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EVALUATION OF SILICEOUS CORED ARMOR FOR THE XM60 TANK (U)

Technical Report No. 11733

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Prepared By

Charles B. Salter

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Harry Spiro

Metals Section, Materials Branch

Research & Development Division

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Technical Report No. 11733

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INTRODUCTION

The development of siliceous cored armor is an attempt to provide for combat vehicles some measure of defense against shaped charges and HEP rounds without overburdening the tank with excessive weight or reducing its efficiency against conventional armor piercing ammunition. This development was initiated in 1952 at the request of CONARC to provide some means for protecting vehicles against shaped charges. The guide lines that were established emphasized the development of built-in protection against shaped charge projectiles without sacrificing protection against kinetic energy projectiles.

The capability of most materials for defeating shaped charges follows a so-called density law which states that the penetration of shaped charge jets is proportional to the square root of the shaped charge liner density divided by the square root of the target density. Consequently, on a weight basis, lighter targets are more advantageous than heavier targets. However, the use of massive quantities of low density material is not desirable for obvious design reasons. Therefore, the material desired is that which is an exception to this density law. The most noteworthy of these is glass. Under proper conditions, the stopping power of glass exceeds that of armor steel on a thickness basis and in many cases glass is more than twice as good as steel on a thickness basis. The development of siliceous cored armor is an effort to utilize this phenomenon of glass in a practical manner. Some discussion relative to the phenomenal stopping power of glass would be appropriate at this point.

Since glass is a vitreous material, it does not flow plastically under ordinary loads. In fact, it theoretically should never flow plastically under any load. Although its modulus of elasticity is relatively low as compared to steel, it is approximately 10,000,000 pounds per square inch. Its elastic limit is high. When a shaped charge impacts glass, the high elastic limit of the glass is brought into play in stopping the jet. If the jet were penetrating a metal target, such as steel, the force of the jet elements would cause the steel to flow plastically, allowing progressively increasing, undisturbed travel to trailing elements. In the penetration of glass, however, the glass instead of flowing plastically, rebounds after the compressive shock wave and, in effect, radially bombards the oncoming jet particles causing disruption of the jet symmetry. Any residual steel backing can thus better withstand the perturbated attack. This has been substantiated with flash radiographs, and with high speed photographs of jets emerging from metallic and glass targets. (Figure I).

In this photograph the jet is seen as it is perfectly aligned in air and as it is after penetrating 1, 2 and 3 inches of glass. It can be noted that the alignment of the jet becomes increasingly disturbed with the increasing thickness of glass, in addition to the fact that a good portion of the jet is missing.

The characteristic of glass which allows it to absorb the energy of the jet and use this energy to attack the jet has been given the term "elastic rebound". This property of "elastic

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rebound" plays an increasingly important part in the ballistic protection afforded for vehicles. In essence, glass absorbs and stores a part of the energy of the attacking projectile whether kinetic or non-kinetic, and subsequently, this energy is released back in the direction of the attacking round. Because of this, kinetic energy attack on siliceous cored armor may cause considerable surface damage to the outside layer of the siliceous cored armor. However, the interior surface of the casting very often does not show any effect of the attack since much of the energy has not been transmitted.

In discussions relative to the effectiveness of siliceous cored armor, much credence will be placed on the TE or effective thickness of the silica. It has been shown that the TE of silica varies with its overall thickness and the angle at which the shaped charge attacks it. Thin slabs of silica have very high TE's in the neighborhood of three. That is to say that, 1 inch of silica is equivalent to 3 inches of steel in defeating shaped charges. However, as the silica increases in thickness, the capability of succeeding thicknesses of silica is diminished. Therefore, 4 inches of silica will have a TE of 1.5 making it equivalent to 6 inches of steel. Bearing this in mind, it must be realized that when silica is placed at obliquity, such as 60°, the effective thickness doubles. Therefore, 4 inches of silica at 60° presents to an oncoming jet, 8 inches of silica and consequently, the TE may drop to a value of 1 or less. Although there is a decrease in TE, with an increase in thickness of silica, there is a weight payoff in utilizing thicker sections of

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silica in defeating shaped charges. For example, 4 inches of silica at 60° on a weight basis is 3 1/2 times as effective as an equivalent weight of steel in defeating shaped charges.

The XM60 hull in steel, is designed to present 3.8 inches of armor at 65°. This provides 9 inches of steel in the path of the shaped charge projectile. If siliceous cored armor is utilized in this and 1 inch of steel is removed and replaced with 4 inches of silica, the effective stopping power is increased to a value of approximately 13.5 inches. Consequently, a 50% increase in protection is provided against shaped charges without any significant increase in weight. This level of protection in the hull is quite adequate in defeating most types of shaped charges as will be shown later in the ballistic test results.

In the XM60 turret, the level of protection afforded is even greater than on the hull. This is because the turret contains heavier armor sections and consequently the utilization of siliceous cored armor in the turret can provide almost complete invulnerability to the direct fired shaped charge weapons which may be utilized by an enemy.

SILICEOUS CORED ARMOR VS.
KINETIC ENERGY PROJECTILES

In order to assess the capability of siliceous cored armor to defeat kinetic energy projectiles, a rather comprehensive program of firings was conducted in 1954 and 1955. This program provided the evaluation of siliceous cored armor panels with a variety of core arrangements against projectiles ranging in size from 57mm to 120mm. From these tests it was concluded that siliceous cored armor panels, 6 inches to 8 inches in thickness, compare favorably with cast homogeneous armor on a weight basis. Table I summarizes the results of this program.

With the establishment of an educational program to train foundries in the manufacture of siliceous cored armor, additional thick panels were obtained. These panels represented the initial effort of the various large armor producers to manufacture siliceous cored armor and do not necessarily represent the current capabilities of these foundries. These panels were evaluated against 90mm and 120mm AP projectiles and the results are depicted in Table II.

It is apparent from this table, that on the average, most of the foundries are quite capable of manufacturing siliceous cored armor with an adequate level of protection against kinetic energy projectiles.

The XM60 is designed to provide protection against 100mm AP projectiles at 1500 yards. The firings into the hulls and turrets of a similar configuration to the XM60, substantiated the ballistic

TABLE I - BALLISTIC TEST SUMMARY OF SILICEOUS CORED CAST ARMOR PLATES TESTED DURING PERIOD OF JUNE 1954 TO AUGUST 1955

Thickness (Inches) Front	Core	Back	Equiv Steel Thick (Ins)	Obliq Degrees	Army Ballistic Limit (fps)	Army Ballistic Limit of Equiv Cast Armor (fps)
PROJECTILE - 76MM APCM62						
1	3	2	3.86	35	Av 2521	2350
PROJECTILE - 90MM AP T33						
1	2	3	4.64	45	2843	2650
1	2	3	4.57	55	> 3149	2940
1	3	2	3.86	55	2816	2750
1	4	2	4.21	55	2881	2815 (estimate)
1	4	3	5.14	55	> 3141	3050 (estimate)
PROJECTILE 90MM HVAP-M304						
1	2	2	4.57	60	> 3968	> Muzzle Velocity
1	3	2	3.86	60	3844	3750 (estimate)
PROJECTILE - 120MM AP T116E4						
1	2	2	4.57	60	> 2660	2770
1	3	4	5.86	45	2930 (Approx)	2930 (estimate)
1	4	3	5.14	45	< 2177	2200 (estimate)
1	4	3	5.14	60	> 2688	2950
1	2	5	6.57	45	> 3205	3100

TABLE II - KINETIC ENERGY PROJECTILES VS. SPECIAL ARMOR PLATE

Company	Projectile	Special Armor Plate Thick	Obliq.	Effect of Striking Plate	Velocity	
General GS 2671 Plate 2/422	90mm AP T33	7"	55°	PP(P)	2728 fps	BL (P) 2790 fps
	" "	"	"	CP(P)	2852 fps	
Continental Heat 8153 Plate #3	" "	"	"	PP(P)	2814 fps	BL (P) 2818 fps
	" "	"	"	CP(P)	2822 fps	
Pittsburgh Plate #2	" "	"	"	CP(P)	2836 fps	NO BL
				Drastic Plate Failure		
Scullin Heat M5328 Plate #7	" "	"	"	PP(P)	2862 fps	NO BL
	" "	"	"	PP(P)	2936 fps	HP -
	" "	"	"	PP(P)	3033 fps	3033 fps
Birdsboro Plate #7-1	" "	"	"	PP(P)	2751 fps	BL
				CP(P)	2812 fps	2782 fps

4" Cast @ 55° - 2785 fps
NOTE: Wt. of 4" Cast Armor = Wt. of 7" Special Armor

Company	Projectile	Special Armor Plate Thick	Obliq.	Effect of Striking Plate	Velocity	
General HEAT GS 2670 Plate #1/342	120mm AP T116E4	8"	60°	PP(P)CP(A)	2949 fps	NO BL
				Severe Face Plate Displacement		
Continental Heat 8153 Plate #2	90mm AP T33	"	40°	PP(P)	2935 fps	BL (P)
	" " "	"	"	CP(P)	3003 fps	2980 fps
				PP(P)	2957 fps	
Pittsburgh Plate #4	" " "	"	"	PP(P)	2639 fps	NO BL
	" " "	"	"	PP(P)	2700 fps	
				Severe Face Plate Displacement		
Scullin Heat M5329 Plate #2	" " "	"	"	PP(P)	2748 fps	NO BL
	" " "	"	"	PP(P)	2845 fps	
	" " "	"	"	PP(P)	2890 fps	

(280) 5" Cast Armor w/120mm @ 60° - 2924 fps
5" Cast Armor w/90mm @ 40° - 2675 fps
NOTE: Wt. of 5" Cast Armor = Wt. of 8" Special Armor

capability of the siliceous cored armor to meet this requirement.

One of the problems in the development of siliceous cored armor that has caused some concern is the effect of damage resulting from incomplete penetrations from AP projectiles. A severe case of this is shown in Figure II.

You will note the front surface is badly ripped open from a partial penetration by a 105mm AP projectile. The primary reason for this condition is found in the "elastic rebound" capability of siliceous cored armor. Although Figure II shows a badly torn outside surface, the round did not penetrate or even bow the inside of the hull. Nevertheless, it is quite possible to reduce this effect by maintaining the thickness of the outside skin to 1 inch minimum.

Figure III shows another hull of the same design manufactured in the program. You will note that this hull does not contain any extraordinary damage due to partial or complete penetrations. The damage incurred can be compared with the damage accrued in a solid steel casting of a similar design. (Figure IV).

A further examination of the interior of the two hulls shows the effects of attack by both 105mm AP rounds and shaped charge projectiles. (Figures V and VI).

The tests on the siliceous cored armor turret did not produce any extraordinary damage pattern. Therefore, the following can be concluded:

a. Siliceous cored armor on an equal weight basis provides equivalent kinetic energy protection to cast homogeneous armor.

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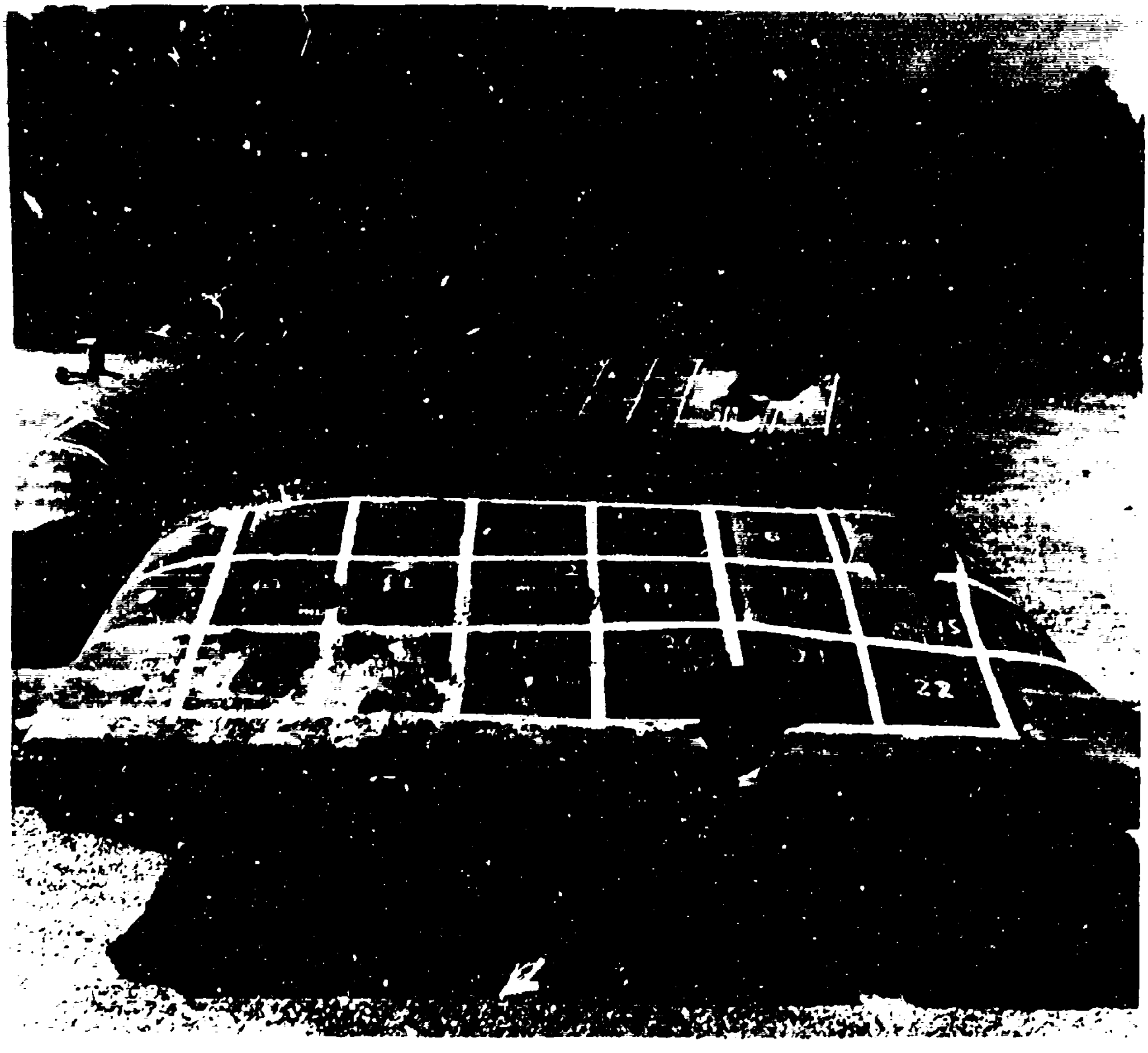

B30079 ABERDEEN PROVING GROUND 17 June 1958

Project OTAC-I/134. Ballistic Testing of Special Turret and Hull Front Nose Castings.

Exterior view of General Steel Castings Hull Front End, Serial No. 1. Attacked with 90mm, HEAT, T108E40, 3.5" Rocket and 105mm, AP, T182E1 Projectiles.

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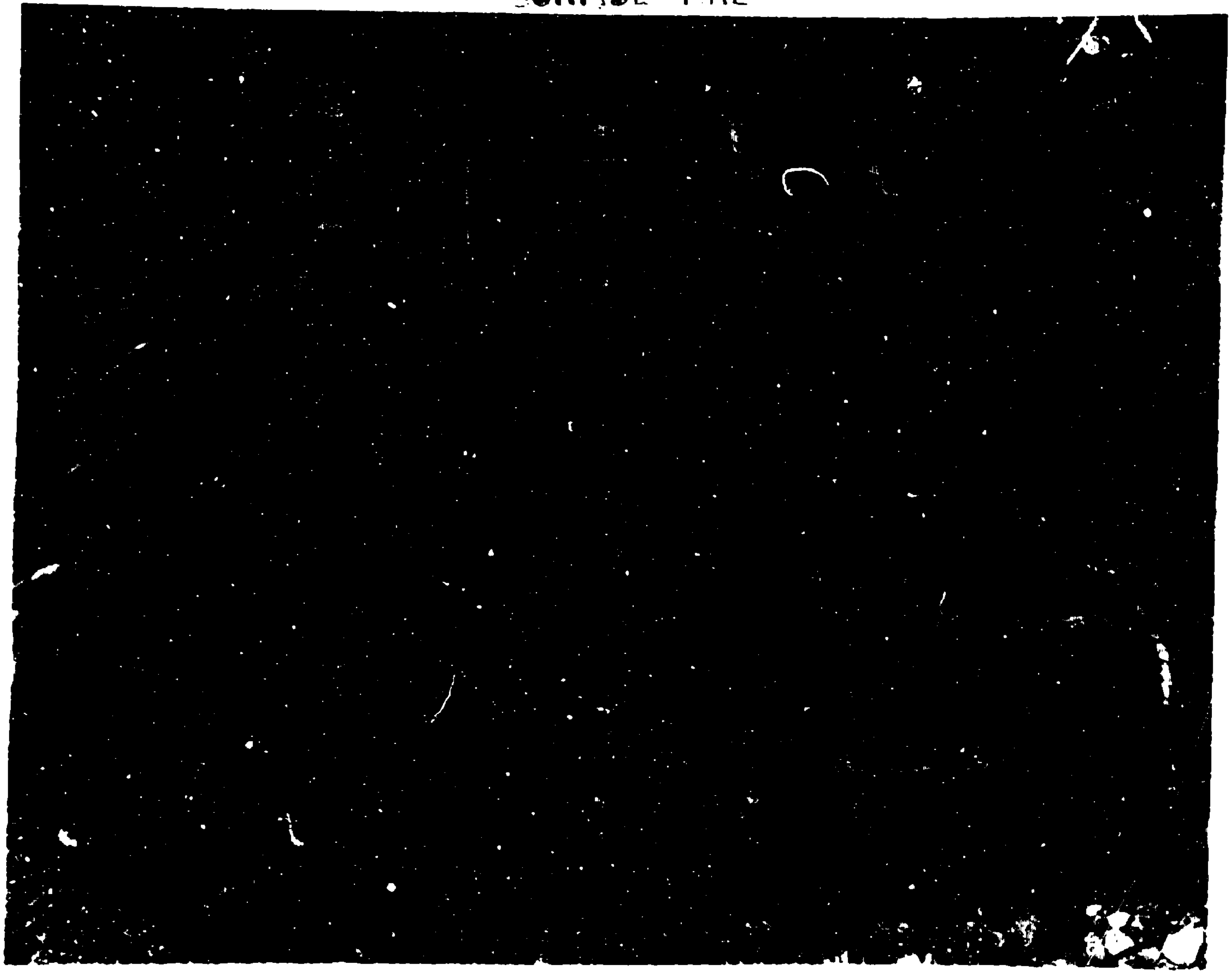
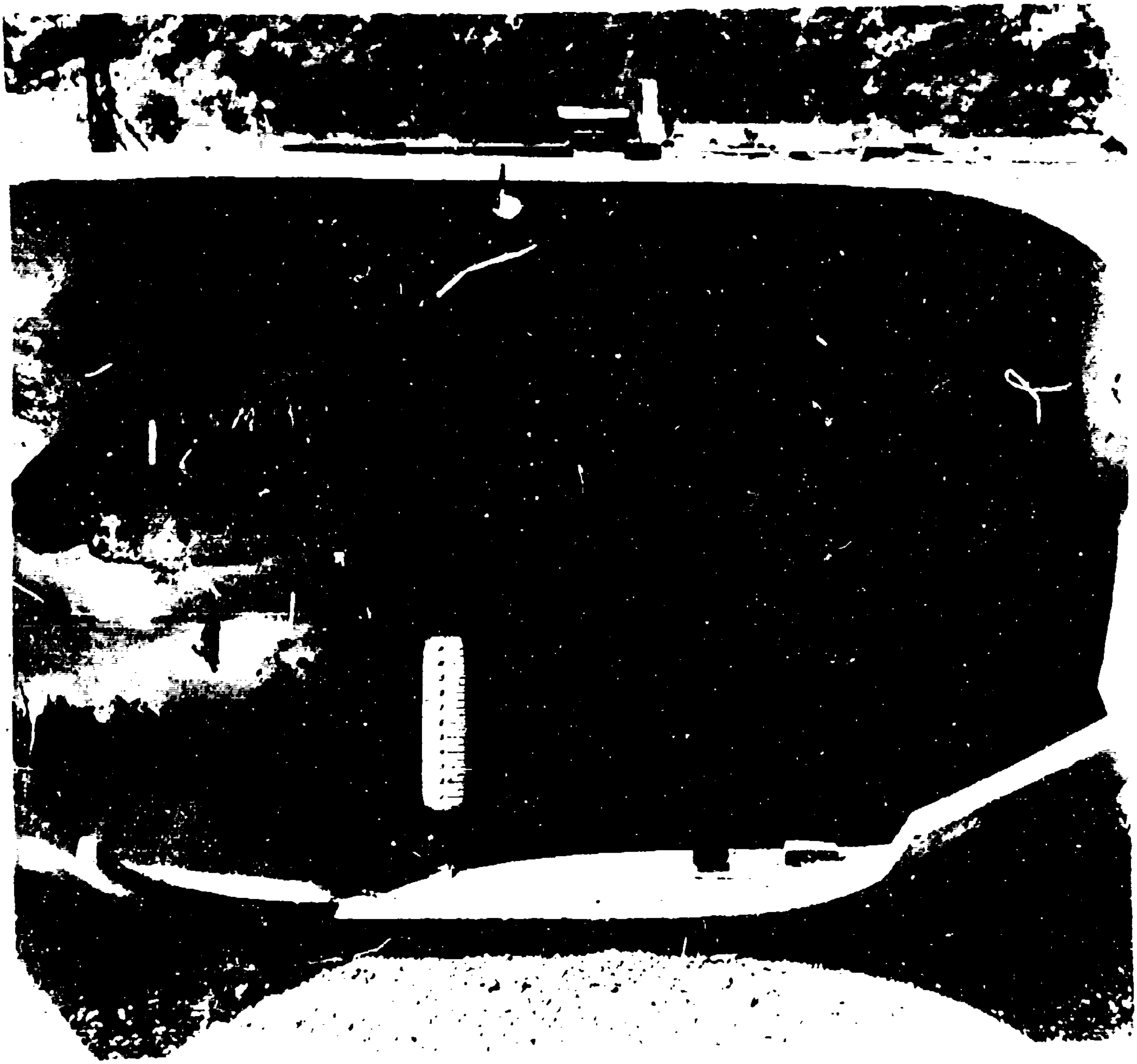


B28697 CONFIDENTIAL ABERDEEN PROVING GROUND 14 February 1958

Project TT2-782/51. Ballistic Evaluation of T95 Tank Castings.



B30080 ABERDEEN PROVING GROUND 17 June 1958

Project OTAC-I/134. Ballistic Testing of Special Turret and Hull Front Nose Castings.
Interior view of General Steel Castings Hull Front End, Serial No. 1.

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B26700 CONFIDENTIAL ABERDEEN PROVING GROUND 14 February 1956

Project TT2-782/51. Ballistic Evaluation of T95 Tank Castings.

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b. The damage caused by AP shot can be controlled by rigidly specifying a minimum outside thickness.

SILICEOUS CORED ARMOR VS. HEAT AND HEP ROUND FIRINGS

The primary reason for the consideration of siliceous cored armor in the XM60 is that this type of armor can provide a good measure of protection against shaped charge penetration without overburdening the vehicle with excessive weight. The capability of siliceous cored armor in defeating various shaped charges is dependent upon many factors. As has been pointed out previously, the thickness of silica in the path of the jet determines to a great extent the equivalent thickness of the silica as compared to steel armor. Other factors which play an important part are the efficiency of the shaped charge and the foundry techniques utilized in the manufacturing of the casting. It has been observed that castings manufactured by untrained foundries have a tendency to bow, resulting most assuredly in a damaged interior core. However, the capability of foundries in producing improved siliceous cored armor has been demonstrated in this program and it can readily be expected that production runs of siliceous cored armor will be of acceptable quality.

There is considerable data available from Carnegie Institute of Technology and from Aberdeen Proving Ground relative to firings of a variety of shaped charges into siliceous cored armor. In these firings, the equivalent thickness of 4 inches of fused silica has varied from values as low as .6 to values as high as 1.64. For the sake of analysis, only the data obtained on the hulls and turrets will be considered for evaluation.

The Development and Proof Services at Aberdeen Proving Ground have tested one steel T95 type hull and 6 siliceous cored armor hulls of equivalent design. These hulls were evaluated using the 90mm T108 HEAT round fired dynamically and 3 1/2 inch HEAT rounds statically detonated. Of 22 observations obtained from a direct frontal attack at 65° obliquity, 11 rounds gave 0 or less residual penetration into the mild steel witness packets placed behind the armor. On the other hand, when these rounds were fired at similar all steel hulls, residual mild steel penetrations of 4 1/2 inches to 7 inches were observed. Since the hulls containing siliceous cored armor had approximately the same weight as the all steel hulls, it can be concluded that additional protection has been achieved without any significant increase in weight. Turrets, similar to the one designed for the XM60, were manufactured from both solid steel and siliceous cored armor. These were tested against 106mm M344 HEAT rounds (dynamically fired) and 3 1/2 inch HEAT rounds (statically detonated). The 3 1/2 inch HEAT round could not penetrate the siliceous cored armor whereas the solid steel turret provided mild steel residual penetration of 1.83 inches. The 106mm M344 HEAT round produced a mild steel residual penetration in the siliceous cored armor averaging less than 1/3 of an inch, whereas the solid steel turret provided an average residual penetration of 6 inches. Once again, the weight of these turrets was approximately equivalent for both solid steel and siliceous cored armor. The data on the HEAT round firings into solid steel and siliceous cored armor has been summarized and is presented in Table III. In obtaining the average values utilized in this table it will be noted that the siliceous cored armor results are depicted as some value less than that reported. This is because the siliceous cored armor in many instances had zero (0) penetration or less and since it was not practical to obtain the minus residual penetration values, minus residual penetrations were arbitrarily called zero. Consequently, the average residual penetration reported is actually greater than the average residual penetration obtained.

Early in the program some experiments were conducted utilizing 90mm HEP T114E3 projectiles against siliceous cored armor. The targets selected were only 4 inches thick and contained only 1 or 2 inches of silica cores. However, it is interesting to note that of the 4 rounds fired against these relatively thin light weight targets only one of the 4 rounds defeated the target and even this defeat produced a mechanism of ductile failure considered quite contrary to the type of defeat generally noted with HEP projectiles. Ordinarily when a HEP round defeats armor it throws off a large spall on the rear of the plate causing considerable damage. This did not occur in any of these firings. If the siliceous cored armor test had been of the size and configuration utilized in this evaluation, there is no doubt that 100% protection against HEP ammunition would have been achieved. Figure VII shows the front and back surface of a 4 inch siliceous cored armor plate after being attack by a 90mm HEP round.

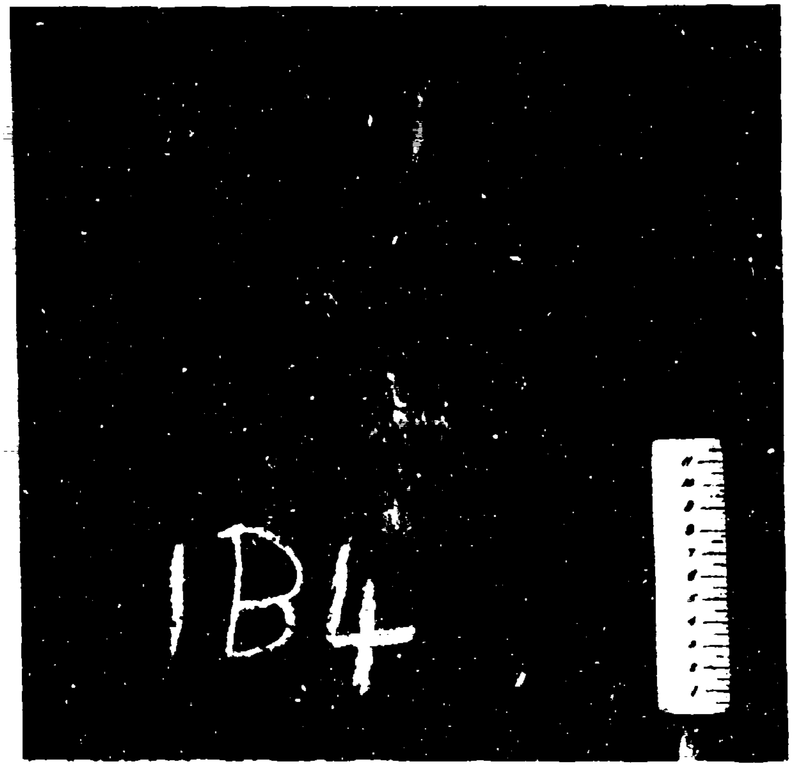
From the above it can be concluded that the utilization of siliceous cored armor in the XM60 will result in the following:

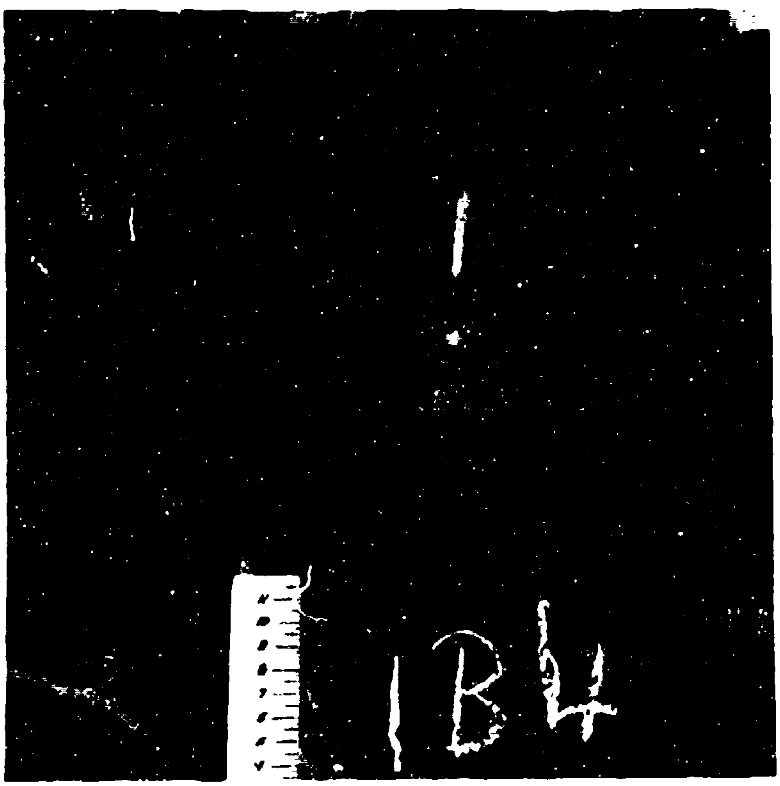
TABLE III

HEAT ROUND DATA

AVERAGE RESIDUAL PENETRATION

HEAT ROUND	SPECIAL HULL	STEEL HULL	SPECIAL TURRET	STEEL TURRET
90 MM T108 DYNAMIC	< 1.13 (11)	7.50 (2)	—	—
3.5" ROCKET STATIC	< 0.75 (8)	6.50 (2)	0.00 (5)	1.83 (2)
106 MM M344 DYNAMIC	—	—	< 0.31 (7)	6.00 (2)





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a. A high level of HEAT round protection in the hull and turret from frontal attack.

b. Invulnerability for the front hull and turret from HEP round attack.

SILICEOUS CORED ARMOR VS HE ROUND FIRINGS.
TESTS AGAINST HIGH EXPLOSIVES

In line with the overall evaluation of the capability of siliceous cored armor, a program was established to test two hull castings against high explosive shells.

The first hull was impacted with 6 120mm HE rounds. The fuze setting on two of the rounds was superquick and the other four maximum delay. The obliquity of the casting (65°) was selected for the initial firings and then lowered to 45° in an effort to obtain failure. The striking velocity of all the rounds was approximately 2300 fps which represents the velocity of the 120mm projectile at 1000 yds. After completion of the firings, two (2) 3 1/2 inch rockets were statically detonated on the castings to establish whether a loss in the shaped charge protection was obtained.

The second hull was impacted with two 120mm HE rounds and three 105mm HE rounds. The fuze settings on the 120mm rounds and two of the three 105mm HE rounds were at maximum delay. One 105mm round used a fuze setting of superquick. The obliquity of the casting for the 120mm fired was set at 30° and 0°. The obliquity for the 105mm firings was 65° and 0°. The results of all the firings on a round by round basis are given in Table 4.

From these tests it is quite obvious that siliceous cored armor, as represented by the hulls, is quite capable of maintaining its integrity against 120mm and 105mm HE rounds at obliquities ranging from 0° to 65° with superquick and/or maximum delay fuze

TABLE IV - BALLISTIC TEST SUMMARY OF SILICEOUS CORED ARMOR HULLS VS. HE PROJECTILES

HULL NO. 3

Round No.	Size (mm)	Obliq. Degrees	Fusing	Velocity fps	Damage
1	120	65	Superquick	2304	No Damage
2	120	65	"	2319	Face - No cracks, Deformation 1 5/8" Rear - 2 fine cracks, 2 1/2", 2 5/8", Large Bulge
3	120	65	Max. Delay	2315	Face - 3 plate cracks, 5", 2", and 1" Hair Crack 3", Bulge Rear - Large Bulge 1" Deformation, 3" hair crack
4	120	65	"	2313	Face - Face crack 11", Depth of Deformation 1 1/4" Rear - 2 1/2" hair crack
5	120	65	"	2307	Face - 2 face cracks, 12 1/2", 4 3/4" Rear - 1 fine crack, 2 3/4"
6	120	65	"	2302	Face - No cracking Rear - 3 1/4" fine crack
7	3.5" HEAT Statically Detonated 12" from center of hit #3	65			Complete Penetration Penetration Residual in Mild Steel, 1.18"
8	3.5" HEAT Statically Detonated In Center of Hit #3	65			Complete Penetration Penetration Residual in Mild Steel, 4.75"

TABLE IV - BALLISTIC TEST SUMMARY OF SILICEOUS CORED ARMOR HULLS VS. HE PROJECTILES

HULL NO. 2

Round No.	Size (mm)	Obliq. Degrees	Fusing	Velocity fps	Damage
1	120	30	Max. Delay	2325	Face - Depth of Deformation 3", Horizontal Crack 2", tongue crack, 3 3/7", 3 1/4" Rear - 2 fine cracks, 1", 3/4", Slight Bulge
2	120	0	"	2310	Face - Slight rupture at apex of hit, 2 face cracks, 3/8", 2 3/4" Inside - 2 fine cracks 3", 3 1/2", Slight bulge
3	105	65	"	2395	Face - Deformation 3/4", No cracks Rear - No Damage
4	105	0	"	2394	Face - Deformation 2 1/2", 3 face cracks 4", 3 3/8", 1 3/4" Rear - Tongue Crack 1 1/2" by 2
5	105	0	Superquick	2398	Face - Deformation 1 5/8", no cracks Rear - No Damage

settings.

Further, it was established that repeated impacts in the same area does not alter the capability of the casting in maintaining its front surface.

It also can be observed from Table 4 that the siliceous cored armor maintains a high level of HEAT round protection after impact from HE rounds except for those areas damaged by the impact.

Figure VIII shows the first hull after impacts from 6 120mm HE rounds and two (2) 3 1/2 inch rockets statically detonated.

Figure IX shows the interior of the same hull.

Figure X shows the results of the second hull impacted with 120mm HE round at 30 and 0° obliquities and from 105mm HE rounds at 65 and 0° obliquities.

Figure XI is the interior of this casting.

From the above, it can be concluded that

a. Siliceous cored armor in the design considered for the XM60 will afford adequate protection against impacts from large caliber HE rounds.

b. After impacts with large caliber HE rounds siliceous cored armor will maintain protection against HEAT rounds except in those areas directly damaged by the HE firings.

T331 ABERDEEN PROVING GROUND 31 October 1958

Project OTAC-I/134. Ballistic Evaluation of Special Turret and Hull Castings.

Exterior view of the upper glacis plate of General Steel Castings Hull Front End, Serial No. 3 attacked with six pounds of Shell, HE, 120mm, T15E2 and two rounds of 3.5" Rocket.

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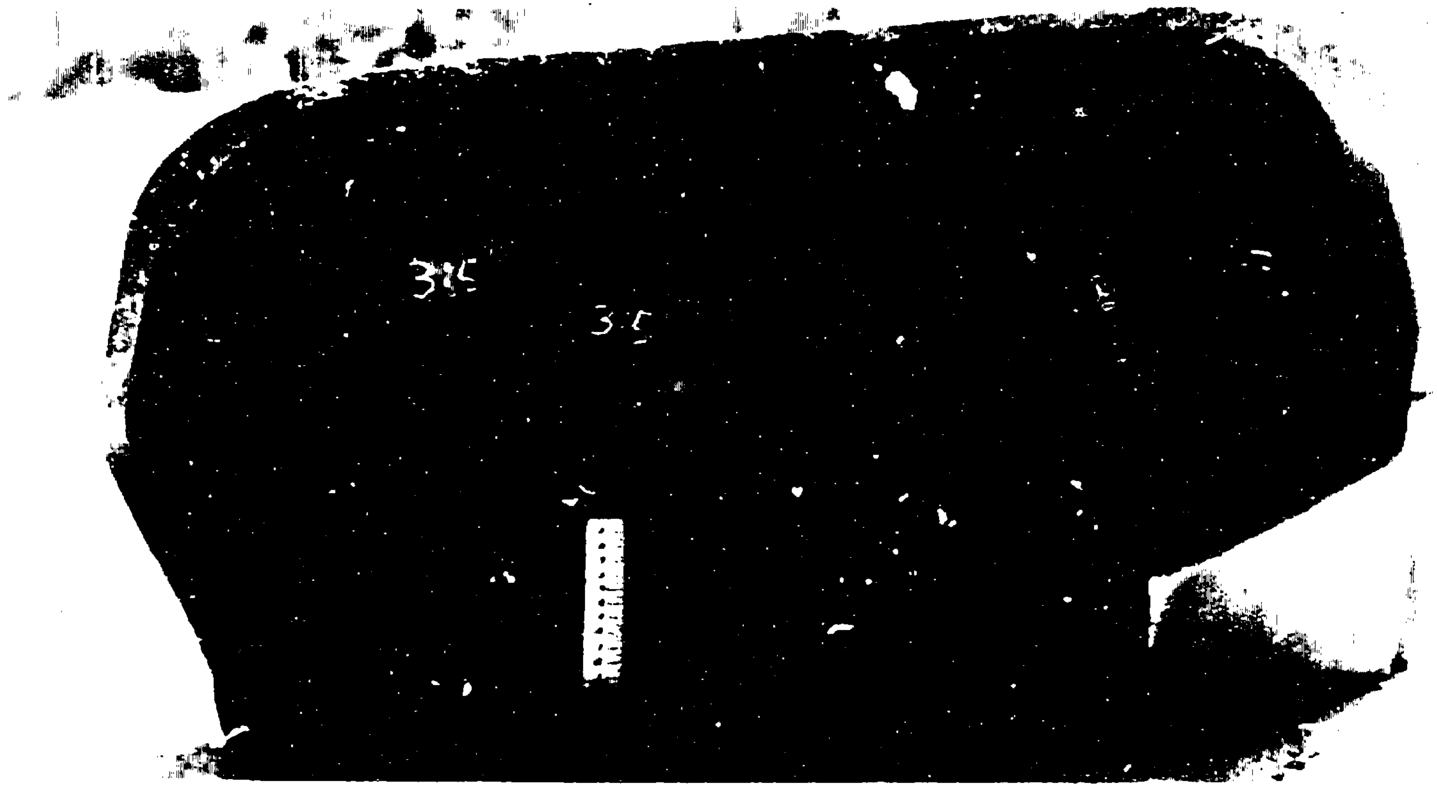

T334 ABERDEEN PROVING GROUND 31 October 1956

Project OTAC-I/134. Ballistic Evaluation of Special Turret and Hull Castings.
Interior view of upper glacis plate of General Steel Castings Hull Front End, Serial No. 3.

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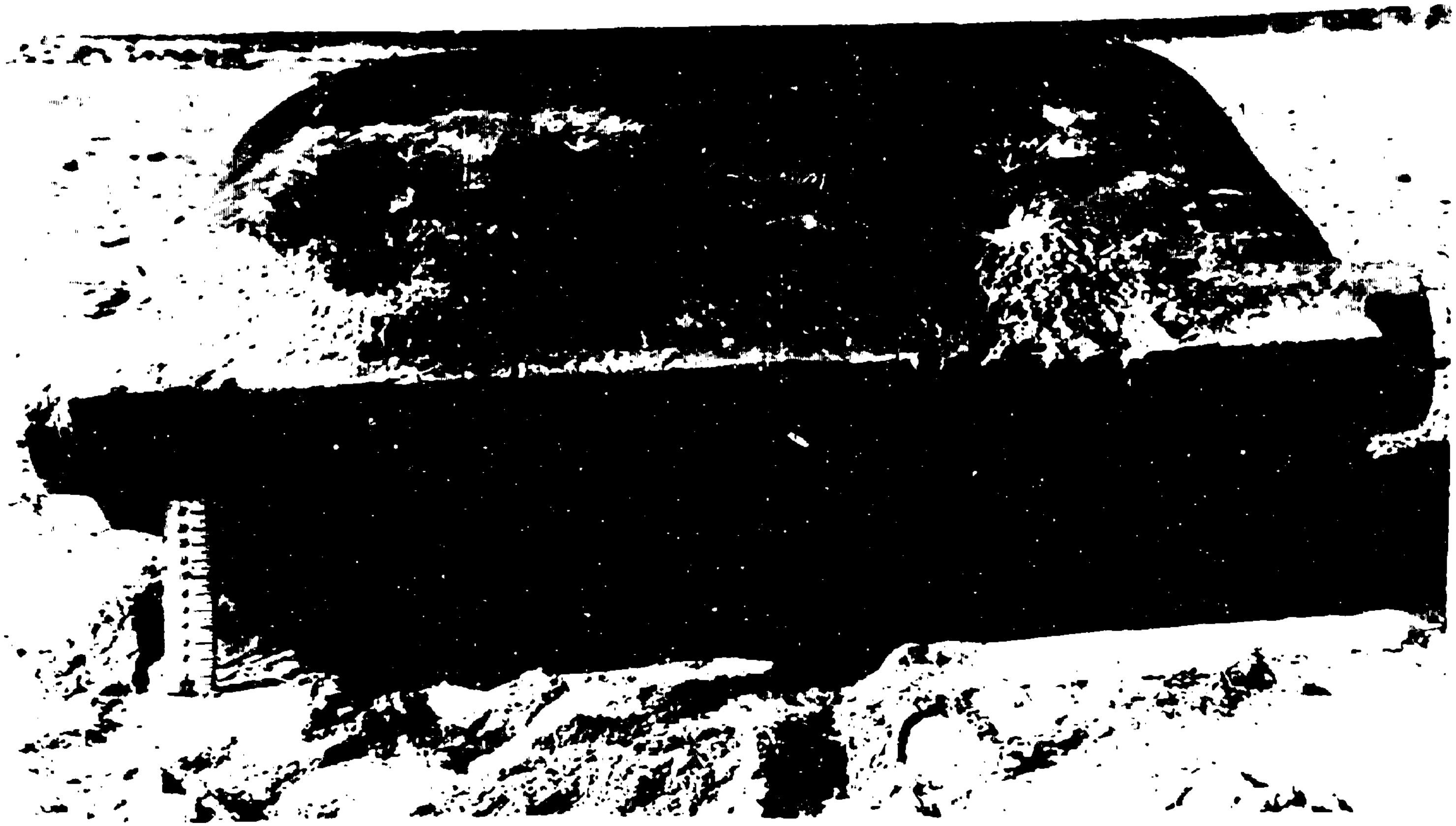
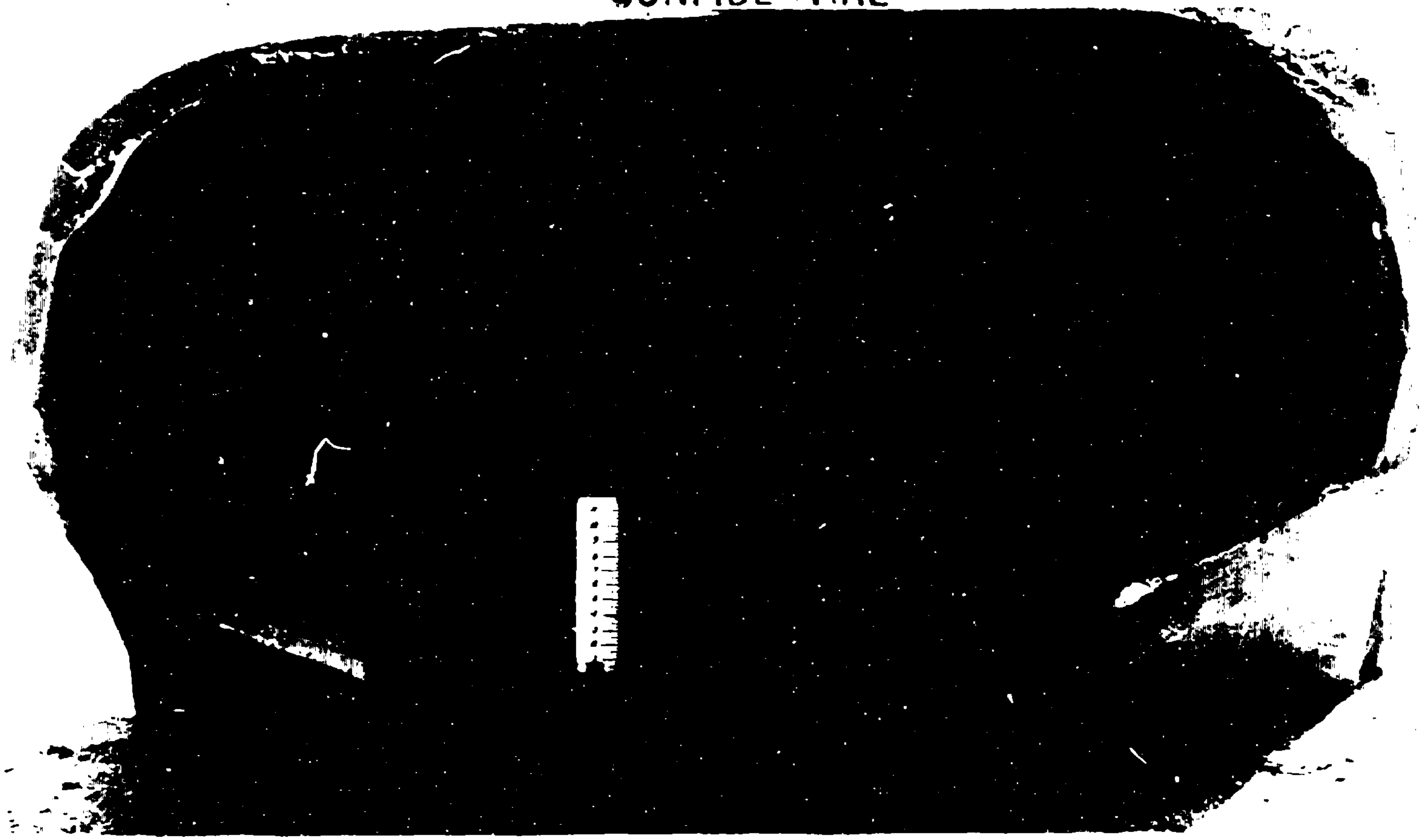


T332 ABERDEEN PROVING GROUND 31 October 1958

Project OTAC-I/134. Ballistic Evaluation of Special Turret and Hull Castings.

Exterior view of the upper glacis plate of General Steel Castings Hull Front End, Serial No. 2 attacked with two rounds of Shell, HE, 120mm, T15E2 and three rounds of Shell, HE, 105mm, T246.

Figure ... Page 2...



T333 ABERDEEN PROVING GROUND 31 October 1958

Project OTAC-I/134. Ballistic Evaluation of Special Turret and Hull Castings.
Interior view of the upper glacis plate of General Steel Castings Hull Front End, Serial No. 2.

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REPAIR OF CASTINGS IN THE FIELD

The partial penetration into siliceous cored armor by large caliber, high velocity, kinetic energy projectiles causes considerable damage to the fused silica core. It was therefore determined that if this armor was to be a practical field material, a simple repair procedure had to be developed utilizing readily available materials and equipment.

Several castings that were severely battered by repeated impacts from kinetic energy and non-kinetic energy projectiles were repaired at Aberdeen Proving Ground utilizing only equipment and materials that are readily available in the field.

Special precautions, best repair practices, and high quality workmanship of the type required in production fabrications, were purposely not adhered to. The actual repairs reflect a compromise between quality, simplicity, and expediency. Some improvements could be achieved by complicating repair procedures making greater demands on skill and substantially increasing the repair time. Whenever possible the original armor was rewelded back in position after [illegible] been dislodged. Austenitic electrodes which do not require any preheating or postheating were used for the repairing. Small patches of rolled homogeneous armor were utilized when the original armor was not available. Since it was not likely that fused silica of adequate size and dimension would be available on the battlefield, a commercial concrete mixture called "Sakrete"

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was obtained to fill any gap in the core resulting from the firing. Figure 12 shows the equipment at Aberdeen Proving Ground utilized in the repair procedure. Figures 13 and 14 show two hulls which had various degrees of damage and were repaired. After repair was completed, the hulls were subjected to additional tests with both 105mm AP ammunition and 3 1/2 inch statically detonated HEAT rounds.

Results of these tests on the repaired castings indicated a good level of shaped charge protection could be achieved. The reason for this is that low density concrete has a TE value of approximately .6 and therefore, is twice as good as steel in defeating shaped charges on a weight basis. However, against impacts from 105mm AP ammunition, the level of protection was lowered from a ballistic limit of approximately 2950 fps to a ballistic limit of approximately 2350 fps. This means that in the repair area there is a loss of protection against 100mm kinetic energy projectiles from 1500 yds to approximately 3500 yds. It should be pointed out, however, that plug welded steel armor also suffers a high loss of ballistic protection. It can be concluded that

a. Siliceous cored armor castings can be repaired in the field using materials and equipment that are readily available to the Army.

b. These repaired castings will afford a high level of protection against shaped charge but a loss in the protection against 100mm AP ammunition in those areas that have been repaired.

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B32056 ABERDEEN PROVING GROUND 28 August 1958

Project OTAC-I/134. Ballistic Testing and Repair of Special Armor Castings.
Overall view of Field Repair Station showing equipment used in accomplishing repairs.

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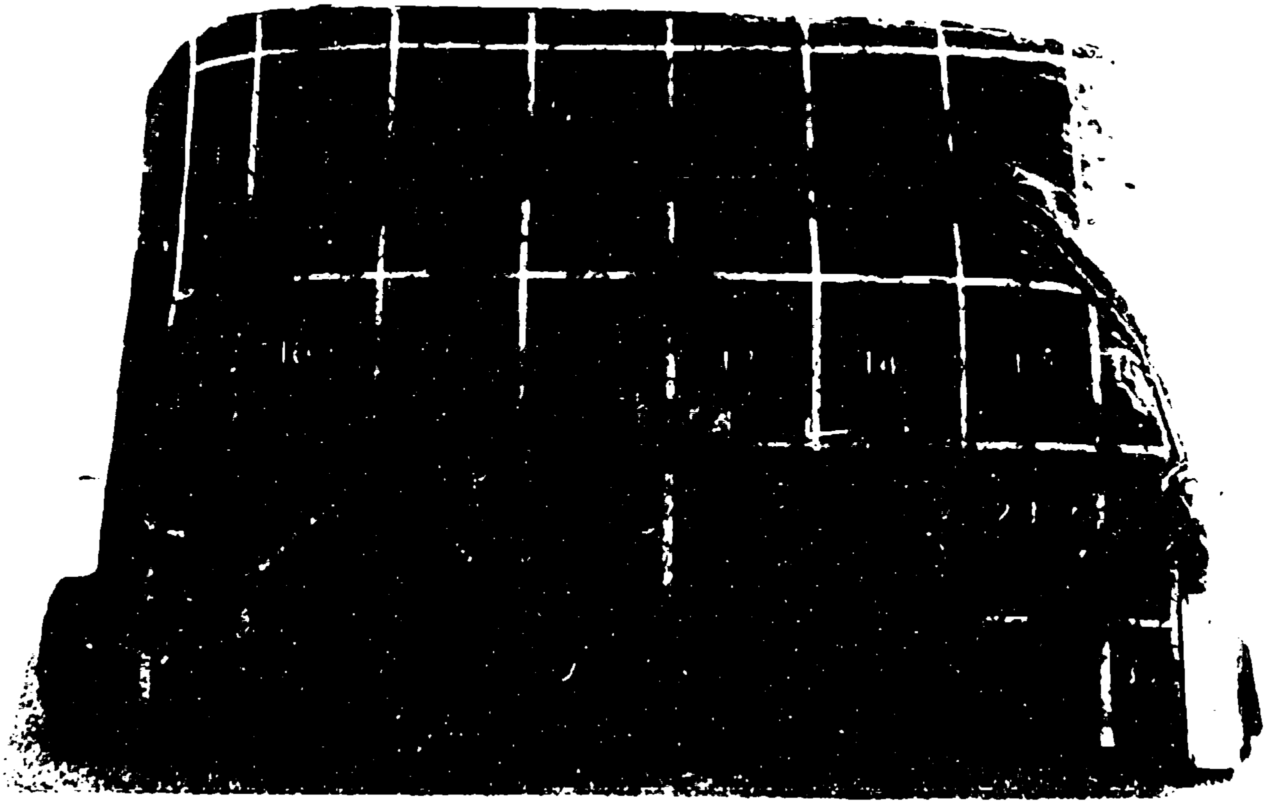

B31259 ABERDEEN PROVING GROUND 13 August 1958

Project OTAC-I/134. Ballistic Testing and Repair of Special Armor Castings.
Front view of Pittsburgh Hull No. 2 after completion of repairs.

Figure 1 Page 33 CONFIDENTIAL

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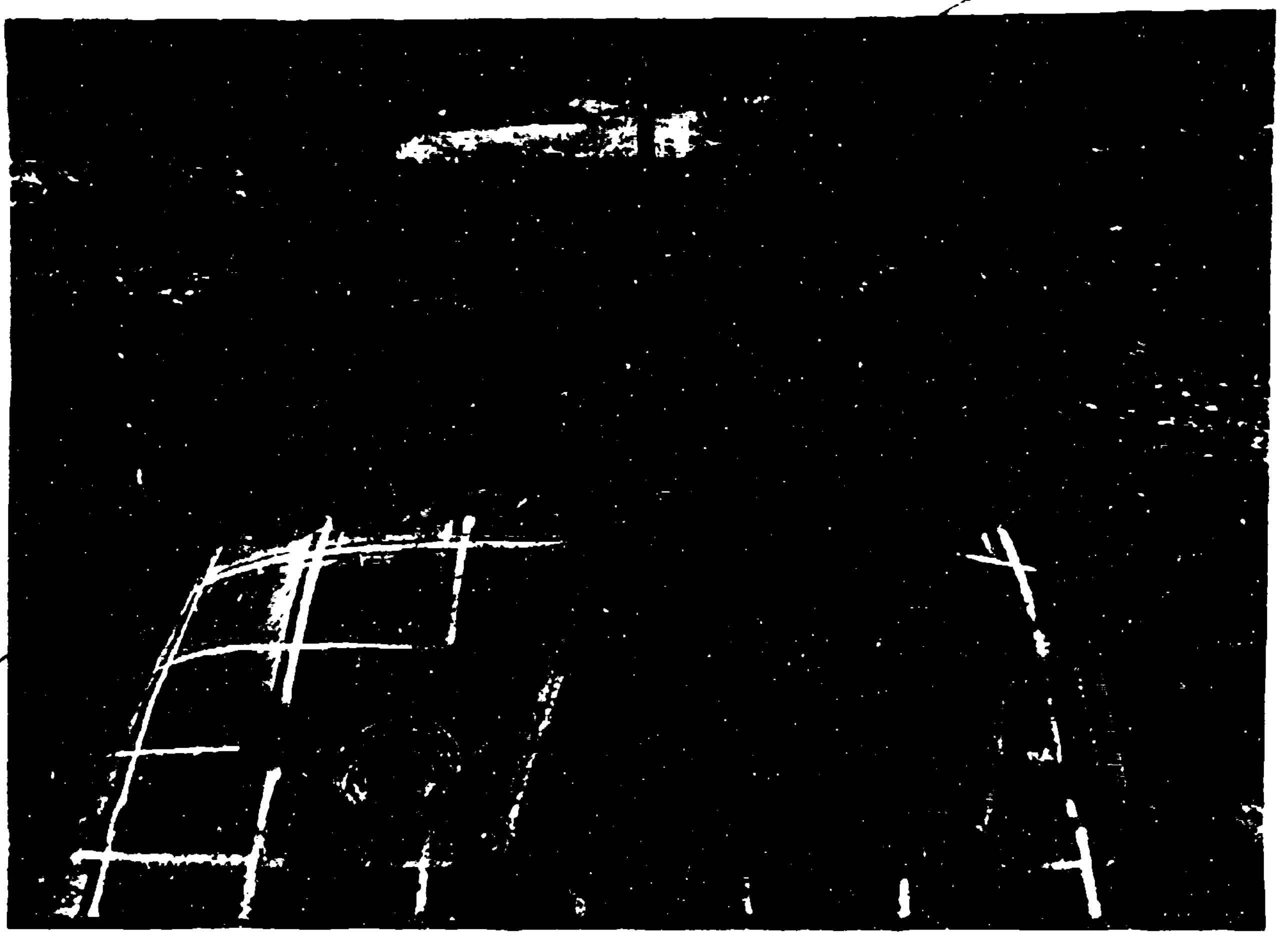

B32049 ABERDEEN PROVING GROUND 28 August 1958

Project OTAC-I/134. Ballistic Testing and Repair of Special Armor Castings.
Exterior view of Continental's Hull No. 3 after completion of repairs.

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PRODUCTION CAPABILITIES - FOUNDRIES

If siliceous cored armor is to be considered for the XM60 tank, production capability must be established by 1 April 1960. This requires the completion of the educational program by the major foundries concerned with casting heavy hulls and turrets for vehicles and the establishment of a facility to fabricate the fused silica cores that will be utilized in the castings.

The educational order for the production of siliceous cored armor by the large foundries can be subdivided into three phases: Phase I required the foundries to manufacture thick plates. Phase II required the manufacture of 3 hulls and 3 turrets by each foundry and Phase III required the manufacture of two additional hulls and turrets from the foundries incorporating design changes for the improvement of the ballistic protection. As of the date of this report, Phase I and Phase II have been completed by all the foundries except one, and Phase III has been initiated.

Although it has been calculated that the utilization of siliceous cored armor will cause a slight increase in weight due to an increase in volume, the actual production experience to date indicates the weight of siliceous cored armor hulls and turrets did not exceed those experienced in the manufacture of the all steel hulls and turrets of similar design.

There is no doubt that when required, the larger foundries experienced in manufacturing of hulls and turrets will have sufficient education to manufacture these hulls and turrets out of siliceous cored armor for the XM60 production. Since the placing of the silica cores in the mold cavity does not represent a novel technique to foundries, it is not expected that the incorporation of siliceous cored armor will require any new facility or any particular significant time delay in production capability in the foundries. Figure 15 shows a typical fused silica core mounted and ready to be placed in the mold for casting. Figure 16 is a completed siliceous cored armor casting. Figure 17 shows the type of core that was utilized in the turrets tested at Aberdeen Proving Ground and manufactured under Phase II of the program. Figure 18 shows the simplified turret design that is being considered for the XM60 turret.

It can therefore be concluded that production capability of the foundries will not be impaired by the introduction of siliceous cored armor into hulls and turrets in the XM60.

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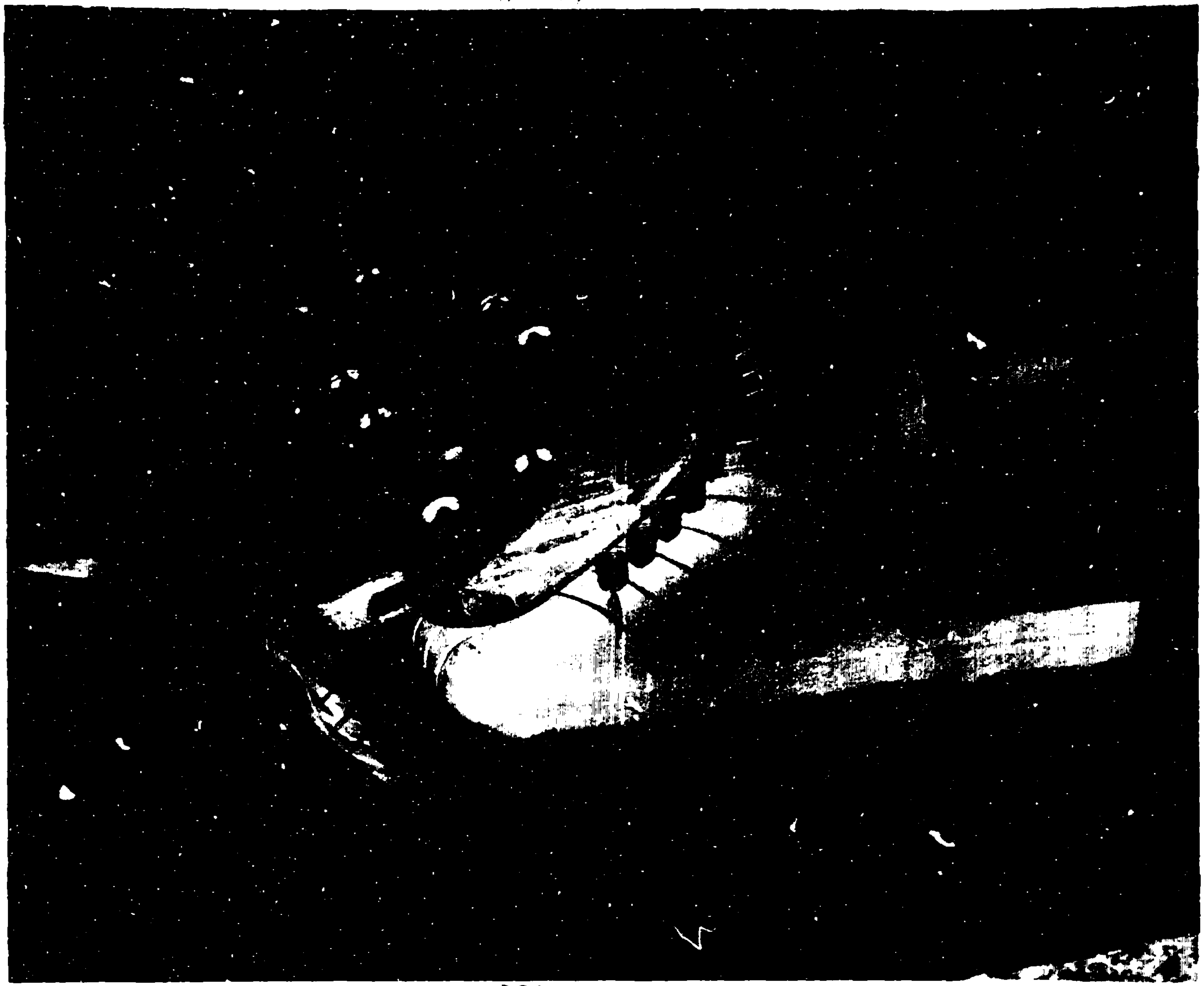

Figure 15 page 37

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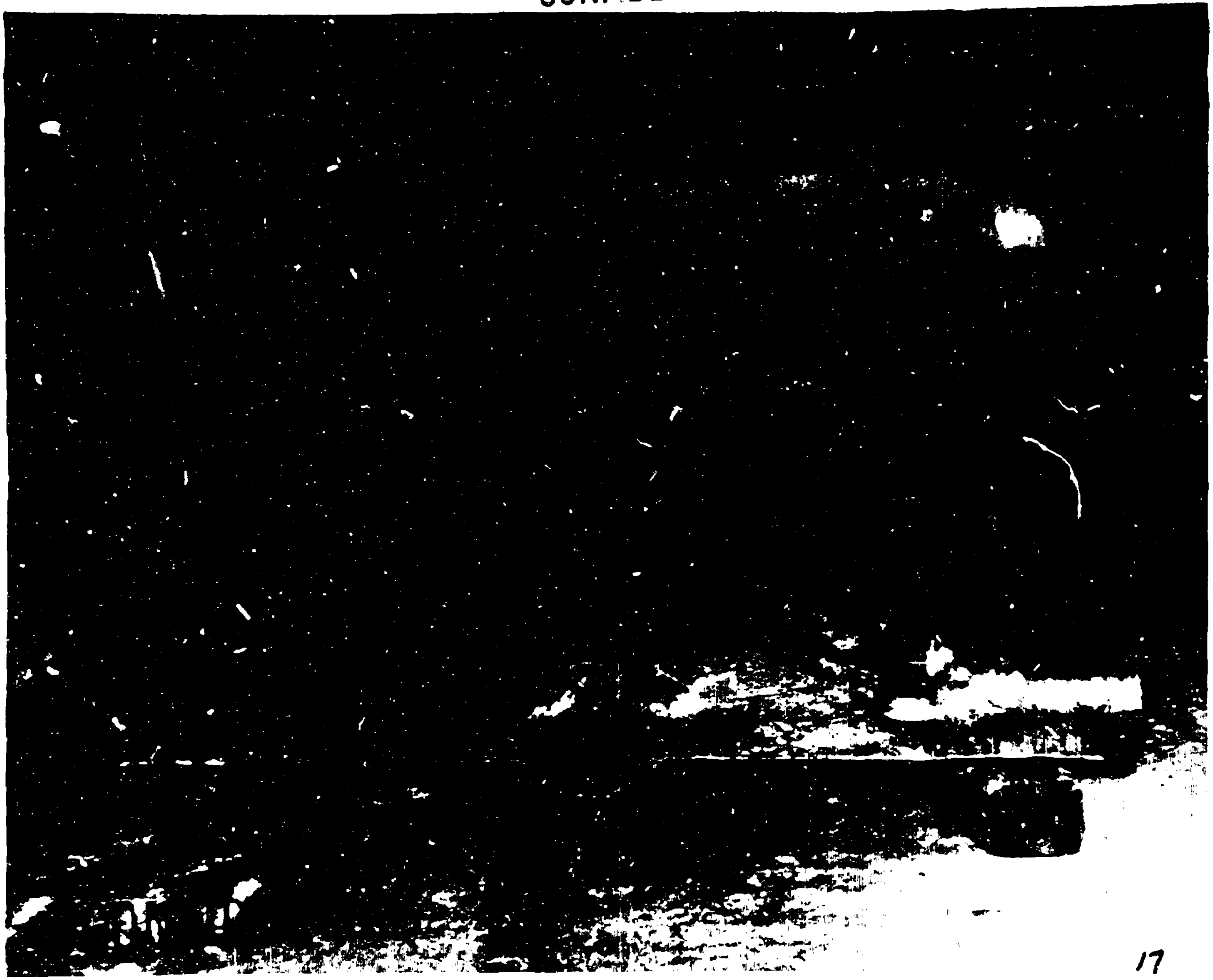

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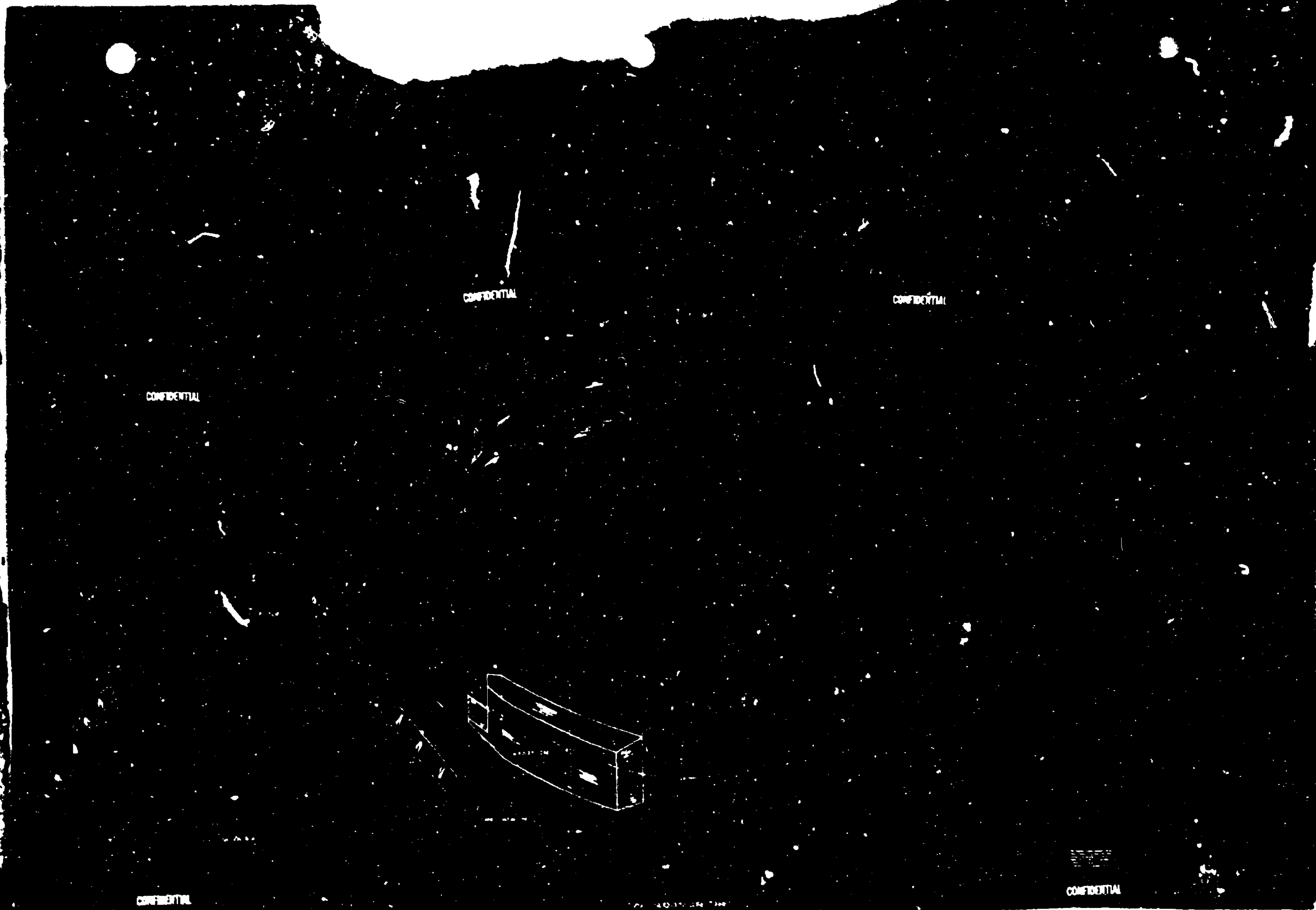
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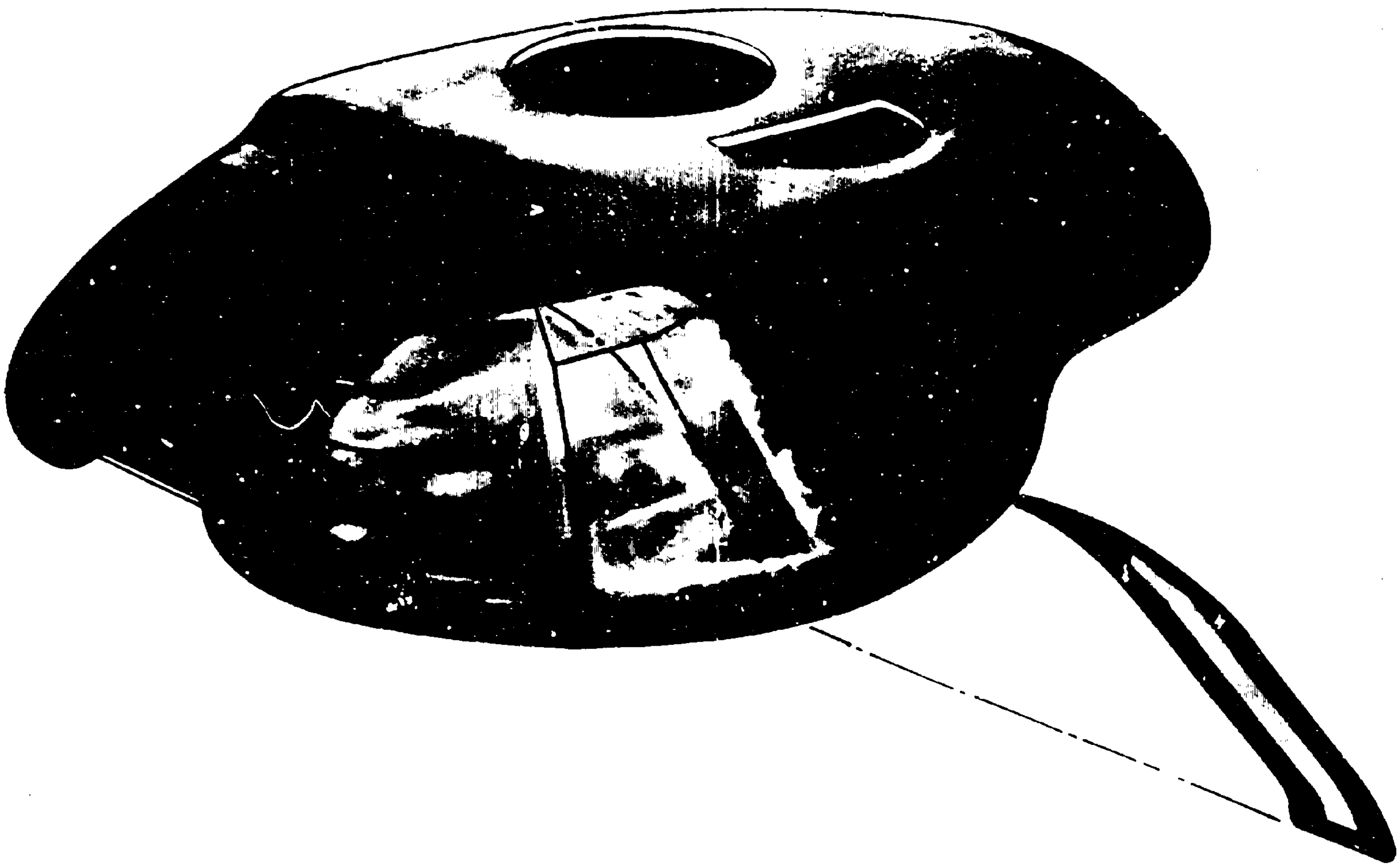

Figure 17

PRODUCTION CAPABILITY:
FUSED SILICA CORES

The major problem that must be overcome in providing siliceous cored armor for the XM60 is the establishment of an adequate production facility for the manufacture of fused silica cores. Since the fused silica utilized in the armor is considerably larger both in area and weight than any other application of fused silica in this country, it was necessary to establish a facility capable of manufacturing these larger cores. Such a facility has been developed and is in operation at the Amersil Company in Hillside, New Jersey. However, the capability of this facility is only sufficient for pilot production and will not be adequate for production runs required for the XM60. It has been estimated that one year will be required to construct additional facilities to meet production requirements of the XM60. Consequently, funds must be made available at the earliest possible date in order to meet production requirements. The current prototype facility was designed to manufacture sufficient silica to build 6 tanks a month. With minor changes to equipment, this production can be increased to supply silica for 12 tanks per month.

However, the utilization of siliceous cored armor in full scale production will require the construction of additional facilities at the earliest possible time. It will be possible during this interim period to stock pile some silica from the current facility in case a slight delay is experienced in the allocation of funds; however, the funds must be made available in early 1959, if production schedules for the XM60 are to be met.

CONCLUSIONS

From the information and material presented in this report, the following conclusions relative to the utilization of siliceous cored armor in the XM60 can be made:

a. Siliceous cored armor will not lower the kinetic energy projectile protection afforded by the hull and turret.

b. Siliceous cored armor will provide a high level of HEAT round protection in the hull and turret from frontal attack.

c. Siliceous cored armor will provide invulnerability for the front hull and turret from HEP round attack.

d. Siliceous cored armor will not be defeated by large caliber HE rounds at any angle of attack.

e. After impacts with large caliber HE rounds, siliceous cored armor will maintain protection against HEAT rounds except in those areas directly damaged by the HE firings.

f. Siliceous cored armor castings can be satisfactorily repaired in the field utilizing materials and equipment currently available to the using forces.

g. Repaired castings will maintain high levels of protection against HEAT and HEP round attacks but will suffer a loss of protection against kinetic energy projectile attack.

h. When production is required for the XM60, sufficient education will be available in the large foundries concerned with the manufacture of hulls and turrets.

i. If siliceous cored armor is to be used in the XM60 expeditious action will have to be taken to establish a production facility for fused silica cores.

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