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Thermal characteristics of the polymeric components of a CF-18 flight data recorder [α,β]

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Abstract

A study of the thermal characteristics of the polymeric components of a flight data recorder has been initiated to assist in the recovery of data from fire damaged tapes, associated with the investigation of accidents involving modern high speed military fighter aircraft. Preliminary results, using dynamic and isothermal thermogravimetry in a nitrogen atmosphere, indicate that the polymeric components in the flight data recorder of one accident experienced a temperature of approximately 500 °C over a three to four hour period.

INTRODUCTION

There have been thirteen crashes of Canadian CF-18 Hornet high speed military fighter aircraft in the last six years. The majority of the flight data recorders have survived, suffering only minor impact and fire damage, but a few have been completely destroyed by the excessive heat that follows high impact crashes. We have attempted to determine the approximate temperature experienced by the polymeric components in the flight data recorder of a crashed CF-18 airplane in which a fire resulted and burned for three to four hours. This research has been initiated as assistance in the recovery of data from fire damaged tapes.

Both dynamic and isothermal thermogravimetry (TG) were used to assess the thermal stability, in nitrogen, of the seven polymeric components present in the upper half of a Normalair–Garrett "TTM" flight data recorder [1]. A photograph of the recorder is presented in ref. 1 and schematic diagrams are included in refs. 2 and 3. Comparison, via visual inspection and touch, of the fire damaged recorder components and the isothermal TG experiment residues allowed us to draw some conclusions.

EXPERIMENTAL

The thermogravimetry experiments were performed on a DuPont 951 thermogravimetry analyzer coupled to a Du Pont 2100 thermal analyst.

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Heating rates of 10 °C min^{-1} were employed for the dynamic experiments. Extrapolated onset temperatures of degradation were used in comparing thermal stabilities. The isothermal experiments were preceded by a 45 min hold at room temperature to remove any oxygen from the system. All experiments were conducted in nitrogen (< 10 ppm of oxygen) at a flow rate of 50 ml min^{-1}.

RESULTS AND DISCUSSION

Since the recorders are hermetically sealed during manufacture [2], the small quantity of oxygen present in these compact units will limit the thermal oxidation that can occur to the polymeric components, and will favour pyrolysis reactions. Two of the items in the fire damaged recorder, the silicone casing seal and the polyimide shim under the recorder head, were sandwiched between metal and therefore had very limited interaction with oxygen during the fire. In addition, owing to the rolled up nature of the Kapton polyimide based magnetic tape (Thermo 465, Raymond Engineering) and its exterior coatings, the polyimide base polymer of the tape would also experience limited interaction with oxygen. Since the flight data recorder was believed to be exposed to fire for 3–4 h, a 3.5 h duration was selected for initial isothermal TG experiments at 500 °C and 600 °C in a flowing nitrogen atmosphere.

Isothermal TG curves of the silicone rubber casing seal indicated 14% and 8% weight loss after 3.5 h at 600 °C and 500 °C respectively, as illustrated in Fig. 1. This grey coloured silicone rubber casing seal, when heated for 3.5 h at 600 °C, turned light brown in colour and became extremely brittle. A second sample heated at 500 °C for 3.5 h did not significantly change colour, and had a similar colour and similar slight brittleness to that of the seal from the fire damaged recorder, thus indicating a fire temperature near 500 °C.

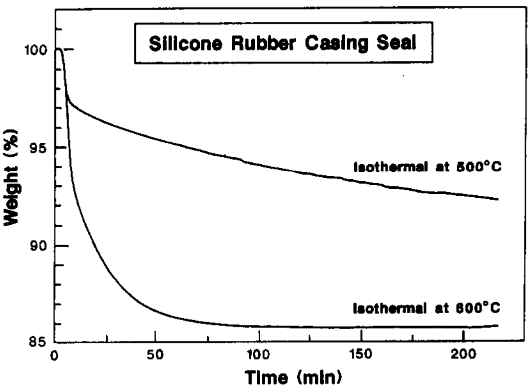

Fig. 1. Isothermal thermogravimetry of the silicone rubber casing seal.

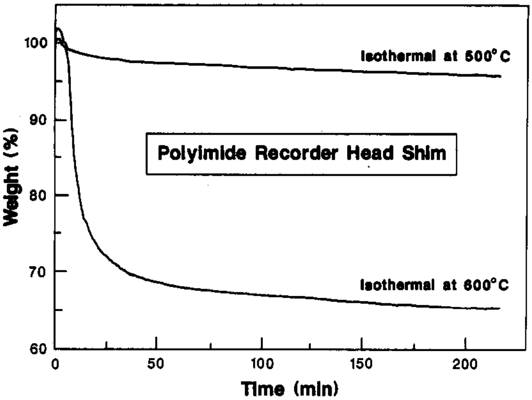

Fig. 2. Isothermal thermogravimetry of the polyimide recorder head shim.

Isothermal TG curves of the polyimide recording head shim indicated 35% and 5% weight loss after 3.5 h at 600 °C and 500 °C respectively, as illustrated in Fig. 2. A sample of the yellow coloured polyimide recording head shim, heated for 3.5 h at 600 °C, turned dark brown and became very brittle. A second sample, heated for 3.5 h at 500 °C, darkened slightly but was still flexible, and was similar in colour and flexibility to that from the fire damaged recorder, thus again indicating an average fire temperature near 500 °C.

A fire temperature near 500 °C was also supported by the dynamic TG experiments for the Teflon wire insulation, the silicone rubber potting material and the rubber brake pad. Both the rubber brake pad and the silicone rubber potting material disappeared in the heat from the fire and showed > 90% and > 40% weight loss respectively, at 500 °C when heated at 10 °C min^{-1} in the dynamic TG experiments (see Figs. 3 and 4). Only traces of white powder (silicon dioxide?) were evident from the silicone

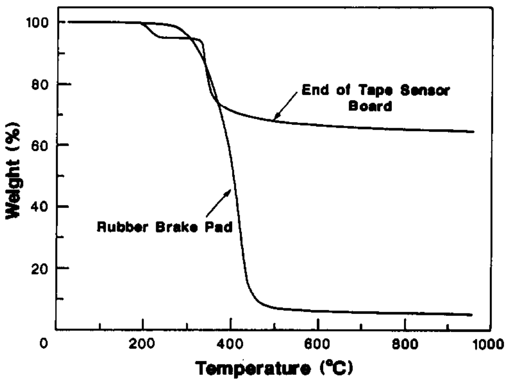

Fig. 3. Dynamic thermogravimetry of the rubber brake pad and an epoxy end of tape sensor board.

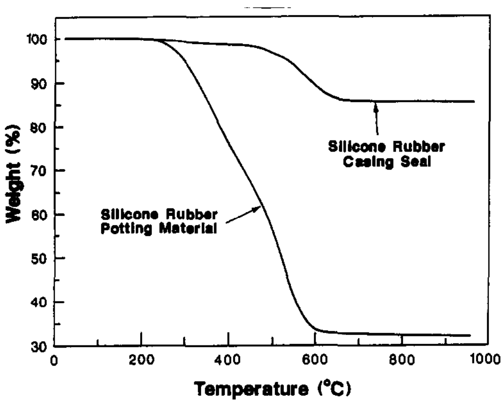

Fig. 4. Dynamic thermogravimetry of the silicone rubber casing seal and of the silicone rubber potting material.

rubber potting material, and this white powder was also present on the outside of the recording head of the fire damaged recorder. Most of the Teflon wire insulation in the fire damaged recorder appeared to be in excellent shape; only minor portions next to the metal housing showed signs of shrinkage or minor degradation. This was not surprising since the dynamic TG experiment for Teflon insulated wire (Fig. 5) indicated a 574°C onset temperature of degradation, which is about 75°C above the estimated temperature experienced by the flight recorder.

Both the polyimide materials, the shim and the magnetic recording tape withstood the fire temperatures, but this was also not surprising when one considers the polyimide TG degradation temperatures. Thermogravimetry of the recording head shim indicated a polyimide degradation temperature of 577°C while that for the polyimide portion of the magnetic tape was 582°C (Fig. 6). The 8% weight loss in the magnetic tape between 200°C and

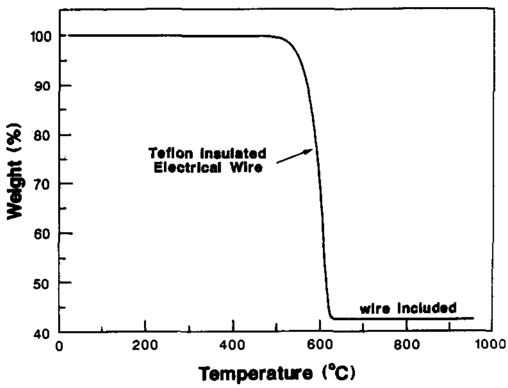

Fig. 5. Dynamic thermogravimetry of the Teflon insulated electrical wire.

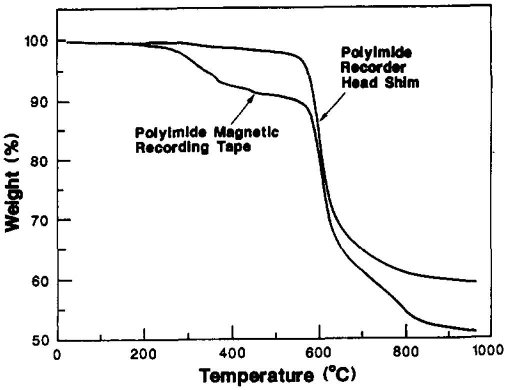

Fig. 6. Dynamic thermogravimetry of the polyimide magnetic recording tape and of the polyimide recorder head shim.

500 ° C most likely results from degradation of the binder, and as such could affect the ability to replay the recorded messages from heated tapes.

The dynamic TG results for the silicone rubber casing seal (Fig. 4) supported the isothermal experiments (Fig. 1) in that only 3.5% weight loss had occurred on heating to 500 ° C in the dynamic experiment and ≈ 8% in the isothermal experiment after 3.5 h at 500 ° C. This was sufficient heating to cause some degradation and slight brittleness in the seal.

CONCLUSION

The weight losses and residue properties of the polymeric components in the upper half of the fire damaged flight data recorder were consistent with a 3.5 h fire and a recorder internal temperature of approximately 500 ° C. In the future, we hope to determine the maximum temperature/duration profile for the magnetic tape that allows retrieval of previously recorded information.

REFERENCES

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2 Aircr. Eng., 51 (6), (1979) 18.
3 R.B. Strange, High Integrity Digital Recording Systems, Proc. Symp. on Design and Application of Aircraft Digital Recording Systems, Royal Aeronautical Society, London, UK, April 18 1985, pp. 48–69.