THIOKOL TECHNOLGY ADVANCES

SOLID ROCKET MOTOR SUCCESSES

PREPARED BY

JAMES O. HIGHTOWER JR.

(FORMER EMPLOYEE OF HUNTSVILLE, GEORGIA, AND UTAH DIVISIONS)

DATE:_____

BIOGRAPHICAL DATA SHEET

JAMES O. HIGHTOWER, JR.

BORN: MARCH 15. 1933
SAN ANGELO, TEXAS

EDUATION:

Attended Lewisburg Elementary School, Lewisburg, Tennessee.
Graduated from Marshall County High School in May, 1951.
Graduated from Middle Tennessee State University, Murfreesboro, Tennessee, June 1955.

DEGREES RECEIVED:

B, S. Degree (Chemistry) Middle Tennessee State University.
Second Lt. R.O.T.C. Middle Tennessee State University.

EMPLOYMENT:

State of Tennessee Road Inspector in Nashville, Knoxville, Maryville, Bristol. Basic Training for 6 weeks at Fort Campbell, Kentucky.
Reported for Active Duty at Fort Knox, Kentucky on September 27, 1955.
Honorably discharged from Army, at Fort Polk, Louisiana
September 26, 1957.
Thiokol Chemical Corporation, Huntsville, Alabama on November 6, 1957.
Served inactive Duty in National Guard for 6 years, retired at the rank of Cap -

BUSINESS TITLES AND FUNCTIONS:

Chemist in Research and Development -
Supervisor--William E. Hunter, 1957-1962
Transferred to Thiokol Georgia Division-Supervisor - Dick Wall, 1962-1966
Transferred to Huntsville Division, Thiokol, -
Supervisor--William E. Hunter, 1966
Supervised Liner and Propellant Development -- Group Leader-1968-1977
CHIEF, Research Section-1977-1987
MANAGER, Research and Development Department-1987-1989
MANAGER, Materials and Process Development Department -1989-1996
MARKETING CONTRACTOR, THIOKOL, UTAH - 1996-1999
RETIRED- CONSULTANT, THIOKOL, UTAH--1999-2002
OFFICIALLY RETIRED from THIOKOL, UTAH--January, 2003

THIOKOL HUNTSVILLE DIVISION

. JOINED ARMY IN HUNTSVILLE APRIL OF 1947.

. THIRTY THREE EMPLOYEES WERE TRANSFERED FROM THE ELKTON DIVISION TO STAFF THE NEW HUNTSVILLE DIVISION.

. THE DIVISION BEGAN FABRICATING MOTORS FOR THE ARMY IN 1949

. THE DIVISION CONTINUED MANUFACTURING OF ROCKET MOTORS FOR THE ARMY, AIR FORCE, AND NAVY AND OTHERS THROUGH THE 1990'S.

INTRODUCTION

. HISTORY OF SOLID PROPELLANTS.

. HUNTSVILLE DIVISION AREAS OF EXPERTISE.

. SPECIFIC AREAS OF TECHNOLOGY IMPROVEMENT.

- . PROPELLANT BINDERS
- . FERROCENE BURNING RATE CATALYSTS.
- . INSULATION AND LINER ADHESIVES.
- . PROPELLANT TECHOLOGY DEMONSTRATION PROGRAM.

. HUNTSVILLE DIVISION ROCKET MOTORS.

- . TACTICAL AND STREGETIC

. GEORGIA DIVISION 156 DIAMETER MOTOR DEMONSTRATION.

. FUTURE NEEDS FOR SOLID PROPELLANT ROCKET MOTORS.

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HISTORY OF SOLID PROPELLANTS

- PRESSED BLACK POWDER (13TH CENTURY)

  KNO_3, 74.0%; C, 15.6%; S, 10.4%

- DOUBLE BASE SMOKELESS (19TH CENTURY)

  NC, 52.1%; NG, 43.0%; DEP, 3.0%; K_2SO_4, 1.3%; DEC, 0.6%

- ASPHALT (ROCKET ASSISTED TAKE-OFF, WWII, J.P.L.)

  $\{CH_2\}_n$, 25%; $KClO_4$, 75%

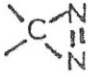
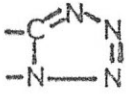
- POLYSULFIDE POLYMERS (THIOKOL, 1948)

  $\{S\text{-}SCH_2CH_2\}$, 29%; ; $KCLO_4$, 47%; NH_4ClO_4, 24%

- POLYURETHANE POLYMERS (1955)

  $\{O\text{-}R\text{-}OCONH\text{-}R'\text{-}NHCO)_n$, 12%; Al, 18%; NH_4ClO_4, 70%

- HIGH ENERGY BINDERS, OXIDIZERS, PLASTICIZERS (1960)

  $-ONO_2$, $>N\text{-}NO_2$, $-N_3$,  , $-CH_2NO_2$, $-CH_2NF_2$,  , $-O\text{-}O-$

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SOLID PROPELLANT CATEGORIES

	SMOKEY	REDUCED SMOKE	MINIMUM SMOKE
• COMPOSITION	BINDER	BINDER	BINDER
	AP	AP	NH_4NO_3
	Al		RDX, HMX
• EXHAUST PRODUCTS	CO_2	CO_2	CO, H_2
	H_2O	H_2O	H_2O
	HCl	HCl	N_2
	Al_2O_3		
• CHAMBER TEMPERATURE,°K	3642	3077	2821
• TYPICAL ISP, LB-SEC/LB	263	252	247

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OVER 50 YEARS OF COMPOSITE PROPELLANT BACKGROUND

PROPELLANT TYPE	YEAR	TYPICAL MOTORS
POLYSULFIDE	1949	FALCONS, RECRUIT, FFARs, HERMES, SERGEANT, LACROSSE, MAVERICK (1.3 - 6600 LB)
PBAA	1955	ZEUS, PERSHING, CASTOR I & IV (270 - 21,000 LB)
CTPB	1960	CASTOR II, SPARTANS, PATRIOT (1100 - 10,000 LB)
HTPB	1968	PATRIOT, MK 70, MK 36, MAVERICK, HELLFIRE, CASTOR IVA, SLAT (22 - 2200 LB)
MINIMUM SMOKE	1976	HELLFIRE, TOW 2, CHAPARRAL, SABER, AAWS-M, ROLAND, STINGER (4 - 100 LB)

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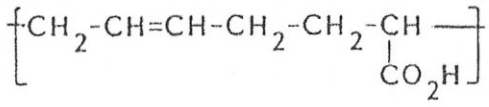
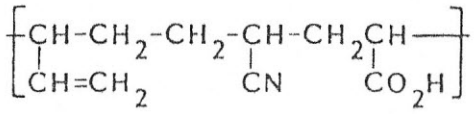
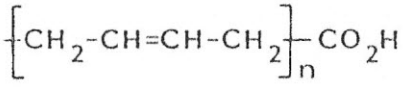
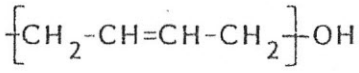
BUTADIENE POLYMERS

POLYMER	STRUCTURE	CURE AGENT	YEAR IN PROPELLANT	COMMENT
• POLYBUTADIENE/ ACRYLIC ACID (PBAA)		EPOXY	1955	HIGHER ISP, LOW STRAIN, 86% SOLIDS
• POLYBUTADIENE/ACRYLIC ACID/ACRYLONITRILE (PBAN)		EPOXY	1958	HIGHER ENERGY DENSITY, POOR LOW TEMP. PROPERTIES
• CARBOXYTERMINATED POLYBUTADIENE (CTPB)		EPOXY/IMINE	1960	HIGHER STRAIN, WEB FRACTION, HIGHER SOLIDS (88%)
• HYDROXY TERMINATED POLYBUTADIENE (HTPB)		ISOCYANATE	1968	HIGHER SOLIDS (90%), STRAIN; BETTER PROCESSING MECHANICAL PROPERTIES

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PBAA PROPELLANT

INGREDIENT	WT., %
PBAA	14.0
EPOXIDE C.A.	
Al POWDER	16.0
AP	70.0

DISADVANTAGES

- Processing properties inferior to HTBP
- High solids loading not practical (>86%)
- Mechanical properties inferior to CTPB and HTPB propellants

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PBAN PROPELLANT

INGREDIENT	WT., %
PBAN, EPOXIDE C.A., Fe_2O_3	14.2
Al POWDER	16.0
AP	69.8

DISADVANTAGES

- Processing properties inferior to HTPB
- High solids loading not practical (>86%)
- Mechanical properties inferior to CTPB and HTPB propellants

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CTPB PROPELLANT

INGREDIENT	WT., %
Z434	11.0
MAPO	
ERA0510	
IRON LINOLEATE	
DIOCTYL ADIPATE	1.0
Al POWDER	20.0
AP	68.0

DISADVANTAGES

- Mechanical properties inferior to HTPB
- Processing properties not as good as HTPB
- Aging properties inferior to HTPB
- Practical solids loading level lower than HTPB

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HTPB PROPELLANT

INGREDIENT	WT., %
R45M/DDI	10.7
HX752	0.3
DOA	1.0
Al POWDER	20.0
AP	68.0

DISADVANTAGES

- Potential hard layer/soft layer near liner
- Potential potlife problem

MAJOR AIR FORCE FUNDED TECHNOLOGY TACTICAL PROPELLANT PROGRAM

. LARGEST PROGRAM EVER FUNDED BY THE GOVERNMENT.

. CONTRACTED TO DEVELOPEW AND DEMONSTRATE PROPELLANT WITH BURNING RATE OF 0.22, 0.5,1.0, 2.0, AND 5.0 INCHES PER SECOND.

.HTPB BINDER WAS UTILIZED.

. PROPELLANTS WITH ALL BURNING RATES WERE DEVELOPED AND CHARACTERIZED.

INSULATIONS AND LINER ADHESIVES

. ASBETOES FIBER WAS INITIAL FILLER.

. CALENDERED POLYISOPRONE RUBBER FILLED WITH PBI CHOPPED FIBER WAS DEVELOPED AND PUT INTO PRODUCTION.

. EACH PROPELLANT TYPE REQUIRED A NEW CASE BOND ADHESIVE.

. NEW LINERS WERE DEVELOPED TO BE COMPATIBLE WITH EACH PROPELLANT BINDER.

. NEW LINERS WERE PUT INTO ROCKET MOTOR PRODUCTION.

HIGH BURN RATE PROPELLANT CATALYSTS

CATALYSTS	DEVELOPERS	PROBLEMS
FERROCENE	UNKNOWN	SUBLIMATION & SENSITIVITY
N BULYL FERROCENE	HUNTSVILLE DIVISION	MIGRATION - SENSITIVITY
CATOCENE	UTC	MIGRATION-SENSITIVITY

THIOKOL ROCKET MOTORS USING LIQUID FERROCENE ADDITIVES

MOTOR	CATALYST/%
SPARTAN 1ST STAGE	NBF/1.5
SPARTAN 2ND STAGE	NBF/2.5
SRAM	CATOCENE/2.0
SPRINT	CATOCENE/6.0
MK 104	CATOCENE/.9
SENTRY	CATOCENE/5.0
MAVERICK (IGNITER)	CATOCENE/1.5
MK 36 (IGNITER)	CATOCENE/1.5

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HUNTSVILLE DIVISION ROCKET MOTOR PROGRAMS

1950s	1960s	1970s	1980s
2-Inch FARR	CASTOR I	SPARTAN	PATRIOT
FALCON	ARBALIST	PATRIOT	SIDEWINDER (MK 36)
LOKI	HIPADS	CASTOR	MAVERICK (R.S.)
HERMES	15 mm RAP	30,40, AND 75 mm	MK 70
SERGEANT	DUCTED ROCKETS	MAVERICK (R.S.)	HELFIRE (M.S.)
LACROSSE	SELECTIVE ZONE	TOW ASSEMBLY	SLAT
MATADOR JATO	SPARTAN	HELLFIRE (R.S.)	TOW 2
BOMARC	CASTOR II	MLRS	AEGIS ER
NIKE-HERCULES	MAVERICK	SIDEWINDER (MK 36)	VSTT
ZEUS	CASTOR IV	STD. MISSILE (MK 70)	RAM
PERSHING	SUPER BOOSTER	PERSHING	CASTOR II,IV,IVA,IVB
	SAM-D	FIREBRAND	SENTRY
		ASALM	CHAPARRAL
		ROLAND	LARS
			VT-1

THIOKOL ALPHA DIVISION

. COMPOSED OF HUNTSVILLE AND GEORGIA FACILITIES.

. GEORGIA FACILITY SUPPORTED AIR FORCE CONTRACT.

. FACILITY LOCATED ON INTERNAL WATER TRANSPORT TO CAPE CANERVAL.

. SCOPE-DESIGN, DEVELOPE AND STATIC TEST 156 AND260 INCH DIAMETER SOLID ROCKET MOTORS.

. 156 INCH DIAMETER MOTOR MANUFACTURED AND SUCCESSFULLY TESTED.

. 260 INCH CASE FAILED DURING HYDRO TEST.

. AIR FORCE CONTRACT TRANSFERED TO N A S A AND CONTRACT WAS CANCELLED. SO WAS A SIMILIAR CONTRACT WITH AEROJET.

156 INCH DIAMETER MOTOR MANUFACTIURE AND TEST

. CASE LENGTH WITHOUT NOZZLE -- 100 FEET

. NUMBER OF 420 GALLON MILES MADE AND CAST--APPROX. 175

. POUNDS PROPELLANT LOADED IN 6 DAYS--APPROX. 80,000 POUNDS

. TEST DATE--FEBRUARY27. 1965.

. THRUST--THREE MILLION POUNDS.

. ACTION TIME--SIXTY SECONDS

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SOLID ROCKET PROPELLANTS - FUTURE DIRECTION

- INSENSITIVE MUNITIONS
- REDUCED HAZARDS
- HIGHER PERFORMANCE
- REDUCED SIGNATURE
- GREATER BALLISTIC FLEXIBILITY
- LOWER COST
- REDUCED TOXIC EMISSIONS