Surface Treatment of HDPE Pipe For Waterway Barrier Applications

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ABSTRACT

HDPE Pipe has been used for nearly 100-years successfully in underground and some above ground applications for the transport of liquids, gasses and solids. More recently, the use of HDPE Pipe in larger diameters (>400mm) as waterway barrier floats for debris booms, boat barriers, ice booms and fish guidance systems has increased. Regardless of application, these boom systems all share a common attribute that they are used on waterways with public access and/or navigational purposes. The natural black HDPE pipe material is not visible to boaters and presents a public safety hazard to boaters and a potential liability to the owners of these systems. This technical bulletin will address three methods of coating HDPE pipe to achieve visibility in order to satisfy these important public safety and liability issues.

HDPE Pipe Production Process

To make HDPE pipe, HDPE resin is heated and extruded through a die which determines the diameter of the pipeline. The wall thickness of the pipe is determined by a combination of the size of the die, speed of the screw and the speed of the haul-off tractor. Polyethylene pipe is usually black in color due to the addition of 3-5% of carbon black being added to the clear polyethylene material. The addition of carbon black is required to create a product which is UV resistant.

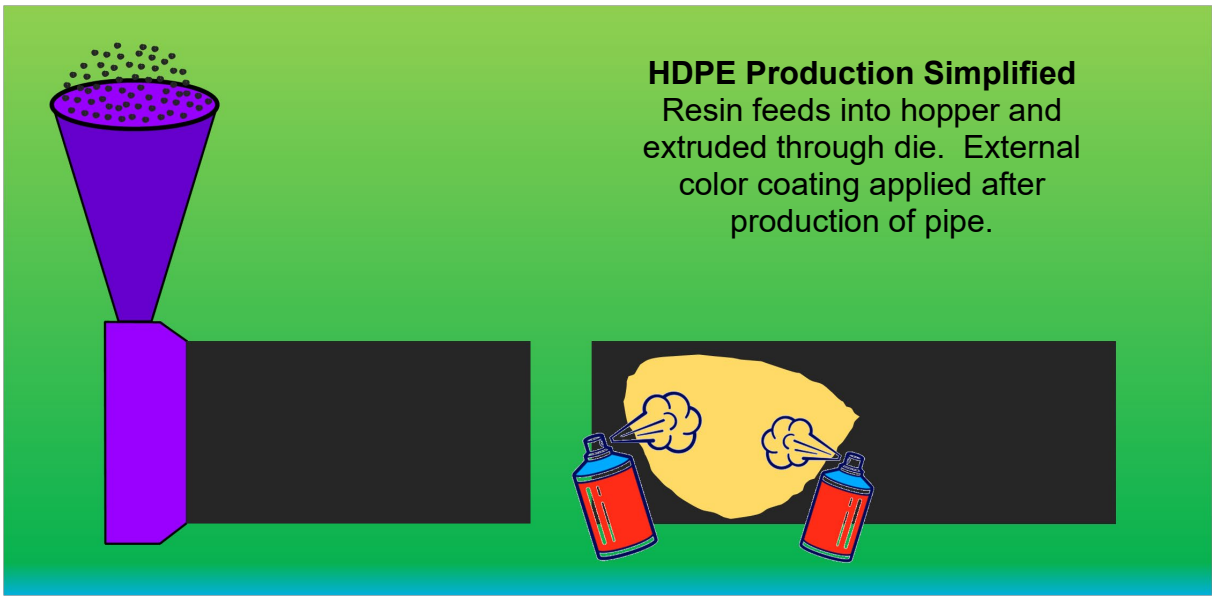


Figure 1: HDPE production and coating illustration.

Until recently, large diameter (>400mm) HDPE pipe was used in underground and to some extent above ground pipe applications involving the transport of various liquids and semi-liquid solids. HDPE plastic itself is nothing new and has been in use for nearly 100 years. In recent years the use of HDPE pipe as floating log & debris booms, public safety boat barriers and floating security barriers has expanded.

HDPE pipe booms are commonly known as Multi-Purpose or Multiple Function booms because they permit the dam owner to satisfy multiple use objectives in a single boom system. Regardless of the primary purpose of the boom, they must be visible on the surface of the water for navigational, public safety and boater safety purposes. In low light conditions of dawn, dusk and during weather events, the natural black color of the HDPE pipe is barely visible on the surface of the water and therefore these pipes present a very clear navigational and safety hazard. Owners of these booms systems are exposed to increased legal risk for being negligent should an incident or fatality occur as a result of a boater impacting these boom systems. Boom manufacturers were therefore challenged to deliver HDPE barriers that would provide visibility in in low light and weather conditions. Standard practices in the USA and Canada are for floating boom systems to be of either Yellow or Orange colors.

Although HDPE pipe is often estimated to last 50 years, they are in fact more likely to have life expectancies of 100 years. The challenge for floating barrier system manufacturers therefore

is to offer a material with a colored surface coating/layer that would not fade, bubble, peel or delaminate once in the field. The cost to remove, clean and prepare the surface of the pipe and then reapply the surface coating layer would eclipse the cost benefits of having a base material that lasts 50+ years.

HDPE Pipe is estimated to last 50+ years.
The exterior color coating therefore
should also deliver similar longevity.

The HDPE production process itself results in a very dense non-porous material. Additionally, the resin is *oil-based*. This dense structure and "lubricity" of the material endows it with excellent resistance to biological attack. These same attributes of dense structure and biological resistance, however, also result in a material that is difficult to coat with external colorants. HDPE, by design, is non-porous. This challenges boom manufacturers to develop reliable external layers that will meet the 50-year design life for the HDPE material.

Three methods of introducing external colors are presented in this bulletin:

- Epoxies and external coating
- Flame resin application
- Co-extrusion

Epoxies & External Coatings

HDPE is highly dense and non-porous. Even under the most controlled clean environment conditions, it is almost impossible to apply a surface coating that will properly adhere to the HDPE surface. In an exposed environment typical for a floating boom, the individual float pontoons are subjected to temperature extremes, impacts by sharp ice, foreign debris, sticks, logs, boats rubbing against the booms and the booms themselves rubbing along an uneven rocky shoreline.

Image 1: Painted HDPE pipe shown 14-months after installation at a hydroelectric plant on the Mississippi river near Lower Saint Anthony Falls, MN (USA).

Image 2: Appearance at time of installation. All looks good.

Flame Resin Applicators (TPU Flame Coating)

A second method of coating the HDPE pipe involves applying a thermoplastic polyurethane paint (TPU) using a flame sprayer. Using this method of application, a manufacturer can achieve surface coating layer thickness of up to 3mm. The advantage of this system is that it allows for the manufacturer to quickly switch between colors and it provides greater reliability over the epoxy/paint method mentioned above.

TPU Flame coating application error

As with the epoxy method, the TPU system requires a detailed pre-preparation that includes cleaning the HDPE substrate material with chemical solvents, lightly sanding the entire surface, applying a surface primer and then applying the TPU paint using a custom flame sprayer in subsequent layers of 200-250µm. This method of coating is recommended to be performed in a dry, non-humid, non-wet weather environment where the temperatures are consistently above 5°C (41°F).

The TPU system is far superior to the epoxy/paint method in that it does result in a better bond between the base HDPE and the outer coating. However, where the TPU succeeds in providing a more reliable bond, it falls short in longevity. The manufacturer of the TPU system states that even under ideal conditions where the material is not exposed to impacts, submersion and ice, this layer will last 12-15 years. In a log boom environment, it should be anticipated that pipes will require recoating at least

once every 10-years. When deciding upon a system that is flame resin coated, the owner should factor the costs to remove, clean and recoat the individual pontoons on a 10-year schedule. Because of the specialized nature of the coating system, this is something that cannot be performed on-site in the field, rather in a controlled facility with the know-how of properly coating plastic pipe.

Image 3: Surface appearance of a flame coated HDPE pipe.

Because the HDPE pipe is being offered with up to a 50-year design life, the TPU system is not compatible with these design objectives.

Eco-friendly, Sustainability Needs

The use of manually applied surface coatings/paints is not eco-friendly and does not contribute towards sustainable design practices. The brightly colored orange and yellow paint chips will be mistaken as food by birds, turtles and fish (Image 4). These paint chips are not biodegradable and will remain in the eco-system for decades.

Image 4: Paint chips and plastic do not bio-degrade. They remain in the eco-system to be mistaken as food by birds, turtles and fish.

Co-Extrusion

A third method of achieving a reliable external jacket layer in a color other than black is through co-extrusion.

Co-extrusion occurs during manufacturing where the yellow (or orange) outer layer (jacket/shell) is co-extruded with the inner black pipe wall and forms an integral part of the pipe (Image 5). The entire wall thickness is of one homogenous HDPE material. The co-extruded layer is not subjected to peeling or delamination because it is a single material and not two distinct layers.

Manufacturing via co-extrusion allows the boom producer to pair the long-term benefits of HDPE material with a surface layer that will provide the same life as the base pipe. For the owner of these co-extruded systems the cost factor to remove and recoat the HDE pipe is removed from the total cost of ownership. Additional benefits of co-extruded pipe include:

- Color layer provides a full exterior color appearance and is made from the same HDPE as inner wall, performance properties are unaffected
- Color fastness and UV protection performance for co-extruded conduit is equal to full wall colors and is suitable for storage outdoors for up to one year
- Total wall thickness = inner black wall thickness + external color layer thickness
- The black inner wall has a minimum of 2% carbon black per condition C of ASTM D 3350
- Co-extruded color layer has UV stabilizers and antioxidants per condition E of ASTM D 3350

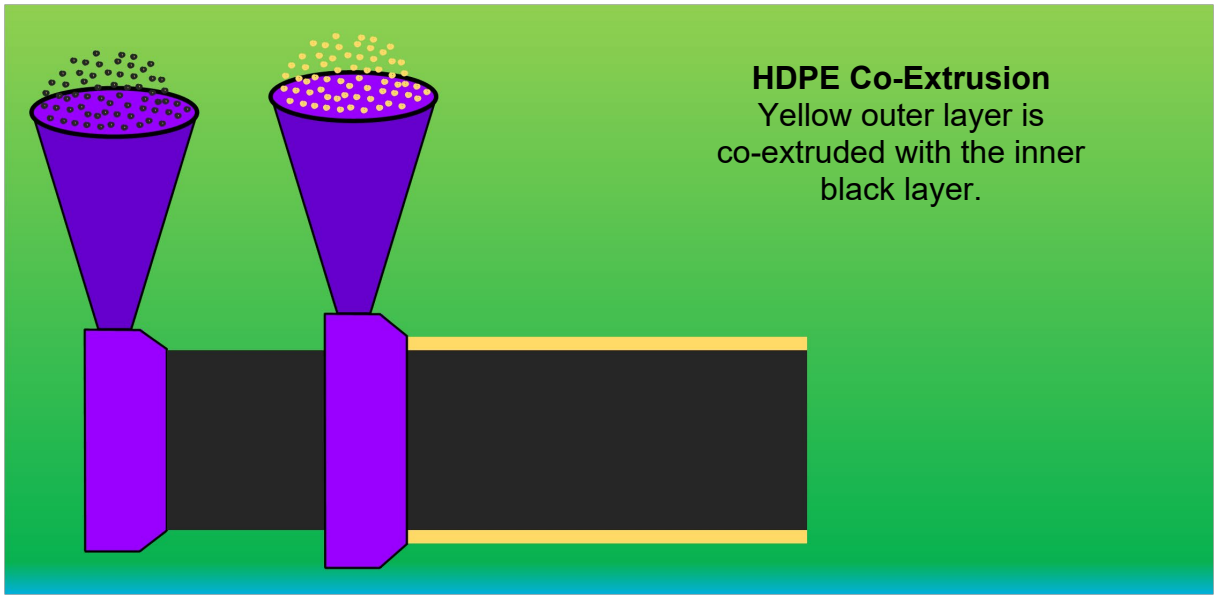


Image 5: Simplified example of co-extrusion

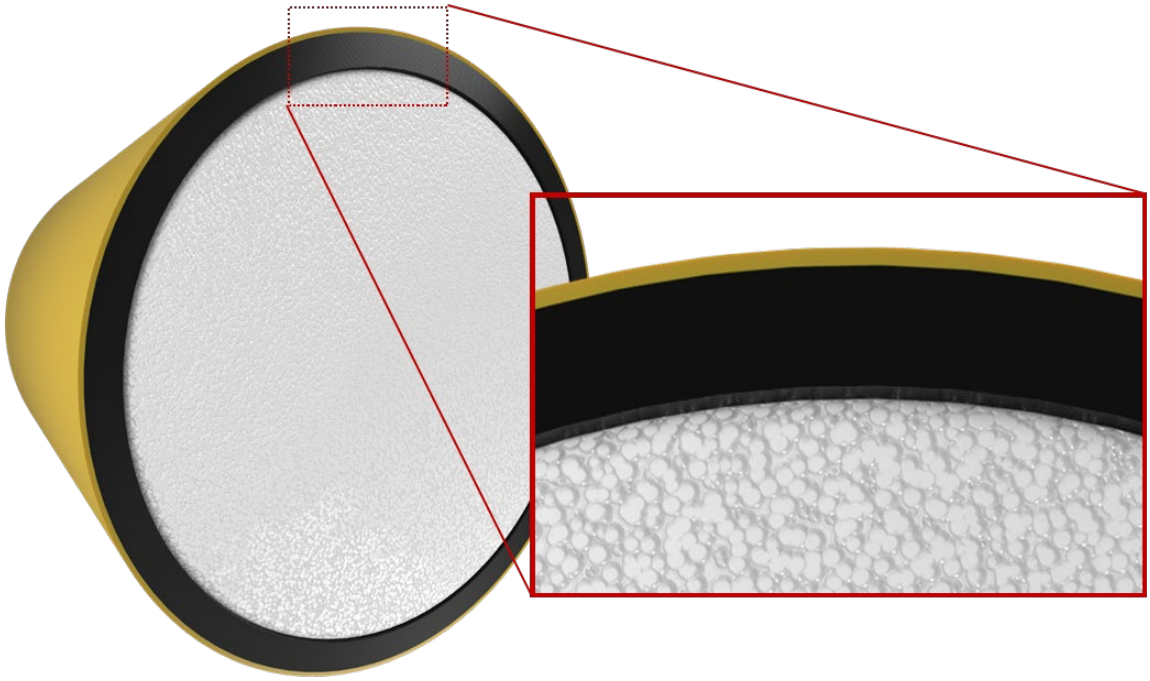
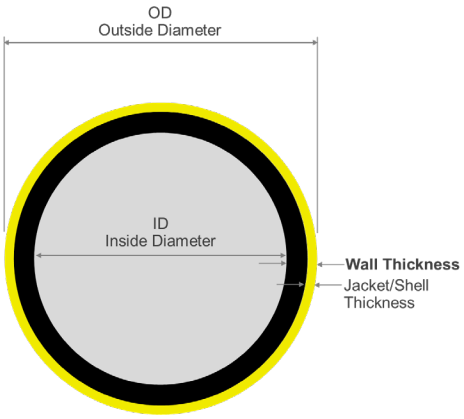


Image 6: Example of the co-extrusion HDPE barrier.



A fourth method to achieve a thick-walled HDPE pipe not discussed in this paper is by producing the entire HDPE wall in a single color. This method is available, but the author considered it so cost prohibitive and difficult to obtain, that we have not included it as a viable option in this discussion.

Comparison of the three methods to achieve externally colored HDPE pipe.

Attribute	Epoxy/Paint	Flame Coating	Co-extrusion
Bond strength to base HDPE material	Poor	Good	Not-applicable *1
Coating/Jacket Thickness	Very thin	Up to 3mm	4 mm
Design Life	<5 years	8-12 years	50+ years
Resistance to abrasion	Poor	Good	Excellent
Impact resistance	Poor	Good	Excellent
Ability for graphics to be applied to surface	No	No	Yes
Cost	Medium	High	High
Eco-Friendly Fish Friendly	Detrimental	Detrimental	Eco-Friendly

*1 Co-extrusion is not bonded to the base material. It is a continuation of the base material.

While this bulletin discusses the application of an external color jacket or layer for HDPE pipe, consideration of the longevity of the actual color and of the effectiveness of the specific color used on the boom should also be considered.

Radiation Energy

Over time, the effects of the sun's ultraviolet (UV) radiation can degrade plastic and cause colors to fade. The effect of the suns UV radiation is expressed as **Average radiation** energy and this number varies by geographic radiation zone. The radiation chart below depicts the average radiation by geographic zone.

Average radiation energy per year chart

Radiation Zone	Region	KWH/m^2/year	KLY/cm^2/year	10^7J/m^2/year
AS 1	**Southern USA** (AZ, NV, FL, TX, CA), Peru, Ecuador, Bolivia, Mexico, Africa, Middle East, North Australia	>2200	>190	>800
AS 2	Australia, India, Thailand	1800-2200	155-190	800
AS 3	**Middle USA**, Japan, South Europe, Rest of South America.	1400-1800	120-155	500
AS 4	**Canada**, Middle Europe	1100-1400	95-120	400-500
AS 5	**Northern Canada**, North Europe, Scandinavia	800-1100	70-95	290-400

Color Chart Classes

The color chart classes indicated refer to results of UV-Stability tests on the ODINBoom pipe formulation at the original manufacturer and are shown for RAL colors 1000 (FS13655) and RAL 2009 (FS12197).

RAL 1000 (Yellow) = Color Class CC-2
RAL 2009 (Orange) = Color Class CC-4

Color Recommendation Chart

	Long Term Color Durability		
Radiation Zone	**Excellent**	**Good**	**Critical**
AS 1	-	CC 2	CC 4
AS 2	CC 2	-	CC 4
AS 3	CC 2	CC 4	-
AS 4	CC 2	CC 4	-
AS 5	CC 2, 4		

Excellent = Good for 60 years
Good = Good for 40 years
Critical = Good for 20 years

What is learned from the above charts is that the external color of the boom directly correlates to the lifespan of the material. Because Yellow is more reflective than Orange, it deflects more sunlight and UV radiation to provide significantly longer boom life when compared to orange colored booms.

Visibility in Low Light Conditions

Yellow is commonly referred to as a colorblind color. What this means is that yellow is the one color that is visible to people with colorblindness. This is important **because 8% of males are colorblind**. To a colorblind individual the color orange and red may appear as a greyish to blackish color (Image 7). Additionally, yellow rates highest on the relative intensity scale meaning it generates the greatest excitement to the cones in your eyes (Image 8).

Image 7: What a colorblind person sees.

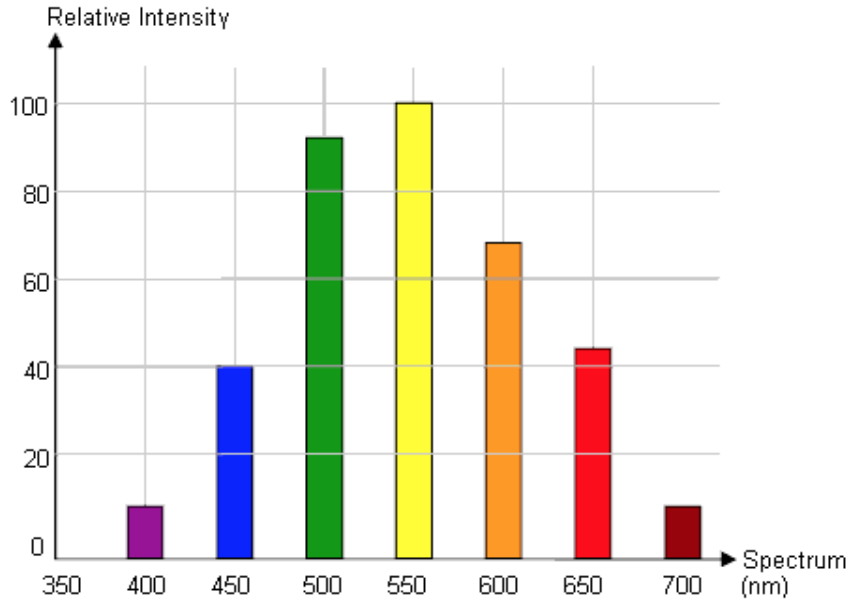


Image 8: Color intensities

Traditionally, the color of choice, not by regulation, for safety booms and barriers in the United States has been orange. Internationally and in Canada, the requirement is for yellow colored booms. As the examples above demonstrate, the yellow colored booms provide the greatest opportunity for visibility and effectiveness especially in low light and weather conditions. Because these HDPE booms must be visible on the surface of the water especially in low light conditions due the choice of color is impactful on the effectiveness of the boom systems especially in helping to reduce the risk and liability on the part of the dam owner who places these booms into service.

Worthington Products recommends that all boom systems be supplied in yellow per Federal Standard FS13655 (aka Blue Angels Yellow).

Summary

HDPE pipe used for floating waterway barriers deliver excellent durability and lifespan. However, the nature of how these boom systems are utilized, requires they service multiple purposes one of which will always involve navigational and boater safety. The booms must be visible. The standard HDPE Black does not satisfy the visibility standard and may even expose dam owners to greater liability should boaters impact the barriers due to the "invisibility" of a black boom on dark water. Manual and flame coatings on HDPE pipe only provide 10-year lifespans and introduce ecological and environmental hazards when these coatings separate from the base HDPE pipe. The coextrusion method of production is an eco-friendly solution that provides a durable external color shell option which lasts the full life of the boom. When designed with a yellow external color (FS13655, Blue Angels Yellow), the booms display greater visibility in low light and weather conditions as well as greater UV resistance.

About Worthington

Worthington Products, Inc. have designed and manufactured floating waterway barrier (boom) systems for more than 20-years with installations in 63-countries. The ODINBoom™ is a co-extruded HDPE pipe manufactured with a highly reflective yellow external skin in a 32mm thick-walled material. ODINBoom is suitable for long term use as a log & debris booms, public safety boat barrier, fish guidance system, ice boom and general floating barrier.

For more information, contact Worthington Products, Inc +1-330-452-7400 or visit www.tuffboom.com.