

# **RSVP Phantom<sup>™</sup> Head II with Bite Feature M a n u a l** **Radiosurgery Verification Phantom**

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## **CAUTION**

Federal law restricts this device to sale by or on the order of a physician, or with the descriptive designation of any other practitioner licensed by the law of the State in which he/she practices to use or order the use of the device.

This product is intended for use by medical physicists with training in radiation therapy. A medical physicist must design and supervise the actual tests performed with this phantom. This manual does not provide information regarding applications of the product only information regarding the product functions.

## **WARNING**

This product has an FH3-4 mm/min flame rating and is considered to be flammable. It is advised not to expose this product to open flame or high temperature (over 125° Celsius or 250° Fahrenheit) heating elements.

## **WARRANTY**

THE PHANTOM LABORATORY INCORPORATED (“Seller”) warrants that this product shall remain in good working order and free of all material defects for a period of one (1) year following the date of purchase. If, prior to the expiration of the one (1) year warranty period, the product becomes defective, Buyer shall return the product to the Seller at:

By Truck  
 The Phantom Laboratory, Incorporated  
 2727 State Route 29  
 Greenwich, NY 12834

By Mail  
 The Phantom Laboratory, Incorporated  
 PO Box 511  
 Salem, NY 12865-0511

Seller shall, at Seller’s sole option, repair or replace the defective product. The Warranty does not cover damage to the product resulting from accident or misuse.

IF THE PRODUCT IS NOT IN GOOD WORKING ORDER AS WARRANTED, THE SOLE AND EXCLUSIVE REMEDY SHALL BE REPAIR OR REPLACEMENT, AT SELLER’S OPTION. IN NO EVENT SHALL SELLER BE LIABLE FOR ANY DAMAGES IN EXCESS OF THE PURCHASE PRICE OF THE PRODUCT. THIS LIMITATION APPLIES TO DAMAGES OF ANY KIND, INCLUDING, BUT NOT LIMITED TO, DIRECT OR INDIRECT DAMAGES, LOST PROFITS, OR OTHER SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER FOR BREACH OF CONTRACT, TORT OR OTHERWISE, OR WHETHER ARISING OUT OF THE USE OF OR INABILITY TO USE THE PRODUCT. ALL OTHER EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANT ABILITY AND FITNESS FOR PARTICULAR PURPOSE, ARE HEREBY DIS

# **TLP290**

7/27/15



# T h e P h a n t o m L a b o r a t o r y

## **RSVP Phantom™ Head II Manual**

### *Contents*

Caution	1
Warning	1
Warranty	1
Indications for use	4
Introduction	5
Schematic drawing	6
Care of the phantom	7
Removing tumor vessel and filling the phantom	8
Using the head frame	10
Filling the tumor vessel	11
Film alignment verification	11
Dosimetry gels	12
Preparing the Ferrous Agarose gel	12
Dose evaluations	13
Thermoluminescent dosimetry	13
Film dosimetry	13
Radiation chambers	14
Using the TLP280 PinPoint adaptor	15
Chemical compatibility chart	16
Bibliography	22

**Indications for use**

The RSVP Phantom™ Head II with Bite Feature is designed for use in a variety of radiosurgery applications including, final quality verification of therapy dose delivery and for comparing the delivered dose profiles for different treatment plans. It is also used for periodic quality assurance evaluations and acceptance testing and to perform re-evaluations after equipment or software upgrades.



## Introduction

In 1993 The Phantom Laboratory, Inc. and Chief Medical Physicist - Charles W. Coffey, II, Ph.D., developed the RSVP Phantom™ head to provide localization and dose verification for radiosurgery systems. Additional developments in 2013 by The Phantom Laboratory, Inc. and Chief Medical Physicist -Michael S. Gossman, M.S., DABR, FAAPM have led to the development of the RSVP Phantom™ Head II with Bite Feature model, which allows for both stereotactic radiosurgery and radiotherapy quality assurance with bite tray jaw system proved to replicate the desired position with an average accuracy of 0.012 mm in published research.

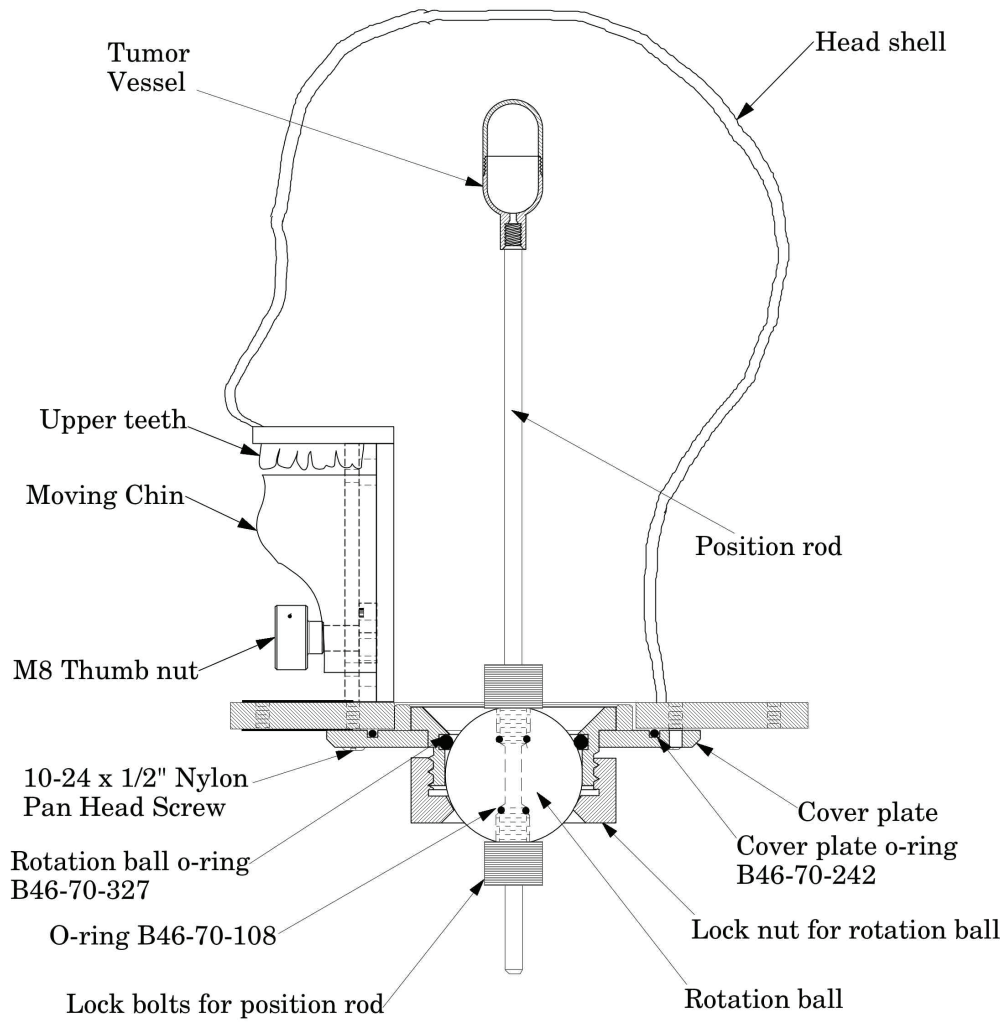
A variety of techniques may be used to measure the radiation dose delivered to the tumor vessel. Quantitative dose measurements may also be obtained by using commercially available probes and ionization chambers.

Because each medical facility has its own unique set of requirements, we do not make specific recommendations on the frequency and expected results of evaluations. When developing your measurement protocols, review the local governing regulations, the needs of your radiologists, oncologists, physicists, and your system manufacturer's recommendations.

If you have questions about the operation of the RSVP Phantom™ Head with Bite Feature or the optional equipment that is available for the phantom, please contact The Phantom Laboratory at the following address:

The Phantom Laboratory, Incorporated  
PO Box 511, Salem NY 12865 USA  
Phone: 800-525-1190 or 518-692-1190  
Fax: 518-692-3329  
[info@phantomlab.com](mailto:info@phantomlab.com)

# **LP290 RSVP Phantom™ with Bite Feature**



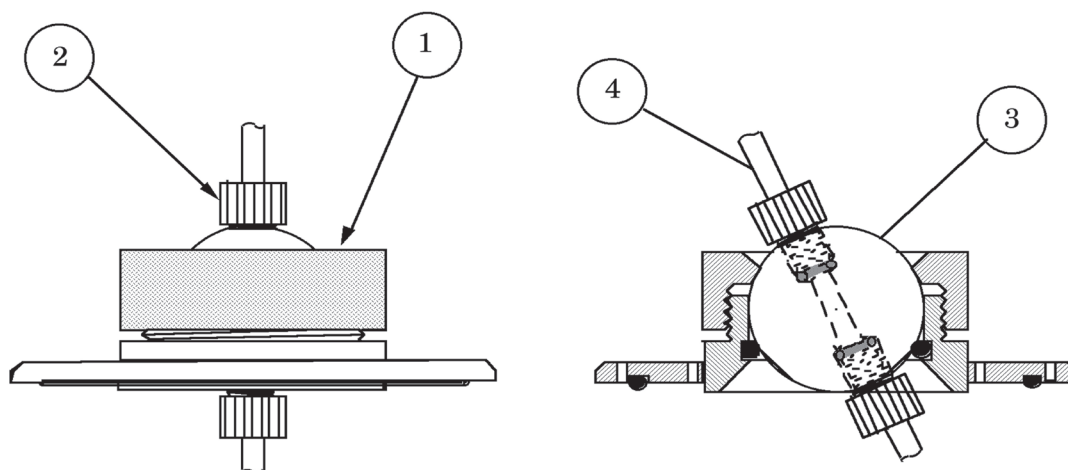
## Care of the phantom

The shell of the RSVP Phantom™ is composed of 0.25-inch-thick cellulose acetate butyrate (CAB), a transparent plastic chosen for its strength and low water absorption. The shell is mounted on a durable polycarbonate end plate, which is attached to a cover plate and an assembly that allows the tumor port to be rotated. The head frame of your radiosurgery system may be screwed directly into the CAB plastic. To avoid unnecessary wear on the phantom shell, be careful not to overtighten the head frame screws. In normal use, the screws may cause small dimples to form in the CAB plastic.

The phantom is designed to be filled with water. Please refer to the Chemical Compatibility Chart for CAB material near the end of this manual prior to using anything besides water. You should never allow a filled phantom to freeze. If water is left in the phantom for an extended period of time, bacteria and other microorganisms may begin to grow and cause the water to become cloudy. If clouding occurs, the phantom should be emptied and washed with a mild detergent and water. Before storing empty all water from the phantom.

The tumor rotation ball assembly is located on the base of the phantom. The ball assembly may be extracted from the phantom by simply removing its lock nut and then lifting the ball out of the assembly. The O-ring that lies under the rotation ball should sit evenly on the lip surrounding the opening that leads into the main body of the phantom. The application of a small amount of petroleum jelly to the O-ring will help ensure that the rotation ball forms a tight seal on the ring. Be careful not to apply too much jelly to the O-ring, because excessive lubrication may cause the ring to slip out of position when the lock nut is tightened. Always remember to loosen the rotation ball lock nut before rotating the tumor ball. If the rotation ball is turned when the nut is tight, the O-ring will be twisted out of position, thereby preventing a proper seal.

## Removing the Tumor Vessel and filling the Phantom



Rotation tumor port

Partial cross section view  
note: ball rotation 26°

Figure 2. The rotation ball port

- |                               |                               |
|-------------------------------|-------------------------------|
| 1. Lock nut for rotation ball | 2. Lock bolt for position rod |
| 3. Rotation ball              | 4. Position rod               |

### Tumor removal

To remove the tumor vessel, the phantom's case should be used to secure the phantom in an inverted position. Begin by removing the rotation ball lock nut. Once this is accomplished, the rotation ball, position rod, and tumor vessel can be lifted out of the phantom as a complete assembly.

### Tumor positioning and filling the head

The following steps are used to place the rotation ball, position rod and tumor vessel into the empty head form. First, position the rotation ball assembly and tumor vessel (or dosimeter) within the head form. Next, loosen the lock bolts on the position rod to insert it through the rotation ball until the rod extends the desired distance into the head form. Tighten the lock bolts when the rod is in the proper position.

Once you have completed the necessary adjustments to the ball, rod, and tumor vessel, remove the intact assembly from the head form and fill the phantom with water. Next, insert the assembly back into the head form and fit the rotation ball lock nut loosely onto the phantom. Rotate the ball until the tumor vessel (or dosimeter) is in the desired position, and tighten the rotation ball lock nut.

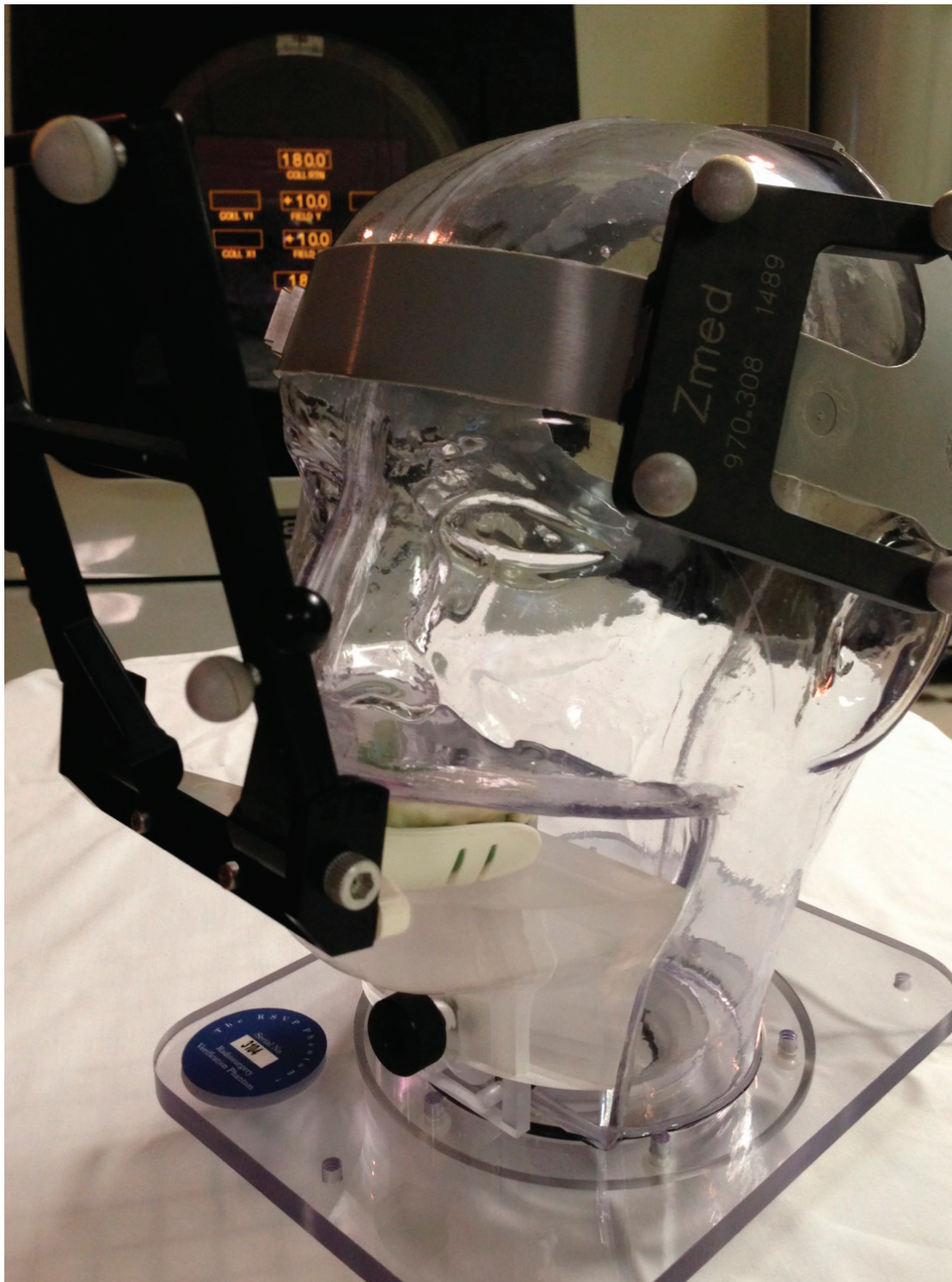
Check for leaks. Small leaks can generally be stopped by tightening the rotation ball lock nut and position rod lock bolt. If you are unable to stop leakage from the rotation ball port, it may be necessary to disassemble the port and check the O-rings to ensure that they are properly seated.

Once the assembly is in the proper position and the phantom is leak-free, you may attach the head frame to the phantom in preparation for scanning.



### Using the bite feature with a dental tray restraining system

The RSVP Phantom bite feature enables a standard size bite tray to be used for immobilization. By loosening the M8 thumb nut the chin can be slid up and down. Follow standard procedures, fill the dental tray with dental caulk and position on the upper phantom teeth, then slide the moving chin up to firmly press against the bottom of the tray. Then remove the tray and allow to harden completely after 5 minutes. After hardening completely the phantom can be positioned.



### Using the head frame

The phantom can also be used the conventional head frame with skull bolts. The case can be used to hold the phantom in an upright position when attaching the radiosurgery head frame, as shown in Figure 3 below.

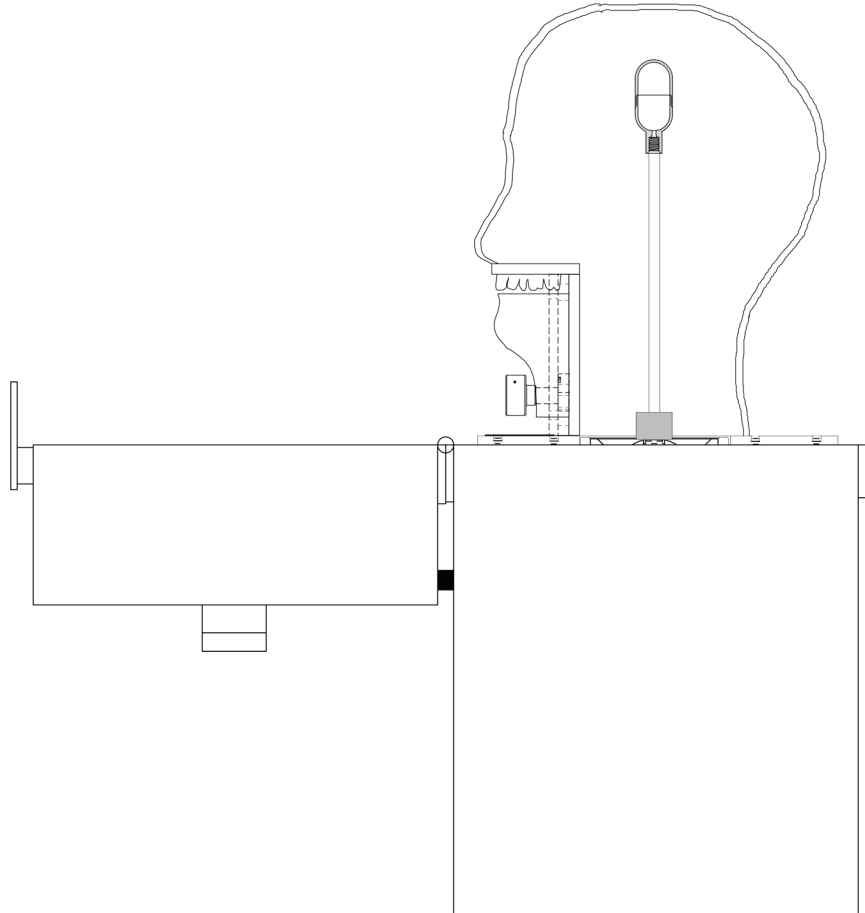


Figure 3. The RSVP Phantom™ Head with Bite Feature secured in an upright position

The head frame of your radiosurgery system should be positioned on the phantom's outer shell just as the frame would be on the patient's head during a radiosurgical procedure. The immobilization screws, on the head frame, may be tightened directly into the CAB plastic. Small dimples may form in the plastic when the screws are tightened, however, these dimples should have no effect on the structural integrity of your phantom. If you have difficulty mounting your radiosurgery head frame to your phantom, please contact The Phantom Laboratory for technical support.

The phantom, head frame, and localization device may now be placed on the imaging table for a scanning procedure. You may find it necessary to use some site-dependent support system to position and secure the phantom, head frame and localization device on your imaging table.

### Filling the tumor vessel

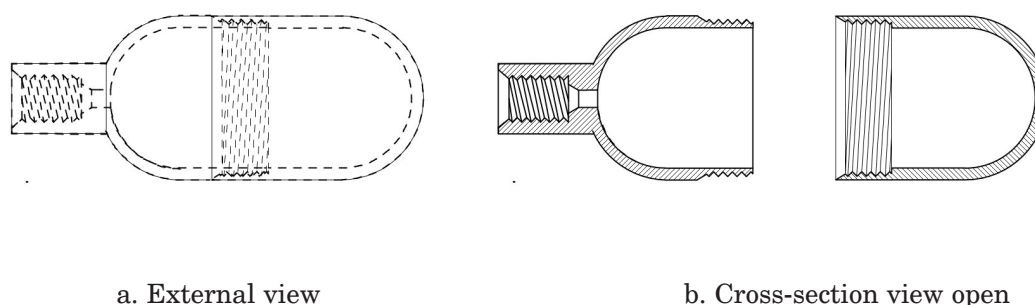


Figure 4. The tumor vessel.

#### Filling tumor vessel with low viscosity liquids

As shown in Figure 4b, the tumor vessel has a small port at the base of the position rod connector. Therefore, you must remove the position rod before adding or removing materials through the port. To fill the tumor vessel with a low-viscosity liquid, you may use a syringe to inject the fluid directly through the port into the tumor vessel. Once the vessel is full, simply rethread the position rod into the connector to close the port.

#### Filling the tumor vessels with high viscosity materials

A different procedure is used for filling the tumor vessel with high-viscosity materials that cannot be readily injected through the port. In such cases, it is necessary to unthread the two halves of the tumor vessel and then place the desired material in each half. While the half of the tumor vessel with male threads should be filled completely with material, the female-threaded half should be filled only to the beginning of the first thread nearest the rounded end. The two halves of the tumor vessel may then be threaded together. Please note that you may set a tumor-simulation mark by inserting a catheter section into the gel before threading the two halves together.

#### Film alignment verification

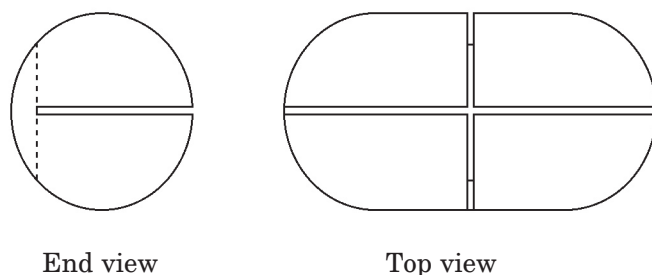


Figure 5. TLP211 5mm plug holder

The TLP227 insert may be used instead of gel for alignment verification. The insert holds film in two planes enabling simultaneous recording of the dose distribution in three dimensions. For alignment verification use a non light sensitive film like the Gafchromic Dosimetry Media.

## Dosimetry gels

The tumor vessel is molded out of Barex® plastic. This plastic is oxygen impermeable. This vessel can be used with a variety of gels. If you prefer not to make your own gel, vessels can be filled by MGS Research Inc. in Guilford CT. 203-453-8679

## Preparing the Ferrous Agarose gel

You may use the following seven-step "recipe" to prepare 50ml of ferrous agarose gel:

WARNING: Beware of any impurities, for example dirt, etc. Impurities will cause the gel to change color prior to irradiation.

- (1) Bring 45ml of triply de-ionized water to a boil.
- (2) Measure 1 gram of agar.
- (3) Add the agar to the boiling water and heat the mixture while stirring continuously for 4 to 5 minutes.
- (4) Remove the mixture from heat and continue stirring for 3 to 4 minutes.
- (5) While the agar mixture is being stirred (step 4), combine 5ml of a ferrous ammonium sulfate solution and 5ml of xylenol orange solution. Directions for preparing these solutions are provided below.
- (6) Once the stirring in Step 4 is completed, add the ferrous ammonium sulfate xylenol orange solution to the agar mixture and stir for an additional 8 to 10 minutes.
- (7) Pour the resulting gel into the two halves of the tumor vessel.

### Original Chemicals Needed:

2 x 10<sup>-4</sup>M Ferrous Ions (Fe<sup>++</sup>)  
 1.5 x 10<sup>-4</sup>M Xylenol Orange  
 5 x 10<sup>-2</sup>N Sulfuric Acid (H<sub>2</sub>SO<sub>4</sub>)  
 1.0% Agar

### Preparing Stock Solutions:

#### Xylenol Orange

- (1) Measure 0.124 grams of xylenol orange.
- (2) Add 100ml of triply de-ionized H<sub>2</sub>O.

#### Ferrous Ammonium Sulfate

- (1) Measure .0784 grams of Fe<sup>++</sup>.
- (2) Add 25ml of H<sub>2</sub>SO<sub>4</sub> (5x 10<sup>-2</sup> Normal).
- (3) Add 75ml of triply de-ionized water.

### Chemical Supply Source:

Fisher Scientific Headquarters, 711 Forbes Avenue, Pittsburgh, PA 15219  
 412-562-8300

Ferrous Ammonium Sulfate crystal [Fe(NH<sub>4</sub>)<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub>·6H<sub>2</sub>O] (Cat.# I77-500)  
 Xylenol Orange Tetrasodium Salt (Cat.# X15-5)

Sigma Chemical Co., St. Louis, MO  
 314-771-5750

Purified Agar (Stock# A-7049)  
 Ferrous Ammonium Sulfate [Fe(NH<sub>4</sub>)<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub>·6H<sub>2</sub>O]  
 Xylenol Orange (Stock# X-3500 Tetrasodium Salt)

## Dose evaluations

Several types of devices may be used to obtain quantitative measurements of the radiation dose delivered to the phantom's tumor vessel. These include TLD chips and radiation-sensitive films, as well as a number of commercially available probes and ionization chambers.

### Thermoluminescent dosimetry (TLD)

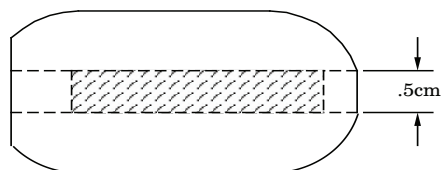


Figure 6. TLP211 5mm plug holder

Note that a standard TLD plug 2.5cm long and 0.5cm diameter (shaded area) has been inserted into the holder.

For TLD measurement, the RSVP Phantom™ may be fitted with the optional TLP211 plug holder, which is designed to hold the standard 25mm by 5mm diameter plugs and capsules used in the RANDO® Phantom. Air gaps in the holder, at either end of the standard Mix D plug can be filled with pieces of RAN235 Mix D plugs by cutting them to length with a sharp knife. Once the plugs with TLD have been inserted, the TLP211 plug holder may be placed into the tumor vessel for positioning.

### Film dosimetry

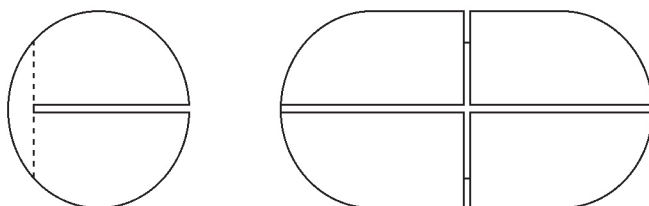


Figure 7. TLP227 Film holder

The TLP227 film holders allows non light sensitive dosimetry film to be placed within the tumor vessel. The TLP227 enables measurements of sagittal or coronal and cross-sectional measurements. The TLP227 insert has 1mm machined slots which hold the film. These slots are not airtight. Physicists concerned about the affect of air on the film dosimetry should use caution when using this insert.

Relative dose measurements may be obtained to evaluate beam profiles and planar iso-dose distributions. A high-quality dosimetry film, such as Gafchromic Dosimetry Media, should be used for film dosimetry measurements. The film must be cut to the proper size and placed in the film holder. The holder is then installed and positioned within the tumor vessel.



**Radiation chambers**

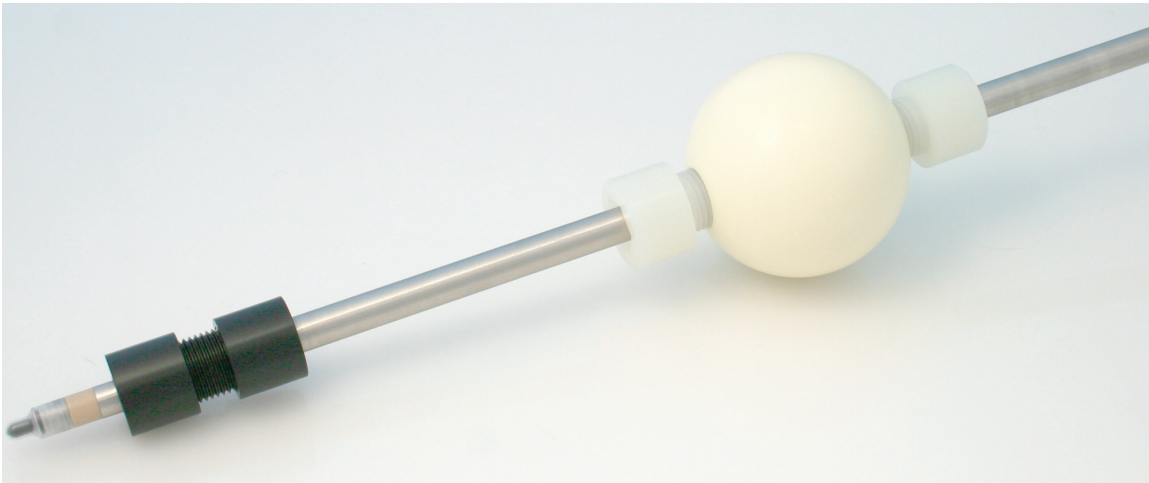
Chambers capable of making direct radiation measurements within the phantom are manufactured by the companies listed below.

Standard Imaging manufactures the Exradin chambers. Special chambers can be ordered from Standard Imaging that will come with long rods capable of passing through the phantom's rotation ball for positioning.

Standard Imaging  
[www.standardimaging.com](http://www.standardimaging.com)

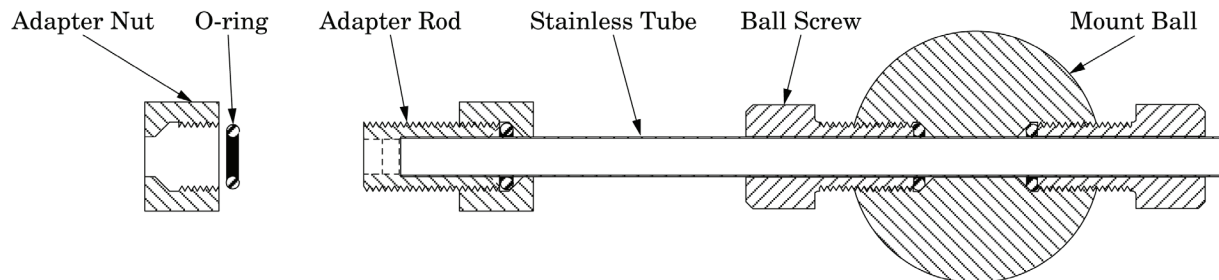
PTW-Freiburg manufactures the PinPoint chambers which can be used in the RSVP phantom with the optional TLP280 adapter. The adapter can be purchased from the Phantom Laboratory.

PTW  
[www.ptw.de](http://www.ptw.de)

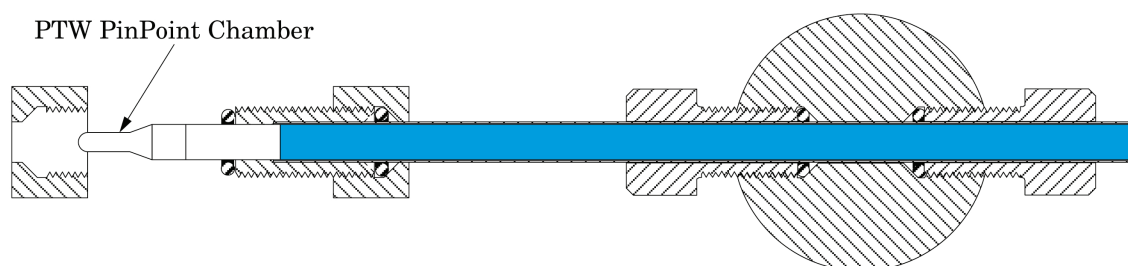


See instructions on next page for TLP280 chamber adapter.

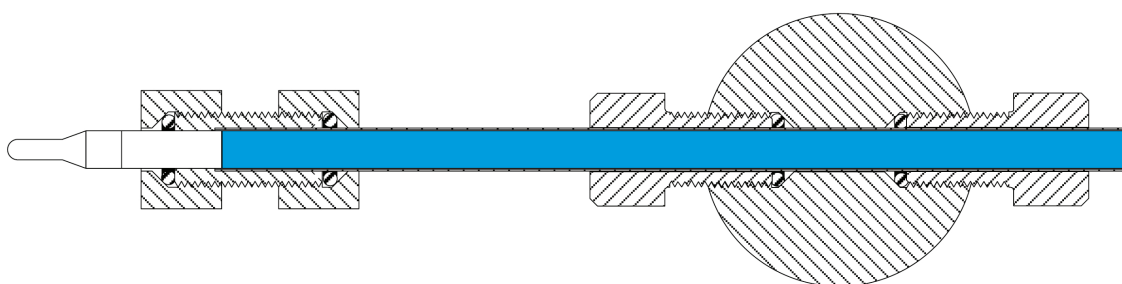
### Using the TLP280 PinPoint chamber adapter



Remove the black adapter nut and O-ring from the end of the adapter rod. Slide the PTW chamber into the tube and through the mount ball to the end of the adaptor rod.



Move the chamber so a portion of the stainless steel part of the chamber is protruding out of the end of the adapter rod as indicated.



Slide O-ring over the chamber so it rests against the adapter rod. Next, reposition the black adapter nut and tighten until it is firmly in place and the chamber is held securely into position.

#### Note:

To adjust the chamber's position in relation to the rotation ball, the ball screws can be loosened and the rotation ball can be slid up or down on the stainless steel tube.

**Chemical compatibility chart**

Reagent Chemicals	Time Exposed	Percent Increase Weight Thickness		Observed Condition of Plastic
Acids				
Acetic, 5%	1 year	3.6	2.1	Slightly softened
Acetic, 10%	2 months	5.2	2.4	Slightly softened
•Acetic, 30%	2 months	13.6	8.6	Softened and swollen
Boric, 5%	2 days	1.3	0.0	Unchanged
Chromic, 6%	8 days (38°C, 100°F)	2.0	0.1	Slightly stained
Citric, 10%	4 months (60°C, 140°F)	1.6	0.8	Slightly softened
Citric, 10%	1 year	1.4	0.6	Unchanged
•Citric, 60%	4 months (60°C, 140°F)	—	—	Surface attacked
Fluosilicic, 10%	2 months	4.5	1.2	Unchanged
Fluosilicic, 28%	2 months	4.7	3.6	Unchanged
Formic, 3%	20 days	—	—	Unchanged
Hydrochloric, 10%	1 year	0.9	0.5	Surface slightly attacked
•Hydrofluoric, 10%	1 month	10.3	5.5	Slightly swollen and softened
•Hydrofluoric, 48%		—	—	Dissolved
Lactic, 50%	2 days	1.6	0.5	Unchanged
•Nitric, 10%	8 months	—	—	Decomposed
Oleic	1 year	2.3	1.5	Unchanged
Phosphoric, 30%	2 months	1.3	0.8	Unchanged
Phosphoric, 50%	2 months	1.6	0.8	Unchanged
•Phosphoric, 75%	2 months	—	—	Partially decomposed
Pyrogallic, 4%	1 week	2.6	1.1	Stained yellow
Stearic	1 week	—	—	Unchanged
Sulfuric, 3%	1 year	1.6	1.0	Slightly discolored
Sulfuric, 10%	1 year	1.5	0.7	Slightly discolored
•Sulfuric, 20%	1 year	0.9	0.3	Slightly softened, surface attacked
•Sulfuric, 30%	1 year	0.4	0.3	Surface attacked
•Sulfuric, 94%		—	—	Disintegrated
Tannic, 10%	4 months (38°C, 100°F)	2.8	1.2	Unchanged
Trichloroacetic, 1%	1 month	3.3	0.5	Unchanged
•Trichloroacetic, 5%	1 month	9.3	3.1	Softened
Alcohols, Monohydric				
n-Amyl	2 days	3.1	3.0	Unchanged
•tert-Amyl	2 days	14.0	11.3	Softened, tacky
•n-Butyl	2 days	6.5	7.2	Swollen
•sec-Butyl	2 days	7.2	10.7	Swollen
•tert-Butyl	2 days	3.6	3.3	Slightly softened
•Diacetone		—	—	Dissolved
•Ethyl (denatured)	2 days	23.0	24.7	Softened
•Ethyl, 50%	1 week	13.4	11.6	Softened
•2-Ethylhexyl	1 week	—	—	Swollen
Hydrocarbons				
Gas, Natural, aromatic-free	1 year	—	—	Showed slight decrease in tensile strength and increase in impact strength
Gas, Natural, 5% aromatic content	23 days	—	—	
				Showed slight decrease in tensile strength and increase in impact strength

•Indicates that material is generally unsatisfactory for use in contact with Tenite butyrate under the conditions of this test



## Chemical compatibility chart continued

Reagent Chemicals	Time Exposed	Percent Increase Weight	Thickness	Observed Condition of Plastic
•Isoamyl	2 days	2.0	2.1	Very slightly softened
•Isopropyl	2 days	23.4	25.1	Softened, tacky
•Methyl		—	—	Dissolved
Methyl, 5%	1 year	2.0	1.2	Slightly softened
•n-Propyl	2 days	15.0	4.4	Slightly softened
•Tetrahydrofurfuryl		—	—	Dissolved
Alcohols, Dihydric and Trihydric				
•Diethylene Glycol	2 months	8.2	6.1	Softened
2-Ethyl Hexanediol-1,3	2 days (38°C, 100°F)	—	—	Unchanged
Ethylene Glycol	1 year	4.2	2.1	Unchanged
Glycerin	1 year	0.0	0.4	Unchanged
Propylene Glycol	2 days	0.4	0.0	Unchanged
•Triethylene Glycol	2 months	8.6	6.7	Softened
Bases				
•Ammonium Hydroxide, 10%	2 months	21.9	12.9	Softened
Calcium Hydroxide, saturated solution	1 week	0.7	0.7	Unchanged
Sodium Hydroxide, 1%	1 year	1.0	0.6	Unchanged
•Sodium Hydroxide, 10%	8 months	3.2	2.2	Brittle
Trimethylbenzyl Ammonium Hydroxide, 5%	17 days	1.1	0.0	Unchanged
Esters				
•n-Butyl Acetate		—	—	Dissolved
•sec-Butyl Acetate		—	—	Dissolved
Di-2-Ethylhexyl Adipate	1 year	0.9	0.3	Unchanged
Di-2-Ethylhexyl Phthalate	1 month (50°C, 122°F)			Small gain
•Ethyl Acetate		—	—	Dissolved
•Ethyl Lactate		—	—	Dissolved
•Ethyl Propionate		—	—	Dissolved
•Ethylene Glycol Monoethyl Ether Acetate		—	—	Dissolved
•Ethylene Glycol Monomethyl Ether Acetate		—	—	Dissolved
•Isoamyl Acetate		—	—	Dissolved
•Isobutyl Acetate		—	—	Dissolved
•Isopropyl Acetate		—	—	Dissolved
•Methyl Acetate		—	—	Dissolved
•n-Propyl Acetate		—	—	Dissolved
Ethers				
•Dichloro Diethyl Ether		—	—	Dissolved
•Diethyl Ether	2 days	46.0	50.0	Considerably swollen
Di-Isopropyl Ether	2 days	0.8	1.1	Unchanged
Ether-Alcohols				
•Ethylene Glycol Monoethyl Ether		—	—	Dissolved
•Ethylene Glycol Monomethyl Ether		—	—	Dissolved
•Toluene	2 days	39.3	54.9	Softened
•Xylene	1 week	41.5	33.2	Softened
Hydrocarbons, Halogenated				
•Carbon Tetrachloride	2 days	14.8	6.8	Surface slightly softened
•Chlorobenzene		—	—	Dissolved
•Chlorobromomethane		—	—	Dissolved
•Chloroform		—	—	Dissolved
•o-Dichlorobenzene	3 days	—	—	Softened and swollen
•p-Dichlorobenzene	3 days	11.1	11.7	Swollen

## Chemical compatibility chart continued

Reagent Chemicals	Time Exposed	Percent Increase Weight	Thickness	Observed Condition of Plastic
•Ethylene Chloride		—	—	Dissolved
•Methylene Chloride		—	—	Dissolved
•Propylene Chloride		—	—	Dissolved
•s-Tetrabromoethane	3 days	—	—	Softened, swollen, and tacky
•Tetrachloroethane		—	—	Dissolved
•Tetrachloroethylene	12 days	—	—	Badly swollen
•Trichloroethylene	1 day	—	—	Badly swollen
Ketones				
•Acetone		—	—	Dissolved
•Cyclohexanone		—	—	Dissolved
•Di-Isopropyl Ketone		—	—	Dissolved
•Methyl Ethyl Ketone		—	—	Dissolved
•Methyl n-Butyl Ketone		—	—	Dissolved
•Methyl Isobutyl Ketone		—	—	Dissolved
•Phorone		—	—	Dissolved
Salts				
Aluminum Acetate, Basic, 33% water slurry	2 months	1.8	0.6	Unchanged
Aluminum Chloride, 10% saturated solution	2 months	1.5	0.7	Unchanged Aluminum Chloride, satu-
Aluminum Sulfate, solid	2 months	0.1	0.0	Unchanged
Ammonium Bifluoride, saturated solution	3 months	1.7	1.1	Unchanged
Ammonium Chloride, saturated solution	1 month	2.3	—	Slightly bleached
Ammonium Nitrate, solid	1 month	2.1	0.8	Unchanged Ammonium Nitrate, solid
Ammonium Sulfate, 10% solution	1 week	0.2	0.2	Unchanged Ammonium Nitrate, 10%
Ammonium Sulfate, 2.5% solution	1 week	1.7	0.8	Unchanged Ammonium Sulfate, solid
Ammonium Sulfate, 40% solution	1 week	0.1	0.6	Unchanged
Ammonium Sulfate, 10% solution	1 year	1.3	0.5	Unchanged
Calcium Chloride, 2.5% solution	1 year	1.5	0.9	Unchanged
Calcium Chloride, 40% solution	2 months	0.4	0.0	Unchanged
Calcium Hypochlorite, 6% solution	1 year	6.0	-3.8	Softened and cracked
Calcium Hypochlorite, 30% solution	13 days	0.8	0.0	Unchanged
Calcium Phosphate, Monobasic, solid	1 year	1.7	0.5	Unchanged
Calcium Phosphate, Dibasic, solid	1 year	- 0.6	0.6	Unchanged
Calcium Phosphate, Tribasic, solid	1 year	- 0.6	0.6	Unchanged
Heptane	1 year	1.6	2.5	Unchanged
Hexane	1 week	—	—	Unchanged
Propane, gas	2 months	0.3	0.6	Unchanged
Propane, liquid	2 months	1.4	4.6	Unchanged
Calcium Sulfate (Gypsum), solid	1 year	- 0.1	0.6	Unchanged
Copper Sulfate (Cupric), 10% solution	2 months	1.7	0.6	Unchanged
Copper Sulfate, saturated solution	2 months	1.7	0.9	Unchanged
Cuprous Chloride, solid	1 week	1.5	—	Unchanged
Ferric Ammonium Sulfate, solid	1 week (38°C, 100°F,	0.3	—	Unchanged
80% RH) Ferric Chloride, 5% solution	2 months	2.0	0.8	Unchanged

Ferric Chloride, 20%	2 months	1.7	1.0	Unchanged
Ferric Chloride, 40%	2 months	1.3	0.4	Unchanged

## Chemical compatibility chart continued

Reagent	Time Exposed	Percent Increase Weight	Thickness	Observed Condition of Plastic
Ferric Chloride, saturated solution	1 month	0.9	0.3	Unchanged
Lithium Bromide, solid	1 week	-	0.7	0.0
Lithium Bromide, 50%	1 week	0.0	0.0	Unchanged
Lithium Bromide, 2.5%	2 days	1.6	1.0	Unchanged
Potassium Aluminum Sulfate (alum), 21%	4 months (38°C, 100°F)	1.9	0.8	Unchanged
Potassium Bromide, 3%	3 days (38°C, 100°F)	1.3	—	Unchanged
Potassium Chloride, solid	1 year	0.1	0.5	Unchanged
Potassium Chloride, 10%	1 year	1.7	0.4	Unchanged
Potassium Chloride, 10%	1 year	1.3	—	Unchanged
Potassium Cyanide, 10%	2 months	1.4	0.3	Slightly discolored (brown)
Potassium Cyanide, saturated solution	2 months	0.5	0.0	Slightly discolored (brown)
Potassium Ferricyanide, 10%	4 days	—	—	Unchanged
Potassium Sulfate, solid	1 year	0.1	0.6	Unchanged
Potassium Sulfate, 10%	1 year	1.4	0.4	Unchanged
Silver Nitrate, 2.5%	2 days	1.5	0.0	Unchanged
Sodium Acetate, 3%	3 days (38°C, 100°F)	1.3	—	Unchanged
Sodium Aluminum Sulfate, solid	1 week	1.6	0.4	Unchanged
Sodium Bicarbonate, 2.5%	2 days	1.7	0.5	Unchanged
Sodium Bisulfate, solid	1 week (38°C, 100°F, 80% RH)	0.1	—	Unchanged
Sodium Bisulfate, 1%	3 days (38°C, 100°F)	1.3	—	Unchanged
Sodium Bisulfite, 20%	1 week	2.1	0.8	Unchanged
Sodium Borate, 2.5%	2 days	1.5	0.5	Unchanged
Sodium Carbonate, solid	1 week (38°C, 100°F, 80% RH)	3.9	—	Unchanged
Sodium Carbonate, 2.5%	1 year	1.3	0.9	Unchanged
Sodium Carbonate, 10%	1 year	1.2	—	Unchanged
Sodium Chloride, 2.5%	1 year	—	—	Unchanged
Sodium Chloride, 10%	1 year	1.3	0.5	Unchanged
Sodium Chloride, saturated solution	2 months	0.8	0.3	Unchanged
Sodium Chloride, saturated solution	2 months (60°C, 140°F)	0.9	0.9	Unchanged
Sodium Chromate, saturated solution	1 week	0.6	0.2	Unchanged
Sodium Cyanide, 10%	2 months	1.0	0.3	Unchanged
Sodium Cyanide, saturated solution	2 months	- 0.2	- 0.4	Unchanged
Sodium Ferrocyanide, solid	1 week	0.8	—	Unchanged
Sodium Fluoride, 4%	1 month	2.5	—	Unchanged
Sodium Hypochlorite, 30%	13 days	1.1	- 2.1	Unchanged
Sodium Nitrate, solid	2 months	0.1	0.1	Unchanged
Sodium Nitrate, 10%	1 year	1.2	0.4	Unchanged
Sodium Nitrate, saturated solution	2 months	0.9	0.4	Unchanged
Sodium Silicate, solid	2 months	0.3	0.2	Unchanged
Sodium Silicate, saturated solution				

2 months      1.2      0.1      Unchanged

# Chemical compatibility chart continued

Reagent	Time Exposed	Percent Increase Weight	Thickness	Observed Condition of Plastic
Sodium Sulfite, 10%	1 week	2.1	0.9	Unchanged
Sodium Thiosulfate, 20%	13 days	1.1	0.0	Unchanged
Sodium Thiosulfate, 24%	3 days (38°C, 100°F)	1.2	—	Unchanged
Tetra (2-Ethylbutyl) Silicate	1 month (50°C, 122°F)	0.7	0.1	Unchanged
Trimethyl Benzyl Ammonium Chloride, 5%	17 days	1.1	0.1	Unchanged
Zinc Chloride (hydrous salt)	1 week	0.5	0.0	Unchanged
Zinc Chloride, saturated solution	1 week	1.4	0.8	Slightly etched
Zinc Oxide, solid	1 week	—	—	Unchanged
Miscellaneous Chemicals and Gases				
Ammoniated Mercury	1 week (60°C, 140°F)	—	—	Unchanged
•Aniline		—	—	Dissolved
•Benzaldehyde		—	—	Dissolved
•Butadiene-1,3, liquid	6 months	19.3	26.4	Swollen and softened
Butadiene-1,3, gas	1 month	2.7	2.3	Unchanged
•Carbon Disulfide	1 week	25.8	1.6	Softened and swollen
•Carbon Disulfide, saturated atmosphere	2 days	17.4	11.8	Warped
•Chlorine, dry	1 week	8.8	2.2	Crazed and brittle
•Chlorine, moist	1 week	7.8	0.1	Crazed and brittle
•Chlorine, saturated solution	1 week	—	—	Considerably softened and swollen
•1,4-Dioxane		—	—	Dissolved
Ethylene Oxide, gas	10 minutes (41°C, 105°F)	—	—	Unchanged
•Ethylene Oxide, gas	1 day	20.9	25.6	Swollen and softened
Formaldehyde, 4%	10 min per day	0.2	—	Unchanged for 5 days
•Formaldehyde, 35%	2 months	13.0	6.7	Swollen and softened
•Furfural		—	—	Dissolved
Hydrogen Peroxide, 3%	1 year	1.7	1.1	Unchanged
Hydrogen Peroxide, 5%	2 days	1.4	1.3	Unchanged
Hydrogen Sulfide, dry	2 months	2.3	0.8	Unchanged
Hydrogen Sulfide, moist	2 months	3.0	1.7	Unchanged
Hydrogen Sulfide, saturated solution	2 months	5.9	2.3	Unchanged
Hydroquinone, 20 g per gallon	1 week	2.4	1.0	Slightly stained yellow
•Methyl Methacrylate Monomer		—	—	Dissolved
•Nitrobenzene		—	—	Dissolved
Ozone, 0.05-0.15 ppm	45 days (outdoors)	—	—	Unchanged
Ozone, 0.7 ppm	45 days (49°C, 120°F)	—	—	Yellowed
•Phenol	1 week	—	—	Decomposed
•Styrene Monomer		—	—	Dissolved
Sulfur, solid	1 week	—	—	Unchanged
•Sulfur Dioxide, dry	2 months	19.4	8.6	Swollen, slightly warped
•Sulfur Dioxide, moist	2 months	31.9	10.2	Considerably swollen and warped

- Sulfur Dioxide, saturated 2 months 23.2      18.1      Swollen and warped

#### Chemical compatibility chart continued

Reagent	Time Exposed	Percent Increase		Observed Condition of Plastic
		Weight	Thickness	
•Sulfur Dioxide in Hydrocarbons		—	—	Dissolved
•Sulfur Dioxide and Hydrocarbon Vapor				
	2 months	19.2	11.5	Swollen
•Titanium Tetrachloride 3 days		—	—	Very brittle
Trinitrotoluene (TNT), water slurry				
	4 weeks	—	—	Stained

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