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DESIGN, DEVELOPMENT AND FABRICATION OF CHEMICAL RELEASE PAYLOADS

Edward F. Allen, Jr., et al

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By

Edward F. Allen, Jr.
Philip E. Beaudoin

SPACE DATA CORPORATION
1331 South 26th Street
Phoenix, Arizona 85034

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Philip E. Beaudoin

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13. ABSTRACT

Rocket borne chemical payload systems were designed, developed, and flight tested to give controlled releases of gases, liquids, solids and explosives.

Chemical systems included liquids and gases: trimethylaluminum/triethylaluminum trimethylborane, nickel carbonyl, diborane, iron carbonyl, tetraethyl lead, nitric oxide and carbonyl sulfide; solids: aluminum oxide and chaff; multi-phase reactions of trimethylaluminum and oxygen; solid combustion reactions to vaporize aluminum, barium, beryllium, lithium, magnesium, sodium, strontium; explosive systems to vaporize trimethylaluminum and iron pentacarbonyl; and shaped charge techniques to vaporize aluminum, barium, lithium and iron.

Chemical handling techniques were developed and engineering field services were provided to launch support.

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Payload, Carbonyl Sulfide						
Payload, Trimethylborane						
Payload, Iron Pentacarbonyl						
Payload, Nickel Carbonyl						
Payload, Tetraethyl Lead						
Payload, Aluminum Oxide						
Payload, Chaff						
Payload, Trimethylaluminum/Oxygen						
Payload, Aluminum/Tungsten Trioxide						
Payload, Barium/Copper Oxide						
Payload, Strontium/Copper Oxide						
Payload, Lithium/Ferric Oxide						
Payload, Lithium/Copper Oxide						
Payload, Sodium/Copper Oxide/Aluminum						
Payload, Sodium/Lithium/Ferric Oxide/ Aluminum						
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Chemical handling techniques were developed and engineering field services were provided for launch support.

1. INTRODUCTION

This report summarizes the work performed by Space Data Corporation under Contract Number F19628-70-C-0211 during the period of April 1970 through November 1972.

The purpose of this program was to provide payload design, development, fabrication, engineering and field services, and flight test of rocket-borne payloads carrying gases, liquids, solids, and explosives.

Chemicals were released as liquids (heated and unheated) or gases (single "point", multiple pulsed, or continuous trail); multi-phase reactions (liquid-gas); mechanically dispersed solids; solid combustion (solid fuel and oxidizer) reactions; and explosive grenades including shape charge grenades.

Chemical systems included liquids and gases TMA/TEA $[(CH_3)_3 Al/(C_2H_5)_3 Al]$, COS, $(CH_3)_3B$, N_iCO_4, B_2H_6, $Fe(CO)_5$, $Pb(C_2H_5)_4$, and NO; solids Al_2O_3 and Chaff; multi-phase reactions of TMA and O_2; solid combusion reactions to vaporize Ba, Sr, Li, Na, Mg and Be; and explosive systems using Composition C-4 directly or with shape charge techniques to vaporize TMA, $Fe(CO)_5$, Fe, Ba, Li, Al, and Ba.

In certain cases, a thermite recation(Fe_2O_3 + 2 Al) was used to heat TMA.

Where solid combustion reactions were used, the metal being vaporized was the fuel, or in certain cases, Al was the fuel. Oxidizers included Fe_2O_3, CuO or WO_3.

Vaporization estimates were made to optimize certain chemical formulations (References 5, 6, 7, and 8).

Each new design was prototyped and ground tested to: check structural adequacy of pressure systems and high temperature systems; check proper electro-mechanical operation; size and check characteristics of burning solids; and determine handling characteristics including sensitivities of hazardous chemicals.

Chemical handling techniques were developed and ground safety procedures were prepared. Engineering field services were provided for the flight tests conducted from Eglin.

Release requirements and chemical formulations were specified by AFCRL.

Table 1 summarizes the payload systems designs provided; whereas, Table 2 is a summary of chemicals flight tested.

2. DESCRIPTION

2.1 General

Systems included: (1) complete payload systems; (2) modules flown in conjunction with other modules on the same rocket vehicle, or flown independently; and (3) subsystems including fluid control, tanks, and programmers.

Payloads were designed to withstand environments described in Reference 1, Appendix A. Slip fit radial screw joints were used between payload modules, nose cones and rockets, except in certain cases where a tension screw joint was used between the payload and the rocket.

Liquid and gases were contained in pressure vessels with release initiated through squib valves and controlled through solenoial valves and metering nozzles, in combinations or separately. Certain systems used a nitrogen accumulator to pressurize a piston against the liquid to control flow. Some releases were initiated with gas generators or thermite heaters to pressureize and rupture a diaphragm.

Solid combustion mixtures (contained in individual cans) were squib (EED) ignited then vented after reaction pressure and heat ruptured a diaphragm.

Explosive grenades were detonated after being sequencially ejected from the carrier vehicle.

Release sequencing (programming) was accomplished with mechanical timers g-activated (Raymond) at rocket launch. In certain cases requiring multiple events, an electronic (R.C. relaxation oscillator) timer was used in conjunction with the mehcanical timer. Programmers contained approved safe and arm devices (Reference 1).

Table 1 summarizes the payload systems provided; whereas, Table 2 is a chemical system summary.

2.2 Nitric Oxide Blowdown Payload (369-11)

Nitric oxide (2.6 Kg) was released from a 4000 cu in tank as a continuous trail through a squib valve, pressure regulator and metering orifice and was carried with an AFCRL photometer experiment (References 7, 9 and 12).

Trimethylaluminum (TMA)/Oxygen Payload (415-10)

TMA and O_2 were mixed in various flow ratios in order to heat and release in pulsed trails the unreacted TMA as a heated vapor. TMA flow was initiated by a squib valve. A nitrogen accumulator with a metering nozzle and solonoid valves were used to control TMA flow. O_2 flow was controlled through a solenoid valve and metering nozzle (References 2 and 4).

2.3 Sodium/Lithium Payloads (416-10 and 416-11)

An approximately stochiometric burning mixture of Fe_2O_3 and Al was used to vaporize Na and Li in a continuous trail. In certain cases, pulse "trails" of Li were obtained by isolating the Li into specific layers of the end burning mixture. Combusion products were vented after combined heat and pressure from the reaction ruptured diaphragms in the can (References 3, 4 and 9).

2.4 Vaporizer (Multi-Event) Payload (435-10, 435-11, 435-12, 453-10)

This payload was developed to sequentially release metal vapors as multiple independent points. Canisters released liquids, heated and unheated solid combustion; reaction products; and explosive grenades including shaped charge grenades. Liquids were heated with a stochiometric mixture of thermite (Fe_2O_3 + 2 Al). Liquid venting resulted from pressure rupturing a diaphragm in the can, either by (1) increased vapor pressure of the contents from heating (435-21) or (2) a pyrotechnic gas generator (435-88).

Combusion products were vented after combined pressure and heat from the reaction ruptured a diaphragm in the can.

Grenade designs included a (1) liquid vaporizer using composition C-4 to provide vaporization energy (453-17, 453-19); (2) flyer plate shaped charge using the energy from the shaped charge of C-4 to propel and impact a tungsten flyer plate against a buffer (Al or Fe) and metal or metal hydride to be vaporized (453-18) and (3) a Mach system shaped charge using the energy of an annulus of C-4 directed inward against a stem or core of metal to ve vaporized (453-20).

Each grenade was detonated after being sequentially ejected from the carrier payload. A gas generator provided ejection energy; whereas, a pyro ignition train delayed detonation until the grenade was clear of the vehicle (References 5, 6, 7, 8, 11 and 12).

2.5 9-Inch Barium/UV 3 Burner Module (468-10)

Three 24 Kg (nBa + CuO) burners (309-24) were combined with an AFCRL UV experiment. Reaction products were "point" released after reaction pressure and heat ruptured a diaphragm at ignition. UV optic shutters (doors) were programmed to close during each release to protect the lenses against hot exhaust products (References 7 and 12).

2.6 TMA Trail or Point Release Module (474-10)

This payload was designed to carry approximately 220 pounds of TMA in a 10.75 O.D. configuration.

For the trail release, a nitrogen accumulator in the nose cone pressurized a piston to give a continuous controlled TMA venting through a metering orifice upon actuation of a squib valve.

For the "point" release, the squib valve was replaced with an explosive charge, i.e., 1-lb. composition C-4.

2.7 X10 Lithium Module (494-10)

Reaction products of three (3) canisters containing 240 gm of mix each are sequentially "point" released upon ignition. Venting results after reaction heat and pressure ruptured the diaphragm (2-inch diameter) in each can. This system was ground tested but not flight tested (Reference 12).

2.8 Chaff Dispenser (444-13 B)

The dispenser was designed to deploy chaff at a controlled rate from a 2.75-inch Folding Fin Aircraft Rocket (FFAR). Upon rocket launch a g-switch initiates a pyro delay gas generator train. Chaff ejection rates were controlled with a fluid dampener. Feasibility of design was demonstrated with successful ground tests.

2.9 Liquid/Gas Blowdown Payload (355-20)

A liquid/gas blowdown system was used to release COS (5 lbs) as a continuous trail from a 100 cu inch tank. Initiation was through a squib valve and metering was through an orifice. A central tube provided venting from the aft center of the tank (Reference 9).

2.10 $Fe(CO)_5$ Point Release Module (460-10)

A tank containing $Fe(CO)_5$ (3.6 Kg) was explosively shattered with composition C-4 giving a point release (Reference 7).

2.11 Squib Valve

A squib valve (273-100) was designed to give a single seal at an AND port. This valve has a 1/2-inch diameter port and functional characteristics are identical to the previously qualified valve (273-10).

TABLE 1

PAYLOAD SUMMARY

PAYLOAD	P/N	ELECTRICAL DWG.
Nitric Oxide Blowdown Payload (10.75 Dia)	369-11	352-77
TMA/Oxygen Payload (7.75 Dia)	415-10	415-32
Dual 4 Kg Sodium Assembly (7.75 Dia)	416-10	416-21
Single 8 Kg Sodium/Lithium Trail Burner (7.75 Dia)	416-11	416-21
4 Kg and 6 Kg Sodium/Lithium Trail Burner (7.75 Dia)	416-14	416-21
Vaporizer Payload 13 Event	435-10	435-115
Vaporizer Payload 28 Event (7.75 Dia)	435-11	435-46
Vaporizer Payload 34 Event (7.75 Dia)	435-12	435-77
Chaff Dispenser Mod IV (2.75 Dia)	444-13	--
9-Inch Vaporizer Payload 33 Event	453-10	435-114
TMA Trail or Point Release Module (10.75 Dia)	474-10	416-21
Barium UV Payload (9 Dia)	486-10	486-33
X10 Lithium Module (9 Dia)	494-10	494-29
Liquid-Gas Blowdown Payload	355-20	355-59
Squib Valve	273-100	--
Fe $(CO)_5$ Point Module	460-10	435-56

TABLE 2

CHEMICAL SYSTEM SUMMARY

CHEMICAL		PHASE	RELEASE[1] RATE - AVE	TYPE RELEASE	P/N	REF
Trimethyl-/Triethylaluminim	$(CH_3)_3\,Al(C_2H_5)_3\,Al$	Liquid	20-40 gm/sec	Trail	35-4, 35-12 35-20[5]	4, 7, 12
		Liquid	24 gm	Point	435-21[8], 435-19[2]	6, 7
Nitric Oxide	NO	Gas	22-40 gm/sec	Trail	369-11	7, 9, 12
Diborane	B_2H_6	Gas-Liquid	63 gm/sec	Trail	421-10	4
Carbonyl Sulfide	COS	Gas-Liquid	90 gm/sec	Trail	355-20	9
Trimethylborane	$(CH_3)_3B$	Gas-Liquid	16-25 gm	Point	435-88	10, 12
Iron Pentacarbonyl	$Fe(CO)_5$	Liquid	18-23 gm/sec	Trail	35-12, 35-20	12
			3.6 Kg	Point	460-10	7
				Point	435-88, 453-17	7
$Fe\,(CO)_5$		Liquid	77 gm	Point[2]	453-17	12
Nickel Carbonyl	$NiCO_4$	Liquid	94 gm/sec	Trail	35-4	12
Tetraethyl Lead	$Pb\,(C_2H_5)_4$	Liquid	80 gm/sec	Trail	35-4	9, 12
Aluminum Oxide	Al_2O_3	Solid (5-10 u)	46 gm	Point	435-81	7

TABLE 2, Continued

CHEMICAL		VAPORIZATION METHOD	RELEASE[1] RATE - AVE	TYPE RELEASE	P/N	REF
TMA/Oxygen	$(CH_3)_2 Al/O_2$	Combustion	Ref 4	Trails	415-10	4
n Ba + CuO	n = 1.7 n = 2.5[4]	Combustion	2.4 Kg	Point	309-24	4, 7, 12
n Sr + CuO	n = 2	Combustion	50 gm	Point	435-81	5, 7
n Al + WO_3	n = 4.5	Combustion	2.4 Kg	Point	309-24	7
n Li + Fe_2O_3	n = 8.4	Combustion	24 gm	Point	435-47	6, 7
n Li + CuO	n = 3 n = 4.5	Combustion	34 gm	Point	435-21	7, 12
n Na + 3 CuO + 2 Al	n = 5.5	Combustion	110 gm	Point	435-81	7, 12
n Na + n Li + Fe_2O_3 + 2.3 Al	n = 1.4	Combustion	90-153 gm/sec	Trail	416-10	3, 4
n Na + Li + Fe_2O_e + 2 Al	n = 3.2 y = 0-.24	Combustion	153 gm/sec	Trail	416-10, 416-11	3, 9
n Mg + CuO	n = 1.5	Combustion	2.4 kg	Point	309-24	12
Be + CuO + 3 BeI_2		Combustion	25 gm	Point	435-81	12
n Be · CuO	n = 1.5	Combustion	2.0 Kg	Point	309-24	12
Al/Al (Buffer)		Shaped Charge[6]	9[3]		453-17	12
Fe/Fe (Buffer)		Shaped Charge	18[2]	Point	453-18	7
Li A! H_4/Al (Buffer)		Shaped Charge	3.5[3]	Point	453-18	7

TABLE 2, Continued

CHEMICAL	VAPORIZATION METHOD	RELEASE RATE-AVE	TYPE RELEASE	P/N	REF
Ba H_4/Al (Buffer)	Shaped Charge (6)	14 gm(3)	Point	453-18	7
Li H/Al (Buffer)	Shaped Charge(6)	2.5 gm(3)	Point	453-18	7'
Li H_4/Al (Buffer)	Shaped Charge(6)	3.5 gm(3)		453-18	7
Fe	Shaped Charge(7)	21 gm(3)		453-20	7
Ba	Shaped Charge(7)	9 gm(3)		453-20	7
Al	Shaped Charge(7)	7.5 gm(3)		453-20	7

(1) Net Chemical
(2) Grenade (C-4 Wt. = 42 gm)
(3) Target Weight
(4) n = moles
(5) 35 - GFE Part Nos.
(6) Flyer Place (C-4 Wt. = 61 gm)
(7) Mach Stem (C-4 Wt. = 35 gm)
(8) Thermite Heated

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