# Characterization of the ADN-based liquid monopropellant FLP-106

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**Abstract**
Ionic liquid monopropellants are promising as green substitutes to hydrazine. The oxidizer ammonium dinitramide, ADN, is used in these types of propellants due to its high solubility. Two monopropellant formulations, FLP-106 and LMP-103S, have received particular attention. This paper presents the continued characterization of FLP-106 with respect to performance, sensitivity and compatibility. Its manufacturing and batch control, and a brief comparison with LMP-103S are also presented.

## Introduction

State of the art monopropellant hydrazine is highly toxic, volatile and carcinogenic, and has limited performance. This has prompted the search for new superior propellants to replace hydrazine. One of the most promising alternatives to hydrazine is ionic liquids. Ammonium dinitramide, ADN, is a promising oxidizer in these types of propellants due to its high solubility. A number of different ADN-based liquid monopropellants have been developed during the last years [1, 2]. Among them, the formulations FLP-106 and LMP-103S have received particular attention. LMP-103S has been selected by SSC/ECAPS and FLP-106 has been selected by FOI as main monopropellant candidate for further development efforts.

FLP-106 is a low viscous yellowish liquid, as seen in Figure 1, with high performance, low vapour pressure and low sensitivity. It is based on a low volatile fuel, water and 64.6% ADN. The development, selection and properties of FLP-106 are reported elsewhere [2, 3]. This paper presents results from the continued characterization of FLP-106 and a comparison with LMP-103S.

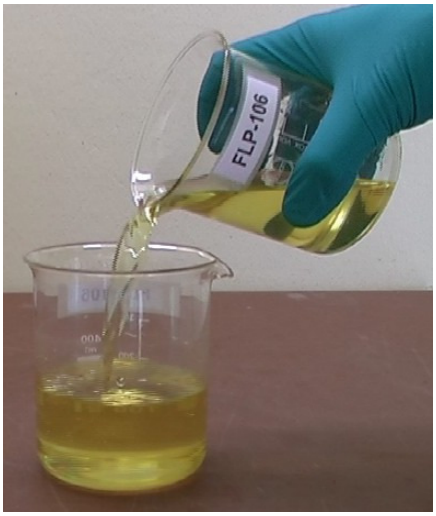


**Figure 1.** Monopropellant FLP-106.

## Performance

In order to calculate the specific impulse, $I_{sp}$, and to evaluate the combustion efficiency of a thruster, the heat of formation, $\Delta H_f$, for the propellant FLP-106 is needed. FLP-106 is a ternary mixture based on ADN dissolved in a fuel/water mixture. To determine the $\Delta H_f$ for the propellant, the $\Delta H_f$ for each component must be known. The heat of formation for water and ADN is reported in the literature [4, 5]. The heat of formation for the fuel used could not be found and was thus determined, using an IKA C4000 adiabatic bomb calorimeter, to be -4188 J/g.

When dissolving ADN the temperature of the mixture decreases substantially. This means that the heat of solution, $\Delta H_s$, is positive and that the enthalpy of the system hence increases.

The ADN heat of solution was measured using a solution/mixing calorimeter based on a Dewar vessel equipped with a magnetic stirrer and a Testo 735-2 precision thermometer. The amount of water in the vessel was approximately 100 g and the sample weight was approximately 1 g. The ADN heat of solution was found to be +35.7 kJ/mol. A typical ADN solubility thermogram is shown in Figure 2.

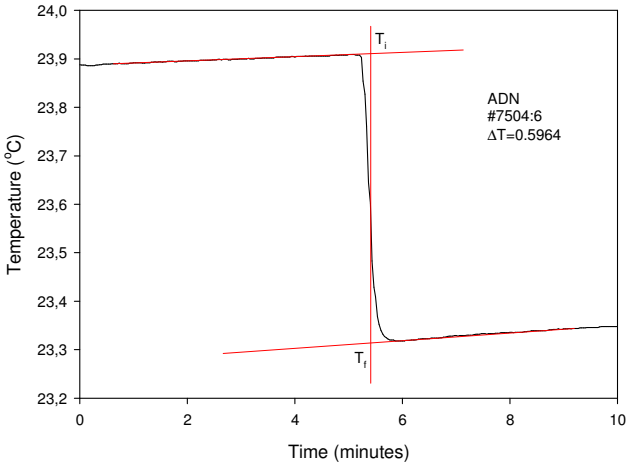


**Figure 2.** ADN solubility thermogram.

The ADN heat of solution determined is valid for dilute solutions only. In FLP-106, with an ADN content of 64.6%, the heat of solution was estimated to be +24 kJ/mol.

With the enthalpies determined, the vacuum specific impulse for FLP-106 was calculated at different nozzle area expansion ratios, using the NASA CEA 600 computer program [6, 7]. The chamber pressure was 1.0 MPa and frozen equilibrium during expansion was assumed. The results are shown in Table 1.