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ANNUAL REPORT ON INVESTIGATION OF HIGH AND LOW TEMPERATURE  
RESISTANT EXPLOSIVE DEVICES

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ABSTRACT: This report covers additional work in the area of investigation of the performance of MDF's (mild detonating fuse) and FLSC's (flexible linear shaped charge) after high temperature exposure. MDF's and FLSC's loaded with RDX (93.5%) and RDX (99.5%) were exposed to elevated temperatures in an obturated system. Observations on the high temperature exposure of MDF's and FLSC's are discussed with recommendations for limits of exposure. The low temperature shock sensitivity of HNS-II/Teflon 90/10 mixture has been determined.

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**ANNUAL REPORT ON INVESTIGATION OF HIGH AND LOW TEMPERATURE  
RESISTANT EXPLOSIVE DEVICES**

This is a third annual report on "Investigation of High and Low Temperature Resistant Explosives Devices" work being conducted for NASA, Manned Spacecraft Center at Houston, Texas under Task NOL-787/NASA T-32602(G) and covers the period 1 January-31 December 1967.

This work is being carried out to investigate the use of high temperature resistant explosives in space applications. This particular report covers studies of the temperature/time exposure limits of RDX MDF's and FLSC's and the shock sensitivity of an HNS/Teflon mixture intended for use in the ALSEP mission.

The identification of commercial materials implies no criticisms or endorsement of them by the U. S. Naval Ordnance Laboratory.

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Captain, USN  
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By direction

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REFERENCE

1. NOLTR 67-133, "Annual Report on Investigation of High and Low Temperature Resistant Explosive Devices (U)," E. Kilmer, 18 October 1967, confidential.

## 1. BACKGROUND

This is the NOL Annual Report for 1967 on the "Investigation of High and Low Temperature Resistant Explosive Devices" work being conducted for NASA Manned Spacecraft Center at Houston. The work carried out for NASA in Calendar Year 1967 under this task (NOL Task-787) was essentially a continuation and an extension of the work begun in 1965. Additional work was done in the area of environmental testing. During the year we worked in the following areas:

- a. Determined the low temperature shock sensitivity of HNS-II/Teflon 90/10 mixture used in the ALSEP\* grenade.
- b. Investigated the performance after exposure to temperatures of up to 300°F of MDF's loaded with RDX (93.5%) and RDX (99.5%).
- c. Studied the performance of RDX-FLSC at 300°F and 220°F in an obturated system.

## 2. SENSITIVITY TESTS (SMALL SCALE GAP TEST)

### 2.1 Low Temperature Sensitivity of HNS-II/Teflon 90/10 (X-581)\*\*

NOL has investigated the shock sensitivity of HNS/Teflon 90/10 at room temperature and at low temperature. The modified small scale gap test was used. Several batches of NOL-prepared HNS-II/Teflon 90/10, the mixture used in the ALSEP grenade, were studied. The shock sensitivity of this mixture was previously reported for sample X-571 in the seventh quarterly progress report (dated 13 Oct 1966). The previous results for X-571 are shown in Fig 1 and those for the latest preparation, X-581, are shown in Fig 2.

Note that a desensitization of the explosive with a decrease in temperature is shown. Of primary importance, is the rapid desensitization of the mixture at densities greater than approximately 1.6 gm/cc at a temperature of -315°F. Therefore, the use of this composition at densities greater than 1.6 gm/cc should be avoided. The room temperature sensitivities were not greatly different, although the X-571 sample was somewhat more sensitive than the X-581. NOL sample

\*APOLLO Lunar Surface Experiments Package.

\*\*NOL identifications for new and experimental explosives and explosive compositions carry an X No. designation.

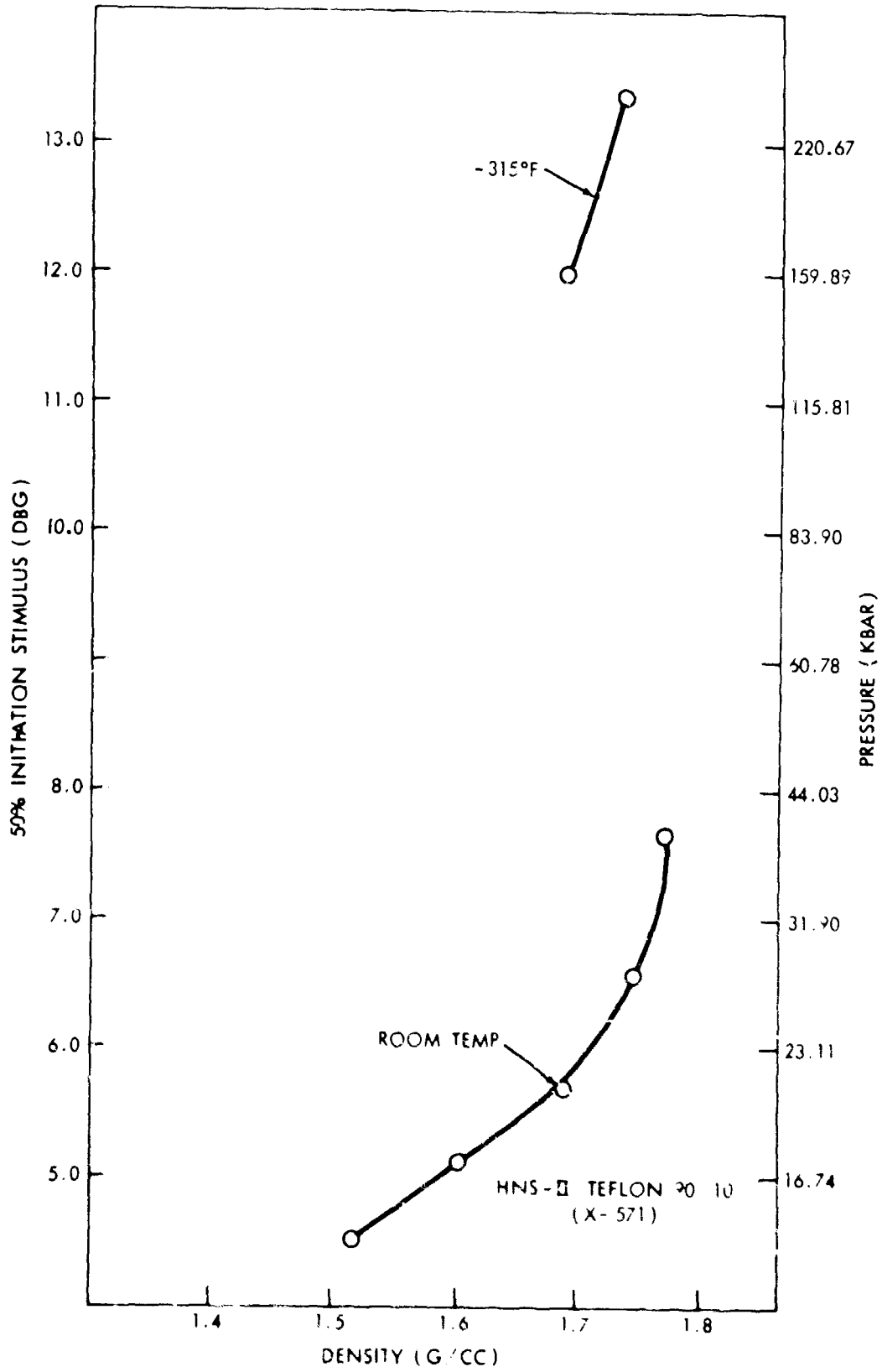


FIG. 1 THE EFFECT OF TEMPERATURE ON THE SHOCK SENSITIVITY OF HNS -II/TEFLON 90/10 (X-571)

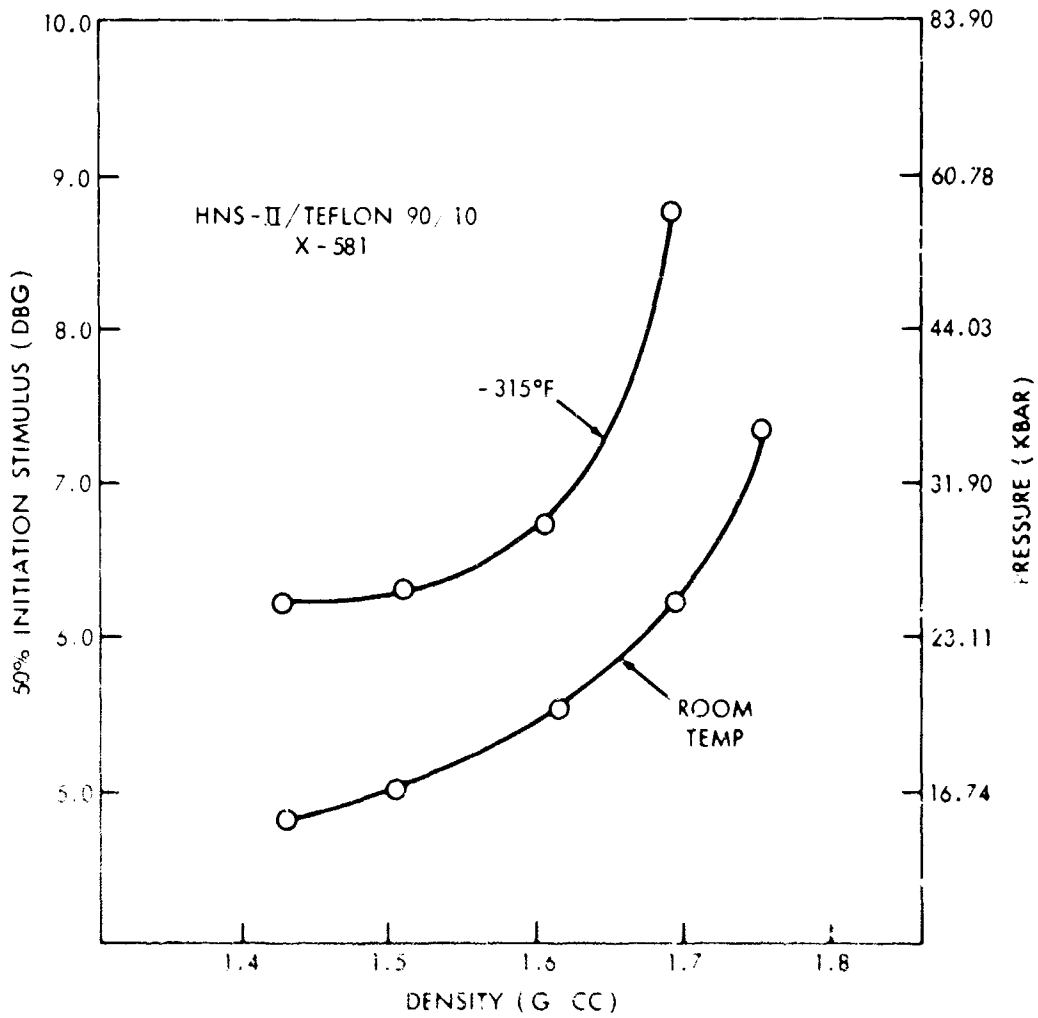


FIG. 2 THE EFFECT OF TEMPERATURE ON THE SHOCK SENSITIVITY OF HNS-II/TEFLON 90/10 (X-581)

X-581 was used in the preparation of the ALSEP grenade. X-571 was a preliminary mix used during the development of X-581.

### 3. HIGH TEMPERATURE TEST FOR RDX-MDF's

#### 3.1 RDX-MDF's and Their Performance Under Various Temperature Conditions

NOL was asked to investigate the effect on RDX-MDF of exposure to 300°F for an extended period of time. Of primary interest was the propagation velocity as a function of exposure time and explosive core load. NASA/MSR requested that RDX (93.5%) and RDX (99.5%) be loaded into MDF and FLSC and studied.

Since MDF's are normally used as detonation transmission lines, it was expected that a core load of 15 grains/ft would be a maximum for spacecraft systems applications. Core loadings of 7 and 2 grains/ft were fabricated for testing of minimum expected core loads used in spacecraft systems. Originally it was contemplated that the explosive cords would be tested in individual sealed containers so that the degradation of explosive could be determined on individual samples without possible contamination from other samples. Preliminary tests by which we were determining proper sealing techniques resulted in complete failure of all MDF's to propagate. Sealing was with an amine cured epoxy resin. It was found that the resin reacted with the RDX at 300°F; a tarry residue oozed from the ends of the MDF when the epoxy resin was in direct contact with the explosive. Decomposition also occurred when some sealing resin was placed several inches from the ends of the unsealed MDF. The vapor from the resin obviously was reactive with the explosive at this temperature. Unsealed control samples of MDF (RDX 93.5% and 99.5%) showed no degradation at this temperature after 100 hours at 300°F.

It was felt, therefore, that a soft solder seal on the MDF sealing container would solve the problem. Solder sealed containers of MDF were tested at 302°F. The results are shown in Fig 3. Note the degradation of the detonation velocity after 60 hours of exposure. An unsealed control sample with liquid solder flux in the same container, but not intimately touching the RDX-MDF, showed the same type of degradation. The flux was common to both the sealed and unsealed sample, and at this time was considered to be the cause of the degradation.

At this point sealing was abandoned and experiments on the long exposure times with the 15, 7, and 2 grains/ft RDX (93.5% and 99.5%) were made in unsealed containers. The results of these experiments are shown in Fig's 4 through 9. The



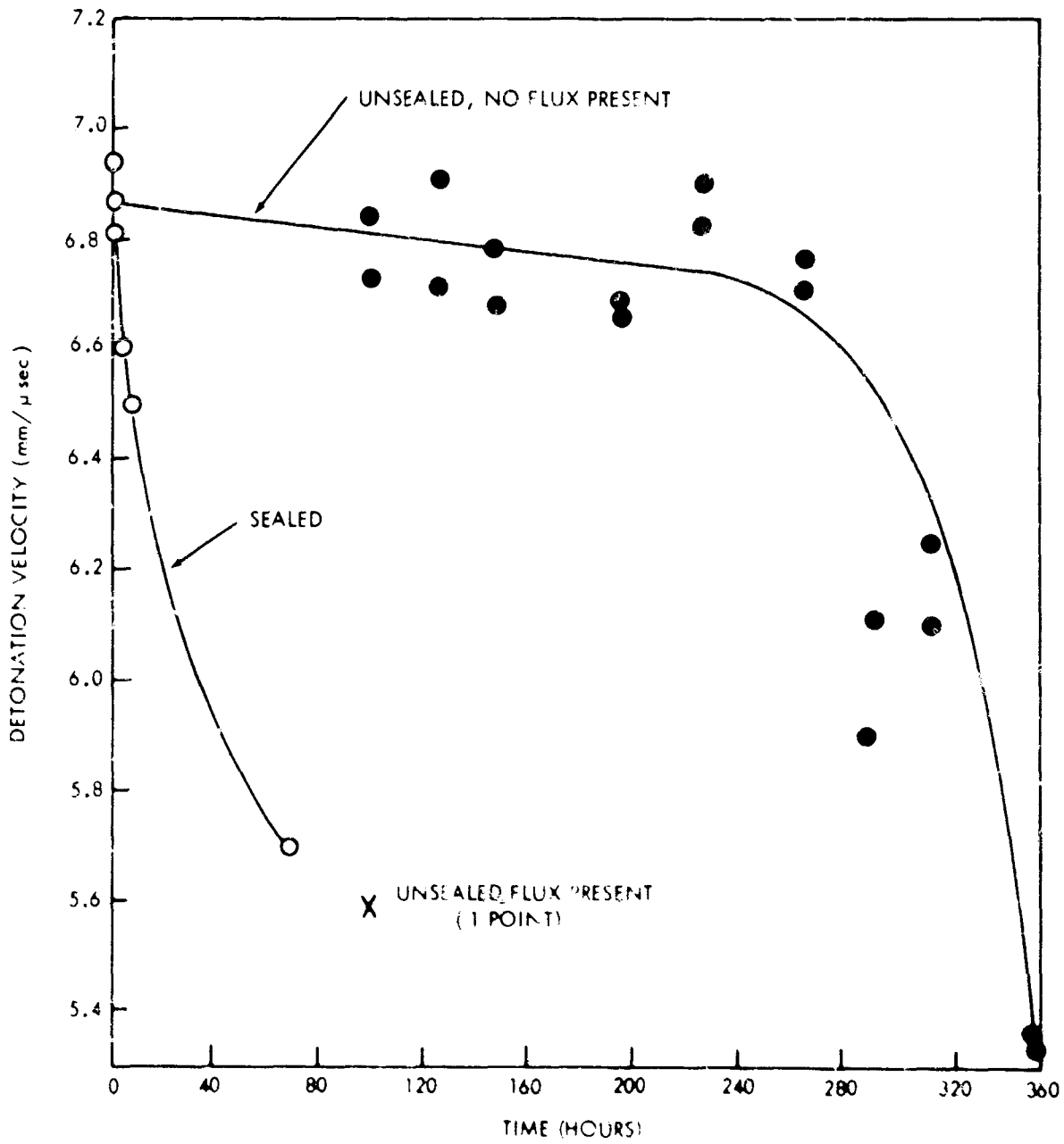


FIG. 3 THE EFFECT OF TEMPERATURE ON THE DETONATION VELOCITY OF RDX-MJF IN THE PRESENCE OF SOLDER FLUX ( 302 °F)

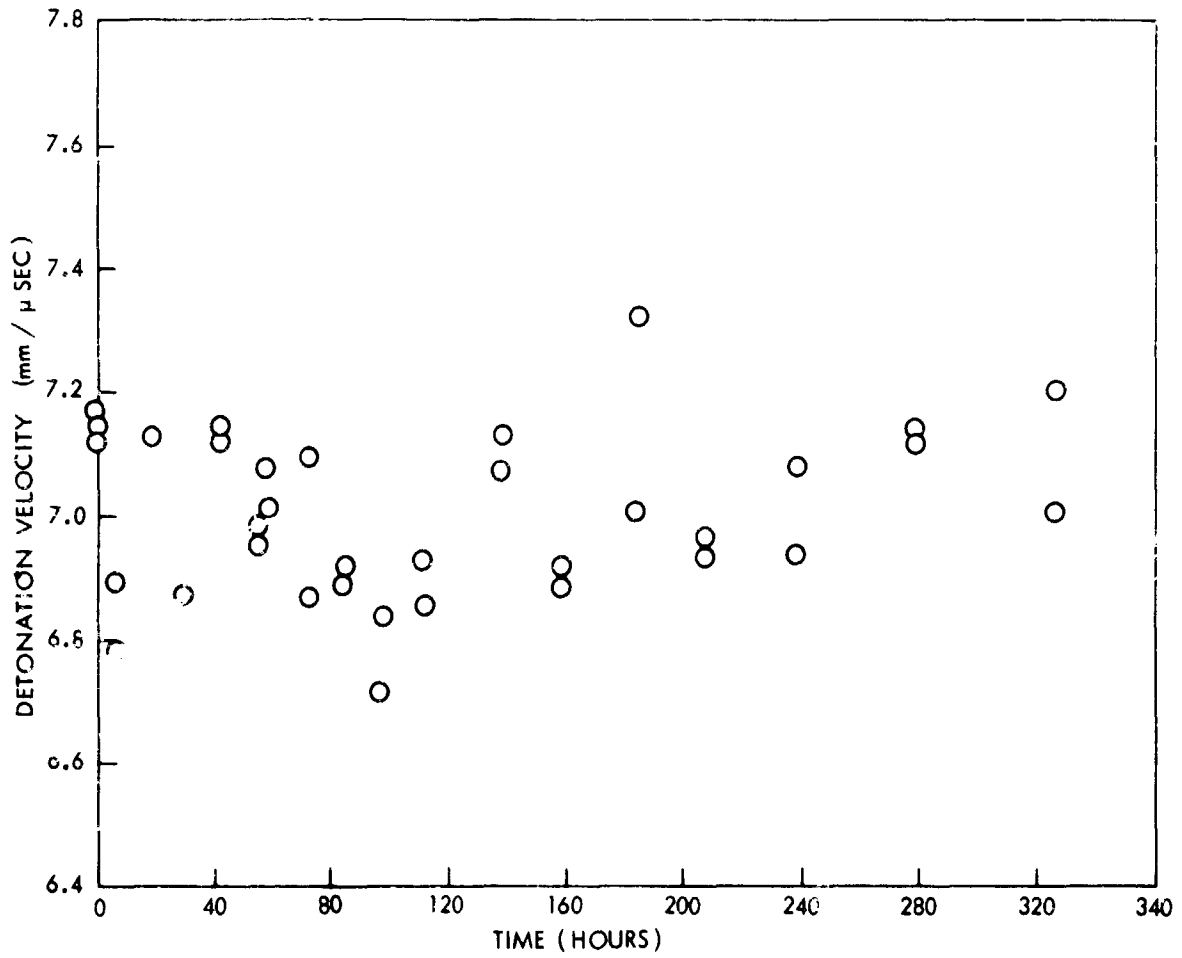


FIG. 4 THE DETONATION VELOCITY OF RDX-MDF (99.5%) 15 GRAINS/FT AFTER EXPOSURE TO 302°F TEMPERATURE (UNSEALED)

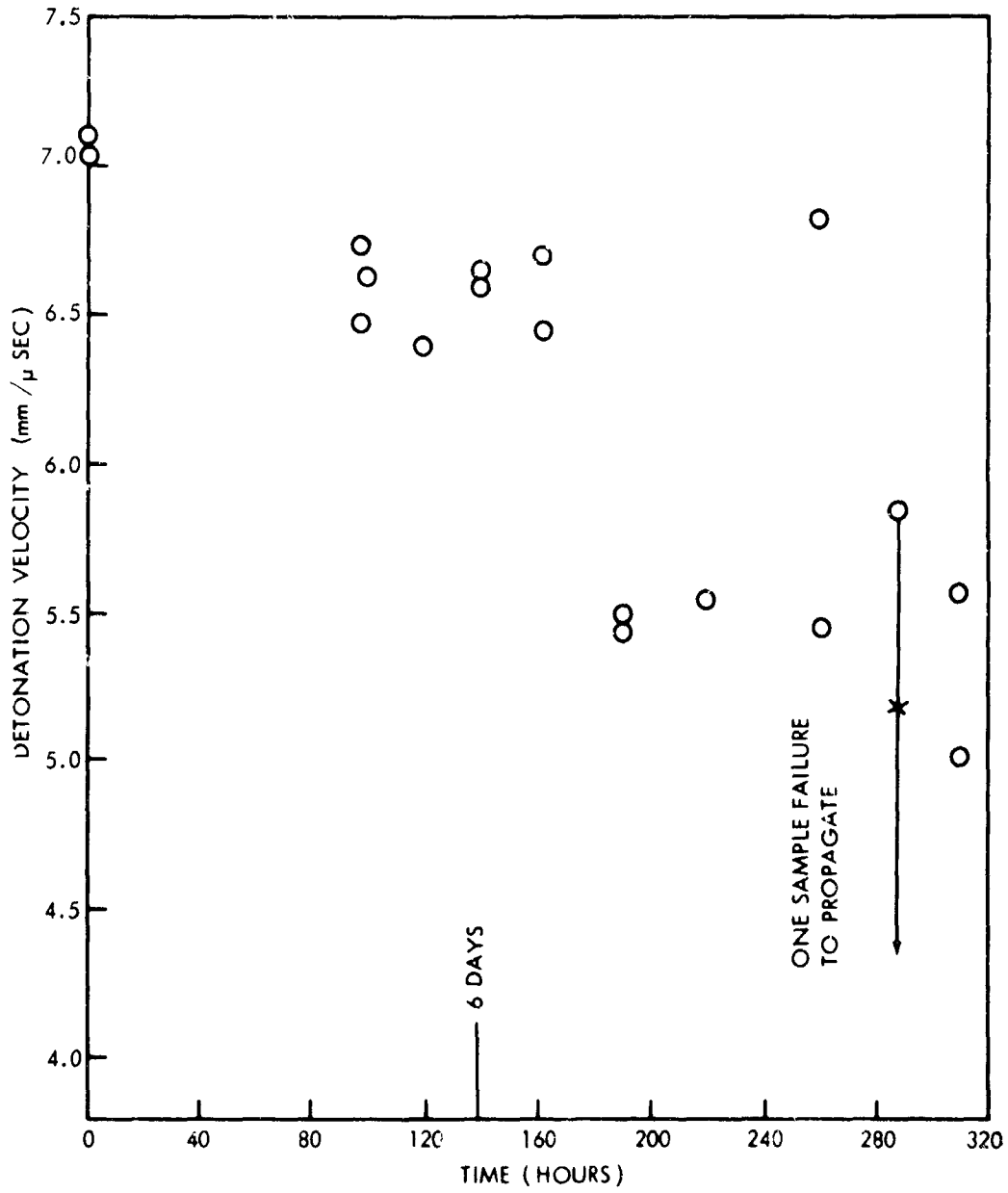


FIG. 5 THE DETONATION VELOCITY OF RDX-MDF (99.5%) 7 GRAINS, FT AFTER EXPOSURE TO 302°F TEMPERATURE (UNSEALED)

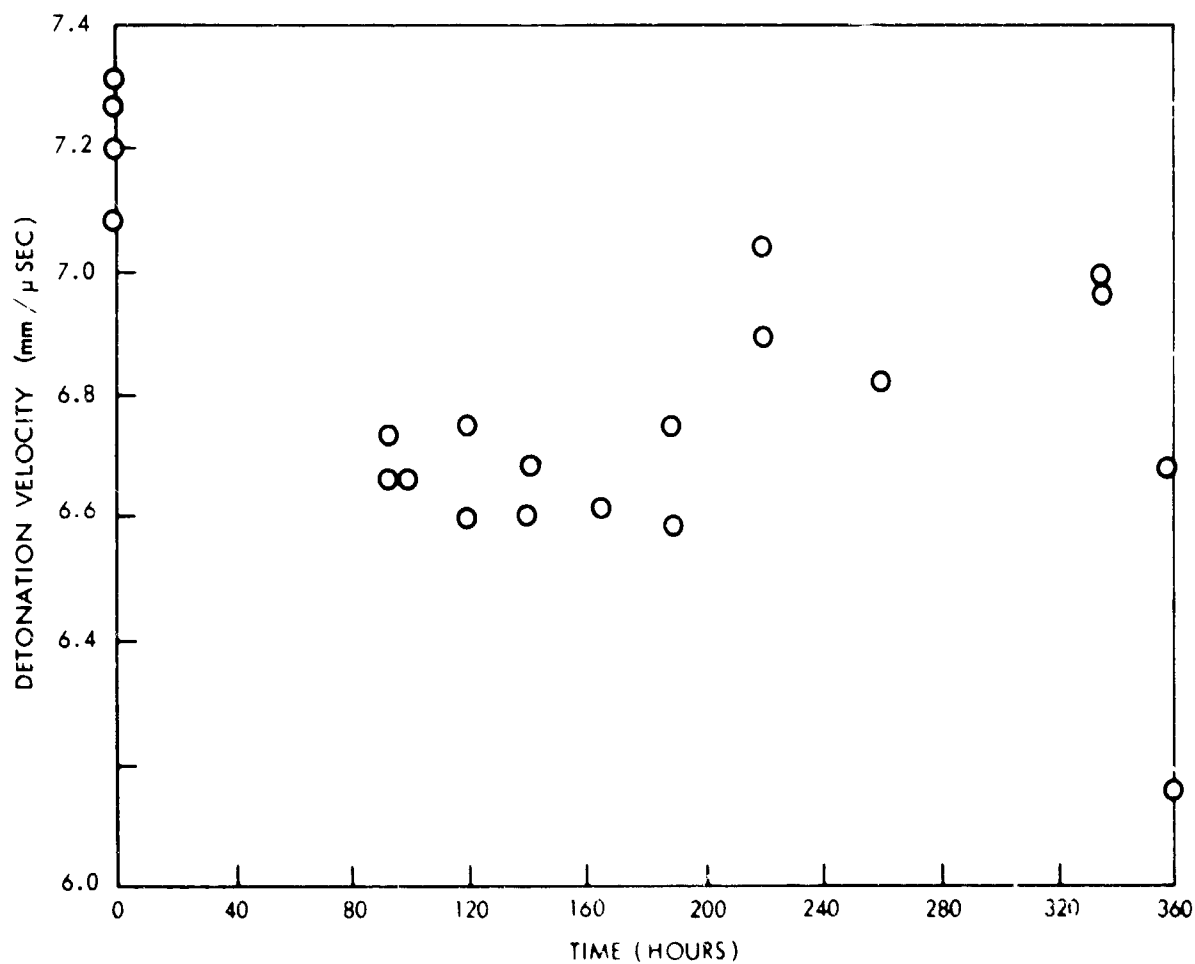


FIG. 6 THE DETONATION VELOCITY OF RDX-MDF (99.5%) 2 GRAINS FT AFTER EXPOSURE TO 302°F TEMPERATURE (UNSEALED)

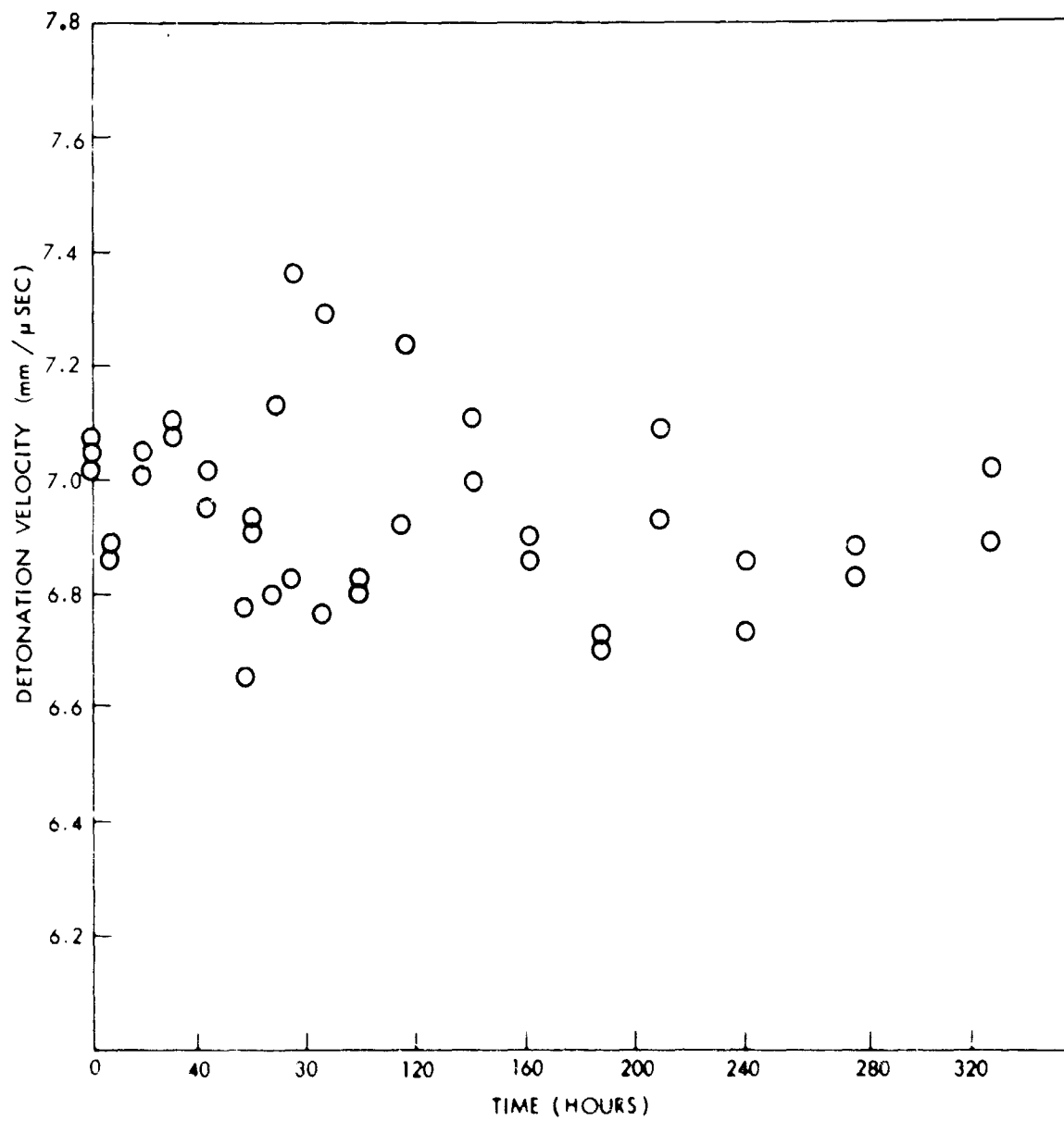


FIG. 7 DETONATION VELOCITY OF RDX-MD7 (93.5%) 15 GRAINS/FT AFTER EXPOSURE TO 300°F TEMPERATURE (UNSEALED)

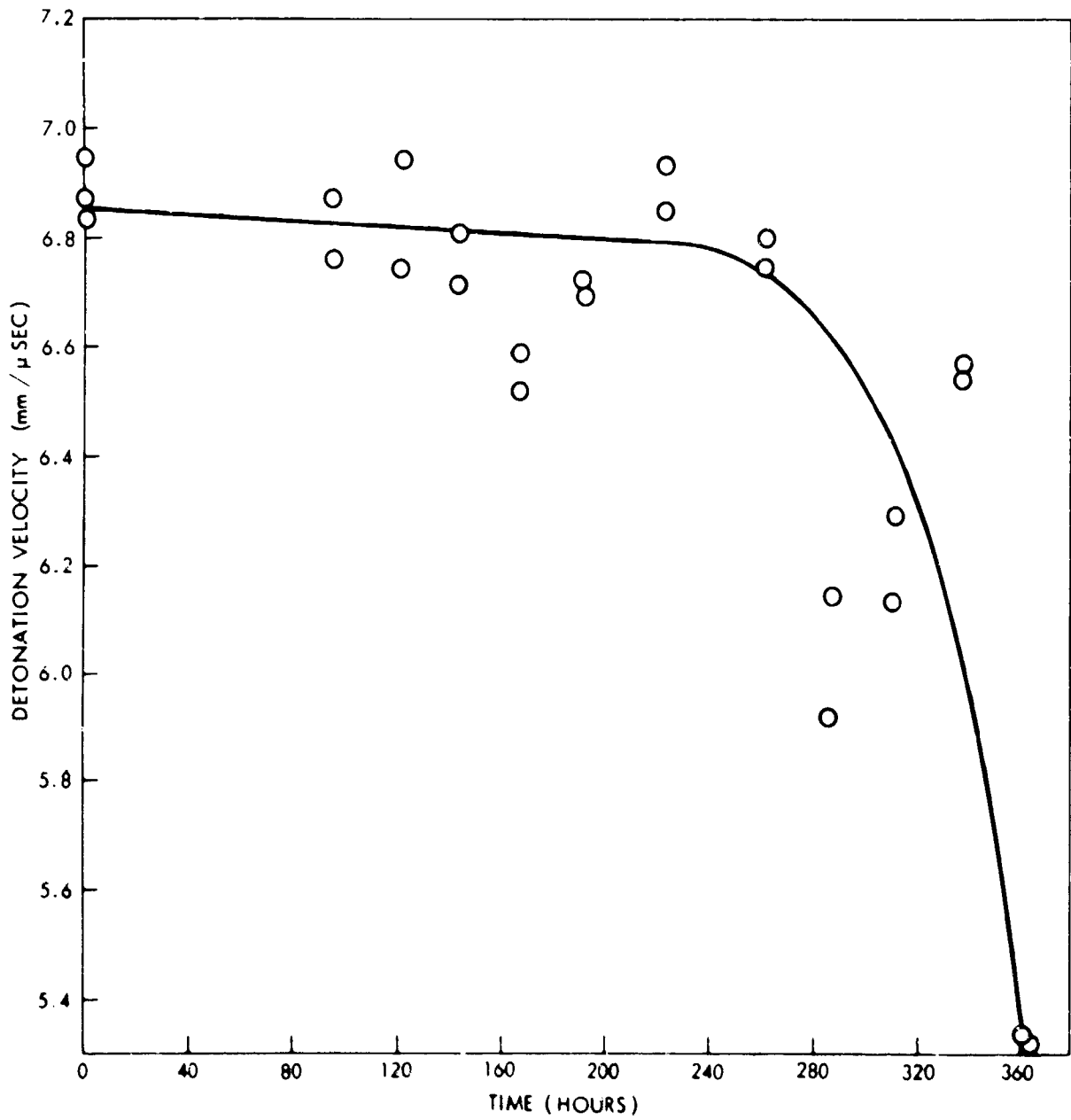


FIG. 8 THE DETONATION VELOCITY OF RDX-MDF (93.5%) 7 GRAINS FT AFTER EXPOSURE TO 302°F TEMPERATURE (UNSEALED)

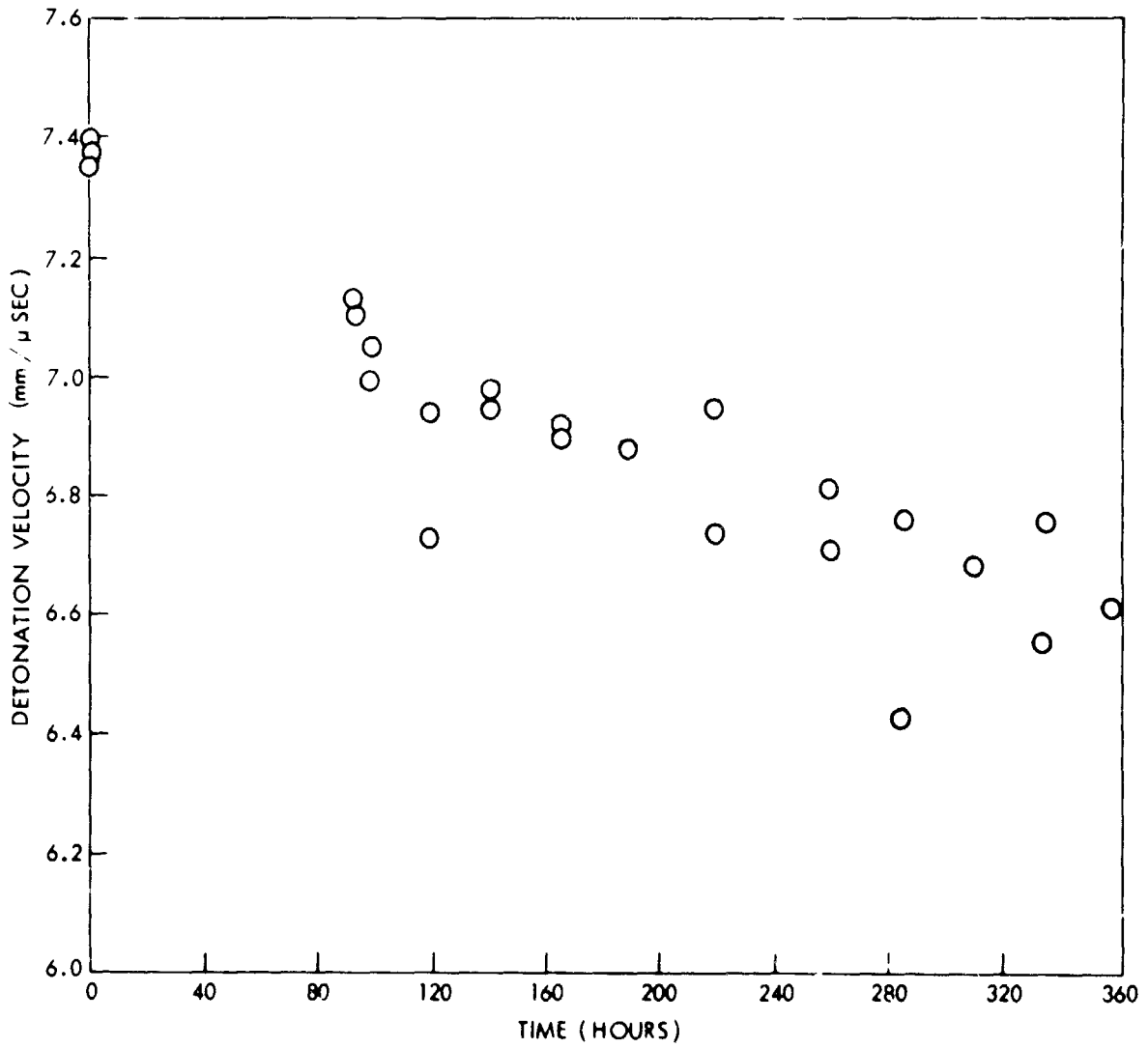


FIG. 9 THE DETONATION VELOCITY OF RDX - MDF (93.5%) 2 GRAINS/FT AFTER EXPOSURE TO 302°F TEMPERATURE (UNSEALED)

15 grains/ft MDF's show no degradation in detonation velocity after exposure to 302°F temperature for about 2 weeks. The RDX (99.5%) 7 grains/ft material showed a definite large decrease of detonation velocity after about 6 days of exposure. In some cases the witness plate on which the MDF was fired showed areas of reduced output characteristic of lowered detonation velocity. In preparing one test sample for detonation velocity measurements, a void was detected in the cord after 286 hours. This section of the sample failed to propagate as shown in Fig 5. The RDX (93.5%) 7 grains/ft material showed a decrease in detonation velocity after 10 days exposure at 302°F. Both 2 grains/ft RDX-MDF's (93.5% and 99.5%) showed a decrease in detonation velocity over a 15 day period but still retained about 88% of their original detonation velocity after 15 days. The greater degradation of the 7 grains/ft RDX-MDF's compared to the 15 and 2 grains/ft material is unexplainable at this time. The data suggests a possibility of contamination in both of the 7 grains/ft RDX-MDF's, but is not conclusive at this point. It was expected that the deterioration would be a function of the core load with the 2 grains/ft failing first. This expected trend has been experienced with the heat resistant explosives DIPAM and HNS.

A cold-sealing method has been devised now for these surveillance tests. The MDF is placed in a clean copper tube which is then closed by crimping and sealed by cold welding. The cold weld is obtained by subjecting the tubing to a high pressure applied at the crimped area. The high pressure is obtained by squeezing the copper between two parallel 1/4-inch diameter steel rods. After the MDF has been sealed into the copper tube, the tube is leak tested. Each sample is sealed into an individual tube with the length of tube chosen to be just a bit longer than the piece of MDF.

Both kinds (93.5% and 99.5%) of RDX-MDF were tested using core loads of 2 grains/ft, 7 grains/ft, and 15 grains/ft at temperatures of 300°F, 255°F, and 220°F. After various conditioning times samples were withdrawn and the copper tube was checked for leakage. Every time leakage was observed the MDF was found to be completely decomposed. Evidently enough gas generation took place during the decomposition to rupture the seal. The effect of conditioning is demonstrated by plotting the detonation velocity of the MDF as a function of the time and temperature of conditioning in Fig's 10 through 15. From these curves a number of statements can be made about RDX-MDF in obturated assemblies.

a. Either of the two RDX's in any of the three core loadings will be relatively unaffected by two weeks at 220°F. This can be seen by comparing the 220°F data in all six graphs.

b. There is no consistent difference between the two kinds of RDX. This can be seen by comparing graph 10 with graph 13, 11 with 14, and 12 with 15. There is more resemblance between the above pairs than there is between 10, 11, and 12; or between 13, 14, and 15.



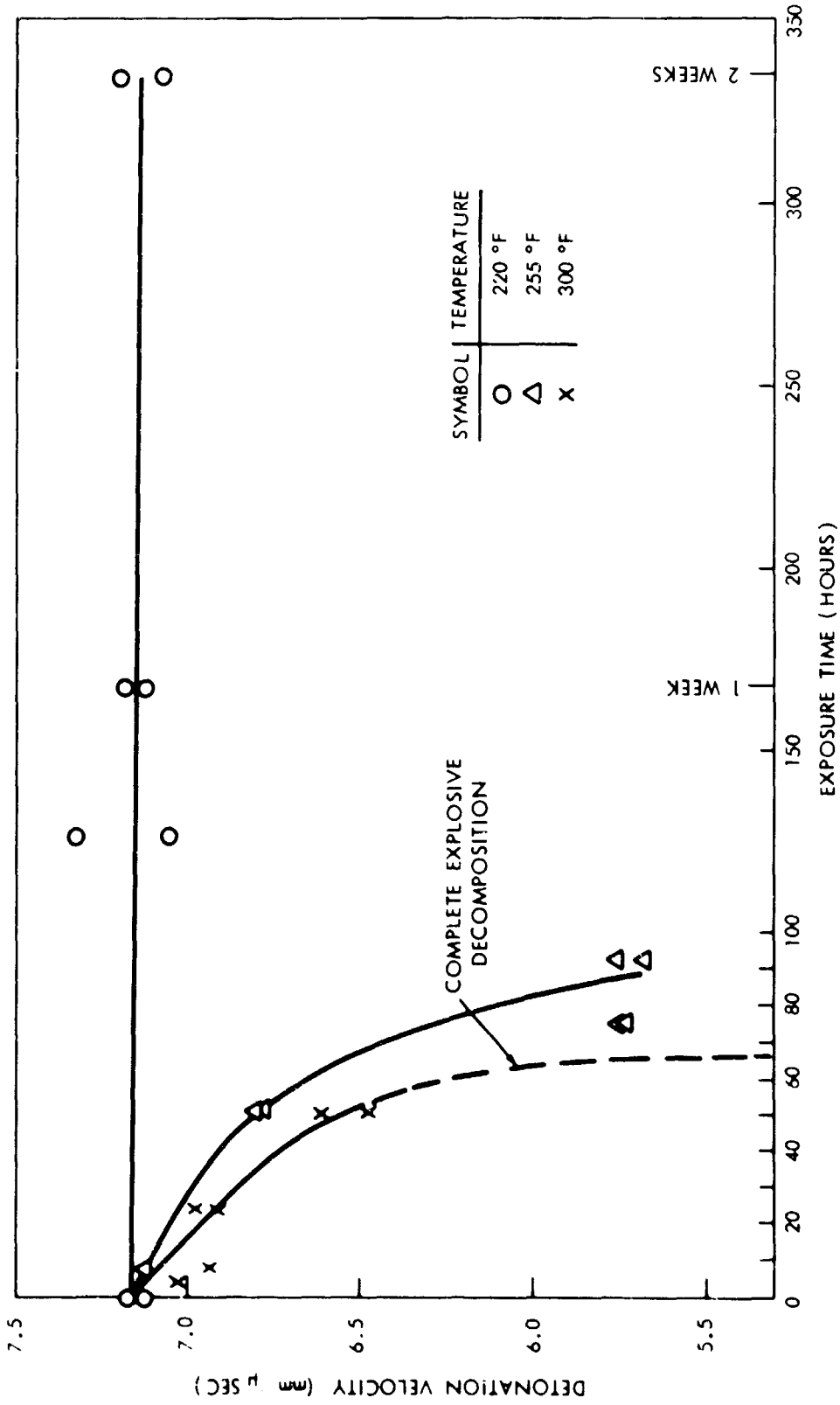


FIG. 10 THE DETONATION VELOCITY OF RDX - MDF (99.5%) 15 GRAINS/FT AS A FUNCTION OF EXPOSURE TIME AT ELEVATED TEMPERATURES (SEALED)

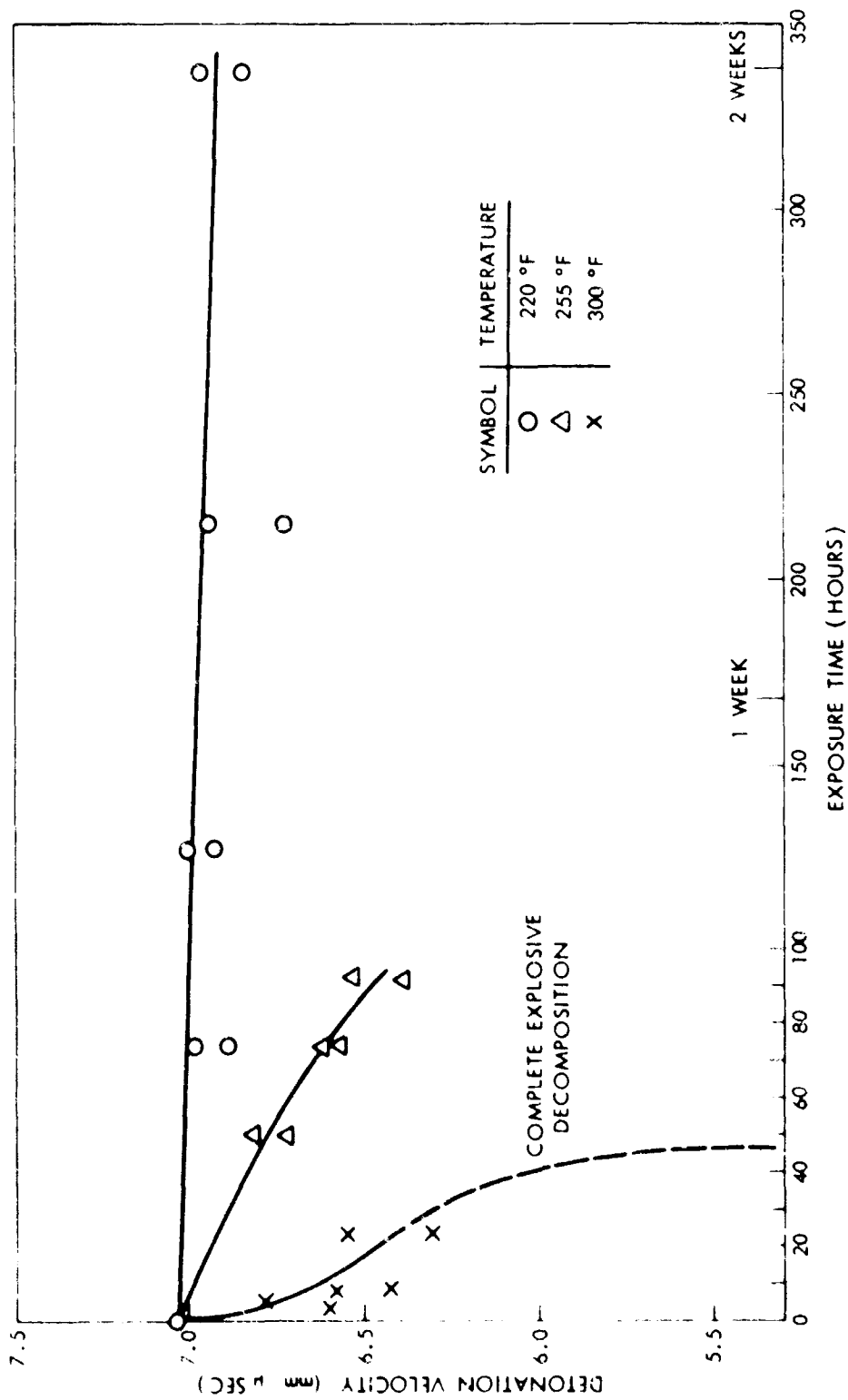


FIG. 11 THE DETONATION VELOCITY OF RDX - MDF (99.5%) 7 GRAINS / FT AS A FUNCTION OF EXPOSURE TIME AT ELEVATED TEMPERATURES (SEALED)

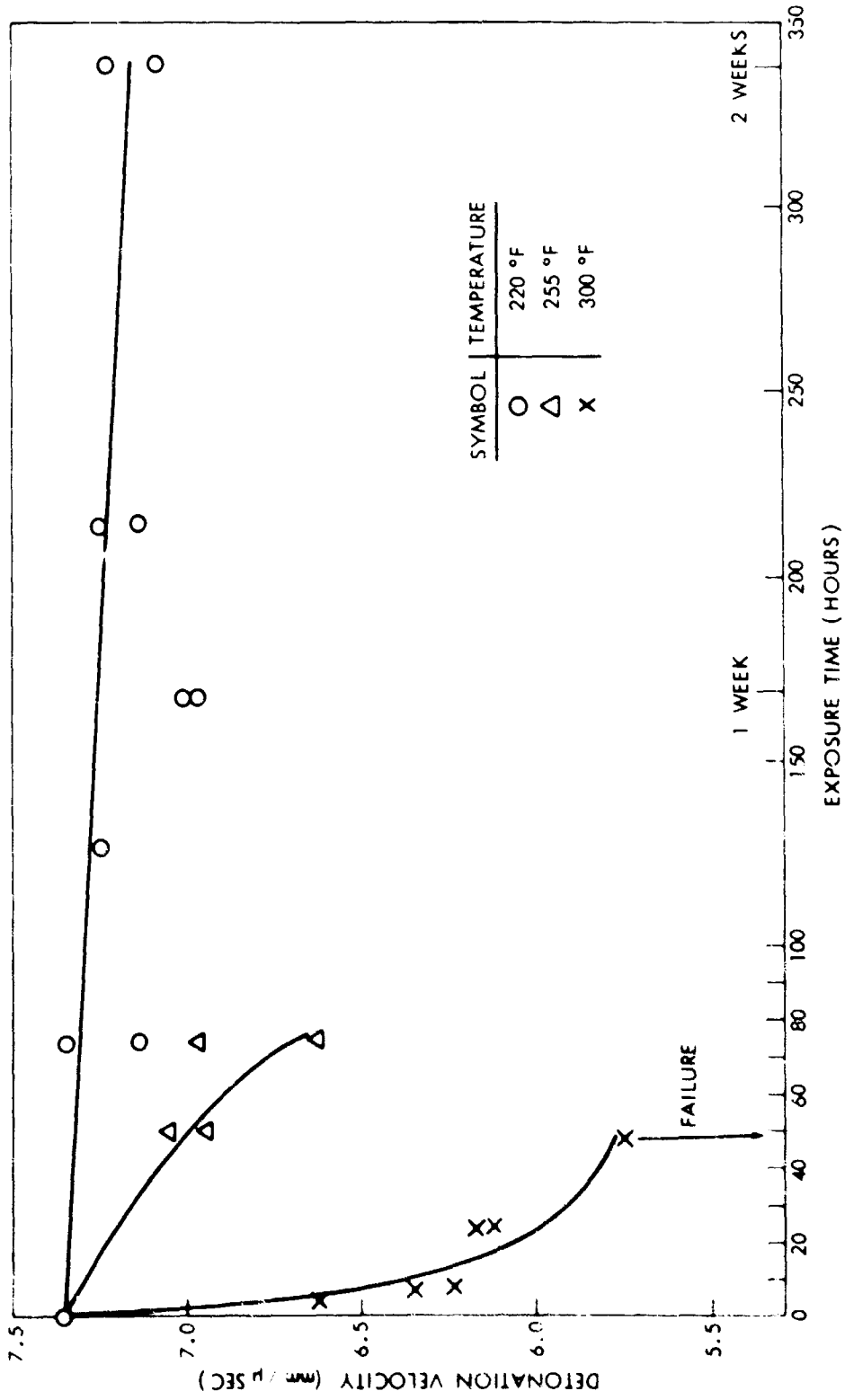


FIG. 12 THE DETONATION OF RDX - MDF ( 99.5% ) 2 GRAINS / FT AS A FUNCTION OF EXPOSURE TIME AT ELEVATED TEMPERATURE ( SEALED )

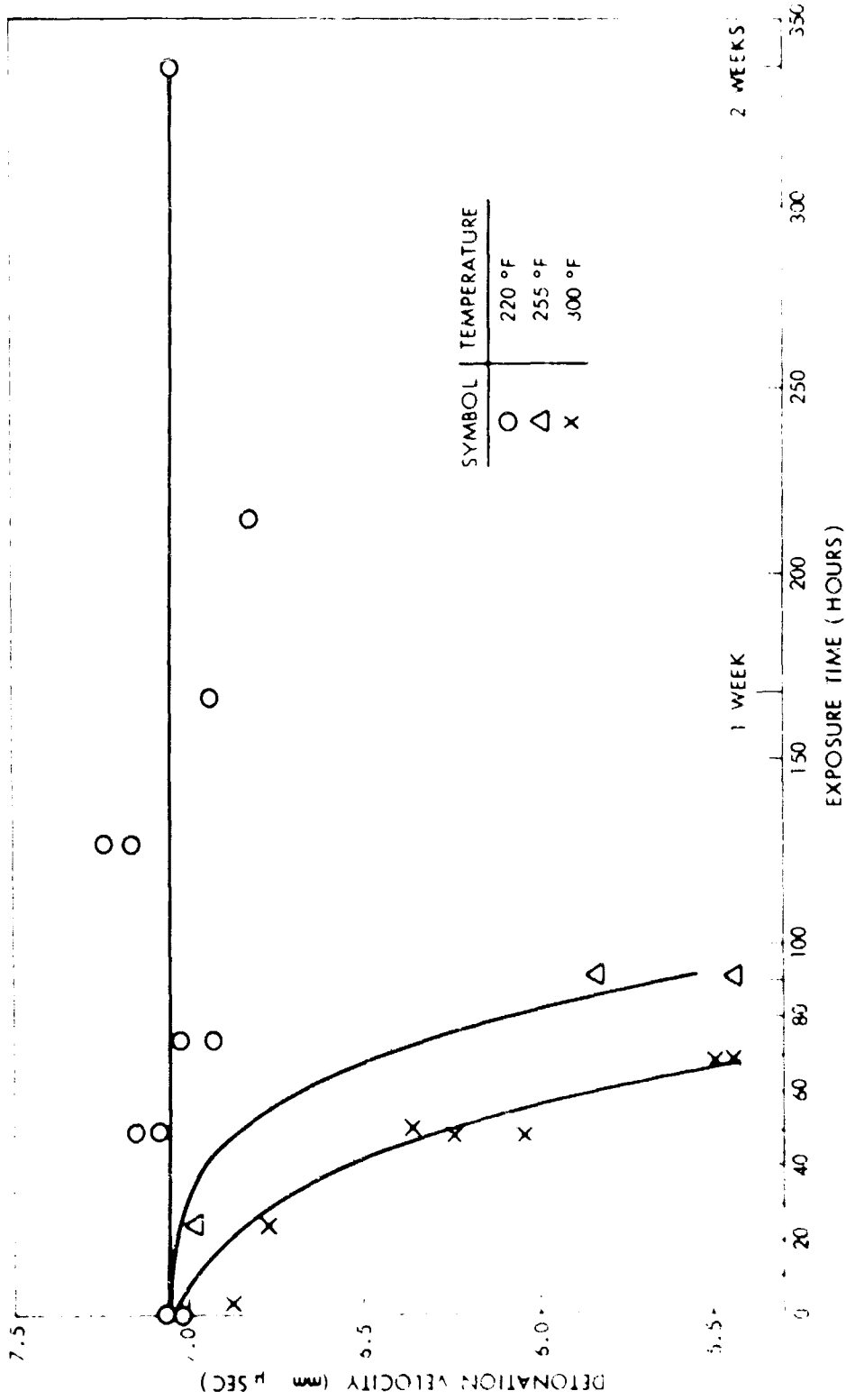


FIG. 13 THE DETONATION VELOCITY OF RDX - MDF (93.5%) 15 GRAINS FT AS A FUNCTION OF EXPOSURE TIME AT ELEVATED TEMPERATURES (SEALED)

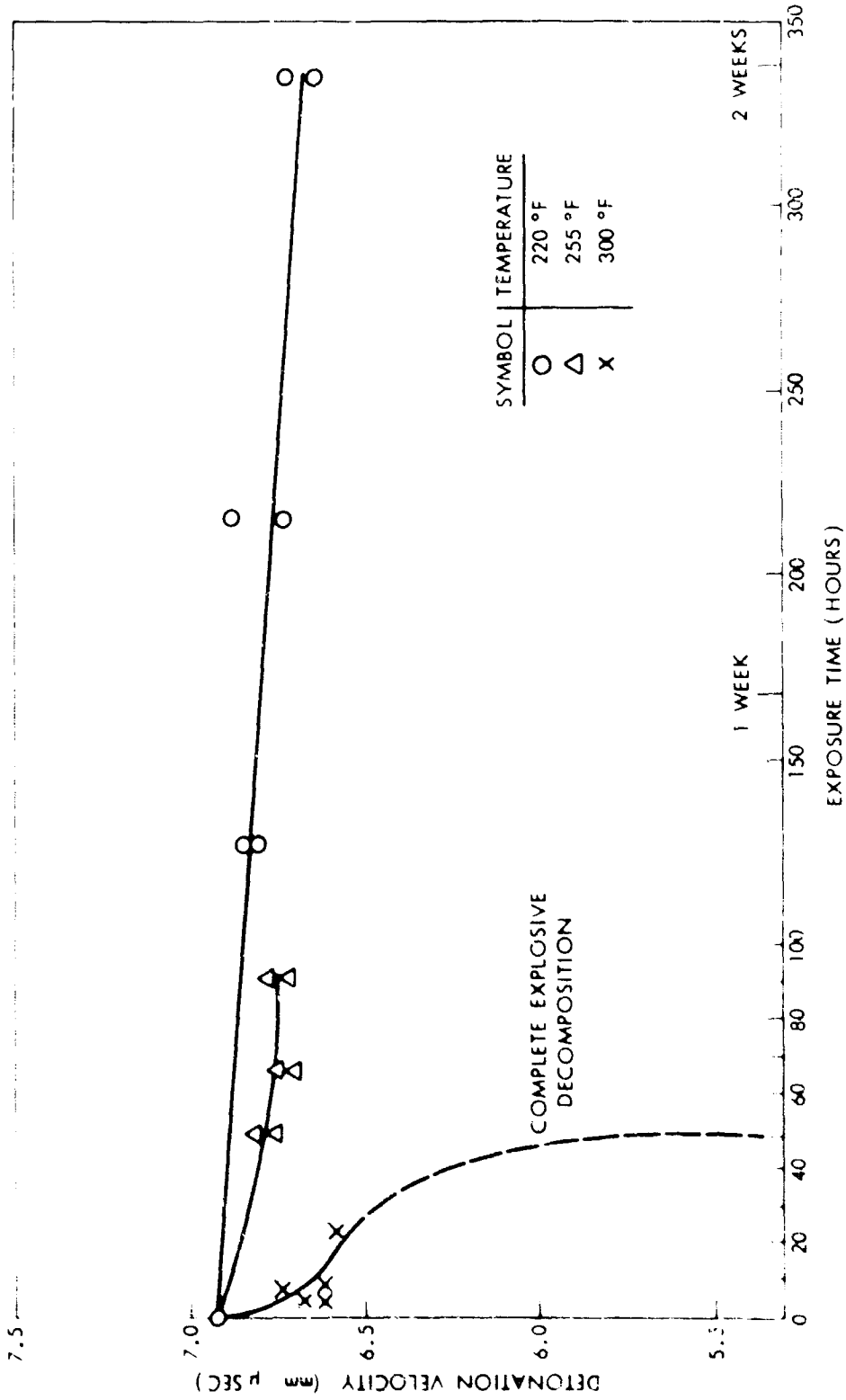


FIG. 14 THE DETONATION VELOCITY OF RDX - MDF (93.5% 7 GRAINS / FT AS A FUNCTION OF EXPOSURE TIME AT ELEVATED TEMPERATURES (SEALED)

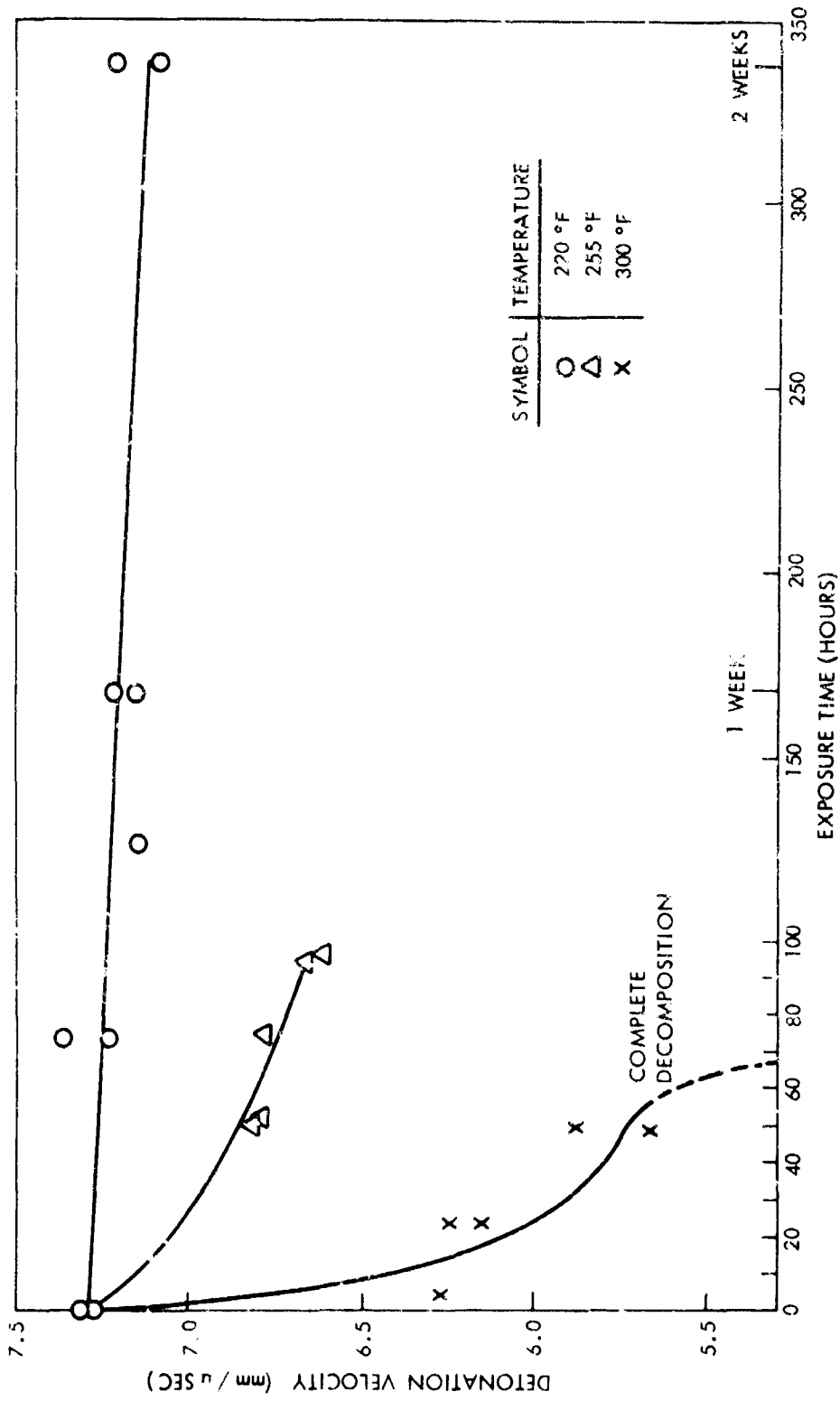


FIG. 15 THE DETONATION VELOCITY OF RDX - MDF ( 93.5% ) 2 GRAINS / FT AS A FUNCTION OF EXPOSURE TIME AT ELEVATED TEMPERATURE ( SEALED )

c. MDF cannot be expected to be reliable beyond 50 hours at 255°F or beyond a very few hours at 300°F.

d. The 15 grains/ft material is the most resistant and the 2 grains/ft material the least resistant to elevated temperature.

e. Under ambient pressure conditions, unsealed RDX-MDF's will perform over a greater time span at elevated temperatures than the sealed samples. At this time the mechanism of decomposition is not known. However, it is believed that an accelerated reaction involving the decomposition of the RDX is caused by a combination of contamination by decomposed RDX, increased pressure, and/or reactive volatiles of decomposition.

In order to limit the number of tests over an extended period of time, the RDX-MDF (93.5%) 7 grains/ft was exposed to temperatures of 220°F, 200°F, and 180°F. Periodically 2 samples each were removed from the lot for testing. In the 220°F testing the detonation velocities indicate a degradation of the MDF after 33 days. As shown in Fig 16 one sample detonated at an acceptable velocity and the second sample had degraded enough so that it could not be initiated. In the 200°F testing (Fig 17) complete decomposition of the explosive cores of both test samples was observed after 63 days. Surprisingly, however, acceptable functioning of both test samples was observed after 93 days of exposure. No explanation can be given at this time for the behavior observed except that it is possible that some minute impurity in the 93.5% pure RDX is causing this random decomposition at elevated temperatures. In any case, marginal performance has been observed even though larger sampling would improve the statistics. In the 180°F testing (Fig 18), some loss of detonation velocity was observed at 93 days but the MDF is still acceptable. The 180°F testing will be extended for a longer period of time.

We know that RDX is much more volatile than DATE (at 212°F the vapor pressures of RDX and DATE are  $10^{-4}$  mm and  $10^{-6}$  mm respectively). DATE has long since been supplanted by DIPAM and HNS in aerospace applications because of the much lower vapor pressures of the latter materials. If RDX is to be used in an aerospace application, it will have to be obturated. But, our results show that the rate of decomposition is accelerated in obturated systems probably because of autocatalysis by the decomposition products.

We must conclude that RDX-MDF should not be used in obturated aerospace systems at temperatures above 220°F for any more than a few hours. If it is kept at temperatures no higher than 200°F, we have demonstrated that it probably would be operable after two weeks, provided there is no contamination introduced in the obturated system which would accelerate decomposition. There is an indication that the RDX-MDF (93.5%) does detonate at an acceptable velocity after 3 months of exposure in a sealed system at a temperature of 180°F.

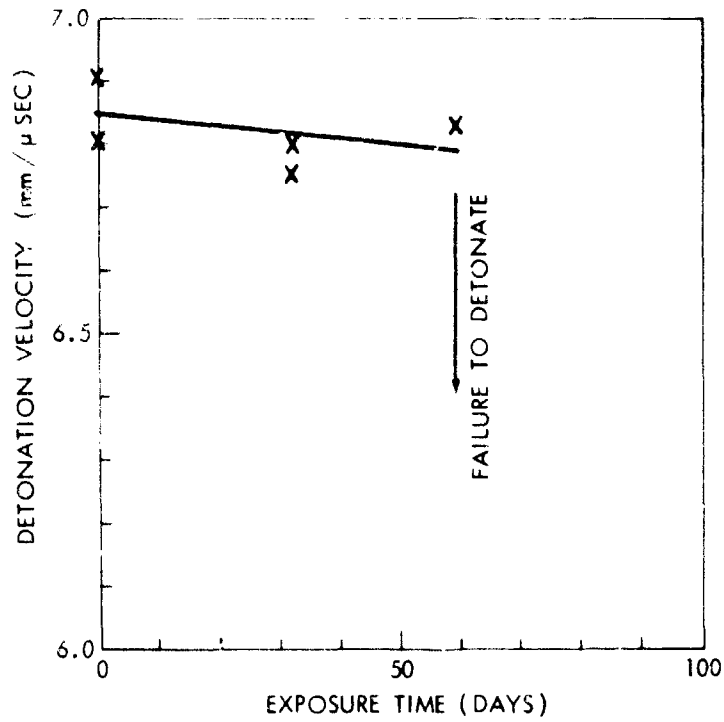


FIG. 16 THE DETONATION VELOCITY OF RDX - MDF (93.5%) 7 GRS/FT AS A FUNCTION OF EXPOSURE TIME AT 220°F (SEALED)

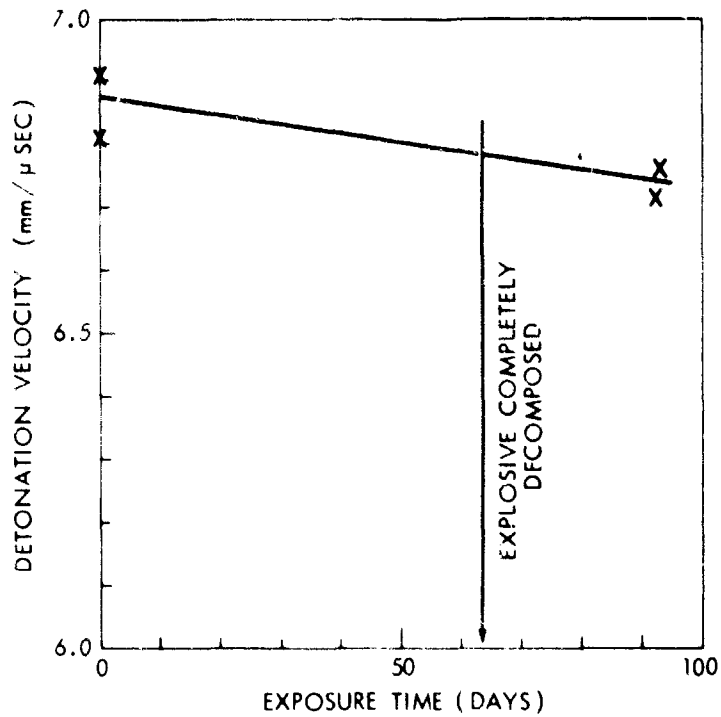


FIG. 17 THE DETONATION VELOCITY OF RDX - MDF (93.5%) 7 GRS/FT AS A FUNCTION OF EXPOSURE TIME AT 200°F (SEALED)



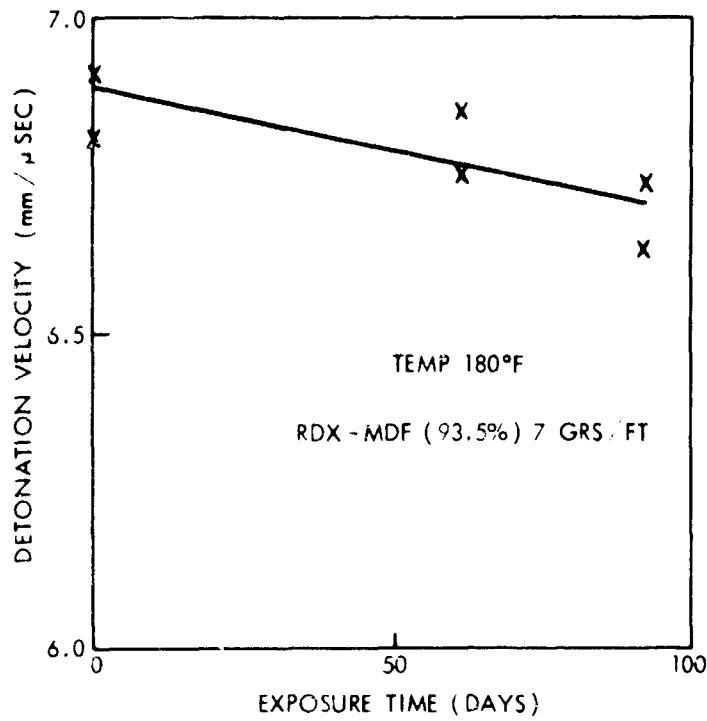


FIG. 18 THE DETONATION VELOCITY OF RDX - MDF (93.5%) AS A FUNCTION OF EXPOSURE TIME AT 180°F (SEALED)

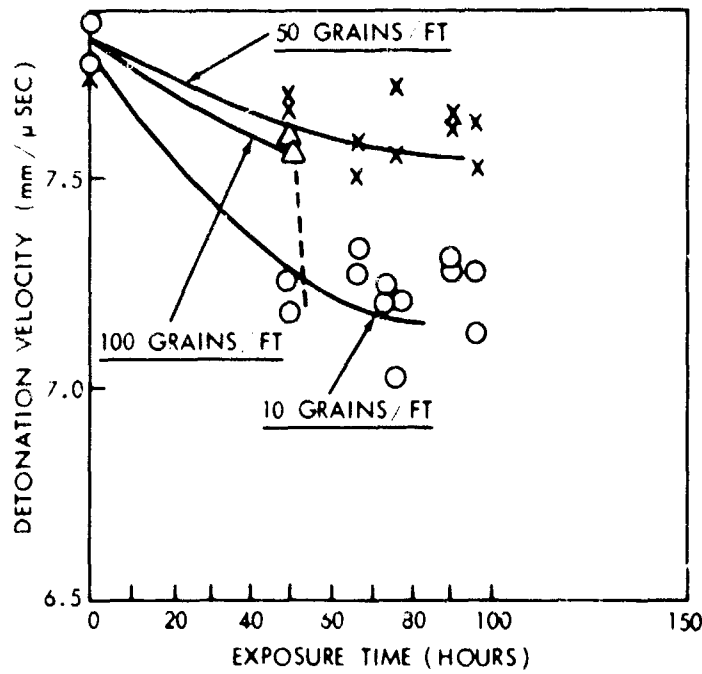


FIG. 19 THE DETONATION VELOCITY OF RDX - FLSC (99.5%) AS A FUNCTION OF EXPOSURE TIME AT 300°F (SEALED)

#### 4. HIGH TEMPERATURE ENVIRONMENTAL TESTING OF RDX-FLSC's

##### 4.1 RDX-FLSC's and Their Performance Under Various Temperature Conditions

As in previous tests samples were withdrawn after various conditioning times. The effect of conditioning was determined by plotting the detonation velocity of the FLSC as a function of the time and temperature of conditioning. The plots are shown in Fig's 19 and 20. The following statements can be made about RDX-FLSC conditioned in an obturated system:

a. The RDX-FLSC (99.5% pure) at 300°F.

The 99.5% pure RDX-FLSC (100 grains/ft) begins to show a severe degradation in performance after 2 days at 300°F (149°C). It is not known at this time why this particular core load of explosive or particular lot of FLSC exhibits this degradation. No detonation velocity tests were made on samples exposed longer than 2 days. All remaining samples were decomposed to such an extent that these measurements would have been impractical. The 10 and 50 grains/ft samples were tested after various exposure times for up to 4 days at 300°F. The results of these tests indicate some reduction of detonation velocity. Also, one sample of the 50 grains/ft material was completely decomposed after 75 hours of exposure. The ability of these RDX-FLSC's to sever aluminum plates is shown in Fig 21. The 10 grains/ft and 50 grains/ft samples showed a reduced capability with time. The 100 grains/ft material showed little fall-off until complete failure after 2 days exposure.

b. The RDX-FLSC (93.5% pure) at 300°F

The 93.5% pure RDX-FLSC begins to show marginal performance between one and two days at 300°F (149°C). This trend in performance has also been reported for 99.5% pure RDX-MDF. Note in Fig 20 that the first observation of degradation was with a propagation failure of a 10 grains/ft sample after only one day exposure at 300°F. A decrease in detonation velocity is shown for the 50 and 100 grains/ft core load samples of FLSC after 2 days of exposure. Complete decomposition of the RDX was observed in the FLSC after longer exposure times. The decrease of performance can be seen also in Fig 22 where the FLSC's loss of ability to sever an aluminum plate is shown as a function of time. It is concluded that the exposure of 99.5% and 93.5% pure RDX-FLSC in lead sheath to a temperature of 300°F will cause relatively rapid degradation of the explosive and the output of the FLSC.

c. The RDX-FLSC (93.5% pure) at 220°F.

By lowering the exposure temperature to 220°F (104°C) 93.5% pure RDX-FLSC's show only a slight degradation of detonation

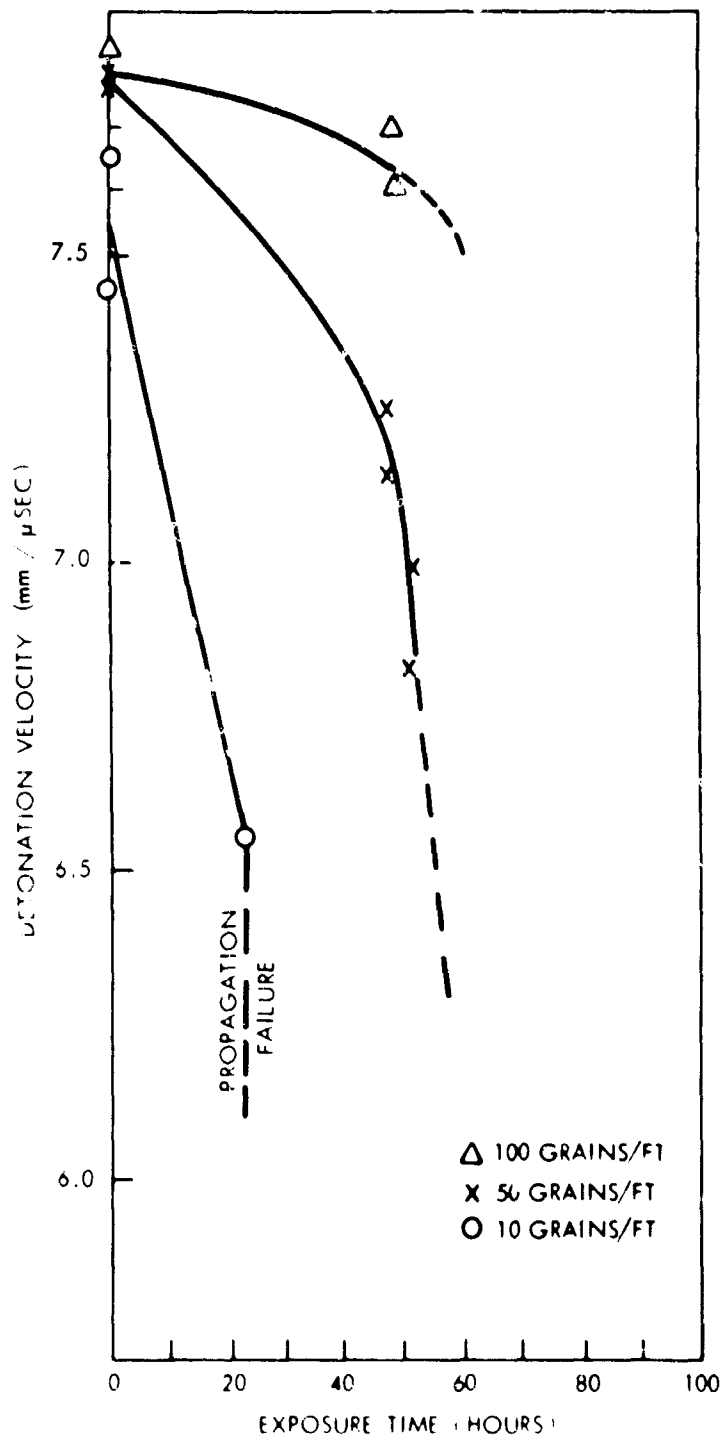


FIG. 20 THE DETONATION VELOCITY OF RDX FLSC (93.5%) AS A FUNCTION OF EXPOSURE TIME AT 300 F (SEALED)

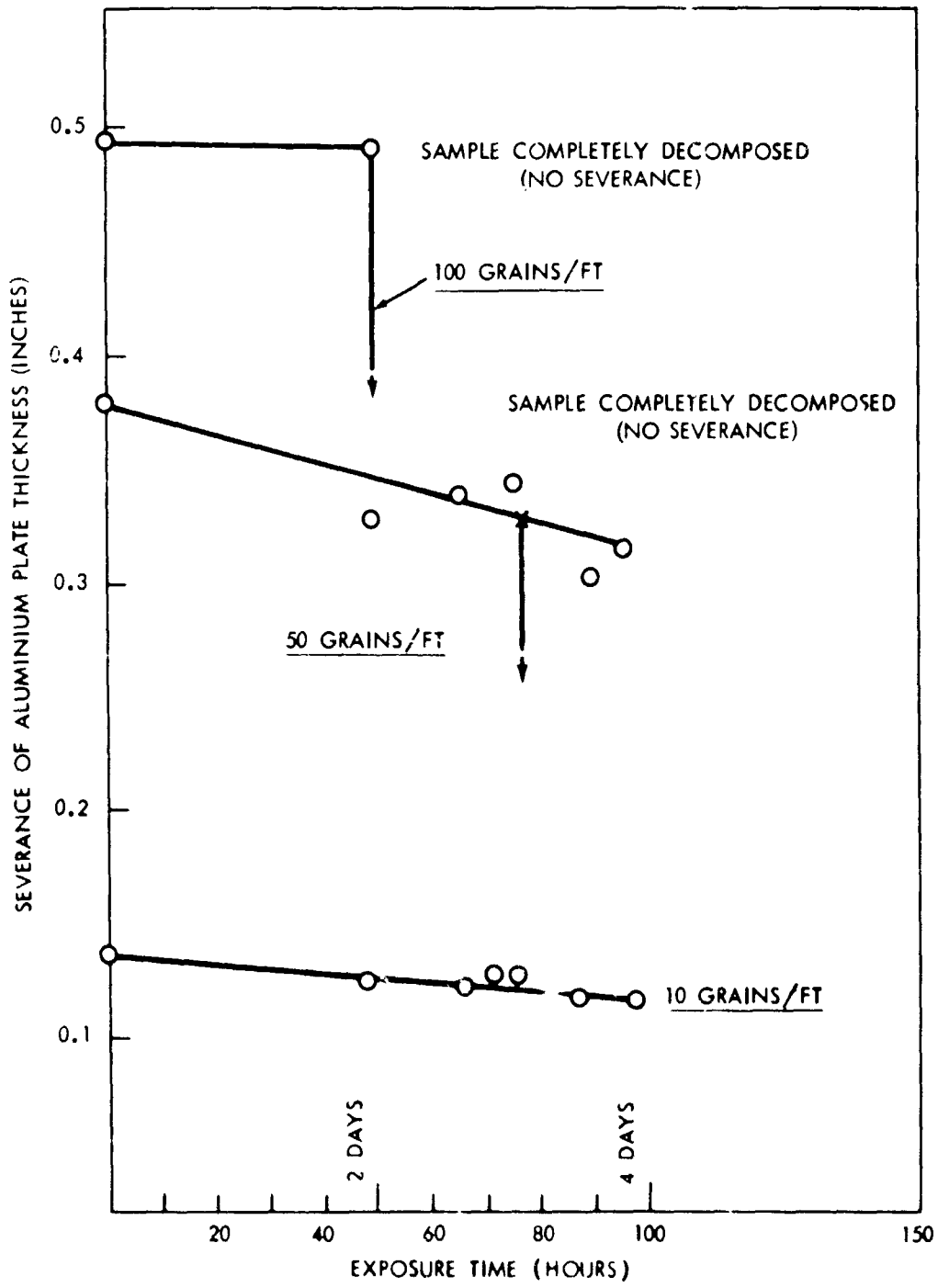


FIG. 21 THE SEVERANCE CAPABILITY OF VARIOUS RDX-FLSC'S (99.5%) AS A FUNCTION OF EXPOSURE TIME AT 300°F

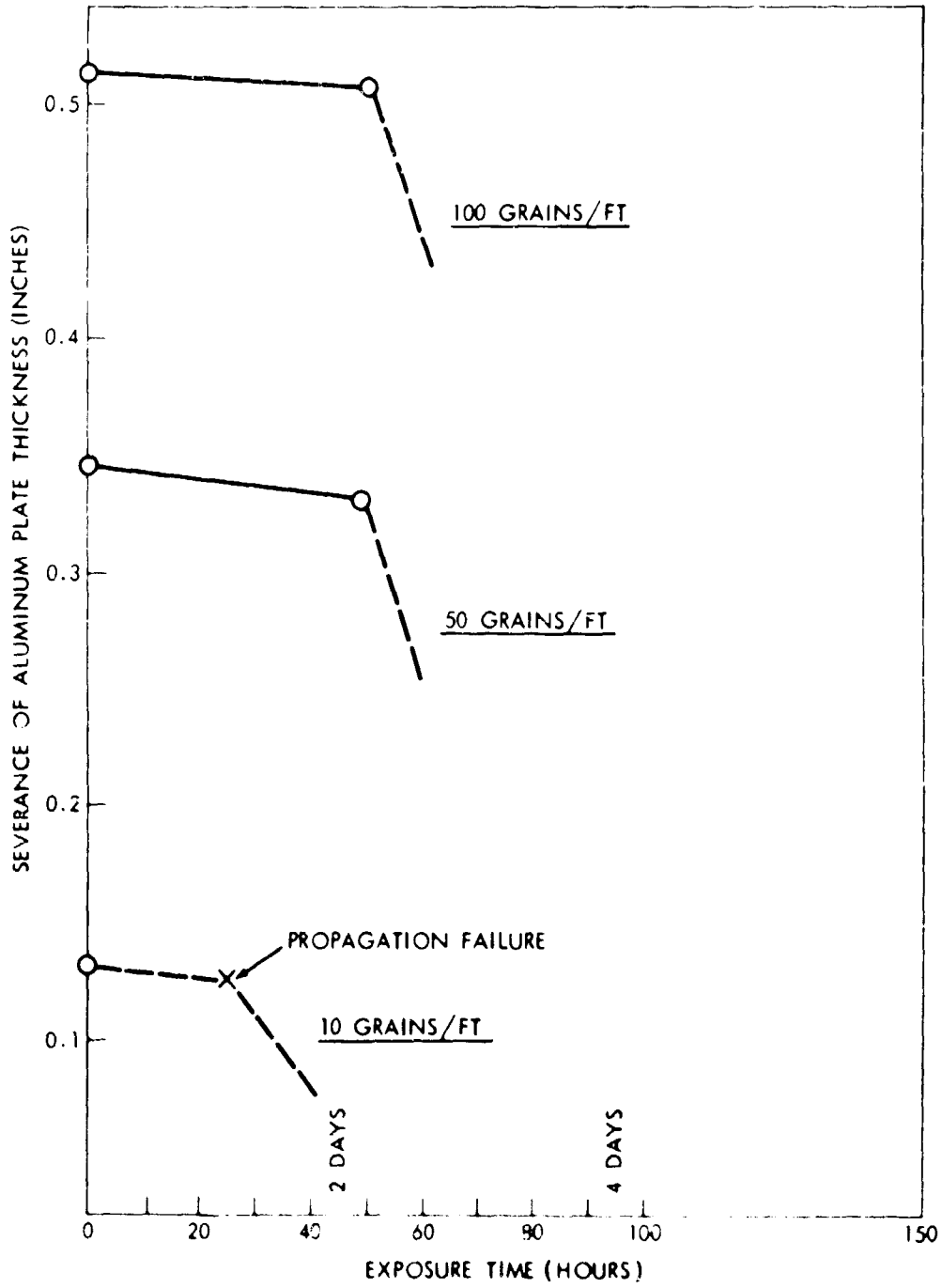


FIG. 22 THE SEVERANCE CAPABILITY OF VARIOUS RDX-FLSC'S (93.5%), AS A FUNCTION OF EXPOSURE TIME AT 300°F

velocity after two weeks of exposure (Fig 23). In addition, no decrease in the severance ability of the 10, 50, and 100 grains/ft FLSC was noted. It is believed that the FLSC's could be exposed to this temperature for longer periods of time without degradation because no change in color of the explosive was noted at the end of two weeks exposure. When degradation of the RDX begins to occur, a yellowing of the explosive is ordinarily observed. It should be pointed out that all the severance data is dependent on the test geometry shown in Fig 24. Any change in confinement or stand-off would affect the amount of severance.

## 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 It has been found that in the small diameters of the SSGT the sensitivity of HNS/Teflon decreases rapidly with decrease in temperature when the density exceeds approximately 1.55 g/cc.

5.2 Relating the observed sensitivity results of the HNS/Teflon mixture with the shock sensitivity determinations on pure HNS<sup>1\*</sup> and other explosives it would appear that the NOL preparation X-581 used in the ALSEP grenade has an acceptable shock sensitivity at observed densities and temperatures.

5.3 RDX (93.5%) and RDX (99.5%) in MDF's should not be used in obturated aerospace systems above 220°F for any more than a few hours. If the RDX-MDF's are kept at temperatures no higher than 200°F, we have demonstrated that they probably would be operable after two weeks.

5.4 There is an indication that the RDX-MDF (93.5%) detonates at an acceptable velocity after 3 months of exposure in a sealed system at a temperature of 180°F. Note plot of performance in Fig 25.

5.5 RDX (93.5% and 99.5%) FLSC's perform satisfactorily after 2 weeks exposure at 220°F.

\*Reference may be found on page iv.

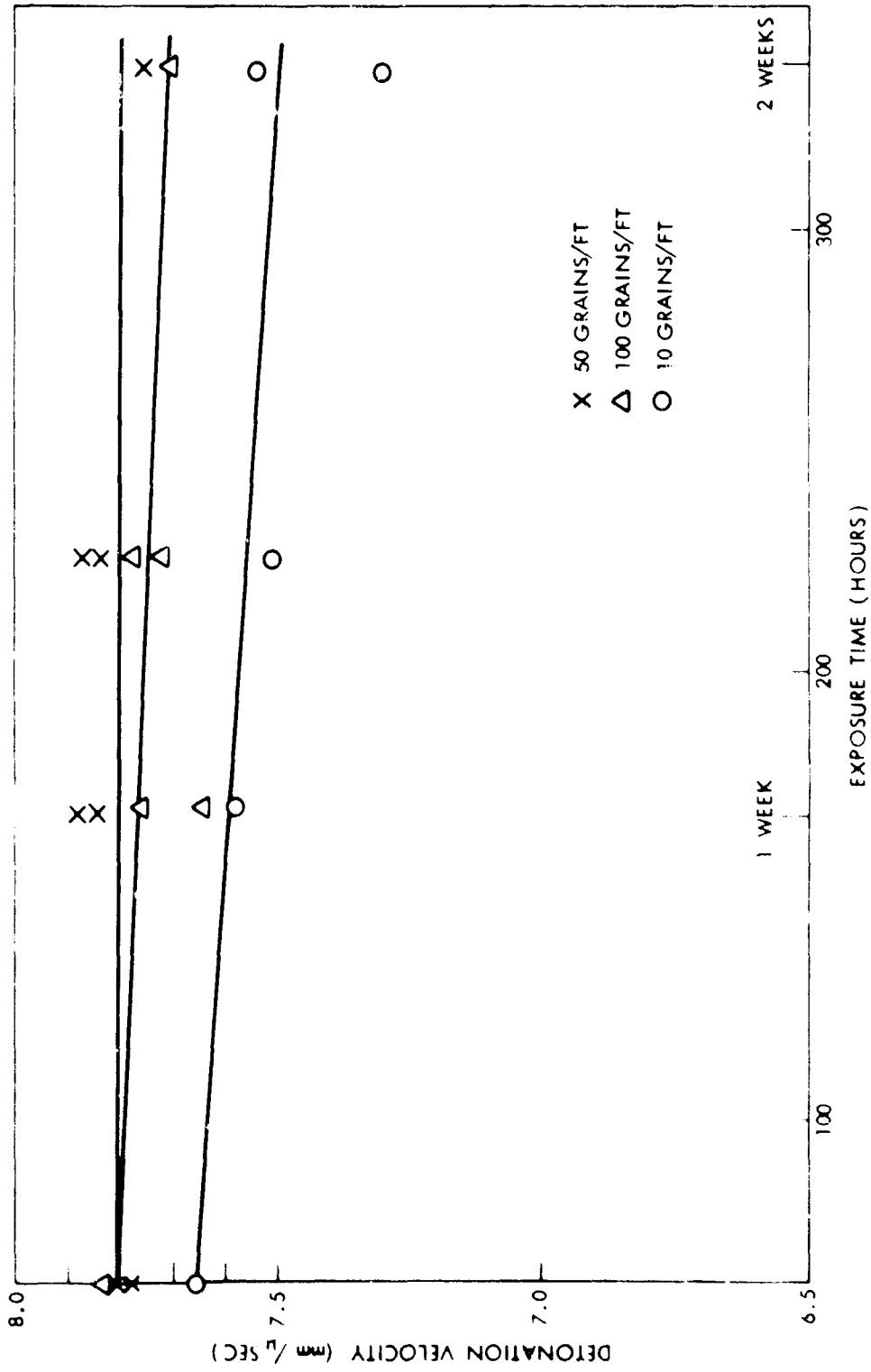
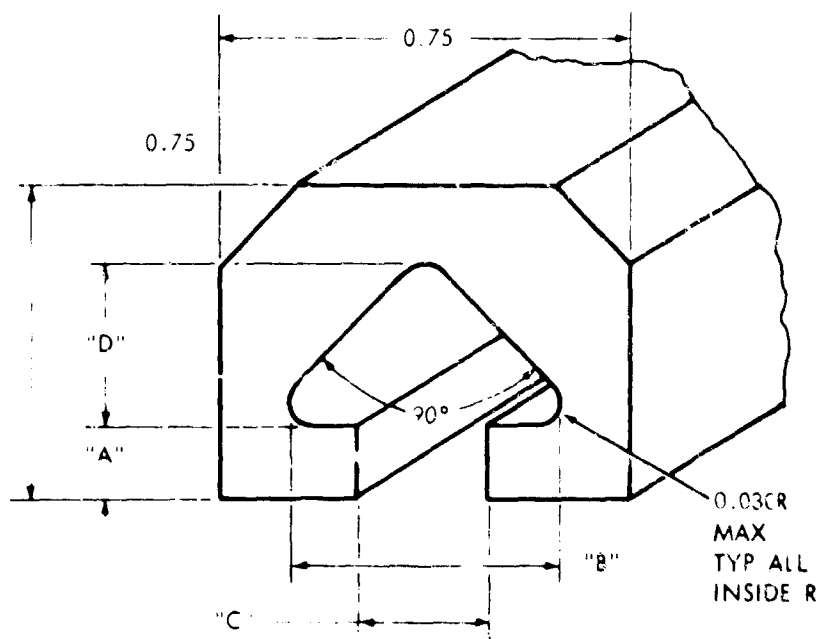


FIG. 23 THE DETONATION VELOCITY OF RDX - FLSC (93.5%) AS A FUNCTION OF EXPOSURE TIME AT 220°F (SEALED)



CORE/LOAD	DIM. "A"	DIM. "B"	DIM. "C"	DIM. "D"
10 GR/FT	0.023	0.162	0.075	0.098
50 GR FT	0.067	0.345	0.150	0.210
100 GR FT	0.112	0.458	0.203	0.290

MATERIAL SILICONE RUBBER  
 ZZ-R-165  
 CLASS IIB, GRADE 80

FIG. 24 FLEXIBLE LINEAR SHAPED CHARGE HOLDER



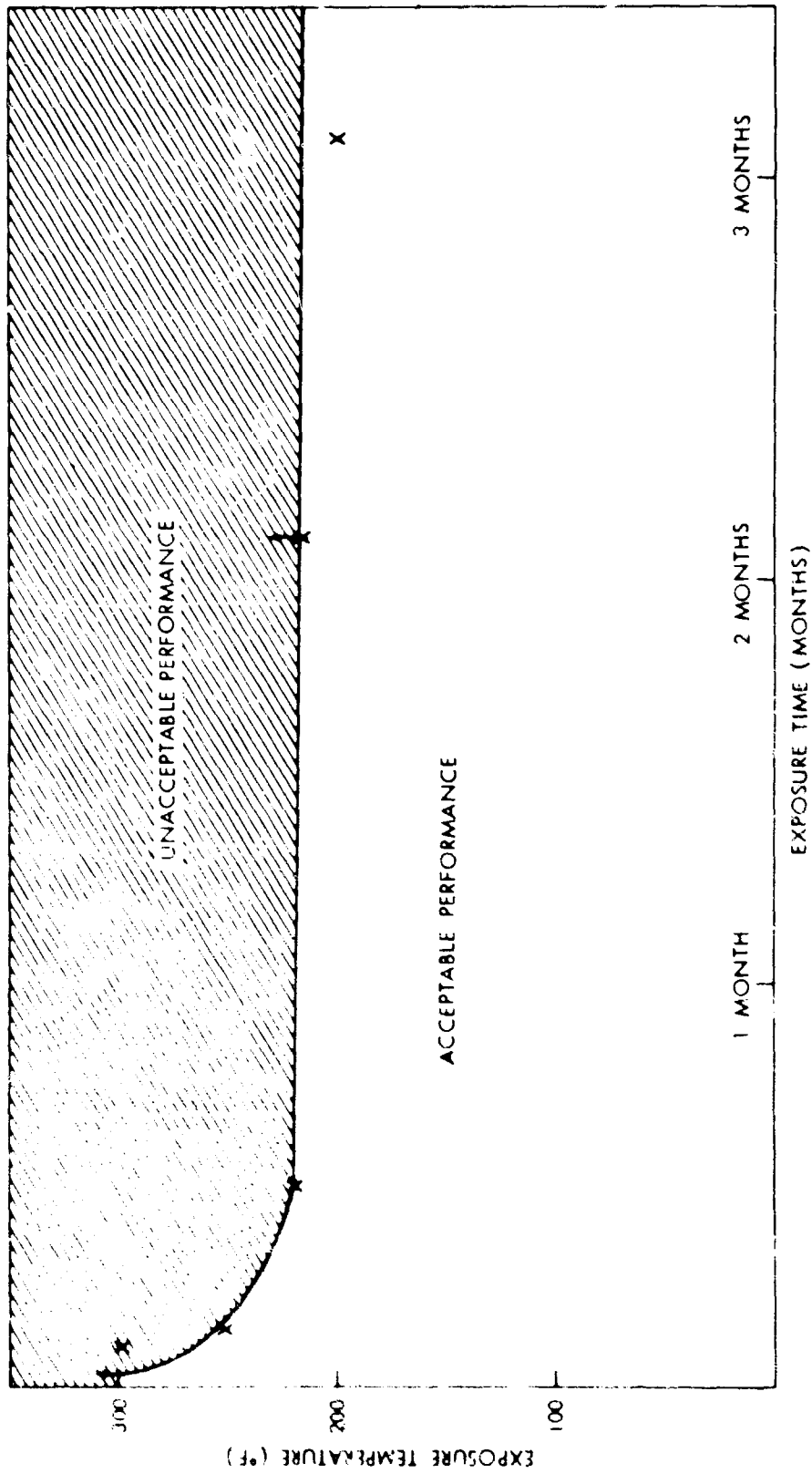


FIG. 25 THE EXPLOSIVE PERFORMANCE OF RDX - MDF'S (99.5%, 93.5%) AS A FUNCTION OF TEMPERATURE AND TIME OF EXPOSURE (OBTURED SYSTEM)

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13. ABSTRACT  
This report covers additional work in the area of investigation of the performance of MDF's and FLSC's after high temperature exposure. MDF's and FLSC's loaded with RDX (93.5%) and RDX (99.5%) were exposed to elevated temperatures in an obturate system. Observations on the high temperature exposure of MDF's and FLSC's are discussed with recommendations for limit of exposure. The low temperature shock sensitivity of HNS-I Teflon 90/10 mixture has been determined.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fuses Explosives, heat resistant Fuses, mild detonating Shaped charge, flexible linear Spacecraft, APOLLO space mission, ALSEP						