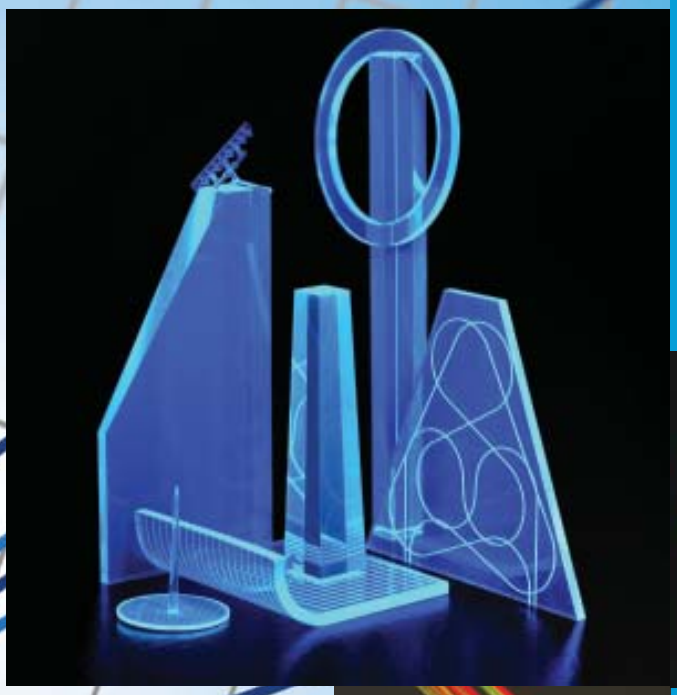
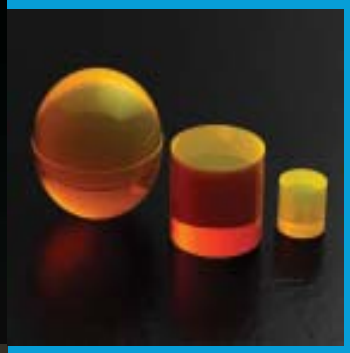
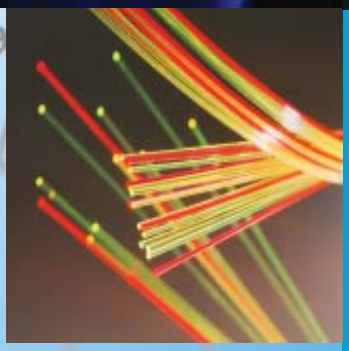
Scintillation Products







Organic Scintillators

SAINT-GOBAIN
CRYSTALS

Contents —

About Saint-Gobain Crystals

Saint-Gobain is a global leader in the manufacture and development of engineered materials such as glass, insulation, reinforcements, containers, building materials, ceramics and plastics. The formation of the Crystals Division reinforces Saint-Gobain's commitment to the development of high performance materials.

Saint-Gobain Facts –

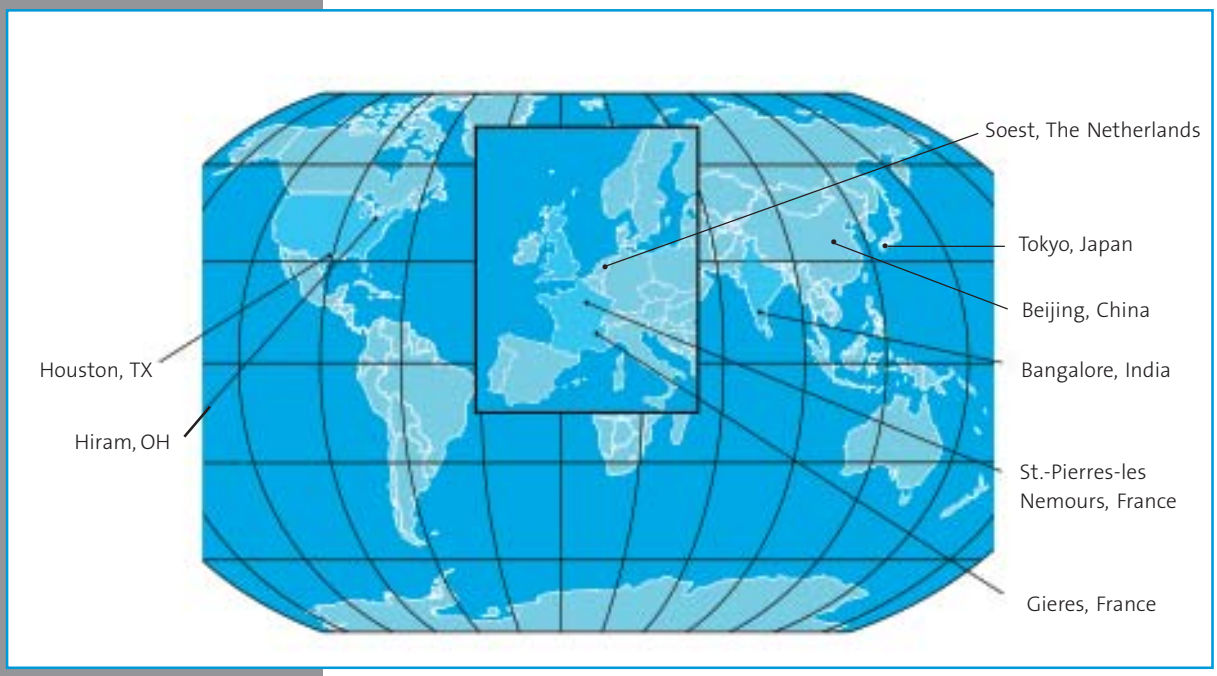
- Established in 1665.
- The first major project was the production of the mirrors for the famous Hall of Mirrors in Versailles Palace.
- Today the Saint-Gobain group is listed among the 100 largest industrial groups worldwide.
- Produces 30 billion glass bottles each year.
- Supplies half of Europe's cars with glass.
- Insulates one-third of all USA homes.

The Scintillation Products business of the Division is a combination of companies that have been prominent in crystal growth or in radiation detection and measurement. Notable names include: Bicron, Harshaw/STI, Crismatec, and NE Technology (inorganic and organic scintillators and detectors); Gamma Laboratories and TGM (gas-filled radiation detectors).

Being a part of Saint-Gobain brings us the long-term industrial strategy and investment benefits of such a dynamic group. There is a coherence centered on materials, applied to increasingly diversified needs. Saint-Gobain encourages research and development and the expansion of relevant technologies and their applications.

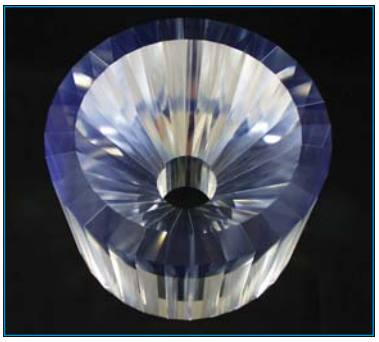
The product line featured in this catalog is made up of our premium plastic scintillators, liquid scintillators, plastic scintillating fibers and related materials. All of our premium plastic scintillators are made of a base of polyvinyltoluene or styrene plus various fluors, which are selected to give each scintillator its characteristic response. Highly purified monomers are the bases for all of our materials, which assures maximum homogeneity and highest quality.

Individual product data sheets are available for each material type. Custom detectors using our plastic or combinations of our plastic and inorganic scintillators are available. We welcome your inquiry for special shapes or custom designs.



Plastic Scintillators

A plastic scintillator consists of a solid solution of organic scintillating molecules in a polymerized solvent. The ease with which they can be shaped and fabricated makes plastic scintillators an extremely useful form of organic scintillator.



General Description –

The scintillation emission of a typical plastic scintillator has a maximum around 425 nm. Plastic scintillators are characterized by a relatively large light output — typically 25-30% of NaI(Tl) — and a short decay time of around 2 ns. This makes the material suited for fast timing measurements.

All plastic scintillators are sensitive to X-rays, gamma rays, fast neutrons and charged particles.

Special formulations are available for thermal neutron detection or with improved X-ray efficiency. Plastic scintillators are the most popular scintillation material for use in calorimeters, time of flight detectors, nuclear gauging and large area contamination monitors.

The exact emission wavelength and decay time depend on the type of organic activator and on the host material. A large number of different plastic scintillators are available, each for a specific application. General characteristics of plastic scintillators are presented in another section of this brochure.

Availability –

Our plastic scintillators are produced in a wide variety of shapes and sizes. Cast sheets are the most commonly used forms.

You also can obtain precision thin sheets, thin film, rods, annuli, ingots and large rectangular blocks, filaments, powders and beads.

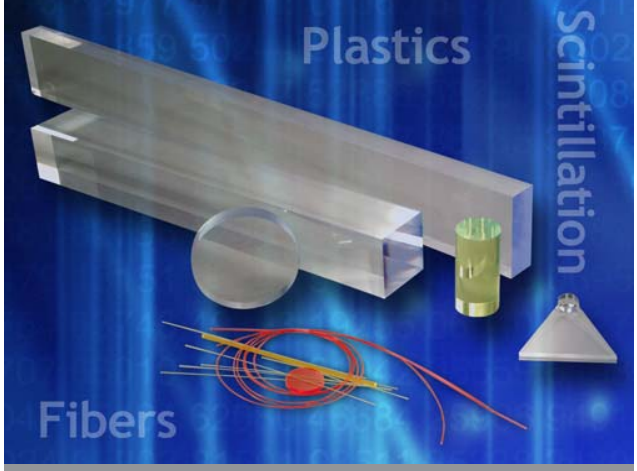
We supply most solid scintillators with their surfaces prepared to optimize light collection. For cast sheets, the cast surfaces are untouched, and the edges are machined and polished or diamond milled.

Rods, annuli and blocks are machined and polished, or coated with a diffuse reflector paint such as BC-620. Such a reflector is used only when there are few reflections of the scintillation light off the scintillator surfaces before the light reaches the PMT. Most applications require finished surfaces.

You can also obtain scintillators as finished detector assemblies. These incorporate light guides, photomultiplier tubes, special radiation entrance windows, and light tight wrappings (or metal housings). Assemblies integrated with light-sensing devices can be made as well.

Plastic Scintillator Applications Guide

Scintillator	Distinguishing Feature	Principal Applications
BC-400	NE-102 equivalent	general purpose
BC-404	1.8 ns time constant	fast counting
BC-408	best general purpose	TOF counters; large area
BC-412	longest attenuation length (NE-110 equivalent)	general purpose; large area; long strips
BC-414		use with BC-484 wavelength shifter
BC-416	lowest cost	“economy” scintillator; large volume
BC-418	1.4 ns time constant	ultra-fast timing; small sizes
BC-420	1.5 ns time constant, low self-absorption	ultra-fast timing; for sheet areas > 100mm^2
BC-422	1.4 ns time constant	very fast timing; small sizes
BC-422Q	quenched; 0.7 ns time constant	ultra-fast timing, ultra-fast counting
BC-428	green emitter	for photodiodes and CCDs; phoswich detectors
BC-430	red emitter	for silicon photodiodes and red-enhanced PMTs
BC-436	deuterated	fast neutron
BC-440	high temperature up to 100°C	general purpose
BC-440M	high temperature up to 100°C	general purpose
BC-444	slow plastic, 285 ns time constant	phoswich detectors for dE/dx studies
BC-444G	285 ns time constant; green emitter	phoswich detectors for dE/dx studies
BC-452	lead loaded (5%)	x-ray dosimetry (<100 keV); Mossbauer spectroscopy
BC-454	boron loaded (5%)	neutron spectrometry; thermal neutrons
BC-490	casting resin scintillator	general purpose
BC-498	applied like paint	beta, gamma detection
BC-480	UV to blue waveshifter	Cerenkov detector
BC-482A	green emitter	waveshifter



Thin Films –
Thin films are ideally suited for charged particle detection and fast timing applications. We supply thin films in the following blue-emitting (410 to 430 nm) scintillator formulations:

- BC-400 General purpose
- BC-404 Highest light output; ideal for beta detection
- BC-418 Fast timing material with decay time of 1.4 ns
- BC-422 Fast timing material with decay time of 1.6 ns

BC-490 Plastic Scintillator Casting Resin –

BC-490 is a partially polymerized plastic scintillator that can be cured to full hardness by the end user. The scintillator thus formed is clear, with scintillation and mechanical properties similar to those of our general purpose plastic scintillators. It is most frequently used in applications that require other materials to be imbedded in the scintillator and those that require unique shapes to be cast, often in special holders.

BC-490 is supplied in complete kits with detailed instructions. Each kit contains three parts: partially polymerized scintillator resin, catalyst and catalyst solvent.

A green-emitting version, BC-490G, is also available.

Plastic Scintillators

Plastic sheets cast from the monomer ensure the highest light yield and best internal light transmission. All raw materials undergo extensive purification prior to polymerization and the finished sheets exhibit highly uniform scintillation and optical properties. Scintillators are machined to final dimensions using diamond tooling to provide optimum quality surfaces for total internal reflection.

Standard Cast Sheet Sizes

Thickness*	Thickness Tolerance	Routine Maximum**
1 mm	± 0.1 mm	30 x 60 cm
1.5 mm	± 0.25 mm	30 x 101 cm
2 mm	+ 0.25/ -0.3 mm	45 x 101 cm
3 mm	± 0.38 mm	63 x 101 cm
5 mm	+ 0.56/ -0.46 mm	63 x 203 cm
6.4 mm	+ 0.64/ -0.51 mm	63 x 203 cm
10 mm	± 0.51 mm	63 x 203 cm
12.7 mm	± 0.64 mm	63 x 203 cm
20 mm	± 0.73 mm	63 x 203 cm
25 mm	+ 0.76/ -1 mm	63 x 203 cm
38 mm	± 0.76 mm	63 x 203 cm
50 mm	± 2 mm	63 x 203 cm
75 mm	± 2.5 mm	60 x 101 cm
100 mm	± 3.8 mm	60 x 101 cm
125 mm	± 6 mm	60 x 101 cm
150 mm	± 6 mm	60 x 101 cm

* This dimension is controlled during the casting process
** Large sizes available, but with different tolerances

Special Large Cast Sheet

Thickness Range	Maximum Width	Maximum Length
1 - 5 cm	30 cm	500 cm
0.5 - 5 cm	45 cm	400 cm
0.5 - 5 cm	60 cm	300 cm
1 - 2.5 cm	100 cm	200 cm
1 - 3.8 cm	120 cm	120 cm

Please ask about other special sizes you may need

Thin Film Specifications (Typical Size)

Thickness Range	Tolerance Range	Sheet Size W x L
.5 - 1.0 mm	±10%	250 x 250 mm
.22 - .49 mm	±10%	225 x 225 mm
.11 - .21 mm	±10%	150 x 200 mm
.04 - .10 mm	±15%	150 x 200 mm
.010 - .039 mm	±20%	150 x 200 mm

- Edges are trimmed or polished (upon request)
- Other scintillators available

BC-702 Thermal Neutron Detector –

BC-702 is a highly-efficient scintillation detector for thermal neutrons, with excellent gamma background discrimination characteristics. The detector material incorporates a lithium compound (enriched to 95% ^{6}Li) matrix dispersed in a fine ZnS(Ag) phosphor powder.

The detector is a 6.35 mm thick disk available in 35 mm, 50 mm, 76 mm and 127 mm diameters. The disk can be mounted directly to a photomultiplier tube or light guide and surrounded by an appropriate moderator.

BC-720 Fast Neutron Detector –

BC-720 scintillator is designed specifically for detecting fast neutrons (above 1 MeV) while being insensitive to gamma radiation. The detector is a plastic disk 15.9 mm thick available in 38 mm, 50 mm, 76 mm and 127 mm diameters. It may be coupled directly to a photomultiplier tube or light guide with a variety of optical greases or epoxies.

BC-704 and BC-705 for Neutron Radiography –

The BC-704 detector is a phosphor screen based on ZnS(Ag) and ^{6}Li and originally manufactured and sold under the number NE-426.

Its wavelength of maximum emission is 450 nm (blue light).

BC-704 is a flat and usually rectangular detector which is non-hygroscopic. The standard screen is mounted on a 1 mm thick aluminum plate, but an unmounted, semi-rigid screen can be supplied on request.

The image from BC-704 may be recorded by one of three methods: (1) photographic film; (2) position-sensitive photomultiplier; (3) TV camera and video recorder.

Absolute scintillation efficiency = approximately 27 eV/photon; each stopped thermal neutron will liberate 1.75 x 10^{5} photons; absolute scintillation efficiency = 9%.

Gamma-ray sensitivity: number of gamma photons giving same light output as one neutron = 4,500 for ^{226}Ra, 1,000 for ^{137}Cs, 450 for ^{60}Co.

The composition and properties of BC-705 are the same as those of BC-704, except that the zinc sulfide is activated with copper, i.e., ZnS(Cu). This lengthens the wavelength of maximum emission to 525 nm (green light) which is more suitable for use with some image intensifiers.

Special Scintillators for Neutrons

Our Zinc Sulfide based plastic scintillators are formulated for the efficient detection of neutrons in the presence of gamma radiation. The chart below compares these specialized detectors to our other neutron detector materials.

Monoline Style Detector Specifications

Housing	0.5 mm thick aluminum
Finish	Clear anodized
PMT	Bialkali photocathode, same diameter as detector disk
Light shield	Satin chrome mu-metal
Base	12-pin (38 mm PMT) or 14-pin phenolic
Operating polarity	Positive
Vacuum capability	No, but can be made for use in vacuum, if required
Operating temperature	+4°C to +40°C @ 10°C/hour rate-of-change

You can obtain complete detector assemblies for both BC-702 and BC-720 scintillators.

Neutron Detectors Table of Comparison

Scintillator	Type	Decay Time ns	Fast n	Thermal n	Gamma Ray Response	Loading Elements
BC-702	disc	110		x	very small	^{6}Li
BC-704	rectangular	110		x	very small	^{6}Li
BC-720	disc	110	x		very small	H
GS20	glass	various	x	x	small	^{6}Li
KG2	glass	various	x	x	small	^{6}Li
BC-400	plastic	2.4	x		yes	H
BC-501A	liquid	3.2	x		yes	H
BC-509	liquid	3.1	x		yes	F
BC-523A	liquid	3.7		x	yes	^{10}B
BC-525	liquid	3.8	x	x	yes	Gd

Optical Plastic Components

Light guides are used to convey scintillation photons to the readout device. Key performance parameters are good optical transmission across a broad range of wavelengths and highly polished surfaces to promote total internal reflection. All light guides are custom designed to suit the particular scintillator geometry and experimental constraints.

Light Pipes –

Plastic light pipes often are used with plastic and liquid organic scintillators to:

- Provide a PMT mounting surface
- Guide the scintillating light to the photocathode
- Back-off the PMT where the scintillator is in a strong magnetic field
- Minimize pulse height variation

Typical light pipe geometries include:

- Right Cylinders - used when the light pipe diameter is the same as the scintillator diameter
- Tapered Cones - are transition pieces between square-to-round or round-to-round cross-section. "Fish Tail" - are transition pieces from thin, rectangular cross-sections to round cross-sections
- Adiabatic - provide the most uniform light transmission from the scintillator exit end to the PMT; the cross-sectional areas of the input and PMT faces are equal

We recommend that, for scintillators <6 mm thick, a fish tail light pipe have a groove machined into its edge which joins the scintillator. The scintillator edge fits into the groove to improve the mechanical strength of the joint. Also, a disk which matches the diameter of the PMT is coupled to the light pipe's other end to act as the PMT mounting surface.

The length of a fish tail or adiabatic light pipe is generally equal to the width of the scintillator, for scintillators 15.2 cm wide or greater.

The light pipe materials we use include

- BC-800 UVT acrylic - for scintillators with emission spectra in the near UV, such as NaI(Tl), BC-418, BC-420 and BC-422
- BC-802 general purpose, non-UVT, PMMA plastic - for most scintillators

Wavelength Shifter Bars –

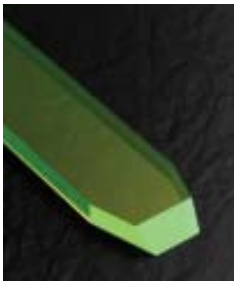
Wavelength shifter (WLS) plastic bars absorb light at one wavelength and emit it isotropically at a longer wavelength. A portion of the re-emitted light is transmitted by total internal reflection along the WLS bar to be read out at the ends.

Often used with scintillator shower stacks, single WLS bars are air-coupled to a stack or plane of scintillator strips. The scintillation light is essentially turned 90° in a very compact structure. However, there is a typical 75% loss of signal amplitude in such a system.

We make wavelength shifter bars from PMMA- and PVT-based materials. These include:

- BC-480 - shifts from near UV (300-360 nm) to 425 nm
- BC-482A - shifts from 420 to 500 nm; for use with BC-408 and BC-412 plastic scintillators
- BC-484 - shifts from 380 to 435 nm; for use with BC-414 plastic scintillator

We also supply WLS optical fibers.



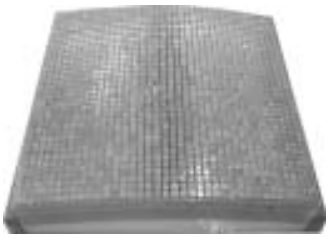
Plastic Scintillating Fibers

We produce a variety of plastic scintillating, wavelength-shifting and light-transmitting fibers. They are available in bulk quantities wound on spools (smaller cross-sections) and as canes (pre-cut straight lengths), or assembled into stacked arrays, bundles, ribbons and complete detectors.

Current sizes range from 0.25 mm to 5 mm square or round cross-sections.

The flexibility of fibers allows them to conform to surface shapes, yielding geometries superior to those of other types of detectors. Examples are detectors for monitoring pipes or barrels.

For more information, call for a copy of our Scintillating Fibers brochure.



Our typical fiber has a PMMA cladding. The core contains a combination of fluorescent dopants selected to produce the desired scintillation, optical and radiation-resistance characteristics.

Common Properties of Single-clad Fibers –

Core material ..... Polystyrene
Core refractive index 1.60
Density 1.05
Cladding material ..... Acrylic
Cladding refractive index 1.49
Cladding thickness, round fibers ... 3% of fiber diameter
Cladding thickness, square fibers .. 4% of fiber size
No. of H atoms per cc (core) ..... 4.82×10^{22}
No. of C atoms per cc (core) ..... 4.85×10^{22}
No. of electrons per cc (core) ..... 3.4×10^{23}
Operating temperature ..... -20°C to +50°C
Vacuum compatible ..... Yes

Common Properties of Multi-clad Fibers –

Second cladding material ..... Fluor-acrylic
Refractive index 1.42
Thickness, round fibers ..... 1% of fiber diameter
Thickness, square fibers ..... 2% of fiber size
Numerical aperture 0.74
Trapping efficiency, round fibers ... 5.6% minimum
Trapping efficiency, square fibers .. 7.3%

Specific Properties of Standard Formulations

Fiber	Emission Color	Emission Peak, nm	Decay Time, ns	1/e Length m*	# of Photons per MeV**	Characteristics/ Applications
BCF-10	blue	432	2.7	2.2	~8000	General purpose; optimized for diameters>250µm
BCF-12	blue	435	3.2	2.7	~8000	Improved trans-mission for use in long lengths
BCF-20	green	492	2.7	>3.5	~8000	Fast green scintillator
BCF-60	green	530	7	3.5	~7100	3HF formulation for increased hardness
BCF-91A	green	494	12	>3.5	n/a	Shifts blue to green
BCF-92	green	492	2.7	>3.5	n/a	Fast blue to green shifter
BCF-98	n/a	n/a	n/a	n/a	n/a	Clear waveguide

* For 1mm diameter fiber; measured with a bialkali cathode PMT
** For Minimum Ionizing Particle (MIP), corrected for PMT sensitivity

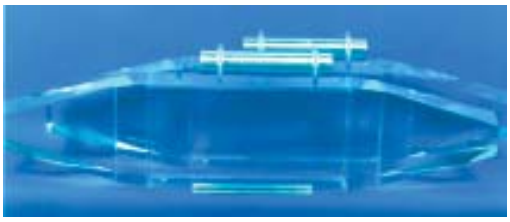
Liquid Scintillators

General Description –

Liquid scintillators have many applications in neutron and gamma detection. They also provide low-cost alternatives to other scintillators in applications where large volumes are required.

Different base materials produce Pulse Shape Discrimination properties, high flash point, performance at low or high temperatures, or other properties. Some scintillators are loaded with organo-metallic compounds to increase their neutron or photon cross-sections. Certain formulations are designed to be economical in large volumes. Liquid scintillator concentrates designed to be diluted on site are available.

Liquid scintillators should be sealed in clean, dry, chemically inert containers. Prior to use, they are deoxygenated to assure that the scintillators achieve their optimum performance.



Liquid Scintillators Application Guide

Scintillator	Distinguishing Features	Principal Application
BC-501A	excellent pulse shape discrimination properties	γ >100 keV, fast n spectrometry
BC-505	highest light output, transmission; high flash point	γ, fast n for large volume detectors
BC-509	negligible hydrogen content; neutron insensitive	γ, fast n
	BC-517 and 519 series are mineral oil based scintillators	*for large tanks[1] and acrylic containers*
BC-517L	standard formulation	γ, fast n, cosmic, charged particles
BC-517H	high light output standard formulation	γ, fast n, cosmic, charged particles
BC-517P	lowest cost, highest H content, high light transmission, chemical inertness, highest flash point	γ, fast n, cosmic, charged particles
BC-517S	highest light output of mineral oil based scintillators	γ, fast n, cosmic, charged particles
BC-519	pulse shape discrimination properties	γ, fast n; n-γ discrimination
BC-521	Gd loaded	neutron spectrometry, neutrino research
BC-523A*	^{10}B loaded; pulse shape discrimination properties	total absorption neutron spectrometry
BC-525	Gd loaded; mineral oil base	neutron spectrometry, neutrino research, for large acrylic tanks
BC-531	high H content; high light output; high flash point; moderate cost, for plastic tanks	fast n, cosmic
BC-533	for low temperatures, high flash point, low cost large volume detectors	γ, fast n, cosmic
BC-537	deuterated benzene base	fast n; pulse shape discrimination
BC-551	lead loaded, xylene base	γ, X-rays <200 keV
BC-553	tin loaded	γ, X-rays

[1]Large tank = volume >40 liters
*Natural boron loaded scintillator = BC-523

Liquid Scintillator
Bicrocells

Our liquid scintillators are available sealed within Bicrocells. Bicrocells are containers, usually made of glass or aluminum, with at least one ground-and-polished port available for viewing by a PMT. The scintillators are deoxygenated for improved stability and light output; and, the Bicrocells have expansion reservoirs containing oxygen-free nitrogen to maintain this condition.

Unless otherwise instructed, glass Bicrocells will be coated with a diffuse white reflector. Non-glass Bicrocells will have an internal white reflector. The reflector and construction materials are selected for long-term compatibility. Aluminum Bicrocells have a clear-anodized surface treatment.

For applicable scintillators, we provide neutron source and pulse shape discrimination test measurements.

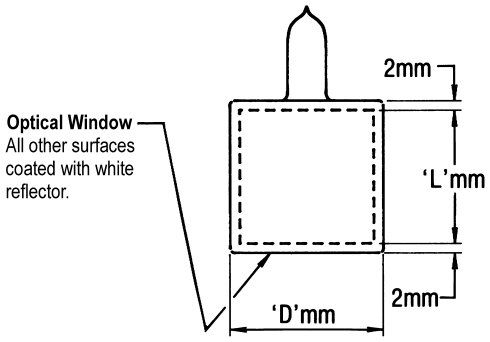
Other geometric shapes are available, including regular and tapered hexes.

Housing Material	Bicrocell Model	Description
Glass	VB-1	Vertical orientation only; one PMT viewing port
	HB-1, 2	Horizontal orientation only; one or two PMT viewing ports
	TPB-1, 2	Horizontal or vertical orientation; one or two PMT viewing ports

Housing Material	Bicrocell Model	Description
Aluminum	MVB-1	Vertical orientation only; one PMT viewing port
	MAB-1F	Any orientation; one PMT viewing port; mounting flange
	MAB-2F	Any orientation; two PMT viewing ports; mounting flange
	MTP-1	Horizontal or vertical orientation; one PMT viewing port

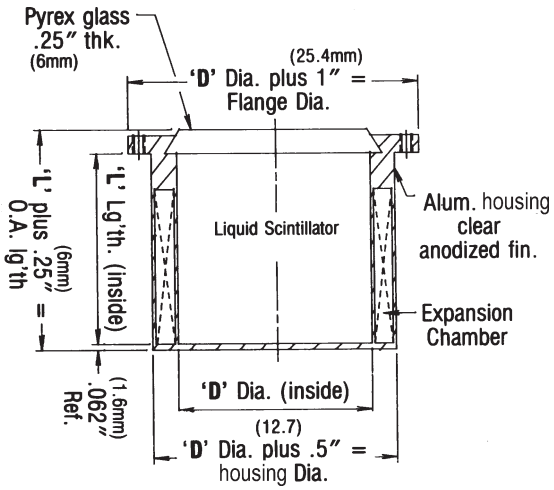
Other Configurations –
Cells can be assembled with a demountable PMT; and other non-standard designs are possible. Glass scintillators may be added to produce composite configurations. Ruggedized designs are also available.

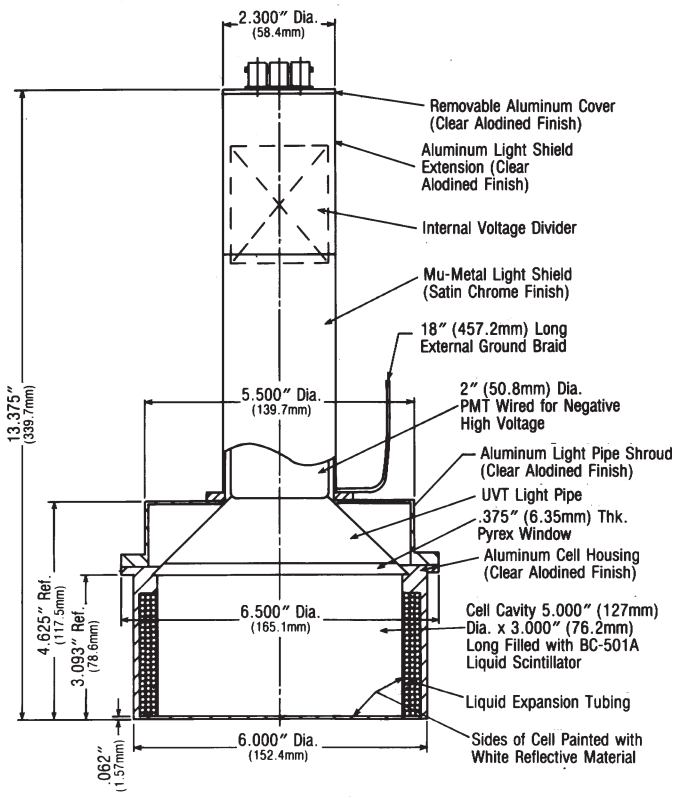
We can also produce cells made of acrylic in various shapes and sizes (usually for large-area detectors). The expansion reservoir and any light guides or PMTs are mounted to exterior surfaces of these cells.



Vertical Bicrocell Model VB-1
For vertical viewing, all glass, one port, gas reservoir at top, reflector on all surfaces except viewing port.

Model MAB-1F Aluminum Bicrocell





Model MAB-1FBC-501A/2L-X cell

Detector Assembly Material
Optical Interface and Wrapping Materials, Reflector Paints

1 BC-600 Optical Cement –
BC-600 optical cement is a clear epoxy resin which sets at room temperature and has a refractive index close to that of our premium plastic scintillators. It is therefore ideal for optically cementing these scintillators to light pipes or optical windows. It is not recommended for coupling scintillators to photomultiplier tubes. For that application we recommend BC-630.

2 BC-630 Silicone Optical Grease –
BC-630 is a clear, colorless, silicone, optical coupling compound which features excellent light transmission and low evaporation and bleed at 25°C. It has a specific gravity of 1.06 and an Index of Refraction of 1.465.

We supply this single-component formulation in 60 ml jars or in 500 ml quantities.

3 BC-634A Optical Interface –
BC-634A is an optical interface material which gives you a consistent, reproducible, optical coupling between scintillators and PMTs. It is formulated for use within the temperature range of -10°C to +60°C.

We supply BC-634 as ready-to-use, flexible disks in specified diameters and in thicknesses of 3 and 6 mm. These come in several degrees of softness (flexibility). The standard formulation is the softest (most flexible) — just hard enough to keep you from tearing the interface while handling it.

BC-637 Optical Coupling –
BC-637 is a silicone-adhesive, coupling compound formulated specifically for making optically clear bonds between scintillators and photomultiplier tubes (or between non-scintillating light pipes and photomultiplier tubes). We designed it to provide a reliable interface between these components in high temperature applications.

It comes as precast pads and is formulated for temperatures up to 200°C.

BC-638 Black Wrapping Tape –
BC-638 is black adhesive tape 50.8 mm wide by .2 mm thick. Wrapping a plastic scintillator in one layer will give you a light-tight seal. We provide BC-638 in 32.9 m rolls.

BC-640 Plastic Masking Paper –
This material is an adhesive-backed, masking paper routinely used for protecting the surfaces of plastic scintillator during handling or storage.

We supply BC-640 in rolls 30.4 cm wide x 182.9 m long.

BC-642 PTFE Reflector Tape –
BC-642 is a 0.08 mm thick (nominal) Teflon® tape, frequently used as a reflecting material for non-hygroscopic scintillators. Three layers give you optimum reflectivity.

It comes in rolls 50.8 mm wide x 13.7 m long.

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4 BC-620 Reflector Paint for Plastic Scintillators

BC-620 is a highly efficient reflector employing a special grade of titanium dioxide in a water soluble binder. It is applied directly onto plastic scintillators, acrylic light guides, glass and metals. It is not intended for direct contact with liquid scintillators (for this application, use BC-622A). It is a diffuse reflector and, therefore, should not be applied to sheets of scintillator or light guide material where the length is much longer than the thickness.

It is recommended mainly for all scintillators having emission spectra about 400 nm.

BC-620 is normally supplied in 1 liter containers.

BC-622A Reflector Paint for Liquid Scintillator Tanks

BC-622A reflector paint is intended for use with liquid scintillators, and is particularly useful in large, steel or aluminum tanks which require application of the paint at the research site. It is a diffuse reflector and, therefore, should not be used on the major surfaces of long, narrow tanks (total internal reflection should be employed in these).

BC-622A is ideal for use with the benzene based BC-537 liquid scintillators.

BC-622A reflector normally comes in 500 ml and 1 liter quantities. The paint resin and hardener are supplied in separate containers.

General Purpose Scintillators: BC-400, 404, 408, 412, 416, 418, 420, 422, 430,444, 454 –

Base: Polyvinyltoluene
Density: 1.03
Refractive Index: 1.58
Coefficient of Linear Expansion: 7.8 x 10^{-5}/°C, below 67°C
Atomic Ratio, H/C: ≈1.1
Light Output: At +60°C = 95% of that at +20°C; independent of temperature from -60°C to +20°C
Vapor Pressure: May be used in vacuum
Solubility: Soluble in aromatic solvents, chlorine, acetone, etc; insoluble in water, dilute acids, lower alcohols, silicone fluid, grease and alkalis.

High Temperature Scintillators: BC-440, 440M –

Base: Special aromatic plastic
Density: ≈1.04
Refractive Index: 1.58
Coefficient of Linear Expansion: 7.8 x 10^{-5}/°C, below 67°C
Atomic Ratio, H/C: ≈1.1
Light Output: At +60°C = 95% of that at +20°C; independent of temperature from -60°C to +20°C. At 150°C, light output is 84% of that at room temperature (BC-438).

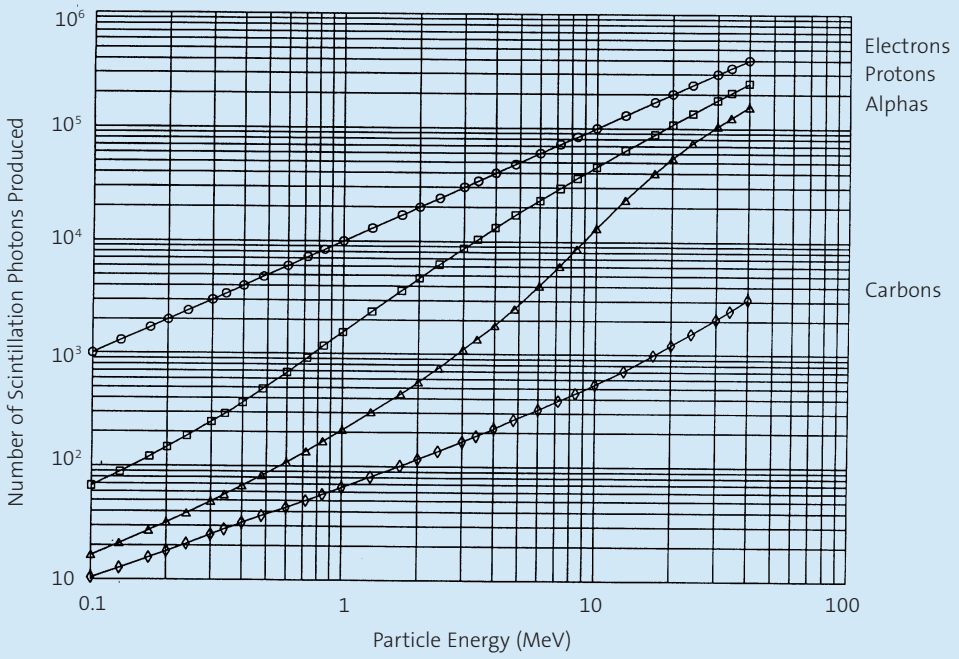
Technical Data
General Characteristics

Structural Properties of BC-408 Premium Plastic Scintillator (Characteristic of all of our PVT-base Scintillator Materials)

Property	Test Procedure	Thickness 50 mm	Thickness 150 mm
Yield Strength MPa	ASTM D638	30.8	28.3
Breaking Strength MPa	ASTM D638	30.8	28.3
Tensile Modulus MPa	ASTM D638	2700	3010
Flexural Strength MPa	ASTM D790	45.6	40.5
Flexural Modulus MPa	ASTM D790	2920	2700
Compressive Strength MPa	ASTM D695	38.1	40.5
Compressive Molulus MPa	ASTM D695	1380	2700
Shore "D" Hardness	ASTM D2240	84	84

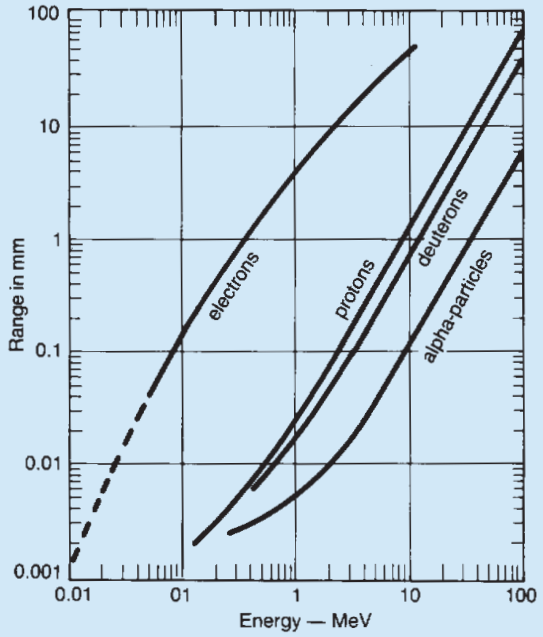
1 MPa (megapascal) = 145 psi = 10^6 Nt/m^2

Response of BC-400
Scintillation Light Produced vs. Particle Energy

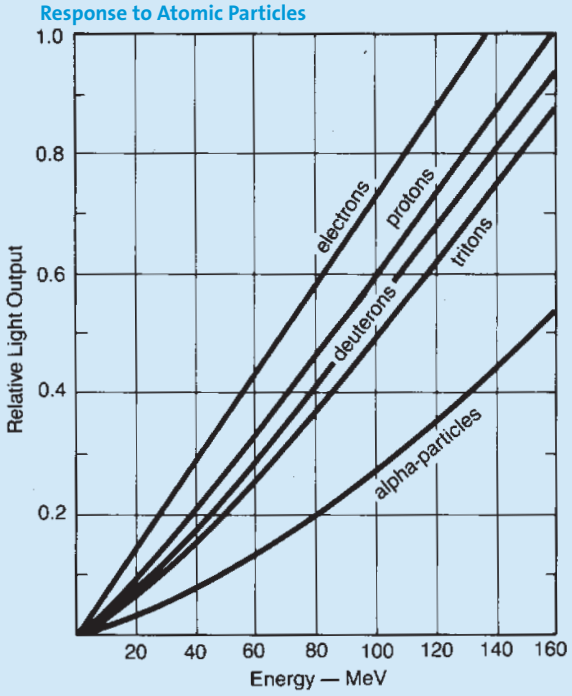


Technical Data
Light Output, Light Collection

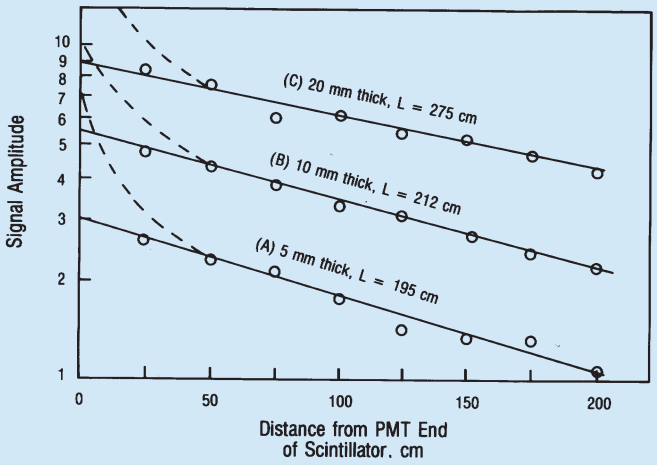
Range of Atomic Particles in Premium Plastic Scintillator



Premium Plastic Scintillator Response to Atomic Particles



Light Collection in BC-412 Cast Sheet



Sheet Size: 120 mm x 2000 mm (4.71"x 80")

- Plot of Technical Attenuation Length using a 150 mm (6") long, triangular light guide connecting the scintillator to the phototube.
- Approximate result when the phototube is coupled directly to the scintillator.

Technical Data
Light Attenuation Attenuation Coefficients

Light Attenuation Lengths for Plastic Scintillators

The Technical Light Attenuation Length (TAL) of a plastic scintillator is defined as the length required to reduce the signal amplitude by 1/e. It is applied to scintillator sheets and rods having lengths of a meter or more, and where total internal reflection is a major factor in the light collection process.

These factors contribute to attenuation length for a given scintillator sheet:

a. Bulk transmission of the material
b. Thickness and shape
c. Reflective properties of the surfaces

The use of light guides and reflectors also can alter the measured attenuation length of a plastic scintillator counter assembly. The effect of thickness on the measured TAL is demonstrated by the following data on 12 cm wide x 200 cm long sheets of BC-408:

5 mm thick TAL = 190 cm
10 mm thick TAL = 210 cm
20 mm thick TAL = 275 cm

This data was taken using a 50 mm diameter, bialkali photomultiplier tube coupled to one end of the scintillator by a light guide and with the opposite end of the scintillator blackened. In actual practice, however, the far end is not blackened. This results in much better light collection performance.

The following are typical bulk attenuation lengths for our premium plastic scintillators used in long sheets:

BC-400	250 cm
BC-404	160 cm
BC-408	380 cm
BC-412	400 cm
BC-416	400 cm
BC-420	110 cm
BC-440	400 cm

Gamma Attenuation Coefficients for Plastic Scintillators

keV	μ_1(cm^{-1})	keV	μ_1(cm^{-1})	keV	μ_1(cm^{-1})	keV	μ_1(cm^{-1})
10	1.90	80	0.176	380	0.110	1200	0.0658
12	1.23	85	0.174	400	0.107	1400	0.0606
14	0.780	90	0.172	420	0.105	1600	0.0561
16	0.620	100	0.167	440	0.103	1800	0.0522
18	0.490	120	0.160	460	0.102	2000	0.0494
20	0.400	140	0.154	480	0.100	2200	0.0465
25	0.290	160	0.149	500	0.0980	2400	0.0437
30	0.250	180	0.143	550	0.0941	2600	0.0414
35	0.230	200	0.138	600	0.0907	2800	0.0394
40	0.215	220	0.134	650	0.0874	3000	0.0378
45	0.200	240	0.130	700	0.0845	3200	0.0363
50	0.196	260	0.126	750	0.0822	3400	0.0352
55	0.189	280	0.123	800	0.0800	3600	0.0335
60	0.186	300	0.121	850	0.0777	3800	0.0323
65	0.183	320	0.118	900	0.0754	4000	0.0312
70	0.180	340	0.115	950	0.0734		
75	0.178	360	0.112	1000	0.0715		

Linear Attenuation Coefficients for Neutron Capture Scintillator BC-454 (1% ^{10}B) *

Neutron Energy	Cross Section Barns/Atom	Linear Attenuation Coefficient (cm^{-1})
0.025 eV	3836.00	2.15
0.1 eV	1929.00	1.08
1.0 eV	610.00	0.34
10 eV	193.00	0.11
100 eV	60.60	0.034
1 keV	19.00	0.011
10 keV	5.89	0.0033
20 keV	4.17	0.0023
30 keV	3.41	0.0019
40 keV	2.98	0.0017
50 keV	2.68	0.0015
100 keV	1.96	0.0011
120 keV	1.80	0.0010
150 keV	1.61	0.00090
200 keV	1.36	0.00076
225 keV	1.28	0.00072
250 keV	1.19	0.00067

*5.6 x 10^{20} Atoms/cm^3 ^{10}B

Gamma Attenuation Coefficients (μ) for BC-452 (5% Pb) and BC-400 (unloaded) Premium Plastic Scintillators

Energy (keV)	5% BC-452 (cm^{-1})	BC-400 (cm^{-1})
20	4.91	0.400
30	1.78	0.250
40	0.919	0.215
50	0.587	0.196
60	0.427	0.186
80	0.272	0.176
100	0.449	0.167
150	0.251	0.151
200	0.188	0.138

Technical Data

Physical Constants of SGC Plastic Scintillators

Scintillator	Light Output % Anthracene[1]	Wavelength of Maximum Emission, nm	Decay Constant, Main Component, ns	Bulk Light Attenuation Length, cm	Refractive Index	H:C Ratio	Loading Element % by weight	Density	Softening Point °C
BC-400	65	423	2.4	250	1.58	1.103		1.032	70
BC-404	68	408	1.8	160	1.58	1.107		1.032	70
BC-408	64	425	2.1	380	1.58	1.104		1.032	70
BC-412	60	434	3.3	400	1.58	1.104		1.032	70
BC-414	68	392	1.8	100	1.58	1.110		1.032	70
BC-416	38	434	4.0	400	1.58	1.110		1.032	70
BC-418	67	391	1.4	100	1.58	1.100		1.032	70
BC-420	64	391	1.5	110	1.58	1.100		1.032	70
BC-422	55	370	1.6	8	1.58	1.102		1.032	70
BC-422Q	11	370	0.7	<8	1.58	1.102	Benzephenone,1%*	1.032	70
BC-428	36	480	12.5	150	1.58	1.103		1.032	70
BC-430	45	580	16.8	NA	1.58	1.108		1.032	70
BC-436	52	425	2.2	NA	1.61	0.960 D:C	Deuterium,13.8%	1.130	100
BC-440	60	434	3.3	400	1.58	1.104		1.032	99
BC-440M	60	434	3.3	380	1.58	1.104		1.039	100
BC-444	41	428	285	180	1.58	1.109		1.032	70
BC-444G	34	490	285	180	1.58	1.109		1.032	70
BC-452	32	424	2.1	150	1.58	1.134	Lead,5%	1.080	60
BC-454 5%	48	425	2.2	120	1.58	1.169	Boron,5%	1.026	60
BC-480	**	425	—	400	1.58	1.100		1.032	70
BC-482A	QE=.86	494	12.0	300	1.58	1.110		1.032	70
BC-490	55	425	2.3	NA	1.58	1.107		1.032	70
BC-498	65	423	2.4	NA	1.58	1.103		1.032	70

[1] Anthracene light output = 40-50% of NaI(Tl)

* 0.1 to 5 weight % also available

** Ratio of Cerenkov light to scintillator light = 10:1

Physical Constants of SGC Liquid Scintillators

Scintillator	Light Output % Anthracene*	Wavelength of Maximum Emission, nm	Decay Constant, ns	H:C Ratio	Loading Element	Density	Flash Point °C
BC-501A	78	425	3.2[1]	1.212		0.874	26
BC-505	80	425	2.5	1.331		0.877	48
BC-509	20	425	3.1	.0035	F	1.61	10
BC-517L	39	425	2	2.01		0.86	102
BC-517H	52	425	2	1.89		0.86	81
BC-517P	28	425	2.2	2.05		0.85	115
BC-517S	66	425	2	1.70		0.87	53
BC-519	60	425	4	1.73		0.87	63
BC-521	60	425	4	1.31	Gd (to 1%)	0.89	44
BC-523	65	425	3.7	1.74	Nat. ^{10}B (5%)	0.916	-8
BC-523A	65	425	3.7	1.67	Enr. ^{10}B (5%)	0.916	-8
BC-525	55	425	3.8	1.56	Gd (to 1%)	0.88	81
BC-531	59	425	3.5	1.63		0.87	93
BC-533	51	425	3	1.96		0.80	65
BC-537	61	425	2.8	0.99 (D:C)	^{2}H	0.954	-11
BC-551	40	425	2.2	1.31	Pb (5% w/w)	0.902	44
BC-553	34	425	3.8	1.47	Sn (10% w/w)	0.951	42

* Anthracene light output = 40-50% of NaI(Tl)

[1] Fast component; mean decay times of first 3 components = 3.16, 32.3 and 270 ns.

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(05-08)