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AIR FORCE SURVEYS IN GEOPHYSICS, NO. 226

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

Characteristics of Upper Atmosphere Barium, Trimethylaluminum, Diborane and Lithium Releases, 1969

WILLIAM K. VICKERY

AIR FORCE SYSTEMS COMMAND
United States Air Force

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AERONOMY LABORATORY PROJECT 7635, ILIR
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WILLIAM K. VICKERY

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Abstract

This report summarizes the flight and engineering aspects of rocket launches made by the Chemical Physics Branch (USAF Project 7635) during the calendar year 1969, inclusive of TMA vapor release system development flights since 1966, for the purpose of releasing chemicals in the atmosphere at high altitudes. Chemical releases provide means for modification of the upper atmosphere, as well as data on atmospheric dynamics and ionospheric properties from which quantitative understanding of increasing accuracy is derived. Results of this research are relevant to the solution of current Air Force problems, such as the precise prediction of the motion of operational satellites and nuclear debris, or the assessment of the effects of solar bursts and nuclear detonations on the propagation of electromagnetic waves through the ionosphere.

The four basic experimental release systems, barium, trimethylaluminum, diborane, and lithium, are designated as individual sections. In addition, information is included regarding new instrumentation tested in some of the flights, in order to improve the acquisition capability of the tracking radar and to transmit vehicle and payload operational data.

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1. INTRODUCTION

During calendar year 1969, AFCRL conducted three field programs of chemical release experiments at Eglin AFB, Florida. These programs were conducted in January, May, and December 1969, with a total of thirteen rockets. Four basic experimental vapor release systems were flown: barium, trimethylaluminum (TMA [with and without an oxidizer]), diborane, and lithium. Table 1 summarizes the 1969 flight schedule.

Detailed payload and flight data are given for the following four releases: (1) barium; (2) TMA; (3) diborane; and (4) lithium. Essential data for the individual flight systems are presented in Tables 1 through 6 and Figures 1 through 30.

All payloads functioned as designed except one TMA/H_2O payload (TANYA) which failed to release and one barium burner on ODET which failed to ignite. Flight predictions for the barium were marred by inaccurate wind compensation at the launch range and by slight overperformance of the rockets, attributable to a short payload length.

Launch azimuth errors for MAE and SOPHIA were 25 and 40 degrees, respectively. Launch elevation errors departed from the desired angle an average of 2 degrees with a maximum of 5 degrees for KAY. These errors are larger than

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Table 1. 1969 Flight Schedule, Eglin AFB, Fla.*

Vehicle No.	Name	Payload	Date	Launch Time
AG 7.626	LILI	TMA/H_2O	6 Jan 69	1835 CST
AG 7.652	NITA	TMA/H_2O	12 Jan 69	1932 CST
AG 7.671	KAY	Barium	6 Jan 69	1741 CST
AG 7.672	MAE	Barium	7 Jan 69	1738 CST
AG 7.673	ODET	Barium	13 Jan 69	1743 CST
AH 7.674	PEARL	Diborane	12 May 69	2004 CDT
AH 7.675	REBA	Diborane	14 May 69	2008 CDT
AH 7.678	QUENNA	Barium	12 May 69	2023 CDT
AH 7.679	SOPHIA	Barium	14 May 69	2028 CDT
AH 7.676	VANESSA	Barium/Lithium	5 Dec 69	0556 CST
AH 7.680†	TANYA	TMA/H_2O	5 Dec 69	0430 CST
AH 7.681	UNA	TMA	5 Dec 69	0500 CST
AH 7.682	WENDY	TMA/H_2O	10 Dec 69	2130 CST

*All barium and diborane releases are at twilight; all others at night.
†Failed to release.

expected. As a result, the barium clouds were at wrong altitudes, or at a geographical position where the cloud was not illuminated by the desired solar wavelengths.

In addition to the chemical release systems, each payload carried a VHF 1/2-watt CW oscillator or 3-watt telemetry transmitter to provide acquisition assistance to the tracking radar, and to relay vehicle and payload operation data. Further, ranging beacons, S-band telemetry antennas, and xenon flashing light units were flight tested on a space available basis.

The flashing light was developed to facilitate pointing narrow-field optical units at chemical releases at the moment of release. These test units had lamp covers protected by a heat shield. In the future, unprotected lamps will be tested.

2. BARIUM RELEASES

Barium payloads (KAY, MAE, and ODET) were flown with the following objective: To provide a test matrix with various mixtures of barium-copper oxide released at three altitudes, in order to study ion production as a function of barium mixture and release altitude. Three mixtures were formulated and ground tested for flight. These, on a molar ratio of barium to one mole of cupric oxide were: 1.3 (69 percent Ba, 31 percent CuO); 1.7 (74 percent Ba, 26 percent CuO); and 2.2 (80 percent Ba, 20 percent CuO).

Closed burner tests were made for the three mixtures. In addition, two tests were made with vented burners equipped with "delayed release burst discs." These discs were selected to keep the burners closed long enough to assure complete reaction of the contents prior to venting. Venting starts nominally 100 msec after ignition, depending upon formulation. Figures 1 through 5 show the results of the five tests as records of pressure versus time.

Prior to a sieve particle-size analysis run on the ground barium, all particles above 0.22 in. were discarded. The barium particles ranged between 74 and 5570 micrometers (0.003 to 0.22 in.), with an average of 565 micrometers (0.022 in.). Figure 6 shows the particle-size distribution for this material. The copper oxide particle size was 200 mesh (74 micrometers).

An individual burner shown in Figure 7 is constructed of 4130 steel, with a design burst pressure of 5,000 psi. Each flight system was equipped with two independent programmers with dual squibs in each burner. Fused resistors were used in the circuit to each burner, in order to forestall drain of the battery by squib shorts after ignition.

Out of the three systems flown, eight of the nine burners functioned satisfactorily. The failure of one to ignite is attributed to open insulation on the squib leads that may have shorted out the squib.

One 3-burner payload was flown (VANESSA) to evaluate barium ion production at E-region heights. Two releases were made at 97-1/2 and 112-1/2 km, with a third control release at 151 km. This payload used the 1.7 molar barium mixture for all three releases, as well as the delay release burst discs.

Two flights of a 4-burner design were made (QUENNA and SOPHIA) for studies of barium ionization as a function of ultraviolet wavelength available to each release. Two releases were to be below a selected UV horizon and two above. As previously indicated, launch errors vitiated these plans. The burners were loaded with the 1.7 molar ratio barium-cupric oxide mixture, with delay release burst discs. All eight burners functioned.

Figure 8 shows the payloads. Figures 9 through 13 show trajectory and release summaries for KAY, MAE, ODET and VANESSA. Table 2 presents data for all barium flights.

Table 2. Barium Flight Summary

Name	KAY		MAE		ODET		QUENNA		SOPHIA		VANESSA	
AFCRL No.	AG 7.671		AG 7.672		AG 7.673		AH 7.678		AH 7.679		AH 7.676	
Vehicle	Niro		Niro		Niro		Niro		Niro		Niro	
Date	6 Jan 1969		7 Jan 1969		13 Jan 1969		12 May 1969		14 May 1969		5 Dec 1969	
Launch Time	1740:59.146, CST		1738:00.454, CST		1743:00.294, CST		2023:02.635, CDT		2027:59.869, CDT		177:59.149, CST	
	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual
QE	80	85.5*	80	81.2	80	82.5	84	81.5	84	85.7	84	83
Flight Az	178	188	176	220	175	165	165	162	180	140	182.8	174
Peak Alt, km	207	208	207	218	207	222	195	192	195	204	158	151
Peak Time, sec	227		227	234	227	237	222	221	222	225	200	201
Impact Rng, km	198		198	191	198	168	115	163	115	98.75	92	114
Impact Time, sec	432						426	434	426	447.6	376	382
Payload Weight, #	80	78	80	78	80	78	100	97.5	100	97.5	141	142
Length O.A., in.								58.5		58.5	89.25	83.5
Diameter, in.		7.75		7.75		7.75		7.75		7.75		6.625/ 7.75
Nose Cone		20		20		20		20		20		20
C.G. "from aft", in.		14.25		14.25		14.25	24	22.75	24	22.75	34	34
Roll Rate, 2nd Stage, RPS	6	7	6	7	6	6	6	7	6	6.75	9	9
Ba Release (Mix)	1.3		2.2		1.7		1.7		1.7		1.7	
Time, sec	160	185.95†	160	160.75	160	160.77	135	134.20	135	133.72	88	87.32
Alt, km	185	202	185	194	185	196	160	157.1	160	165.4	100	97.5
Rng, km	70	70	70	65	70	58	33.5	47.0	33.5	27.4	18	23

Table 2 (Contd). Barium Flight Summary

Name	KAY		MAE		ODET		QUENNA		SOPHIA		VANESSA	
AFCRL No.	AG 7.671		AG 7.672		AG 7.673		AH 7.678		AH 7.679		AH 7.676	
Vehicle	Niro		Niro		Niro		Niro		Niro		Niro	
Date	6 Jan 1969		7 Jan 1969		13 Jan 1969		12 May 1969		14 May 1969		5 Dec 1969	
Launch Time	1740:59.146, CST		1738:00.454, CST		1743:00.294, CST		2023:02.635, CDT		2027:59.869. CDT		177:59.149, CST	
	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual
BA Release (Mix)	1.7		1.3		2.2		1.7		1.7		1.7	
Time, sec	248	248.37	248	247.01	248	No Function	148	147.70	148	147.72	104	103.33
Alt, km	205	208	205	217	205		170	167.0	170	176.3	115	112.5
Rng, km	112	94	112	105	112		37.2	52.4	37.2	30.4	22	20.5
Ba Release (Mix)	2.2		1.7		1.3		1.7		1.7		1.7	
Time, sec	323	323	323	160.77	323	323.61	165	165.1	165	164.72	200	198.77
Alt, km	165	166	165	181	165	188	180	177.4	180	187.1	158	151
Rng, km	150	111	150	139	150	119	42	59.3	42	34.1	46	56.5
BA Release (Mix)							1.7		1.7		Na-Li	Na-Li
Time, sec							188	187.67	188	187.90	See	See
Alt, km							190	186.7	190	197.4	Fig.	Fig.
Rng, km							48.5	68.4	48.5	39.1	13	13

*No radar track; estimated from release positions

†Timer setting error

3. TRIMETHYLALUMINUM VAPOR RELEASES

The discussion for this section is developed around a twofold purpose: first, to present the characteristics of trimethylaluminum (TMA) vapor development flights since 1966; and second, to give a summary of payload and flight data for 1969 flights.

3.1 Characteristics

Over the past few years, emphasis has been placed on the formation of a series of discrete spherical releases of a luminous wind marker to enable the measurement of twilight and nighttime vertical and horizontal wind motions. TMA is useful as a horizontal wind marker when released as a continuous trail, both at twilight and at night. This material, normally released as a liquid, has been used in the past for many releases.

Several twilight flights were directed particularly to an evaluation of various TMA liquid release techniques. In some of these flights, TMA was released only as puffs above 130 km, and again, as puffs superimposed on a continuous release (JILL, MYRA, and NINA) from 90 to 130 km. The upper puffs above 130 km remained distinct puffs. Puffs below 130 km merged into the trail almost immediately after release, precluding vertical motion measurements (see Figure 14).

Since the vapor pressure of octane corresponds closely to the vapor pressure of TMA, a chemical change was made for MYRA and NINA by substituting normal octane for the TEA usually added to the TMA as an antifreeze (TMA freezes at room temperature). This change was made for the purpose of improving vaporization efficiency. However, no improvement was effected.

Puffs of water (as a quench) were released in a continuous TMA trail (INGER), making visible gaps in the trail during the lower portion of the "up leg." Gaps were not seen in the corresponding portion of the "down leg." At higher altitudes, gaps were not visible but the re-entry bag contained a large number of concentric cylinders.

Two night flights (BETTY and NITA) were devoted to the development of a TMA vapor release system designed to surmount a major problem associated with liquid release; that is, the movement of liquid droplets with the rocket, filling the space between puffs at altitudes between 90 and 120 cm. The "fill-in" is so rapid that discrete puffs released in this region do not exist long enough (100 sec minimum) to permit vertical motion measurements.

For the first development flight (BETTY), a small amount of water (7 percent) used as an oxidizer, was mixed with the TMA in a swirl-cup type combustion chamber 6 in. in length. The TMA/H_2O reaction was expected to consume approximately 30 percent of the TMA. The heat of combustion then elevated the excess TMA to the vapor state (see Figure 15).

Vacuum chamber tests were made in order to obtain the percentage of oxidizer flow versus temperature, both in the combustion chamber and in the downstream. At 5-3/4 percent oxidizer flow the temperature of the exhaust products, approximately 1 ft from the combustion chamber exhaust nozzle, was at the boiling temperature of TMA (285°F). To provide a temperature of 350° and complete vaporization without too great a consumption of TMA, 7 percent was selected. (Chamber temperatures were 600°F.)

To produce a puff release was the original objective of this first development flight (BETTY). However, this objective was not met owing to a problem of orifice clogging; that is, TMA flow rates were approximately 100 g/sec as against H_2O at approximately 7 g/sec. The small water flow rate resulted in oxidizer orifice sizes ranging from 0.015 to 0.025 in diameter. The formation of aluminum oxide during the combustion process closed the small oxidizer orifice after only one puff in interrupted flow, whereas buildup of deposits during continuous flow was not a problem. BETTY was then flown as a trail release in order to test the vaporizer concept. This flight was judged successful, on the basis that no re-entry bag, characteristic of liquid releases (see Figure 18), was formed.

In further development, a self-cleaning orifice has been constructed which uses nitrogen gas flow around the TMA and H_2O nozzles, in order "to wash" the aluminum oxide away. The gas flow was continuous, whereas the liquid flow was interrupted in order to provide the desired release. This device was tested on NITA (Figure 16), using a continually repeated 9-sec sequence consisting of three 3-sec pulses of 0, 30, and 90 g/sec TMA flow (10 percent H_2O). Although the material substantially filled the 3-sec spaces during which no release was made, there were small breaks. This gave encouragement for further testing. Complete vaporization may not have occurred during venting owing to the short length of the combustion chamber (also 6 in.).

In order to provide a direct comparison between the liquid and vapor release techniques, two flights (UNA and WENDY) released 30-g and 45-g puffs of TMA (with 7-1/2 percent H_2O), respectively, to give approximately equal net TMA releases. Essentially, the trajectories were identical; the releases were spaced far enough apart to provide for evaluation of "fill-in" between puffs. The combustion chamber on WENDY was lengthened to approximately 20 in., in order to assure complete vaporization prior to venting. "Zero length" plumbing was used on UNA by placing the flow control valve and the orifice together at the opening in the payload shell for the purpose of preventing dribble between releases.

UNA (Figures 17 and 18), the liquid TMA release, produced distinct puffs above 120 km. Below 120 km the puffs were connected with a broad filament.

Even these connected puffs were useful down to 105 km; point wind measurements were made. Below 105 km, the puffs were not distinguishable within the filament. On flight WENDY, the puffs were connected with a much thinner filament, so that the puffs below 120 km had a tadpole appearance (Figure 19). Point winds were measurable from all releases above about 95 km.

Comparing releases of equal net chemical, one observes: (1) that the liquid releases are about twice the intensity of the vapor releases; (2) that trail intensity and persistence are greater than that of discrete puffs for equal flow rate; (3) that releases at twilight are more persistent than night releases. For example, puff releases of 200 g of TMA (JILL, MYRA, and NINA) above 140 km at twilight are persistent for hundreds of seconds, whereas puff releases (GRACE) of 200 g of TMA, above 140 km at night are persistent for only about 30 seconds.

Re-entry bags, characteristic of liquid releases, did not appear on all vapor TMA flights (see Figure 18). While vapor TMA releases have been demonstrated, the intensity and persistence of the TMA/H_2O system have not proved satisfactory. Flight tests of TMA and oxygen gas are planned in view of improving these two parameters. On the problem itself, a possible explanation may be in the use of an oxidizer (water in this case) which, aside from providing energy in the heat of combustion, could cause breaking of some of the TMA chemical bonds. This would considerably reduce the amount of TMA excess available for the chemiluminous reaction. The same may hold true for the oxygen gas system.

3.2 Summary of Payload and Flight Data

Details of the five flights of 1969 are given here. To look at the specific objectives: LILI was to investigate the effects of varying the percentage of oxidizer flow, holding constant the TMA flow, whereas NITA was to investigate the effects of varying the total flow, using a constant 10 percent flow of oxidizer. TANYA and WENDY were to compare "puffs" made using the TMA vapor system with "puffs" made when releasing liquid TMA (UNA). For LILI, target flows were 70 g/sec of TMA with 0, 5, and 10 percent oxidizer, each in 3-sec pulses. The actual flow rates were measured at 0, 7, and 14 percent. Because of a finite plumbing length between the flow control valve and combustion chamber, there was a small oxidizer flow in the nominally zero case. LILI was a very weak release, with little data.

For NITA, the material was released in 3-sec pulses at rates of 0, 30, and 90 g/sec. The zero flow case did not produce a 3-sec long gap in the trail, but it did make an easily identifiable break. No difference in brightness could be assigned to the 30 and 90 g/sec portions of the release.

For these two flights, the payloads had reasonably complicated plumbing and control systems for the purpose of effecting the required releases. For example, these were the first flights to use a self-cleaning nozzle in the TMA and H_2O orifice system for the prevention of clogging caused by aluminum oxide deposits. Nitrogen gas flowing around the orifices "blows away" any material that would otherwise deposit. The N_2 source was the N_2 pressurizing gas from the H_2O tank. These payloads are shown schematically in Figure 20. Further, the water was carried in a large volume tank (same size as the TMA tank) in order to provide the volume necessary for the storage of gas at relatively low pressure, performing a dual function of controlling the H_2O flow and carrying out the gas flush. Figure 21 gives a trajectory summary of these two flights. The arrangement of the 6-inch combustion chamber and flow control valve is not shown here, but it is similar to the more compact and simplified version designed for use with TANYA and WENDY (Figure 22).

TANYA and WENDY were differently constructed from NITA and LILI as shown by their possession of the following: (1) a simplified combustion chamber, together with plumbing, to minimize plumbing lengths from the flow control valves to the combustion chamber, obviating continued venting after valve closure; (2) a combustion chamber exhaust pipe approximately 20 in. in length, assuring vaporization of excess TMA by the heat of combustion prior to venting; (3) oxidizer flow of approximately 7 percent; (4) a small tank for the water, that is, 7 percent of volume of TMA tank; (5) a large volume tank (same size as the TMA tank) for N_2 gas for nozzle cleaning.

The separation of the N_2 gas supply and the water systems greatly simplified the flow calibration problems. TANYA failed to release. WENDY produced distinct puffs (although tadpole in appearance).

UNA carried a standard CRL liquid TMA releasing system. The placing of the flow control orifice and valve next to the payload skin allowed use of essentially "zero length" plumbing and prevented continued venting after valve closure. This system did not produce discrete puffs below 125 km. The payload is shown schematically in Figure 24.

Trajectory and release summaries for WENDY and UNA are given in Figures 25 and 26. Flight and payload data for all flights are summarized in Tables 3 and 4.

4. DIBORANE RELEASES

Diborane originally was chosen as a release material because as a gas it could be released as an intermittent trail to measure vertical motions. It was

Table 3. TMA Payload Data

Name Number	LILI AG 7.626		NITA AG 7.652		TANYA AH 7.680	UNA AH 7.681	WENDY AH 7.682
TMA							
Module Type	35-1340		35-1340		35-1340B	35-1340B	35-1340B
Chemical Formulation (by weight)	80% TMA/10% TEA		80% TMA/10% TEA		80% TMA/20% TEA	80% TMA/20% TEA	80% TMA/20% TEA
Net Chemical wt (kg)	3.62		3.62		3.62	3.62	3.64
Nitrogen Pressure (atm)	8.2		8.2		5.8	4.4	5.8
Volumetric Ratio, Liq/Gas	~1/1		~1/1		~1/1	~1/1	~1/1
Tank Vol (liters)	12		12		12	12	12
Nitrogen Flush	Used N_2		Used N_2				
Module Type	from		from		34		34
Tank Vol (liters)	Oxidizer		Oxidizer				
Nitrogen Pressure (atm)	Tank		Tank		17		17
Oxidizer							
Module Type	35-1340		35-1340		35-1328B		35-1328B
Chemical Formulation (by weight)	60% H_2O 40% CH_3OH		60% H_2O 40% CH_3OH		60% H_2O 40% CH_3OH		60% H_2O 40% CH_3OH
Net Chemical (gm)	684		910		284		284
Tank Volume (liters)	12		12		1.065		1.065
Nozzles							
TMA Nozzle Dia (in.)	0.082		0.94	0.046	0.128	0.128	0.128
Av. Flow (gm/pulse)	60		90	30	50	30	45.5
Oxidizer Nozzle Dia (in.)	0.031	0.041	0.031	0.016	0.040		0.040
Av. Flow (gm/pulse)	8.5	4.2	9	3	3.5		3.5
Percent Oxidizer to Fuel (%)	14	7	10	10	7		6.8
Nitrogen Nozzle Size							
TMA side (in.)	0.025		0.025		0.025		0.027
Oxidizer side (in.)	0.025		0.025		0.022		0.022
Vent Duration, sec (17 to 3.3 atm)	~60		~60		180		180

Table 4. TMA Flight Summary

Name	LILI		NITA		TANYA		UNA		WENDY	
AFCRL No.	AG 7.626		AG 7.652		AH 7.680		AH 7.681		AH 7.682	
Vehicle	Niro		Niro		Niro		Niro		Niro	
Date	6 Jan 1969		12 Jan 1969		5 Dec 1969		5 Dec 1969		10 Dec 1969	
Launch Time	1835:00.106, CST		1932:00.089, CST		0429:59.950, CST		2129:59.990, CST		0500:00.137, CST	
	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual
QE	84	85.1	84	85	84	84	84	82.7	84	82
Flight Az	176	200	174	165	184.4	182	184	183	173	160
Peak Alt, km	157.5	154	157.5	158	156	157	156	157	156	156
Peak Time, sec	200	195	200	198	204	197	204	200	204	201
Impact Rng, km	94.5	76	94.5	80	102.5	105	100	112	100	120.5
Impact Time, sec	383	385	383	391		382		384		390
Payload Weight	145	144	145	144	135	136	135	133	135	132.5
Length, O.D.		114		105		113		77		113
Diameter		7.75		7.75		7.75		7.75		7.75
Nose Cone		20		20		20		20		20
C.G. "from aft"		55.5		54		51 3/4		36		50
Roll Rate, 2nd Stage	10	10	10	10	10	8	10	7	10	12

also thought to be chemiluminescent and thus usable for nighttime releases. Accordingly, it would be an improved release chemical for the replacement of liquid TMA. TMA is useful as a horizontal wind marker when released as a continuous trail both at night and at twilight. However, since TMA is a liquid, it is not readily releasable as an intermittent trail which would serve to mark vertical as well as horizontal winds.

Diborane was first successfully flown at Fort Churchill (Golomb) during a morning twilight when the solar horizon allowed sunlight to illuminate the upper portion of the trail alone. This phenomenon was attributed to resonance fluorescence of the BO_2 bands. As the solar horizon descended, the lower portion of the trail became visible.

In spite of the fact that nighttime negates the usefulness of diborane, it still appears to be adequate for the making of puff releases at twilight. Two test flights (PEARL and REBA) were made at Eglin AFB, Florida, in May 1969.

4.1 Puff Release Techniques

Five pounds of diborane were put in a 17-liter steel tank, which also served as an aerodynamic envelope. The release (see Figure 27 for sequence) was controlled with a pilot-operated flow control valve. On the first flight (PEARL), the duration of each puff was 200 msec; on the second (REBA), 600 msec. All other nominal release parameters were the same. A timer was to activate the valve ("puff") at 3-1/2-sec intervals at lower altitudes (80 to 120 km, ascending and descending); at 7-1/2-sec intervals (120 to 150 km, up and down); and 20-sec intervals (above 150 km). The differences observed in switching altitudes are attributable to differences in actual rocket trajectories.

The gas pressure was not regulated; the amount of material in each puff decreased throughout the release sequence. The computations for the amount of material per puff are based on flow rate data obtained from ground tests using nitrogen gas releases, with corrections made for compressibility effects. The curve has been verified at a single point with a diborane ground test. Future ground tests with diborane are planned in order to verify the calculated data.

Figures 28 and 29 present diborane compressibility and flow rate curves used for these flights. In a previous flight, unsuccessful partially because of a rocket malfunction, diborane was released at altitudes between approximately 55 and 90 km at night, with no visibility. Again, 1.8 kg of diborane was carried in a 17-liter tank; telemetry showed that it released for 20 sec, that is, measured from start of release until tank pressure reached 6.8 atm. Figure 30 shows the payload configuration.

Flight and payload data are summarized in Table 5.

Table 5. Diborane Flight and Payload Data Summary

Name	PEARL		REBA	
AFCRL No.	AG 7.674		AG 7.675	
Vehicle	Niro		Niro	
Date	12 May 1969		14 May	
Launch Time	2004:00.10, CDT		2004:59.99, CDT	
	Pred.	Actual	Pred.	Actual
QE	84	82.5	84	86.3
Flight Az	165	163	180	166
Peak Alt, km	196	190.5	196	204
Peak Time, sec	223	219.5	223	223
Impact Rng, km	115	143.5	115	74
Impact Time, sec	426	426	426	437
Payload Weight, #	101	94.5		94.5
Length O.A., in.		81.5		81.5
Diameter, in.		7.75		7.75
Nose Cone ∢		20		20
C.G. "from aft", in.		34.5		34.5
Roll Rate, 2nd Stage, RPS	6	6	6	6
Payload Data				
B_2H_6				
Module Type		355-16		355-16
Net Chemical (kg)		2.27		2.27
Tank Volume (liters)		17		17
Nozzle Dia (in.)		0.185		0.185
Tank Pressure				
at 80°F, atm		46		46
at release*, atm		54.5		54.5

*Due to assumed aerodynamic heating.

4.2 Release Characteristics

Upon release, the diborane does not become visible immediately. Preliminary analysis of data is insufficient to relate the time of appearance either to amount of material per puff or to altitude. Nevertheless, the data suggests the following: For larger amounts of material per puff, the time of appearance after release is earlier; it is also earlier for lower altitudes (115 vs 140 km).

The material released above approximately 150 km diffused into a large "blob" during the time required for it to become visible. This "cloud" may have obscured some puffs at lower altitudes in the line of sight from one or more triangulation stations so that those puffs could not be used for position or motion measurements. (See Figure 27.)

5. LITHIUM RELEASES

The standard GCA Corporation sodium lithium vaporizer was used to provide a normal vapor trail (VANESSA). The nominal characteristics of this unit are shown in Table 6. The burning time of 150 seconds was not verified by triangulation photography due to outgassing of a small amount of vapor on the descending portion of the trajectory to about 120 km. Three barium canisters, flown on the same rocket, were vented out the side of the payload. No adverse effects on the sodium release were noted due to the tumbling induced by the barium release. The payload and release summary is included in the barium section in Figure 13 and Table 2.

Table 6. Characteristics of Sodium Lithium Vaporizer - GCA Corporation

Item	Amount
Burning time	150 sec
Total chemical	8 kg
Net sodium	1 kg
Net lithium	0.33 kg

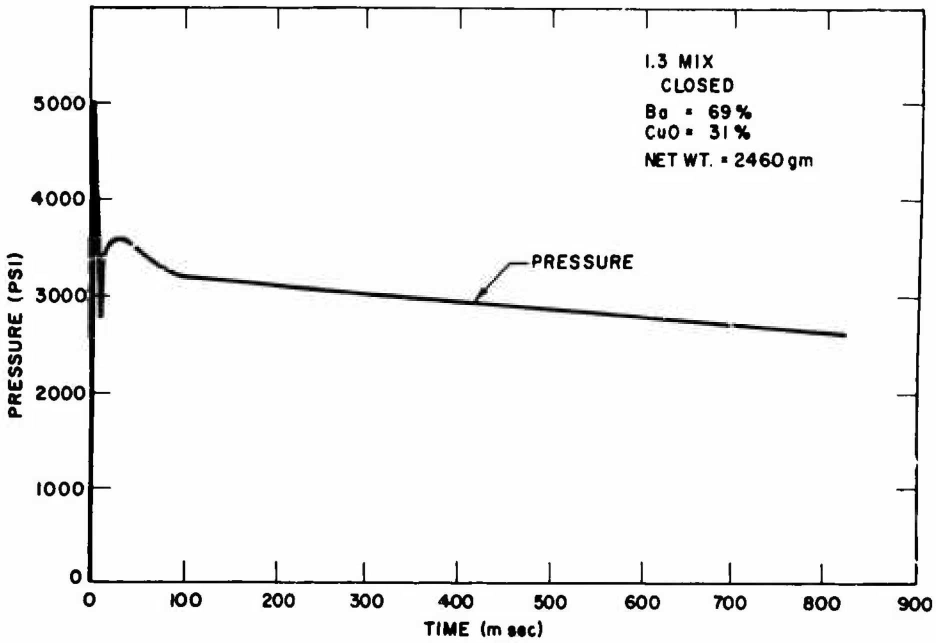


Figure 1. Closed Container Pressure for 1.3 Barium Mix

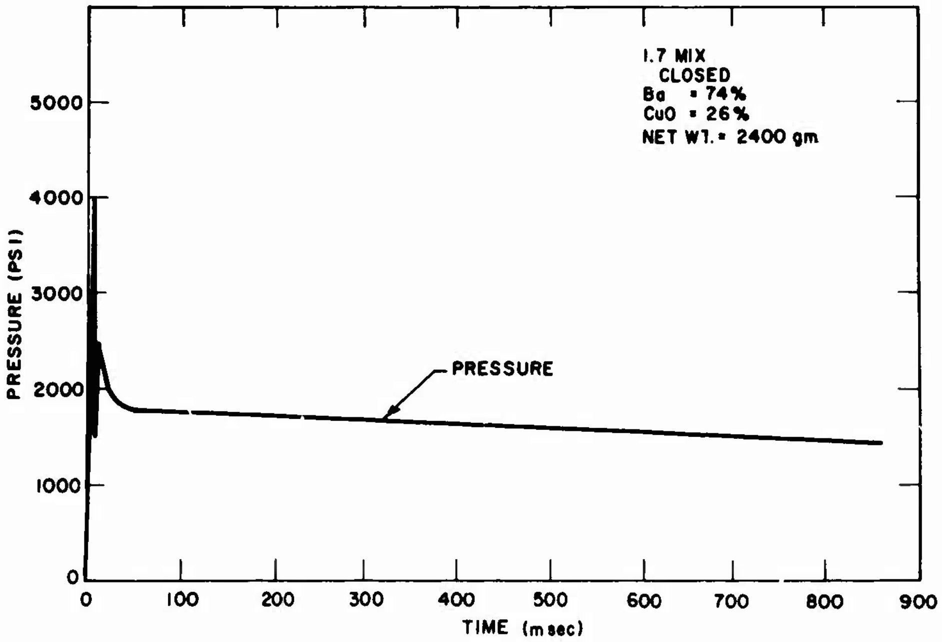


Figure 2. Closed Container Pressure for 1.7 Barium Mix

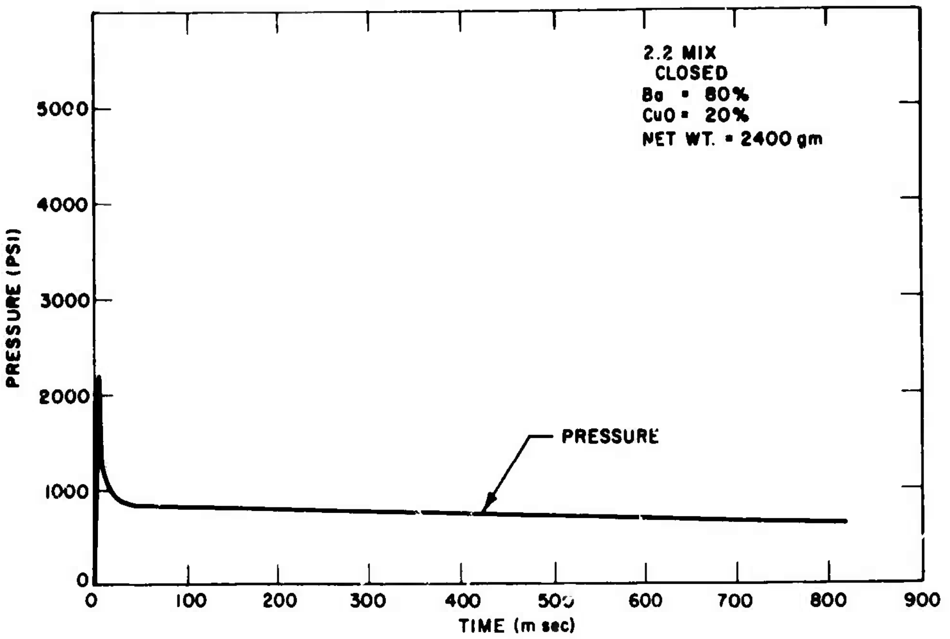


Figure 3. Closed Container Pressure for 2.2 Barium Mix

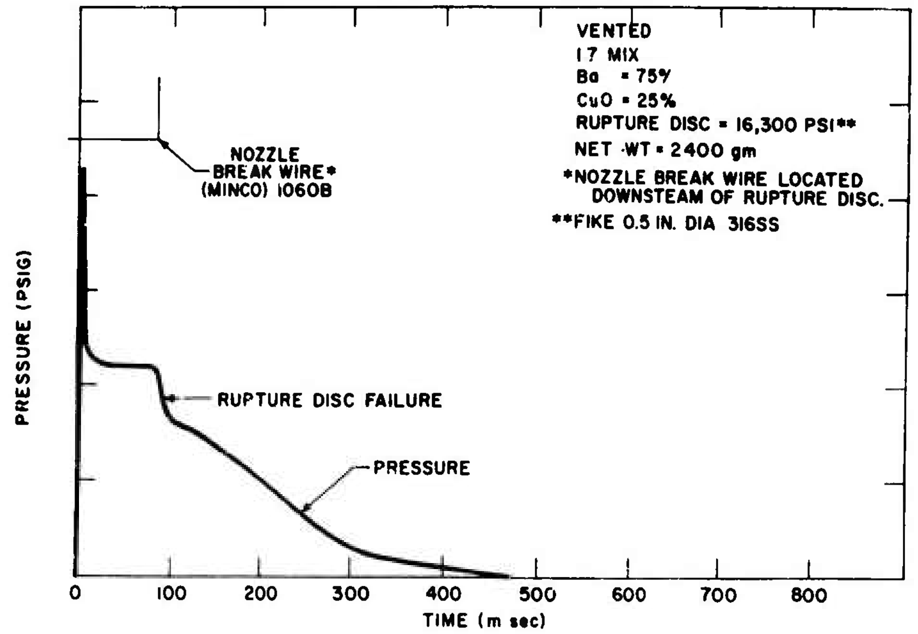


Figure 4. Vented Container Pressure for 1.7 Barium Mix

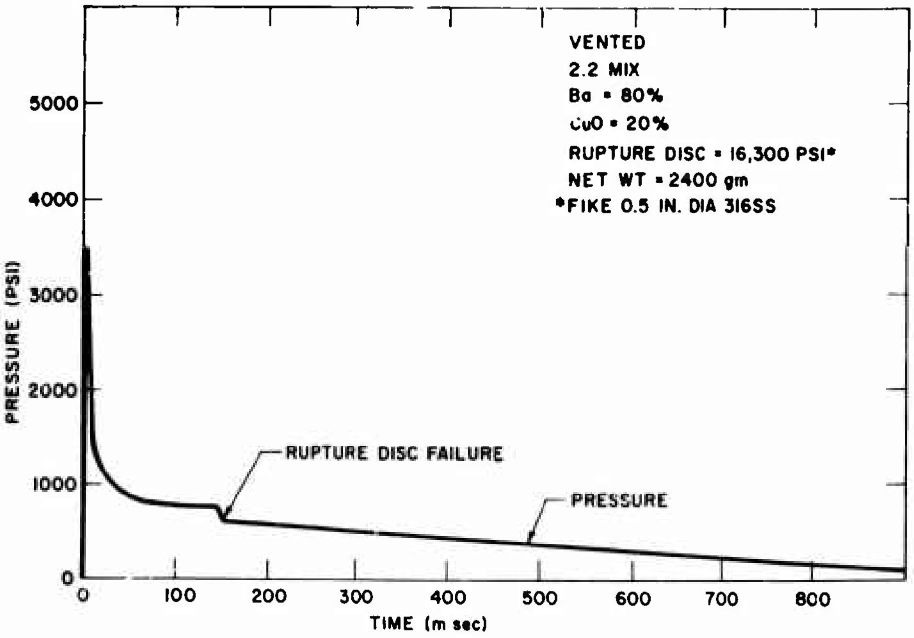


Figure 5. Vented Container Pressure for 2.2 Barium Mix

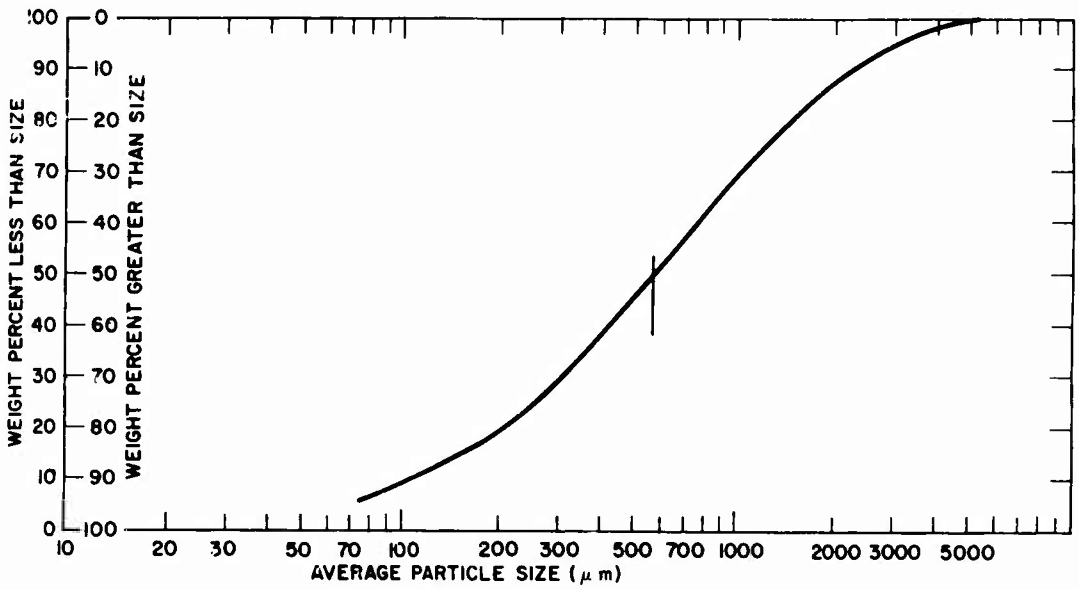


Figure 6. Barium Particle Size Analysis

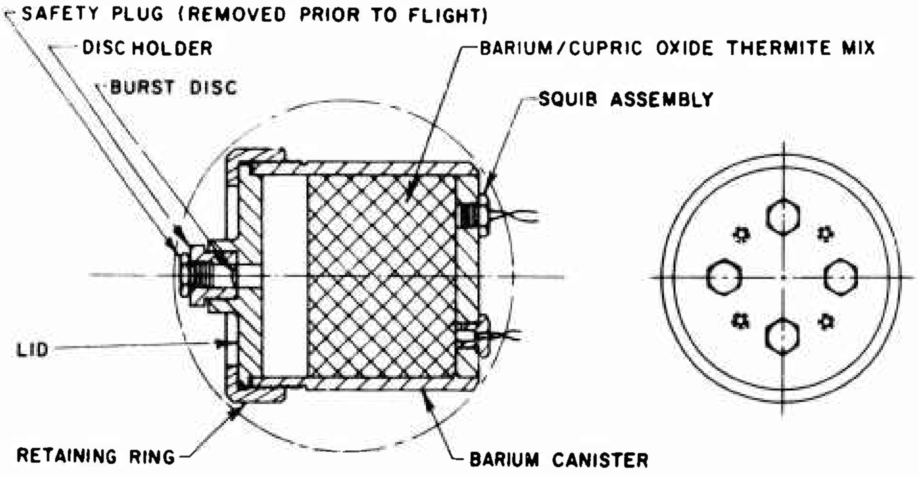
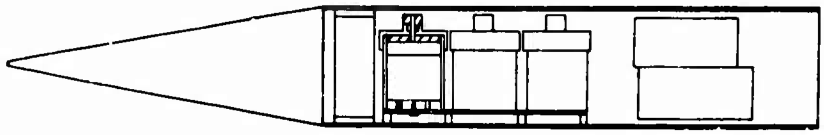
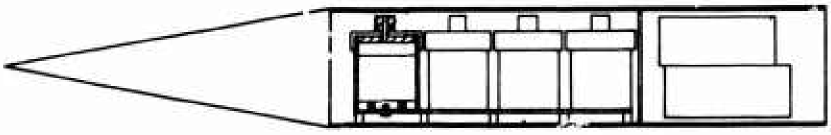


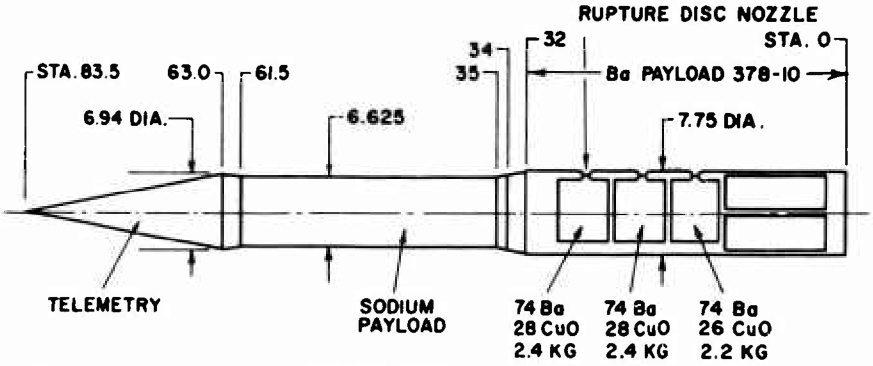
Figure 7. Cross Sectional View of Barium Burner



3 - BURNER BARIUM - KAY, MAE, ODET



4 - BURNER BARIUM - QUENNA, SOPHIA



3 - BURNER BARIUM WITH SODIUM VAPORIZER - VANESSA

Figure 8. Rocket Payloads for Barium Releases

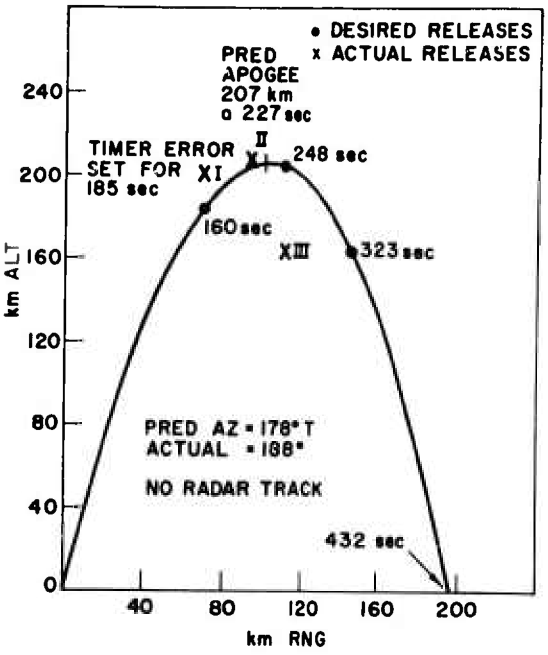


Figure 9. Trajectory Summary for Chemical Release KAY

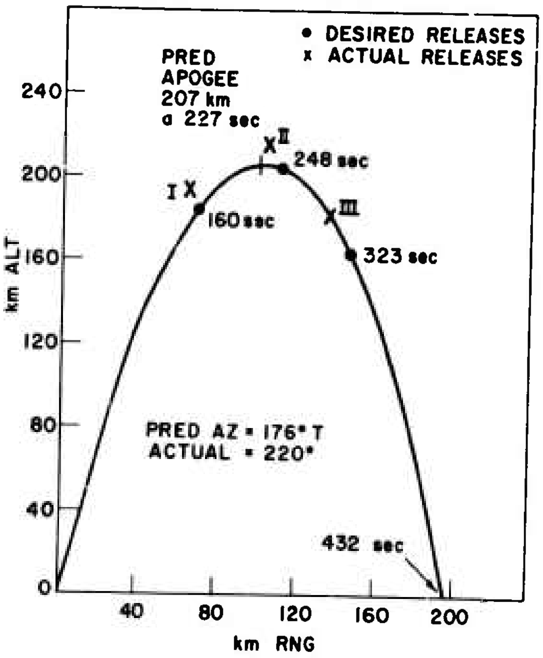


Figure 10. Trajectory Summary for Chemical Release MAE

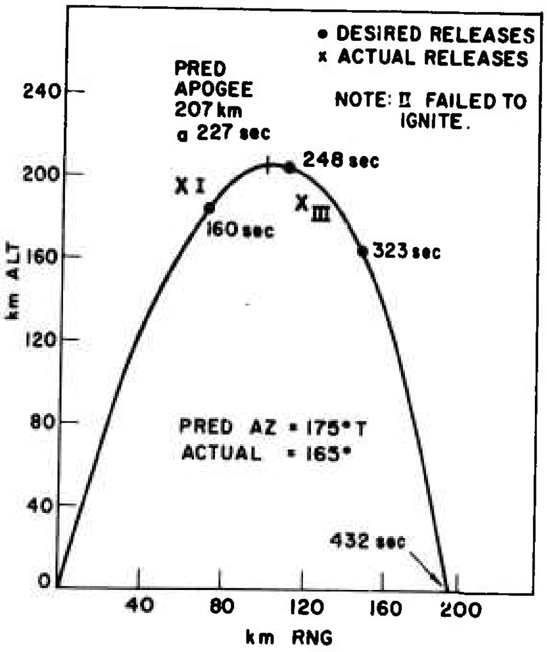


Figure 11. Trajectory Summary for Chemical Release ODET

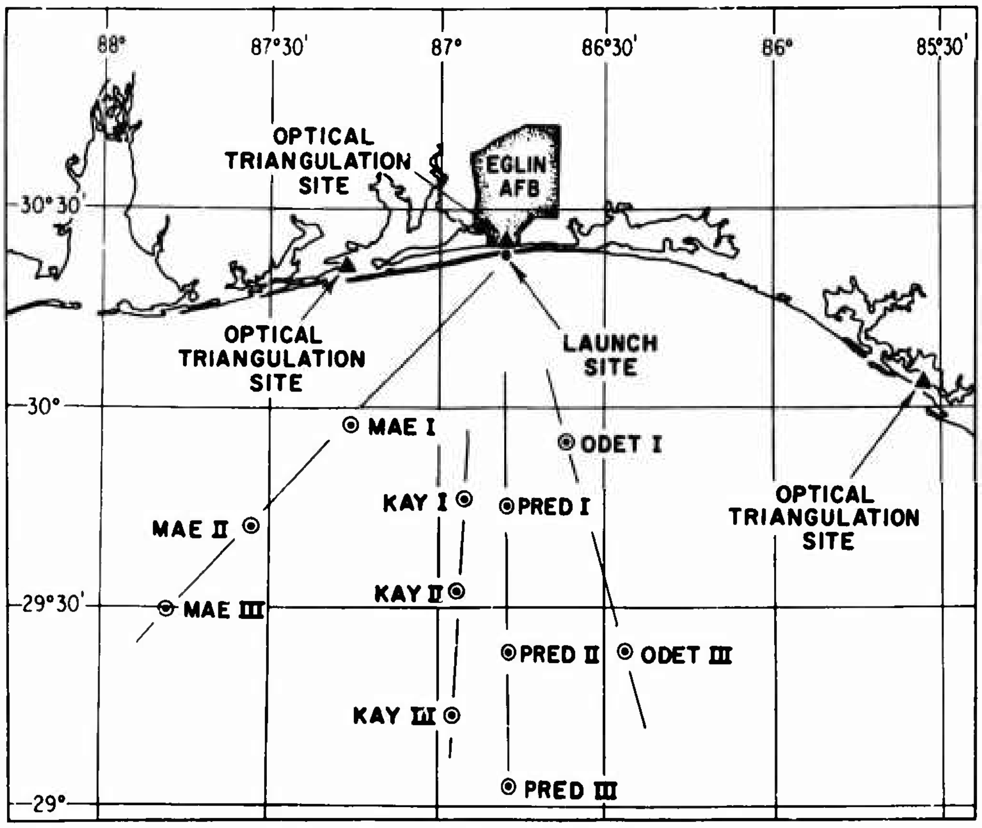


Figure 12. Actual Barium Release Positions for KAY, MAE, and ODET

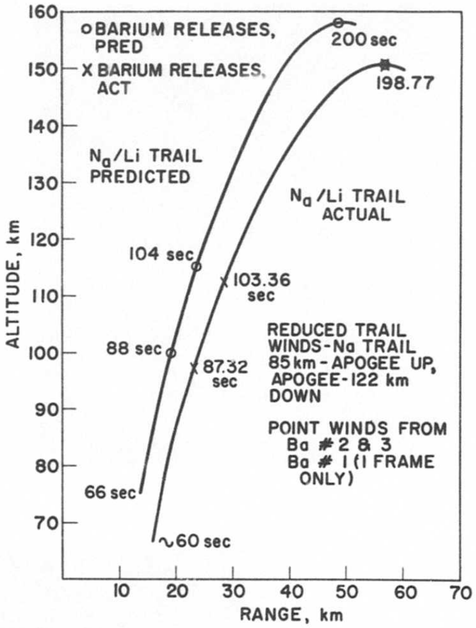


Figure 13. Trajectory Summary for Chemical Release VANESSA

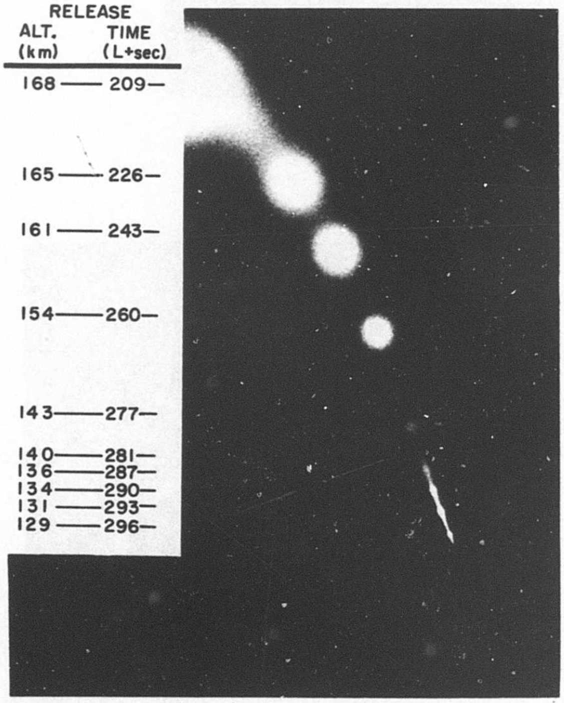


Figure 14. MYRA

Figure 15. BETTY TMA + H_2O

Figure 16. NITA

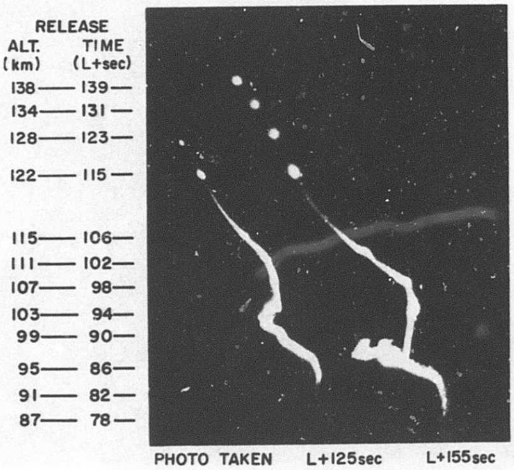


Figure 17. UNA Liquid TMA "Puffs" Up Trail

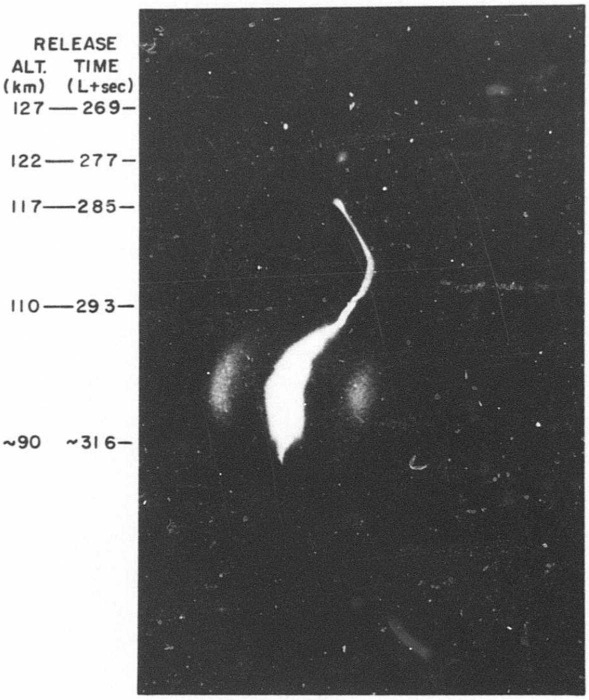
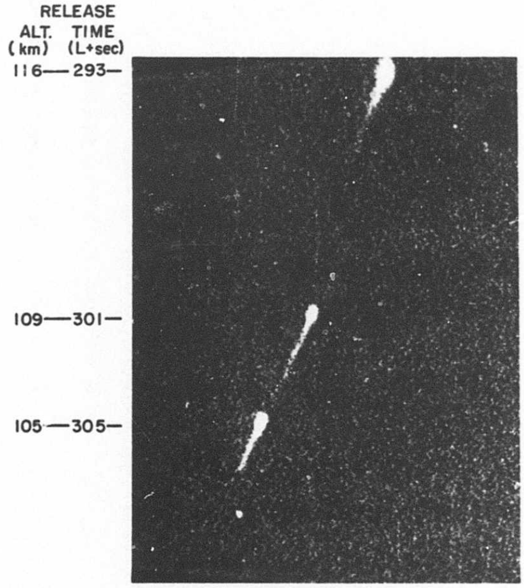


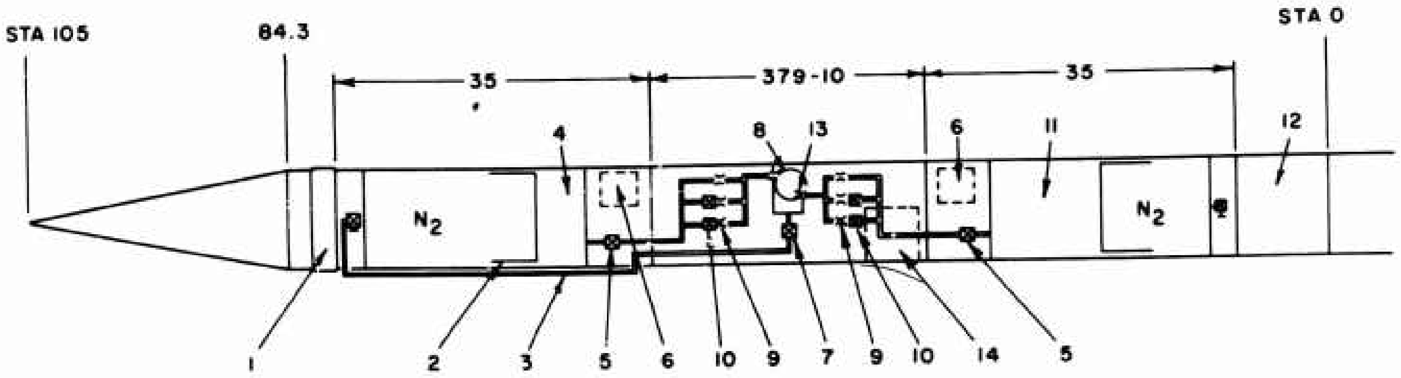
PHOTO TAKEN ~ L + 320 sec

Figure 18. UNA Liquid TMA "Puffs" Down Trail and Reentry Bag



TV PICTURE ~ 307 sec

Figure 19. WENDY Down Leg



NOTE: ONLY ONE TMA ORIFICE WITHOUT SOLENOID VALVE USED ON LILI

1. CW BEACON
2. PISTON
3. NITROGEN LINE
4. 60 WATER/40 METHANOL
5. SQUIB VALVE (CONAX)
6. PROGRAMMER (SINGLE EVENT)
7. SQUIB VALVE (SDC)
8. MIXING CHAMBER, WITH SELF CLEANING NOZZLES
9. METERING ORIFICE
10. SOLENOID VALVE
11. 80 TMA/20TEA
12. BALLAST
13. SELF CLEANING NOZZLE
14. MULTI-EVENT PROGRAMMER

LILI CARRIED FLASHING BEACON BEHIND CW BEACON (OA LENGTH = 114")

Figure 20. TMA Vaporizer Payload Schematic for Releases LILI and NITA

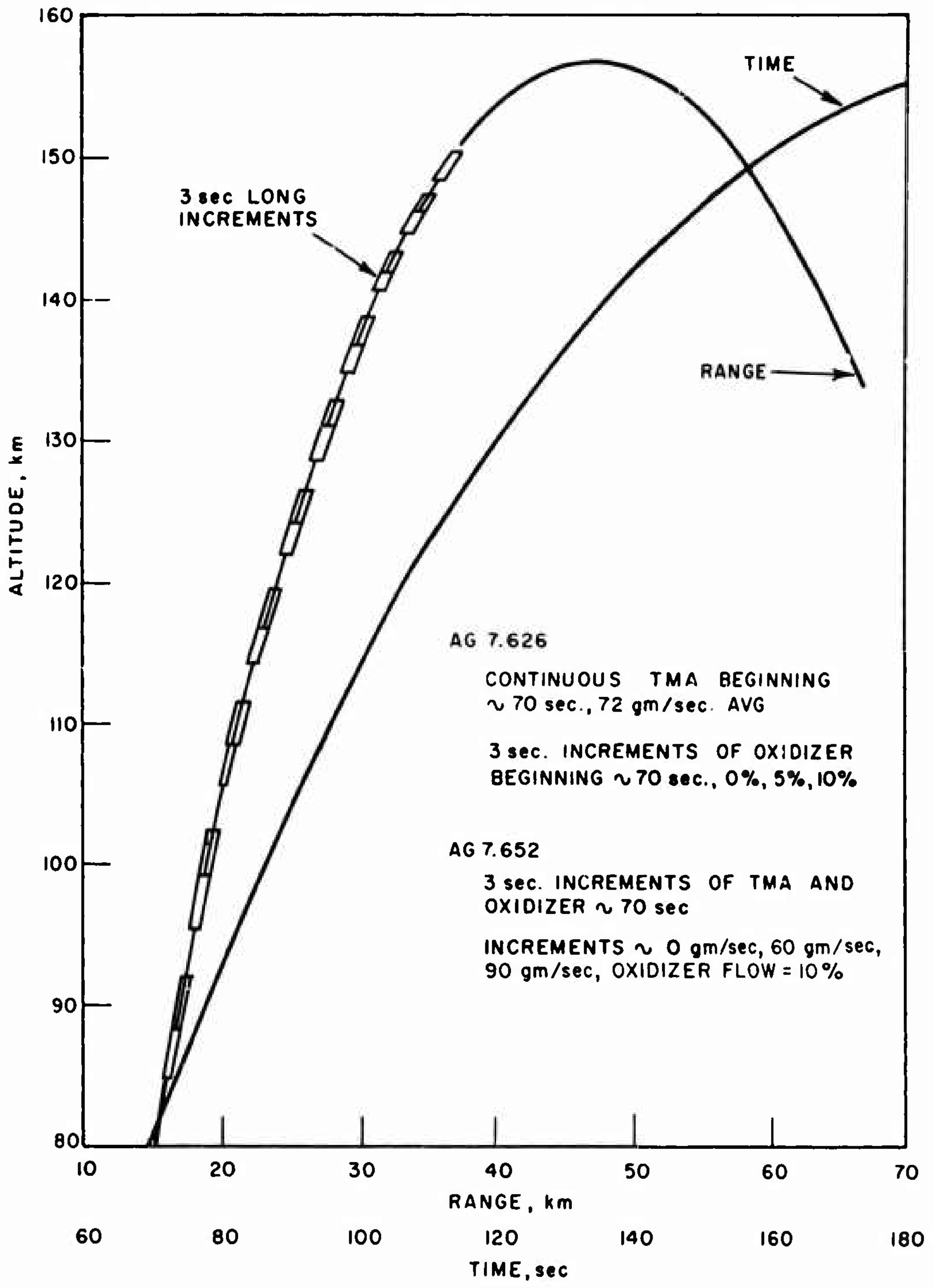


Figure 21. Trajectory Summary for Chemical Releases LILI and NITA

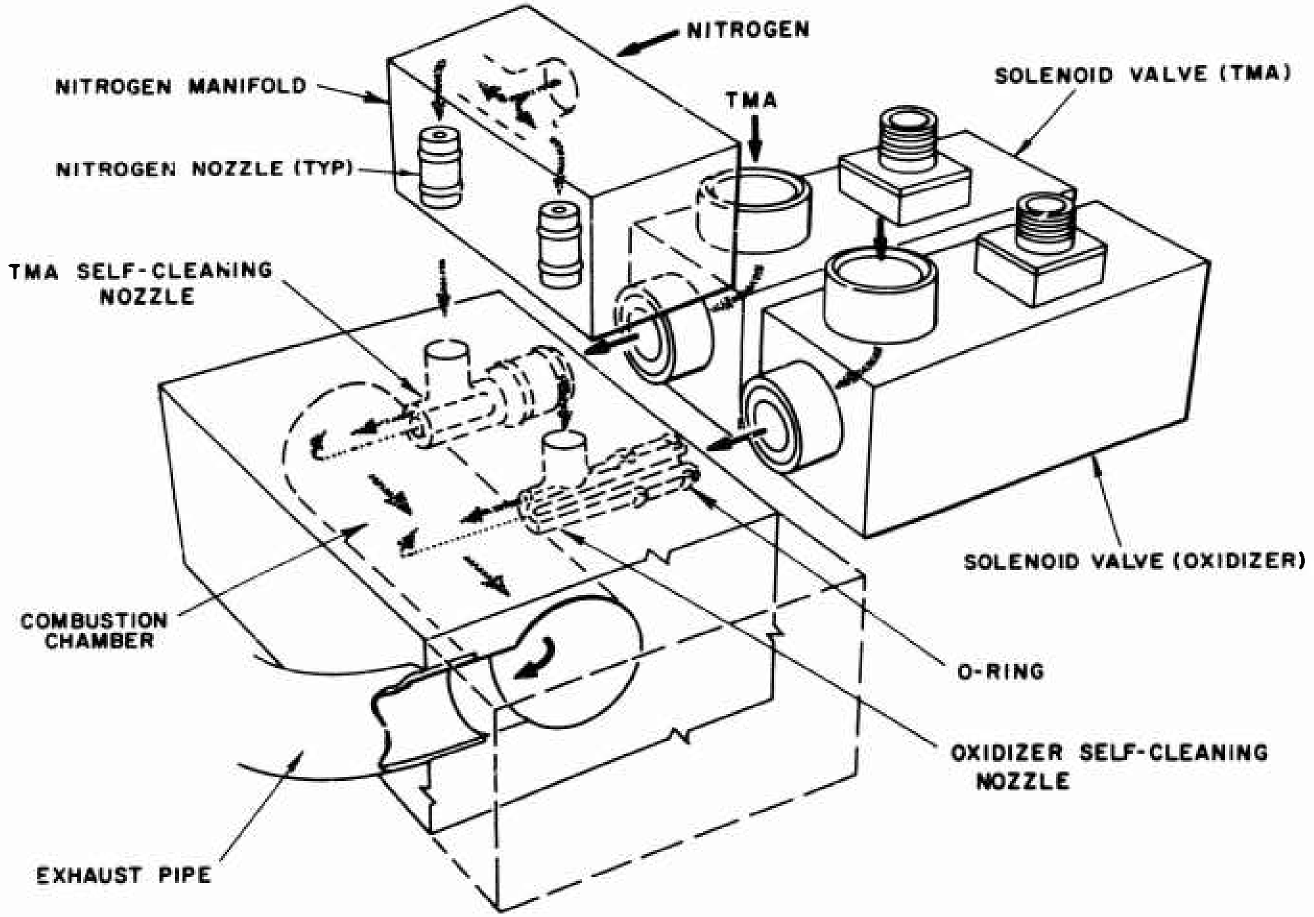


Figure 22. Combustion Chamber and Flow Control Valve for Releases TANYA and WENDY

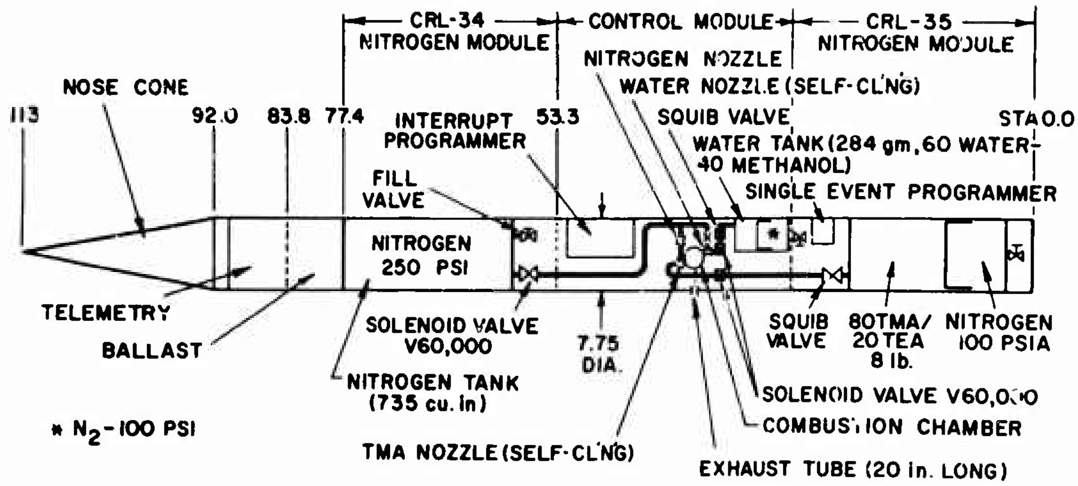


Figure 23. TMA Vaporizer Payload Schematic for Releases TANYA and WENDY

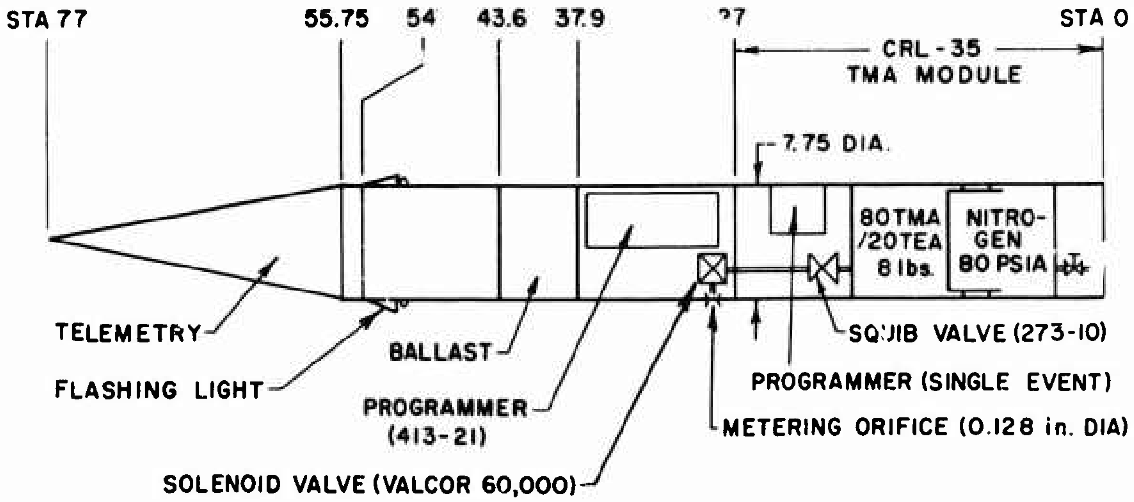


Figure 24. TMA "Liquid" Puff Payload

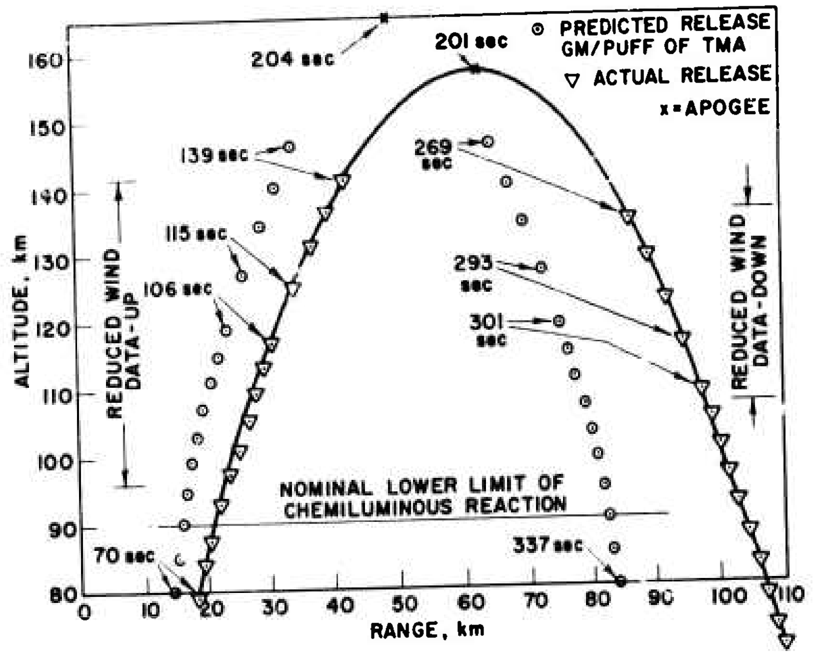


Figure 25. Trajectory Summary for Chemical Release WENDY

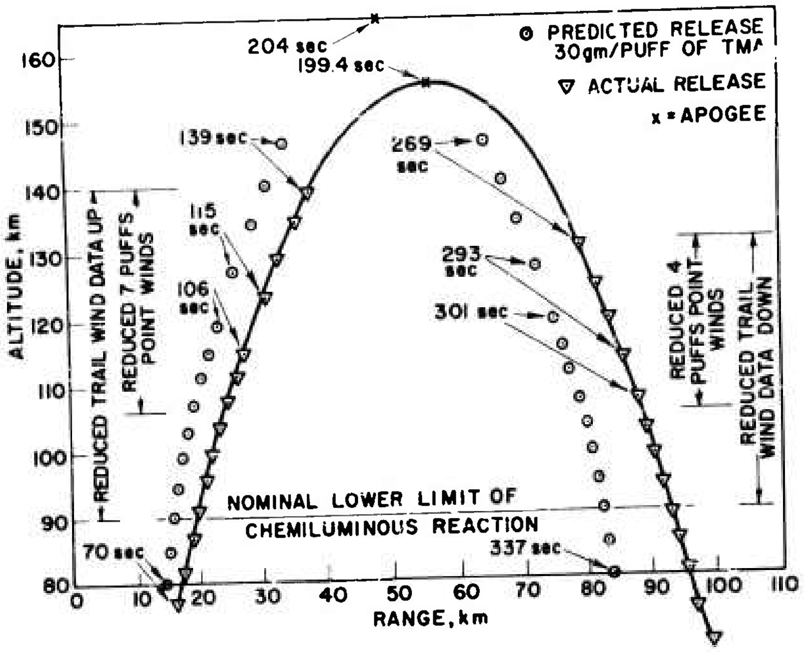


Figure 26. Trajectory Summary for Chemical Release UNA

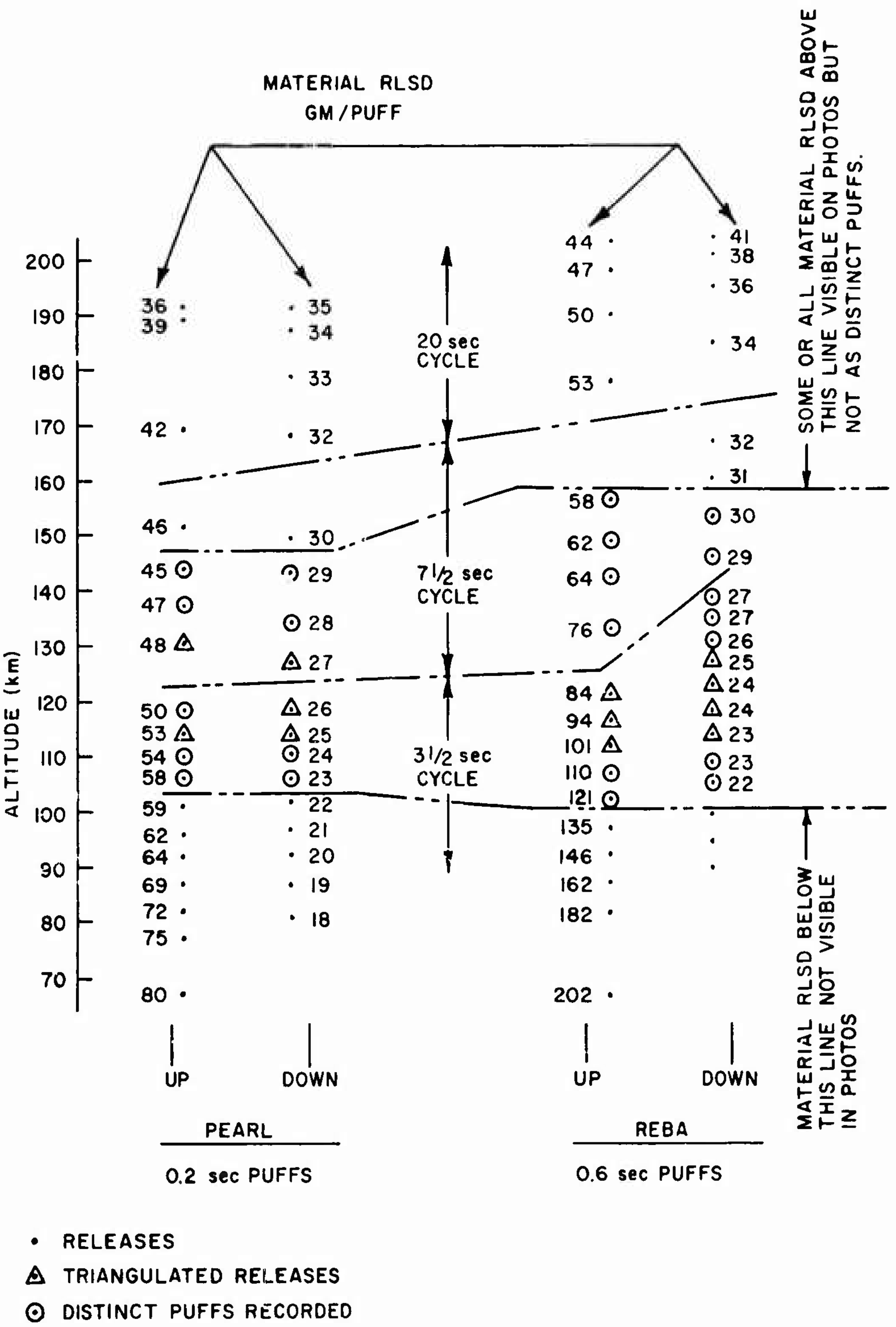


Figure 27. Computed Amount of Diborane per Puff for Releases PEARL and REBA

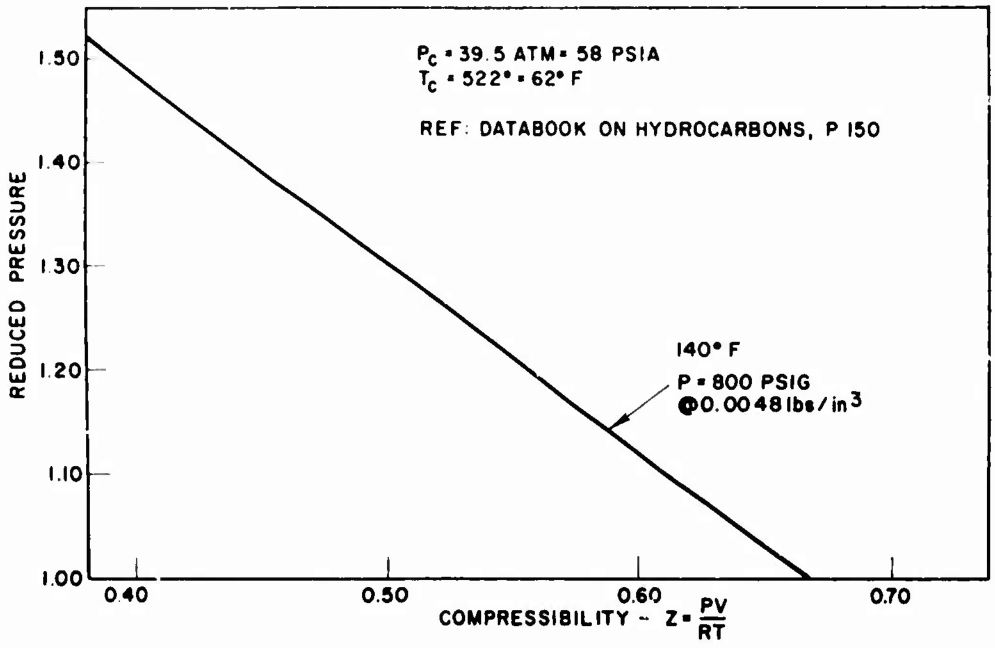


Figure 28. Data on Diborane Compressibility

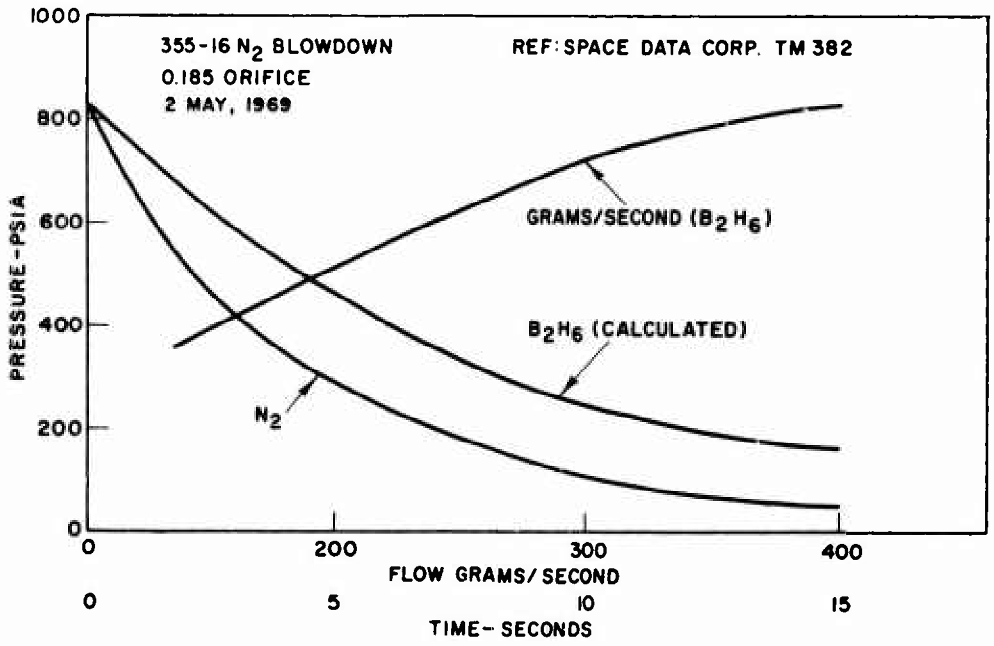


Figure 29. Diborane Pressure Decay and Mass Flow Rate

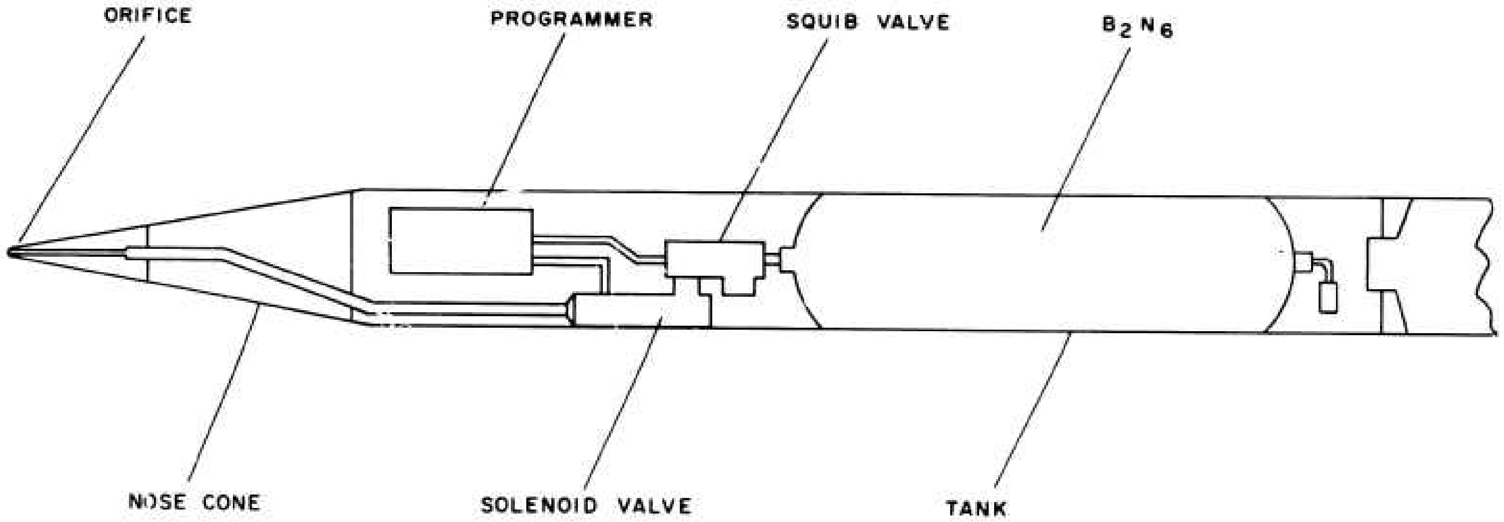


Figure 30. Payload Configuration for Diborane Releases

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13. ABSTRACT

This report summarizes the flight and engineering aspects of rocket launches made by the Chemical Physics Branch (USAF Project 7635) during the calendar year 1969, inclusive of TMA vapor release system development flights since 1966, for the purpose of releasing chemicals in the atmosphere at high altitudes. Chemical releases provide means for modification of the upper atmosphere, as well as data on atmospheric dynamics and ionospheric properties from which quantitative understanding of increasing accuracy is derived. Results of this research are relevant to the solution of current Air Force problems, such as the precise prediction of the motion of operational satellites and nuclear debris, or the assessment of the effects of solar bursts and nuclear detonations on the propagation of electromagnetic waves through the ionosphere.

The four basic experimental release systems, barium, trimethylaluminum, diborane, and lithium, are designated as individual sections. In addition, information is included regarding new instrumentation tested in some of the flights, in order to improve the acquisition capability of the tracking radar and to transmit vehicle and payload operational data.

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