ent in the flame region had to be weak and were imperceptible in the fluorescence images.

Conclusions

Planar LIF images of OH in a supersonic combustion test section were obtained by the excitation of the $Q_2(11)$ rovibronic transition. OH densities were obtained from these images by calibration with an OH source generated by the thermal dissociation of H_2O in an atmospheric air furnace. Peak OH concentrations of 2.6×10^{16} cm^{-3} were measured with a predicted uncertainty of ~21%.

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New Stabilizers for Double-Base Propellants

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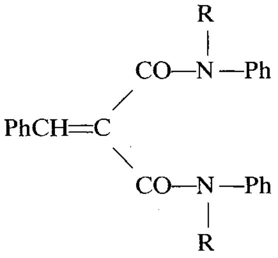
I. Introduction

A NUMBER of malondianilide derivatives have been used in a wide range of industrial applications,[1–5] in other different fields,[6–10] and in continuation of our previous work.[11–13] We have investigated *N*,*N*-diphenylmalondianilide derivatives (1*a*, *b*) to use them as stabilizers for double-base propellants, to examine the explosive properties of the malondianilide molecule, and to study another type of application of these compounds. The compounds prepared as indicated in previous literature[14–16] and the structural assignment have been proved by elemental analysis and IR spectrum:



1*a*, R = H
b, R = C_2H_5

II. Experimental

The sample mixtures, which contain nitrocellulose (12.10% N) 56%, nitroglycerin 27%, dinitrotoluene 9%, dibutylphthalate 4%, dianilide compound 3%, and transformer oil 1%, are treated according to the different steps used in production of double-base propellant.

The stability tests,[17] the calorific test carried out on the samples, and the results are tabulated in Table 1. The tests of calorific value prove that the compound (1*b*) has an endothermic action and ranged between −25 cal/g to −33 cal/g (average −29 cal/g). The comparison was carried out between centralite 1 sample (diethyldiphenylurea, 22.6 cal/g) and stabilizer 1*b* sample.

The results of the stability tests shown in Table 1 indicate that the dianilides have a distinct stabilizing effect in double-base propellant. This fact was clearly confirmed by the calculation of the half lifetime of sample III in comparison with sample I as a stabilizer. Storage tests at 100, 90, and 80°C were done under the same conditions and weight of the samples.[18] The rest of the stabilizer was calculated periodically as shown in Table 2 by using column partition chromatography after the samples were extracted by using different solvents.

The rest of the stabilizers before and after storage for different times are shown in Table 3. The needed time to use 50% of the original stabilizer (sample I = 1.43 and sample III = 1.45%) at different temperatures is tabulated in Table 4.

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Table 1 Stability tests of dianilide (samples II and III) compaired with centralite I (sample I)

No stabilizer	Abel heat test at 80°C, min	Storage test at 100°C, days	Dutch heat test at 105°C 8 h	24 h	48 h	72 h	Bergmann-Junk test—120°C NaOH, 0.05 N solution, 5 g	Calorific value, cal/g	Deflagration temperature, 5°C/min
I CI	>45	>12	0.20%	0.20%	0.14%	0.10%	4.4 ml	776	175
II 1*a*	>45	>12	0.27%	0.18%	0.14%	0.11%	4.6 ml	—	172
III 1*b*	>45	>12	0.27%	0.20%	0.13%	0.12%	4.5 ml	765	174

Table 2 Time of taking samples from the apparatuses

Apparatus 1 at 100°C, days	Apparatus 2 at 90°C, days	Apparatus 3 at 80°C, days
1	5	15
2	10	30
4	20	60
8	40	120

Table 3 Stabilizer percent (CI and 1*b*) before and after storage in three different temperatures and times

	Storage at 100°C		Storage at 90°C		Storage at 80°C	
Sample	Days	Stabilizer, %	Days	Stabilizer, %	Days	Stabilizer, %
I	0	2.86	0	2.86	0	2.86
I	1	2.30	5	1.77	15	2.05
I	2	1.82	10	1.26	30	1.44
I	4	0.93	20	0.64	60	0.66
I	8	0.33	40	0.22	120	0.15
III	0	2.90	0	2.90	0	2.90
III	1	2.26	5	1.80	15	2.02
III	2	1.80	10	1.30	30	1.49
III	4	0.89	20	0.68	60	0.65
III	8	0.32	40	0.23	120	0.16

Table 4 Time needed to consume 50% of stabilizer at different temperatures

	Time at different temperatures, days		
Sample	100°C	90°C	80°C
I	2.85	8.5	31.5
III	2.80	8.5	31.0

The results from Table 4 are obtained from the six curves of the relation between the stabilizer percent and time in days from Table 3. The relation between the temperature T and log time t from Table 4 gave a straight line Fig. 1 sample I, and Fig. 2 for sample III.

With the results of the straight lines in Figs. 1 and 2 (1.43 and 1.41), and the results of the intersection points at 65.5°C (220 days for sample I and 205 days for sample III), Berthelot's law can be used to estimate the half lifetime of the double-base propellant at 30°C by using a new stabilizer 1*b* in comparison with the classical stabilizer centralite 1 as shown hereafter.

$$t_1 = \frac{t_2 \times 10a[(T_2 - T_1)/10]}{365}$$

where

t_1 = the nominal age of the powder
t_2 = the time which consumed 50% of stabilizer at 65.5°C
T_2 = 65.5°C
T_1 = the ordinary temperature, 30°C

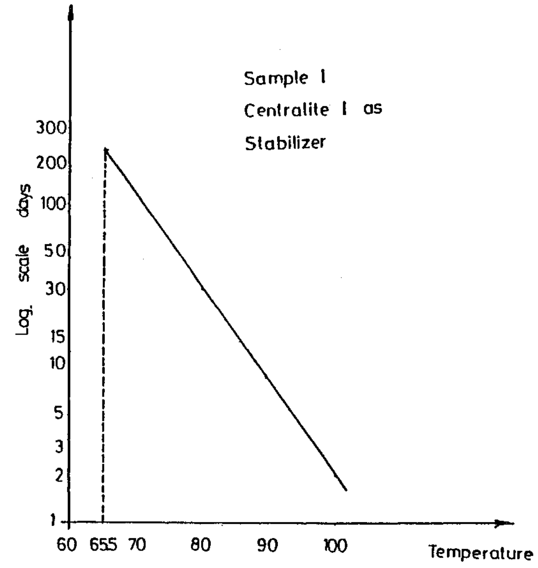

Fig. 1 Relation between temperature and log. time.

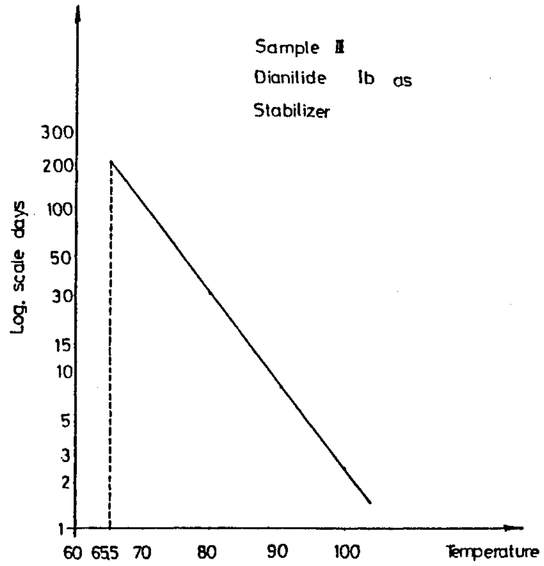

Fig. 2 Relation between temperature and log. time.

The mathematical application of the previous equation (Berthelot's law) gave the following results, half lifetime of sample I = 36.9 yr and half lifetime of sample III = 33.5 yr.

III. Discussion of the Results

There are no differences in the results of the stability tests between the three samples shown in Table 1, especially the Bergmann-Junk test 120°C and the storage test at 100°C. This fact was clearly confirmed by the application of Berthelot's law to calculate the half lifetime of sample III (*N*,*N*-diethyldianilide) in comparison with sample I (CI), the results indicated that there was no difference between the two samples.

These results are in comparison with the last application of Berthelot's law by Soliman[19] which shows the difference between the two samples for more than 30 yr. The findings that the benzal-malondianilide 1*a* and its derivative *N*,*N*-diethyl have a remarkable stabilizing effect can be seen from the stability tests in Table 1. Berthelot's law applications (half-life period) support the idea that compound 1*b* can be considered a good stabilizer for double-base propellants.

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Hypervelocity Scramjet Mixing Enhancement

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Introduction

EXPLORATION and utilization of space, both near Earth and within the solar system, and eventually, interstellar, is a continuing national interest. A major key to the effective utilization and exploration of space is an efficient, convenient, and cost-effective launch system into low Earth orbit. While major strides are being made in payload miniaturization, launcher performance/cost will remain a critical issue. One set of options for more effective launchers involves air-breathing propulsion, perhaps operating over portions of the ascent in a "combined cycle" mode. A particularly critical component of hypersonic air-breathing propulsion systems is the combustor, which is, historically, heavy due to requisite size/length and high aerodynamic and thermal loading and responsible for major portions of the total engine losses. One of the prime determinants of combustor efficiency is the distance required to "mix and burn," and therefore, effective mixing enhancement (including adequate fuel penetration) can provide a significant contribution to the viability of air-breathing hypersonic propulsion.

The penetration and mixing enhancement problem for hypersonic air breathers must obviously be worked within the context of overall engine efficiency and thrust production. There are a multitude of extant mixing enhancement techniques,[1,2] the problem is obtaining a resultant net performance enhancement when the additional losses associated with the mixing enhancement approach are accounted for. At the higher speeds (e.g., $M > 12$) the thrust imparted to the vehicle from the fuel injection process is increasingly important,[3] requiring nearly parallel injection, a process that is not conducive to rapid mixing. The high Mach number end is also increasingly sensitive, in terms of net thrust, to losses of all types, mitigating against the use of instream injection struts with their high wave drag and heat transfer losses. The mean shear between the fuel jet and local stream flow becomes small in the Mach 12–15 range due to the high efflux speed of the regeneratively heated hydrogen fuel, further reducing the innate shear-induced mixing, but reducing the "convective Mach number." Therefore, in terms of criticality and payoff, the high Mach number range is the most important (air-breathing) regime for mixing enhancement.

The overall mixing problem in the combustor is nonsimple. The mean flow entering from the inlet is highly three dimensional and replete with unsteady shock and expansion waves, thick turbulent boundary layers, and embedded vortical entities. The combustor itself contains multiple fuel injection sites whose individual character could be different and whose three-dimensional flowfields interact with each other and with the incident flow, along with various types of possible front-side cooling-induced flow phenomena. These flow features and their interacting combinations are quite different from the simplex flows employed in most (laboratory, shear-dominated) mixing enhancement studies.

Mixing enhancement for engine performance improvement is the totality of increased micromixing (from small-scale turbulence/molecular mixing), increased "contact area" between air and fuel in a global sense (from "stirring" and multiple injection sites), and increased "path length" (e.g., from swirl). Known parameters having a first-order effect upon turbulent shear layers, and therefore, candidates for incorporation into synergistic mixing enhancement schemes, include pressure gradients, flow curvatures, energy release, proximity to transition/Reynolds number, shock/expansion waves, three-dimensional mean flow details, compressibility, adjacent surfaces, and stream fluctuation fields. Fuel distribution is also influenced by injection location(s) and approaches and action of "inviscid" wave systems. From these considerations an approach to scramjet mixing enhancement can be suggested that involves synergistic utilization of pre-existing flow features along with stirring and low loss turbulence enhancement approaches, all in the context of injection techniques consistent with achieving the required fuel coverage/penetration and fuel thrust. In particular, utilization should be made of the initiation and encouragement of innate instabilities that affect flows that are already turbulent (e.g., the Gortler instability, etc.).

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