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ADHESIVE BONDING OF TATB/KEL-F 800

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ABSTRACT

Triaminotrinitrobenzene (TATB) bonded with a copolymer of chlorotrifluoroethylene and vinylidene fluoride (Kel-F 800) has been selected as the high explosive for use in the B77 bomb. The plastic-bonded explosive (RX-03-BB, 7.5% Kel-F 800) has high strength and is less sensitive to shock initiation than most previously used high explosives. Adhesive bonding of RX-03-BB has proved to be difficult, however, because of the chemical composition of both the TATB and the binder.

We have made studies of the critical surface tension of the TATB, the binder, and the RX-03-BB using contact-angle measurements. Surface-tension measurements were made on modified epoxies and used as a guide in formulating new adhesives. Our new adhesive, EXPLOSTIK 473, has a surface tension less than RX-03-BB and has satisfactory bond strength to over 75°C.

DETAILS

RX-03-BB (92.5% TATB, 7.5% Kel-F 800) has been selected as the HE for use in the B77 because of its high strength (greater than 10-MPa tensile strength) and because it is less sensitive to shock initiation than previously used HE's based on HMX or RDX. It is necessary to bond machined parts in weapons assembly, and it is desired that any failure of the bond be in the RX-03-BB. This has posed a severe bonding problem because of the low surface energies of the TATB and the binder, and possibly because of the graphitic structure of the planar crystals of TATB. Initial attempts to bond RX-03-BB with familiar adhesives gave low values with adhesive failures. Adiprene L-100/MOCA failed at about 5.5 MPa. The Halthanes with additives or primers failed at 2.5 to 5 MPa.

Basic adhesion theory states that the surface tension of the adhesive should be lower than the critical surface tension of the substrate. In other words, wetting and spreading of the adhesive on the substrate are necessary to obtain a good bond.

We measured critical surface tensions of TATB, the binder, and the RX-03-BB by measuring contact angles of a series of liquids of known surface tension,

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and extrapolating the cosine of the contact angle θ to 1.0. As would be expected, they were low-surface-energy solids with critical surface tensions as shown in Table 1.

Table 1. Critical surface tension of RX-03-BB and its components.

Material	Surface tension, 10^{-2} N/m
Kel-F 800	3.1
Pressed TATB	4.1
RX-03-BB	3.7

Surface tension measurements on some common epoxy resins as well as the pure epoxies showed them to have higher values than the critical surface tension of the RX-03-BB (Table 2); obviously they would not wet well.

Table 2. Surface tension of some epoxy resins.

Resin	Surface tension, 10^{-2} N/m
Epon 282/Versamid 140	3.9–4.1
Epon 282/Merginamid L-425	3.8
Pure DGEBA (DER 332)	4.7
Epon 828	5.0

We are able to formulate some modified epoxies with surface tensions lower than the RX-03-BB by blending aliphatic epoxies with the bisphenol A based epoxy and adding a small amount of a fluorocarbon surfactant, as shown in Table 3. These formulations bonded well to the RX-03-BB, and tests showed them to be compatible. However, the glass transition temperature T_g was about 40°C as measured by TMA, and the bond strength dropped off rapidly above this temperature.

Table 3. Modified epoxies that will bond RX-03-BB.

Formulation 1		Formulation 2	
DER 332	80	DER 332	80
Epon 871	20	Epon 812	20
V-140	100	V-140	150
FC-430	0.3	FC-430	0.3
Surface tension: 3.2×10^{-2}		Surface tension: 3.6×10^{-2}	
Breaks RX-03-BB		Breaks RX-03-BB	

To get the desired high strength up to 75°C, we were forced to go to a ''hotter'' system with a higher cross-link density. We did this in two ways: (1) we used a shorter-chain aromatic epoxy, ERE 1359, a diglycidyl ether of resorcinol in place of DGEBA resin, and (2) we added diethylene triamine to the curing agent. It may be recalled that Versamid 140 is a reaction product of diethylene triamine and fatty acid dimer. This formulation we call EXPLOSTIK 473 and is shown in Table 4. Preliminary tests show it to be compatible with RX-03-BB, and specimens of the HE bonded with the new adhesive break in the HE at test temperatures up to 75°C. Note its low surface tension of 2.6×10^{-2} N/m.

Table 4. EXPLOSTIK 473: a new epoxy adhesive for bonding RX-03-BB.

Component	wt%
Epon 871 (DGEster of fatty acid dimer)	3.9
ERE 1359 (DGEther of resorcinol)	54.6
Versamid 140	39.0
Diethylene triamine	2.3
Fluorocarbon surfactant FX-430	0.2
Surface tension: 2.6×10^{-2} N/m	
Breaks RX-03-BB up to 75°C	

HANDLING CHARACTERISTICS OF EXPLOSTIK 473

Figure 1 shows the viscosity vs time profile on a thin film as measured with a cone and plate rheometer. The slow increase of viscosity affords ample application time. While the applied adhesive cures slowly, a 130-g mass will gel with moderate exotherm in 34 min.

To establish safe handling times after the applications of EXPLOSTIK 473, a quantitative evaluation of reaction rate was necessary. DDS (dynamic dielectric spectroscopy) was employed for this purpose. Capacitance and dissipation factor were measured in the frequency range of 100 Hz to 1 KHz, Fig. 2. Loosely defined, capacitance reflects the ability of a dipole to comply with a change in polarity while dissipation factor denotes the measurement of the actual response. As we view the curves of the capacitance vs time at room temperature, we see a slow drop over a period of about four hr. There is no sudden drop indicating rapid gelation but rather a slow, progressive hardening.

In viewing the dissipation vs time curves, one must bear in mind that the lower the loss tangent value, the higher the molecular weight at a given temperature; and that large molecules are more responsive to high frequencies and small ones more responsive to low frequencies. With these points in mind, we observe a peak in the 1 KHz scan indicating a steadily increasing molecular weight commencing at about 1.25 hr with the smaller molecules joining the developing network at about three hr. After about six hr, essentially all activity subsides indicating cure to be complete at room temperature.

One point remained to be demonstrated – whether or not our new formulation would retain sufficient integrity at 75°C. DDS was again employed by monitoring loss tangent vs temperature from 23°C to 172°C. In Fig. 3, the heating rate was constant at 1.65°C/min. At about 55°C, we observed a low-order dispersion peak suggesting some additional residual cure to be taking place. At 113°C the 100-Hz scan went through a secondary transition with the 1-KHz scan following at 131°C. Such loss tangent maxima are associated with glass transition. By cooling our sample at the same rate, we were able to verify this event as a reversible transition which reappeared at the same temperature.

EXPLOSTIK 473 should perform well at temperatures to about 100°C.

BK/hr/wl

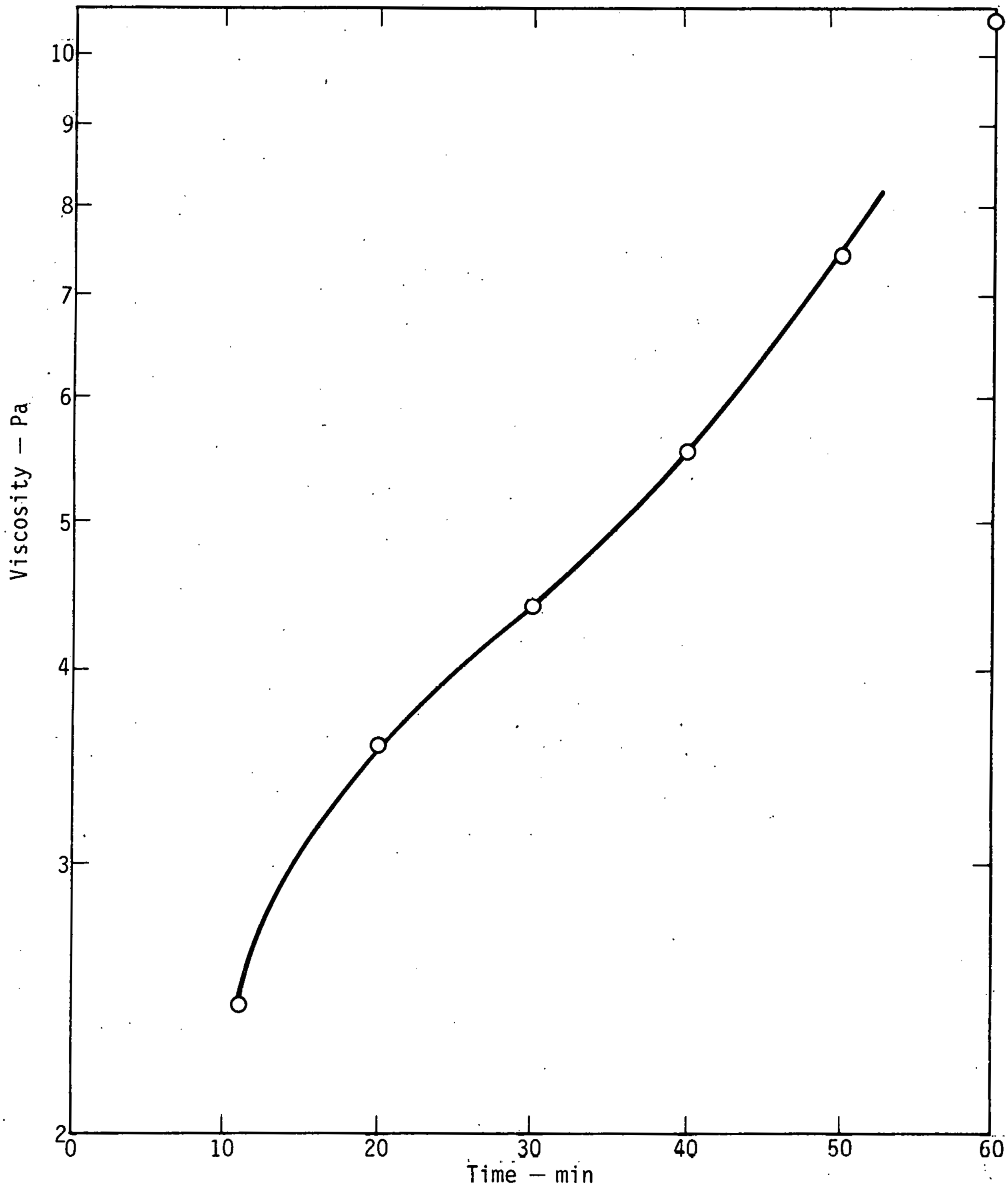

Fig. 1. Viscosity vs time at room temperature for EXPLOSTIK 473. Rotovisko torsional rheometer with cone and plate attachment was used. Gardener gel time for 130-g mass is 34 min.

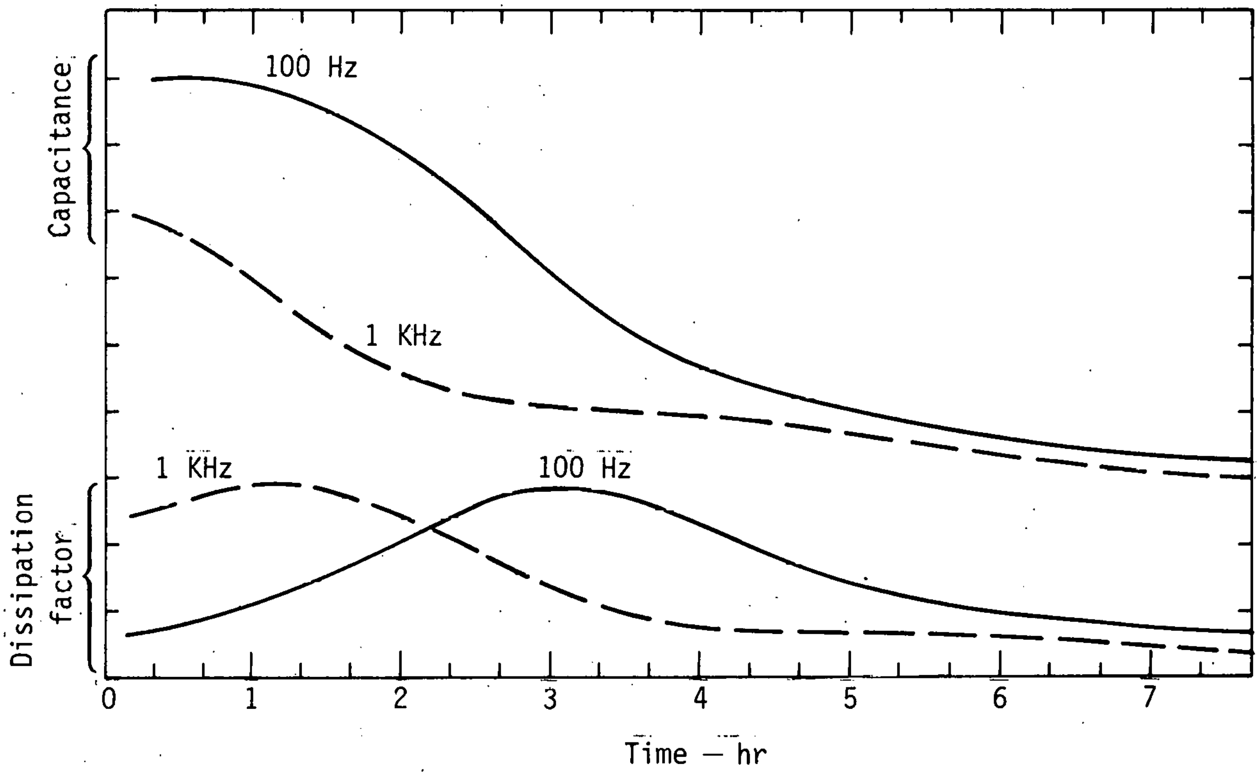

Fig. 2. Capacitance and dissipation factor vs time at room temperature for EXPLOSTIK 473. Curves show slow gelation with cure in 7 hr.

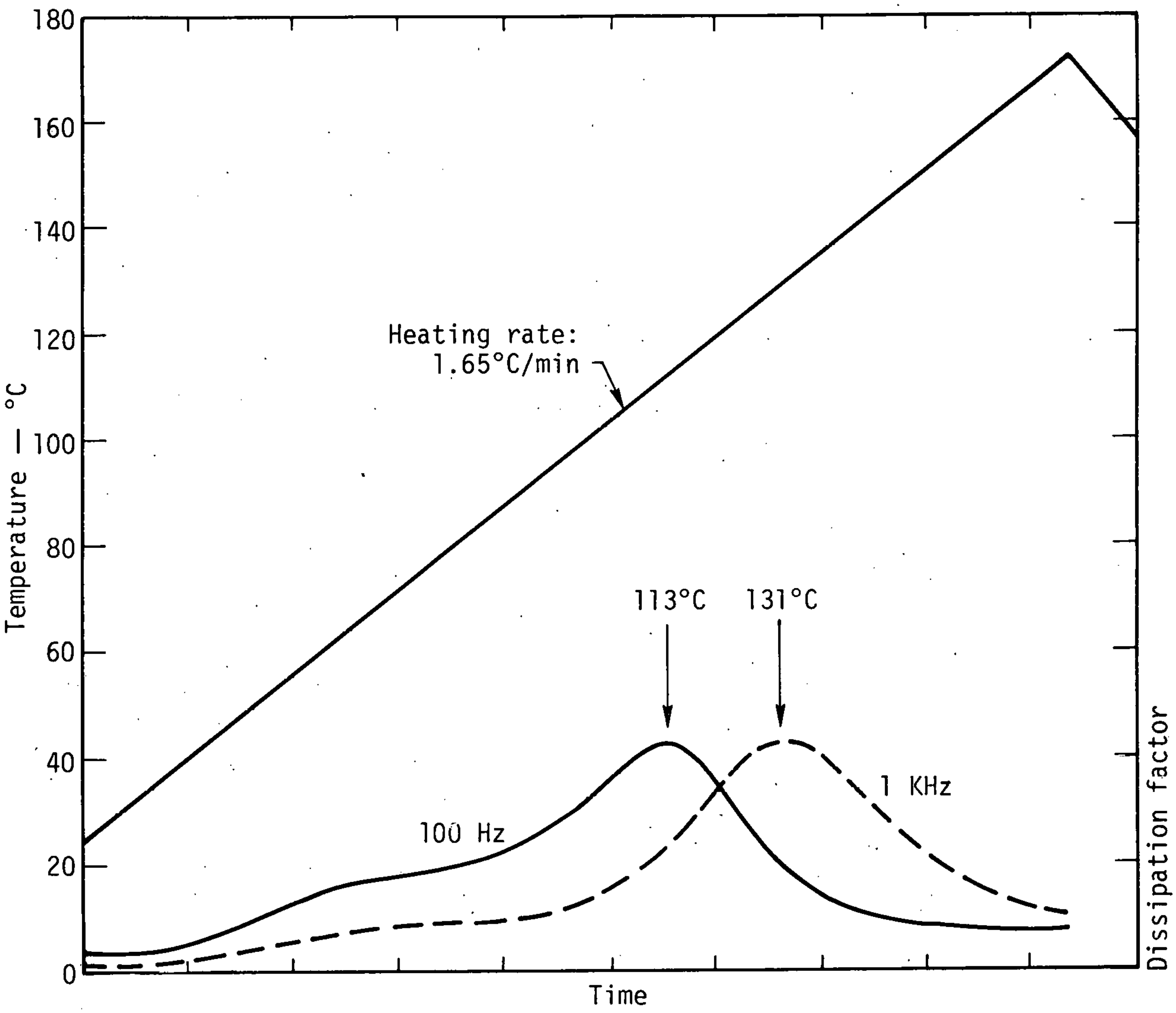

Fig. 3. Dissipation factor vs temperature, showing T_g maxima for EXPLOSTIK 473. Heating rate is 1.65°C/min.

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