# Optimizing The UV-Curable Tight Buffering Fiber Process

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## Abstract

Flame retardant UV-curable materials have shown promise in tight-buffered cables. They provide benefits such as ease of processing compared to thermoplastics and improved attenuation at low temperatures. New pigmented materials have been designed to provide V-0 flame retardancy along with color identification of the cables. The resins have been tested in cables with acceptable attenuation results [1]. Optimization of the application process is very important for the cable manufacturer to ensure concentricity and to minimize scrap, thus improving production yields and overall product quality. This paper describes some of the optimization methods.

## Keywords

Flame retardant; tight buffer; premise cable; UV coating; low smoke; halogen free; thermoplastic

## 1. Introduction

Tight-buffered cables have been used in premise applications for over two decades. Most commonly, the cables are made utilizing a thermoplastic coating which is extruded onto a 250µm optical fiber. Common thermoplastics in the industry include Polyvinylchloride (PVC), Nylon 12 and Polyethylene. While variations of these materials meet GR-409 cable specifications and NEC building code requirements for flame retardancy, they can often pose processing problems such as slow line speeds, high scrap rates, etc.

UV-curable resins, however, typically have fast line speeds, lower scrap rates and have been used in the optical fiber industry as protective coatings for more than 25 years. A new series of opaque, UV-curable resins has been recently developed which is flame retardant, halogen free, lead free and also easy to process [1]. The non-halogenated aspect of the resins is a significant benefit for cable designers who face increasingly strict government regulations in Europe, the U.S. and Japan on the use of halogenated cable materials such as PVC.

UV-curable resins are liquid when applied onto fiber and harden when exposed to UV light of the right wavelength and intensity. The resulting coating is a crosslinked system that is resistant to both chemicals and moisture. This process allows a high degree of flexibility in creating upjacketed fiber designs: 500µm, 600µm or 900µm tight buffered fibers can easily be made using the same resin and equipment.

## 2. New Acrylate Materials

### Flame retardancy comparison

The tight buffer materials used in this study have smoke and flammability properties similar to a Low Smoke Zero Halogen Polyethylene (LSZH PE) and are suitable for riser applications [1]. One of the indices of flame retardancy is the limiting oxygen index (LOI), which measures the tendency of a material to sustain a flame. The greater the number, the less susceptible the polymer is to burning. Both the pigmented UV curable resins and LSZH PE have LOI values >30 and both pass smoke density testing per ASTM E662.

### Preconditioning of Acrylate Materials

Due to the flame retardant additives, these UV-curable resins tend to settle over time and therefore care must be taken before use to ensure a homogeneous mixture. To mix in the settled material, a rolling method was preferred because it minimized the amount of air bubbles introduced into the resin. Starting with the preconditioning recommended for UV-curable inks, flame retardant tight buffer resins were rolled at a rate of 8rpm for approximately 8 hours. Once mixed, the resin did not need remixing for approximately three days. The resins had a viscosity low enough that they could be applied at room temperature—however, for line speeds >400m/min, the resin was heated to 33°C to allow for an acceptable pressure level.

## 3. Process Conditions for Upjacketing with UV-curable Resins

### General line conditions

UV upjacketed fibers were processed with a modified Nextrom OFC-52 coloring machine which was equipped with two Fusion units. Each unit had a high (100%) and low (67%) power switch and a 10-inch, 11 mm, 600 W/in, D lamp. To minimize surface tack, nitrogen was set at a flow rate of 30L/min and, to prevent die drool, the initial speed was set at 100 m/min and then quickly ramped up to the desired speed.

Due to the large amount of coating being applied (compared to inking fiber) a slight increase of the payoff tension was needed to offset the fiber vibration. At 600 m/min, the total tension was about 1.5 – 1.6 N, and the coating pressure was 5 bars (for 900µm fiber). Finally, during the ramping down step after the targeted fiber length was coated, the speed was reduced. Once it reached 200m/min, the coating flow was shut off to avoid overflow and ensure a clean stop. The amount of scrapped fiber was approximately 30 meters at each end.

### Reducing Scrap-managing the ramping steps

In order to achieve uniformity of the upjacketed fiber diameter and thus reduce the amount of scrapped fiber, a multi point pressure vs. speed ramping scheme was developed. The scheme calls for a slower ramp-up to reach full application speed and a fast ramp down, such as 40 seconds. Tables 1 and 2 are examples of ramping schemes used for 500µm and 900µm tight buffered fibers. The total time it took to reach full line speed was approximately 120 seconds and each speed level was maintained for 10-20 seconds. This slower ramp up scheme eliminated any die drool experienced when a fast ramp up scheme was used (0 to 400m/min in 10 seconds).

UV-curable materials typically shrink between 1-2% during cure and the pigmented, opaque buffers behave similarly. Therefore it is recommended that a 2% allowance should be added to the desired final tight buffered fiber diameter. For instance, it was noted that immediately after cure, the BETA Lasermike would read 510µm, however, when rewinding the fiber, the diameter was correctly read at 500µm. This discrepancy in diameter readings has been observed every time the fiber is upjacketed, therefore, the fiber diameter needs to be adjusted higher by 1-2% if monitoring immediately after the coating process.

**Table 1. Process conditions for 500µm fiber with existing color line at various speeds.**

| **Coating: DU-3017** | | **Temperature: 33ºC** |
|---|---|---|
| Dies (µm) | Entry: 275 | Exit: 700 |
| Speed (m/m) | Diameter (µm) | Pressure ramp (bar) |
| 150 | 520 | 1.6 |
| 200 | 518 | 1.7 |
| 300 | 517 | 1.8 |
| 400 | 515 | 1.9 |
| 500 | 510 | 2.0 |
| 600 | 504 | 2.1 |
| 700 | 503 | 2.2 |

**Table 2. Ramping up scheme for 900µm Fiber using upgraded OFC-52 designed for upjacketing**

| **Coating: DU-3007** | | **Temperature: 35ºC** | |
|---|---|---|---|
| Dies (µm) | Entry: 270 | Middle: 265 | Exit: 1100 |
| Speed (m/m) | Diameter (µm) | Pressure ramp (bar) | |
| 100 | 915 | 1.2 | |
| 200 | 918 | 1.7 | |
| 300 | 928 | 2.4 | |
| 400 | 911 | 3.0 | |
| 500 | 907 | 3.6 | |
| 600 | 920 | 4.3 | |
| 700 | 922 | 4.9 | |
| 800 | 923 | 5.4 | |

### Concentricity

The most common method used to monitor an optical fiber's concentricity during the coating process is with the use of a laser light which shines on the fiber, thus creating a scattering pattern (Figure 1). This method requires a difference in the materials' refractive index between the UV-coating and the silica. The bigger the difference, the stronger the intensity:

$$\text{Intensity} \propto (\Delta n)^2 \propto (n_{\text{coating}} - n_{\text{Fiber}})^2$$

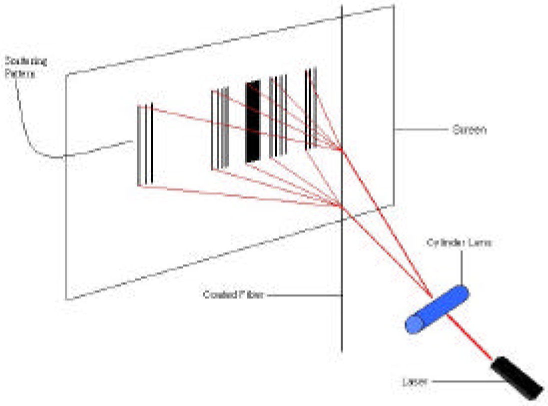


**Figure 1, Schematic diagram of fiber concentricity monitoring**

While it is quite easy to observe the difference in refractive index between two clear materials, it is not so with opaque materials. Therefore care needs to be taken when upjacketing with pigmented, flame retardant buffer resins. Proper alignment of all spools, capstans and wheels is of utmost importance.

In addition, one technique used to further optimize concentricity is choosing the right die design. It is preferred to use a small entry die such as 270µm, and a middle die which is also 270µm or even slightly smaller, in between the entry and exit die. The middle die has a slight vortex and as the fiber passes through the liquid, hydrodynamic forces further center the fiber. The centering effect of the middle die can be seen in the two photographs. Figure 2a is an example of a 900µm tight buffered fiber made without the middle die and Figure 2b is a 900µm tight buffered fiber made with the middle die.

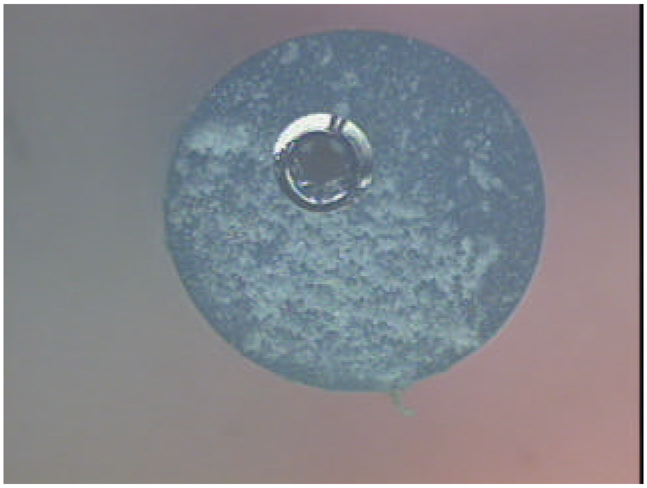


**Figure 2a. 900um tight buffered fiber without middle die.**

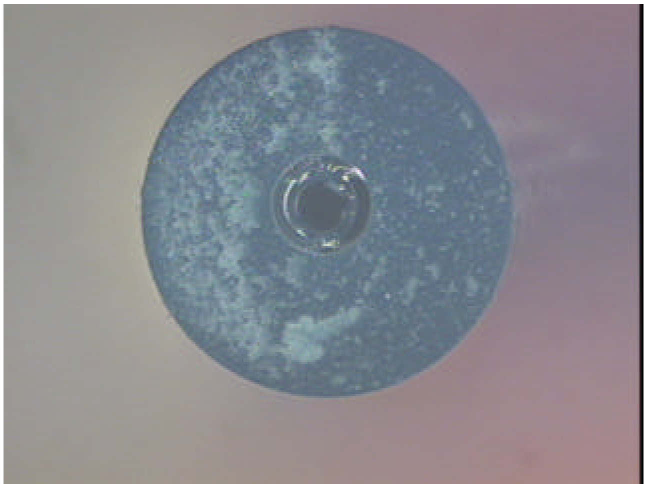


**Figure 2b. 900um tight buffered fiber with middle die.**

### Diameter Tolerance

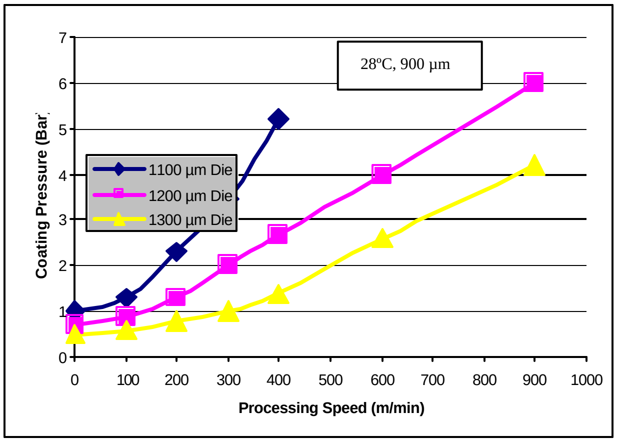
Unlike the normal coloring process, the diameter of the upjacketed fiber is strongly influenced by the viscosity of the coating and the processing conditions (speed, temperature, and pressure). In addition, the die design and the size of the exit die also contribute heavily to the final diameter of the upjacketed fiber.

While the concentricity of clear materials is easier to monitor online than with opaque resins, the opposite is true of diameter measurements. The diameter of tight buffered fiber is measured online with an instrument such as a BETA Lasermike. The outgoing laser light reflects back to the monitor, which reads the diameter. The light reflection is more intense with opaque materials than it is with clear resins, therefore the diameter control for tight buffered fibers made with pigmented flame retardant materials can be very tight as long as a close monitoring procedure is used. We were able to adjust pressure in real-time and this allowed for excellent diameter control. The currently accepted diameter variation for tight buffered fibers is +/- 30um with thermoplastics, however with UV-curable tight buffer resins, we were able to achieve +/- 5um for both 500um and 900um fibers.

### Exit Die Effects

The size of the exit die depends on the desired finished diameter of the upjacketed fiber. For 500µm fiber, a 650-700µm exit die is preferred. For 900µm fiber, exit dies ranging from 1100-1300µm can be used. The exact size of the exit die needed depends on the viscosity of the coating, the process speed and the coating temperature. Figure 3 shows the relationship between process speed and the coating pressure needed to maintain a 900µm diameter for a coating at 28ºC. Three different die sizes were used and generally, the faster the line speed, the larger the exit die needed to maintain the coating diameter at a reasonable pressure level.

**Figure 3. Process speed versus coating pressure for three different die sizes.**



## 4. Material Usage

### 500um Tight-Buffered Fibers

The amount of resin needed to upjacket fiber to 500um was estimated to be 0.2kg/km—therefore, 1kg of coating could upjacket 5km of fiber. For this study, we used an existing ink line with the only upgrade being larger dies. We were able to place a 1kg bottle directly into the pressure pot normally designed for ink. This allowed for utilization of an existing piece of equipment (except for larger dies) and thus minimized any equipment expenses needed to convert production from thermoplastic extrusion to UV curing.

### 900um Tight-Buffered Fibers

The amount of resin needed to upjacket fiber to 900um was estimated to be 0.8kg/km, therefore, 1kg of coating could upjacket 1.25km of fiber. For this study, we needed to use equipment that had been upgraded to accommodate the larger pressure pot and delivery tubes.

### Color Changes

Color changes were accomplished by removing the brown Nalgene bottle from the pressure pot and flushing the system with Acetone which included the three-way switch valve and connecting tubing. The Acetone was flushed into a separate container which was stored in the back of the unit. The dies needed to be removed and cleaned with the solvent also. The new color was then added to the pressure pot, the system purged, and the new color was ready to be applied. The whole process required approximately 10-15 minutes.

## 5. Conclusions

UV-curable resins are proving themselves to be very useful materials in tight buffered fiber cable constructions. They are available in pigmented, flame retardant versions which are non-halogenated and lead free. The same resin can be used to produce 500µm, 600µm or 900µm tight buffered fibers. By making sure the resins are thoroughly mixed before use and the proper die design is used, high quality, flame retardant tight buffered fibers can be produced in a very economical way. Process speeds of 800m/min are feasible which are 3-4x faster than currently used thermoplastic extrusion processes. The use of a middle die can be extremely beneficial to concentricity. In addition, a slow ramp up scheme and a fast ramp down scheme has been found to minimize the amount of scrap fiber thus making short production runs more cost effective.

## 6. Acknowledgements

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## 7. References

[1] Montgomery, Eva; Murphy, Ed; Gan, Keqi; Dake, Ken; Hatch, Nathan, "UV Curable Buffer Resins vs. Thermoplastics: A closer look at new flame retardant, UV-curable materials in tight buffered cables," *Proceedings of the 52nd IWCS/FOCUS*, 98-101 (2003).

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