld through the material adjacent to the rod, otherwise the temper of the metal at this crucial point is destroyed and the holding power is greatly reduced. Spotwelding should be limited to either the outer part of the thick portion or to one of the two tool mounting-hole regions. (If both mounting-hole regions are spotwelded to the same plate it is no longer possible to expand the ring for rod insertion or removal.) When spotwelding in the neighborhood of a mounting hole, the user must take care not to close up the mounting hole with splashings from the spotwelder. Should this occur it is very difficult to use the tool.

(8) Spotwelding Cylinders to Plates

Usually it is desirable to spotweld cylinder parts to the plates used to mount them, rather than relying on a friction fit. This is done in several ways. The parts may be welded directly by passing the spotweld current through a clamp attached to the metal plate to a copper rod inserted inside the cylinder. This weld tends to be weak due to the large area contact. A stronger spotweld can be made by using a SS-WR wire ring part. These parts may be easily fabricated in odd sizes by winding stainless wire to a diameter which will just slip over the cylinder. The ring should first be spotwelded to the plate (about four times, 90º apart) and then to the cylinder (again four times, 45º rotated), rather than the other way around. Another convenient method is to take small strips of stainless steel (approximately 0.25a thick by “a” wide by 3a long), bend them in the middle, then spotweld them first to the plate and then to the cylinder.

(9) Wirenuts and Wound Wire Stock

A convenient means of joining wires, rods, and making electrical connections, is by using the various wirenuts and wound wire stock furnished. In addition to that furnished, however, it is easy to make up new wirenuts and wound wire stock. With stainless steel, Oxalloy, tantalum, or molybdenum, wirenuts are made by winding wire on a rod whose diameter equals the final inside diameter desired. When using tungsten a smaller rod is needed to allow the wire to spring back. The metal rod may be placed in the chuck of the small drill press (generally the smaller the better), and wire wound at low speed. In using this method however, one must be extremely careful to stop before the end of the wire comes by, otherwise a nasty cut will result.

Wirenuts may be made up to join one size rod to another, or made up with special shapes on the ends. One useful design using special ends involves standard SS-WW stock cut into short coils (this is a 0.31a diameter wire wound around a 0.62a diameter rod; the resulting outside diameter of the coil just fits through a standard 1.25a diameter mounting hole). If a short length of wire from one end is unwound, then rewound as the first turn of the second layer, and then spotwelded onto a plate with the coil projecting through a mounting hole, a convenient plug-in connector results. As usual, friction can be controlled by the amount of kink put into the coil.

(10) Filament Lead Size

New users of eV Parts often under-design filament leads while over-designing all other electrical connections. A 10 ampere filament lead constructed of 0.062 inch diameter stainless steel 304 wire will seriously overheat; it is necessary to use Oxalloy wire or copper wire, or to go to a much larger diameter. On the other hand, virtually any wire of any diameter which can be handled physically, will adequately pass a few microamperes; the only consideration is that the wiring be structurally sound (uninsulated wires must not sag and touch one another). For general light wiring, 0.031 inch stainless 304 works well. If wirenuts are used for filament leads, 0.031 inch (minimum) Oxalloy should be used. It is easy to melt wirenuts made out of stainless.

(11) Spotwelding Copper Wire

It is sometimes necessary to use large diameter copper wire to carry very large currents, and either not possible or not desirable to use the stainless clad Oxalloy. In such cases the following simple trick will allow the copper wire to be spot-welded. Take a piece of stainless steel wire with a diameter approximately one quarter to one third that of the copper wire to be welded, and wind a closely spaced coil around the copper wire three or four wire diameters long. Then place the copper wire with its surrounding coil between the jaws of a vice and squeeze the stainless coil, pushing it into the copper, until the flattened coil has a thickness only slightly more than the original copper wire. In the process of flattening the coil, the copper wire inside is also flattened and partially extruded between the coil turns. It is now possible to make strong stainless welds to the coil; particularly strong welds result if small rectangular stainless plates are first welded on each side of the flattened coil to force it to retain its shape.

(12) Mounting Tungsten Filaments

In mounting tungsten filaments (the most convenient kind for many applications) several precautions are needed. Firstly, be careful that the filament mounting posts do not become too hot, either due to joule heating, or due to heat conduction from the filament. For high power filaments, a refractory metal should be used for the mounting posts. Secondly, do not attempt to spotweld tungsten directly to tungsten, or tungsten directly to molybdenum. The resulting welds are weak and typically fail at the most awkward time.

A better weld can be made by slipping a thin piece of tantalum foil (or tantalum wire) between the pieces to be spotwelded. This actually results in two welds, a weld from the tungsten to the tantalum, and one from the tantalum to the tungsten or molybdenum post. Tantalum itself makes excellent filament mounting posts. Thirdly, observe that forming a tungsten filament at room temperature, the filament will tend to stress relieve upon first reaching high temperature. The resulting movement may throw the filament out of line with small apertures or slits. This effect may be minimized by heating the filament to red heat (where it just begins to oxidize) outside of vacuum (using a variac and a small transformer). While the filament is red hot, it may be pushed into any desired position using any convenient pointed metal object; further movement at high temperature will be minimal.

Fourthly, note that tungsten, because of recrystallization, tends to become very brittle after operation at high temperatures; a used filament can shatter like a piece of glass. Great care must be taken in handling used filaments. It is essential that the filament mounts be rugged enough so that motions involved in connecting or disconnecting the filament leads are not transmitted through the mounts to the filament itself.

(13) Duplicating Plate Parts in Nonstandard Materials

The following is a simple technique which allows the fabrication of individual standard parts out of non-standard metals. Take a stainless steel part of the type to be duplicated, and a piece of the non-standard sheet stock from which it is desired to form a standard part. Place the standard part on top of the sheet stock, and lightly spotweld the two together. Place the sandwich underneath a hand operated punch press using the holes in the standard part as guides, and punch holes in the new material. Now trim the edges of the sheet on a small shear using the edge of the standard part as a jig. Then break the spotwelds, carefully, to separate the old and new parts. Adaptations of this technique can also be used to make variations on standard parts which cannot be made conveniently from the parts themselves. Good punches and dies are required in making high quality parts.

(14) Fusing Ends of Ceramic Rods

A convenient way of terminating ceramic rods particularly with the smaller diameter rods, is to fuse the ceramic end into a small droplet using a high temperature torch. This fusing process may be accomplished in the following manner: set up a small high temperature torch (natural gas-oxygen works fine) with its flame pointing vertically upwards (mount the torch in a small vice or lean it against a couple of fire bricks). Now place the rod about 1 mm above the tip of the high temperature cone (the tip of the cone should be about 1/2 of a rod diameter back from the rod end); rotate the rod at about 1 rps. It is possible to construct a jig to hold and rotate the rod automatically; normally, however, this is not necessary. Most experimenters can do a perfect job by hand after practicing a few times.

(15) Holding Wires Inside Ceramic Tubes

Several methods exist for rigidly attaching a wire passing through a ceramic tube part to the tube. If only a moderate restraining force is required, the wire may be given a slight kink prior to pushing it through the ceramic tube. The friction resulting from the wire straightening out as it enters the tube holds the wire. A more rigid attaching method, which is particularly useful for filament leads, results if the center wire is spotwelded to a small piece of stainless strip (or wire) which in turn is spot-welded to a lock ring clamped near the end of the tube. A third method is to take a SS-SC screw clamp, insulate the two halves from one another with a ceramic spacer, and spotweld small wires between the clamp halves and the wire to be supported.

(16) Butt Spotwelding Rods

Frequently, it is desirable to butt weld a rod part directly onto a plate or to butt weld two rod parts together (for example, two rod parts of different diameter or a rod part and a tube). This is accomplished easily if a spotwelding clamp is made out of a copper block by drilling a hole of rod diameter, then splitting a block parallel to the hole axis, and installing a screw to allow the block to be tightened around a rod. The clamp should be placed close to the end of the rod to be spotwelded, and the welder current passed between the clamp and a flat electrode underneath the plate to be spotwelded. To spotweld two rods together, two clamps are required.

(17) Difference Between TU and SP Parts

Be careful to note the difference between Al2O3-TU parts and Al2O3-SP parts (particularly between C-size TU parts and B-size SP parts or between D-size TU parts and C-size SP parts). The tubing (TU) parts are intended for threading through mounting holes and have precision ground outside diameters; the spacer (SP) parts are intended for threading onto rod or tubing in order to properly space plates. While both are made out of high purity aluminum oxide, the spacers are made by hot pressing, while the tubing is made by extrusion and finished to tolerance by diamond grinding. Because of the close tolerance grinding, the tubing parts are more expensive.

Occasionally, it may be desirable to use long lengths of C tubing threaded on B rods as spacers for B plates. Note that the effective TU-C part outside diameter, when used with the B plates is 2.5a, as compared with 2a for the standard B spacers; this means that the tubing will stick out past the plate edges (whereas the spacers are flush with the edges). While this protrusion of ceramics beyond the metal is often undesirable, it may be used to space (and electrically isolate) a shield surrounding the entire structure away from the plates. Unless high voltages are present and surface arc-over is a problem, it is usually better to use the metal-spacer parts to achieve wide gaps between plates.

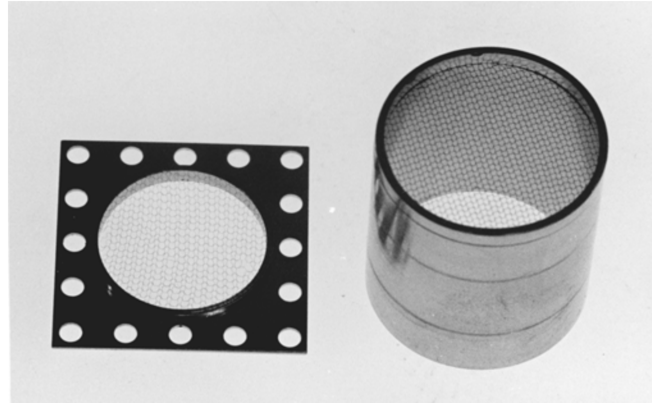


Figure 3-5 Two methods of mounting tungsten knitted grid. Left, grid held between a SS-CY-1000/100 and a thin ring made from stainless sheet stock (mounted on a SS-PL-C5x5-R1000 plate). Right, grid pinched between two cylinder parts (spotweld grid to the shorter cylinder first).

(18) Making Grids

Fine woven tungsten mesh grid material is furnished for making gridded apertures and the like (see Figure 3-5). This is best done in the following way: Remove the material from its packing and unfold it, note that the material is woven in a tubular form with a chain stitch (like a nylon stocking). Now, using scissors, cut along a line parallel to the axis around which the material was woven and lay the resulting piece out flat (it has to be held down). Since the material was kinked in folding it flat for shipping, the cut should be made along a kink since this material is damaged already. The material may now be either stretched and spotwelded over an opening, or held in place by pinching it between two closely mating circular rings, or pinched between an SS-CY cylinder part and either a stainless strip or an SS-WR wire ring part Very attractive grids may be made by spotwelding stretched grid material across the opening in one end of a cylindrical part, and then spotwelding a second cylindrical part of equal diameter down onto the first. Properly stretched woven grid material will remain flat despite violent temperature gradients; it has the additional advantages of providing high transmission and being relatively hard to damage. Note that other types of grid materials are available and may be used if desired.

(19) Low Backscatter Surfaces

In order to collect particles without significant backscatter (either electrons, ions, or neutral particles), a surface is needed which is "black" to the particles in question. (In this sense the blackest possible surface would be a hole with nothing on the other side.) One method for reducing the backscatter on any given surface is to increase the ratio of the true surface area to the projected area as seen by an incoming particle. One technique of accomplishing this is to take a strip of thin foil or sheet stock, crinkle it by running it through a pair of fine tooth gears, and winding it into a spiral with sheets of uncrinkled foil interleaved. When the resulting small channels are oriented in the direction of the incoming beam, a significant drop in particle backscatter results.

(20) Disassembly for Cleaning

Nearly all apparatus needs to be disassembled periodically for cleaning, replacement of filaments, insertion of fresh samples, changing of electrode spacings or other modifications. A great deal of time can be saved by designing structures with disassembly requirements in mind. Frequently, rods and spacers are used in such a way that a structure can be disassembled easily from one end but not the other (as for example, when fused ends are used on the rods). In an electron gun it is usually convenient to make the filament end the easily disassembled one.

(21) Time Sharing Vacuum Systems

Frequently it is desirable (when possible) to mount an entire experimental apparatus on a single vacuum flange. This is particularly true of student experiments. In laboratories where large numbers of students must use a small number of vacuum systems this scheme can facilitate time sharing of the systems. If each student is given his own flange with feedthroughs (mechanical motion, cooling water, etc. already built in) switching vacuum systems from one experiment to another requires only a few minutes. It is also possible for several students to use a multiple port vacuum system simultaneously.

(22) Cleaning Procedures

If the parts are to be used in vacuum of better than 10^{-8} torr or in static vacuum systems or in vacuum systems with low pumping speed, it is desirable to clean structures prior to use. The normal cleaning techniques of established high vacuum practice may be used; note that the ceramic parts and the metal parts may be cleaned separately if desired. One particularly attractive way of cleaning stainless steel parts is to dip them in Diversey DS9-333 (Johnson Diversey, Sturtevant ,WI), followed by rinses in distilled water.

In cleaning parts, be careful not to trap water or cleaning fluids in small cracks and crevasses where virtual leaks may result. In designing structures, avoid blind holes, large flat areas spotwelded together, and other geometries which may result in gas traps. It is wise to bake structures in air after cleaning, but before insertion into vacuum, to drive off trapped water.

(23) Insulating Contamination Layers

When working with charged particles of 100 volt energy or less, care must be taken to avoid insulating contamination layers on electrode surfaces. These layers can result from oxides (as when an inappropriate electrode material such as aluminum is used), or more commonly from the polymerization of residual organics. The problem is particularly critical when attempting to pass low energy electrons through apertures or slits in not very good vacuum. Difficulties may be avoided by not allowing electrons to actually strike the critical electrode or slit. They may also be avoided by maintaining the critical slit at about 250ºC (which prevents the initial condensation of organic contaminants). The effect may be reduced by frequent cleaning, or by using a roughened surface (such as achieved by sandblasting, or by coating with aquadag, or by coating with acetylene smoke). Perhaps the best solution is to get rid of organic contaminants by providing ultra high vacuum. Contamination resulting from charged particle bombardment (or more accurately, chemical reactions induced by charged particle bombardment) has been extensively researched; the reader should refer to the literature.

(24) Charge-up of Insulating Parts

In designing all kinds of charged particle apparatus it is imperative that all electrons, ions, and neutral particles are prevented from striking the insulating parts. Condensing neutral particles may degrade the surface resistance. The polymerization of organic contaminants under particle bombardment may also occur on insulators, and these layers may also degrade the surface resistance.

Charged particle bombardment will usually cause an insulating surface to charge up directly, resulting in the generation of electric fields. Note that an insulator bombarded by electrons need not charge negatively, since substantial secondary electron currents may be emitted (depending upon the primary electron energy). Every surface has a surface potential. The only difference between an insulating surface and a metal surface as far as a charged particle traveling nearby is concerned, is that for an insulating surface the potential will be a function of position across the surface, and may change in an uncontrolled way. The only apparent solution to all these problems is to prevent particles from hitting insulators. In the eV design, insulator protectors have been included for this purpose.

(25) Stray Magnetic Fields

When working with very low energy electrons it is necessary to be extremely careful about stray magnetic fields. Since such fields appear under every rock and bush it is wise to check for stray fields using a gaussmeter. This should be done while all electronic equipment is turned on (do not forget the magnetic fields due to high current filament leads). Note that the SS-LR parts are magnetic and cannot be used in some applications. Note also that forming or spotwelding operations on stainless steel type 304 or 316 parts may result in local regions of metal which are slightly magnetic. Annealing the completed structures in vacuum or hydrogen will remove the unwanted magnetism. However, annealing in hydrogen will degrade the best vacuums.

(26) Secondary Emission Effect on Power Supplies

In building electron lenses where the electrons may strike the lens electrode surfaces (hopefully in small numbers) care must be taken to see that the resulting current does not cause a large change in electrode potential due to the high impedance source frequently used to drive these electrodes. Note that in cases where substantial secondary currents flow, the net current to the electrode may be the opposite of that anticipated. If current flows the wrong way, then the physical power supply must actually become a power sink. Most commercial supplies however, are intended for use only as power sources. A frequent result is that the regulator in the commercial supply cuts off, the output voltage goes up, and the operator no longer has any control over the electrode potential in question. In such cases a power "supply" is not needed. Note that a resistor of appropriate value is an excellent source of negative power.

(27) Shielding of Electrode Wiring

It is usually necessary to shield electrode wiring from the charged particle beams. Do not run a high voltage wire next to a low voltage beam (or vice versa); do not run an electrometer current-measuring lead near any beam. As far as shielding electrometer leads against the stray particle pickup is concerned, electrons should be regarded like rubber balls; complete shielding by a metal guard electrode is usually required. In order to prevent insulator leakage the guard electrode, or any other electrode which physically contacts an insulator supporting the low current lead, should be run at the same electrical potential as the current lead. In some cases this may require a triaxial feedthrough through the vacuum wall. Where metal vapors are present, as in evaporators and some cross beam experiments, it is desirable to protect high impedance, low current leads with multiple insulator protectors, and to maintain the shields at a low enough temperature so that the sticking probability of a metal atom is high.

4 eV Parts® PACKAGES

Kimball Physics eV Parts® are available packaged in three ways: as individual part types in standard packages (std pkg), as groups of part types called Assortments, or as balanced sets called Parts Systems. Visit www.KimballPhysics.com for complete details.

INDIVIDUAL PARTS

Standard packages each contain parts of just one type and are priced identically, with manufacturing costs determining the quantity of parts per package. For example, with stainless steel plates, SS-PL-C-6000 (a C size, 6"x2" rectangular plate) has two plates per standard package, while SS-RP-C125 (a C size round plate with 0.125" diameter) has 50 plates per standard package, but the price of each package is the same.

Some parts (such as clamping plate assemblies, screw clamp assemblies, element clamps and a lock ring tool) are sold and priced individually, not as standard packages.

ASSORTMENTS

Assortments are a simple way of ordering groups of standard packages comprising most parts of a particular generic type. For example, eV 146 Series C Insulator Assortment contains most of the various insulator parts of that series.

eV 140 SERIES C5x5 PLATE ASSORTMENT:
Contains 19 Std Pkgs with 92 parts of 19 types, including most of the SS-PL-C5x5-X parts and one package of SS-PL-C-6000.

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Contains 12 Std Pkgs with 48 parts of 12 types, includes one package of each C screw clamp type.

eV 144 LARGE SIZE CYLINDER ASSORTMENT:
Contains 9 Std Pkgs with 20 parts of 9 types, includes one package each SS-CY-1500/3000 through SS-CY-1000/100.

eV 146 SERIES C INSULATOR ASSORTMENT:
Contains 26 Std Pkgs with 240 parts of 14 types, includes two packages of each Alumina spacer type, one each of the shorter tubing types, two each of Al2O3-TU-C-4000, Al2O3-TU-C-3000, and Al2O3-TU-C-2000, and four packages of Al2O3-TU-C-6000.

eV 120 SERIES B 5x5 PLATE ASSORTMENT:
Contains 20 Std Pkgs with 97 parts of 20 types, including all the SS-PL-B5x5X parts and one package of SS-PL-B-3000.

eV 122 SERIES B SCREW CLAMP ASSORTMENT:
Contains 12 Std Pkgs with 48 parts of 12 types, includes one package of each B screw clamp type.

eV 124 SMALL SIZE CYLINDER ASSORTMENT:
Contains 15 Std Pkgs with 60 parts of 15 types, includes one package each SS-CY-750/1500 through SS-CY-250/100.

eV 126 SERIES B INSULATOR ASSORTMENT:
Contains 15 Std Pkgs with 174 parts of 12 types, includes one package of each Alumina spacer type, one each of the shorter tubing types, and two each of the longer tubing and rod types (Al2O3-TU-B-4000, Al2O3-TU-B-3000, and Al2O3-RO-B-6000).

eV 105 RAW MATERIALS ASSORTMENT:
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eV 130 SERIES CB PLATE PART ASSORTMENT:
Contains 9 Std Pkgs with 34 parts of 8 types, includes two packages of SS-PL-CB5x5-S800, and one each of the other series CB plate parts.

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