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NEW INFRARED FLARE AND HIGH-ALTITUDE IGNITER COMPOSITIONS (U)

CHARLES A. KNAPP

JULY 1959

FELTMAN RESEARCH AND ENGINEERING LABORATORIES
PICATINNY ARSENAL
DOVER, N. J.

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by

Charles A. Knapp

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Feltman Research and Engineering Laboratories
Picatinny Arsenal
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Approved:

S. SAGE
Chief, Pyrotechnics Laboratory

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(S) OBJECT

To conduct research on and to develop infrared flare decoy systems with energy output rich in the 1.8 - 2.8μ spectral region for the protection of jet aircraft against infrared-seeking missiles. (This work is being conducted under Air Force contract (33-616) 58-45.)

(S) SUMMARY

(S) Breakthroughs have been achieved with both infrared flare compositions and high-altitude igniter compositions. Preliminary tests of a new flare composition (SI-119) show that its burning rate and high ignitability are unaffected by increasing altitude up to 100,000 feet (8 mm Hg) and that its peak infrared energy output (watts) and efficiency (joules/g and cc) increase with increasing altitude. The new composition, which consists of molybdenum trioxide/chromic oxide/zirconium, shows considerable promise for use in decoy systems for jet aircraft. Both the currently used teflon/magnesium/nitrocellulose compositions and the older, less efficient sodium nitrate/magnesium/Laminac compositions are adversely affected by increasing altitude: peak energy output and efficiency decrease severely, burning rate decreases greatly, and the flares become very difficult to ignite. At high altitude the SI-119 composition is far superior to teflon compositions, especially during the first 12 seconds of burning.

(C) New high-altitude igniter compositions containing molybdenum trioxide/chromic oxide/zirconium/nitrocellulose (SI-122 and 131) have also been formulated which ignite teflon compositions at altitudes up to 100,000 feet (highest altitude simulated). These new igniter compositions should perform as well or better with sodium nitrate compositions. They are superior to the 90/10/5 barium chromate/boron/nitrocellulose composition which, unless partially confined, is unreliable above 40,000 feet altitude and is more sensitive to frictional forces.

(C) RECOMMENDATIONS

In view of the encouraging results with respect to burning characteristics and energy output obtained with new infrared flare compositions containing molybdenum trioxide/chromic oxide/zirconium further research and development should be conducted. With higher energy oxidizing agents this type of composition may equal or exceed the total efficiency of the teflon composition at lower altitudes as well as at 100,000 feet. It is also expected that the advantages of burning rates unaffected by decreasing pressure plus excellent ignitability could be maintained.

It is further recommended that more extensive tests be conducted with the new high-altitude igniter compositions ($MoO_3/Cr_2O_3/Zr/NC$) to determine optimum composition and reliability. The use of coarser zirconium should be investigated to further reduce sensitivity to friction and impact.

The use of conductive igniter

characteristics at the higher altitudes. Although research and development of projection systems (for use with jet aircraft) are also continuing, only the most outstanding flare and igniter composition developments are discussed in this report.

(C) RESULTS AND DISCUSSION

Development of Flare Composition

4. Composition formulations with heats of reaction and heats of combustion data are listed in Table 1 (p 7). Since the calorimetry tests were conducted under confined conditions, these results probably represent upper energy limits. At high altitudes where vacuum conditions exist, combustion efficiency and reaction energy are reduced due to lower flame temperatures and much slower burning rates. This was shown in a previous report (Ref 2) where a composition consisting of 54% magnesium, 30% teflon, and 16% Kel F gave an average heat of reaction in one atmosphere of helium of 1521 calories/gram and at 5 millimeters of helium of 1212 calories/gram.

5. Further evidence of the deleterious effects of reduced pressure on burning characteristics can be seen in Table 2 (p 8) and Figure 1 (p 12). The efficiency of sodium nitrate/magnesium/Laminac and teflon/magnesium/nitrocellulose compositions in the form of pressed flares decreases sharply with increasing altitude (decreasing pressure). The peak infrared energy output of the teflon composition decreases 70% from sea level to 60,000 feet and 95% from sea level to 100,000 feet. In addition, its burning rate decreases approximately 2 and 7 times, respectively. Nevertheless, the teflon/magnesium/nitrocellulose system is far superior to the sodium nitrate system. This may be due to the large quantity of incandescent carbon (high emissivity) produced by the reaction of the teflon composition.

6. A radical departure from the above trends occurred with a composition consisting of $MoO_3/Cr_2O_3/Zr$ (SI-119). This composition became significantly more efficient with increasing altitude. Peak energy output and efficiency increased up to 60,000 feet and tapered off slightly at 100,000 feet. The burning rate of the SI-119 composition remained essentially unchanged at the higher altitudes. These effects can be seen in Table 2 (p 8) and Figure 2 (p 13). It is important to note that whereas at sea level composition SI-119 was much less efficient and produced a much lower peak energy output (in watts) than the teflon system, at 60,000 feet the peak energy of SI-119 was about 4 times higher than that of the teflon system (although efficiency was still lower). At 100,000 feet (simulated altitude) the peak energy level of SI-119 was about 20 times greater than that of the teflon system, and its efficiency (in joules/cc) was approximately the same (over the entire burning period). If only the first 12 seconds of burning are considered it can be seen from Table 3 (p 9) that composition

SI-119 is far superior to the teflon system in peak energy output at 60,000 and 100,000 feet, and efficiency at 100,000 feet. All flares in the above study were end burning and had approximately the same burning surface area.

7. Table 1 (p. 7) shows Composition SI-119 to have a relatively low heat of reaction and combustion. It is anticipated that its reaction energy can be greatly increased by incorporating chemicals producing higher energy. One approach is the use of perchlorates as oxidizing agents. For example, $KClO_4$ with zirconium produces 1610 calories/gram and 6150 calories/cc (based on calculated true density). Other perchlorates can give even higher energies (Ref 3). Another approach is the use of superoxides of the first two periodic groups. For example, the calculated heat of reaction for KO_2 and zirconium is 1170 calories/gram. The use of higher oxygen complex compounds of molybdenum (M_2MoO_5) with the alkali metals should also be investigated. In addition, the use of excess zirconium may also be of value. Composition SI-119 is approximately stoichiometric, assuming ZrO_2, Mo, and Cr as products. Still another approach to the optimum composition is a mixture of the zirconium (SI-119) and the teflon compositions.

8. Another important advantage of Composition SI-119 is that it is highly ignitable. It is also used as an igniter composition and can be initiated directly by an M1A1-type squib (containing 90/10 barium chromate/boron) up to 100,000 feet. It is believed that squibs or primers could be eliminated if desired, since this new composition can probably be ignited by hot wires (squib principle). Simplifying the system by eliminating components might logically lead to increased reliability. To slow down the relatively fast burning rate of SI-119 and to reduce its sensitivity to friction coarser zirconium (Ref 4) and binders could be used.

9. Composition SI-119, which contains no binder, was pressed into a paper flare case for testing. If necessary, it can be converted into a caseless flare by means of binders in the same manner as the sodium nitrate/magnesium and teflon/magnesium compositions. To meet requirements, binders can also be used to adjust the burning rate. It is anticipated, however, that even with the incorporation of binders the burning rate of composition SI-119 will remain relatively unaffected by changes of altitude over the range of sea level to 100,000 feet.

Development of Igniter Composition

10. Two new igniter compositions containing $MoO_3/Cr_2O_3/Zr$/nitrocellulose (SI-122 and SI-131) have been developed for use with teflon/magnesium/nitrocellulose flare formulations. Although these igniter compositions were not tested with sodium nitrate/magnesium/Laminac flare compositions the results of Reference 4 indicate that they should

perform even better with flares of this type. Static ignition test results with flare compositions are given in Table 4 (p 10). Ignition of the flare compositions was accomplished over the simulated altitude range of sea level to 100,000 feet with completely unconfined systems. At 100,000 feet, however, ignition of the flares by the igniter was erratic. Preliminary tests with these igniters indicate that at 100,000 feet the type of surface of the flare may be critical. Flares with porous surfaces ignited consistently while those with hard glazed surfaces did not. It should be pointed out that when the standard Rita igniter composition, SI-56 (barium chromate/boron/nitrocellulose), is completely unconfined, it performs erratically between 40,000 and 60,000 feet. Above 60,000 feet it fails completely to ignite the flare composition.

11. Data on the sensitivity of the igniter compositions to impact and frictional forces is given in Table 5 (p 11). It can be seen that the SI-122 igniter composition ($MoO_3/Cr_2O_3/Zr/$ nitrocellulose) is less sensitive than SI-56 ($BaCrO_4/B/$ nitrocellulose). SI-56 has an impact value of 3 inches and SI-122 an impact value of 12 inches. SI-56 is sensitive to both steel and fiber (friction pendulum test) whereas SI-122 is sensitive to steel only.

(C) EXPERIMENTAL PROCEDURE

12 (U) Compositions containing binder were prepared in a Lancaster blender. A small amount of acetone (10 cc/100 g of mix) was used to insure proper blending. Blending time was approximately 20 minutes.

13. (U) Binderless compositions were blended in an Abbe ball mill for ½ hour. Rubber stoppers were used to insure proper blending.

14. (C) SI-122 and 131 were blended by stirring with a wooden rod in a mortar. The nitrocellulose was used as a 10% solution in acetone. Excess acetone (up to 30 cc/100 g mix) was used for blending. While still wet with acetone these compositions were applied to the flare sides with a paint brush.

15. (C) Caseless flares were pressed in one increment at 7,000 psi. Cased flares were pressed in 1-inch increments at 15,000 psi.

16. (C) Materials

$NaNO_3$, USP, DR, 23 micron	Davies Nitrate Co.
MoO_3, 12.5 micron	Fisher Scientific Co., Lot 762932
Cr_2O_3, less than 1 micron	Fisher Scientific Co., Lot 516340
Teflon, reprocessed, 23, 52, and 92 micron	Davies Nitrate Co.
Kel-F, pulverized, 28 micron	Kellogg Co., Lot [illegible]-14
Mg, atomized, 23 micron, granulation 200/325	Ruffert Chemical Co.
Mg, atomized, 100 micron, granulation 50/100	Ruffert Chemical Co.

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Zr, 2.3 micron	Foote Mineral Co., Grade Z, Lot 70262	
Nitrocellulose, 12.6% nitrogen, linters	:	
Laminac Resin Nos. 4116 and 4134, commercial grade	American Cyanamid Corp.	

17. (C) All flares were tested in an upright position (Fig 4, p 15) in the Picatinny high-altitude test chamber (Fig 3, p 14). Energy measurements were taken from a horizontal side-on position, using lead sulfide detection equipment.

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TABLE 1

Composition Formulas and Reaction Energies

Composition, pbw	Particle Size, microns	FY-719	FY-698	FY-893	FW-155	FW-156	FW-166	FW-168	SI-119	SI-122	SI 1
$NaNO_3$	23	47.6	33.5	60	–	–	–	–	–	–	–
MoO_3	12	–	–	–	–	–	–	–	31.3	31.3	25
Cr_2O_3	0.5	–	–	–	–	–	–	–	20	20	16
Teflon	23	–	–	–	46[a]	30[a]	46[a]	46	–	–	.
Kel-F	28	–	–	–	–	16	–	–	–	–	–
Mg	23	47.6	61.7[b]	40	54	54	54	54	–	–	.
Zr	2.3	–	–	–	–	–	–	–	48.7	48.7	5[illegible]
Laminac		4.8	4.8	–	–	–	–	–	–	–	.
Nitrocellulose, 12.6%		–	–	–	2	2	2.6	2	–	4	
Reaction Energies											
ΔH_R [c]		1932	1608	1877	–	–	–	1684	510	–	.
ΔH_C [d]		2908	3745	2010	–	–	–	3756	1203	–	.

[a] 51 microns

[b] 180 microns

[c] Heat of reaction, 1 atm helium

[d] Heat of combustion, 30 atm oxygen

TABLE 2

Emission and Burning Characteristics of Flare Compositions At Various Simulated Altitudes[a]

Composition[b]	Approximate Dimensions, in.	Altitude 10^3 feet	No. Items	Burning Time, sec	Burning Rate sec/in.	Peak Energy 10^3 watts	Total Energy 10^3 joules	Total Efficiency joules/g	joules/cc
FY-719	1.35 × 1.5	S L[c]	2	5.3	3.5	2.3	12	220	337
		60	1	16.0	10.7	0.4	6	110	167
		100	3	28.0	19.9	–	–	–	–
FY-698	1.35 × 1.5	S L	1	8.5	5.6	4.0	35	630	980
		60	2	22.8	15.2	0.4	8	150	240
		100	1	50.5	33.6	0.1	6	110	176
FY-893	1.3 × 3.0	SL	1	9.8	3.4	3.4	39	300	630
		60	1	37.0	9.0	0.2	6	35	69
FW-168	1.35 × 1.5	SL	1	7.6	4.9	19.0	144	2440	3920
		60	2	16.5	10.5	6.0	99	1670	2710
		100	1	56.0	36.1	.9	33	560	902
SI-119	1.3 × 6.2	SL	1	5.0	0.8	8.0	40	90	300
	1.3 × 6.5	60	[illegible]	4.8	0.7	22.0	126	280	900
	1.3 × 5.3	100	[illegible]	4.0	0.8	20.0	91	210	790

[a] All flares burned from one end in cigarette fashion. To achieve this, Compositions FY-719, FY-698, and FW-168 were made as caseless flares and the curved sides were coated with Laminac resin (80/20, Nos. 4116 - 4134). FY-893 and SI-119 were pressed into thin-walled (1/16 inch) wax-coated paper cases.

[b] Composition formulas are given in Table 1 (p 7).

[c] Sea level

TABLE 3

A Comparison of the FW-168 and SI-119 Compositions for the First 12 Seconds of Burning

Composition[a]	Altitude 10^3 feet	Burning Time, sec	Approximate Length, in.	Peak Energy 10^3 watts in 1st 12 sec	Peak Energy Watts/sq in. Burning Surface	Total Energy 10^3 joules in 1st 12 sec	Efficiency joules/g in 1st 12 sec	Efficiency joules/cc in 1st 12 sec
FW-168	SL[b]	7.6	1.5	19.0	13.3	144	2,440	3,920
	60	16.5	1.5	6.0	4.2	72	1,220	1,920
	100	56.0	1.5	0.9	.63	7	120	190
SI-119	SL	5.0	6.2	8.0	6.	40	90	300
	60	4.8	6.5	22.0	16.6	126	280	900
	100	4.0	5.3	20.0	15.[illegible]	91	210	790

[a]Composition formulas:

FW-168	Teflon	46 pts
	Mg	54 pts
	NC	2 pts
SI-119	MoO_3	31.3 pts
	Cr_2O_3	20.0 pts
	Zr	48.7 pts

[b]Sea level

TABLE 4

Static Ignition Test Results of New Igniter Compositions[a]

Igniter Composition[b]	Flare Composition[b]	No. of Items Tested	Approximate Dimensions, In.	Altitude, 10^3 ft	Remarks
SI-122	FW-155	4	1.35 × 1.6	SL[c]	All ignited
SI-122	FW-155	3	"	60	All ignited
SI-122	FW-155	13	"	80	FW-155 ignited in 6 cases[d]
SI-122	FW-155	12	"	100	FW-155 ignited in 6 cases[e]
SI-122	FW-156	1	1.35 × 1.75	SL	All ignited[f]
SI-122	FW-156	3	"	60	All ignited[f]
SI-122	FW-156	1	"	80	All ignited[f]
SI-122	FW-156	1	"	100	All ignited[f]
SI-122	FW-166	2	2.5 × 4.3	60	All ignited
SI-131	FW-155	2	1.35 × 1.6	SL	All ignited
SI-131	FW-155	2	"	60	All ignited
SI-131	FW-155	5	"	80	All ignited
SI-131	FW-155	15	"	100	FW-155 ignited in 8 cases[g]

[a] The igniter compositions were applied to the circular surface of the caseless flares. The flat ends were not coated.

[b] Composition formulas are given in Table 1 (p 7).

[c] Sea level

[d] All flares in this group had hard glazed surfaces.

[e] All flares which failed to ignite had hard, glazed surface. All flares (5) having rough, porous surface did ignite. One flare having hard, glazed surface also ignited.

[f] These flares had rough, porous surfaces.

[g] All flares which failed to ignite had hard, glazed surface.

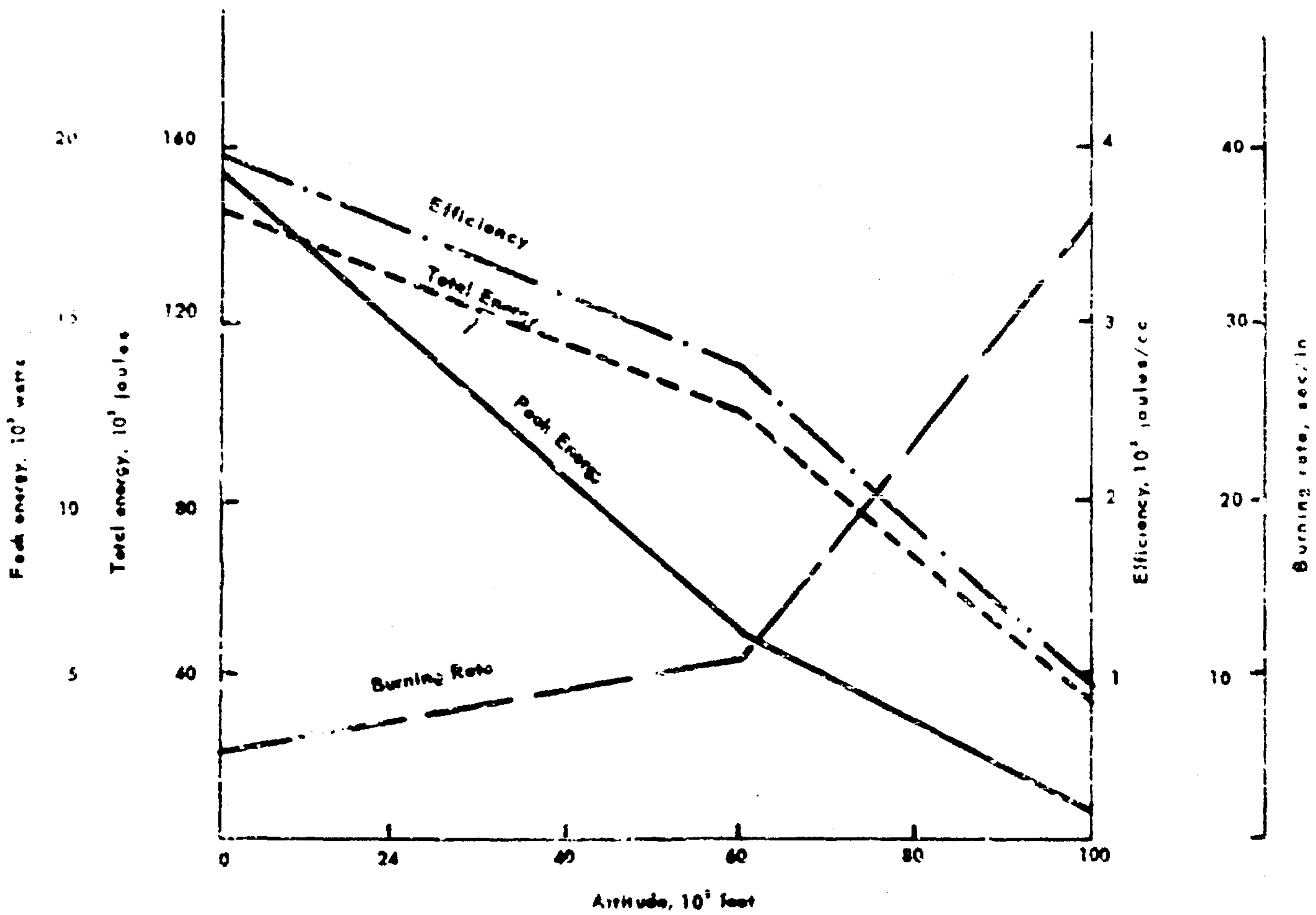

Fig 1 Effect of Altitude on the Infrared Emission and Burning Rate of FW-168

(teflon/magnesium/nitrocellulose)

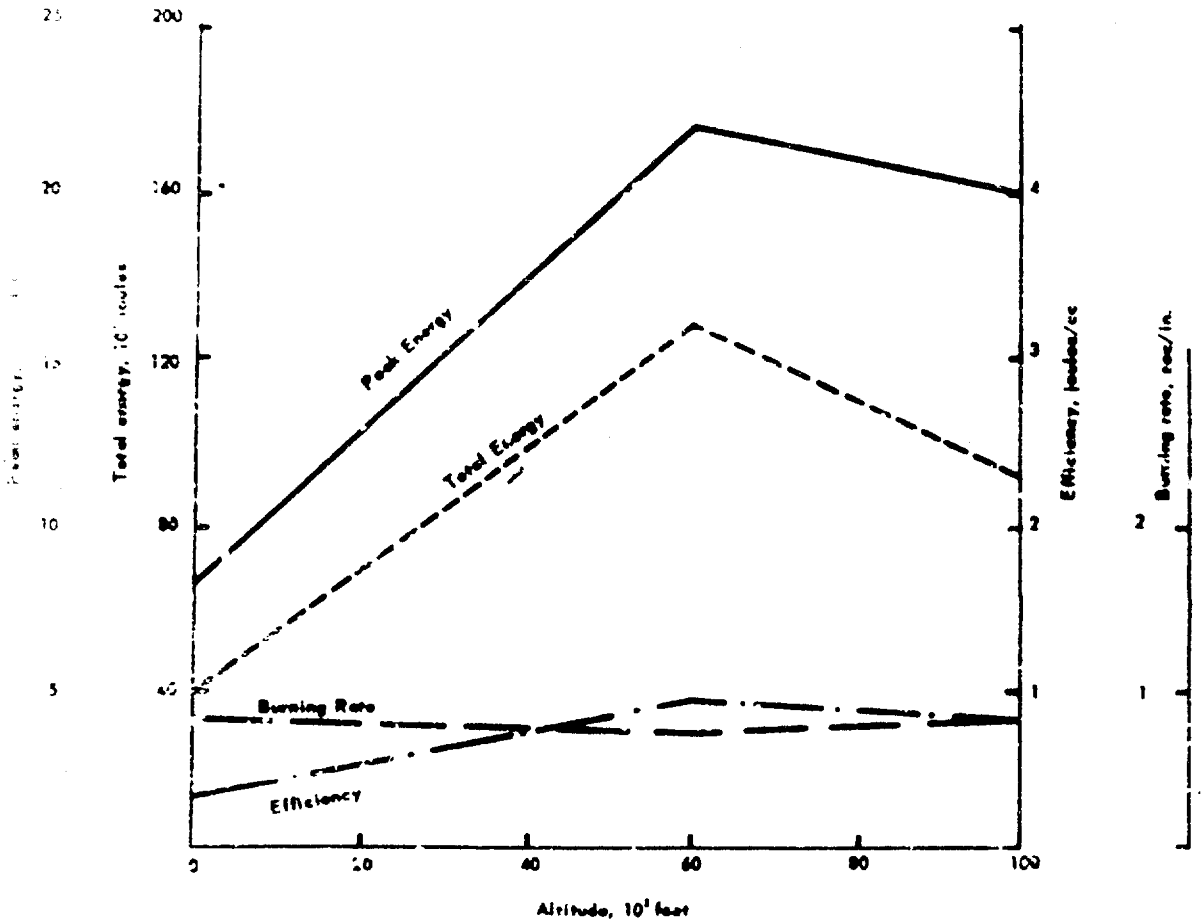

Fig 2 Effect of Altitude on the Infrared Emission and Burning Rate of SI-'19

($MoO_3/Cr_2O_3/Zr$)

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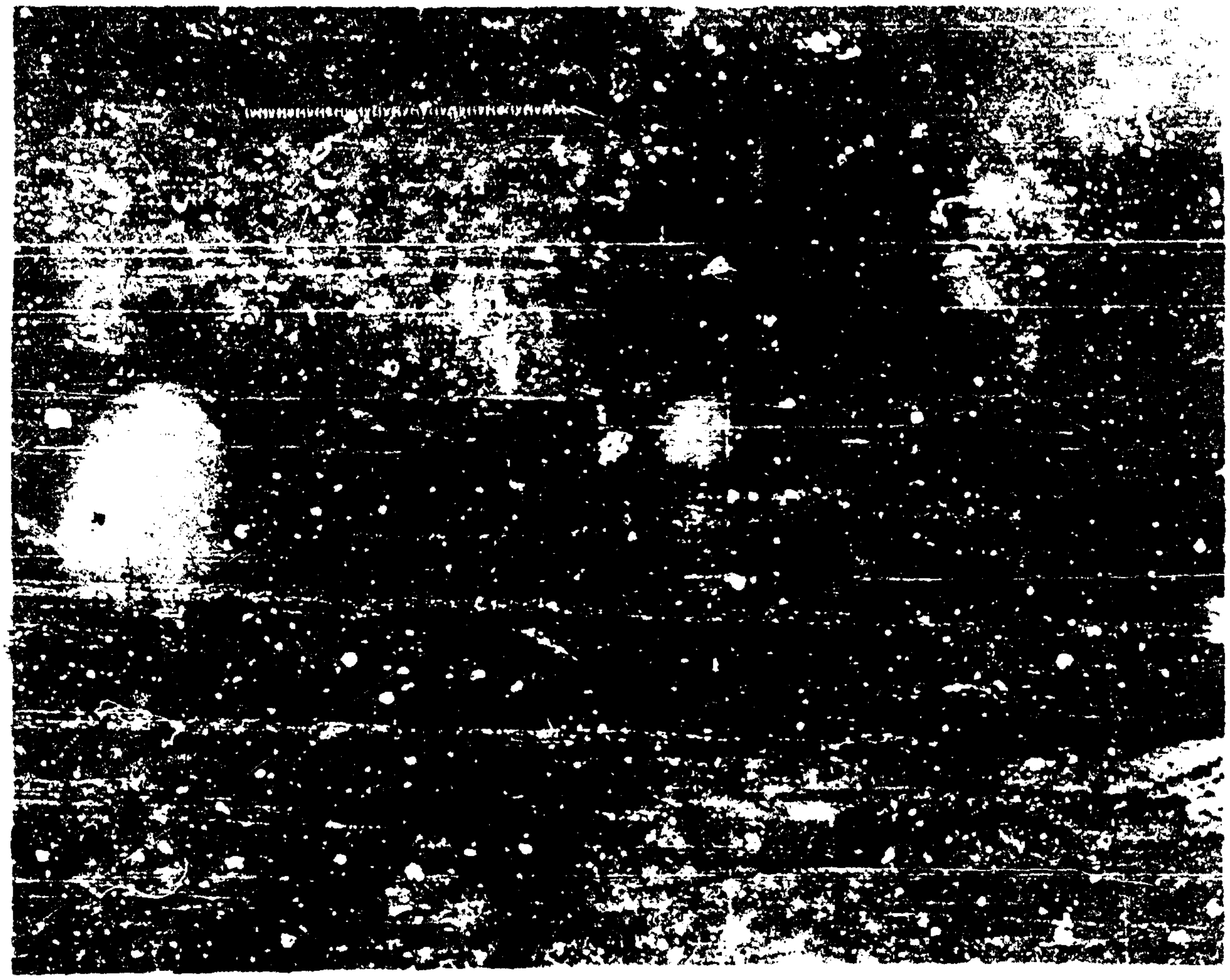

Fig 3 Pyrotechnic High-Altitude Test Chambers for Dynamic Testing at Altitudes up to 150,000 Feet (Tank volume, 8000 cubic feet)

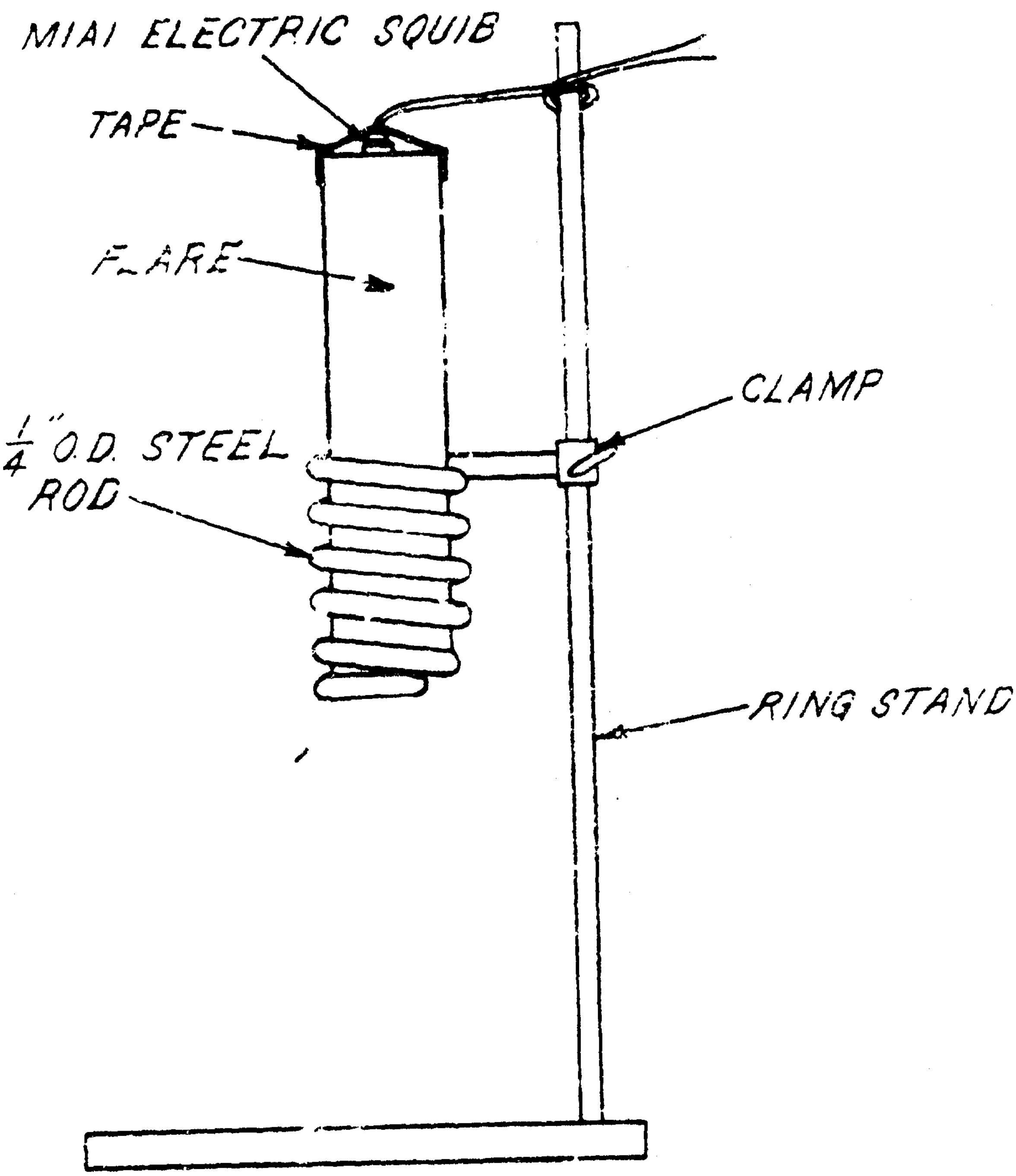

Fig 4 Static Burning Test Fixture for Caseless Flare

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