HISTORY OF ABSORPTION COEFFICIENT TESTING OF UV STABILIZED THERMOPLASTIC POLYMERS VIA CARBON BLACK

Jared Weitzel
General Cable Corporation
Presented at ICC Fall 2014 – A14D
Colorado Springs, CO
October 6, 2014

Presentation Outline

- Introduction to UV Stability Testing
- Historical Background
  - Purpose of Optical Testing
  - Testing Process Overview
- Current Testing Methods
  - ASTM D3349
- Current Testing Requirements

Introduction to UV Stability Testing

- Polyethylene started being used for cable coverings in the 1940's.
- Bell Laboratories started a long term aging project on carbon black, UV stabilized cable coverings at the same time.
- Outdoor cable standards for Utility/Industrial/Telecom cables with black thermoplastic polyethylene insulation/jackets contain requirements for Absorption Coefficient (AbsC) in the range of 320-400.

Historical Background

- In 1966 John B. Howard [1] of Bell Telephone Laboratories published a paper titled “Use of the Spectrophotometer to Control Carbon Dispersion Quality in Polyethylene” in Polymer Engineering & Science.
  - ASTM Committee D20 appointed Subcommittee VII in 1955 to “develop an optical test procedure for measuring the quality of carbon dispersion in weather-resistant polyethylene compositions.”
  - This paper is the first published draft of the test procedure that has become the present day ASTM D3349 test procedure.

Purpose of Optical Testing

- Simultaneously assess following attributes:
  - Carbon black quantity
  - Carbon black quality (effectiveness: size and shape)
  - Carbon black dispersion
- 375nm testing light wavelength is in the wavelength region of 300-400nm identified in [2] as being the primary contributor to photo degradation of polyethylene. Further refined to 350-400nm in [1].

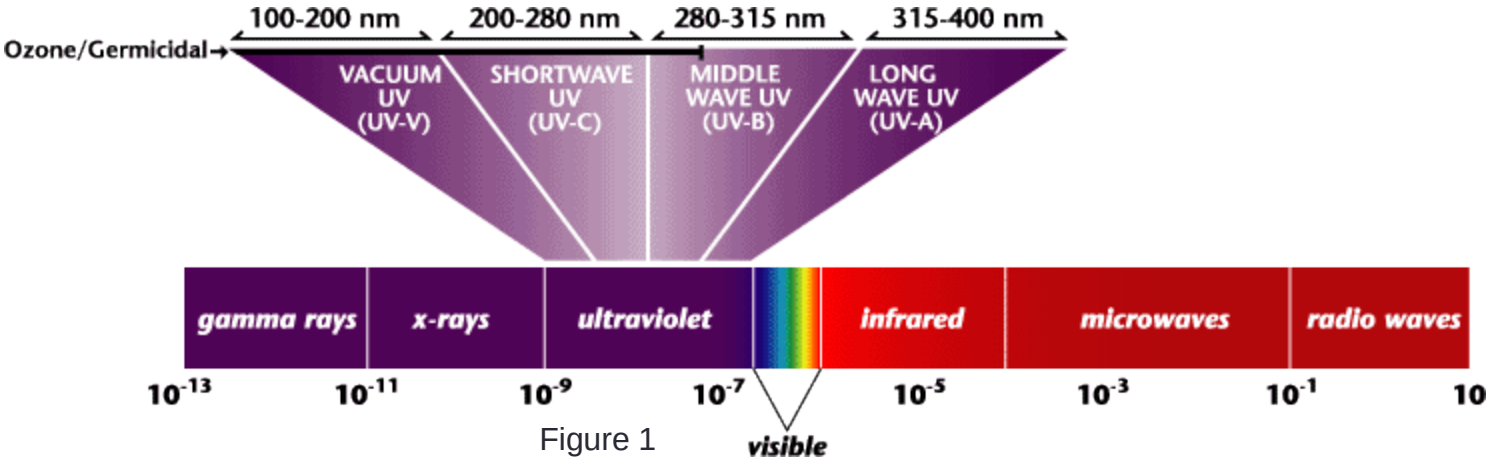

Figure 1

Historical Background (cont.)

- It was noted in this work that the difficulty in performing this test lies primarily in the sample preparation.
- Paper shows that a multitude of carbon black types were tested over a range of wavelengths at 3% loading to develop the procedure.

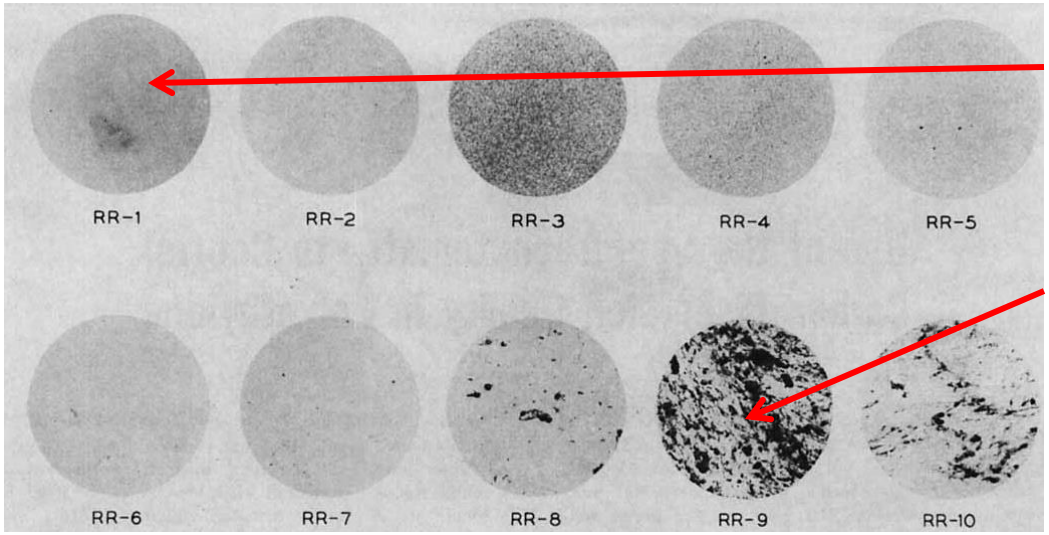

Figure 2 [1]

Type of Black	Average Particle Size[1] (mμ)	Visual Disp. Ratings[2]	Weather Resist.[3]	Sample No.
Fine Channel	12	B	88%	RR-1
Fine Channel	12	C+	64%	RR-7
Fine Channel	12	D	69%	RR-8
Lrg. Channel	25	B	82%	RR-6
Fine Furnace	40	B	68%	RR-2
Fine Furnace	40	D	40%	RR-9
Acetylene	40	B+	55%	RR-3
Large Furnace	75	B+	57%	RR-4
Lampblack	100	B+	51%	RR-5
Lampblack	100	D	25%	RR-10

(1) Data from supplier.
(2) Under microscope at 100X. A = Excellent, D = Poor.
(3) Percent of orig. elongation for 5 × 10^{-4} cm. film after 375 hrs. in Weather-O-Meter (Schulken et. al., Ref. 8).

Figure 3 [1]

Testing Process Overview

- Sample preparation

Figure 4 [3]

Figure 6 [3]

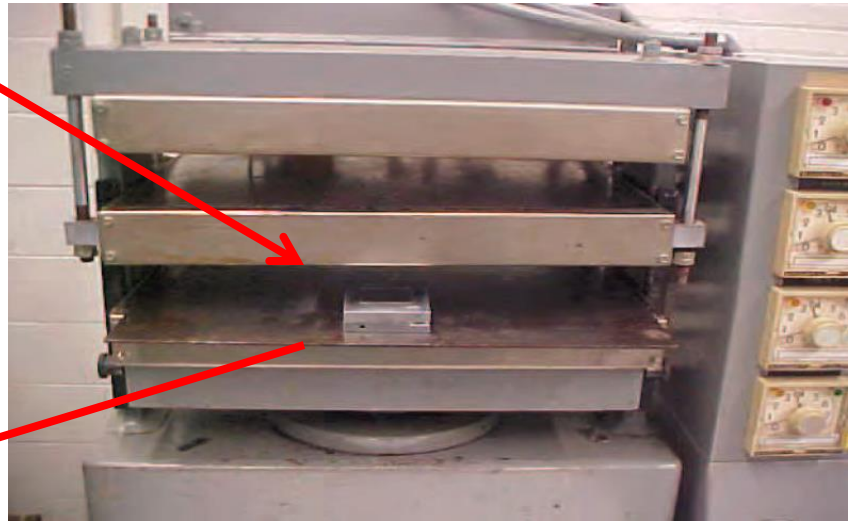

Figure 5 [3]

Testing Process Overview (cont.)

- Sample preparation

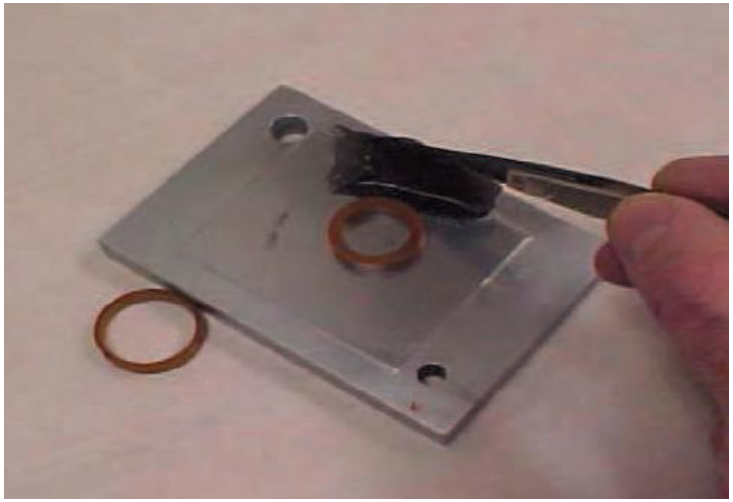

Figure 7 [3]

Figure 8 [3]

Testing Process Overview (cont.)

- Spectrophotometer

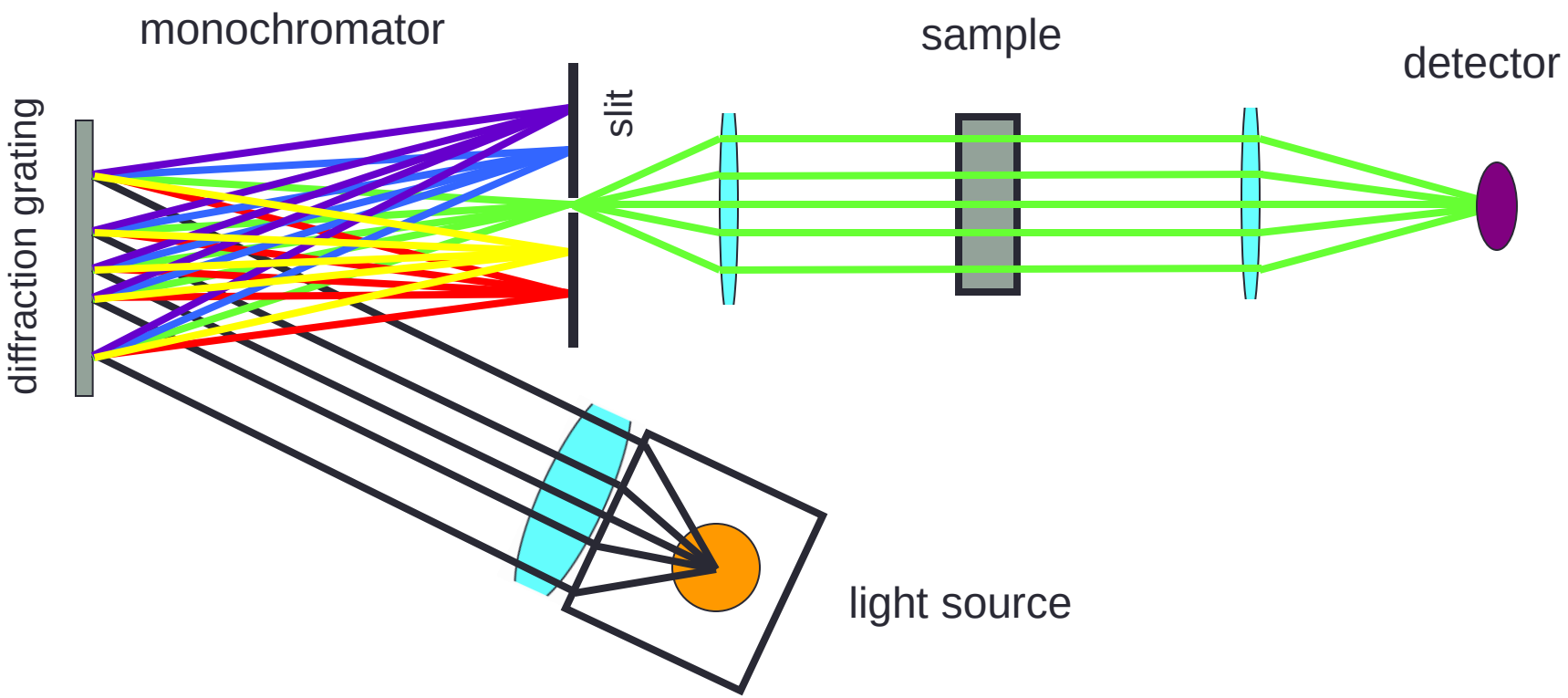

Figure 9

Historical Background (cont.)

- In 1969 J. B. Howard and H. M. Gilroy [2] of Bell Telephone Laboratories published a paper titled “Natural and artificial weathering of polyethylene plastics” in Polymer Engineering & Science.
  - Long term experiments (up to 22 years) of aged cable data.
  - Cables aged naturally in New Jersey and artificially with Carbon Arc Weather-O-Meter exposure.
  - Results showed correlation between degradation of polymer physical properties and AbsC.

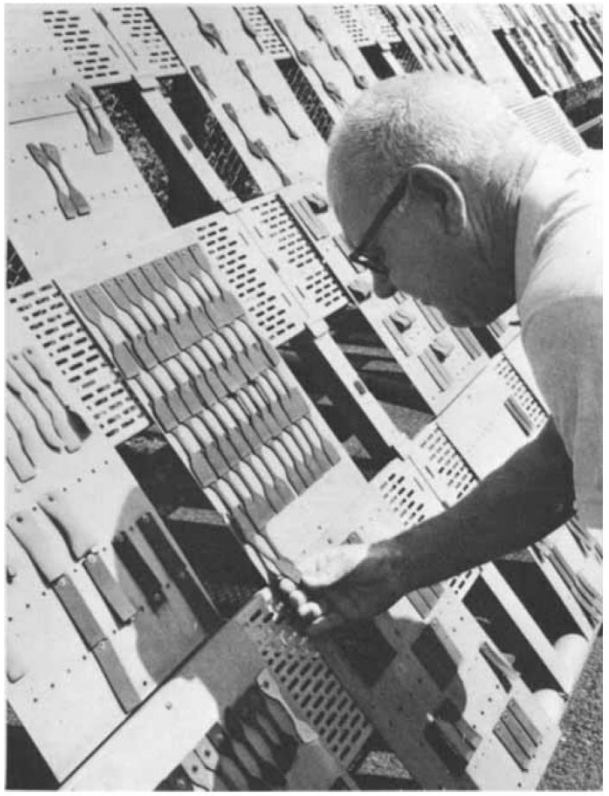

Fig 10. Bell Lab’s outdoor exposure racks at Murray Hill, NJ [2]

Current Testing Methods

- Absorption Coefficient
  - ASTM D3349 – Results in 1000 absorbance/meter

- Retained Physical Properties After Artificial Aging
  - Carbon-Arc Weather-O-Meter ASTM G 152 (open) or ASTM G153 (enclosed). Results in % T&E retention after specified # of hours.
  - Xenon-Arc Weather-O-Meter ASTM G 155. Results in % T&E retention after specified # of hours.

Current Testing Requirements

(In 1000 absorbance/meter)

- ICEA S-95-658 (<=2000V LV)
  - **Thermoplastic PE** has **320** requirement
- ICEA S-76-474 (600V LV OH)
  - **Thermoplastic PE** has **320** requirement
- ICEA S-81-570 (600V LV UG AR)
  - **Thermoplastic PE** (75°C rated) has **320** requirement
- ICEA S-96-659 (2001-5000V Nonshielded)
  - **Thermoplastic PE** has **320** requirement
- ICEA S-94-649 (5-46kV MV – Concentric Neutral)
  - **Thermoplastic PE/PP** has **320** requirement
- ICEA S-97-682 (5-46kV MV – Other Shields)
  - **Thermoplastic PE/PP** has **320** requirement
- ICEA S-93-639 (5-46kV MV)
  - **Thermoplastic PE** has **320** requirement
- ICEA S-108-720 (>46-345kV HV)
  - **Thermoplastic PE** has **320** requirement
- ICEA S-70-547 Weather Resistant Conductors
  - **Thermoplastic PE** has **320** requirement

References

- [1] Howard, J. B. (1966), Use of the spectrophotometer to control carbon dispersion quality in polyethylene. Polym Eng Sci, 6: 217–226. doi: 10.1002/pen.760060308
- [2] Howard, J. B. and Gilroy, H. M. (1969), Natural and artificial weathering of polyethylene plastics. Polym Eng Sci, 9: 286–294. doi: 10.1002/pen.760090409
- [3] DeMair, R. F. (2005), Effect of focused vs. unfocused light beam of 375nm on the absorption coefficient of carbon black pigmented linear low density. IEEE/PES/ICC Spring 2005.