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NAVWEPS REPORT 7338

THE THERMAL BEHAVIOR OF EXPLOSIVES SUBJECTED TO SIMULATED AERODYNAMIC HEATING, II: DATB (U)

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28 FEBRUARY 1962

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U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NAVWEPS 7338

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CONFIDENTIAL

THE THERMAL BEHAVIOR OF EXPLOSIVES SUBJECTED TO SIMULATED AERODYNAMIC HEATING, II: DATB (U)

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ABSTRACT: Measurements were made of unidirectional heat flow, at rates up to 100°C per minute, into a two-dimensional analogue of a warhead filled with the explosive DATB (1, 3-Diamino-2, 4, 6-Trinitrobenzene). In this experimental arrangement, deflagration of DATB discs 2-cm thick and 12.7 to 17.8 cm in diameter, occurred when the hottest DATB layer reached 314°C (+ 10°C). No high order detonations occurred. Extrapolation of the data, obtained with initial warhead-exterior temperatures of 337°C to 450°C, leads to the prediction that such a DATB-filled warhead would ignite in about 9 seconds if caught in an oil fire.

Explosions Research Department
U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

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Explosive-filled missiles are now subjected to very severe skin-friction effects during increased flight time at supersonic speeds. The exposure to these effects may cause the explosive to attain its self-ignition temperature prior to achieving its mission. To prevent this, the explosive must be insulated, or the warhead must be loaded with an explosive capable of accepting such thermal exposures. Payload and missile design may in many instances force the omission of insulation. In these instances, it is therefore desirable to utilize explosives with superior temperature stability; one such explosive is 1, 3-Diamino- 2, 4, 6-Trinitrobenzene (DATB). This study was undertaken to gain a basic understanding of the reaction of this explosive to conditions simulating aerodynamic heating, and as such, it represents a continuation of similar studies with other explosives reported in the authors' previous publication, NAVORD Report 6216, "The Thermal Behavior of Explosives Subjected to Simulated Aerodynamic Heating, I (U)", dated 15 October 1959. The study was performed under WEPTASK No. RUME 3-E000/212 /F008 10 004, Problem Assignment 012, Explosive Properties, (formerly Task 301-664/43006/08040, Explosives Applied Research).

The data are believed to be essentially correct, but the conclusions and opinions expressed are those of the authors and may not necessarily represent the final opinion of the Laboratory.

The authors are especially indebted to Mr. Eugene H. Duck who gave careful assistance in the experimentation and thus made much of this work possible, and to Mr. Carl Brown for the precise machining of the test charges. Useful discussions with Dr. A. D. Solem, former Chief of this Division, are acknowledged.

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THE THERMAL BEHAVIOR OF EXPLOSIVES SUBJECTED TO SIMULATED AERODYNAMIC HEATING, II: DATB (U)

1. INTRODUCTION

1.1 The skin-heating of missiles and war planes during flights at supersonic speeds has put the explosive components in warheads to a severe thermal test. Experimental and theoretical data have been obtained (1, 2, 3) which place limits on the use of conventional explosives in these applications. These limitations could result in reducing the explosive load, limiting the capabilities of the warhead. To this end, the evaluation of the response of explosives to heating cycles corresponding to those experienced at supersonic flying speeds is an important research objective. This is the second report (4) of work done to obtain experimental data useful to the designers of warheads, especially continuous-rod warheads, that might be subjected to severe aerodynamic heating. This report will discuss the work done on an explosive that exhibits strong resistance to thermal shocks, DATB (1, 3-Diamino-2, 4, 6-Trinitrobenzene), whose properties, gleaned from References 5, 6, and 7, are tabulated for convenience in Table 1.

2. EXPERIMENTAL CONDITIONS

2.1 The Arrangement.

The present experiments were performed using the method previously described by the authors (4). In this method, a two-dimensional analogue to a steel-confined, cylindrical warhead was used in order to reduce the theoretical analysis to one-dimensional heat flow: the steel-cased warhead was "rolled out" to give a flat explosive slab lying on a flat steel plate. The experimental equivalent, therefore, was a steel disc 1-cm thick and 17.8-cm in diameter, which supported an explosive disc 2-cm thick and 17.8-cm (or in some tests, 12.7-cm) in diameter. During the experiment, the bottom of the steel plate was heated rapidly by lowering the assembly onto a massive brass block (Figure 1) preheated to the desired "initial forcing temperature". Heating of the steel disc at rates up to 100°C per minute could be obtained by this means. To preserve the brass block, a 1-cm thick, 18-cm diameter, replaceable copper disc was placed on the block in all of the experiments. (See Figure 2.)

One-dimensional heat flow in the temperature-monitored region was further assured by making the temperature measurements along the periphery of a 2.54-cm diameter test section at the center of the steel and explosive. Iron-constantan thermocouples of No. 30 gauge wire were imbedded in radial grooves (Figure 2) near the top surface of the replaceable copper disc, at the top and bottom surfaces of the steel, and at various depths within the explosive. (In contrast with our previous tests, thermocouple T_{E-1}, 1-mm within the explosive, had to be eliminated in most of the DATB tests because the deep groove needed for the thermocouple so weakened the sample disc that it fell apart.) After the thermocouples were imbedded in the grooves in the charges, loose explosive was packed into the cavity so that each thermocouple junction was in intimate contact with explosive.

2.2 The Explosive Charges.

Two explosives were tested: pure DATB, and DATB bonded with 5 per cent (by weight) of the phenolic resin BRL 2741*. The charges were formed by mechanical pressing, using normal pressing procedures in the case of the pure DATB charges. In producing the plastic-bonded charges, the molds were preheated to 90°C and the compressed charges were cured under pressure at this temperature for 15 minutes. The charges, formed to the desired diameter in the mold, were then cut to proper thickness and machined flat on both faces. All charges had densities of 98% of their theoretical maximum densities.

3. THE RESULTS

3.1 Summary of Observations.

Experiments were conducted with seven sample discs of DATB and two sample discs of DATB/BRL 2741 (95/5). The results of the experiments are summarized in Table II. In this table:

> The "cycle duration" was the time elapsed between the initial contact of the free steel surface with the heat source, and the deflagration of the sample**.
>
> The "initial forcing temperature" was the temperature recorded by the thermocouple T_{Cu} located in the shallow groove on the top

---

*Produced by the Bakelite Corporation, New York.

**Sample 1 was subjected to three thermal cycles, the first two of which were terminated before deflagration occurred. In these two cycles, the "cycle duration" was the time from the initial contact of the steel-explosive fixture with the heat source, to its removal from the heat source surface of the copper disc, immediately prior to the initial contact of the steel disc. The "final forcing temperature" was the temperature recorded by this thermocouple at the termination of the thermal cycle.

The temperature at the upper surface of the copper disc could not be maintained constant. At the time of contact a rapid drop in temperature of the disc occurred because of the large flux of heat into the steel explosive fixture. Then, as the steel and explosive warmed up, the flux of heat decreased and the temperature of the brass block tended to recover through its own heating system. The "mean forcing temperature" is the average temperature of the copper disc, as recorded by T_{Cu}, taken over the cycle duration.

The "final steel-wall temperature" was the temperature recorded by thermocouple T_{Cu-S} located in the groove on the bottom surface of the steel at the instant of ignition of the DATB (or at the termination of the first two cycles of the first sample).

The "final temperature of the steel-explosive interface" was recorded by thermocouple T_{S-E} located in a groove (1.6-mm wide and 1.6-mm deep) in the surface of the steel facing the explosive. Ignition of the explosive was indicated either by an abrupt termination of the recording for this thermocouple or by actual observation of flame through the bombproof window.

3.2 Tests with the Various Samples.

3.2.1 Sample No. 1 (DATB).

Three thermal cycles were imposed on the first DATB sample. Using an initial forcing temperature of 122°C, the temperature-time curves attained during the first thermal cycle are shown in Figure 3. The test was terminated after 600 seconds, at which time the maximum temperature experienced by any of the explosive was 96.5°C (the temperature indicated by thermocouple T_{S-E}). The other thermocouples imbedded in the explosive indicated smooth temperature increases; for example, thermocouple T_{E-8}, located 8-mm from the steel-explosive interface, rose almost linearly from its initial temperature of 13°C, to 45°C at the end of the test.

Visual examination of the recovered sample indicated no obvious damage to the test explosive disc. Accordingly, the sample was subjected the next day to a second thermal cycle, this time with an initial forcing temperature of 309°C (Figure 4). This test was terminated after 354 seconds in order to preserve the sample for a possible third cycle. The maximum explosive temperature attained at that time was 217°C, while the temperature 8-mm within the explosive was 60°C, 43 degrees above the initial temperature of the sample. Again, a visual examination of the test explosive showed no damage.

The third cycle was therefore imposed, using an initial forcing temperature of 400°C, Figure 5. Placing the steel-explosive system on the heat-transfer block caused the temperature of the copper disc (i.e., the forcing temperature) to drop to 310°C within 2 minutes, after which it slowly rose to 360°C by the end of the test. These observations correlate with the fact that the temperature rise in the steel wall began at a rate exceeding 200°C per minute, but, as heat flowed into the DATB this rate of temperature rise naturally decreased. Although the temperature at the steel-explosive interface was 306°C when the explosive ignited 548 seconds after the test began, the temperature was only 200°C in the explosive layer 4-mm from the interface. This difference of temperatures clearly demonstrates the ability of relatively thin layers of insulation to retard significantly, the flow of heat into the explosive.

Although this sample received two thermal cycles before being forced to deflagrate on its third cycle, the temperature of ignition, 306°C, agrees within experimental error (Table I) with the ignition temperature obtained for other samples directly heated to deflagration on the first cycle. The agreement indicates that moderately severe thermal cycling produces no significant changes in the ignition temperature of DATB (at least to the extent of these tests).

3.2.2 Sample No. 2 (DATB).

Figure 6 shows the temperature-time profiles for the direct deflagration of a 12.7-cm diameter sample using an initial forcing temperature of 446°C. Ignition of the sample occurred when the steel-explosive interface temperature reached 317°C. It is of interest that, for times beyond about

200 seconds after heating started, thermocouple T_{E-1} (located within the explosive, 1-mm from the steel-explosive interface), recorded a rising temperature of a type that indicated self-heating of the explosive. This evidence of relatively slow self-heating persisted some 100 seconds before a "run-away" occurred, at which time the steel-explosive interface temperature reached 317°C. On subsequent tests, evidence of such self-heating was observed in nearly all cases where the initial forcing temperature exceeded 400°C.

3.2.3 Sample No. 3 (DATB).

Self-heating was again seen in the temperature-time profiles for sample 3 (Figure 7). This sample ignited after 243 seconds under an initial forcing temperature of 500°C. Thermocouple T_{S-E}, at the steel-explosive interface, recorded 340°C when thermocouple T_{E-2} first responded to explosive self-heating (after 190 seconds), and finally 349°C when the sample ignited. This final interface temperature was some 25 degrees higher than that recorded for the other six DATB samples. No reason is known for this discrepancy. An explanation would be possible if one assumes a small air space between the explosive and steel due, for instance, to warping of the charge.

3.2.4 Sample No. 4 (DATB).

An initial forcing temperature of 354°C was used to deflagrate the fourth sample. This temperature dropped to 270°C within 2 minutes, after which it slowly increased, exceeding 320°C after about 15 minutes. Because of these relatively low temperatures, several "peculiarities" were observed in the heating curves (Figure 8). The temperature 2-mm within the explosive, recorded by thermocouple T_{E-2}, exceeded the temperature of the copper-steel interface, T_{Cu-S}, after about 1100 seconds. The relatively smooth temperature rise at T_{E-2} indicates that a fairly large amount of heat was being generated for a long time, in a smooth and reasonably gentle process. Only when significant amounts of the explosive experienced temperatures in the region of 320°C did ignition occur. Smoke was generated, beginning at about 1200 seconds, when T_{E-2} indicated a temperature of about 306°C. Full ignition (with flame) was observed at 1700 seconds when T_{E-2} recorded a temperature of 331°C. All of these observations were compatible with the idea of a destructive distillation going on, in which the amount of energy evolved per unit time was too small to cause a "run away" until temperatures of about 320°C were reached.

3.2.5 Sample No. 5 (DATB).

Sample No. 5 was subjected to an initial forcing temperature of 450°C and it ignited after 340 seconds when the steel-explosive interface temperature reached 316°C (Figure 9). (Sample No. 5 had a diameter of 17.8-cm while all previous samples had diameters of 12.7-cm.) The ignition temperature and ignition time for Sample No. 5 compare favorably with the ignition temperature, 317°C, and the ignition time, 307 seconds, of Sample No. 2 subjected to an initial forcing temperature of 446°C. These data demonstrate that the experiment was yielding data of reasonable reproducibility.

3.2.6 Sample No. 6 (DATB).

Sample No. 6, also 17.8-cm in diameter, ignited after 208 seconds under an initial forcing temperature of 550°C (Figure 10). The final steel-explosive interface temperature recorded at ignition was 325°C. This sample also exhibited some self-heating, as indicated by the behavior of thermocouple T_{E-3} which recorded an excessive temperature rise 20 seconds prior to ignition.

3.2.7 Sample No. 7 (DATB).

Sample No. 7 was also subjected to an initial forcing temperature of 550°C; it ignited in 188 seconds (Figure 11), some 20 seconds sooner than sample No. 6. The steel-explosive interface temperature recorded at ignition of sample No. 7 was 320°C, as compared to 325°C for sample No. 6. Sample No. 7 also exhibited pronounced self-heating as shown by the recording of thermocouple T_{E-6} imbedded in the explosive six millimeters from the steel-explosive interface. The temperature in this layer rose abruptly from 90°C to 210°C, 18 seconds prior to ignition of the sample.

3.2.8 Samples No. 8 and 9 (DATB/BRL 2741 (95/5)).

Two samples of DATB, plastic-bonded with 5 per cent by weight of BRL 2741, were driven to ignition using a forcing temperature of 450°C (Figures 12 and 13). Each sample lasted 600 seconds before deflagrating, or nearly 300 seconds longer than pure DATB tested under the same conditions. (Samples No. 2 and 5, shown in Figures 6 and 9.) In each of these tests the samples began to smoke heavily when the steel-explosive interface temperature reached 300°C; however, no flames appeared until the steel-explosive interface temperature reached

363°C (± 3°C). When ignition did occur, the temperature in the 2-mm thick explosive layer was nearly 150°C less than the steel-explosive interface temperature. These results indicate that:

> The ignition began on the surface of explosive.
>
> A 2-mm thick layer of the plastic-bonded explosive has considerable insulating value.
>
> Addition of the thermo-setting plastic binder to DATB substantially increased the resistance of the explosive to flame and deflagration.

4. DISCUSSION

4.1 Ignition Temperature of DATB.

If one can identify the Final Steel-Explosive Interface Temperature as the highest temperature reached by any mass element of explosive, then Figures 5 through 11 show that DATB will ignite when some portion of the explosive experiences a temperature of 314°C (± about 10°C). (The one exception, (Figure 7) where this final temperature reached 349°C, is believed to have been caused by a slight warping of the explosive sample.) Using essentially steady-state, equilibrium conditions in their determination, Loftus and Gross (8) found that DATB ignited rapidly when thermocouples within the explosive recorded 295°C.

It is believed that these two sets of data can be reconciled as follows:

> The present measurements represent a non-equilibrium, forced-heating situation. If self-heating plays a significant role in the development of ignition then the more rapid heating of the sample, the smaller the role of self-heating, and consequently, the higher the (maximum) temperature of the explosive at the moment of ignition. This fact is demonstrated in Figure 14, where both the Final Steel-Wall Temperature and the Final Forcing Temperature are plotted against the Final Steel-Explosive Interface Temperature. Now, if the experimental conditions had been set so that the temperature rise was sufficiently gradual, that an essentially constant temperature existed at any one time, then the "Temperature Equilibrium Line" in Figure 14 would describe

the temperatures of all components of the experimental set-up. But, under the vigorous heating conditions actually used, a severe thermal gradient existed, such that self-heating of the explosive became an important parameter. Thus, at higher forcing temperatures, the self-heating of the explosive did not become significant until the last few seconds, so that the explosive did not ignite until significant amounts had reached higher temperatures than were attained at lower forcing temperatures.*

If one plots the Final Forcing Temperature against the highest temperature reached by the explosive (i.e., Final Steel-Explosive Interface Temperature) this dependence on self-heating is seen clearly. Extrapolation of this curve to where it intersects the Temperature Equilibrium Line then gives an estimate of the ignition temperature of DATB under conditions where the entire explosive sample is heated very slowly. In Figure 14, this temperature is seen to be 293°C. Similar reasoning applies to the Final Steel-Wall Temperature curve in Figure 14; it intersects the Temperature Equilibrium Line at a temperature of 298°C. These two values, bracketing the 295°C reported by Loftus and Gross, lend support to this value for the ignition temperature of DATB under conditions of slowly rising temperatures.

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*It is to be noted that the "temperature" recorded by even a small thermocouple is nevertheless a kind of an average temperature over a finite volume of the explosive in which it is immersed. Local temperatures within this volume ("hot spots") could readily exceed this mean value. Rapid heating of this entire volume apparently permits the attainment of a higher average temperature before one or more of these hot spots "runs away" exponentially. Conversely, slower heating (as in the case of essentially-"equilibrium" heating of the sample) gives more time, and hence increased probability, for one of the hot spots to develop into a deflagration before the average temperature of the volume element reaches the value attained in the case of the more rapid heating.

(These results show that the term "Ignition Temperature" of an explosive is meaningful only when the precise experimental conditions are cited. Thus, in our own case, we cite the "Ignition Temperature" as 314°C ± 10°C. Figure 15 shows that the upper bound applies to the more rapid heat input, and the lower bound applies to rapid, but slower input. For more gentle heating cycles, ignition temperatures approaching 295°C might be more accurate.)

4.2 Relationship Between Mean Forcing Temperature and Ignition Time for DATB.

Under conditions of our experiments, the logarithm of the time required for ignition of DATB appears to be simply related to the reciprocal of the mean forcing temperature, Figure 15:

$$\log_{10} t = -0.09113 + \frac{1.716}{T} \times 10^3$$

where t is in seconds, and T is the mean forcing temperature in degrees Kelvin. While this relationship was derived from data obtained at mean forcing temperatures between 337°C and only 450°C, it is of interest to extrapolate these data to estimated temperatures within an oil fire (1500 - 2000°K). The equation predicts an ignition time of about 9 (± 2)seconds in such an environment. (In view of the long extrapolation and the uncertain nature of the heat-transfer characteristics within such an oil fire this predicted time could be in error by a factor of as much as two or three.) For temperatures associated with aerodynamic heating, say from 330°C to 500°C, it is believed that reasonable estimates of ignition times (for our test geometry) are obtained from this formula. For mean forcing temperatures between 500°C and 1,000°C, a decreasing reliance should be placed on the predictions it makes.

At temperatures below 330°C the time-to-ignition does not fit the above formula. We ran one test at a mean forcing temperature of 318°C (Figure 8). After about 1200 seconds on the heating block, the DATB began to give off significant amounts of yellowish-black fumes. The test was continued for another 500 seconds while more fumes continued to evolve, now with occasional, small flashes of fire. At this point, the test was terminated, as the actual experimental conditions were no longer precisely known. It was concluded that at "about 1700" seconds the DATB disc was more or less destroying itself by decomposition and sublimation. In Figure 15 this uncertainty is expressed by plotting this point as a long rectangle instead of a small circle. Similarly, Rosen's thermal stability data (9) would imply that at 280°C some 100 minutes would see the destruction of a DATB disc, and a rectangle was drawn accordingly.

Some liberties were taken in drawing the two straight lines in Figure 15, as if they described two distinct thermal domains. It is considered more likely that there is a continuous curve connecting the two regions such that time tends toward "infinity" more rapidly than indicated in Figure 15, as the temperature decreases. Similarly, on the other end of the curve, time may not decrease as rapidly as indicated, as temperature of an oil fire gave a lower limit of the time, and that such an actual experiment would yield times two or three times greater than the predicted 9 seconds.

4.3 Effect of Plastic Binders.

The addition of 5 per cent BRL 2741, forming a plastic-bonded composition, permitted the explosive to withstand an initial forcing temperature of 450°C for about twice as long as the plain 100 per cent DATB. While it would be tempting to accept this at face value, some caution must be exercised before doing so. The Final-Steel-Explosive Interface Temperatures in the two duplicate tests were 360°C and 366°C, some 50°C more than was required to ignite pure DATB. It is to be noted that this temperature is recorded by the thermocouple placed within the steel disc: any warping of the explosive disc, producing a thin insulating layer of air between the explosive and steel discs, would give rise to a spurious, high temperature and an equally spurious, long time to ignition. These results should be confirmed in a geometry not susceptible to such a defect, perhaps one with cylindrical symmetry.

5. CONCLUSIONS

Under conditions of rapid heating, ignition of DATB in a steel-cased warhead will begin when the steel-explosive interface reaches 314°C (+ 10°C) (The addition of an insulator only 1 or 2-mm thick between the steel and the explosive would therefore "buy" several more minutes of flight time under conditions simulated by these experiments.)

Ignition begins at the steel explosive interface, even though the interior of the explosive is still relatively cool.

Within the limits of the small number of tests made, it is concluded that the line ignition temperature of DATB is unaffected by several thermal cycles, provided none of the DATB experiences temperatures near the ignition temperature.

The equation

$$\log_{10} t = -0.09113 + \frac{1.716}{T} \times 10^3$$

where t is in seconds, and T is the mean forcing temperature in degrees Kelvin, relates the ignition-time, temperature data for a DATB-filled warhead having a 1-cm thick steel case, under conditions of rapid heating. If the warhead is immersed in an oil fire this equation predicts an ignition time of about 9 seconds.

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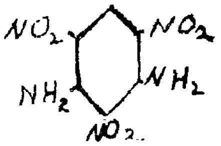
TABLE I

Chemical, Physical, and Detonation Properties of DATB

Formula



Molecular Weight	243
Melting Point	290°C
Vacuum Thermal Stability	100°C-no gas evolution 260°C-2.1 cc/g/hr
Ignition Temp.	315°C
Specific Heat	.261 cal/g-deg °C
Heat of Combustion	705.91±0.09 K cal/mole
Heat of Formation	29.23±0.09 K cal/mole
Activation Energy	37.0 K cal/mole
Thermal Conductivity	6.19×10^{-4} cal/sec cm°C
Co-efficient of Linear Expansion . .	52×10^{-6} cm/cm/°C
Crystal Density	1.837 g/cm^3
Detonation Velocity (D) (ρ = 1.80 g/cm^3).	7600 m/sec
$\frac{dD}{d\rho}$	2852 $\frac{m/sec}{g/cm^3}$
Detonation Failure Diameter . . .	0.53 cm
Detonation Pressure (ρ = 1.80 g/cm^3). . .	251 Kb
Detonation Energy	800 cal/g
Isentropic Exponent (k).	3.1
Plate-Push Value (TNT=2930 ft/sec) . .	3130 ft/sec
50% Impact Hammer Height (NOL) . . .	>320 cm

TABLE II

Summary of Experimental Data

Sample No.	Figure No.	Explosive	Cycle Duration (sec)	Temperature (°C)			Temp. (°C)		
				Initial (sample)	Initial Forcing	Mean Forcing	Final Forcing	Final Steel Wall	Final Steel HE Interface
1	3	DATB	600	13	122	105	108	98	96.5**
1	4	"	354	17	309	260	275	220	217 **
1	5	"	548	17	400	337	360	312	306
2	6	"	307	24	446	388	400	328	317
3	7	"	243	32	500	425	444	355	349
4	8	"	1700	27	354	318	338	305	302
5	9	"	340	27	450	376	412	328	316
6	10	"	208	30	550	450	447	337	325
7	11	"	188	23	550	450	436	330	320
1	12	*	600	20	450	405	420	370	360
2	13	*	600	20	452	405	422	370	366

* DATB/BRL 2741 (95/5)

**Sample not brought to deflagration. All other tests terminated on deflagration of sample.

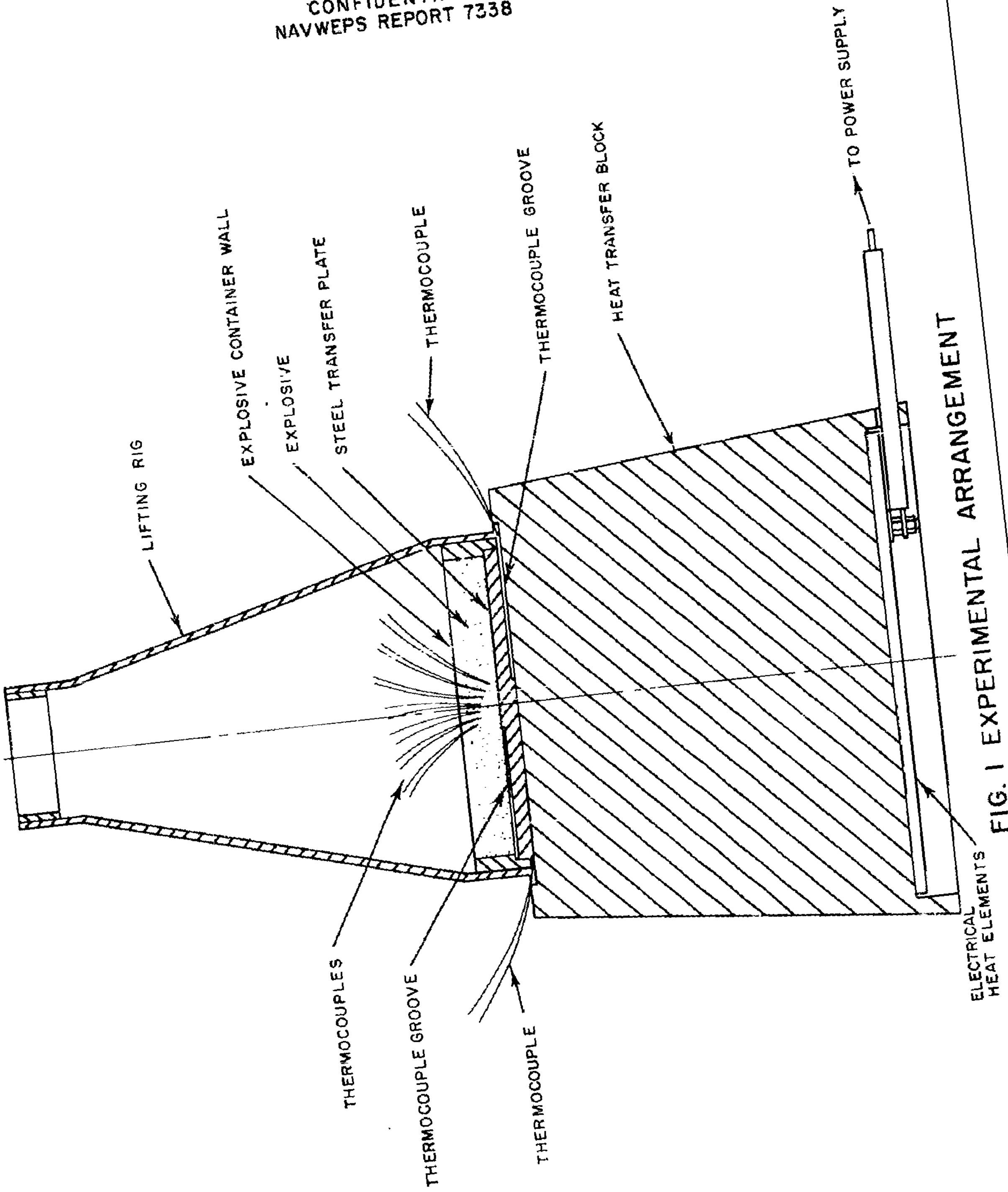


FIG. I EXPERIMENTAL ARRANGEMENT

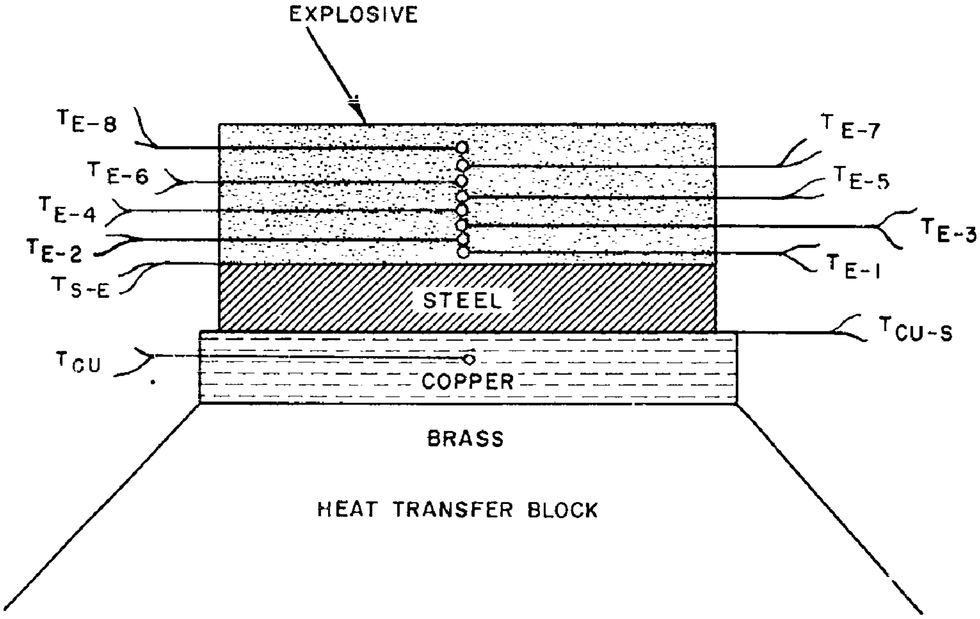


FIG. 2 THERMOCOUPLE DESIGNATIONS

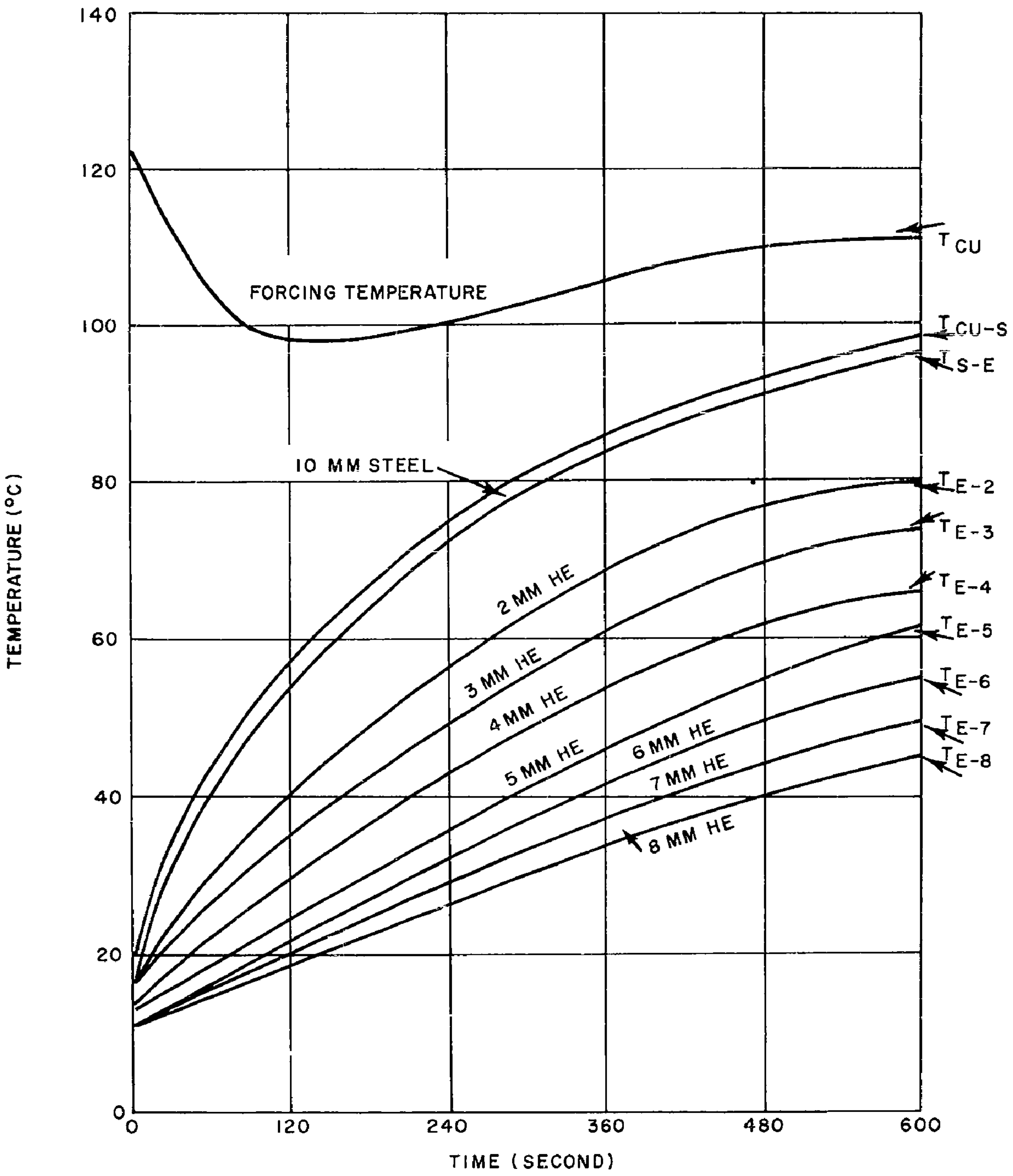


FIG. 3 SAMPLE 1, FIRST THERMAL CYCLE. INITIAL FORCING TEMPERATURE, 122°C.

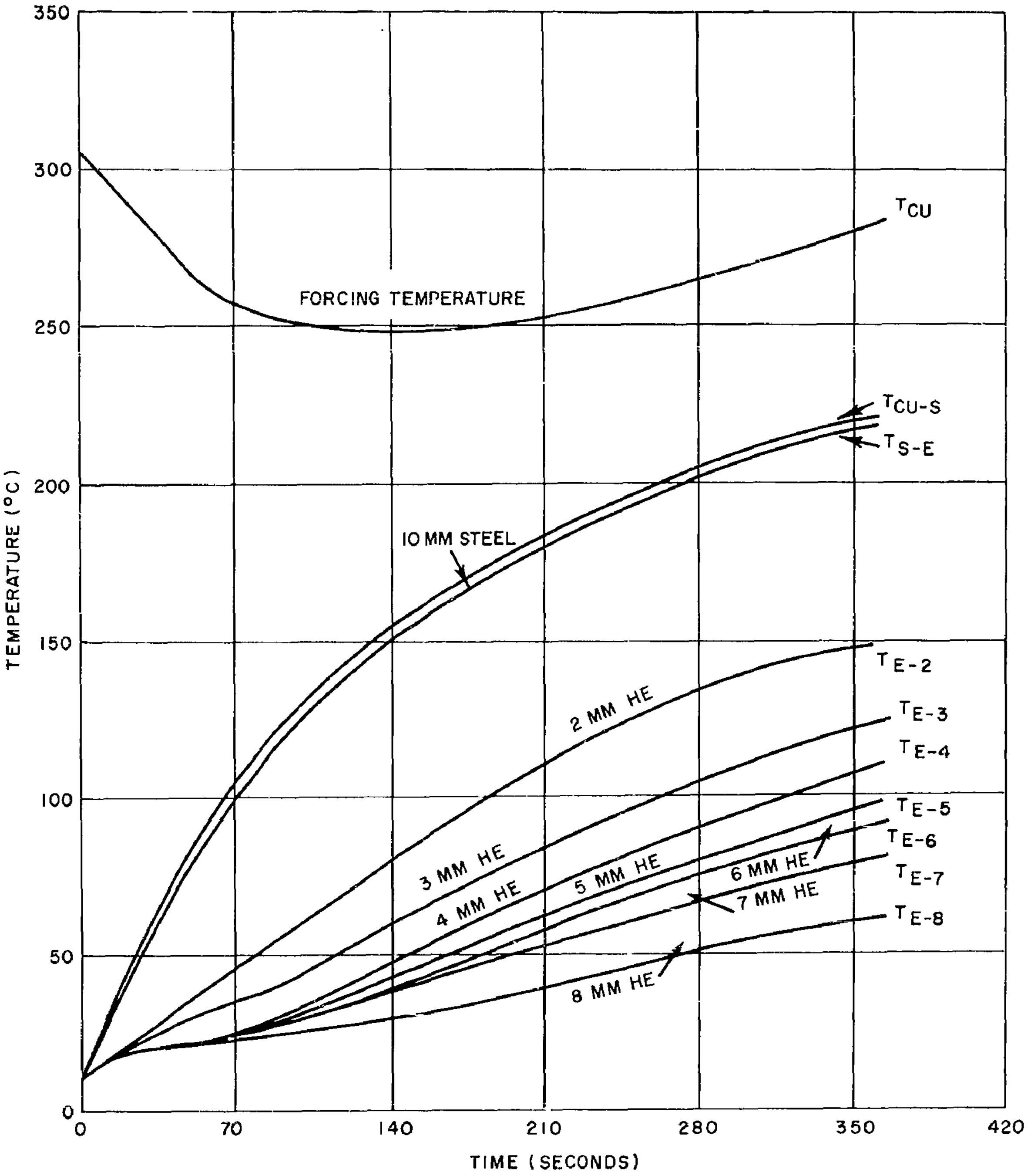


FIG. 4 SAMPLE 1, SECOND THERMAL CYCLE.
INITIAL FORCING TEMPERATURE, 309°C.

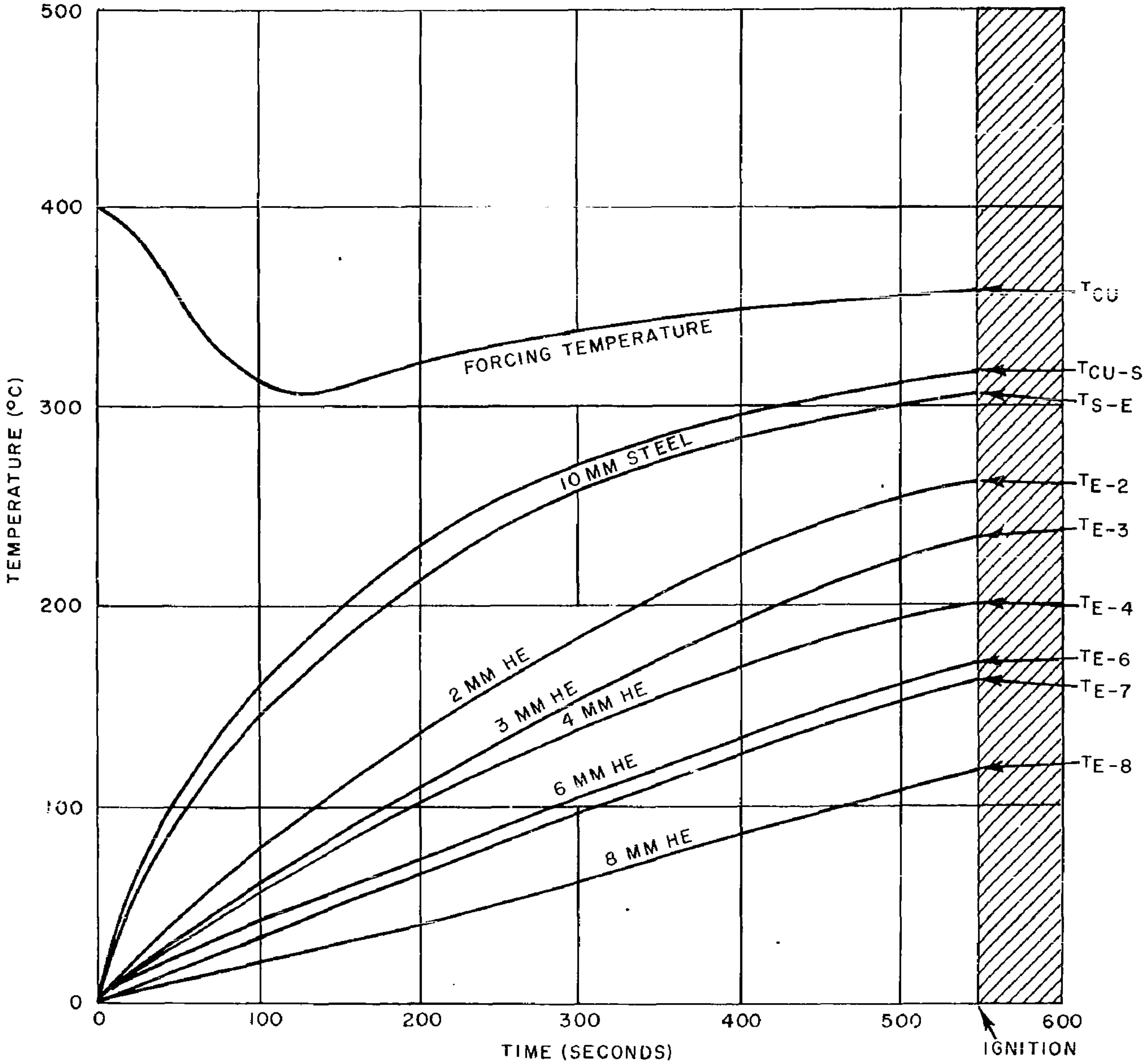


FIG. 5 DEFLAGRATION OF SAMPLE I, THIRD THERMAL CYCLE. INITIAL FORCING TEMPERATURE, 400° C.

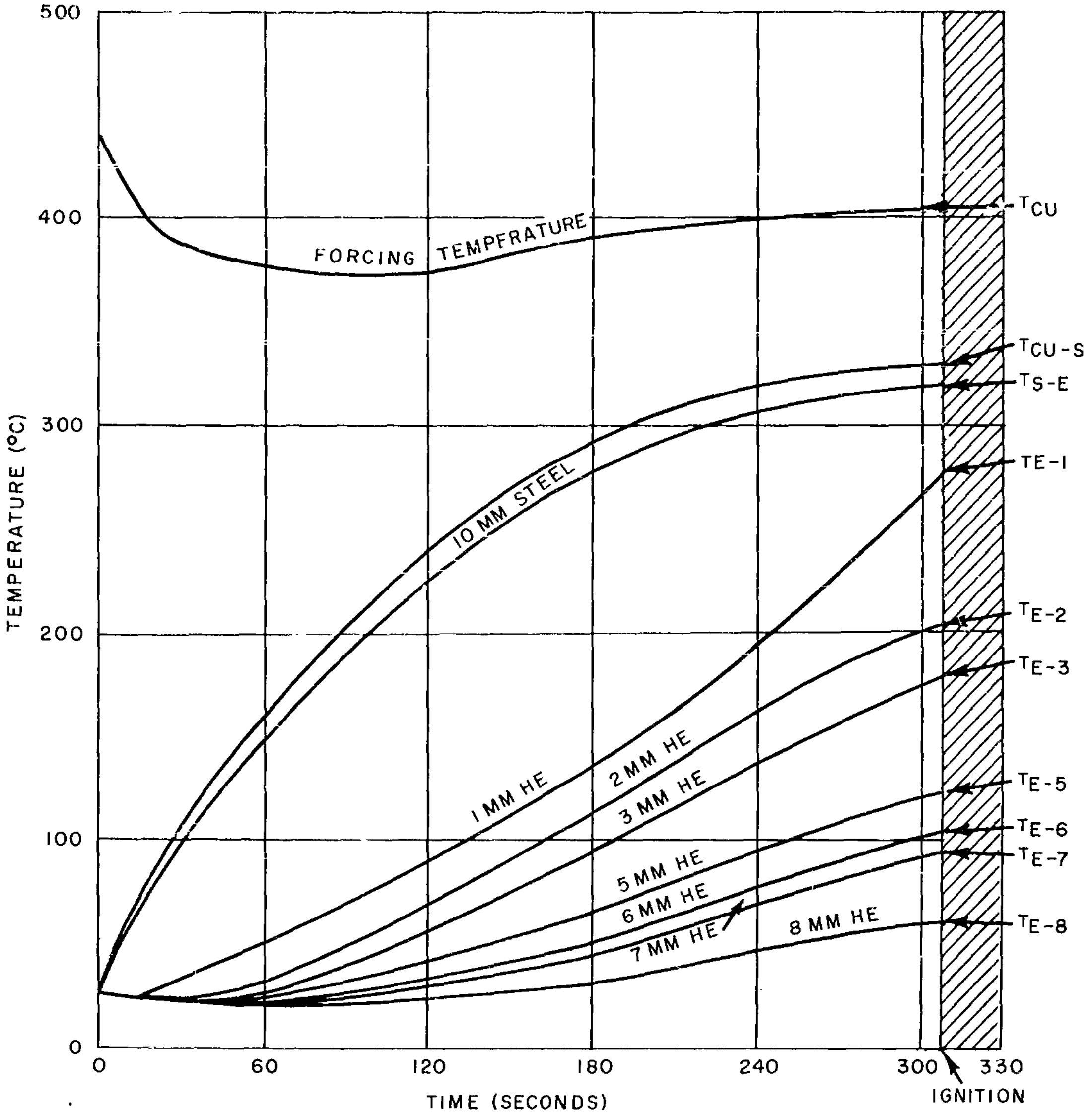


FIG. 6 DEFLAGRATION OF SAMPLE 2, FIRST THERMAL CYCLE. INITIAL FORCING TEMPERATURE, 446 °C.

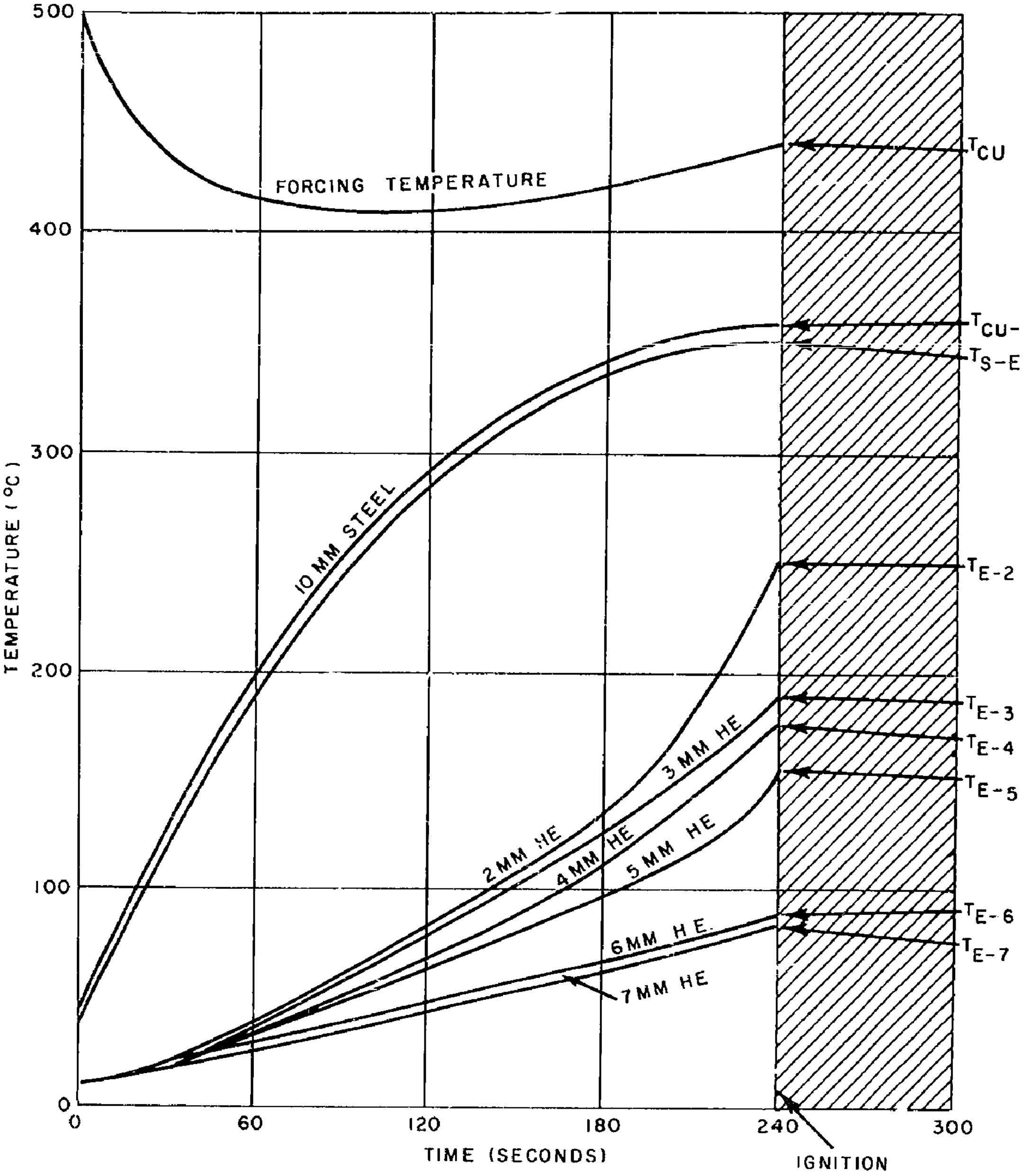


FIG. 7 DEFLAGRATION OF SAMPLE 3, FIRST THERMAL CYCLE. INITIAL FORCING TEMPERATURE, 500 °C.

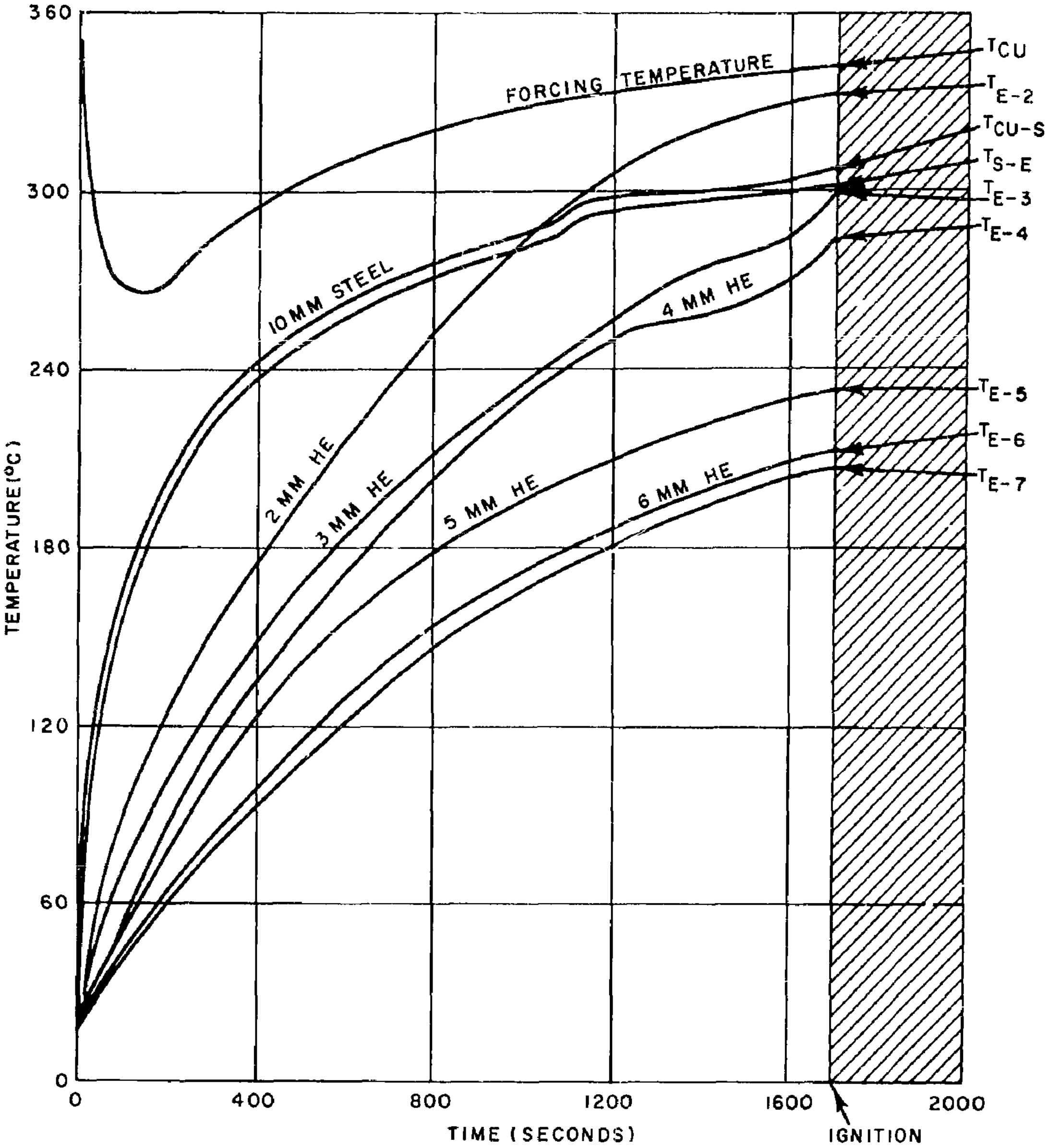


FIG. 8 DEFLAGRATION OF SAMPLE 4, FIRST THERMAL CYCLE. INITIAL FORCING TEMPERATURE, 354 °C.

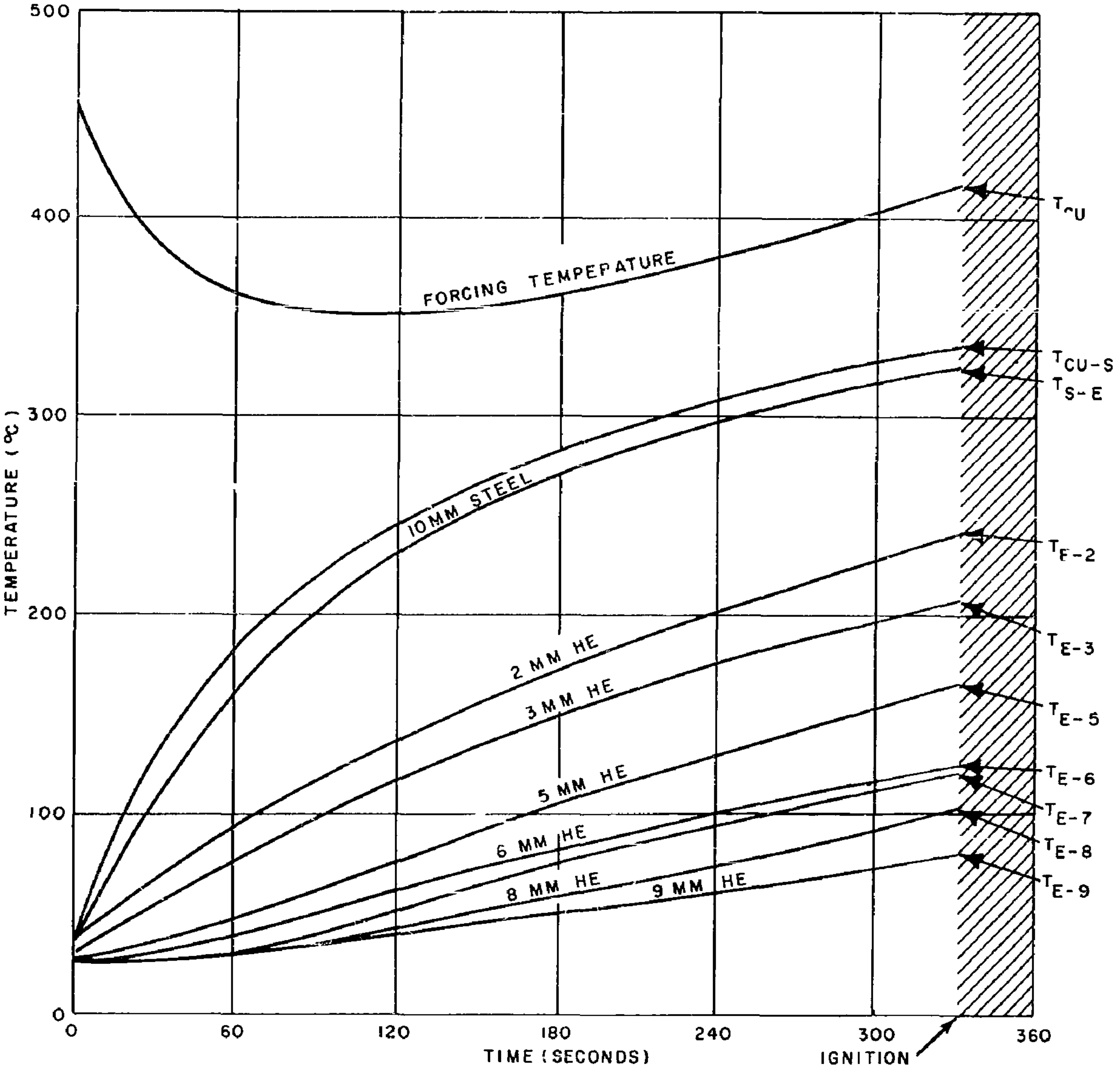


FIG. 9 DEFLAGRATION OF SAMPLE 5, FIRST THERMAL CYCLE. INITIAL FORCING TEMPERATURE, 450 °C.

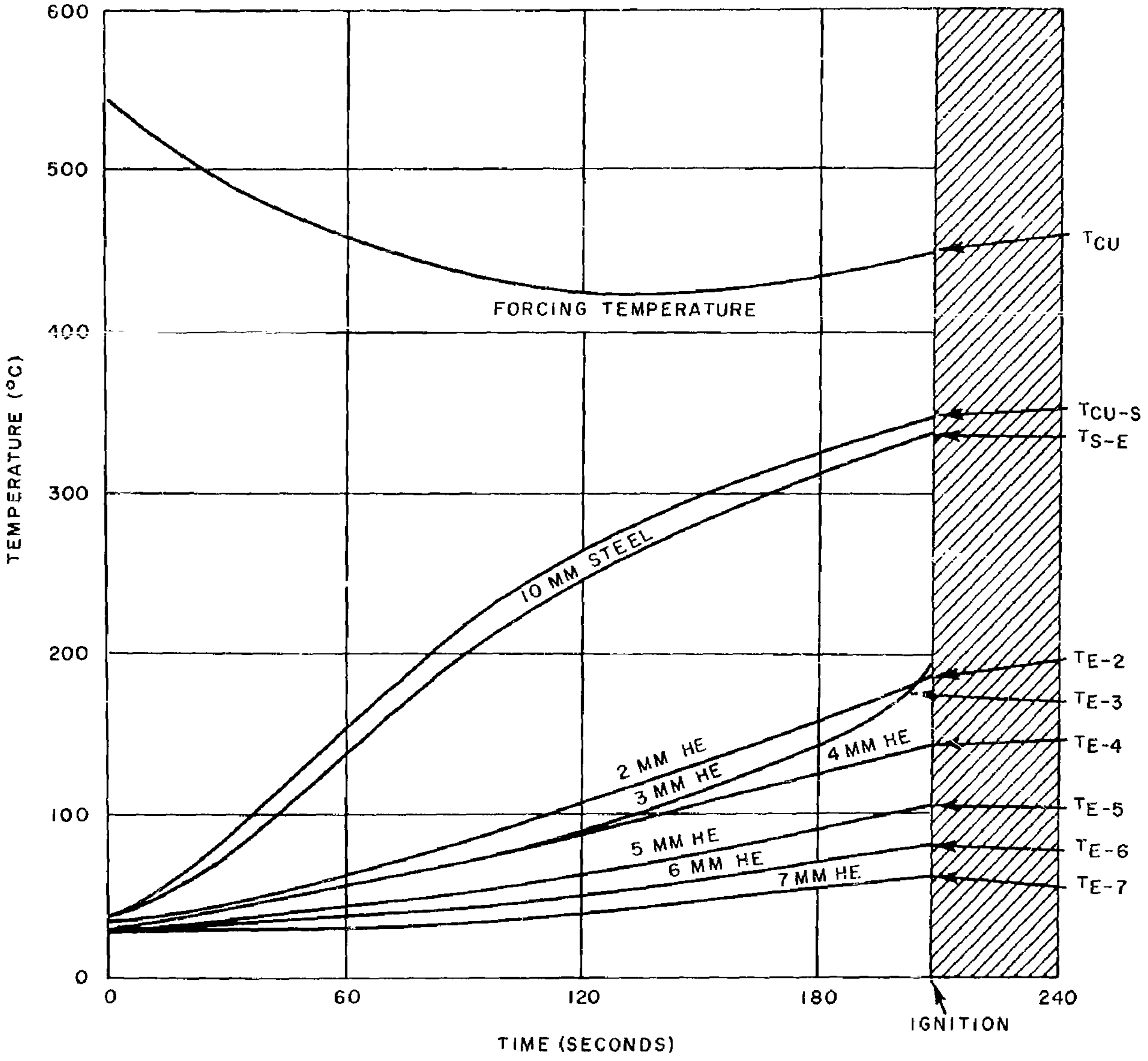


FIG.10 DEFLAGRATION OF SAMPLE 6, FIRST THERMAL CYCLE.
INITIAL FORCING TEMPERATURE, 550°C.

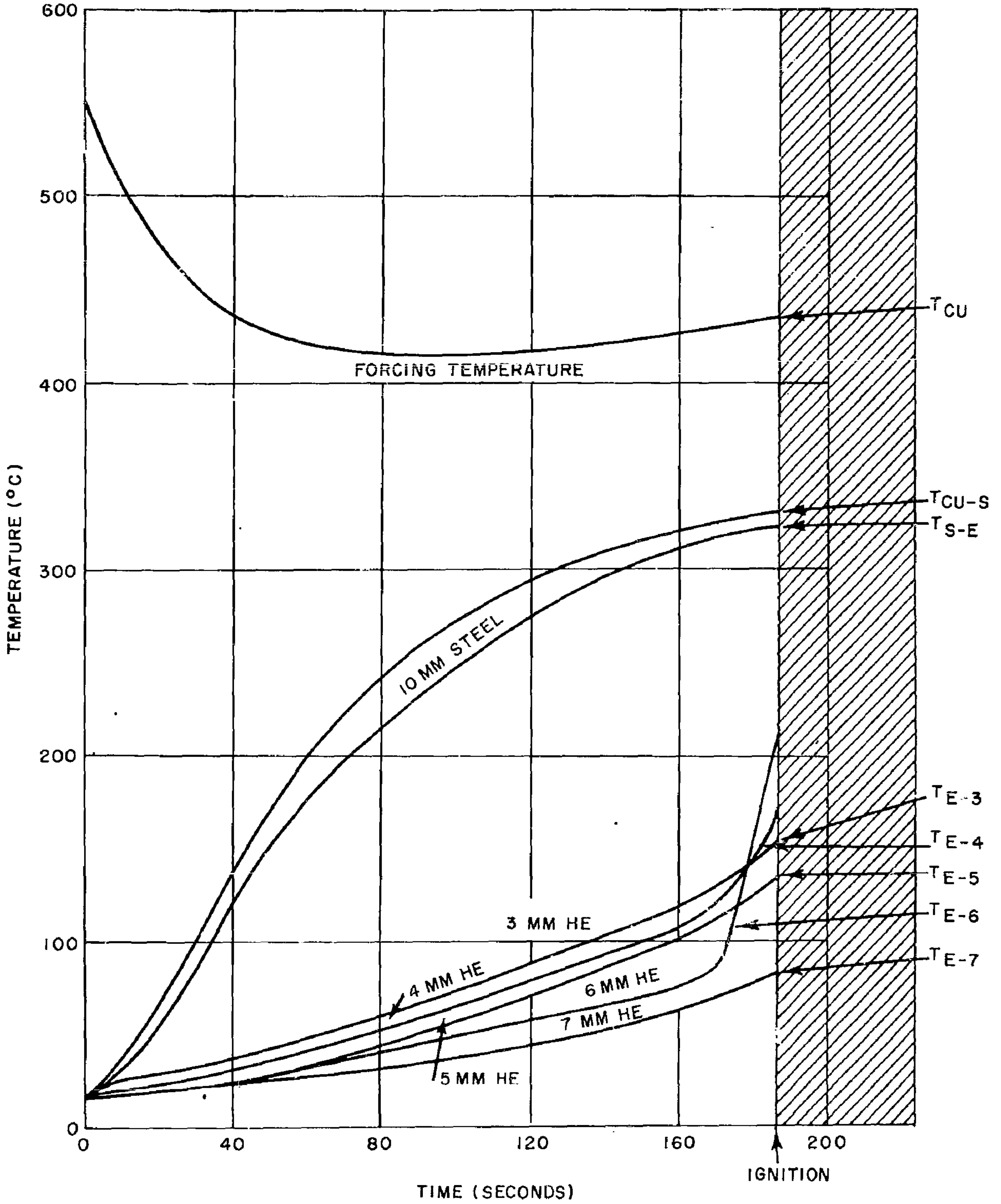


FIG. 11 DEFLAGRATION OF SAMPLE 7. FIRST THERMAL CYCLE. INITIAL FORCING TEMPERATURE, 550°C.

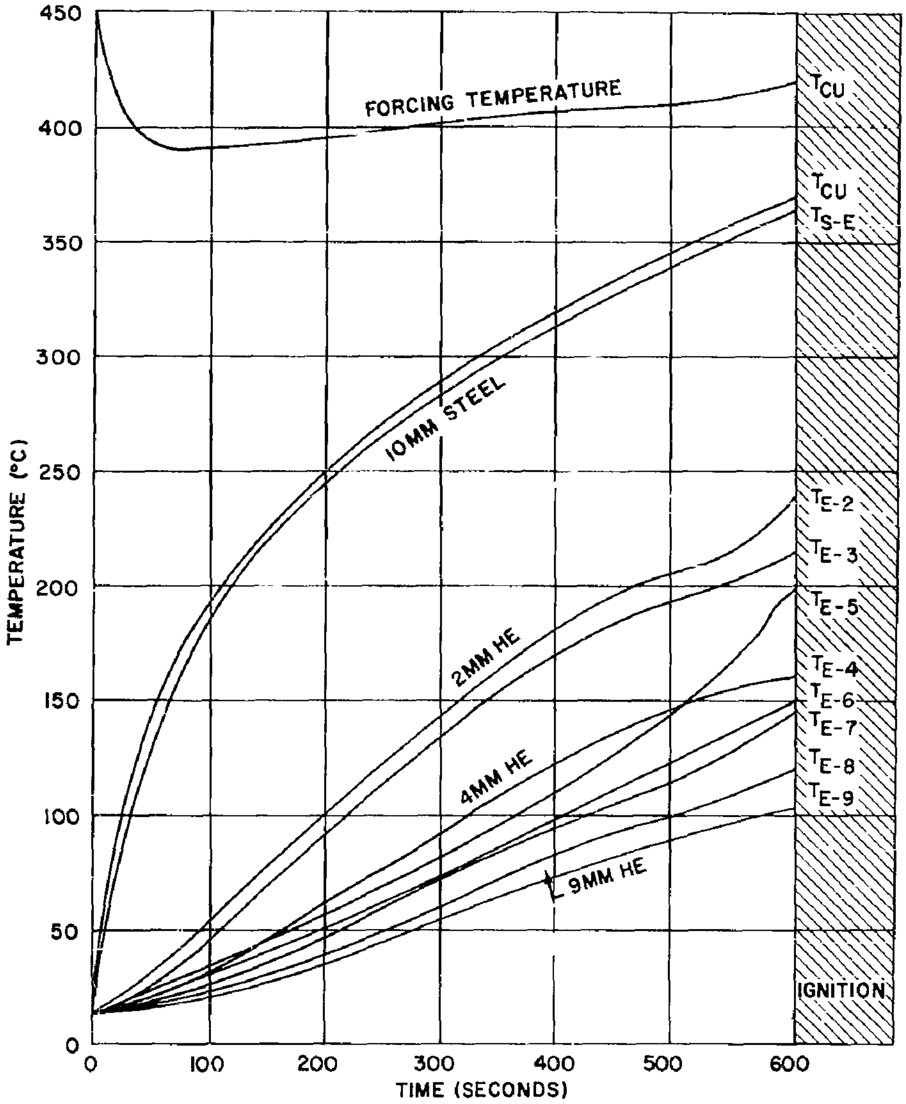


FIG. 12 DATB/BRL. 2741 (95/5), DEFLAGRATION OF SAMPLE I.
INITIAL FORCING TEMPERATURE, 450°C.

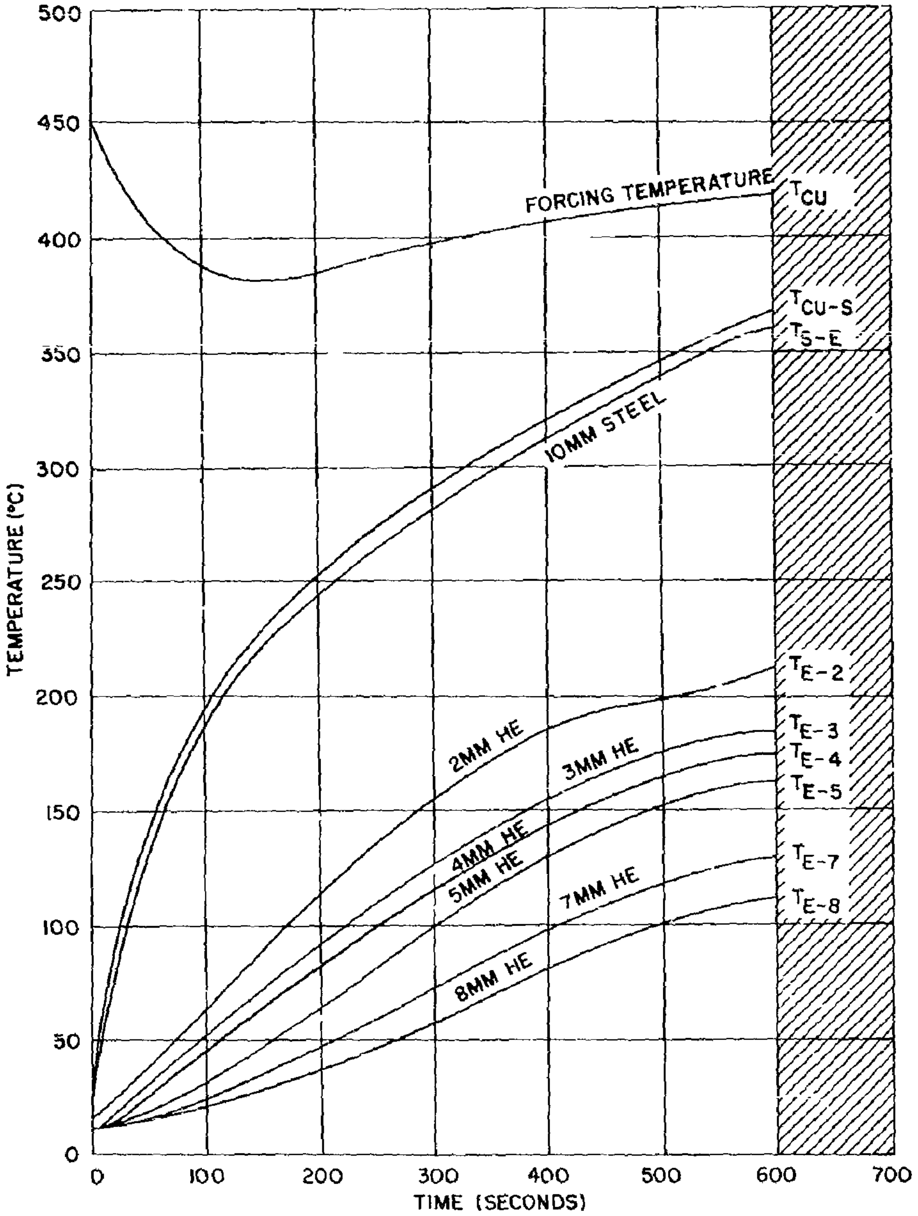


FIG. 13 DATB/BRL 2741, DEFLAGRATION OF SAMPLE 2. INITIAL FORCING TEMPERATURE, 452°C.

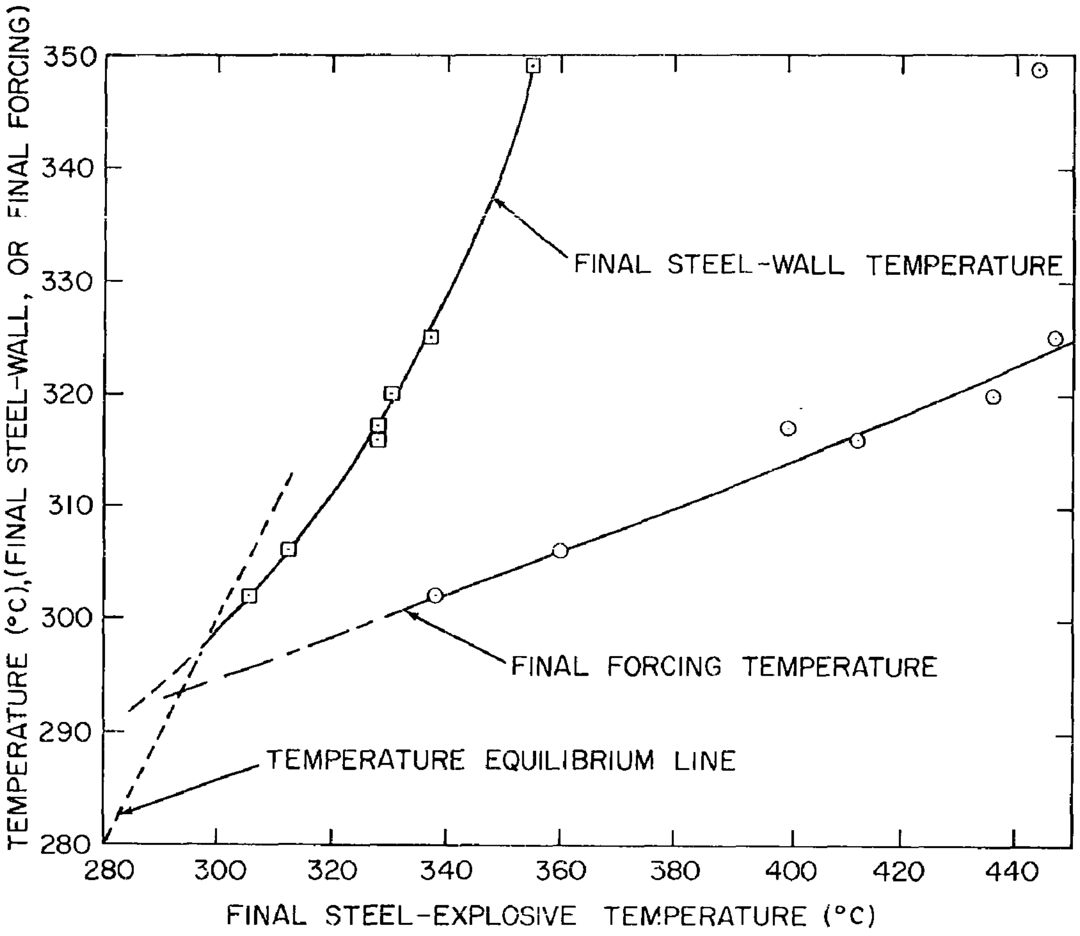


FIG. 14 TEMPERATURE CORRELATIONS AT TIME OF IGNITION OF DATB SAMPLES.

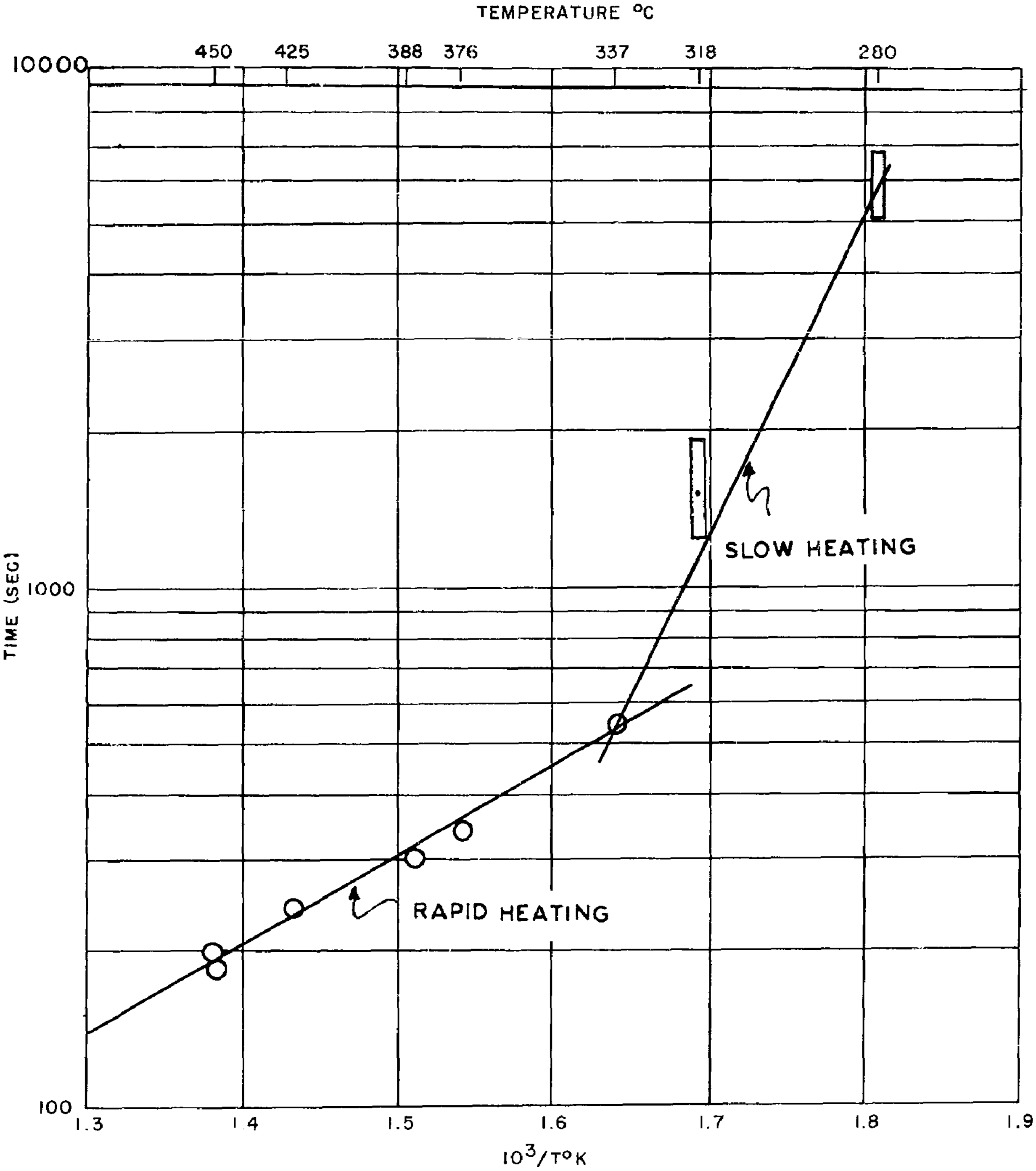


FIG. 15 IGNITION TIME AS A FUNCTION OF MEAN FORCING TEMPERATURE.

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Abstract card is confidential

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2. Warheads - Explosives
3. Explosives - Aerodynamic heating

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II. Coleburn, Nathaniel L.
III. Drimmer, Bernard E., jt. author
IV. Project
V. Project

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