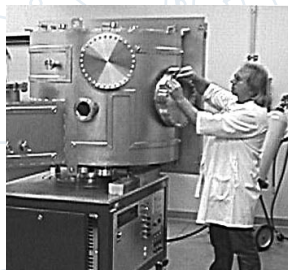
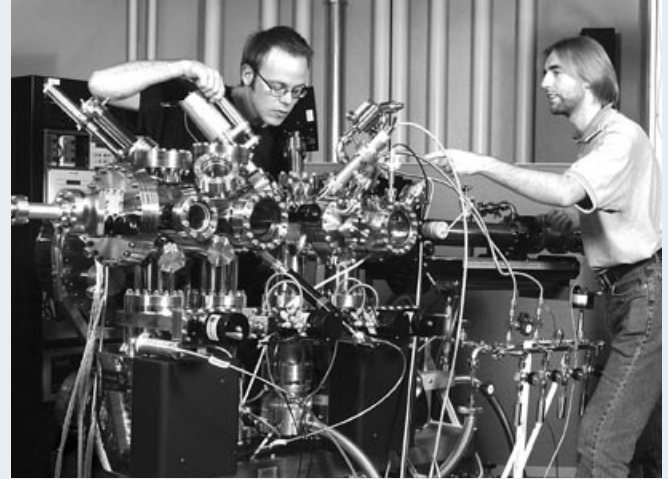


MOCVD reactor chamber

Nor-Cal Products has earned a reputation as a world-class manufacturer of high and ultra-high vacuum chambers. The quality, appearance and performance of our chambers are unequalled. We supply single chambers designed from customer specifications for university or national laboratory research projects, as well as production quantity chambers that are built-to-print for equipment manufacturers. Thin-film deposition and compound semiconductor processing are common applications for our high-vacuum, O-ring sealed chambers that operate at pressures down to 1×10^{-9} Torr. Vacuum fired 316L stainless steel, electropolishing and metal seals are recommended for ultra-high vacuum surface science chambers that operate at pressures in the 1×10^{-11} Torr range. Nor-Cal can fabricate vacuum chambers up to approximately 5 x 5 x 5 feet with doors, stands, water jackets and Mumetal shields. (Consult the factory for exact capabilities.) We offer a complete line of vacuum chamber accessories that include load locks, sample transfer and positioning devices, liquid and electrical feedthroughs, viewports and roughing components.



Vacuum coating chamber



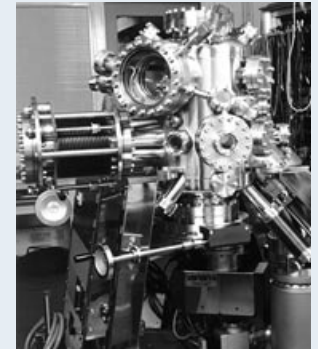
"The system utilizes several types of analyzers around the analysis chamber. Designed to be ergonomic and user-friendly, the system's frame components are on the floor level, maximizing accessibility to the research instruments. Electropolished 316L vacuum fired stainless steel was selected for the chambers in order to obtain a base pressure less than 3×10^{-11} mbar. Based on previous projects, we selected Nor-Cal Products to manufacture the vacuum chambers and components. We are very pleased with their quality, service and on-time delivery."

Jan-Olof Forsell
Design Manager, Gammadata Scienta and SSRL



"I would like to reiterate how impressed we've been by the professional service we've received from Nor-Cal Products. I've interacted with engineers and salespeople from many vacuum equipment suppliers. It never fails to surprise me how uneven the service is. Salespeople are often uncommunicative, giving the impression that they're not in the least bit interested in your business, and technical people often don't know their products. It's incredibly refreshing, therefore, to interact with people, such as those at Nor-Cal, who are both courteous and well informed."

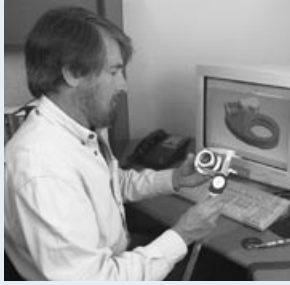
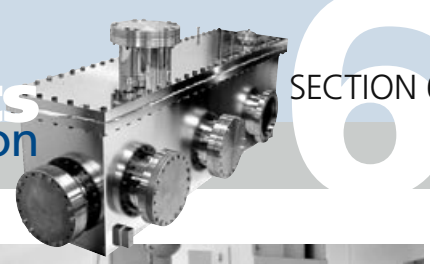
Susan Watson, PhD
Department of Physics,
University of California, San Diego



"This vacuum system was optimized for investigations into the magnetic properties of a wide range of materials using soft x-rays from synchrotron radiation sources. For such work, ultra high vacuum is necessary and this Nor-Cal Products chamber has a base pressure of 5×10^{-11} mbar after baking. The use of independent rotary stages for positioning of the sample and in-vacuum electromagnet provide a very high degree of flexibility by allowing any combination of sample surface and applied field relative to the incident soft x-rays."

Dr. Jonathan Hunter-Dunn
MAX-Lab
Lund University, Sweden

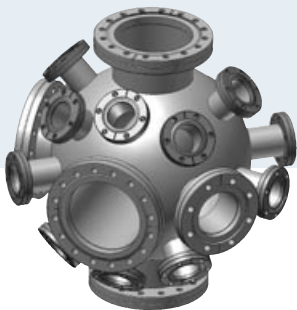
All dimensions are in inches
unless otherwise noted



Engineering

As part of our commitment to quality and customer satisfaction, Nor-Cal's engineering staff thoroughly reviews each custom vacuum component for manufacturability before the production process begins. All customers benefit from the combined experience of our engineers, whose input during the design and production phase often results in cost savings and a superior product. Questions regarding design, specifications and testing are directed back to the customer for final approval.

Our engineers design from customer specifications, sketches or drawings and oversee custom component production using existing tooling and facilities. For our customers who do not have drafting personnel available and require a complex assembly, we can provide complete CAD drawings for approval after receipt of order. Nor-Cal engineering and R&D departments use AutoCAD and AutoDesk Inventor software. You may email drawings direct to our engineering department at prints@n-c.com. Acceptable exchange file formats are DXF, IGES, SAT and STEP versions. Direct formats are DWG, IDW, IPT and IAM. You may also download drawings of our most commonly used standard components from our website.



Manufacturing

Machining procedures are consistent with good UHV practices. Machine coolant is sulfur-free to reduce outgassing. All Nor-Cal components are designed to minimize entrapments that cause virtual leaks under vacuum. State-of-the-art CNC machining equipment is used to produce parts with consistently high quality.

GTAW fusion welding is used exclusively for a vacuum-tight metal bond. Purging with an inert gas reduces or eliminates oxygen entrapment and carbide precipitation that cause outgassing. Whenever possible welds are made on the inside, or are full penetration to eliminate entrapments and virtual leaks. External stitch welds are used in conjunction with internal vacuum welds for structural reinforcement, as necessary.



Materials

Nor-Cal Products uses 304 stainless steel tubing, spheres or roll-ups to fabricate vacuum vessels; however, 304L, 316 or 316L stainless steel can also be supplied. We have found that optimal vacuum performance can be obtained by using 2B rolled sheet with no secondary grinding for the body followed by electropolishing after ports are welded. Normally our standard material is dual certified 304/304L low carbon range stainless steel.

Flanges and baseplates are made from 304 stainless steel that has been specially treated to remove impurities inherent in 300 series steels. Flanges 4 1/2 inches OD and smaller are made from 304 electroslog remelt (ESR) bar stock. ESR is a refining process that produces stainless steel with higher purity, fewer inclusions and more uniform grain structure to eliminate microscopic leak paths.

Larger flanges are made from Argon Oxygen Decarburization (AOD) 304 stainless steel. This material is certified to meet ASTM-240 and has less than .01% sulfur to prevent sulfur stringers. Grain size is per ASTM E-112. Maximum inclusion size is per ASTM E-45. Roll-forged rings, 316L, Mumetal, aluminum and other materials can be supplied upon request.



Cleaning

A biodegradable detergent is used to remove machine lubricants before the parts are washed and rinsed with deionized water. Nor-Cal offers in-house bead blasting, chem cleaning and electropolishing of vacuum chambers. Glass shot cleans, hones, polishes and peens while removing scale. Some customers request bead blast on the exterior of the chamber with electropolish on the interior.



Electropolishing is considered the most desirable cleaning and surface conditioning process for stainless steel vacuum chambers. It is an electrochemical process that benefits the finished part in a number of ways simultaneously. Deburring, passivation and stress relieving are achieved while the machine-produced surface roughness is eroded. Electropolishing attacks the microscopic "peaks" of the surface more rapidly than the "valleys"; thereby maintaining critical dimensions while improving surface finishes. Normally .0003 to .0004 inches would be removed to lower the microfinish from 32 to 8 RMS. Electropolishing a 2B stainless steel rolled sheet achieves approximately a 90% reduction in surface area. This is most important for vacuum chambers because it produces faster pumpdown

and a lower base pressure. In addition to the improved mechanical properties of the surface, iron is removed electrochemically. This leaves the surface rich in chromium and nickel, which have extremely low vapor pressures. The result is the lowest outgassing rates possible from stainless steel. Having an in-house facility allows Nor-Cal to do multi-step electropolish in order to reduce "shadowed" areas on chambers with difficult geometries. Our electropolish tanks can accommodate chambers up to 60 x 50 x 65 inches.

All stainless steel parts are descaled and passivated in an acid solution to remove weld scale and other oxide layers. This process leaves the surface free from most contaminants that might impact the vacuum environment or promote intergranular corrosion. (Contact our factory for Ion Chromatography (I.C.) test data.) Chem cleaning can be used as a final cleaning step for chambers up to 35 x 53 x 33 inches to remove organic and metallic contaminants. The chamber is immersed in a series of controlled chemical baths and deionized water rinses and dried using filtered air. Chem cleaning results in the cleanest surface possible for ultra high vacuum components. (Contact our factory for I.C. test data.)

Inspection

Nor-Cal uses the most up-to-date equipment and procedures for the inspection of vacuum chambers. Every weld is leak checked with a helium mass spectrometer to insure leak rates of 1×10^{-9} mbar l/sec. or less. Mechanical inspection is accomplished with a coordinate measuring machine (CMM). We can provide our customers with CMM inspection reports of their chambers on request.

Our chamber qualification and test equipment is available to customers for an additional fee who request residual gas analysis (RGA) scans and leak checks of their chamber after vacuum baking. The test equipment includes vacuum pumps, gauges, RGA, quartz heaters, nitrogen back fill and a leak detector. Chamber bake out is achieved with high intensity infrared radiant lamps that are strategically placed throughout the chamber. Baking under vacuum removes high and low molecular weight volatile compounds. Non-water cooled UHV chambers are typically baked for at least 24 hours at 150°C . (The maximum temperature of system components such as seals, chamber materials, valves, etc. may limit maximum baking temperatures.)

Uniform bakeout temperature is achieved by wrapping the associated system components in high temperature fiberglass materials.

After cool down our RGA will provide partial pressure data, determining the level of residual volatile compounds. Typical scans produce atomic mass levels below 1×10^{-9} Torr for atomic masses greater than or equal to 44. Total system pressures are between 5×10^{-9} and 7×10^{-10} Torr. Chamber design, seals and pumps used, and the maximum bake temperature over time effect the residual gas composition and ultimate pressures reached. Following chamber scanning, chambers are leak tested using a NIST traceable helium mass spectrometer leak detector with a final allowable leak rate of 1×10^{-10} mbar l/sec. or less.



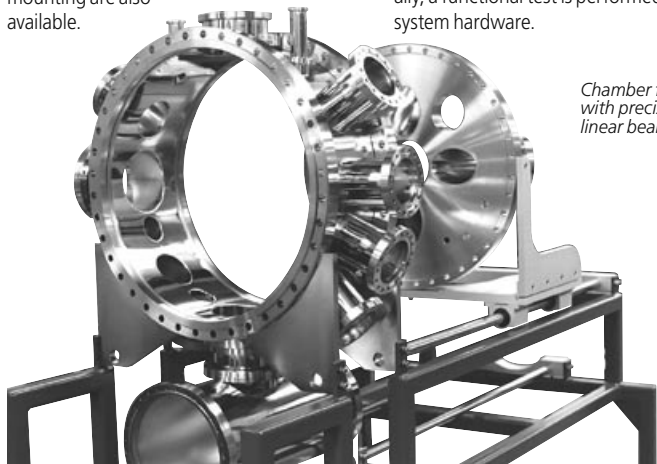
Mechanical inspection of process chamber with CMM (coordinate measuring machine)

Frames

Frames are usually constructed from $1\frac{1}{2}$ or 2 inch mild steel box tubing, which is powder coated. However, aluminum or a variety of other materials are available. In addition to leveling pads and castor wheels, we can design and fabricate frames with precision rotational and linear bearings for moving components, such as chamber lids. Integrated hoist assemblies, pump mounting, cabinets and panel rack mounting are also available.

System Integration

Nor-Cal can assemble an entire system including chamber, frame, pumps, gauges, valves, manipulators and other components to customer specifications in our 1,100 square foot, class 1000, final assembly area. After completion our vacuum technicians can complete a thorough system qualification, including bake out, RGA scan and leak check using the procedures described above. Additionally, a functional test is performed on all system hardware.



Chamber frame with precision linear bearings



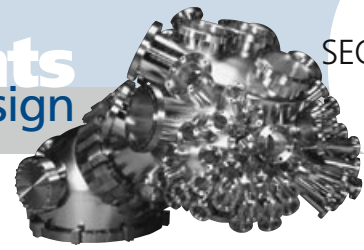
Leak testing of chamber on chamber qualification test bench



System integration

Packaging

Vacuum chambers and other large components are packaged appropriately for truck, ship or airfreight to our customer's location. Unless specified otherwise, flanges are covered with aluminum foil to prevent internal contamination and scratching of the flange faces. Protective plastic covers are placed over the foil for additional protection. The chamber is then wrapped in 4 mil plastic and placed in a wooden crate. Foam is injected into plastic "pillows" which expand to fill the voids in the crate, suspending the chamber inside. Depending on customer specifications for systems, after qualification the chambers can be disassembled or purged with nitrogen gas, clean room packaged and shipped. Alternatively, some chambers have been packaged and shipped under vacuum.



The information presented on the following three pages is provided as a general guideline to the vacuum engineer or end user to aid in the design of their vacuum chamber. In addition to the specific areas which are discussed, these considerations should be addressed when designing a vacuum chamber:

Chamber Material	Vacuum Level	Surface treatment	Special Requirements	Additional Hardware	Required Inspection Reports
304SS, 304LSS, 316SS, 316LSS, aluminum, etc.	Base pressure and acceptable leak rate	Glass bead finish, electropolish, chemical clean, etc.	Vacuum bakeout, vacuum fire or RGA scan.	Blank-off flanges, manipulators, viewports, etc.	CMM inspection report printouts or certificate of conformance and/or material certificates

By first determining the basic design parameters from those mentioned above, the actual process of designing, specifying and estimating the cost of your chamber will follow more smoothly. Nor-Cal sales estimators are available for any assistance you require. Engineering drawings can be e-mailed directly to prints@n-c.com.

Typical Chamber Configurations



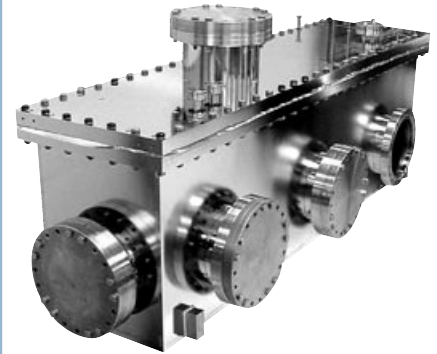
Spheres and Hemispheres

Spun hemispheres can be purchased in a wide range of standard sizes and welded together to form a spherical body. Often a large tube is attached to the bottom of the sphere for attachment of the pump. A number of smaller, radial ports can be positioned around the sphere for attachment of the load lock and various instruments. This is a common configuration for UHV analyzer chambers with a single target. This configuration is lighter, less expensive to manufacture and has less internal volume than cylindrical configurations with machined lids.



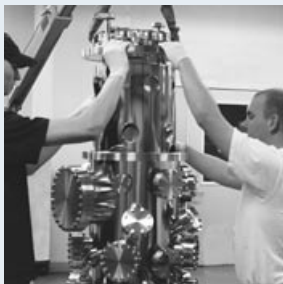
Cylindrical

Cylindrical chamber bodies come in a variety of sizes and are made of tubing or roll-ups. The base plate and lid of the chamber can be made from die-formed dished heads, hemispheres or blank flanges. Dished heads and hemispheres are lighter and typically less expensive than machined flanges. This configuration is commonly used for analyzer chambers with multiple levels and targets, and for processing chambers with carousels or robotic arms.



Rectangular

Rectangular chambers are generally more expensive than other configurations. However, they may be the preferred choice because of a requirement for accessibility, or when large chamber mass is required for vibration dampening. Rectangular chambers are fabricated from plate material that is welded, or they are machined from solid billets. Depending on material thickness and span, stiffening bars may be required to prevent deflection of the walls while the chamber is under vacuum.



Double wall construction

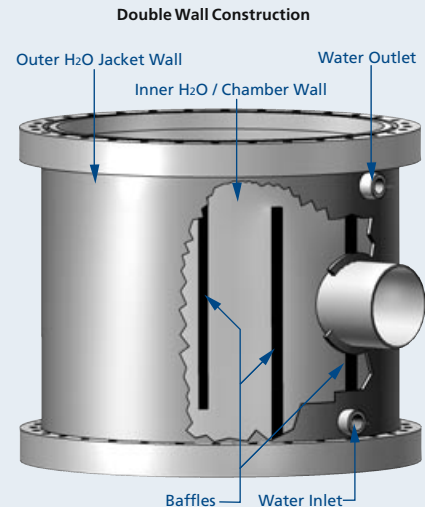


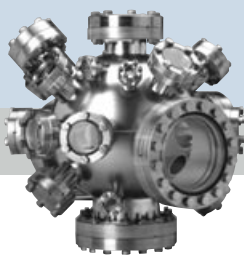
Water channel construction

Water Cooled Chambers

Nor-Cal Products frequently provides water cooled chambers and flanges for diffusion, CVD, and other high temperature vacuum applications. Normally the construction techniques involve water channels or double walled construction. Water channels require considerable hand fitting and therefore tend to be more expensive than double walled construction. Double wall water-cooled chambers are fitted with internal baffles to provide consistent circulation throughout the chamber, resulting in excellent internal temperature uniformity.

Water-cooled chambers manufactured by Nor-Cal undergo a rigorous leak test to insure that they are free from water leaks. First the water cavities are stressed by pressurizing them with dry nitrogen. The water cavity is then pumped down with a helium leak detector, while helium is applied with a probe to all welds on the inside and outside of the chamber. (Consult the factory for pressure and integrity acceptance criteria.)





STANDARD CHAMBER DIMENSIONS

Nor-Cal can manufacture vacuum chambers with metric size tubes, roll-ups, and spheres, however inch sized materials are more readily available in the US and can be furnished for a lower price. For further clarification, contact an estimator at the factory or see our website.

Chamber Wall Thickness

Recommended minimum wall thicknesses are listed in the table below. Thicker walled material should be specified for chambers with ports having angular tolerances of less than $1/2^\circ$, or for processes that require large mass for vibration dampening.

CHAMBER DIAMETER	WALL THICKNESS
Under 17 inches	0.120
17 through 28 inches	0.188
Over 28 inches	0.250

Roll ups

Roll ups are formed from 2B rolled finish, flat sheet that is formed into a cylinder and stitch welded on the outside seam, before applying a vacuum weld to the inside. They can be obtained in a range of wall thicknesses and any diameters. Dished head and sphere diameters are typically available in the United States in nominal inch sizes.

Tubing

Nor-Cal stocks a broad variety of 304, 304L and 316L stainless steel tubing sizes that can be used for ports. Usually the port flange determines the diameter of the port tubing, but oversized tubing (i.e., $1\frac{3}{4}$ inch OD tubing for $2\frac{3}{4}$ inch OD CF flanges) is occasionally used for additional clearance for instrumentation. The table below lists common tubing sizes used for vacuum chamber ports.

TUBE OD	TUBE ID	WALL THICKNESS
$1/2$	0.402	0.049
$3/4$	0.680	0.035
1	0.870	0.065
$1\frac{1}{4}$	1.120	0.065
$1\frac{1}{2}$	1.370	0.065
$1\frac{5}{8}$	1.490	0.065
$1\frac{3}{4}$	1.630	0.065
2	1.870	0.065
$2\frac{1}{2}$	2.370	0.065
3	2.870	0.065
4	3.834	0.083
5	4.834	0.083
6	5.834	0.083
8	7.760	0.120
10	9.760	0.120
12	11.760	0.120



Port Lengths

Port lengths should be sufficiently long to allow the flange bolts to be inserted into the bolt holes from the underside of the flange unless tapped flanges are used. When designing chambers we typically dimension the ports so there is a minimum of three times the flange thickness from the port flange face to the outer wall of the chamber. If designing a chamber which utilizes NW clamps for assembly please refer to the chart below for clamp clearance details.

Standard Tolerances

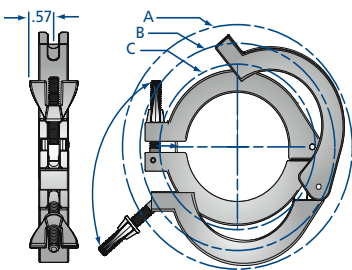
Unless otherwise specified by the customer, standard tolerances will be adhered to during fabrication. These tolerances are acceptable for most analytical or process vacuum equipment and can normally be achieved without secondary machining operations after welding. Tighter tolerances required for specific applications are frequently provided for a slightly higher cost. Standard tolerances for machined dimensions are $\pm .005$ inches (although tolerances of $\pm .002$ inches are commonly held on critical flange dimensions). Standard tolerance for any welded dimension, such as a port length or chamber height up to 24 inches, is $\pm .020$ inches ($\pm .060$ inch for chambers >24 inches, but <72 inches in length). Standard tolerance for polar and azimuthal angles is $\pm 1/2^\circ$.

TOLERANCE MEASUREMENTS

Machined dimensions	± 0.005
Welded dimensions up to 24	± 0.020
Welded dimensions over 24	± 0.060
Focal length	± 0.020
Port alignments	$\pm 1/2^\circ$

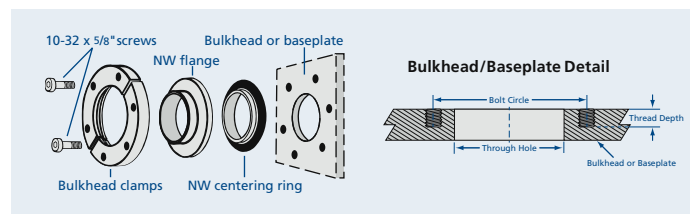
NW Clamp Clearance

FLANGE SIZE	Min. Dia. to Install A	Max. Dia. Closed B	Min. Dia. Closed C
NW-10	2.86	2.65	1.75
NW-16	2.86	2.65	1.75
NW-25	3.32	3.00	2.24
NW-40	4.00	3.72	2.90
NW-50	5.45	4.62	3.69



NW Bulkhead Detail

FLANGE TYPE	BOLT CIRCLE	THREAD SIZE	THREAD DEPTH	BLIND TAPPED HOLES	THROUGH HOLE
NW-16	1.50	10-32	0.300	6	0.90
NW-25	1.89	10-32	0.300	6	1.26
NW-40	2.44	10-32	0.300	6	1.84
NW-50	3.25	10-32	0.300	8	2.35



Bolt Pattern Orientation

Our components are manufactured with the primary axis straddling adjacent bolt holes on the mounting flange (American Standard). Most components can be furnished with the axis passing through a bolt hole axis (European Standard) on request. Leak check groove orientation should be indicated on drawings if critical.

