

# Overcoming the Formulation Difficulties related to the use of Non-Phthalate General Purpose Plasticizers: DEHCH

## Purpose

DEHCH (Diethylhexyl-cyclohexane) is a Phthalate free, general purpose plasticizer. It can be compared to products such as DOTP and DINCH in today's market place. We evaluated DEHCH vs. Santicizer® Platinum P-1400. While our Santicizer® Platinum P-1400 is not a general-purpose plasticizer, we have evaluated the material in several different scenarios.

#### **Samples Evaluated**

- 1. DEHCH(Diethylhexyl-cyclohexane)
- 2. DOTP (Dioctyl Terephthalate)
- 3. DINCH (Diisononyl 1,2-Cyclohexane dicarboxylic acid ester)
- 4. Santicizer® Platinum P-1400
- 5. Santicizer® 160
- 6. Santicizer® 261A
- 7. Blend 70% DEHCH, 30% Santicizer® Platinum P-1400
- 8. Blend 70% DEHCH, 30% Santicizer® 160
- 9. Blend 70% DEHCH, 30% Santicizer® 261A

# Formulations

Mill Sheet

| Description            | Amount (phr) |
|------------------------|--------------|
| Resin – K Value 70     | 100          |
| Plasticizer            | 50           |
| Heat Stabilizer        | 3            |
| Epoxidized Soybean Oil | 2            |
| Titanium Dioxide       | 1            |
| Calcium Carbonate      | 10           |
| UV Stabilizer          | 0.5          |
| Total                  | 166.5        |

Plastisol

| Description        | Amount (phr) |
|--------------------|--------------|
| Resin – K Value 70 | 100          |
| Plasticizer        | 50           |
| Heat Stabilizer    | 2            |
| Titanium Dioxide   | 1            |
| Calcium Carbonate  | 10           |
| UV Stabilizer      | 0.5          |
| Total              | 163.5        |





## Testing

- 1. Fusion Time and Temperature Valtris Test
- 2. Water Sensitivity ASTM D1239
- 3. Alkaline Resistance ASTM D1239
- 4. Kerosene Extraction ASTM D1239
- 5. Silica Migration ASTM D1239
- 6. Viscosity plastisol only Valtris Test
- 7. Shore A mill sheet only ASTM D2240
- 8. Weathering ASTM G155 cycle 1

# **Executive Summary**

- DEHCH as General Purpose plasticizer competes well compared to DOTP and DINCH in both the plastisol and mill sheet formulations.
- Santicizer<sup>®</sup> Platinum P-1400 is not to be used as a General Purpose plasticizer but tested as a General Purpose
  plasticizer performs just as well or better than the other general purpose plasticizers tested in both plastisol and
  mill sheet formulations.
- The best way to use Santicizer<sup>®</sup> Platinum P-1400 would be to blend with DEHCH. From the testing of the mill sheet and plastisol formulations you will see a decrease in fusion time and temperature, improvements on water sensitivity, alkaline resistance, kerosene extraction, silica migration, and shore hardness.
- The Santicizer<sup>®</sup> 160 and 261A would also be good alternatives to Santicizer<sup>®</sup> Platinum P-1400 as they perform similar to the Platinum product.
- Weathering results show that the DEHCH blend with Santicizer<sup>®</sup> Platinum P-1400 and Santicizer<sup>®</sup> 261A perform the best, as they show the lowest color change between the samples tested.





## Mill Sheet Testing











#### Mill Sheet

|   | Water<br>Sensitivity  | Alkaline<br>Resistance | Kerosene<br>Extraction | Silica Migration<br>% Weight Loss |        | Shore A |
|---|-----------------------|------------------------|------------------------|-----------------------------------|--------|---------|
| Sample Description                          | % Water<br>Absorption | % Weight<br>Loss       | % Weight<br>Loss       | 1 day                             | 7 days | Average |
| DEHCH                                       | 12.65                 | -0.11                  | 38.03                  | 0                                 | 0.38   | 86.6    |
| DOTP  | 5.53                  | -0.07                  | 40.45                  | 0                                 | 0.42   | 88.0    |
| DINCH                                       | 10.43                 | -0.12                  | 63.01                  | 0                                 | 0.26   | 87.0    |
| Santicizer® Platinum P1400                  | 3.55                  | -0.23                  | 1.43                   | 0                                 | 0.09   | 81.6    |
| Santicizer® 160                             | 6.81                  | -0.36                  | 0.65                   | 0                                 | 0.16   | 80.5    |
| Santicizer® 261A                            | 4.69                  | -7.71                  | 1.53                   | 0                                 | 0.16   | 83.6    |
| 70% DEHCH/30%<br>Santicizer® Platinum P1400 | 2.97                  | -3.45                  | 11.08                  | 0                                 | 0.27   | 75.5    |
| 70% DEHCH/30%<br>Santicizer® 160            | 9.24                  | -13.95                 | 10.33                  | 0                                 | 0.22   | 81.6    |
| 70% DEHCH/30%<br>Santicizer® 261A           | 1.02                  | -22.48                 | 12.42                  | 0                                 | 0.27   | 76.5    |

#### Mill Sheet – Weathering Data

|   |                      | Δb      |         |         |         |  |
|---|----------------------|---------|---------|---------|---------|--|
| Sample Description                          | Initial "b"<br>Value | 100 hrs | 200 hrs | 300 hrs | 400 hrs |  |
| DEHCH                                       | 3.28                 | -0.67   | -0.75   | -0.87   | -0.88   |  |
| DOTP  | 3.79                 | -0.70   | -1.03   | -1.06   | -1.23   |  |
| DINCH                                       | 3.66                 | -0.58   | -1.30   | -1.34   | -1.34   |  |
| Santicizer® Platinum P1400                  | 4.57                 | -0.92   | -0.95   | -1.44   | -1.46   |  |
| Santicizer® 160                             | 4.36                 | -1.14   | -1.46   | -1.48   | -1.78   |  |
| Santicizer® 261A                            | 2.74                 | -0.06   | -0.06   | 0.00    | 0.04    |  |
| 70% DEHCH/30%<br>Santicizer® Platinum P1400 | 1.93                 | -0.04   | -0.47   | -0.53   | -0.56   |  |
| 70% DEHCH/30%<br>Santicizer® 160            | 2.00                 | 0.14    | -0.09   | -0.11   | -0.66   |  |
| 70% DEHCH/30%<br>Santicizer® 261A           | 1.99                 | -0.15   | -0.27   | -0.37   | -0.40   |  |





#### **Mill Sheet Conclusions**

- DEHCH in a mill sheet formulation performs like DOTP and DINCH for fusion time and temperature. While the Santicizer® Platinum P-1400, 160, and 261A also perform similar to each other as they are all fast fusers. The best bet would be to use the DEHCH in combination with the fast fuser of Santicizer® Platinum P-1400 for efficiency and cost purposes.
- Water sensitivity results show that the DEHCH by itself does not perform very well, but when a fast fuser is added to the formulation water sensitivity seems to decrease significantly. For this test, we followed ASTM D-1239, where plastisol disks are submerged in water and you are looking for a change in weight., or how much water was absorbed into the fused disk. The data shows that Santicizer® Platinum P-1400 and Santicizer® 261A are superior to the other samples tested for water sensitivity, having absorbed the least amount of water.
- Alkaline resistance (ASTM D543) data shows that all the samples have a negative percent weight loss, meaning the samples gained weight or retained some of the alkaline solution the samples were submerged in. DEHCH by itself performs pretty well for alkaline resistance having gained the least amount of weight compared to the other samples tested.
- Kerosene Extraction (ASTM D-1239) data shows the General Purpose Plasticizers have significant weight loss when exposed to Kerosene, while the fast fusers do not show this same level of loss. The blends of DEHCH and Santicizer® products show a happy medium between the General purpose and fast fusers and would be beneficial depending on the customers' requirements.
- For the Silica migration test we are looking for migration of the plasticizer out of the fused disc and into the silica material. As tested we did not see any migration within 1 day, and on 7 days, all products performed relatively the same.
- Shore A hardness or efficiency of the plasticizer show with this formulation that the Santicizer® Platinum P-1400, 160, and 261A are more efficient than the General purpose plasticizers, and blends with DEHCH help efficiency even more.
- Weathering all samples were tested for 400 hrs exposed to Xenon Arc according to ASTM F1515. Delta b
  readings were taken of the samples showing the change in "yellow" values. From the data present, all samples
  moved blue (negative b) except the Santicizer® 261A sample which really didn't show much of a color change at
  all. The blends of DEHCH and both Santicizer® 261A and Platinum P-1400 show to be the next best for color
  differences, as they moved the least amount of color over the 400 hrs.

#### **Plastisol Testing**

<u>Please note:</u> When making the Plastisols, the 100% Santicizer® 160 and 261A were too thick to test, therefore they were eliminated totally from the testing group.





## Plastisol Viscosity



## Plastisol Fusion Time & Temperature



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#### Plastisol

|   | WaterAlkalineKeroseneSensitivityResistanceExtraction |                  | Silica Migration<br>% Weight Loss |       |        |
|---|--|------------------|-----------------------------------|-------|--------|
| Sample Description                          | % Water<br>Absorption                                | % Weight<br>Loss | % Weight<br>Loss                  | 1 day | 7 days |
| DEHCH                                       | 0.52   | -0.20            | 49.34                             | 0     | 0.88   |
| DOTP  | 0.36   | -0.26            | 37.90                             | 0     | 0.86   |
| DINCH                                       | 54   | -0.30            | 55.90                             | 0     | 1.24   |
| Santicizer® Platinum P1400                  | 0.22   | -0.19            | 5.38                              | 0     | 0.01   |
| 70% DEHCH/30%<br>Santicizer® Platinum P1400 | 0.34   | -0.20            | 19.49                             | 0     | 0.92   |
| 70% DEHCH/30%<br>Santicizer® 160            | 0.66   | -0.25            | 29.04                             | 0     | 1.80   |
| 70% DEHCH/30%<br>Santicizer® 261A           | 0.59   | -0.18            | 56.46                             | 0     | 1.11   |





## Plastisol – Weathering Data

|   |                      | Δb      |         |         |         |  |
|---|----------------------|---------|---------|---------|---------|--|
| Sample Description                          | Initial "b"<br>Value | 100 hrs | 200 hrs | 300 hrs | 400 hrs |  |
| DEHCH                                       | 2.78                 | -1.94   | -2.28   | -2.59   | -2.68   |  |
| DOTP  | 3.80                 | -2.83   | -3.02   | -3.11   | -3.49   |  |
| DINCH                                       | 3.30                 | -2.76   | -2.77   | -3.01   | -3.14   |  |
| Santicizer® Platinum P1400                  | 3.74                 | -3.30   | -3.43   | -3.46   | -3.50   |  |
| 70% DEHCH/30%<br>Santicizer® Platinum P1400 | 1.81                 | -1.34   | -1.73   | -1.94   | -1.99   |  |
| 70% DEHCH/30%<br>Santicizer® 160            | 2.14                 | -2.01   | -2.05   | -2.14   | -2.36   |  |
| 70% DEHCH/30%<br>Santicizer® 261A           | 2.37                 | -1.82   | -2.29   | -2.30   | -2.41   |  |

## **Plastisol Conclusions**

- Viscosity stability for a plastisol is important test to determine how the product would handle being stored over time. We looked at initial and 7 day viscosity changes on a TA Discovery HR-2 rheometer. Samples were run at 25°C at increasing shear rates. The blue bars are the initial viscosity and the orange bars are after 7 days. All data was recorded at 20 1/s. All samples except the DOTP perform well for 7 day viscosity stability.
- DEHCH in a plastisol formulation performs like DOTP for fusion time and temperature. DINCH does not perform as well as both the DOTP and DEHCH samples. The Santicizer® Platinum P-1400 definitely decreases fusion time and temperature compared to the General Purpose controls. The Santicizer® Platinum P-1400, 160, and 261A as blends with the DEHCH also perform like each other as they are all fast fusers.
- Water sensitivity (ASTM D-1239) results show that Santicizer® Platinum P-1400 performs the best for water sensitivity or amount of water absorbed into the discs. With the blend of DEHCH and Santicizer® Platinum P-1400 performing the second best.
- Alkaline resistance (ASTM D543) data shows that all the samples have a negative percent weight loss, meaning the samples gained weight or retained some of the alkaline solution the samples were submerged in. Santicizer® Platinum P-1400 performed the best for alkaline resistance at it had gained the least amount of weight. The blend of DEHCH and Santicizer® Platinum P-1400 performed just as well as the DEHCH by itself.
- Kerosene Extraction (ASTM D-1239) data shows the General Purpose Plasticizers have significant weight loss when exposed to Kerosene, while the Santicizer® Platinum P-1400 and DEHCH blend with Santicizer® Platinum P-1400 performed the best for Kerosene Extraction. They had the least amount of weight loss.
- For the Silica migration test we are looking for migration of the plasticizer out of the fused disc and into the silica material. As tested we did not see any migration within 1 day, and on 7 days, the Santicizer® Platinum P-1400 performed the best of all samples tested.
- Weathering all samples were tested for 400 hrs exposed to Xenon Arc according to ASTM F1515. Delta b
  readings were taken of the samples showing the change in "yellow" values. From the data present, all samples
  moved blue (negative b). The blends of DEHCH and both Santicizer® 261A and Platinum P-1400 show to be
  the best for color differences, as they moved the least amount of color over the 400 hrs, with the Platinum P1400 blend being the best, with the least amount of color change.

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#### **Valtris Overview**

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