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REPORT

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AN EVALUATION OF TEMPERATURE AND HEAT FLUX OF GASLESS AND GASSY PERCUSSION PRIMERS

L.V. de Yong

Approved for Public Release

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A knowledge of the energy output of percussion primers is paramount in assessing their suitability as igniters in pyrotechnic devices. A simple heat flux probe is described that is used to compare the thermal output of gasless and gassy percussion primers. Temperature and heat flux were measured for both primers at a range of distances from the primer vent. Analysis shows the gasless primer produces a greater heat flux and larger temperature than the gassy primer indicating a larger thermal energy output.

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A knowledge of the energy output of percussion primers is paramount in assessing their suitability as igniters in pyrotechnic devices. A simple heat flux probe is described that is used to compare the thermal output of gasless and gassy percussion primers. Temperature and heat flux were measured for both primers at a range of distances from the primer vent. Analysis shows the gasless primer produces a greater heat flux and larger temperature than the gassy primer indicating a larger thermal energy output.

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AN EVALUATION OF TEMPERATURE AND HEAT FLUX OF GASLESS AND GASSY PERCUSSION PRIMERS

1. INTRODUCTION

A knowledge of the energy output of percussion primers is important in assessing their behaviour as suitable igniters in pyrotechnic trains. Several authors [1,2] have defined the energy required for ignition of a pyrotechnic composition in terms of not only the physical and chemical properties of the composition but also the heat flow into the composition from the ignition source. This heat flow is related to the temperature of the ignition source (since the pyrotechnic must reach its characteristic ignition temperature before burning) and the rate of heat flow or heat flux. If the flux is not large enough, the time to ignition may be too long to cause ignition in a practical time frame or combustion may start but not be sustained. Clearly there exists a need to know what energy a primer will supply and what energy a pyrotechnic needs to ignite and whether one matches the other.

Conventional techniques of measuring primer output have typically relied on one of its output characteristics. These have included light output, radiant energy, volume of gas produced or pressure. Thermal measurements are complex because of the speed of the primer action. Similarly, pressure or volume of gas measurements assume the greater the pressure/time integral the greater the primer efficiency or ignitability. However, this premise is invalid if the primer products contain a large proportion of condensed phase material.

Previous work [3] showed that using a Flash Tube, the distance between primer and pyrotechnic acceptor for 50% ignition of the acceptor was up to 100% greater for a gasless primer compared to a gassy primer. In the present work, a simple heat flux probe has been constructed to qualitatively compare the temperature and heat flux from a standard M42 gassy percussion primer containing PA101 and an MRL developed M42F1 gasless percussion primer [4] containing MRL(X) 408 (See Table 1).

2. THEORY

The heat flux gauge works on the calorimetric principle. The rate of heat transfer per unit area (heat flux) to the gauge is derived from measurements of temperature and the thermal capacity of the gauge. If one assumes the gauge attains a constant rate of temperature rise, then:

$$q = \frac{Q}{A} = \left(\frac{CW}{A}\right) \frac{\partial T}{\partial t} \tag{1}$$

where q = heat flux

Q = rate of heat transfer

A = surface area of the gauge

C = the specific heat of the gauge

W = weight of the gauge

$\frac{\partial T}{\partial t}$ = constant rate of temperature change

3. EXPERIMENTAL

Figure 1 shows the arrangement developed for temperature/heat flux measurement. A 0.25 mm thick, 13.0 mm diameter copper plate was attached to a canvas impregnated bakelite backing block using silastic adhesive. The front surface of the probe was coated black using 3M Nextel Black paint and a thermocouple was welded to the rear surface. The thermocouple was Copper/Constantan of 0.075 mm diameter to provide a fast response. The thermocouple signal was detected using a differential amplifier with a gain of 1000X and the output was recorded using a UV Galvanometric recorder.

Several copper discs were manufactured with a mean weight of 0.2852 g. The specific heat of the copper disc was not determined experimentally but was assumed to be 0.390 $Jg^{-1}{}^{\circ}C^{-1}$.

The probe was inserted into a 13 mm diameter brass tube and the primer above it ignited. This was carried out for both primers at a range of distances between the primer and probe.

4. RESULTS AND DISCUSSION

Typical temperature/time profiles for both primers are shown in Figure 2. These were analysed to determine maximum temperature rise and the corresponding heat flux which was calculated using equation 1 assuming a steady state temperature rise. These results are shown in Table 2 and are the average of approximately five separate experiments at each distance.

The thickness of the copper plate was chosen as a compromise between a thin plate giving a high temperature and high thermal emf and a thick plate having low temperature and low thermal emf but being robust enough to withstand ejection of the primer anvil. Initial experiments showed a decrease in maximum probe temperature with increasing thickness as would be expected (Figure 3). However, it was also observed that less than approximately 0.20 mm thickness, the probe plate was easily damaged by the occasional ejection of the primer anvil with the M42 primers. Consequently a plate of 0.25 mm thickness was used for future experiments.

Measurements of the maximum probe temperature and its relationship with the distance from the primer are shown in Figure 4. This was obtained from the data in Table 2 using a least squares fitting technique. The maximum probe temperature over all distances is greater for the M42F1 gasless primers than for the M42 primers. Also, the difference between the probe temperature for both primers increases with distance from the primer.

The probe shows a similar maximum temperature for both primers at small distances (< 50 mm). This is most probably due to similar flame temperatures for both primers. Kelly [5] has reported a flame temperature of 2650°C for the M42 primer using a radiant energy technique whilst theoretical thermochemical calculations yield a value of 2830°C for the M42F1 gasless primer. As the distance between the probe and the primer increases, the ignition products cool down via heat transfer to their surroundings. Figure 4 confirms this behaviour for both the M42 and the M42F1 gasless primer.

Using the probe temperature data and equation 1, heat flux values were calculated (Table 2). Figure 5 shows a least squares fit of the probe heat flux with distance for both primers. This clearly shows a slightly different decrease in heat flux with distance for the two primers. At a distance less than 150 mm, both primers show similar heat flux values. Beyond 150 mm however the heat flux of the M42F1 gasless primer becomes significantly greater than for the M42 primer. The differences in the heat flux could be due to a number of factors. Firstly, the superior heat flux of the M42F1 gasless primer could be due to the greater temperature of its ignition products. Since the difference between the M42 and M42F1 ignition products temperature increases with distance, then the difference between the M42 and M42F1 heat flux will increase with distance. Secondly, the superior heat flux of the M42F1 gasless primer at larger distances may be due to simply more efficient heat transfer to the probe. Clearly, further analysis is required to determine whether the superior heat flux of the M42F1 gasless primer is due to its products temperature, more efficient heat transfer to the probe or a combination of both.

It should be noted that heat losses have been neglected in this analysis. The probe will loose heat from its surface by radiation and convection and through the thermocouple wires and the thermocouple lead at the rear surface of the probe by conduction. However, these losses will only be significant at long heating times, and at high temperatures. Since the maximum probe temperature is 23.4°C and the longest heating time is 100 ms, these temperature losses have been neglected. Heat will also be lost to the probe surroundings (outer brass tube and probe support). Although these may not be constant for both primers this assumption enables comparison of probe data to real ignition systems where different heat losses will be present for the two primers.

5. CONCLUSIONS

A simple heat flux probe has been developed and used to qualitatively compare the heat flux and temperature output of both a gassy (M42) and gasless (M42F1) percussion primer. Results show that the M42F1 gasless primer produces a greater heat flux and greater temperature output than the M42 primer indicating a larger thermal energy output.

6. REFERENCES

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4. Bentley, J. and Elischer, P., "Gasless Pyrotechnic Caps", Proc. 6th International Pyrotechnics Seminar, Colorado, 1978.

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TABLE 1

CHEMICAL COMPOSITION OF M42 AND M42F1 PRIMERS

COMPONENT	PERCENTAGE	
Boron (Amorphous)	9.5	
Lead Oxide	85.5	M42F1 Gasless Primer
Tetracene	5.0	
Barium Nitrate	22.0	
Antimony Sulphide	10.0	
Basic Lead Styphnate	53.0	M42 Gassy Primer
Tetracene	5.0	
Aluminium	10.0	

TABLE 2

THERMAL OUTPUT OF M42 AND M42F1 PRIMERS

	M42 Primer				M42F1 Primer			
Distance (mm)	$\frac{\partial Q}{\partial t}$ (Watts)	$\Delta T(^0C)$ $\bar{X}$	$\Delta T(^0C)$ σ	Heat Flux (Watts cm^{-2})	$\frac{\partial Q}{\partial t}$ (Watts)	$\Delta T(^0C)$ $\bar{X}$	$\Delta T(^0C)$ σ	Heat Flux (Watts cm^{-2})
50	64.0	19.0	1.4	12.6	34.2	23.4	1.3	6.8
75	8.3	7.5	1.0	1.6	25.0	12.4	0.3	4.9
100	22.4	7.0	1.0	4.4	15.3	7.5	0.8	3.0
150	5.8	3.0	0.3	1.2	10.0	6.0	1.0	2.0
200	2.3	0.7	0.04	0.5	6.9	2.4	0.2	1.4
300	1.0	0.5	0.05	0.2	5.4	1.0	0.1	1.1

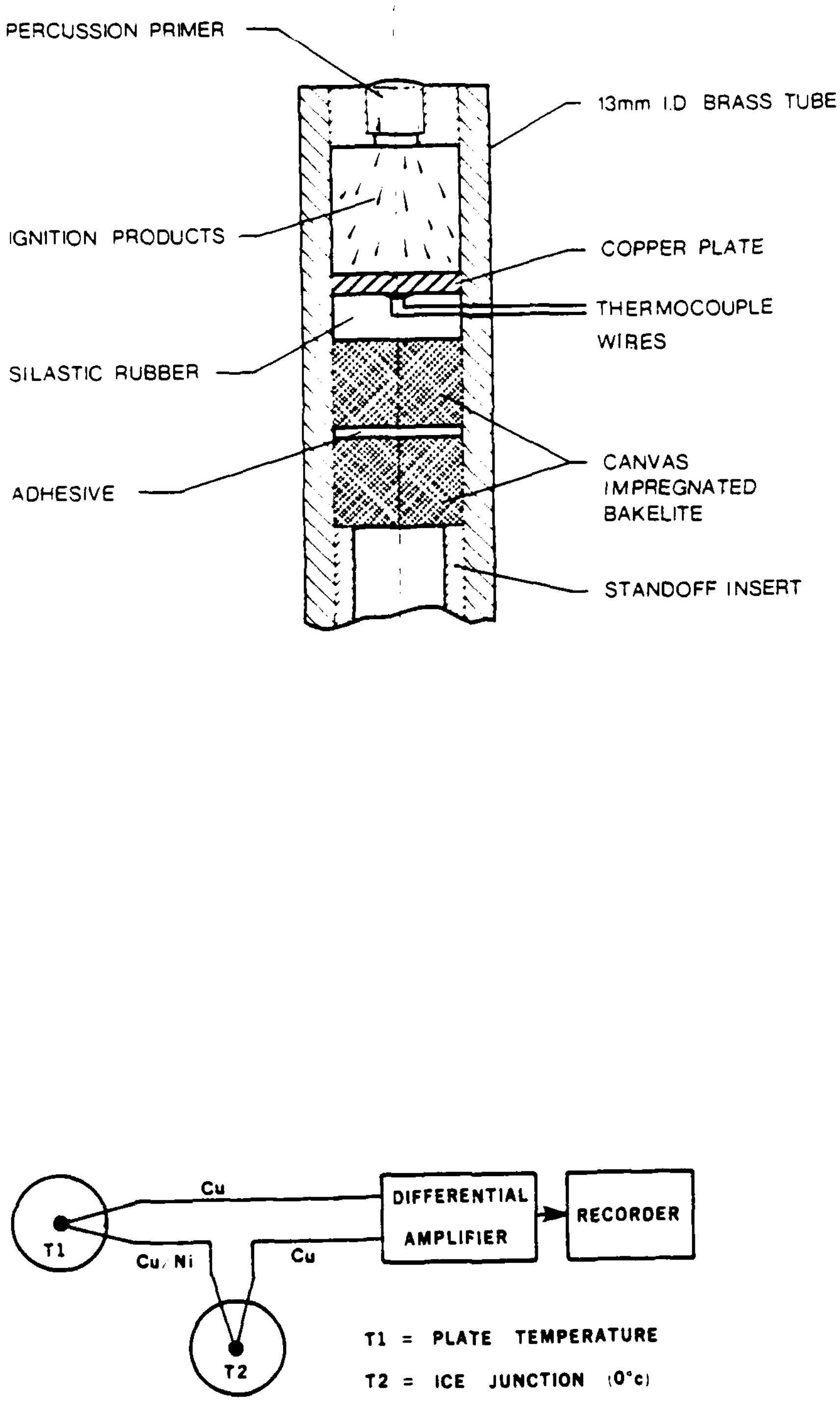

FIGURE 1. Heat flux measurement.

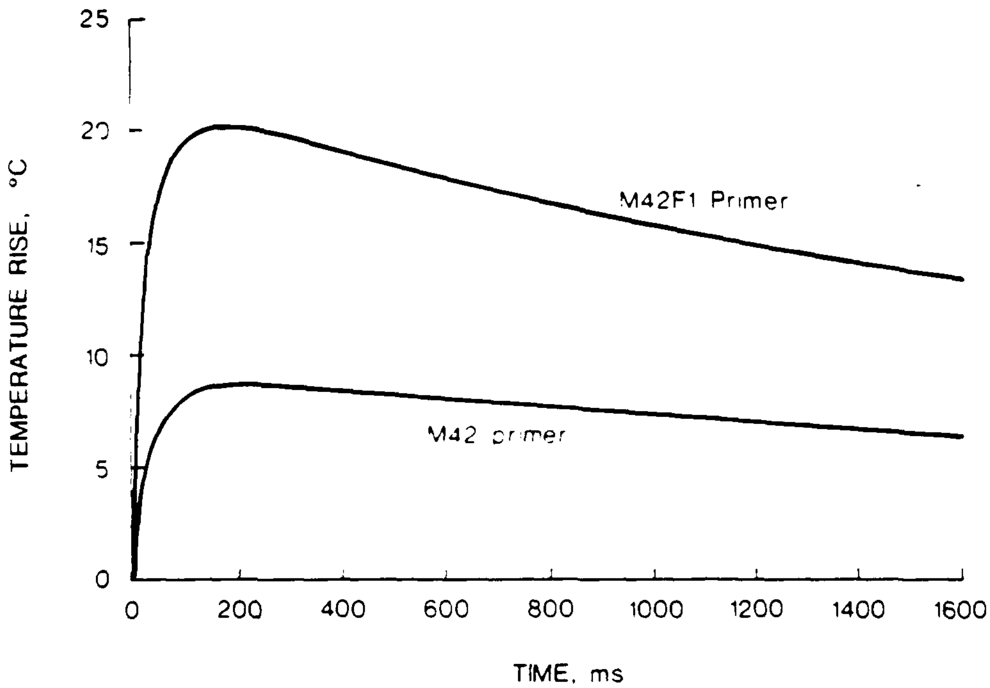

FIGURE 2. Heat flux probe temperature/time profiles.

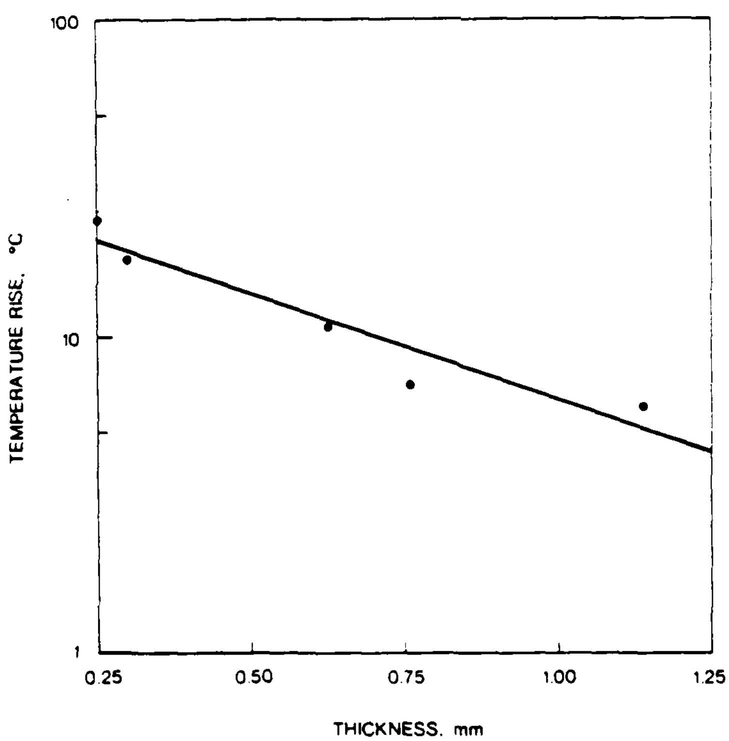

FIGURE 3. Temperature change with probe plate thickness.

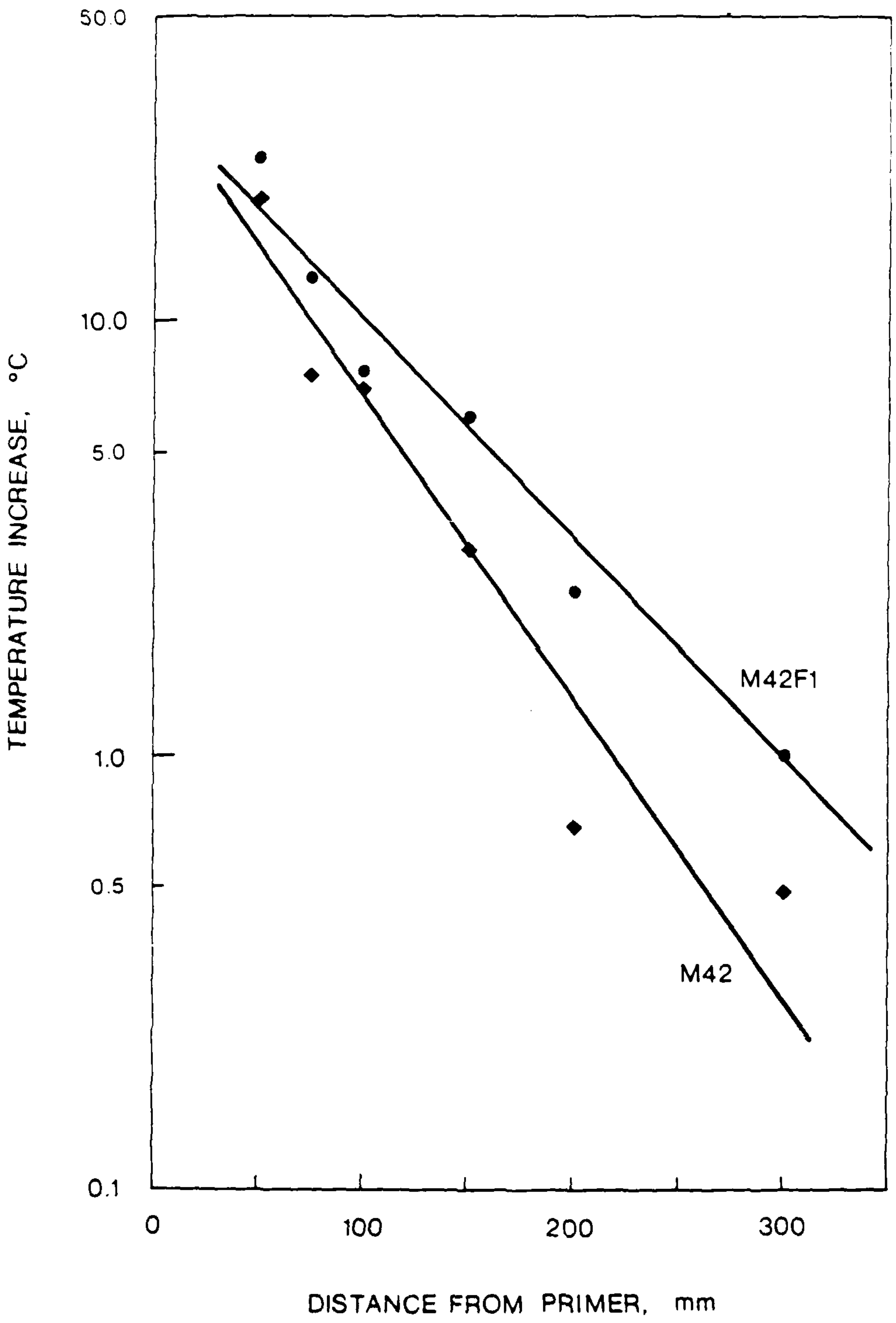

FIGURE 4. Temperature change with distance from primer.

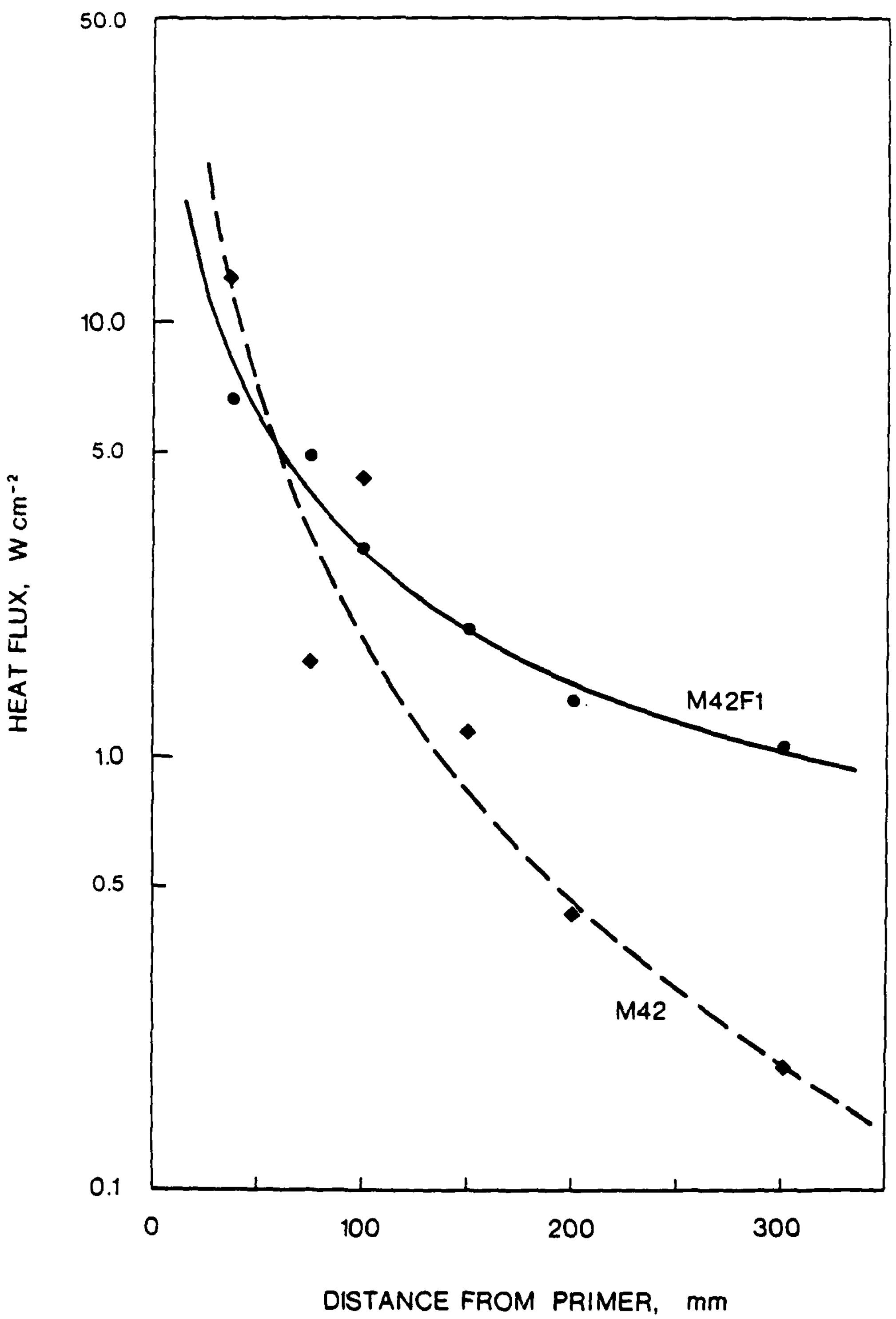

FIGURE 5. Variation in heat flux with distance from primer.