

DOVERPHOS[®] S-9228 & DOVERPHOS[®] S-9411

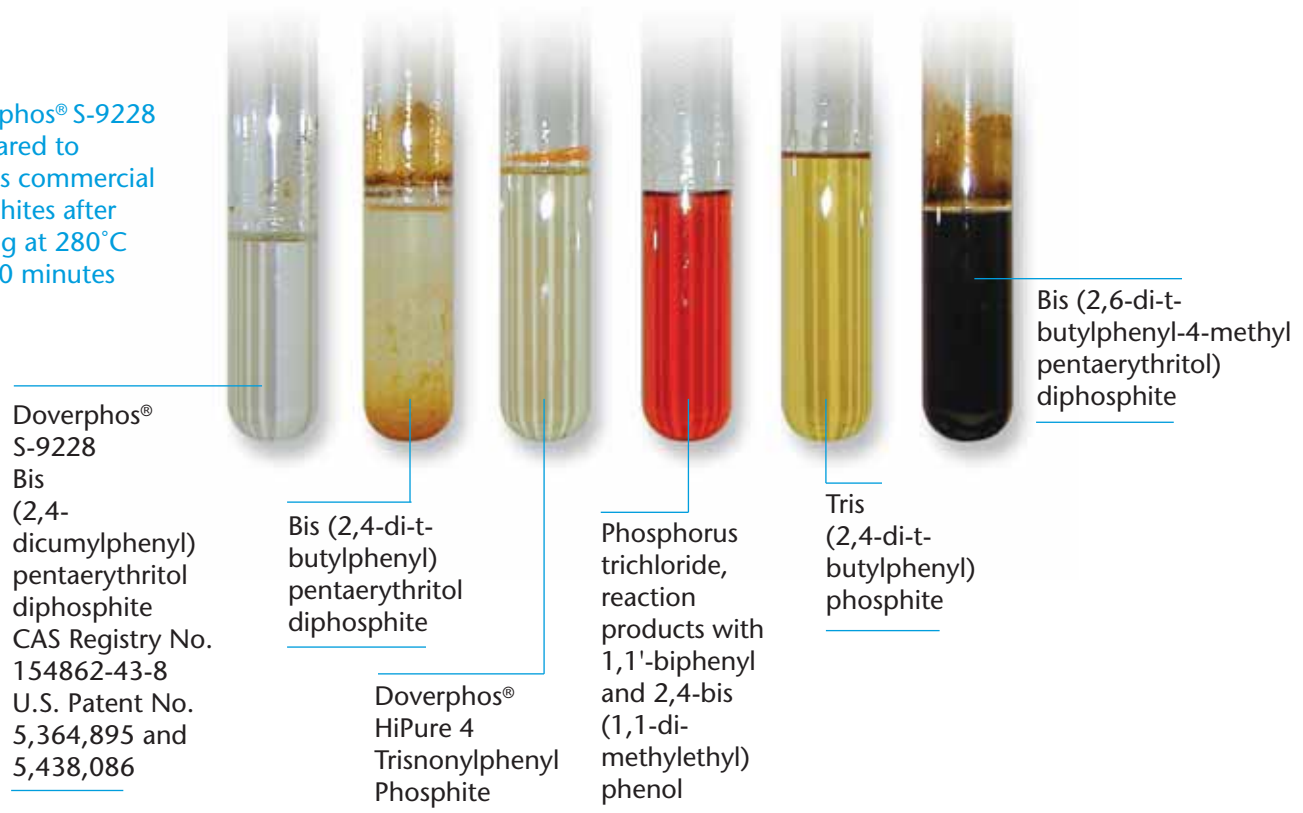
HIGH PERFORMANCE PHOSPHITE STABILIZERS



Doverphos® S-9228

Clearly superior performance

Doverphos® S-9228 compared to various commercial phosphites after heating at 280°C for 120 minutes



Dover's patented **Doverphos S-9228's** high molecular weight, low volatility, and high phosphorus content provide superior thermal stability that offers outstanding protection against discoloration and thermal degradation. Its unsurpassed hydrolytic stability prevents the formation of black specs.

Additional advantages of S-9228 include:

- Excellent for high temperature processing
- Low migration
- Low gel counts
- REACH approved
- Global Regulatory sanction for use in food contact applications
- FDA sanctions for use in all polymers with no limitations on Conditions of Use and Food types

Doverphos S-9228 & Doverphos S-9411 provide processing stabilization for:

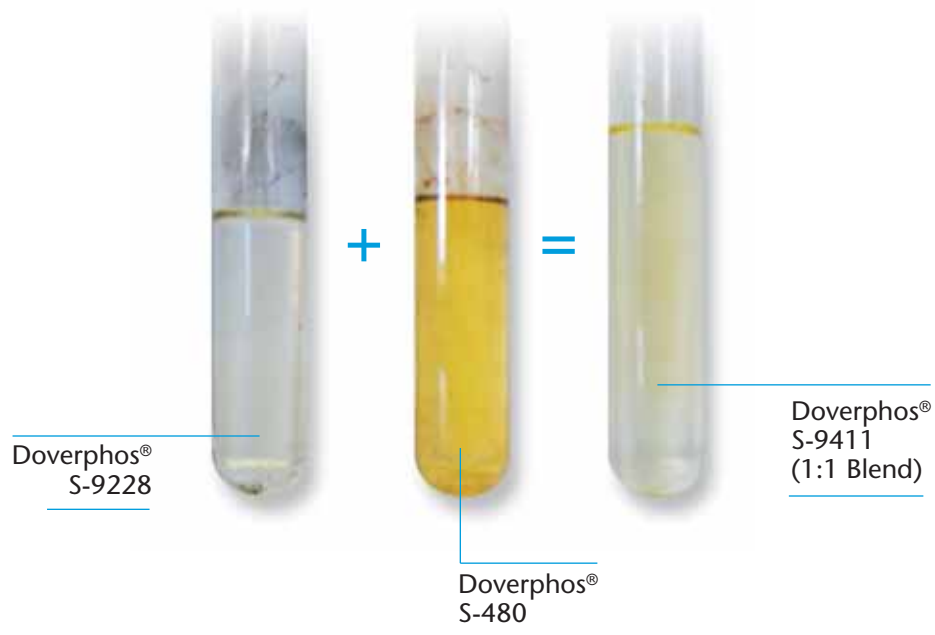
- Polypropylene (PP)
- High Density Polyethylene (HDPE)
- Linear Low Density Polyethylene (LLDPE)
- Powder Coatings

High Temperature Polymers:

- Polyester
- Polycarbonate (PC)
- Polyamides
- Polyetherimides

Doverphos® S-9411

Excellent balance of performance & cost



Dover's patented Doverphos S-9411 is an excellent cost/performance processing stabilizer for various polymer formulations in a broad application temperature range. It offers improved color control over standard phosphites and better hydrolytic stability than other high performance phosphites.

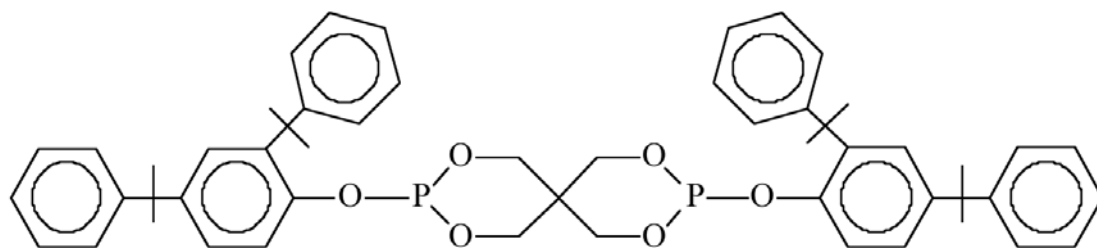
Doverphos S-9411 provides these advantages of S-9228 at lower cost:

- Excellent for high temperature processing
- Low migration
- Low gel counts
- REACH approved
- Global Regulatory sanction for use in food contact applications
- FDA sanctions for use in all polymers with no limitations on Conditions of Use and Food types

Dover has quadrupled production capacity for Doverphos S-9228 and S-9411 since 2009 to meet increasing demand. Doverphos S-9228, S-9228T, S-9228PC, S-9411, and S-9411T are neat products, available as powders and compacted granules. S-9228T and S-9411T are special grades with improved hydrolytic stability, used mainly in polyolefin applications. S-9228PC is a special polycarbonate grade with excellent thermal stability and very low metal content.

Doverphos S-9411 is a 1:1 blend of S-9228 and S-480. Custom blends of Doverphos S-9228 are also available.

Doverphos® S-9228 Properties & Characteristics

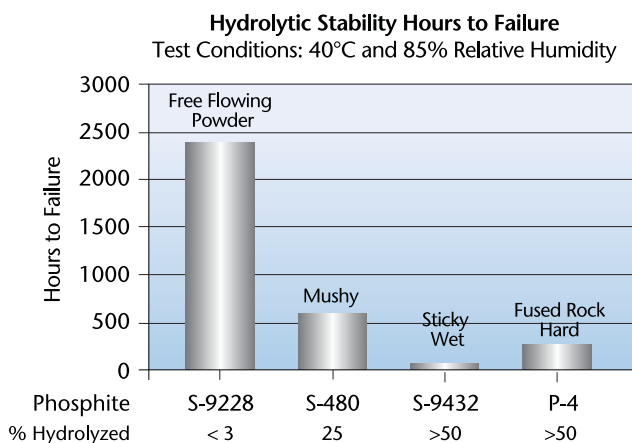
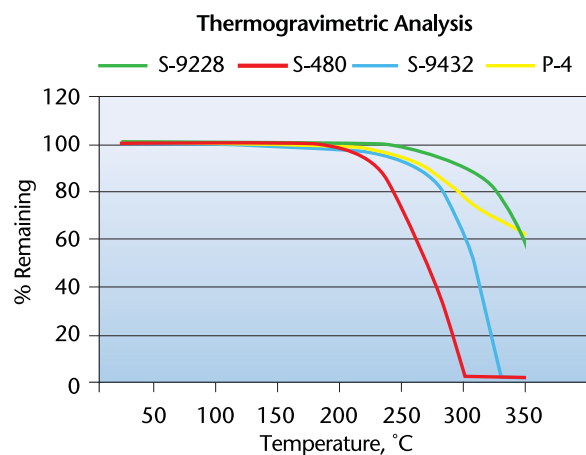


Typical Properties:

| | |
|--------------------|----------------------------------|
| Physical Form: | Free Flowing Powder and Granular |
| Color: | Off White |
| Molecular Weight: | 852 |
| % Phosphorus: | 7.3 |
| Melting Point, °C: | 225 Minimum |

Key properties:

- High molecular weight
- Low volatility
- High phosphorus content

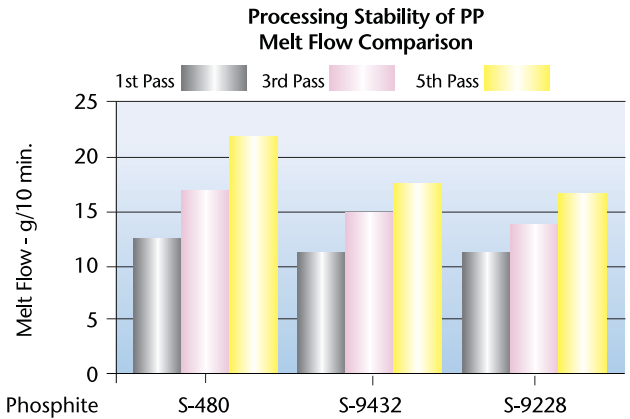
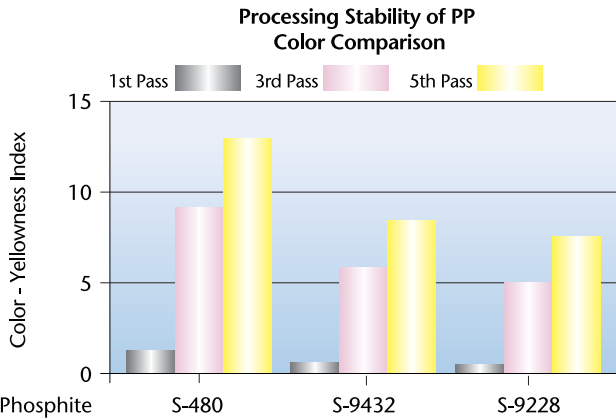


Doverphos S-9228 offers:

- Superior thermal stability and low volatility under extended high temperature conditions
- Excellent atmospheric and in-polymer hydrolytic stability
- Outstanding processing protection against discoloration and thermal degradation

Doverphos® S-9228 Performance in Key Polymer Systems

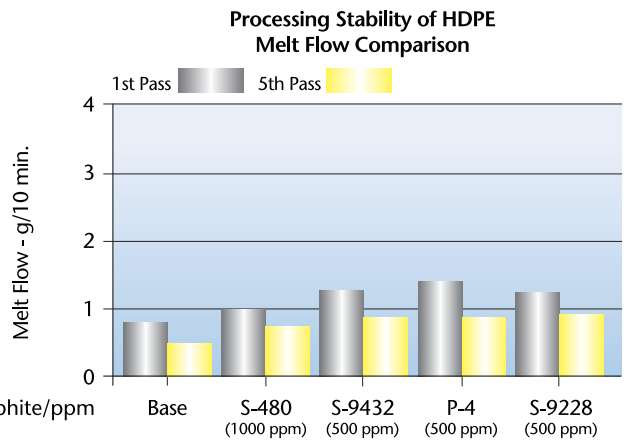
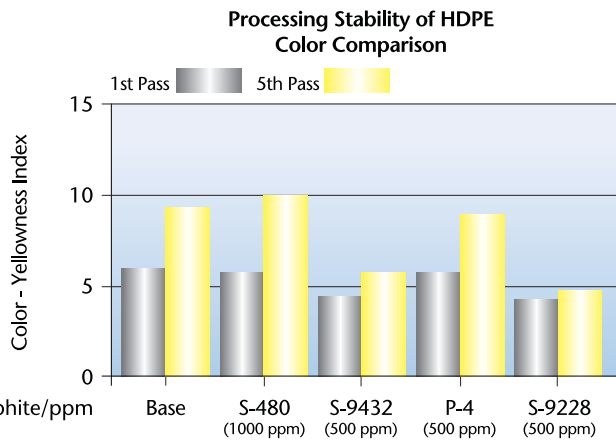
Polypropylene (PP)



Polymer: PP (Ziegler Natta) 12 MFI Additives: 0.05% CaSt; 0.05% Dovernox® 10 and 0.05% Phosphite / Test Conditions: Multiple Pass Extrusion @ 300°C

Doverphos® S-9228 demonstrates superior color and melt flow stability over a wide range of processing temperatures. In polypropylene systems that use only a phosphite as the process stabilizer, phosphite efficiency is paramount.

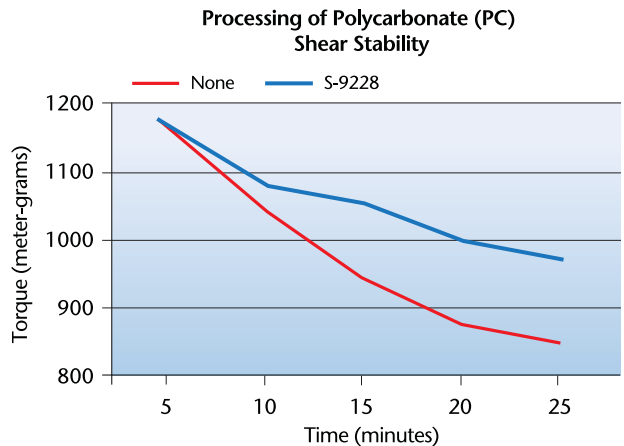
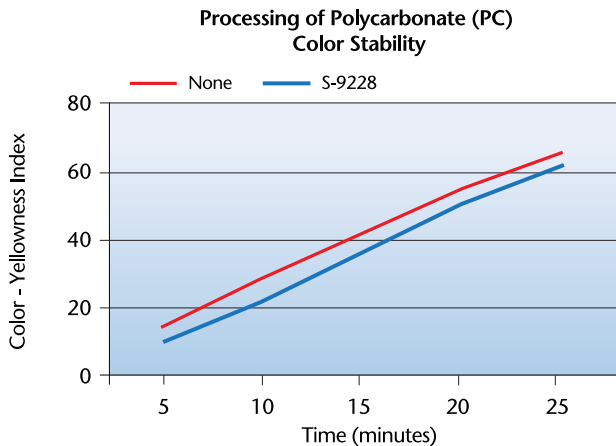
High Density Polyethylene (HDPE)



Polymer: HDPE (Cr Catalyzed) / Base: 0.05% CaSt; 0.05% Dovernox® 10 / Phosphite as Indicated / Test Conditions: Multiple Pass Extrusion @ 260°C

Doverphos S-9228 provides excellent color and melt flow stability in high density polyethylene. Typically, performance improvements can be achieved at much lower loading levels than are commonly used with other organophosphites.

Polycarbonate (PC)



Polymer: Branched Polycarbonate / Additive: None and S-9228 @ 0.2% / Test Conditions: Torque Rheometry at 300°C and 100 RPM

Doverphos® S-9228 withstands polycarbonate processing temperatures where most phosphites degrade or volatilize, and provides color and shear stability over extended test conditions. Doverphos S-9228 also provides similar protection for engineering thermoplastics and other high temperature polymers.

Doverphos® S-9228 & S-9411

Perfect for Pipe

Doverphos S-9228, S-9228T, S-9411, and S-9411T are excellent phosphite stabilizers for PP and HDPE pipe—especially water pipe—offering significant advantages:

- High molecular weight and low migration from HDPE and PP
- High performance allows use at lower levels, reducing amount available to migrate
- Degradation and byproducts are high molecular weight and low migration
- Good hydrolytic stability, especially S-9228T and S-9411T
- Excellent long-term heat stability, along with the appropriate primary antioxidant
- DSC studies show good resistance to water and chlorinated water when used with the appropriate primary antioxidant

S-9228 Performance in HDPE Pipe Applications

OIT Results for HPDE after Exposure to Tap Water at 60 °C

| Formulation | A | B | C | D ¹ |
|----------------------------------|-------|-------|-------|----------------|
| ZnSt | 250 | 250 | 250 | |
| S 9228T | 2000 | 1000 | 2000 | |
| DN 10 | | 1000 | 2000 | |
| Cyanox® 1790 | 1000 | | | |
| Ethanox® 330 | | 1000 | 2000 | |
| OIT (initial)² | | | | |
| Induction ³ | 18.91 | 12.87 | 23.59 | 10.46 |
| Threshold ⁴ | 11.99 | 11.07 | 21.97 | 10.07 |
| wt (mg) | 4.6 | 4.6 | 4.6 | 4.6 |
| Tap Water (5000 h) | | | | |
| Induction | 16.50 | 7.86 | 14.08 | 7.37 |
| Threshold | 16.47 | 7.52 | 13.97 | 5.54 |
| wt (mg) | 4.5 | 4.5 | 4.5 | 4.6 |

OIT Results for HPDE after Exposure to 5% Bleach at 60 °C

| Formulation | A | B | C | D ¹ |
|----------------------------------|-------|-------|-------|----------------|
| ZnSt | 250 | 250 | 250 | |
| S 9228 T | 2000 | 1000 | 2000 | |
| DN 10 | | 1000 | 2000 | |
| Cyanox® 1790 | 1000 | | | |
| Ethanox® 330 | | 1000 | 2000 | |
| OIT (initial)² | | | | |
| Induction ³ | 18.91 | 12.87 | 23.59 | 7.37 |
| Threshold ⁴ | 11.99 | 11.07 | 21.97 | 5.54 |
| wt (mg) | 4.6 | 4.6 | 4.6 | 4.6 |
| 5% Bleach (5000 h) | | | | |
| Induction | 13.97 | 4.10 | 9.23 | 0 |
| Threshold | 11.18 | 2.98 | 8.88 | 0 |
| wt (mg) | 4.5 | 4.4 | 4.2 | 4.4 |

¹ Control

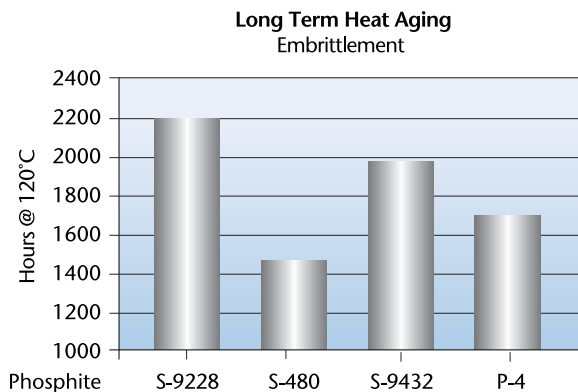
² OIT @ 235 °C (air)

³ Induction time in minutes

⁴ Threshold at 0.05 W/g (min)

Ideal for Automotive and Appliance Applications

Doverphos S-9228 and S-9411 provide thermal stability to polymer systems that must resist embrittlement and prevent color formation. This performance is critical in products such as transportation vehicles, dishwashers, toasters, and dryers.



Polymer: HDPE (Cr Catalyzed) / Additives: 0.05% Dovernox® 76; 0.05% Phosphite / Extrusion: Single Pass @ 260°C, press 1mm plaque

Doverphos® S-9411 Properties & Performance

Typical Properties:

| | |
|--------------------------|----------------------------------|
| Color & Physical Form: | Off White, Free Flowing Granular |
| Acid Number/mg/KOH/g: | <1 |
| Specific Gravity; 25°C: | 1.2 |
| % Phosphorus: | 6 |
| Melting Point Range, °C: | 180–230 |

Doverphos S-9411 Summary of Properties & Advantages

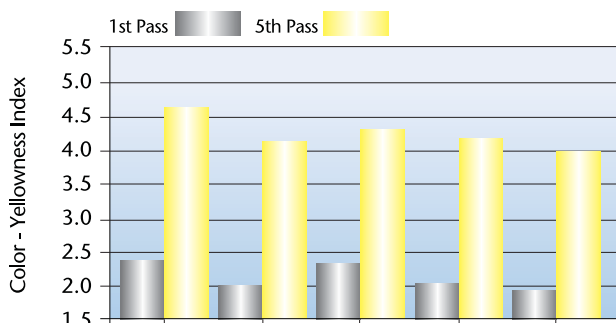
| Phosphite | Cost | Performance | Hydrolytic Stability | FDA SML | Cost Performance |
|-----------|------|-------------|----------------------|---------|------------------|
| S-9411 | 4 | 4 | 5 | 5 | 5 |
| S-9228 | 3 | 5 | 5 | 5 | 3 |
| S-480 | 5 | 2 | 5 | 5 | 3 |
| S-9432 | 3 | 4 | 2 | 2 | 3 |

Rating: 5, Best; 1, Poorest

Doverphos S-9411 provides good performance, excellent hydrolytic stability, and excellent global regulatory clearance for food contact applications at reasonable cost. Its utility is illustrated in the data below.

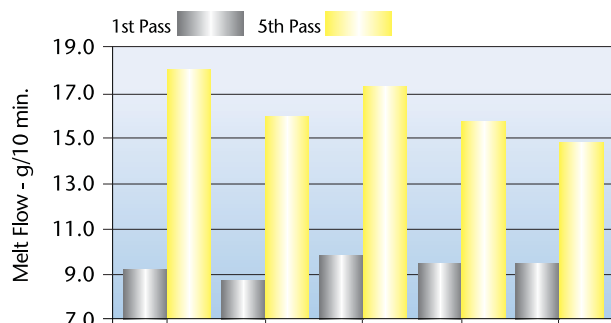
Polypropylene (PP)

Processing Stability of Polypropylene (PP)
Color Comparison



Phosphite/ppm S-9432 (800 ppm) S-9228 (800 ppm) S-9411 (800 ppm) S-9411 (1000 ppm) S-9411 (1200 ppm)

Processing Stability of Polypropylene (PP)
Melt Flow Comparison



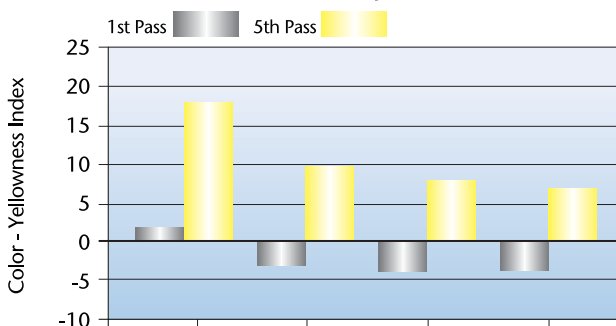
Phosphite/ppm S-9432 (800 ppm) S-9228 (800 ppm) S-9411 (800 ppm) S-9411 (1000 ppm) S-9411 (1200 ppm)

Phosphites as Indicated. / Base PP contains 500ppm CaSt; 800ppm Dovernox® 10 / Test Conditions: Multiple Pass Extrusion @ 260°C

Doverphos® S-9411 yields almost equal performance to the high performance phosphites S-9228 and S-9432.

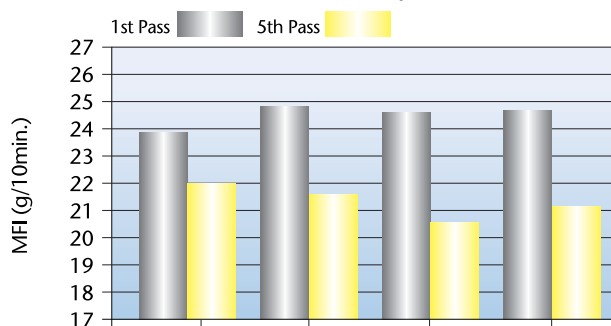
High Density Polyethylene (HDPE)

Processing Stability of HDPE
Color Comparison



Phosphite/ppm PEPQ (800 ppm) S-9228T (800 ppm) S-9411T (800 ppm) S-9411T (1000 ppm)

Processing Stability of HDPE
Melt Flow Comparison



Phosphite/ppm PEPQ (800 ppm) S-9228T (800 ppm) S-9411T (800 ppm) S-9411T (1000 ppm)

Base HDPE contains 500 ppm ZnSt; 700 ppm Dovernox® 10; Phosphite as Indicated / Test Conditions: Multiple Pass Extrusion @ 190 & 250°C

Doverphos S-9411T gives very good cost/performance in HDPE compared to both S-9228 and PEPQ. At equal levels, S-9411T performs nearly as well as the higher cost phosphites, and provides equivalent performance at slightly higher levels.

Key to Additives in Performance Comparisons:

| | |
|-------------------|--|
| Doverphos® S-480 | Tris (2,4-di-t-butylphenyl) phosphite |
| Doverphos® S-9432 | Bis(2,4-di-t-butylphenyl) pentaerythritol diphosphite |
| Dovernox® 10 | Tetrakis methylene (3,5-di-t-butyl-4-hydroxyhydrocinnamate methane |
| Dovernox® 76 | Octadecyl 3,5-di-t-butyl-4-hydroxyhydrocinnamate |
| P4 | Tetrakis (2,4-di-t-butylphenyl) 4,4'-bisphenylene diphosphonite |



Dover Chemical Corporation
3676 Davis Road N.W.
Dover, Ohio 44622
USA

www.doverchem.com
Phone: 1-330-987-8599
Toll Free: 1-800-321-8805

Customer Service

Phone: 1-800-75-DOVER (36837)
Fax: 1-330-602-8921
Email: Customerservice@doverchem.com

International

International inquiries: ICC Industries New York
Fax: +1-212-521-1959
Email: 9228@iccchem.com

ICC Amsterdam:
Phone: +31-20-644-8888
Fax: +31-20-644-6364
Email: Netherlands@iccchem.com

Japan:
Phone: +81-3-3291-2019
Fax: +81-3-3233-2978
Email: Dover-JP@iccchem.com

China:
Phone: +86-21-6403-8456
Fax: +86-21-6418-6080
Email: Dover-CN@iccchem.com



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