# REPLACEMENTS FOR PCB CAPACITOR FLUIDS

## ACTION SECTION

### Situation

1. P. G. Benignus (retired market manager for Aroclor dielectrics) recently told David Wood (his replacement in SCD) that he is now a consultant to Aerovox (second to G.E. in motor-run capacitors). Variability in DOP is creating "clean-up" problems and this is the area of consultancy. It is believed that significant progress has been made. Mr. Benignus was reminded that Plasticizers Division had esters such as Santicizer 261 close to Aroclor 1016 in $D_K$ and 10% higher in $D_K$ than DOP. Clean-up difficulties with these esters had discouraged further work by M.I.C.

2. SCD was contacted by Mr. John Hutzler, chief engineer of Aerovox, on January 27. He requested five gallons of Santicizer 261 and wants to know its price. Mr. Hutzler claims Aerovox has made progress in purification of phthalate ester, drying of capacitor paper, degassing and additives.

3. Prodelec (French supplier of PCB's) is working at least with ASEA (Large Swedish capacitor producer) on the use of benzyl neocaprate as a PCB replacement.

4. DOP does not appear to be totally satisfactory in the power factor capacitor segment (~'30% of U.S. capacitor fluid market). High $D_K$ is not a need in this segment. Westinghouse is using MIPB (monoisopropyl biphenyl). Although G.E. announced plans to use DOP/TCB mixtures, they have approached SCD to obtain samples of the base-stock (Santosol 100) in SCD's original PCB replacement (MCS 1588). SCD has sampled G.E. with MCS 1889 (Santosol 100) and MCS 1972.

### Recommendations

1. Marketing sample Aerovox with five gallons of Santicizer 261 together with a Certificate of Analysis showing not only normal plasticizer specification properties but also values on properties routinely ran by WGK on Aroclor 1016.



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Recommendations

2. Marketing quote Aerovox Santicizer 261 at plasticizer schedule for product meeting current plasticizer specifications. Price subject to revision if an electrical-grade specification is proposed by Aerovox and capable of being met by Monsanto.

3. CD and R&D evaluate opportunities for Plasticizer esters as PCB capacitor fluid replacements in light of current market developments.

4. Encourage SCD to follow evaluation of benzylated aromatics (ie. Santosol 100 type products) in PF capacitors at G.E. and B.I.C.C. (U.K.) and Westinghouse.

Action Requested

1. Manager, CD to inform Hutzler of Aerovox that Plasticizers Division will sample Santicizer 261 and wishes to get meaningful feedback on their evaluation. Current price for plasticizer-grade Santicizer 261 is $0.39/lb. FOB plant in bulk. This price would be subject to revision if electrical properties were added to the specification and within Monsanto's capability to supply.

2. Marketing to enter a no-charge five gallon sample of Santicizer 261 for Aerovox and provide a Certificate of Analysis covering standard plasticizer properties plus electrical properties run by WGK on Aroclor 1016. (The availability of this information will be necessary for meaningful discussions of clean-up/performance data obtained by Aerovox.)

3. CD request MESA to supply information on Prodelec's activities with benzyl neo-caprate. (Done)

4. CD encourage SCD's sampling of benzyl aromatics to major PF capacitor manufacturers and follow up on the evaluations. (Done)

5. CD and R&D arrange a meeting in the near future to evaluate most promising avenues for exploration of Plasticizers Division products as capacitor fluids.

BACKGROUND SECTION

Conclusions of Study

U.S. Capacitor Market

1. U.S. market for capacitor fluids ($\overline{M}$ Lbs.):



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U. S. Capacitor Market

1.

| | 1973 | 1974 | 1976 |
|---|---|---|---|
| Ballast/Motor-run | 15.5 | 14.2 | 14.6 |
| PF | 5.7 | 6.2 | 3.7 |
| Aroclor 1016 | 21.2 | 20.4 | 18.3 |
| Non PCB Equivalent* | 15.5 | 15.0 | 14.0 |

*Assumes non-PCB has $D_K \equiv$ Aroclor 1016 and specific gravity of 8-9 #/gallon versus Aroclor 1016 at 11.5#/gallon.

Although DOP has S.G. of just over 3#/gallon, its $D_K$ is ~10% less than Aroclor 1016. As a result, capacitors must be made bigger cancelling out reductions in weight.

2. U.S. market for phthalate ester in ballast/motor-run capacitors with $D_K \equiv 4.8$ (Santicizer 261 = 4.7) is 11-12 $\overline{M}$ lbs/year. Over 95% of market is held by 8 producers of which the 5 largest are:

| | Aroclor 1016 ($\overline{M}$ Lbs.) | | | |
|---|---|---|---|---|
| | 1973 | 1974 | 1976 | Approximate S-261 Potential |
| G.E. | 6.8 | 6.8 | 5.9 | 4.6 |
| Aerovox | 1.8 | 1.9 | 2.0 | 1.6 |
| Universal* | 2.1 | 1.7 | 2.2 | 1.7 |
| EUC | 1.2 | 1.0 | 0.8 | 0.6 |
| Mallory | 1.5 | 1.0 | 1.2 | 0.9 |
| | 13.4 (86%) | 12.4 (87%) | 12.1 (83%) | 9.4 (85%) |

*Universal makes ballast types only.

3. U.S. market for fluid in PF capacitors is essentially 100% held by 4 manufacturers:

| | Aroclor 1016 ($\overline{M}$ Lbs.) | | | |
|---|---|---|---|---|
| | 1973 | 1974 | 1976 | MCS 1889** Equivalence |
| G.E. | 2.5 | 2.3 | 1.7 | 1.8 |
| Westinghouse* | 2.1 | 2.4 | 1.2 | 1.8 |
| McGraw-Edison* | 0.5 | 0.8 | 0.2 | 0.4 |
| Sangamo | 0.6 | 0.7 | 0.6 | 0.4 |
| | 5.7 | 6.2 | 3.7 | 4.4 |

*Began conversion to non-PCB fluids in 1976.
**MCS 1889 is used to denote Santosol 100 for PF capacitor use.



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U. S. Capacitor Market

4. There seems every indication that the capacitor market in the U.S. will be segmented into two categories as regards fluid usage: ballast/motor-run and PF types. Both segments represent potential opportunities for Plasticizers Division either thru Santicizer 261 or other ester sales (ballast/motor-run) or benzyl chloride pull-through (PF types).

5. U.S. market potential for non-PCB fluids.

Ballast/Motor-run

| | |
|---|---|
| Potential DOP Volume ($D_K$ = 4.1) | ~ 14 - 15 $\overline{M}$ lbs./year |
| Potential S-261 Volume ($D_K$ = 4.7) | ~ 11 $\overline{M}$ lbs./year |
| Potential Customers | 8 - 10 |
| G.E. Market Share | 40 - 48% |

PF

| | |
|---|---|
| Potential MCS 1889 Volume* | ~4.4 $\overline{M}$ lbs./year |
| Potential Customers | 4 |
| G.E. Market Share | ~ 40% |
| Westinghouse Market Share | ~ 40% |
| *Benzyl Chloride Potential | ~ 3.3 $\overline{M}$ lbs./year<br>~(6.6M lbs. S-160) |

PCB Fluid Replacements

Ballast/Motor-run

--DOP is the front-runner to replace Aroclor 1016 in ballast/motor-run types.

--Low-moisture DOP is supplied mainly by Hatco, U.S.S. and Reichold at ~0.5 - 1.0¢/lb. over regular DOP prices.

--Exxon's DINP and Monsanto's Santicizer 711 are not attractive to the capacitor industry because both have lower $D_K$ than DOP and hence would have to be sold at significantly lower prices than DOP. (In ballast/motor-run, a lower $D_K$ means a bigger capacitor must be made to give equivalent capacitance; hence not only is more fluid required but also more paper and aluminum foil and a bigger can.)



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Ballast/Motor-run

--Santicizer 790 is also lower in $D_K$ than DOP:

| | $D_K$ |
|---|---|
| DOP | 4.3 |
| S-790 | 4.1 |
| S-711 | 4.0 |

--Santicizer $C_7P$ should have a higher $D_K$ than either S-711 or S-790. Because it may be no more difficult to clean up than DOP, it may be worth consideration as an alternate to Santicizer 261 (if Santicizer 911 becomes a significant product creating the need to find $C_7$ outlets).

--In this report $D_K$ values cited for phthalate esters are taken from R. E. Hatton's memo to Messrs. Lamkin and VanGelder dated September 1, 1976. $D_K$ values were measured at 100° C/60 $H_z$ after the esters were subjected to simple clean-up procedures described in the memo.

PF

--Westinghouse has opted for MIPB at ~55 c/lb. Tanatex is believed to be the major supplier.

--Westinghouse believed the base-stock (MCS 1889) for SCD's MCS 1588 showed some promise over MIPB. SCD intends to push for more complete evaluation at Westinghouse.

--G.E. apparently feels Westinghouse, in favoring MIPB over esters, may have been smarter. As a result, G.E. has approached SCD and been sampled (under MCS numbers) with Santosol 100 (MCS 1889) and its scheduled NCR replacement MCS 1918 (benzyl xylene).

--Sangamo has followed G.E. in esters.

--McGraw-Edison worked closely with Dow on a replacement fluid. This product, which was priced significantly higher than MCS 1588 with little performance advantage, is not expected to be viable in the long term.

--B.I.C.C. (largest U.K. capacitor manufacturer) is evaluating (under MCS numbers) the same benzyl aromatics SCD has sampled to G.E.



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PF

--Recently announcements have been made concerning a Prodelec/ASEA development to use benzyl neo-caprate as a PCB replacement. ASEA is predominantly in PF types. Prodelec (Rhone-Poulenc) is still supplying PCB's but is not a producer of benzyl chloride. Clarification of European activities has been sought from MESA.

International Capacitor Markets

Given M.I.C.'s strong position world-wide in benzyl chloride/benzyl phthalates, a significant opportunity could exist outside the U.S. If we can recapture part of the motor-run and/or PF markets in the U.S. with S-261/Santosol 100 products, chances are high we could make significant headway in Europe and Latin American because:

--PF types hold higher market share than in U.S.

--DOP quality is lower than in U.S. (particularly in Latin America).

SCD has extensive world-wide customer and market data on capacitor fluids.

Pricing of PCB Replacement Fluids

Ballast/Motor-run

--G.E. claimed that MCS 1588 ($D_K \equiv$ Aroclor 1016) had to be priced at \$0.65 - 0.85/lb. to be cost competitive with DOP (then at \$0.25 - 0.27/lb.).

--Clean-up costs for DOP are believed to be ~ \$0.10/lb. (Aerovox indicated that a clean-up DOP was worth in the high 30's to them.)

--Values on fluids with varying $D_K$ can then be guesstimated:

| | |
|---|---|
| $D_K$ of 4.8 (Aroclor 1016) $\equiv$ | \$0.65/lb. |
| $D_K$ of 4.3 (DOP) including clean-up cost of \$0.10/lb. $\equiv$ | \$0.40/lb. |
| $\Delta$ Cost for 0.5 $D_K$ units | \$0.25/lb. |
| $\Delta$ Cost/0.1 $D_K$ units | \$0.05/lb. |



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Ballast/Motor-run

| Product | $D_K$ | Cleaned-Up Value | Plasticizer-Grade Value | Current Market Price |
|---|---|---|---|---|
| S-711 | 4.0 | $0.25/lb. | $0.15/lb. | $0.315/lb. |
| S-790 | 4.1 | 0.30 | 0.20 | 0.31 |
| S-261 | 4.7 | 0.60 | 0.50 | 0.39 |

This is a rough approximation. Determining true differentials is fairly complicated but SCD has obtained data from E.U.C. which we could use to calculate the accuracy of these predictions. A $D_K$ higher than 4.8 is worth more than $0.65/lb. to manufacturers of motor-run capacitors.

P.F.

--MIPB was initially offered to Westinghouse at ~$0.65/lb. but two years ago Tanatex signed a contract with Mead (carbonless copy paper solvent) at ~$0.45/lb. Mead's volume is greater than Westinghouse potential.

--SCD cannot compete with Tanatex MIPB because Tanatex uses BTX by-product biphenyl and have their own alkylation facilities.

--MCS 1889 (Santosol 100) economics are:

| | | |
|---|---|---|
| C.O.G.S. (SCD basis) | $0.35/lb. | (YTD |
| C.O.G.S. (Plasticizers basis) | $0.24/lb. | June 1977) |

[SCD obtain benzyl chloride on a transfer price basis.]

--Manufacture of a benzyl xylene (MCS 1972) might be ~$0.04/lb. lower in cost because of the lower mixed xylene cost compared to ethyl benzene (MCS 1889).

Potential Capacitor Fluid Candidates

P.F.

--For P.F. capacitors, benzyl aromatics seem to have a reasonable chance of being technically acceptable. MIC has a strong raw material and manufacturing position. SCD has a great deal of application and environmental data on MCS 1889. The market, although small, is well-defined. On a MIC basis, MCS 1889 could return 40 - 50% gross profit in direct competition with MIPB at $0.45/lb. if evaluations show equal performance.



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P.F.

--Phthalate esters do not appear to be preferred fluids in PF capacitors.

--If MCS 1889 or another benzyl aromatic are not acceptable, it is recommended that no effort be expended to develop another candidate for P.F. capacitors.

Ballast/Motor-run

--In assessing which esters we should promote in ballast/motor-run capacitors, the following factors need to be kept in mind:

  --Fluids with $D_K$ less than DOP (ie. < 4.3) will require to be priced significantly under DOP and/or require much easier clean-up.

  --Fluids equal in $D_K$ to Aroclor 1016 (ie. 4.8) are worth at least $0.65/lb. on a "cleaned-up" basis to the capacitor manufacturer. The potential sales volume of such a fluid will be a percentage of that for Aroclor 1016 representing the ratio of specific gravities (ie. If non-PCB fluid is 8.9 lbs./gallon, then the percentage is 77.4% because Aroclor 1016 had a specific gravity of 11.5 lbs./gallon.)

  --Fluids with $D_K$ greater than Aroclor 1016 are of great interest to capacitor manufacturers and should command prices in excess of $0.75/lb. if they exceed $D_K$ of 5.0. Potential sales volume will be reduced significantly compared to Aroclor 1016 because (a) capacitors can be made smaller and (b) because of lower specific gravity.

  --Capacitor manufacturers seem to be expending much effort on fluid "clean-up." Improvements or breakthroughs in this area will encourage them to look at fluids with $D_K$ equal to or higher than Aroclor 1016 rather than down in the DOP area.

  --Ester classes that satisfy the criteria of $D_K$ equal to or greater than Aroclor 1016 include: benzyl phthalates, triaryl phosphates, trimellitates and Benzoflex 9-88. They are of interest to MIC in that order.

  --Changing fluids is probably a two-year program at minimum for capacitor manufacturers. It is also expensive. Environmental data will also weigh heavily in the decision to change. It will probably take a cost/performance advantage of $0.10/lb. to make it worth it to G.E. to change and at least $0.20/lb. for other manufacturers (although they will tend to follow G.E.).



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Ballast/Motor-run

--The potential for fluid (particularly high $D_K$) could decline in ballast/motor-run capacitors if metallized film types can be satisfactorily designed and demonstrated in the U.S. Europe is ahead of the U.S. in this technology, but several U.S. manufacturers have invested in test equipment. Such a change in the U.S. is probably at least 3 - 4 years away and ability to obtain and use a fluid of $D_K$ equal to or higher than Aroclor 1016 could slow down the development.

--R&D activity by Plasticizers Division should be restricted to trying to "clean-up" fluids equal to or higher in $D_K$ than Aroclor 1016 (ie. 4.7 - 4.8). (A possible exception might be DC7P if its $D_K$ is at least equal to DOP, ie. 4.3.) Easily cleaned-up fluids of $D_K$ 4.7 and higher should be worth $0.60/lb. and up to capacitor manufacturers in ballast/motor-run.

--R&D (J. K. Sears memo to B. K. Daniels, June 24, 1976) indicated that adding chelators or blending with MCS 1889 (Santosol 100) might be assist in cleaning up benzyl phthalates or Santicizer 154.

ALTERNATE SOLUTIONS

1. Be cost/performance competitive at G.E. with either S-711 or 790 (6 - 7M lb. potential in ballast/motor-run). Rejected because required pricing would be at least $0.15/lb. below DOP. (This will be double-checked with SCD's data from E.U.C.)

2. Introduce DC7P to the ballast/motor-run capacitor industry (U.S. potential 14 - 15M lbs.). This alternate is only valid if DC7P is at least equal in $D_K$ to DOP and can be easily cleaned up. Acceptance by G.E. would require ongoing availability of at least 4 - 5M lbs./year $C_7$ alcohol and industry-wide acceptance would require ~10M lbs./year of $C_7$ alcohol. As a sole source DC7P supplier, imbalances with S-911 could create difficulties in Monsanto being a dependable supplier to the capacitor industry. Rejected except as a back-up for consideration if benzyl phthalates are unacceptable as capacitor fluids.

3. Ignore the ballast/motor-run segments of the capacitor industry. Rejected because an opportunity still exists for Plasticizers Division to obtain a share of this 11 - 15M lb. market (depending on $D_K$ of candidate fluids). Aerovox interest (~15% market share) in S-261 should at least be pursued and Prodelec's association with benzyl caprate as a PCB replacement in Europe indicates benzyl phthalates (with Monsanto sole U.S. supplier) may be active candidates.



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ALTERNATE SOLUTIONS

4. Ignore both ballast/motor-run and PF segments of the capacitor industry. Rejected because benzyl phthalates have not yet been completely ruled out as candidates for ballast/motor-run capacitors; and SCD has supplied benzyl aromatics to major PF capacitor manufacturers for evaluation. Plasticizers Division has a vested interest in supporting programs which can significantly increase benzyl chloride sales.

5. Leave any potential in the capacitor industry for SCD to pursue. Rejected because SCD has already decided (May 1976) that opportunities for plasticizer esters as capacitor fluids should be pursued by Plasticizers Division. Although SCD has sampled benzyl aromatics to major PF capacitor manufacturers, there is a question (raised by SCD) given the market size and our transfer policy on benzyl chloride whether this potential if realized should be a SCD or Plasticizers Division activity.

C. Paton

1/31/78



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