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DEVELOPMENT OF A SAND-CAST MAGNESIUM ALLOY BASEPLATE FOR THE MEDIUM MORTAR. PHASE I

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY

This report describes the work on Phase I of the development of a cast magnesium alloy baseplate for the 81 mm mortar, carried out during the period 1960-1961 by the Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, for the Army Equipment Engineering Establishment (formerly Army Development Establishment), Department of National Defence, Ottawa, Canada.

The report is divided into two parts, one on the metallurgical examination of castings produced by two commercial foundries, and the other on the evaluation of the cast baseplates under simulated service (static breakdown) tests. These are followed by a short note on firing tests and some conclusions.

Although the simulated service tests and the firing tests showed that the castings were 30 to 50% stronger than the previous (1956) cast magnesium baseplates, it was concluded that both casting quality and design had to be improved to obtain sufficient strength to withstand stresses introduced by the use of more powerful ammunition.

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INTRODUCTION

A Summary Report (1) was issued on the development of a cast magnesium baseplate for the 81 mm mortar, carried out during the period 1960-1964 by the Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, for the Army Equipment Engineering Establishment (formerly Army Development Establishment), Department of National Defence, Ottawa, Canada.

The present report describes in detail the work on Phase I of the investigation (1960-61), and is divided into two parts: I. Metallurgical Evaluation, and II. Simulated Service Tests. These are preceded by some recapitulation from the Summary Report (1) of the earlier work on magnesium baseplates and the authorization of the present investigation and its program, and followed by a short note on Firing Tests.

Earlier Work

The application of a sand-cast magnesium alloy mortar baseplate was considered at the end of World War II, because of the obvious advantages of light weight and the relief of limited forging capacity. Unfortunately, the properties of the then available magnesium casting alloys were not sufficient to achieve the weight reduction necessary for comparable strength, and this, coupled with the lack of reliability of casting quality, defeated the project.

The project was reactivated in 1949, at the request of the Directorate of Armament Development, Department of National Defence (File No. HQS 8236-9-257 (DAD), dated 2 June 1949). The Mines Branch undertook the design and development work, which was based on the application of the new high-strength magnesium casting alloy ZK61-T6, introduced by the Mines Branch.

Considerable development work on the cast magnesium baseplate followed, the final design of the prototype castings, designated "Type 3A", being very successful: the net weight of the magnesium alloy casting (without socket) was about 17.5 lb, and the baseplates successfully withstood both the limited firing tests (design tests) at the Canadian Armament Research and Development Establishment, Defence Research Board, Valcartier, Que., and minor user evaluation tests at the Royal Canadian School of Infantry, Camp Borden, Ontario. The Directorate of Army Development recommended, therefore, final engineering tests to establish the cast magnesium baseplates as an alternative to the standard forged aluminum alloy baseplate. Unfortunately, further development work on this project was terminated (File No. HQS 7616-28 (DAD), dated 2 May 1957).

The various phases of foundry development of the magnesium mortar base casting during the period 1949-56 were reported in Mines Branch Investigation Reports Nos. PM2773 (1951), PM3002 (1953), PM3053 (1954), and PM3141 (1956). All prototype castings of the baseplate, described in these reports, were cast in the Experimental Foundry of the Physical Metallurgy Division, Mines Branch; however, some heat treating operations were carried out commercially at Light Alloys Limited, Haley, Ontario, because of lack of a suitable heat treating furnace in Ottawa.

Present Investigation

In June 1960, a new project was authorized to continue the development of a magnesium alloy baseplate for the medium (81-mm) mortar (File No. HQS 6016-60-535 (DD 2-c), dated 14 June 1960), and the Mines Branch agreed to carry out the redesign, metallurgical development, and evaluation of the baseplate castings. A joint US-Canadian Conference on the development of mortar baseplates was held in Ottawa on 20-21 July 1960. Some strengthening of the baseplate casting design was thought necessary because of change to more powerful ammunition. A tentative program for the development and testing work was discussed and agreed upon by the representatives of the US and Canadian Army agencies, and of the Mines Branch. A detailed program was later issued by the Army Development Establishment (Canadian Army Equipment Specification ADE-X21, dated 21 October 1960).

The program was based on the belief that all further development work on the baseplate should be carried out on castings produced by commercial foundries according to design and metallurgical advice furnished by the Mines Branch. All castings were to be examined and, if found satisfactory, subjected to static breakdown tests by the Mines Branch, with firing tests at CARDE, and fatigue tests at the Watervliet Arsenal, USA.

In case of successful results in the first phase of the program, a larger number of castings would be procured from a commercial foundry for final engineering evaluation tests to be conducted in the USA. If the castings supplied in the first phase of the program proved unsatisfactory, the Mines Branch was to revise the design and repeat ordering castings and their examination until a satisfactory solution was found. As it turned out, four separate phases of the investigation were necessary for its final completion.

It was agreed to designate all prototype castings with a cast-on identification mark, including a letter and two numbers. The letter was to identify the producing foundry, the first number to denote the design and the last number the sequence of casting in the particular production batch (e.g. B2-4 identifies the fourth casting of design 2 produced by foundry B; A4-3 the third casting of design 4 produced by foundry A).

PART I. METALLURGICAL EVALUATION

Initial Investigation

The baseplate was redesigned to strengthen the casting for higher loading requirements and two patterns were produced incorporating these design changes. To check the patterns, two baseplates were cast in the Mines Branch Experimental Foundry. The first casting was produced without use of chills (as done in the earlier development work), the second was cast using a chill in the recess of the centre hub. Both castings were aged only (64 hr at 130°C, 265°F) because of lack of suitable solution heat treating furnaces.

Both castings were subjected to simulated service tests (breakdown tests under four point support conditions). The first casting broke under a load of only 83,000 lb, while the second (chilled) casting withstood 110,000 lb. Both fractures occurred in the same location, as shown in Figure 1. In each case the fracture started at the tension side, in the vicinity of the junction between the arm and the spade in an area where heavy microporosity was detected. Sectioning of the castings and metallographic examination substantiated the results of the breakdown tests and the microporosity (in the area indicated in Figure 1) was found to be of the layer-porosity type (directed perpendicularly to the axis of the arm).

The tests performed on the initial castings revealed the critical area of the casting and consequently the design was modified to increase the thickness and height of the arm in this area. (Design 1, Mines Branch drawing No. MPB-17a, as shown in Figure 2).

Commercial Foundry Work

Since the development program was to be based on castings produced by commercial foundries, two foundries (called in this report "A" and "B") were selected to obtain an assessment of commercial casting quality. It was expected that the final phase of the project would be carried out on castings produced by the foundry which supplied, during the prototype work, castings of higher quality and more consistent properties. The patterns produced by the Mines Branch to design 1 were supplied to the foundries and they were advised of the importance of soundness in the critical areas, as revealed by the breakdown tests on the initial castings produced at the Mines Branch.

The foundries were instructed to adhere strictly to the Mines Branch design of the casting (Figure 2), and to the specifications of Canadian Standard CSA.HG.9 for alloy ZK61-T6, but otherwise were given a free hand to use their best production techniques to obtain top casting quality. All castings had to meet A-1 radiographic aircraft quality requirements.

Ten prototype castings were ordered from each of the two foundries. The first satisfactory casting was cut up at the foundry and tested for tensile properties and the other nine were shipped to the Mines Branch for further testing.

Figure 3 shows the location of test bars cut out of the castings. Table 1 lists the results of the tests obtained by the two foundries on their first castings. Location "C" was considered to represent the critical area of the casting. The decision of both foundries to consider the first castings as satisfactory was probably due to the low requirements of the CSA.HG.9 specification for test bars cut out of castings, which were met comfortably in the critical area. These castings were established as a standard for the production of the subsequent castings.

Examination of Castings

All castings received from the suppliers were examined radiographically by our Non-Destructive Testing Section and rated according to the soundness of area "A" on Figure 1. In the arbitrarily chosen rating system used in Tables 2 and 3, "A" represents completely sound metal, and "C" metal containing considerable microporosity. Table 2 lists all castings received from foundry A and their disposition; Table 3 similarly lists the castings of foundry B.

Table 4 lists the ranges of chemical analyses, grain size determinations and tensile properties obtained in separately-cast test bars, which were supplied by the foundries with the baseplate castings (three test bars for each melt). Chemical analyses and grain size determinations were made on samples taken from the grip sections of broken test bars.

Tables 5 and 6 present the results of tensile tests and grain size determinations obtained on test bars cut from various locations (see Figure 3) of the baseplates. Test bars taken from locations A to D were machined to 0.375 in. diameter and 1.5 in. gauge length (PMD drawing No. 8). Test bars from locations E and F were flat bars of 2-inch gauge length and 1/2-inch gauge width (PMD drawing No. 69).

Test bars cut from location C represent the critical area of the casting. Castings from foundry A show higher and more consistent properties, especially for the ultimate tensile strength and the 0.2% yield strength. Casting B1-7 was found to be defective due to some germination (grain growth) during solution heat treatment and "burning" (incipient melting).

Examination of Castings after Simulated Service Tests

Three castings from each foundry were selected (as listed in Tables 2 and 3) for simulated service (static breakdown) tests. These tests and the results are described in Part II of this report. The castings broke through the arms (Figure 4), with the exception of baseplate A1-4 which broke in the flange (Figure 5).

The fractures of the broken castings were examined and it was found that all showed various amounts of microporosity at the tension side of the arms, except casting B1-4 which showed no porosity at all but had some inclusions. Microporosity at the compression side was found only in castings of foundry A. Most castings (with the exception of B1-4) showed excessive plastic deformation in the area of the socket, which caused the steel socket inserted for testing to jam.

Two castings subjected to static loading (A1-10A and B1-5) and casting B1-7 which exhibited very large grain size (see Table 6), were examined for possible segregation of alloying elements by sampling for chemical analyses in the locations shown in Figure 6. Table 7 presents the results of this survey of chemical compositions of different areas of the castings. Considerable inverse segregation of zinc was found, which was especially pronounced in the castings of higher zinc content. This phenomenon, common to all magnesium casting alloys (2), occurs under various conditions of solidification, and may affect heat treatment response and mechanical properties in different parts of the casting. As may be seen in Table 7, casting B1-7 shows zinc content as high as 7.27% which is responsible at the higher solution heat treating temperature (500°C, 930°F) for incipient melting ("burning"), especially if it coincides with low zirconium content. As shown in Table 6, this casting had unusually low mechanical properties.

Two test bars were cut from critical areas of all six baseplates which were tested in breakdown tests. The properties obtained on these test bars, cut from arms which did not fail in the breakdown tests, are listed in Table 8. Castings from foundry A show higher and more consistent results than those from foundry B.

Examination of Castings for Grain Size

Casting B1-7 showed excessive grain size and extremely low properties (Table 6). Since foundry B used a higher solution heat treating temperature (500°C, 930°F) and at the same time used an alloy composition with higher zinc content (average approximately 6.25% Zn), it was decided to check those castings which had been selected for firing tests and for the US Army fatigue tests (see Table 3), for possible germination (grain growth) on the machined and polished edge of the flange close to the spade. Table 9 shows the results of these grain size determinations, which indicate that only casting B1-7, which as shown in Table 7 contained very high zinc content (up to 7.27% Zn), showed germination.

Examination of Castings after Firing Tests

The castings returned after the firing tests were examined for any defects in the fractures. The baseplates broke during the firing tests in all cases in the same location of the arm (approximately 6 inches from the edge of the flange). Casting B1-6 broke through three arms in the same location. Test bars were cut from the critical area of arms which did not fail but which were subjected to some plastic deformation during the firing tests. Results of tensile tests are listed in Table 10.

Casting B1-11 was subjected to the firing tests to evaluate the effect of considerable microshrinkage in the critical areas of arms No. 2 and 4 (X-ray rating "C" in Table 3). This casting failed in the early stages of the firing tests, confirming the importance of soundness in the critical area. The fractures of the arms of this casting showed evidence of considerable porosity.

PART II. SIMULATED SERVICE TESTS

The results of static and dynamic tests on cast magnesium alloy baseplates for the 81 mm mortar, developed in 1955 and designated "Type 3A", were presented in Mines Branch Investigation Report IR 59-64 (3).

These tests gave information regarding the maximum static load required for fracture of the baseplate casting while supported (a) at four points and (b) in sand *. Additional data were also provided on safety factors determined from measurements performed during dynamic loading of the baseplates under different conditions.

Due to the use of a more powerful ammunition, the average thrust load during firing was increased considerably and, as determined from field tests, was reported to be approximately 100,000 lb. Thus the baseplate had to be redesigned to meet the increased loading demands. The first redesign was limited to the modification (strengthening) of the cross-beams, where initial failure was expected to occur.

Simulated service (static breakdown) tests were undertaken in order to determine the following essential characteristics of the design:

(a) The maximum strains developed at the critical sections while the baseplates were under load.

(b) The total load required for fracture under different loading conditions.

(c) The yield strength of the baseplate as determined from increment loading. This yield strength is defined as the load corresponding to the point on the load-deflection diagram where the curve begins to deviate from the straight line.

Static Load Tests

Six mortar baseplates (three from each of the two foundries) were subjected to static load tests in a Tinius Olsen Universal Testing Machine of 300,000 lb capacity. The baseplates were supported, during these tests, either at four points or in sand.

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* The four-point-support test is carried out under strictly standardized conditions and its results allow reliable comparison for technical evaluation of the castings.

Although the sand test closely simulates some actual service conditions and proves useful in the development stages of the baseplates, it should be noted that the results of this test are not always comparable, because they depend on the condition of the sand (sand grain size and structure, moisture content, ramming conditions, etc.).

For the four-point-support tests (4), the legs of the baseplates were placed on 1-in. diameter hardened steel rollers which rested on hardened steel blocks suitably positioned on the platen of the testing machine (see Figure 7). To fix the location of the steel rollers, semi-circular grooves of 5/8 in. radius were machined in the legs of the baseplates at a distance of 8-27/32 in. from the centre.

For the sand support tests (4), the baseplates were placed in a large tub of building sand. This tub had an outside diameter of 24.5 in. and a depth of 14 in. and was fabricated from a 1/2-in.-thick steel plate to resist deformation.

The loads were applied to the baseplates through a hardened steel socket, which replaced the standard aluminum alloy socket, and a special plunger fixed to the crosshead of the testing machine.

Prior to each static load test, six SR-4 type A5 electrical resistance strain gauges were fixed to the baseplates, two on each of the bottom surfaces of two arms and one on each of the top surfaces of these arms. The location of the strain gauges is shown in Figure 8. In every case, two of the strain gauges on the bottom surface were two inches from the centre and, with one exception, the other two strain gauges on this surface were 5-3/4 in. from the centre. On one baseplate the latter two strain gauges were 6-5/8 in. from the centre. The strain gauges on the top surface of the baseplates were located on two arms, 2-7/8 in. from the centre of the plates.

Two of the three baseplates from foundry "A" were loaded in sand; the other being loaded under conditions of four-point-support, while in the case of baseplates from supplier "B", two were subjected to four-point-support tests and one to a test in sand.

Each baseplate was loaded in increments to failure, the static strain being measured with each load increment until the strain gauges became inactive. An attempt to protect the gauges during the sand tests was made by placing plastic containers filled with grease under each of the gauges fixed to the underside of the baseplates. After each load increment the load was returned to a datum of 5000 pounds and strain gauge readings were taken which permitted the determination of permanent strain.

During the four-point-support tests, the total deflections of the baseplates and loading assembly were measured for each load by means of a dial gauge placed between the platen and crosshead of the testing machine.

Results of Tests

The results of the total strains as determined by SR-4 electrical resistance strain gauges and measured at the critical sections (Figure 8) were plotted in the form of curves as shown in Figures 9 to 12.

The equivalent loads for permanent sets of 0.01%, 0.03% and 0.1% are given in Table 11.

Additional information was obtained on the deformation and stiffness characteristics of the complete structure by measuring the deflection of the baseplate at each increment of load, in the four-point-support test. Figures 13 and 14 show the results for baseplates representative of lots A1 and B1.

The mode and location of typical fractures for the four-point-test and sand test are shown in Figures 4 and 5.

Discussion of Results

The results of the SR-4 strain gauge analyses shown in Figures 9 to 12 indicated that, at the lower load levels, the largest strains were recorded at the section where gauges 1 and 3 were located. However, initial local yielding occurred at a load as low as 50,000 lb for the four-point-support test and at the section where gauges 2 and 4 were positioned. This load was much less than the thrust load of 100,000 lb for which the baseplate was to be designed.

For the sand support test, the tension strains at the preselected areas of the crossbeams were substantial in magnitude and contributed, in one case, to the fracture of the baseplate. However, two failures occurred at the fillet sections between the ring and the crossbeams, and the reinforcing rib and spade.

Generally, the strains were at least twice as great in tension as in compression at the same section, and indicated that the design was not balanced.

From the results given in Table 11, the total loads for fracture for both the four-point-support test and the sand test were considerably lower than the anticipated load based on the safety factor requirements as specified in a previous report (3). The yield strength, determined from the deflection measurements shown in Figures 13 and 14, was approximately 70,000 lb in each case.

From Table 11 it may be seen that the equivalent permanent set for a yield strength of 70,000 lb was approximately 0.1%. This value was considered excessive for this mortar baseplate design.

From the analysis of the strains measured in these static load tests, it appeared that the baseplate would be overstressed when subjected to a firing load. However, to obtain complete design data, it was decided to proceed with firing tests on these baseplates.

PART III. FIRING TESTS

Seven baseplate castings were selected (see Tables 2 and 3) for design (firing) tests at the Canadian Armament Research and Development Establishment, DRB, Valcartier. Six of these plates were selected for the design testing program, and one casting (B1-11), which showed considerable microporosity in the critical areas of the arms, was submitted to establish the effect of the X-ray detected unsoundness on the firing test results.

The test program and results of the firing tests were reported by G. C. Silverthorn (5) with the following conclusions:

> "The failure of all six baseplates indicates that further strengthening of the casting is required. The strength of the castings has improved 30 to 50 per cent over the castings made in the previous project.
>
> It is recommended that an intermediate lot of four to six baseplates from each of the two foundries be cast. This intermediate lot is considered necessary as the baseplates from the first cast lots were inconsistent both in quality and in dimensions. Small changes in design will also be made to increase the strength. As a result of the experience gained from the first castings, it is expected that a higher quality baseplate can now be made."

CONCLUSIONS

1. The metallurgical evaluation of castings produced by two commercial foundries to Mines Branch design 1 (drawing MPB 17a, Figure 2) showed that the casting quality was not sufficient for a successful mortar baseplate.

2. Simulated service (static breakdown) tests showed that the strength and deformation characteristics of the baseplate produced to design 1 might not meet the present dynamic load requirements.

3. All baseplates subjected to firing tests failed, although it was found that the strength of the casting has improved 30 to 50 per cent over the castings made in the previous (1956) project.

4. It was recommended that an order be placed with the two foundries for a second lot of castings, which would incorporate quality improvement based on the experience of the first phase, and some further strengthening of the baseplate design.

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Design work and design calculations on the mortar baseplates were done by Dr. T. W. Wlodek, Senior Scientific Officer, Mines Branch, with the assistance of Mr. J. Harbec.

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TABLE 1

Tensile Properties of Test Bars Cut from Castings (reported by the foundries)

Casting No.	Location (see Figure 3)	UTS, kpsi	0.2% YS, kpsi	Elong. % in 2 in.
Foundry A				
A1-1*	A	40.8	21.7	7.5
	B	38.6	23.0	6.0
	C	37.7	26.0	4.0
	D	36.1	23.5	3.5
	E	35.9	26.7	3.5
	F	32.5	26.7	2.0
Foundry B				
B1-1**	A	34.9	19.2	9.0
	B	39.8	22.0	11.0
	C	38.6	21.4	8.5
	D	38.2	20.6	11.0
	E	32.4	25.0	5.0
	F	32.0	22.8	3.0
CSA.HG.9 min		42.0	26.0	5.0

* heat treated 10 hr at 480°C (895°F), still air cooling, 48 hr at 150°C (300°F)

**heat treated 2 hr at 500°C (930°F), still air cooling, 48 hr at 130°C (265°F)

TABLE 2

Castings Produced by Foundry A

Casting No.	Melt No.	X-Ray Rating	Disposition of Casting
A1-1	KE 145	A	cut up for test bars
A1-4	KE 147	A	sand test
A1-7	KE 149	A-B	firing test
A1-8	KE 149	B	4-point-support test
A1-10A	KE 150	C	sand test
A1-10	KE 151	A	firing test
A1-12	KE 152	A	firing test
A1-13	KE 152	A	U.S. Army (fatigue test)
A1-14	KE 153	A	U.S. Army (fatigue test)
A1-15	KE 153	C	cut up for test bars

TABLE 3

Castings Produced by Foundry B

Casting No.	Melt No.	X-Ray Rating	Disposition of Casting
B1-1	ZK 469	B	cut up for test bars
B1-3	ZK 470	C	4-point-support test
B1-4	ZK 471	A	4-point-support test
B1-5	ZK 472	C	sand test
B1-6	ZK 473	A	firing test
B1-7	ZK 474	C	cut up for test bars
B1-8	ZK 475	B-C	U.S. Army (fatigue tests)
B1-9	ZK 476	C	rejected
B1-10	ZK 477	A	firing test
B1-11	ZK 481	C	firing test
B1-12	ZK 483	A	firing test
B1-13	ZK 484	A	U.S. Army (fatigue tests)

TABLE 4

Properties of Separately-Cast Test Bars

Foundry		Composition, %		UTS	0.2% YS,	Elong.	Grain Size
		Zn	Zr sol.	kpsi	kpsi	% in 2 in.	0.001"
A*	max.	5.91	0.68	43.8	29.5	10.0	2.6
(7 melts)	min.	4.92	0.62	41.8	26.9	7.0	2.1
	ave.	5.50	0.64	43.2	28.7	9.0	2.3
B**	max.	6.49	0.78	44.6	30.0	10.5	3.0
(12 melts)	min.	5.56	0.66	40.1	27.0	4.5	2.0
	ave.	6.25	0.73	42.9	28.7	8.0	2.4
CSA.HG.9	min.	5.5-6.5	0.6	42.0	26.0	5.0	-

* heat treated: 10 hr at 480°C (895°F), still air cooling, 48 hr at 150°C (300°F)

** heat treated: 2-4 hr at 500°C (930°F), still air cooling, 48 hr at 130°C (265°F)

TABLE 5

Properties of Test Bars Cut from Castings (Foundry A)

Location (see Fig. 3)	Casting No.	UTS, kpsi	0.2% YS, kpsi	Elong. % in 4D	Grain Size 0.001"
A	A1-1	38.4	23.9	6.5	2.5
		38.9	24.7	6.5	2.2
	A1-15	34.3	23.3	4.5	2.2
		40.1	21.6	11.0	2.8
B	A1-1	38.5	23.8	6.5	2.0
		32.8	24.2	2.5	2.0
	A1-15	36.5	21.4	5.5	2.0
		36.8	22.3	6.5	2.8
C	A1-1	37.7	27.1	4.5	1.3
		38.9	29.2	4.0	1.8
	A1-15	41.4	27.7	8.5	0.9
		42.7	25.5	11.5	1.8
D	A1-1	40.1	24.5	8.0	2.5
		36.5	24.0	3.5	2.0
	A1-15	32.9	21.3	4.0	2.5
		34.3	22.2	4.5	2.5
E	A1-1	35.4	25.8	4.0	1.8
	A1-15	33.6	25.0	2.0	1.8
		32.6	24.5	2.0	2.5
F	A1-1	39.7	27.0	5.0	1.8
	A1-15	36.7	24.5	4.0	1.8
		37.8	23.6	5.5	1.8
CSA.HG.9 min.	-	31.5	19.5	1.25	-

TABLE 6

Properties of Test Bars Cut from Castings (Foundry B)

Location (see Fig. 3)	Casting No.	UTS, kpsi	0.2% YS, kpsi	Elong. % in 4D	Grain Size 0.001"
A	B1-1	30.9	17.8	6.0	2.5
		33.3	17.2	6.5	2.5
	B1-7	35.3	18.5	5.5	8.0
		32.6	19.7	4.0	8.0
B	B1-1	30.5	19.3	4.0	2.5
		26.0	18.7	1.5	2.5
	B1-7	31.6	22.2	2.5	8.0
		33.2	21.5	3.5	6.0
C	B1-1	39.8	24.0	8.0	2.2
	B1-7	17.5	- *	0.0	4.0
		18.1	- *	0.0	5.0
D	B1-1	38.4	19.4	10.0	2.2
		36.0	20.3	8.0	2.5
	B1-7	25.3	20.4	3.0	5.0
		24.7	20.6	1.5	6.0
E	B1-1	33.2	24.9	3.0	2.0
		35.3	23.8	5.0	2.0
	B1-7	30.4	26.3	2.0	5.0
		34.1	27.5	2.0	5.0
F	B1-1	34.3	23.4	4.5	2.0
		33.8	23.6	4.0	1.8
	B1-7	25.2	- *	1.0	5.0
		31.2	24.9	2.0	5.0
CSA.HG.9 min.	-	31.5	19.5	1.25	-

* Test bar broke before yield was reached.

TABLE 7

Chemical Composition at Various Locations of the Castings

Casting No.	Location (see Fig. 6)	Chemical Analysis, %		
		Zn	Zr (sol)	Zr (insol.)
A1-10A	J1	5.15	0.79	0.24
	J2	5.20	0.74	0.19
	J3	5.37	0.77	0.10
	J4	4.96	0.73	0.15
	J5	5.21	0.69	0.18
	J6	5.26	0.65	0.20
B1-5	J1	5.72	0.64	0.28
	J2	6.25	0.65	0.18
	J3	6.51	0.71	0.16
	J4	5.51	0.69	0.25
	J5	6.46	0.63	0.22
	J6	6.16	0.53	0.27
B1-7	J1	5.67	0.55	0.15
	J2	6.98	0.52	0.13
	J3	7.09	0.55	0.11
	J4	6.30	0.49	0.16
	J5	7.27	0.50	0.15
	J6	7.09	0.51	0.13

TABLE 8

Properties of Test Bars Cut from Castings Statically Tested
(all test bars cut from location C, Figure 3)

Casting No.	Arm No.	UTS, kpsi	0.2% YS, kpsi	Elong. % in 4D	Grain Size 0.001"
A1-8	2	42.4	30.5	10.0	1.8
	4	40.7	29.6	7.5	2.0
A1-10A	2	42.6	26.0	15.5	2.0
	4	40.3	26.6	10.0	2.8
A1-4	2	42.8	30.2	8.5	1.0
	4	43.2	29.5	14.5	2.0
B1-3	2	38.6	26.4	4.5	2.2
	4	40.2	27.7	10.0	2.2
B1-4	2	41.1	32.4	8.0	2.2
	4	36.3	27.4	4.5	2.2
B1-5	2	33.5	25.2	4.0	1.8
	3	40.2	28.2	7.5	2.0
CSA.HG.9	min	42.0	26.0	5.0	-

TABLE 9

Grain Size Determinations on Flanges of Castings

Casting No.	Grain Size, 0.001"
A1-8	1.8
B1-6	1.8-2.0
B1-7	6.0-8.0
B1-8	1.8-2.0
B1-9	3.0
B1-10	2.5
B1-11	2.5
B1-12	2.5
B1-13	2.8

TABLE 10

Properties of Test Bars from Castings after Firing Tests (all bars cut from location C, Figure 3)

Casting No.	Arm No.	UTS, kpsi	0.2% YS, kpsi	Elong, % in 4D
A1-7	1	39.6	27.1	8.0
	3	41.6	27.4	10.5
A1-10	2	37.6	26.3	8.5
	4	41.2	26.8	11.5
A1-12	1	42.2	29.7	10.5
	3	37.5	27.2	8.0
B1-6	3	41.8	29.8	8.5
B1-10	1	40.6	28.7	8.5
	3	41.7	24.7	13.5
B1-11	1	39.2	29.3	5.5
	3*	44.1	33.4	6.5
B1-12	1	41.4	29.5	10.0
	3	39.4	27.2	8.0
CSA.HG.9 min.	-	31.5	19.5	1.25

* test bar preloaded above the yield strength.

TABLE 11

Results of Laboratory Tests on Cast Magnesium Alloy Baseplates

Base-plate No.	Type of Support	Load for 0.01% Perm Set	Load for 0.03% Perm Set	Load for 0.1% Perm Set	Yield Strength lb	Breaking Load lb	Remarks	Average Weight lb
A1-4	sand	40,000	68,000	100,000	-	263,000	Fractured through ring at spade and reinforcing rib at fillet.	18.8
A1-10A	sand	35,000	48,000	100,000 *	-	192,000	Fractured through beam at socket.	
A1-8	4-pt	40,000	56,000	75,000	70,000	140,000	Fractured through beam at spade.	
B1-4	4-pt	40,000	50,000	70,000	70,000	105,000	Fractured through beam at spade	18.6
B1-3	4-pt	34,000	44,000	60,000	70,000	108,000	Fractured through beam at spade	
B1-5	sand	40,000	50,000	100,000	-	195,000	Fractured through beam at spade and reinforcing rib at fillet.	

* Estimated from data obtained from compression gauges.

NOTE: Load for permanent determined from gauge #2 (tension on underside of beam - 2 inches from centre of socket)

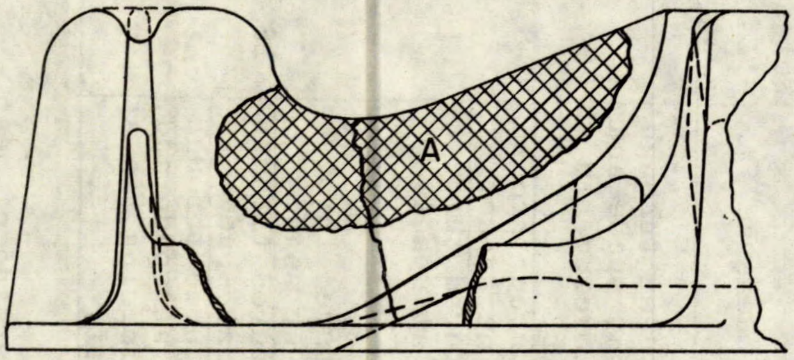


Figure 1. Location of fracture and heavy microporosity area "A". (critical area in tension side of arms).

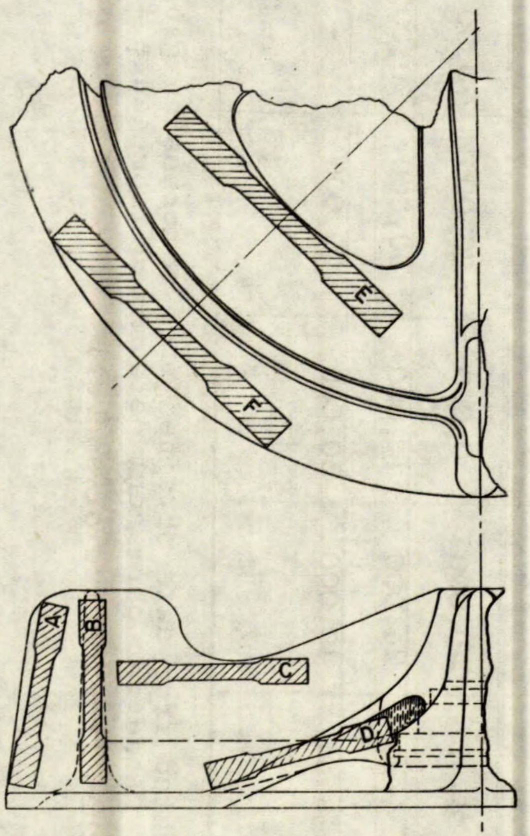


Figure 3. Location of test bars cut out from casting.

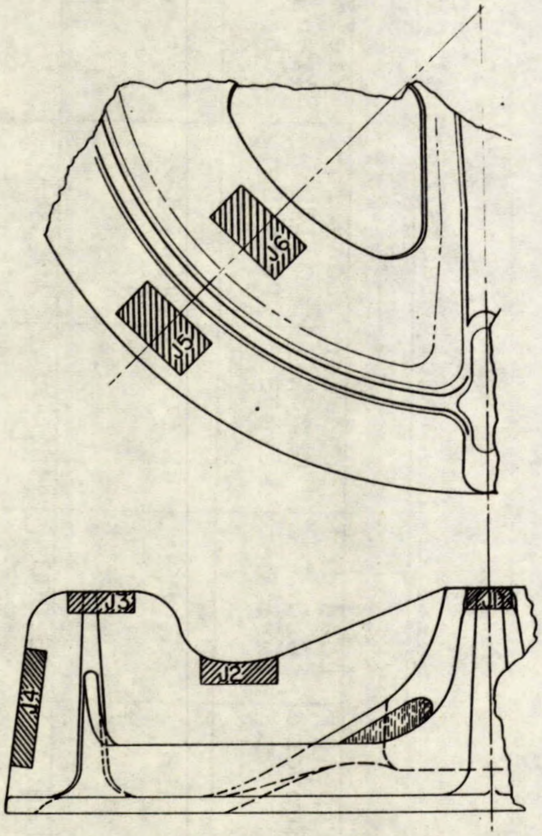
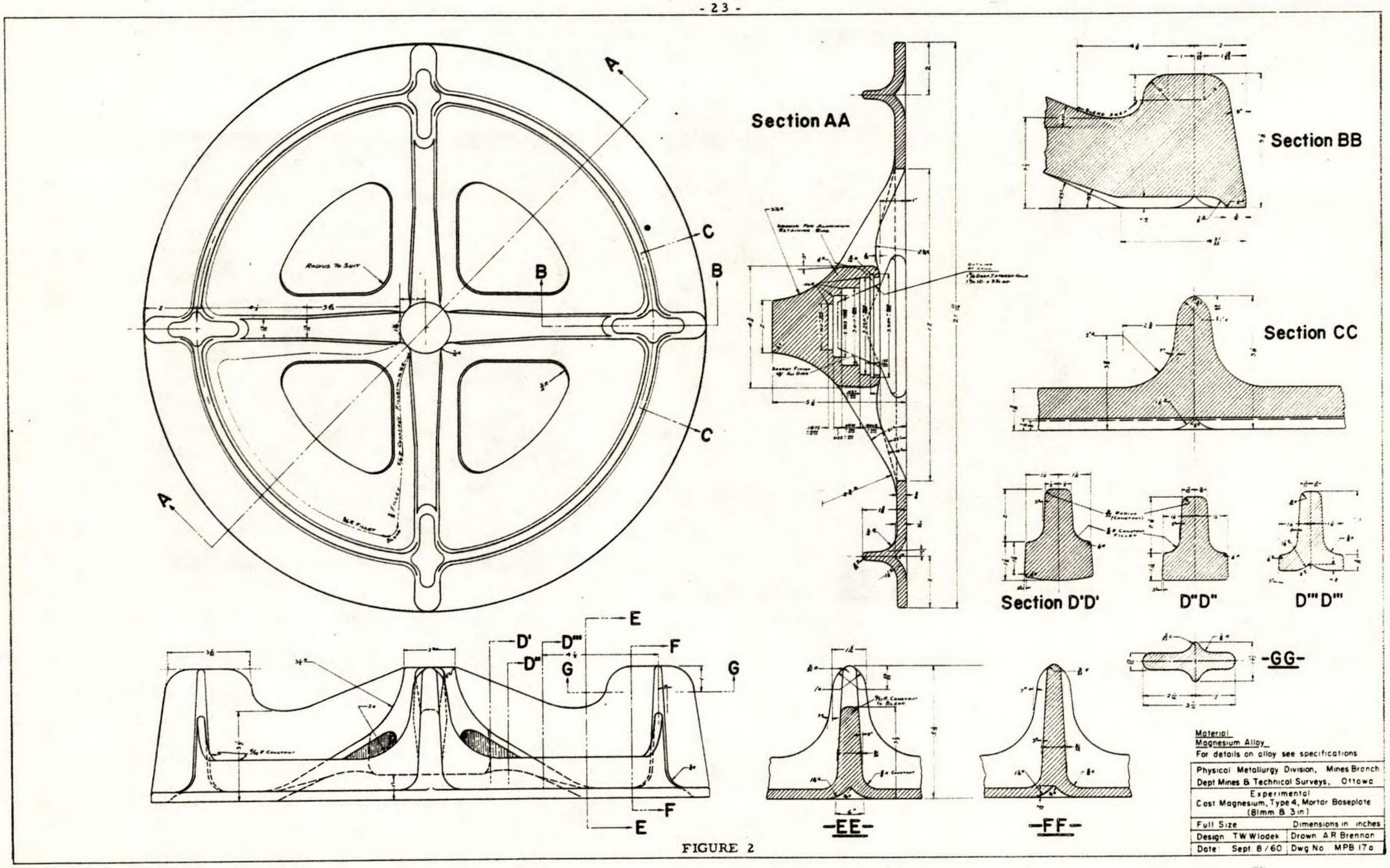


Figure 6. Location of samples for chemical analyses for segregation study.



Material
Magnesium Alloy
For details on alloy see specifications

Physical Metallurgy Division, Mines Branch
Dept Mines & Technical Surveys, Ottawa
Experimental
Cast Magnesium, Type 4, Mortar Baseplate
(81mm & 3in)
Full Size Dimensions in inches
Design T W Wlodek Drawn A R Brennan
Date: Sept 8/60 Dwg No MPB 17a

FIGURE 2

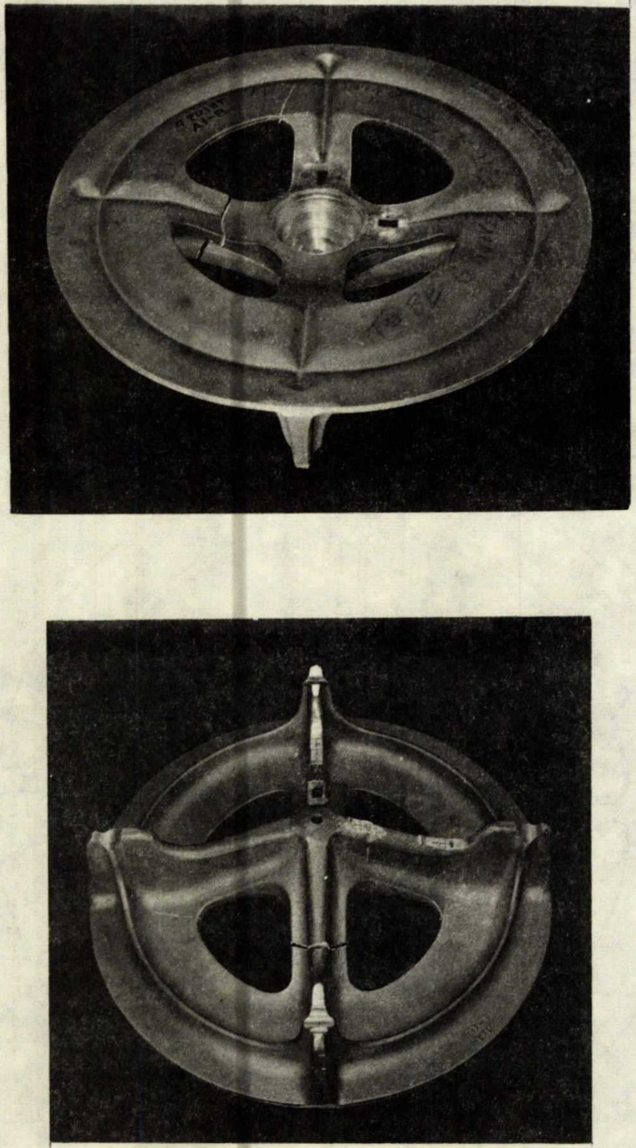


Figure 4. Baseplate Al-8 broken in four-point-support test.

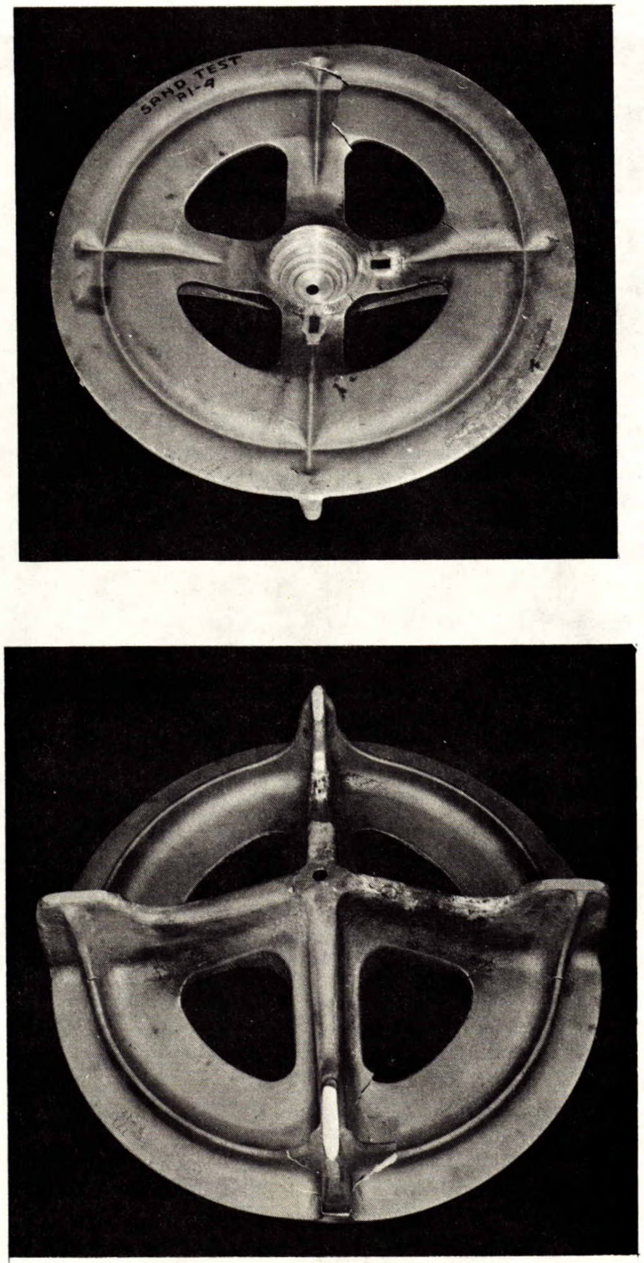


Figure 5. Baseplate A1-4 broken in sand test.

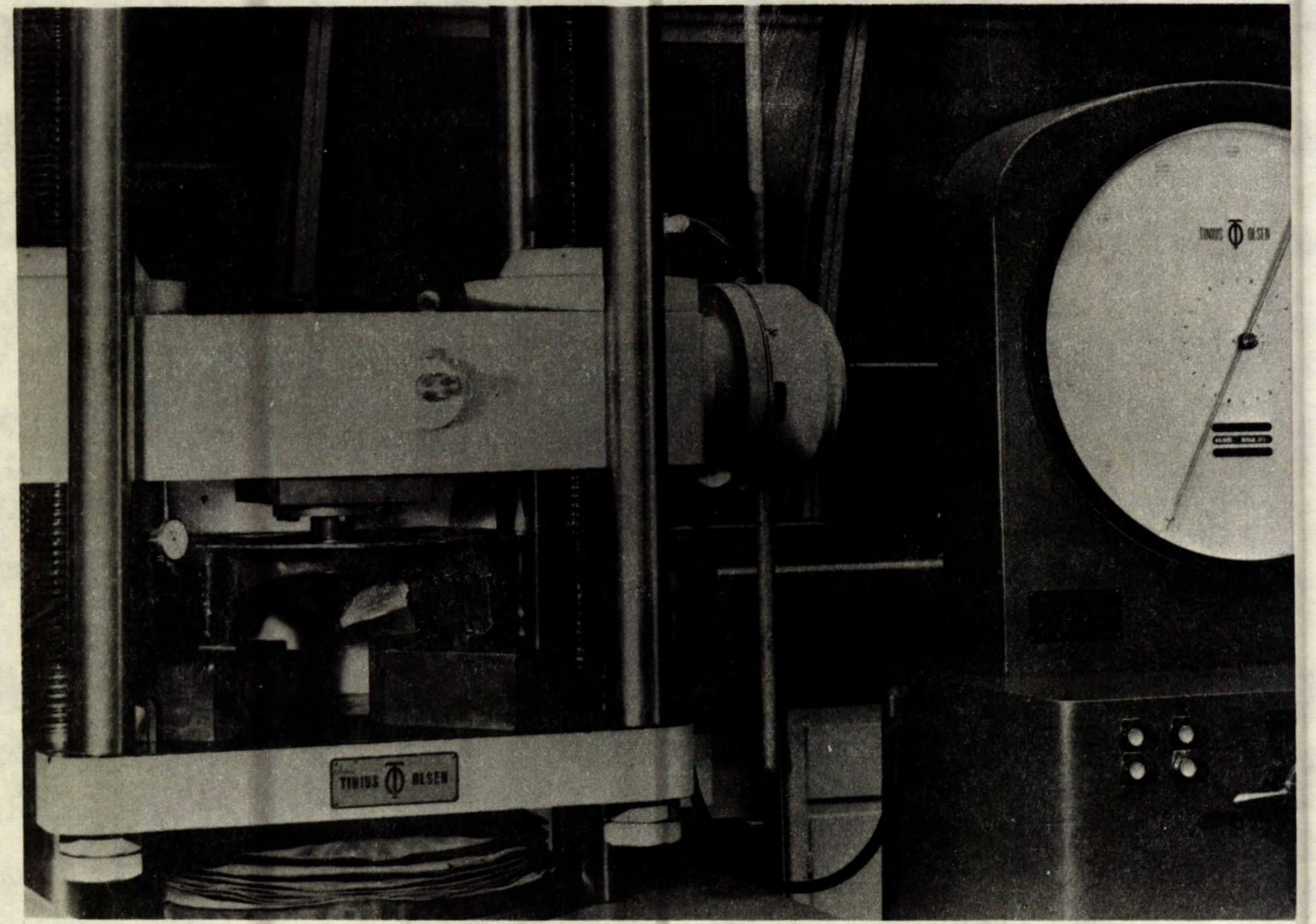
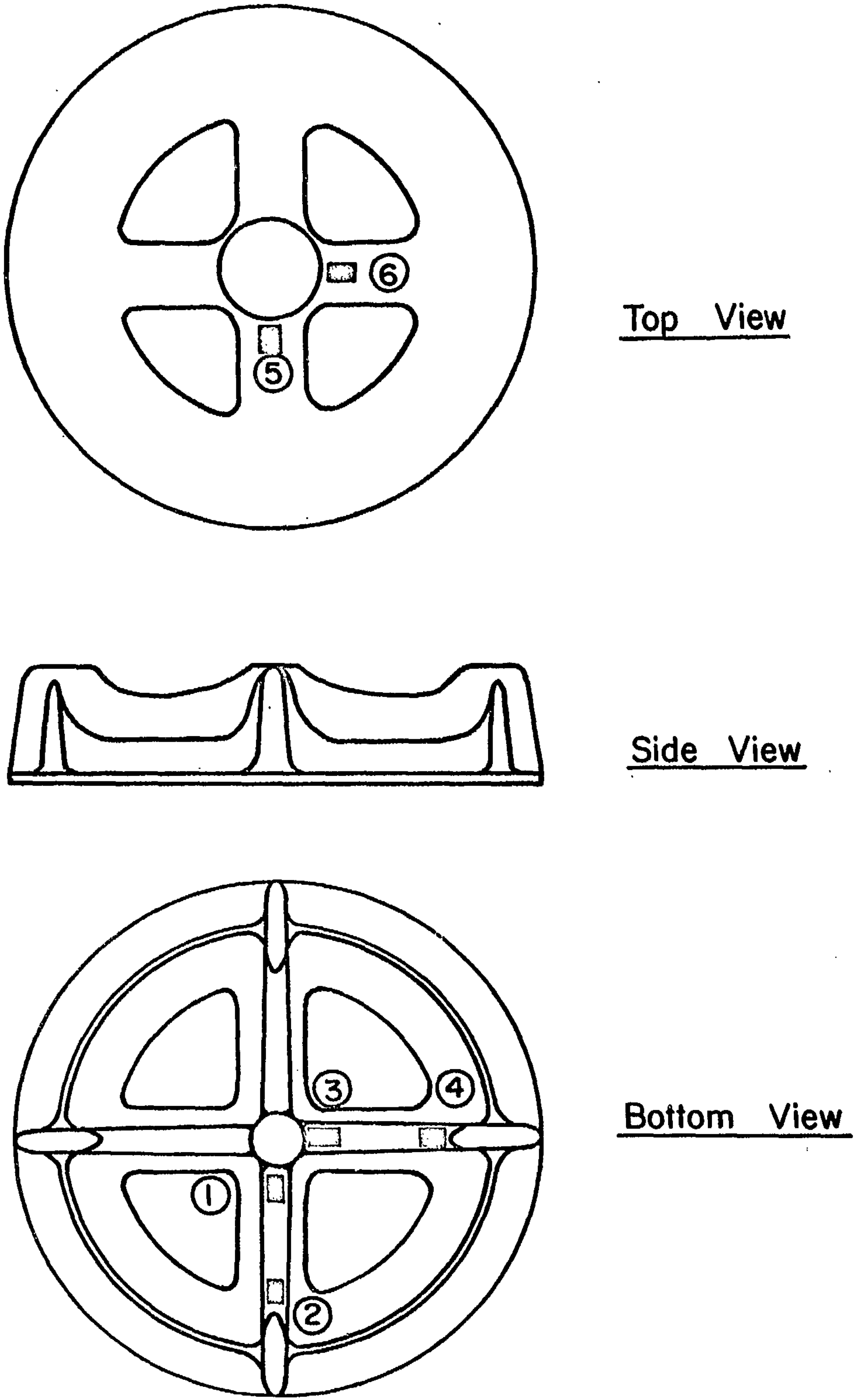


Figure 7. Mortar Baseplate Positioned for Four-Point-Support Test.



Position of Strain Gauges.

Figure 8. Location of strain gauges at the critical sections.

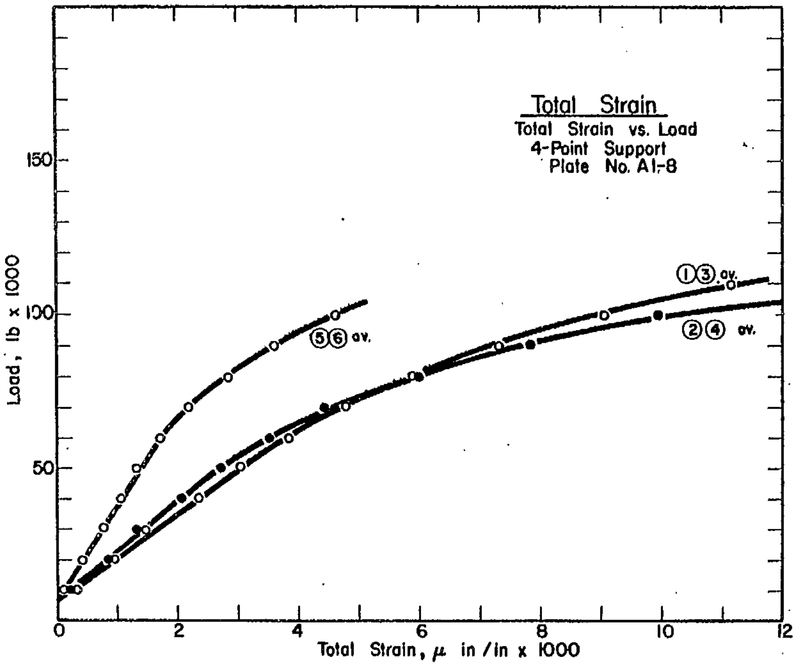


Figure 9. Total strain for four-point-support test, representative of lot A1.

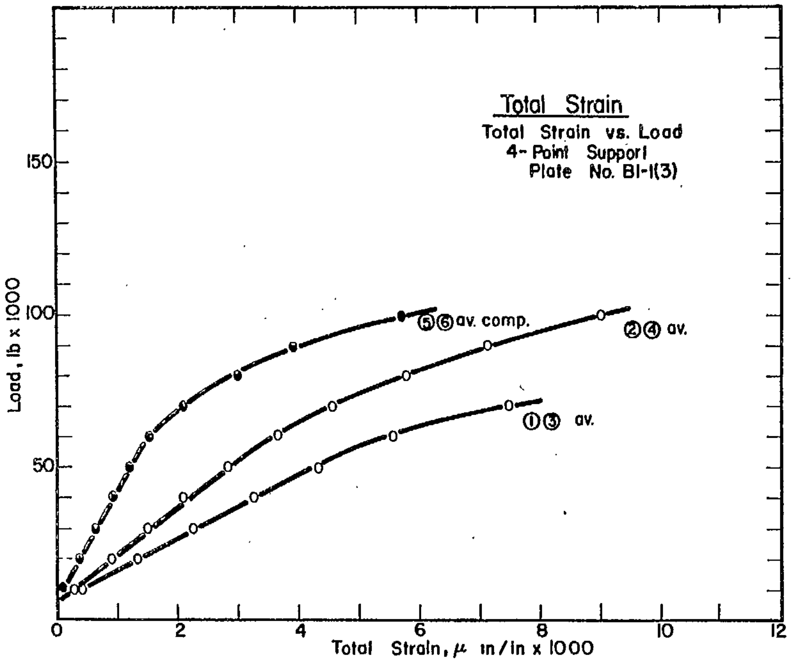


Figure 10. Total strain for four-point-support test, representative for lot B1.

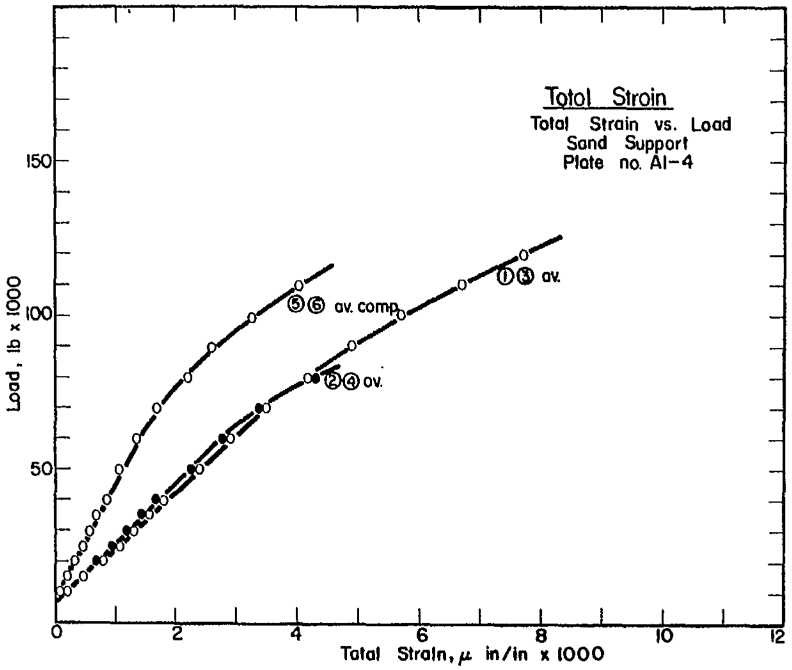


Figure 11. Total strain for sand test, representative of lot A1.

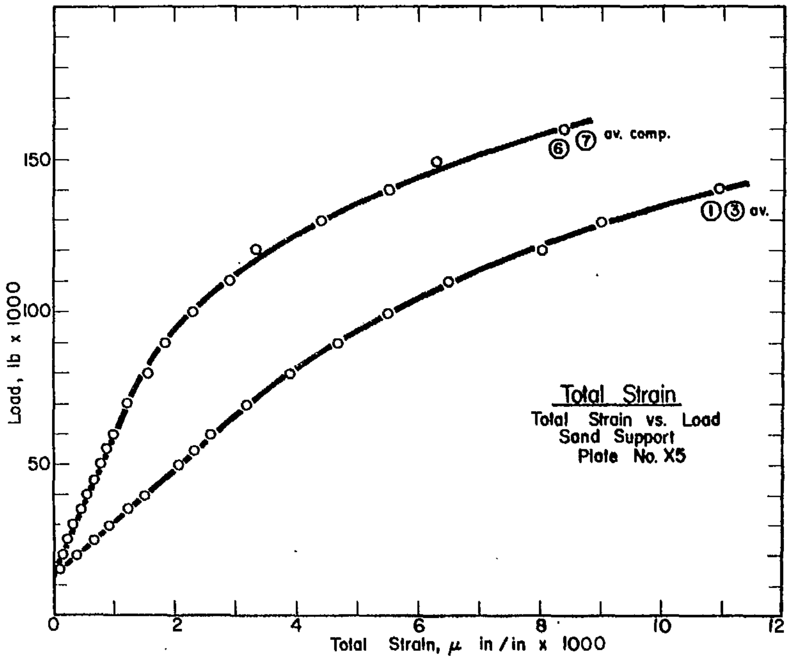


Figure 12. Total strain for sand test, representative of lot B1.

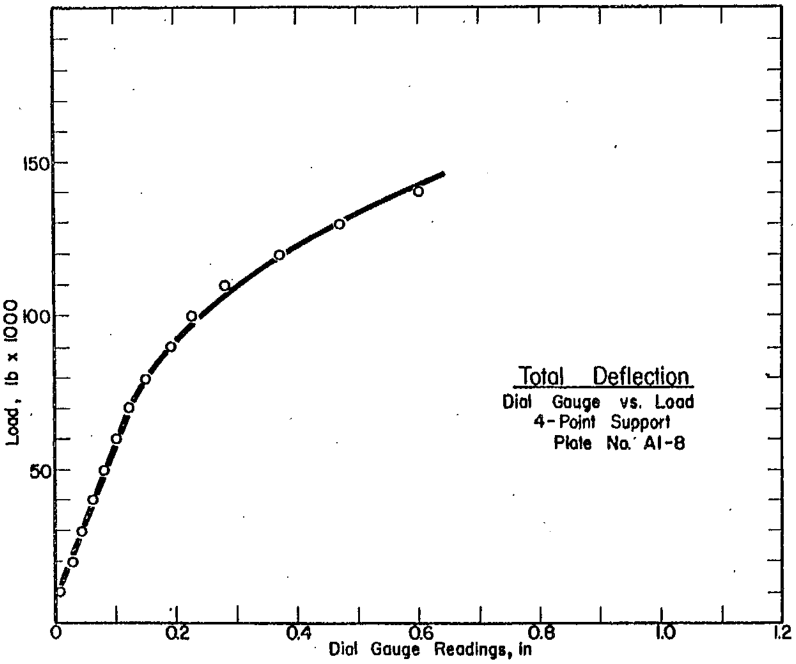


Figure 13. Deflection diagram, representative of lot A1.

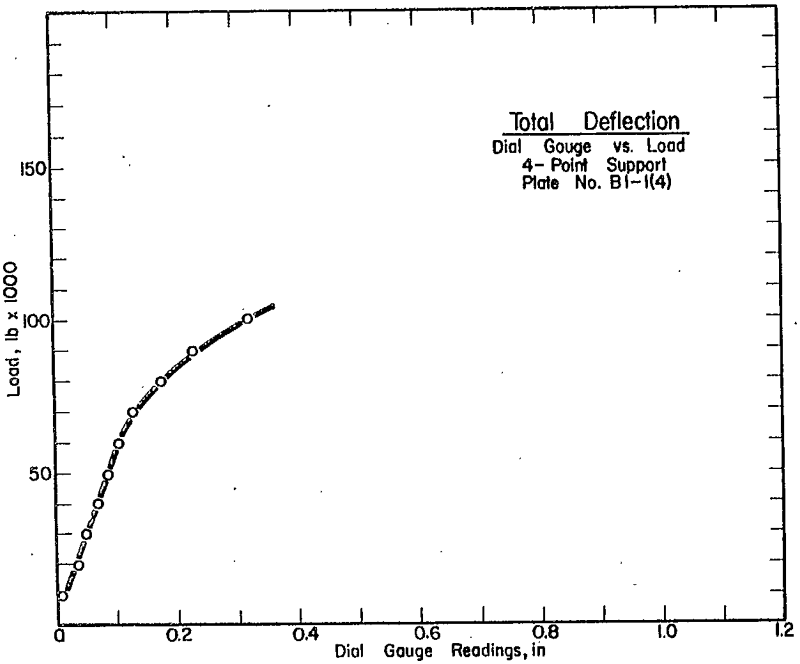


Figure 14. Deflection diagram, representative of lot B1.