AN ENVIRONMENTALLY-ACCEPTABLE ENERGY-DENSE PROPELLANTS

By

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UNCLASSIFIED

EXAMPLE: AN ENVIRONMENTALLY HAZARDOUS PROPELLANT

- COMPOSITION N-43 (AS 3550C)
  - APPLICATION:
    - U-2 AIRCREW-ESCAPE ROCKET MOTOR
  - SPECIFIC PROBLEMS AND CHALLENGES:
    - MOTOR IS HIGHLY VOLUME-LIMITED: HIGH (ρ X Isp) NEEDED
    - TOXIC PROCESS-WASTE
    - LEAD TOXICITY FROM EXHAUST
    - DIBUTYL PHTHALATE IS A POOR PLASTICIZER (MP-31°F)
    - CTPB RESIN NO LONGER MANUFACTURED
  - ADVANTAGES:
    - HIGH DENSITY-IMPULSE
    - CLASS 1.3 COMPOSITION
    - NO KNOWN SAFETY-LIFE

ALTERNATIVE APPROACH TO N-43

- **FORMULATE AN ENVIRONMENTALLY-FRIENDLY PROPELLANT**

  1. REPLACE LEAD NITRATE WITH ALTERNATE DENSE METAL/METAL SALTS.
  2. EMPLOY BONDING AGENTS THAT BOND ALL OXIDIZERS AND METAL SALTS/HYDRIDES
  3. REPLACE AP OXIDIZER TO ELIMINATE HCL IN EXHAUST
  4. REPLACE DI-N-BUTYL PHTHLATE WITH BETTER PLASTICIZER (LOWER Tg)
  5. REPLACE HTPB WITH HIGHER DENSITY BINDER INGREDIENTS

- **IM REQUIREMENTS WILL BE ADDRESSED IN NEW FORMULATIONS BASED ON ADMIRAL WAYNE MEYERS DECREE THAT ALL MOTOR SYSTEMS WILL BE INSENSITIVE (1985)**

CTPB BONDING AGENTS

- **BONDING AGENT / CURATIVE; ONE AND THE SAME INGREDIENT:** MAPO, ERL-0510, HX-868
- **STRAIN-EVALUATION CYCLINDERS:**
  - CTPB PROPELLANTS: SEC'S NOT SEALED PRIOR TO TEMPERATURE CYCLING.
  - HTPB PROPELLANTS:
    - HIGH FAILURE RATE WHEN SEC'S NOT SEALED.
    - INDICATED CTPB BONDING AGENTS SUPERIOR TO HTPB
    - THEREFORE HTPB SEC'S WERE SEALED.

HTPB BONDING AGENTS

- **AZIRIDINES:** MT-4, HX-752
  - GOOD WETTING, BUT PRODUCES HIGHEST DEWETTING/MICROPOROSITY.
- **AMINES:** TEPAN, TEPANOL
  - POOR SOLUBILITY IN ESTER PLASTICIZERS.
  - CAN'T MAXIMIZE BINDER-FILLER INTERACTION.
  - SLOW TO GENERATE AMMONIA.
- **COMPLEXERS:** HYDANTOINS,ISOCYANURATES
- **ORDER OF BINDER-FILLER EFFECTIVENESS:**

  COMPLEX-FORMERS > AMINES > AZIRIDINES

HTPB BONDING AGENTS

- **BONDING AGENT DISCUSSION SINCE 1960'S**
  - **SOLUBILITY IN BINDER VS LESS SOLUBILITY.**
    - HENRY ALLEN CAMP: MORE SOLUBLE WAS BETTER
    - ADOLPH OBERTH CAMP: LESS SOLUBILE
    - CONSAGA OPINION: MORE SOLUBILE & DUAL FUNCTION AS BONDING AGENT / CURATIVE
  - **BASED ON NAVY PRODUCTION CONSULTING / PROPELLANT CHARACTERIZATION EXPERIENCE**
    - MK 104 DTRM:
      - PROCESS TEMPERATURE/SOLUBILITY ISSUES WITH TEPANOL LED TO MECHANICAL PROPERTY, MIX REPRODUCIBILITY AND MOTOR FAILURE ISSUES.
      - HTPB JATO MOTORS USING COMPLEXER BONDING AGENTS OBTAINED BEST EM AT -70°F
  - **IM PROGRAMS:**
    - MK 111 VS 135 TOMAHAWK MOTORS: MK 135 HAS BETTER IM PROPERTIES.
    - CONSAGA DILATATION STUDIES DEMONSTRATED THAT COMPLEX-FORMING > TEPAN > TEPANOL > HX-752.

OPTIMIZED HTPB BONDING AGENTS

- DUAL PURPOSE INGREDIENT:
  - CURATIVE AS WELL AS A BONDING AGENT
  - BASED ON COMPLEX FORMING BONDING AGENTS
  - DEVELOPED IN CONJUNCTION WITH MACH I
  - MINIMIZES MICROPOROSITY / DILATATION
  - MAXIMIZES BINDER-FILLER INTERACTION (BEST BONDING AGENT)
  - ONLY BONDING AGENT CLASS (COMPLEXERS) THAT BONDS ALL CURRENT OXIDIZERS, METAL HYDRIDES, INERT SALTS,ETC.

THEORETICAL CALCULATIONS

Binder/Oxd/ Metal	Density, g/cm³	Isp, lbf-sec/lbm	ρ-Isp, lbf-sec/cm³	Exhaust Temp., °F
CTPB/AP/ $Pb(NO_3)_2$	2.7549	196.6	541.5	4253
HTPB/AP/ZrH_2	2.5081	217.9	546.5	2817
GAP/ADN/AL	1.8082	293.4	530.4	4546
GAP/ADN/ZrH_2 (1)	1.8742	282.2	528.8	3619
GAP/ADN/ZrH_2 (2)	1.9429	277.4	538.9	3578

***<u>NOTE</u>: (1)=20% ZrH_2, (2)=15% ZrH_2**

ADN OXIDIZER

- RUSSIANS DEVELOPED & USED ADN IN STRATEGIC MOTORS, 1970'S-1990'S.
- US HAS NOT SUCCESSFULLY DEVELOPED ADN PROPELLANTS.
  - PROBLEMS:
    - ADN IS VERY MOISTURE SENSITIVE, GREATER THAN AN
    - DID NOT USE A BONDING AGENT OR ENCAPSULATION
    - LOW MELTING TEMPERATURE (92°C)
  - SOLUTIONS:
    - ENCAPSULATE ADN TO PROTECT AGAINST MOISTURE & CONTAIN LIQUID IF IT MELTS
    - USE COMPLEXER BONDING AGENTS IN PROPELLANTS

INSENSITIVE MUNITIONS

- **INSENSITIVE MUNITIONS:**
  - SUCCESS IS A FUNCTION OF THE AMOUNT OF MICROPOROSITY AND DIAMETER/SIZE OF THE MOTOR.
  - MICROPOROSITY: A FUNCTION OF THE EFFECTIVENESS OF THE BONDING AGENT IN DEVELOPING THE BINDER-FILLER INTERACTION.
- **PROPELLANT MICROPOROSITY AFFECTS:**
  - AGING, TEMPERATURE CYCLING, MOISTURE SUCEPTIBILITY, MECHANICAL/BALLISTIC PROPERTIES, AND HAZARDS/FRIABILITY TESTS.

CONCLUSION

- BASED ON THEORETICAL CALCULATIONS AND PRIOR RESEARCH STUDIES, AN ENVIRONMENTALLY CLEAN PROPELLANT CAN BE DEVELOPED TO REPLACE THE N-43 SYSTEM.
- COMPLEXING BONDING AGENTS WERE DEVELOPED IN THE 1970'S THAT BOND ALL CURRENT OXIDIZERS, METAL HYDRIDES, AND SALTS USED IN INERT PROPELLANT SIMULANTS. THESE MATERIALS IMPROVE MECHANICAL PROPERTIES, LOWER BURNING RATE SLOPES, AND ACHIEVE/IMPROVE IM CHARACTERISTICS.

AN ENVIRONMENTALLY-ACCEPTABLE ENERGY-DENSE PROPELLANT

"WHEN YOU CHANGE THE WAY YOU LOOK AT THINGS . . .

. . . THE THINGS YOU LOOK AT - CHANGE."

- DR. WAYNE W. DYER