

# Comparative analysis of electro-mechanical properties of enameled winding wires filled with a silica nanofiller

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**Abstract:** This study deals with the use of a nanofiller, **AEROSIL® R 972**, a form of fumed silica with an average diameter of around 16nm and specific surface area of 110m<sup>2</sup>/g. This nanofiller is used in combination with the **Polyamide Imide Wire Enamel** to create a nanocomposite **AI 32 S suspension**. The investigation is a comparative study, using different proportions of nanofiller and a reference sample containing no filler, to determine any potential changes in electrical and mechanical properties of the wire enamel. Experimental results showed improvements in surface finish of the coat, viscosity, abrasion resistance and breakdown voltage.

**Keywords:** **AEROSIL® R 972**, silica, nanofiller, enamel, polyamide imide, viscosity, abrasion resistance, breakdown voltage

## 1. Introduction

Nanotechnology is a fast-growing sector, particularly its electrical and material applications. It is widely anticipated that nanoparticles can often be combined with traditional resins and insulation varnishes to create nanocomposite materials that improve the mechanical and electrical properties of wire enamel, i.e. the insulation coating and enamel used in winding wires.

### 1.1 Background

This study was conducted in conjunction with Precision Wires India Ltd (PWIL), a leading manufacturer of Enamelled Copper Winding Wires in India. Enamelled Wires are produced by applying a number of coats of wire enamels to copper conductors. The resultant coated conductor is cured in a precisely controlled heated enamelling oven. PWIL was interested in the feasibility of using nanofillers to upgrade the properties of wire enamels and the enamelled wires produced using the same.

### 1.2 Theory

Nanofillers are inorganic materials which are solids and behave as additives. Their main function is, as the name suggests, to "fill" the voids in between (in

this case) the polymer matrix. The nanofiller will alter the characteristics of the wire enamel polymer matrix based upon how well it is dispersed within the polymer and how it interacts with the matrix [1].

The application of these fillers to wire enamel could improve electrical and mechanical properties of the insulation, eventually leading to energy conservation and greater efficiency.

Insulated winding wires are used in various electrical applications, for instance, inverter drives and inverter driven motors. The voids in the insulation material of the wire are often subjected to the stress of high voltage gradients, leading to ionization of gas that fills these spaces, known as the corona discharge [2]. This leads to leakage of current, thus energy losses, and if not properly repaired, can lead to complete breakdown of the insulation. This effect can be reduced by filling these voids with nano "fillers".

Enhanced smoothness and mechanical strength may enhance the manufacturing process, for instance, when the wire is wound around reels to be packaged and transported, having a smoother surface means the wire can slip upon itself and allow for easier winding. Also, greater mechanical strength would mean fewer abrasions and scratches, leading to improved surface quality.

### **1.3 Related Work**

There is precedent for conducting this sort of study. Using nanofillers to improve properties of insulating materials has demonstrated positive results in several investigations. In [3], positive effects were seen in enamelled wires with regards to surface erosion, wire life and homogeneity in the material, with the application of a fumed silica nanofiller. In [4], electrical properties such as dielectric strength and partial discharge showed improvements with the application of nanofillers.

## **2. Materials and Methods**

Inorganic Nano sized Silica and Alumina are commonly used to bring about improvements in mechanical properties. Generally, nanoparticles used as additives in very small quantities of around 1-5% give good results in terms of surface finish and mechanical scratch resistance when used in paints and other various types of coatings [4].

One important point is that as one increases the quantum of addition of nanofillers in paints and coatings, it is observed that the task of incorporation/dispersion of the nanofillers becomes more and more challenging and requires specialized equipment such as high speed ball mills equipped with specialized grinding media.

### **2.1 Formulation**

PWIL makes heavy use of the Polyamide Imide as a top coat wire enamel, therefore this investigation focuses on Polyamide Imide, in combination with the nanofiller, AEROSIL® R 972 fumed silica having an average particle size of

16nm and silica content of  $\geq 99.8\%$  [**Annexure A**], to create the nano-filled polyamide imide AI 32 S suspension wire enamel composite.

The investigation was divided into two parts:

- Incorporate Nanofillers into **Polyamide Imide wire enamel** to investigate changes in the mechanical properties of the enamelled wires produced.
- Incorporate Nanofillers into **Polyamide Imide wire enamel** to investigate changes in the electrical properties of the enamelled wires produced.

## 2.2 Materials

In order to ascertain the effectiveness of the nanofiller, 4 samples of the with wire enamel with the nanofiller in varying degrees of concentration were prepared. These were compared with regular the Polyamide Imide wire enamel as a reference.

1. Reference sample A: Unfilled Polyesterimide Base Coat (9 coats) + Unfilled Polyamide Imide AI 32 S Top Coat ( 1 coat)
2. Sample B1: Unfilled Polyesterimide Base Coat (9 coats) + Filled Polyamide Imide AI 32 S Top Coat containing concentration of AEROSIL® R 972 of 0.250% (1 coat)
3. Sample B2: Unfilled Polyesterimide Base Coat (9 coats) + Filled Polyamide Imide AI 32 S Top Coat containing concentration of AEROSIL® R 972 of 0.500% (1 coat)
4. Sample B3: Unfilled Polyesterimide Base Coat (9 coats) + Filled Polyamide Imide AI 32 S Top Coat containing concentration of AEROSIL® R 972 of 1.000% (1 coat)
5. Sample B4: Unfilled Polyesterimide Base Coat (9 coats) + Filled Polyamide Imide AI 32 S Top Coat containing concentration of AEROSIL® R 972 of 1.500% (1 coat)

## 2.3 Constraints and considerations

- In order to ensure a good quality dispersion with the nanofiller, a dispersing/coupling agent is generally added. This, as mentioned in section 1.2, would ensure that the dispersion of the nanofiller is stable and settling is prevented, thus allowing the filler to properly intercalate with the polymer matrix. It creates the link between the organic matrix and inorganic filler. In this case, since silica ( $\text{SiO}_2$ ) is an extremely fine insoluble powder with a very large Specific Surface Area ( $110\text{m}^2/\text{g}$ ) [**Annexure A**], there would be a tendency to agglomerate and settle. The dispersing agent W&D™ 875 [**Annexure B**], produced by M/s K-Tech Ltd, was used. The dispersing agent quantity was increased in proportion to the nanofiller quantity.
- A reasonably high-speed mixer would be required to ensure proper dispersion of the nanofiller within the wire enamel. A Cowell Disperser was

used.

- For proper application of the nanofilled wire enamel on the wire, it is necessary that the nanoparticles remain in proper suspension. Therefore, after incorporation of the nanoparticles and dispersing agent, the nanofilled wire enamel was left to rest in the laboratory for a few days to observe for any settlement of the nanoparticles.
- To determine the effectiveness of the silica nanofiller, different samples of nanofilled wire enamel would have to be prepared, each containing a different proportion of the filler. This would then be compared to a reference wire sample made from unfilled wire enamel.

#### 2.4 Preparation of nanofilled Polyamide Imide AI 32 S suspension

1. Charge 100kg of AI 32 S Polyamide Imide Wire Enamel into the disperser
2. Take W&D™ 875 in the ratio of about 6% of the weight of the Nano Particle to be incorporated [**Annexure B**]. Make a solution of W&D™ 875 by taking 0.2kg of N-Methyl 2 Pyrrolidone (NMP), 0.2kg of Mixed Xylene and the required quantity as described above of W&D™ 875. Stir for five minutes at room temperature to ensure proper mixing
3. Add the above solution into the above AI 32 S. Stir in the disperser at high speed for 15 minutes
4. Incorporate AEROSIL® R 972 in the required quantity (see Table 1) gradually over a period of about 30 minutes under constant stirring into the above mentioned solution.
5. Continue stirring for about 3 hours.
6. Evacuate into a drum using a pump and store.

#### 2.5 Testing and Evaluation

After the composite enamel was created and rested for a few days, it was tested standalone, and also applied to the standard PWIL General Purpose 0.5mm round wire offering for testing.

The resultant composition matrix is as shown in table 1

**Table 1:** Sample composition matrix A-B4

|                | A       | B1      | B2      | B3      | B4      |
|----------------|---------|---------|---------|---------|---------|
| AI 32 S        | 100kg   | 100kg   | 100kg   | 100kg   | 100kg   |
| AEROSIL® R 972 | 0       | 0.250kg | 0.500kg | 1.000kg | 1.500kg |
| W&D™ 875       | 0.015kg | 0.015kg | 0.030kg | 0.060kg | 0.090kg |
| NMP            | 0.20kg  | 0.20kg  | 0.20kg  | 0.20kg  | 0.20kg  |
| Mixed xylene   | 0.20kg  | 0.20kg  | 0.20kg  | 0.20kg  | 0.20kg  |



Figure 1: *Cowell's Disperser for mixing.*



Figure 2: Sample of nano-filled wire enamel.

In order to determine the mechanical properties of the prepared nano-filled enamels, the following tests were conducted:

- Smoothness and flow of the enamel was modelled by using viscosity, as a measure of smoothness. This was done via the Hoeppler Falling Ball Viscometer with the DIN 53015 standard. This test was conducted at 25°C.
- Mechanical strength was measured with an abrasion test

For electrical properties, breakdown voltage was measured for the different samples by using a high voltage breakdown voltage tester.

### 3. Results

This section shows the results collected from the tests conducted on the nano-filled enamel and wire sample that was prepared with the nano-filled enamel.

#### 3. 1 Mechanical testing

The tests for the mechanical properties were conducted as per section 2.5. 5 trials each were conducted separately for the viscosity tests and the abrasion tests, noted in Tables 2 and 3 respectively. Qualitative features of the enamel were also noted across the trials, noted in Table 4.

**Table 2:** Results in viscosity (mPas) of wire enamel with samples B1-B4 vs reference sample.

|    | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 |
|----|---------|---------|---------|---------|---------|
| A  | 2950    | 2951    | 2951    | 2940    | 2941    |
| B1 | 3451    | 3450    | 3466    | 3449    | 3455    |
| B2 | 2740    | 2760    | 2752    | 2768    | 2761    |
| B3 | 2009    | 2021    | 2014    | 2011    | 2020    |
| B4 | 1924    | 1935    | 1941    | 1941    | 1937    |

**Table 3:** Results in abrasion resistance (N) of wire enamel with samples B1-B4 vs reference sample.

|    | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 |
|----|---------|---------|---------|---------|---------|
| A  | 8.814   | 8.814   | 8.813   | 8.815   | 8.815   |
| B1 | 8.818   | 8.819   | 8.819   | 8.818   | 8.817   |
| B2 | 8.851   | 8.852   | 8.855   | 8.855   | 8.854   |
| B3 | 8.867   | 8.868   | 8.869   | 8.870   | 8.868   |
| B4 | 8.881   | 8.882   | 8.882   | 8.887   | 8.889   |

**Table 4:** Qualitative results of wire enamel with samples B1-B4 compared to reference sample.

|    | Flow      | Spots    | Continuity | Finish      | Settling |
|----|-----------|----------|------------|-------------|----------|
| A  | Good      | Very few | High       | Glossy      | None     |
| B1 | Rough     | Few      | Low        | Dull matte  | Some     |
| B2 | Good      | Very few | High       | Matte       | None     |
| B3 | Very good | None     | Very high  | Glossy      | None     |
| B4 | Excellent | None     | Very high  | Very glossy | Some     |

### 3.2 Electrical testing

The tests for electrical properties were conducted as shown in Table 5. 8 separate trials for the voltage breakdown with each of the sample types was conducted.

**Table 5:** Results of breakdown voltage (V) test with samples B1-B4 compared to reference sample.

|         | A    | B1   | B2   | B3   | B4   |
|---------|------|------|------|------|------|
| Trial 1 | 2901 | 2900 | 2901 | 2902 | 2910 |
| Trial 2 | 2902 | 2900 | 2902 | 2904 | 2911 |
| Trial 3 | 2902 | 2901 | 2902 | 2902 | 2910 |
| Trial 4 | 2901 | 2901 | 2903 | 2903 | 2911 |
| Trial 5 | 2902 | 2901 | 2902 | 2904 | 2911 |
| Trial 6 | 2901 | 2901 | 2903 | 2903 | 2910 |
| Trial 7 | 2901 | 2901 | 2903 | 2903 | 2910 |
| Trial 8 | 2902 | 2900 | 2902 | 2903 | 2911 |

## 4. Discussion and observations

The results from section 3 are analysed below.

### 4.1 Qualitative analysis

In general, there were improvements seen in certain qualitative measures across the trials. That is, as the relative quantity of the nanofiller was increased, the qualitative properties improved. As evidenced from Table 4, there was general improvements in flow, fewer spots/scratches, better continuity and better gloss finish. The results support the initial hypothesis that was suggested by the theory in section 1.2. This is also consistent with findings that others have had with similar experiments, such as [5] and also in other circumstances where nanofillers are used as in [6]

### 4.2 Quantitative analysis

The results for mechanical tests were collated from Tables 2 and 3. Average values were calculated for both the viscosity and abrasion test measurements and plotted, as seen in Figures 3 and 4 respectively.

There are a few salient observations that can be made here:



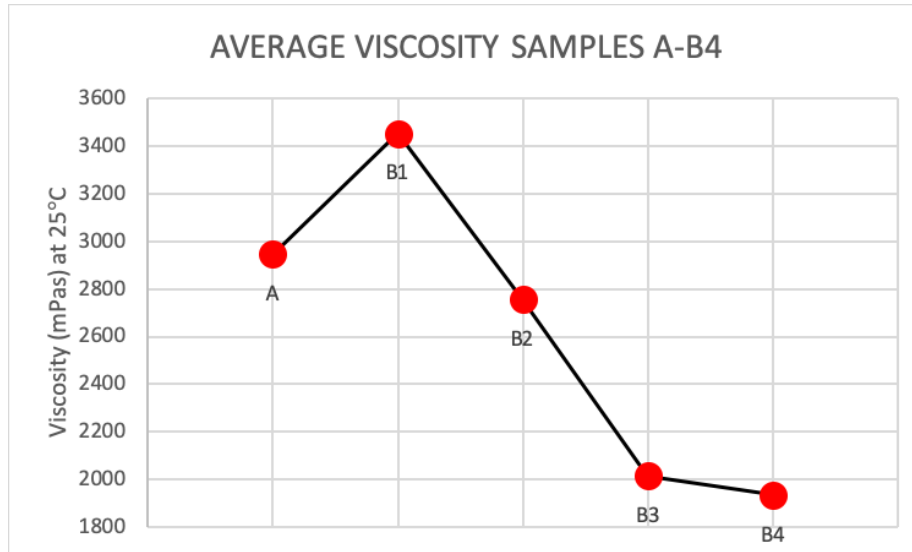


Figure 3:

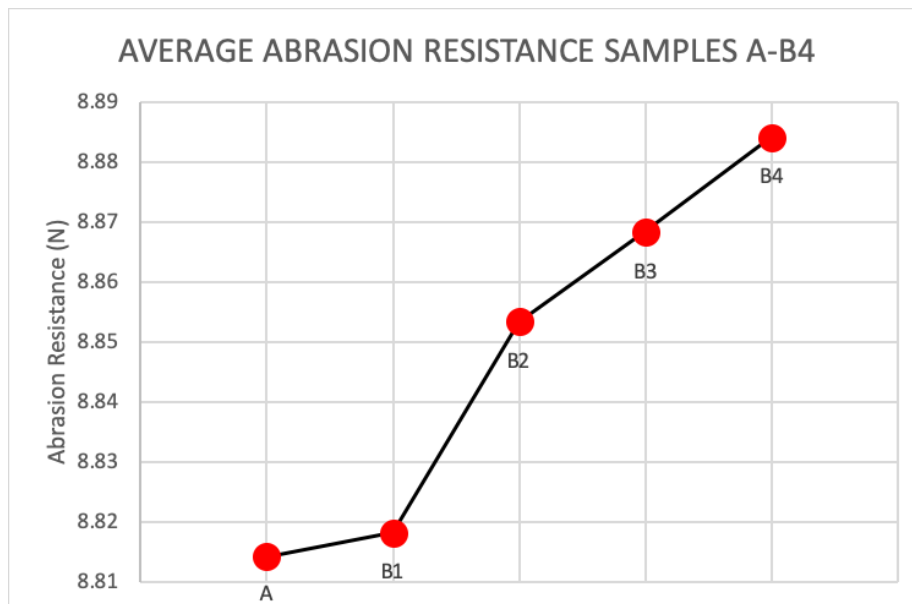


Figure 4:

- The general trend for viscosity was that viscosity decreased as the quantity of nanofiller was increased. This supports the qualitative observations in section 4.1 where improved flow and continuity was noticed as the quantity of nanofiller was increased.
- The general trend for abrasion resistance was that abrasion resistance increased as the quantity of nanofiller increased. In other words, the wire with more nano-filled enamel was more resistant to abrasion.
- It is important to note that these trends can be stated for the range of nanofillers used, i.e. 0-1.5% of the charge by weight. This does not necessarily imply that viscosity, abrasion resistance and other mechanical properties will perpetually get better as the quantum of nanofiller in the enamel increases. For instance, the  $\text{viscosity}$  between B3 and B4 at 79.4 mPas was much lower than the  $\text{viscosity}$  between B2 and B3 at 741.2 mPas. This may suggest that adding more nanofiller only yields significant viscosity improvements up to a point, after which there may only be marginal improvement. This claim can also be corroborated by the qualitative results from Table 2, where in sample B4, unlike B2 and B3, there was some settling of solid particles visible in the enamel, which impacted viscosity as a result.

The results for electrical tests were collated from Table 5. Average values were calculated for the breakdown voltage test measurements and plotted, as seen in Figures 5.

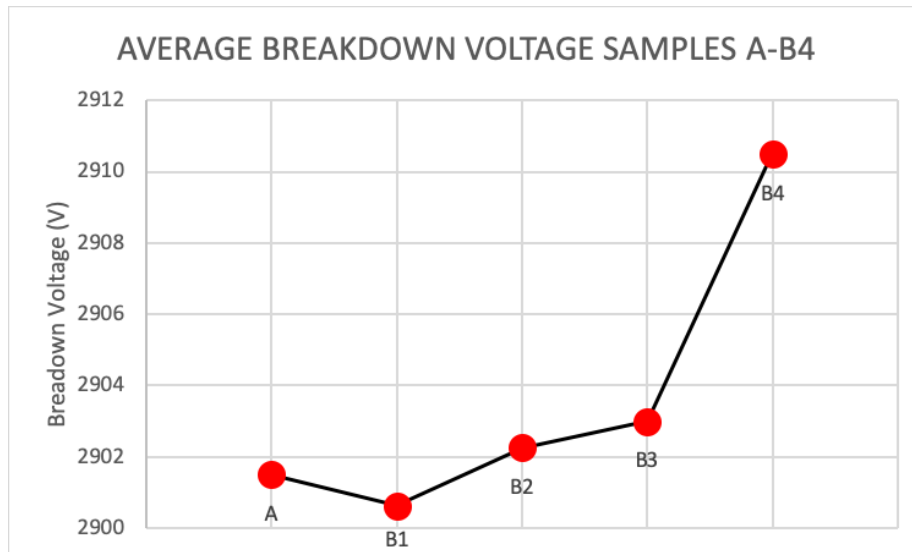


Figure 5:

There are a few salient observations that can be made here:

- The general trend for breakdown voltage was that breakdown voltage increased as the quantity of nanofiller increased. This once again supports the theory mentioned in section 1.2, as the nanofillers would fill the “voids” in the polymer matrix, thereby providing greater resistance to breakdown due to arc-ing and corona discharge.
- Just as with the trends in the mechanical properties, it can only be stated that the electrical properties as measured by breakdown voltage improved for the range of nanofillers used, i.e. 0-1.5% of the charge by weight. In fact, it is interesting to note that  $\text{breakdown}$  between B3 and B4 is much higher at 7.5V than that between B2 and B3 at 0.75V. This rapid spike may indicate that even more nanofiller could potentially result in an even higher breakdown voltage. In [7], fillers were used in quantities as high as 5% by weight, and although a different type of filler, the principle still carries over.

#### 4.3 Other observations

- Sample B1 was somewhat of an aberration in many trends. In Figure 3 for instance, it is the only sample that did not adhere to the trend of reducing average viscosity. In Figure 5, it produced reduced average breakdown voltage, even lower than the non-filled sample A, while all the other samples saw improved results. In addition, in the qualitative observations, there was some settling of solid particles visible – even though the nanofiller amount was so low. These results for B1 may be explained by the fact that the nanofiller did not mix completely and did not achieve a homogenous mixture in the wire enamel. One possible reason for that is the amount of dispersing agent, W&D<sup>TM</sup> 875, that was used in sample B1 – 0.015kg, as seen in Table 1; it was the same as Sample A, which contained no nanofiller. Therefore, this may have resulted in lack of dispersion of the filling material. Perhaps a larger amount of the dispersing agent would have yielded more favourable results.
- While certain trends were observed from the test data and analysis, it is illogical to assume that these trends are indefinite. For example, it would certainly not be the case that viscosity would decrease forever, or breakdown voltage would increase forever, as the amount of nanofiller increased. It would be physically impossible, say, if equal parts of nanofiller and base enamel were used, to even properly create a homogenous mixture. This suggests that there are certain optimal amounts of nanofiller that will yield the best results. This is not the objective of this study, rather an assertion that these optimums can be determined empirically by isolating the variable to optimize for.
- Along those lines, it is not necessarily the case that the same amount of nanofiller will produce the best electrical properties as well as best mechanical properties. For instance, when comparing Figures 3 and 5, it is seen that viscosity was reducing at a lower rate than breakdown voltage was

increasing, as the quantity of nanofiller increased – particularly between B3 and B5. This may suggest that the enamel was already approaching its optimal viscosity result under the circumstances but could require much more nanofiller in order to reach an optimal breakdown voltage result. In order to optimize for multiple variables in combination, in this case viscosity, abrasion resistance, breakdown voltage – it may be the case that sub-optimal results have to be chosen for individual variables.

## 5. Conclusion

The study showed that additions of small quantities of the nanofiller AEROSIL® R 972, a silica based compound, to the Polyamide Imide wire enamel, produced wire enamel with lower average viscosity, better abrasion resistance, and better breakdown voltage. The resultant enamel was also smoother, had better gloss finish and fewer defects. As a result, the wire enamel had better electrical and mechanical properties.

## 6. Acknowledgements

I'd like to thank Precision Wires India Ltd for their help with providing facilities and equipment in order to conduct this study.

## References

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## **Appendix**

### **ANNEXURE A**

Product information sheet, AEROSIL® R 972 (nanofiller)

### **ANNEXURE B**

Product information sheet, W&D™ 875 (coupling agent)

## Product Information

### ► AEROSIL® R 972 Hydrophobic Fumed Silica

AEROSIL® R 972 is a fumed silica aftertreated with DDS (Dimethyldichlorosilane)

#### Applications and Properties

##### Applications

- Silicone rubber and silicone sealants
- Paints and coatings
- Printing inks and toner
- Adhesives
- Cable compounds and gels
- Plant protection

##### Properties

- Hydrophobic component for thickening and reinforcement of RTV-1 K silicone sealants.
- Improves shelf-life of silicone sealants.
- Water resistant, hydrophobising of liquid systems.
- Rheology control of (complex) liquid systems.
- For use in coatings as anti-settling agent, for pigment stabilization and improvement of corrosion protection.
- Improves hydrophobicity and rheology of offset printing inks.
- Improvement and maintenance of free flow and anti-caking characteristics of powders.

#### Physico-chemical Data

| Properties                                                                           | Unit              | Typical Value |
|--------------------------------------------------------------------------------------|-------------------|---------------|
| Specific surface area (BET)                                                          | m <sup>2</sup> /g | 110 ± 20      |
| Carbon content                                                                       | wt. %             | 0.6 - 1.2     |
| Average primary particle size                                                        | nm                | 16            |
| Tapped density (approx. value)*<br>acc. to DIN EN ISO 787/11, Aug. 1983              | g/l               | approx. 50    |
| Moisture*<br>2 hours at 105 °C                                                       | wt. %             | ≤ 0.5         |
| Ignition loss<br>2 hours at 1000 °C based on material<br>dried for 2 hours at 105 °C | wt. %             | ≤ 2.0         |
| pH<br>in 4% dispersion                                                               |                   | 3.6 - 5.5     |
| SiO <sub>2</sub> -content<br>based on ignited material                               | wt. %             | ≥ 99.8        |

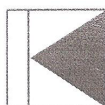
\* ex plant

The data represents typical values and not production parameters.

AEROSIL® R 972 / Jul 08 / [www.aerosil.com](http://www.aerosil.com)

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Figure 6:



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Chemistries...

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Website: <http://www.ktechindia.net>

#### Product Technical Data Sheet

| W & D™ 875                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                      | <input checked="" type="checkbox"/> Paints & Coatings Additives         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| 1. Product                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | W & D™                                                                                                                                                                                                                                                               |                                                                         |
| Name                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 875                                                                                                                                                                                                                                                                  |                                                                         |
| Grade                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                      |                                                                         |
| Specific Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Hyper dispersant for pigment pastes.                                                                                                                                                                                                                                 |                                                                         |
| 2. Product Characterization                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                      |                                                                         |
| A Chemical Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                      |                                                                         |
| Chemical Type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | V.O.C free polymeric preparation                                                                                                                                                                                                                                     |                                                                         |
| Composition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Proprietary preparation                                                                                                                                                                                                                                              |                                                                         |
| Registration Status                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Ingredients listed in EINECS, TSCA, DSL, MITI, AICS & ECL                                                                                                                                                                                                            |                                                                         |
| B Physical Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                      |                                                                         |
| Form of Supply                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Viscous Liquid                                                                                                                                                                                                                                                       |                                                                         |
| Colour                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | On Gardner scale, 10-12 units                                                                                                                                                                                                                                        |                                                                         |
| Odour                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | None                                                                                                                                                                                                                                                                 |                                                                         |
| Specific Gravity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 0.900± 0.055                                                                                                                                                                                                                                                         |                                                                         |
| NVM                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 95 % @ 120° C for 1 hr.                                                                                                                                                                                                                                              |                                                                         |
| Solubility                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Soluble in glycols, oils, Spindles                                                                                                                                                                                                                                   |                                                                         |
| Viscosity by Brooke field                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150-650 cps @ 25° C, By Spindle 4 @ RPM 100                                                                                                                                                                                                                          |                                                                         |
| C Toxicity Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Non-hazardous, safe & eco-friendly, no health hazards known LD 50 > 3000 mg / kg. (Please refer product's MSDS)                                                                                                                                                      |                                                                         |
| D Storage Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Shelf life – 360 days from the date of manufacturing,<br>Flash Point >100 ° C                                                                                                                                                                                        |                                                                         |
| 3. Technical Recommendations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                      |                                                                         |
| Recommended Dosage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 5 – 20 % on Inorganic, 10-30% on organics, 30-80% on carbon black                                                                                                                                                                                                    |                                                                         |
| Mode of Incorporation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | In mill base, prior to pigment addition                                                                                                                                                                                                                              |                                                                         |
| Precautions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Dosage need optimization                                                                                                                                                                                                                                             |                                                                         |
| Mode of Action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Hyper dispersant, stabilization by Ionic & hindrance                                                                                                                                                                                                                 |                                                                         |
| 4. Visible Effects in Application Property                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <ul style="list-style-type: none"><li>• Improves colour strength &amp; Gloss development</li><li>• Reduces grinding time, stabilizing time</li><li>• Reduces Tear &amp; Wear of dispersing &amp; Mixing equipments</li><li>• No Synerisis &amp; Separation</li></ul> |                                                                         |
| 5. Recommended Field of Application                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | W&D™ 875 is highly recommended for PU Pigment Paste Preparation, FRP Pigment pastes preparation, Polyether pigment pastes, Epoxy pigment pastes and offset inks.                                                                                                     |                                                                         |
| <p>Disclaimers clause: "All recommendations for the use of our products, whether given by us in writing, orally or to be implied from the results of tests carried out by us are based on the current state of our knowledge. Notwithstanding any such recommendation, buyer or user shall remain responsible for satisfying himself that the products as supplied by us are suitable for his intended process or purpose. Since we cannot control the application, use of processing of the products, we cannot accept responsibility thereof. Buyer has to ensure that the use of the products will not infringe any third party's intellectual property rights. We warrant that our products are free from defects in accordance with, and subjects to our general conditions of sale and supply."</p> |                                                                                                                                                                                                                                                                      |                                                                         |
| Date of Issue                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 07/04/2012                                                                                                                                                                                                                                                           | Speciality Additive Division                                            |
| Issue No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 02                                                                                                                                                                                                                                                                   | K-TECH (INDIA) LIMITED                                                  |
| Revision No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 01                                                                                                                                                                                                                                                                   | An ISO 9001 Certified Company                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                      | <a href="http://www.ktechindia.net">www.ktechindia.net</a>              |
| Helpline No.: 00-91-9820082351                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                      | Email us at: <a href="mailto:ktechlab@gmail.com">ktechlab@gmail.com</a> |

Figure 7: