FAILURES DUE TO COMPOSITIONAL FACTORS

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1.0 Abstract

Failures generally are due to problems of design, composition or processing. In this paper, examples are given in which failure was due primarily to composition. In some cases, components of the known formulation were at fault. In others, contaminants introduced externally were the cause of failure. Among the types of failure were odor, color, materials sticking together unintentionally and other problems resulting from transfer of formulation components to other materials.

2.0 Introduction

In this paper examples are given in all of which composition is the factor out of control causing failure. The other two primary factors influencing failure are processing and design. Failure is meant very broadly here; a contaminant may not cause fracture, for example, but it affects appearance and could contribute to fracture. An unintentional color change may not affect performance but color is important in many applications, such as electrical wiring. Compositional problems may involve the polymer, formulation additives and other materials from outside the product.

3.0 Failures or Problems Originating within the Formulation

3.1 Polymer

3.1.1 Nondispersed gel – small diameter tubing for a medical application had random bumps on the outside that appeared clear, i.e., not containing barium sulfate as the rest of the tubing did. The infrared spectrum of the clear bumps was identical to that of the host polymer. The clear bumps were due to polymer gel, i.e., crosslinked. As such, it does not fuse with uncrosslinked polymer and will not incorporate additives. The tubing would probably perform satisfactorily, but it was not acceptable due to its appearance.

3.1.2 FEP polymer discoloration – Some lots of FEP compounded with barium sulfate were discolored, readily seen for the white material. The problem was traced to certain lots of FEP. Thermogravimetric analysis (TGA) of good and bad FEP showed a striking difference (fig. 1). The bad lots started to decompose abruptly at several degrees lower temperature than normal FEP. The problem was solved by using FEP which had the normal TGA thermogram.

3.1.3 Liquid soap dispenser made of HDPE leaked after short test time. A change to a more stress crack resistant copolymer was recommended.

3.2 Intentional additives in the formulation

3.2.1 Small EPDM O rings did not separate and feed readily through a dispenser for automatic assembly into a part. The problem was a high content of hydrocarbon oil which made the O rings tend to stick together. A compromise in the formulation was needed in terms of hydrocarbon oil content.

3.2.2 A PVC jacket over an electrical cable developed an oily liquid beneath the jacket up against a copper wrap. The PVC had a relatively high content of aliphatic ester plasticizer, which has lower compatibility with PVC than phthalate plasticizer. The tension within the cable probably contributed to exudation.

3.2.3 The odor of a part was objected to. It had been crosslinked with a peroxide. Typically the byproducts of peroxide decomposition have an odor and tend to remain in the polymer for some time.

3.2.4 Undispersed additives – cases of both filler and pigment undispersed particles have been experienced. Not only is it an appearance problem, but such locations can act as sites for fracture initiation.

3.2.5 The force required to strip off the thin insulation shield layer from insulation of electrical power distribution cable is controlled by adding metal stearate and wax to lower the adhesive bond strength. A trend toward the stripping force being unacceptably too low was due to the content of stearate and wax being higher than normal.

3.2.6 Antioxidant content of a HDPE liquid soap dispenser was so low that the oxidative induction time test (ASTM D3895) gave zero OI time at 200°C by DSC. Additional antioxidant other than the very low content supplied by the resin manufacturer had not been added. Because the soap dispenser is intended for long term use it was recommended that antioxidant be added to the polymer to reduce chances of oxidative degradation and fracture.

3.2.7 Bloom on the surface of an electrical cable was found by infrared spectroscopy to be a halogenated flame retardant in the formulation. The particular flame retardant was identified by comparison to knowns.

4.0 Failures Originating from Outside the Formulation

4.1 PVC cable jacket was discolored due to contact with cured neoprene. Figure 2 is the gas chromatogram of the relatively volatile compounds of the neoprene. Hydrogen sulfide is present as well as other sulfur compounds. They are byproducts of sulfur curing. The hydrogen sulfide and/or other sulfur compounds reacted with the pigment to cause it to lose its color.

4.2 Contamination from processing or other sources – A nylon contaminant (fig. 3) in an electrical cable was identified by infrared spectroscopy and the particular nylon by its melting point by differential scanning calorimetry (DSC). An acrylic polymer was identified as a contaminant in another instance.

4.3 A stain on a clear plastic (fig. 4) was identified by thermal desorption gas chromatography/mass spectroscopy (TD/GC/MS) as due to unintentional contact with solvent. The compounds found in the stain were not present outside the stain area.

4.4 Liquid cleaner caused staining of polycarbonate eyeglass lenses. Isopropanol is a component of the cleaner. GC/MS found that acetone was present also. Acetone is not an intentional component. It is, however, the oxidation product of isopropanol:

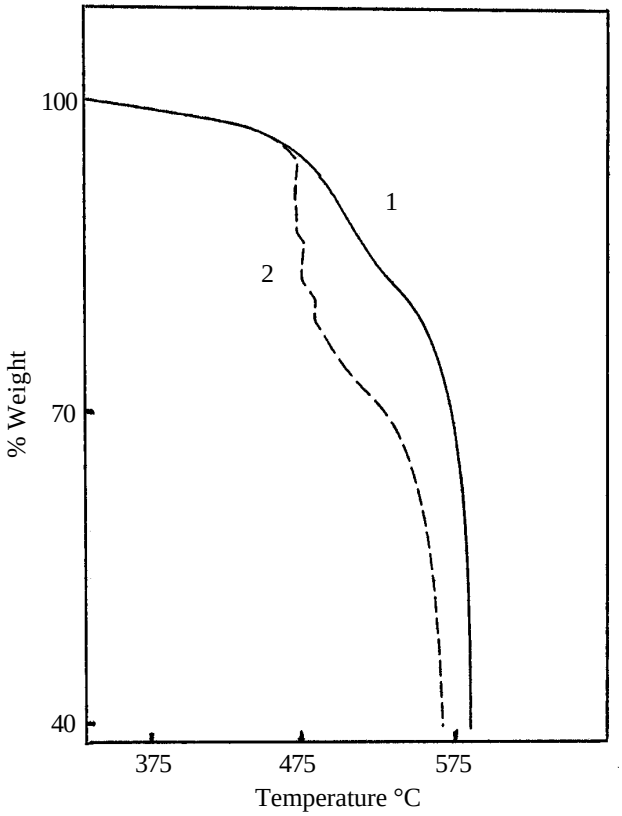
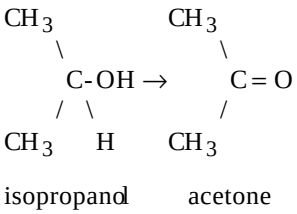


Figure 1. Thermograms of FEP: 1 – normal, 2 – decomposes at lower temperature.



Acetone is sufficiently active as a solvent for PC that it affected the appearance of the lenses. Possibly the isopropanol used was contaminated with acetone.

4.5 Contaminant on the surface of a printed circuit board was identified as an aromatic carbonyl compound. It interfered with proper wetting of a coating.

5.0 Conclusion

Examples have been given of plastics failure due to factors within the formulation – polymer and additives, and to factors from outside the formulation. In many cases the effects are subtle and not easily identified. Sophisticated analytical methods are often needed to identify the source of the problem.

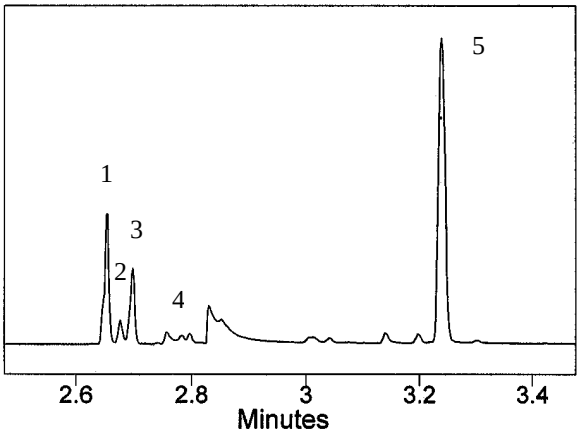


Figure 2. Gas chromatogram (GC/MS) of sulfur compounds in neoprene 1 – CO_2; 2 – H_2S; 3 – COS; 4 – SO_2; 5 – CS_2.

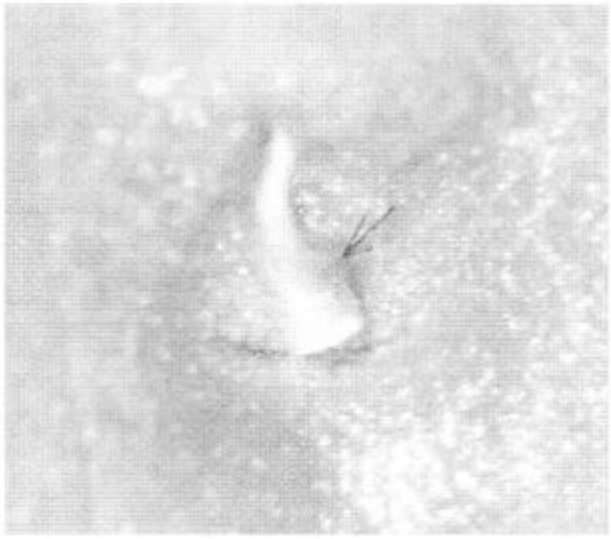


Figure 3. Nylon contaminant in an electrical cable. 100X

Figure 4. Stain on clear plastic due to solvent.

Key Words: plastics failure, compositional factors