Dr. J. Conway

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

SUMMARY REPORT

by

J. W. MEIER

PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

The present report is a summary of work on the metallurgical development of a cast magnesium alloy baseplate for a 81 mm mortar carried out during the period of 1960-1964.

The report includes a short outline of the history of development work on the cast magnesium alloy baseplate for the medium mortar, a general description of the work during the four phases of the present project, and a summary of the results obtained on the final design of the magnesium baseplate.

* Principal Metallurgist (Non-Ferrous Metals), Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

CONTENTS

INTRODUCTION

The present report is a summary of work on the metallurgical development of a cast magnesium alloy baseplate for a 81 mm mortar carried out during the period of 1960-1964 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.

This report includes a short outline of the history of development work on the cast magnesium alloy baseplate for the medium mortar, a general description of the four phases of the present project, and a summary of the results obtained on the final design of the magnesium baseplate. To facilitate the understanding of the development phases of the project, a brief discussion has been added dealing with the new concept of "premium-quality" castings, which has made possible the successful use of cast metal for highly stressed products, as well as a note on high-strength magnesium casting alloy research at the Mines Branch.

A more detailed account of the metallurgical development and evaluation work, including the results of simulated service (static break-down) tests, and stress determinations on mortar baseplate castings, is given in four separate reports (each dealing with one phase of the project), designated as Mines Branch Investigation Reports IR 65-13 to IR 65-16.

The description of the design of the mortar baseplate, of all its modifications and redesigns, as well as of the calculations leading to the design changes, is not included in the present report series. This work was done by Dr. T. W. Wlodek, Senior Scientific Officer, Mines Branch, and will be reported separately.

EARLIER WORK

The development 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 re-opened 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 a new high-strength magnesium casting alloy, developed at the Mines Branch(1-3) and designated ZK61-T6.

Considerable development work on the cast magnesium baseplate followed, whereby the results of the final design of the prototype castings designated "Type 3A" were very successful: the net weight of the magnesium alloy casting (without socket) was about 17.5 lb, and the baseplates withstood successfully both the limited firing tests (design tests) at the Canadian Armament Research and Development Establishment, DRB, Valcartier, Que., and minor user evaluation tests at the Royal Canadian School of Infantry, Camp Borden, Ont. The Directorate of Army Development recommended, therefore, final engineering tests to establish the cast magnesium baseplate 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 of 1949-1956 were reported in Mines Branch Investigation Reports Nos. PM 2773 (1951), PM 3002 (1953), PM 3053 (1954) and PM 3141 (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 solution heat treating furnace in Ottawa.

It is of interest to note, that some of the magnesium alloy baseplate castings, which were left over from the above program, were stored unprotected outside the Mines Branch foundry building for at least five years. In spite of the fact that the castings were only chrome pickled (no paint coating), visual examination of the castings in 1962, when the castings were removed to an Army storehouse, showed no signs of any surface deterioration or corrosion.

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 metallurgical development and evaluation of the baseplate castings. A joint USA-Canadian Conference on the development of mortar baseplates was held in Ottawa on 20 - 21 July 1960, and a tentative program for the development and testing work was discussed and agreed upon by representatives of the USA and Canadian Army agencies, and of the Mines Branch. Some strengthening of the baseplate casting was thought necessary because of change to more powerful ammunition. 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 of 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.

Before describing the work carried out in the four phases of the project and summarizing the results obtained, a short discussion is considered desirable to deal with the more general principles of modern methods used in the production of high-quality castings[4, 5] and of some magnesium alloy research work carried out at the Mines Branch to aid the development of satisfactory magnesium mortar baseplate castings[6-8].

PREMIUM-QUALITY CASTINGS

The main objection of designers and users of castings for applications in highly-stressed engineering components was always the inability of the foundry industry to produce castings of consistent quality. Castings were produced to specifications, which based their requirements on radiographic examination and on properties of separately-cast test bars, and it was known that these properties represented the "melt quality" of the alloy and not the properties of the actual production casting. It was also known that the properties in the different sections of the production castings varied considerably, depending on local solidification conditions. The foundry industry, in general, would guarantee only "melt quality" (that is the alloy composition, proper heat treatment, and mechanical properties obtained on separately-cast test bars).

The aircraft and, more recently, the spacecraft industries were first to insist on castings of guaranteed and strictly controlled properties. Considerable research effort followed and it was demonstrated by various institutions(4) not only that high properties could be obtained in castings, but also that these results can be obtained consistently. Industrial effort followed and it was shown that "premium-quality castings" can be made using any casting process, although most of the pioneer work was carried out on heavily chilled sand castings.

What is "premium-quality"? It is not only better internal quality of the casting and resultant higher mechanical properties, but the most important feature is the high integrity of the product, that is to say it is the reliability of properties in designated areas of each and every single casting, which are guaranteed with confidence by the foundry. To achieve this, it is necessary to have higher purity of metal and closer alloy composition limits; strict quality control in each individual melting, casting and heat treating operation; proper mould design to obtain optimum solidification conditions in designated areas of the casting; and careful evaluation of casting properties(5).

The novel concept of "premium-quality castings" guaranteed by the foundry is representative of the quiet "revolution" which is modernizing the casting industry to enable the production of scientifically engineered castings. As it was stated(4), "premium-quality castings are not castings in the ordinary sense of the word; their high reliability and high guaranteed properties make them more akin to and competitive with forgings".

It should be noted that, to produce premium-quality castings, conventional equipment and manufacturing techniques are used; the only departure from traditional founding is that each foundry operation has to be carefully studied and, once established, strictly controlled.

The cooperative effort to implement this new concept was so successful that recently the U.S. Military Specification for High-Strength Magnesium Alloy Castings, MIL-M-46062(MR) dated 25 June 1963, was issued, which for the first time specifies minimum properties in designated areas of castings, graded according to the importance of the area from design considerations. These guaranteed "minimum" properties in the casting are in most cases much higher than those specified in other castings for separately-cast test bars (see U.S. Federal Specification QQ-M-56b).

RESEARCH ON HIGH-STRENGTH MAGNESIUM ALLOYS

After the end of World War II, in 1945, the Canadian Bureau of Mines (at present the Mines Branch) established an extensive research program in the field of magnesium and magnesium alloy technology. The aims of this endeavour were (a) to help the newly created Canadian magnesium industry in its conversion to peace time conditions and to establish a broader basis for the inclusion of this new industrial metal into the Canadian economy; and (b) to assist the Canadian Armed Forces in the development of materials of high strength-to-weight ratio for use in aircraft and airborne equipment.

A considerable part of this research effort was directed to the development of high-strength magnesium casting alloys. The first successful result of these studies was the development[1-3] of magnesium casting alloy ZK61-T6, which had the highest strength-to-weight ratio of any non-ferrous casting alloy. Further work on alloy research at the Mines Branch lead to the development of a new alloy family, based on the magnesium-zinc-silver-zirconium system[6,7], of exceptionally high tensile strength and good ductility. Although these Mg-Zn-Ag-Zr alloys are still in the experimental stage, it is already known[8] that their properties are superior to those of any commercial magnesium casting alloy and that they are especially suitable for "premium-quality castings".

Work on various prototype castings for the Armed Forces, such as the mortar baseplate, necessitated a series of investigations on the various factors[9] affecting mechanical properties of magnesium casting alloys. Attention was drawn to the close relationship between the mechanical properties of casting sections and their grain size and structure[9].

Problems encountered during the development work reported here on the magnesium baseplate casting for the medium mortar led to additional studies on the effect of proper solidification conditions (section thickness, distance from chill) and heat treating cycles (solution temperature and time, cooling rate from solution temperature, ageing temperature and time) on the mechanical properties of magnesium casting alloy ZK61-T6. The results of these studies, already reported[10], were very useful in the final phases (Phases 3 and 4) of the development work on the magnesium baseplate and its successful conclusion.

FIRST DEVELOPMENT PHASE (1960-61)

As already noted, 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 a better assessment of commercial casting quality, and it was expected that the final phase of the project would be carried out on castings produced by the foundry which supplied, during the initial work, castings of higher quality and more consistent properties. It was decided to request the foundries to adhere strictly to the Mines Branch design of the casting, and to the specifications of Canadian Standard CSA.HG.9 for alloy ZK61-T6. Otherwise, the foundries 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.

Details of metallurgical examination and results of simulated service tests (breakdown tests on whole castings) are presented in Mines Branch Investigation Report IR 65-13. Additionally, actual service (firing) tests* with stress analyses using strain gauges and stress-coat methods, were carried out.

In general, the results of the static and dynamic (firing) tests showed both the strength and the casting quality to be inadequate. The tests also revealed the production characteristics of the foundries. Foundry A produced average but very consistent casting quality, Foundry B supplied the best and the worst castings.

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* G. C. Silverthorn - "Design Test of Magnesium Baseplate for Medium Mortar" - Deputy Quartermaster-General (Equipment and Engineering) Interim Report No. 200, Department of National Defence (Army), Ottawa, Canada (19 Oct. 1961).

SECOND DEVELOPMENT PHASE (1961)

The second phase of the investigation was, in general, a repetition of the first phase of the work. Some further redesign to strengthen the baseplate was carried out at the Mines Branch, and additional castings were ordered from the same two commercial foundries. All results of metallurgical examinations and mechanical tests, obtained in the first phase, were shown to the foundries, especially the location of defects visible on the fractured sections of the castings, and means of improvement of the product quality were discussed. It was agreed, that the foundries should concentrate their attention on the most critical areas of the casting (tension side of the arm) as determined from stress-coat, strain gauge, and breakdown tests.

Results of the tests in the second phase are presented in Mines Branch Investigation Report IR 65-14. These results showed that Foundry A still had average and very consistent results, while Foundry B considerably improved their overall quality. Breakdown tests, carried out on castings of both foundries, revealed that the improvement in casting quality was not sufficient, and also that a more substantial redesign of the casting was necessary.

THIRD DEVELOPMENT PHASE (1961-62)

At a meeting between representatives of the Army Development Establishment, DND, and the Mines Branch, held on 26 September 1961, the unsatisfactory results of the first two phases of the investigation were reviewed and, after a thorough discussion of the problem, it was agreed that the work of the third phase should consist of a more substantial redesign of the baseplate and a major effort to improve the casting quality. To achieve this without undue delay (unavoidable if each design alteration had to be re-ordered in a commercial foundry) it was decided to carry out the work on this phase of the program in the Experimental Foundry of the Mines Branch.

Eight altered designs were tried, but the main effort was directed to improve the casting quality by better gating and risering. To secure the most favourable solidification conditions, considerable chilling was used in the most critical areas. As previously mentioned, additional investigational studies(10) were carried out on the effect of solidification conditions and heat treating cycles, and special equipment was built for the most effective cooling from solution temperature by an individually directed air blast.

As the result of successful static breakdown, dynamic load tests* and firing tests**, one casting design (designated "C4") was finally chosen for its best strength-to-weight ratio. Figure 1 shows the view of this final design of the medium mortar baseplate casting and Figure 2 the design drawing No. MBP 20-1 of this baseplate. This design featured two significant changes in the shape of the main beams. These beams had been given a symmetrical cross-section and their depth had been increased adjacent to the socket.

Stress analyses performed during the evaluation tests and the mode of breaking of the plates revealed additional areas of high stress concentration, located at the socket between the arms (Figure 3) and at the joint of the reinforcing rib and the spades (Figure 4).

Soundness in these areas was improved by the application of additional chills and Figures 5 and 6 show the mode of fractures in the corrected castings. It should be added that the plates before correction broke in a simulated service test, performed in sand, at a load of 245,000 lb (Figure 3) and of 237,000 lb (Figure 4), respectively. The corrected plate shown in Figure 5 broke at 320,000 lb and the entirely sound casting (Figure 6) withstood 360,000 lb.

The above emphasizes how close cooperation between designer and end-user, and the casting engineer pays dividends; results of stress-analyses and simulated service tests showed the areas where improvement of casting quality would have most effect, and the breakdown strength of the castings was improved by 50%, exceeding the performance of the standard forged aluminum alloy baseplate. The availability of proper

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* C. Briercliffe - "Some Internal Ballistic and Thrust Measurements for the 81 mm Mortar (U)" - CARDE Technical Report 461/63 - Canadian Armament Research and Development Establishment, Valcartier, Quebec (Sept. 1963).

** G. W. Guy -"CARDE Trials of 81 mm Mortar C29 (Modified) with Baseplate, Cast Magnesium C3 and C4 (U)" - CARDE Technical Note 1572/64- Canadian Armament Research and Development Establishment, Valcartier, Quebec (February 1964).

design data allowed the metallurgist to increase the strength of the casting by a relatively simple and inexpensive modification of the mould arrangement.

Figure 7 shows a graph illustrating the difference in the total deflection vs load of the initial castings (A1 and A2 - phase one and two of the investigation), the standard forged aluminum baseplate, and the final design (C4) of the sand-cast magnesium plate, during the simulated service (breakdown) tests. The considerable increase in the stiffness of the C4 design should be noted.

Details of metallurgical development work, casting quality examinations and simulated service tests are presented in Mines Branch Investigation Report IR 65-15.

FOURTH DEVELOPMENT PHASE (1963-64)

The fourth and final phase of the project was carried out once more on commercially produced castings. The foundry (Foundry A) was requested to cast 40 baseplates to the finally approved design (see Figures 1 and 2) and to adhere strictly to the mould design, developed at the Mines Branch (as shown in Figure 8), which was carefully chosen to obtain the required mechanical properties in critical areas; otherwise standard equipment and routine foundry methods were used. The gross weight of the casting (before trimming) was 42 lb, net weight before shipping 24 lb. The total weight of cast-to-shape magnesium chills used in the cope was 5.5 lb, and an additional 12 lb of cast-to-shape copper chills were used in the drag. The heat treatment of the castings was carried out according to the routine foundry schedule, which provided a solution heat treatment for 10 hr at 480 °C (895 °F), uniform air blast cooling, and ageing for 48 hr at 130 °C (265 °F).

It is worth noting that, while a total of forty-one ZK61-T6 alloy castings were made, only one was rejected after all of the castings were closely examined radiographically. This shows that, although metallurgical development of premium-quality castings is time-consuming and costly, once the proper casting conditions are established and strictly adhered to, a very small rejection rate in the actual production run may be achieved.

The castings withstood successfully all service evaluation tests (including firing* tests). Details of metallurgical examination and of results of static breakdown tests are presented in Mines Branch Investigation Report IR 65-16.

DISCUSSION OF RESULTS

Table 1 presents a comparison of typical results of simulated service (static breakdown) tests. A detailed description[12] of the performance of these tests is given in Mines Branch Investigation Report IR 65-13 (on Phase I of the present Investigation); two types of these tests** were used: the four-point-support test (where the baseplates are supported with the spades on bearing blocks), and the sand test (where the baseplate is placed in a large container filled with building sand). The considerable improvement in the performance data in the various phases of the investigation is evident. For the explanation of data obtained on baseplates C4 - 14 and C4 - 17 it may be added that these are the corrected plates shown in Figures 5 and 6, and it may be seen that the comparatively small improvements in mould design resulted in a marked increase of the breaking loads.

Table 2 shows the results of tensile tests obtained on test bars cut out of critical areas, designated as Class 1 and 2 (according to U.S. Military Specification MIL-M-46062 (MR) dated 25 June 1963) as well as from unspecified areas. Although at the time of casting of the A4 (Phase 4) design this specification was not yet issued, it is interesting to compare our results with the stringent minimum requirements of this specification.

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* J. Huot - "Engineering Test of the A4 Design Cast Magnesium Baseplate for the 81 mm Mortar.Evaluation of Trial Data" - CARDE Technical Note 1623, Canadian Armament Research and Development Establishment, DRB, Valcartier, Quebec (December 1964).

** 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.).

Although some of the lowest test results (YS) were somewhat below the specified minima, in general the results may be considered as very satisfactory, particularly if the less favourable heat treatment schedule (480 °C (895 °F) instead of 500 °C (930 °F) - which is standard for alloy ZK61-T6), and the small amount of risering and total weight of chills are taken into account. This may be compared with a premium-quality aircraft casting tested recently[11], where 70 lb of magnesium and 78 lb of chills were used for a casting of 10 lb shipping weight.

The table shows also that lower properties in unspecified areas, which from the structural design point of view are not significant, do not affect the results obtained in the simulated service (breakdown) tests carried out on whole castings, as may be seen in the last column of Table 2. (It should be explained that results of breakdown tests given in Table 2 were obtained on four-point-support tests.)

So much for the development of the ZK61-T6 alloy plate. To compare the performance of the final plate design in other high-strength magnesium casting alloys, a few castings were made in alloys AZ92-T6 and QE22-T6. Since the gating, risering and chilling was designed for alloy ZK61-T6, only a few castings were ordered from the commercial foundry. Additionally, one casting was made in the Mines Branch foundry in the new experimental alloy ZQ64-T6, one of the very promising alloys of the Mg-Zn-Ag-Zr family[6-8].

Table 2 shows the results of test bars, cut out of some randomly chosen castings in the ZK61-T6 series, and from all of the AZ92-T6, QE22-T6 and ZQ64-T6 castings. The test bars were cut from Class 1 and 2 designated areas, as well as from unspecified parts of the castings. The results of the four-point-support (breakdown) tests should be compared with those typical for the standard forged aluminum alloy baseplate, which average 190,000 lb[12]. Each of the alloys used, with the exception of AZ92-T6, showed higher strength than the aluminum alloy forging.

Especially outstanding are the properties of alloys ZK61-T6 and ZQ64-T6, which in both cases could be even further increased by use of hot water quenching after solution heat treatment. Alloy QE22-T6 exhibits very good yield strength values, but has relatively lower tensile strength and elongation, and shows a poorer performance in the simulated service tests. The suitability of alloy QE22-T6 for premium-quality castings is more limited, because an ample margin of UTS over YS and good ductility is required to increase the reliability of castings from the designer's point of view.

CONCLUSIONS

1. Full cooperation between the designer, end-user, metallurgist and foundryman has resulted in the development of a sand-cast magnesium alloy baseplate which meets the design requirements for the medium mortar with respect to strength and stability.

2. The use of high strength magnesium alloys (ZK61-T6, and especially the recently developed ZQ64-T6) and the application of premium-quality casting methods has now made possible the development of a redesigned magnesium alloy medium mortar baseplate casting which is 10% lighter than the standard aluminum alloy forging and has up to 30% higher strength in four-point-support tests with twice the rigidity.

3. A comparison of the simulated service test loads required to cause fracture of the cast magnesium and the standard forged aluminum baseplates indicates that the weight of the cast magnesium alloy baseplate (24 lb) could be reduced, with further redesign, by at least 15% without lowering its strength below that of the standard baseplate.

ACKNOWLEDGEMENTS

Work on the development of the magnesium alloy medium mortar baseplate was carried out by a team of staff members of the Physical Metallurgy Division, Mines Branch, under the chairmanship of the writer of this Summary Report. Mr. B. Lagowski, Senior Scientific Officer, Non-Ferrous Metals Section, was responsible for the metallurgical foundry development and all evaluations of casting quality; Mr. J. Harbec, Scientific Officer, Mechanical Testing Section, carried out and evaluated all simulated service tests; Messrs. J. O. Edwards, Head, Non-Ferrous Metals Section, and P. J. Todkill, Head, Mechanical Testing Section, assisted considerably with their technical advice.

As already noted, 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

Comparison of Results of Simulated Service Tests on Cast ZK61-T6 Alloy Baseplates

(compared with Standard Forged Aluminum Plate)

Design of Baseplate	Four-Point-Support Test		Sand Test	Remarks
	Load* for Initial Permanent Set, lb	Breaking Load*, lb	Breaking Load*, lb	
Mg Casting Type 3A		97,000	152,000	1956 production
A1	70,000	140,000	198,000	) Phase 1
B1	65,000	106,000	135,000	)
A2	70,000	142,000	225,000	) Phase 2
B2	70,000	185,000	253,000	)
C3	120,000	237,000	232,000	) Phase 3
C4	120,000	206,000	250,000	)
C4-14	-	-	320,000	)
C4-17	-	-	360,000	)
A4	120,000	237,000	300,000	Phase 4
Al forging**	95,000	190,000	320,000	Standard plate

* Average values of all results for particular design.

** Mines Branch Investigation Report IR 62-18 (Nov. 1962)(12).

TABLE 2

Tensile Properties of Test Bars Cut Out of Prototype Castings

Alloy Designation		Designated Areas Class 1 UTS, kpsi	Designated Areas Class 1 YS, kpsi	Designated Areas Class 1 El, %	Designated Areas Class 2 UTS, kpsi	Designated Areas Class 2 YS, kpsi	Designated Areas Class 2 El, %	Unspecified Areas of the Casting UTS, kpsi	Unspecified Areas of the Casting YS, kpsi	Unspecified Areas of the Casting El, %	Simulated Service Tests** Breaking Load lb
ZK61-T6	max	46.4	33.2	14.0	44.5	30.2	10.0	41.5	29.5	6.5	
	min	44.4	28.3	8.0	43.2	28.2	8.0	38.2	20.0	2.5	
	ave.	(10) 45.5	31.8	10.0	(8) 43.9	29.4	9.1	(12) 39.4	25.9	4.1	237,000
	Mil*	42	29	6	37	26	4	30	21	1.25	
QE22-T6	max	42.2	35.0	5.5	41.2	32.8	5.5	40.1	30.2	3.5	
	min	39.7	30.1	3.5	39.6	31.7	3.5	38.4	25.8	2.5	
	ave.	(7) 40.7	33.4	4.3	(6) 40.5	32.3	4.2	(8) 39.3	28.3	2.7	217,000
	Mil*	40	28	4	37	26	2	28	20	2	
AZ92-T6	max	46.2	25.6	4.5	41.8	26.8	4.5	38.9	25.2	2.0	
	min	41.7	20.2	3.5	35.1	21.4	2.5	35.1	20.5	1.0	
	ave.	(6) 43.9	22.8	4.5	(5) 36.9	24.0	3.2	(6) 36.6	23.2	1.4	178,000
	Mil*	40	25	3	34	20	1	17	13.5	0.25	
ZQ64-T6	max	49.2	40.1	9.5	47.2	31.5	7.5	45.9	30.1	7.0	
	min	48.7	32.8	8.0	44.0	29.9	6.0	39.2	19.1	4.5	254,500
	ave.	(3) 49.0	36.0	8.5	(3) 45.7	30.7	6.5	(4) 42.9	26.0	6.0	

* Mil - minimum in Military Specification MIL-M-46062 (MR) dated 25 June 1963.

** Four-Point-Support Tests.

NOTE: Numbers in brackets give number of specimens tested.

Test bars for Class 1 and Class 2 areas were cut out from 1-1/4-inch-thick sections.

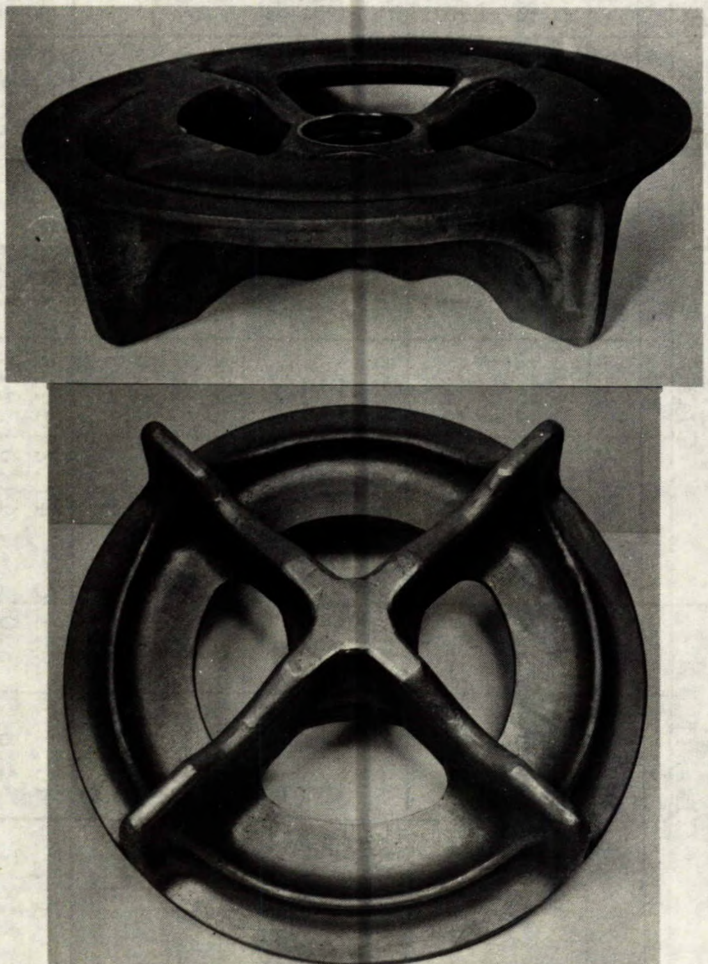
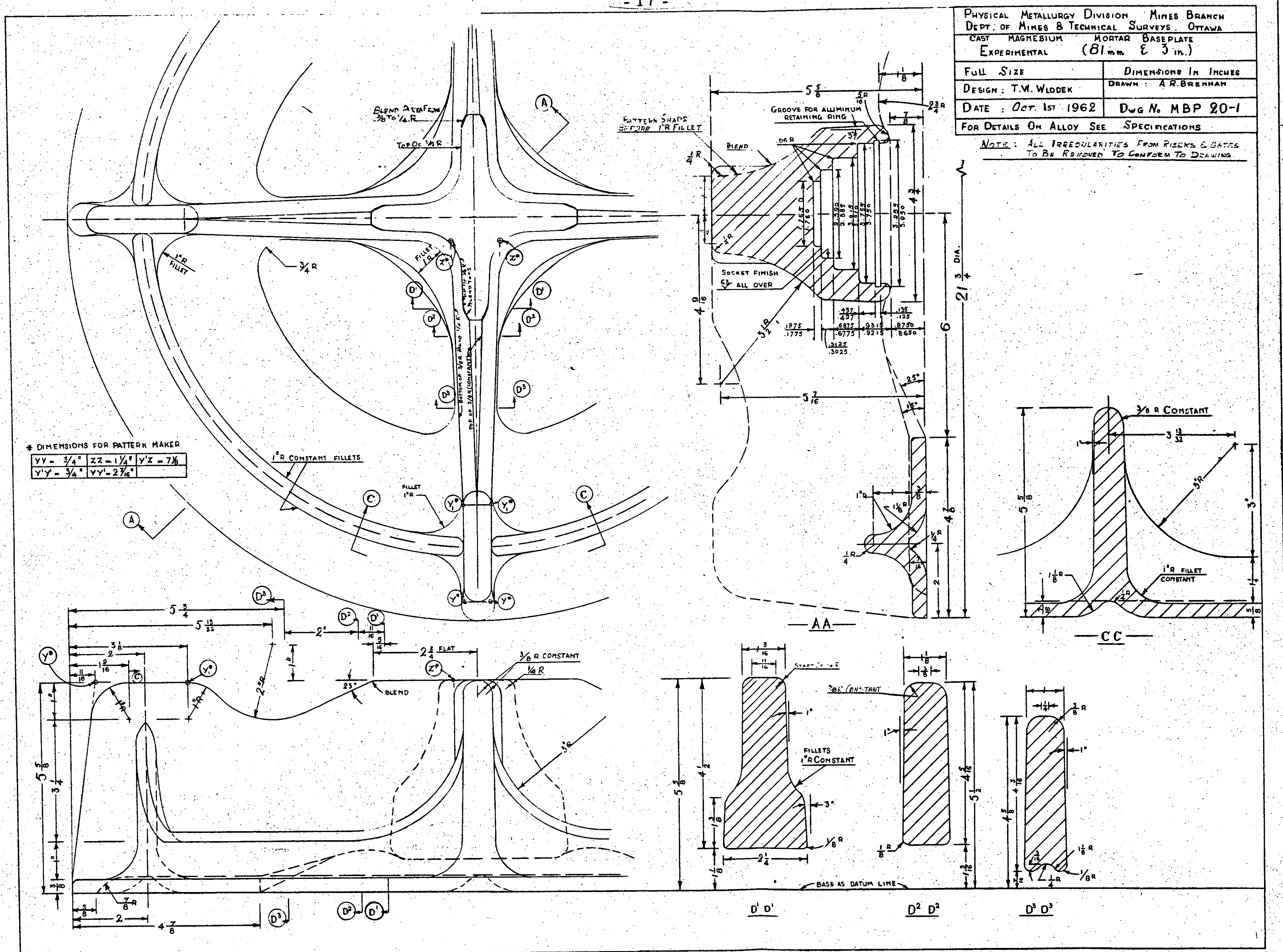


Figure 1. Views of medium mortar base casting.



PHYSICAL METALLURGY DIVISION MINES BRANCH
DEPT. OF MINES & TECHNICAL SURVEYS. OTTAWA
CAST MAGNESIUM MORTAR BASEPLATE
EXPERIMENTAL (81 mm & 3 in.)
FULL SIZE
DIMENSIONS IN INCHES
DESIGN: T.W. WLODEK
DRAWN: A.R. BRENNAN
DATE: OCT. 1ST 1962
DWG No. MBP 20-1
FOR DETAILS ON ALLOY SEE SPECIFICATIONS
NOTE: ALL IRREGULARITIES FROM RISERS & GATES TO BE REMOVED TO CONFORM TO DRAWING
* DIMENSIONS FOR PATTERN MAKER
YY - 3/4" ZZ - 1 1/4" Y'Z - 7 1/8
Y'Y' - 3/4" YY' - 2 7/16"
GROOVE FOR ALUMINUM RETAINING RING
PATTERN SHAPE BEFORE 1"R FILLET
SOCKET FINISH 63 ALL OVER
1"R CONSTANT FILLETS
3/8 R CONSTANT
1"R FILLET CONSTANT
FILLETS 1"R CONSTANT
BASE AS DATUM LINE
AA
CC
D¹ D¹
D² D²
D³ D³

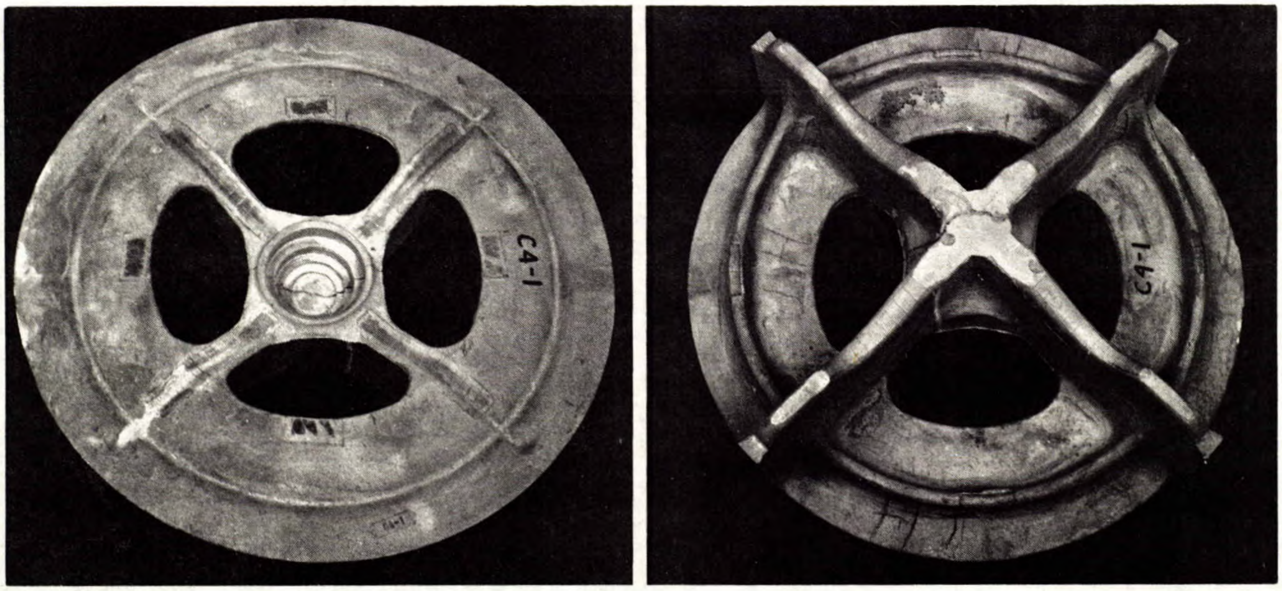


Figure 3. Typical fracture for all castings of C3 and C4 design in static load breakdown tests.

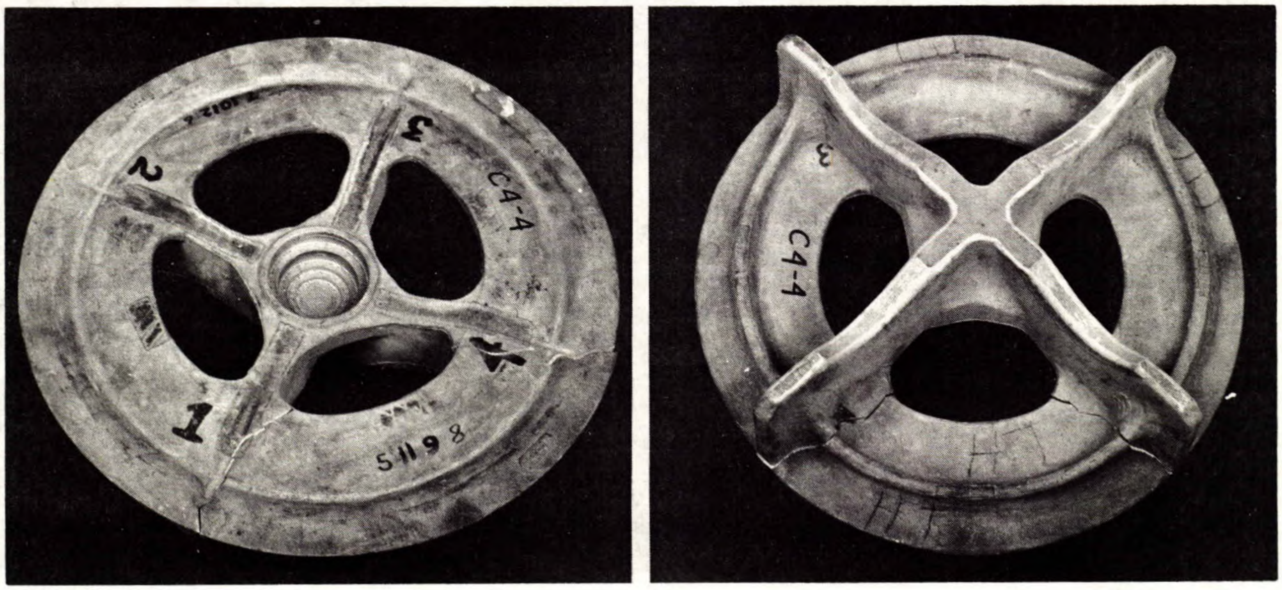


Figure 4. Fracture of casting due to unsoundness in reinforcing rib (tested in sand).

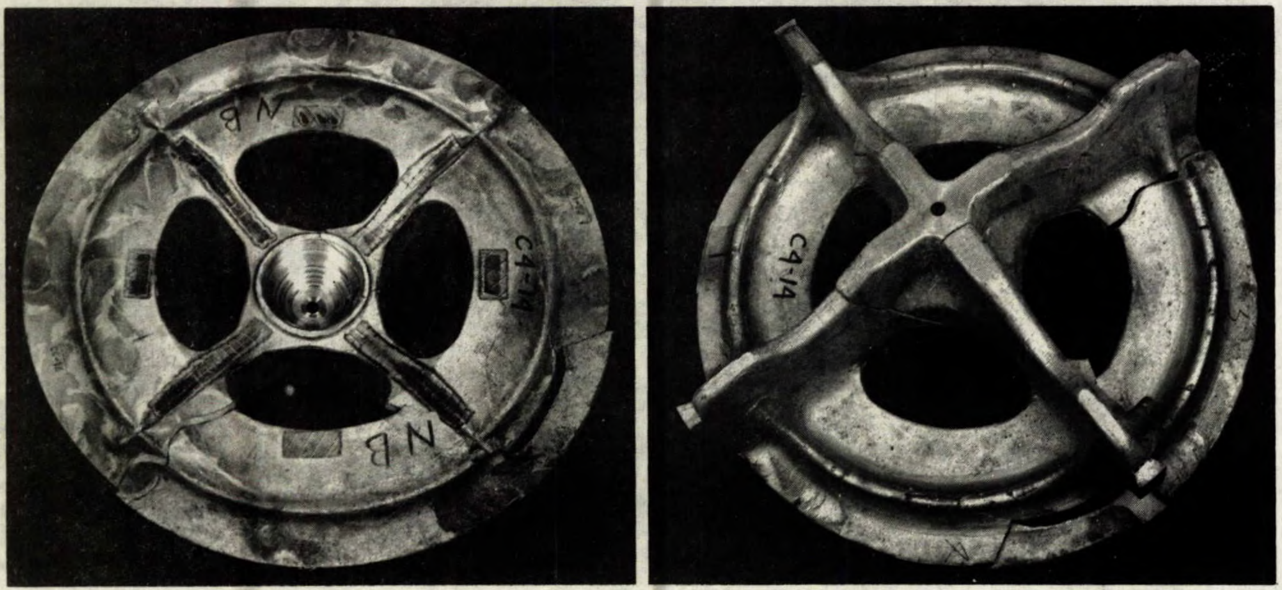


Figure 5. Mode of fracture with improved soundness in socket and sound reinforcing rib.

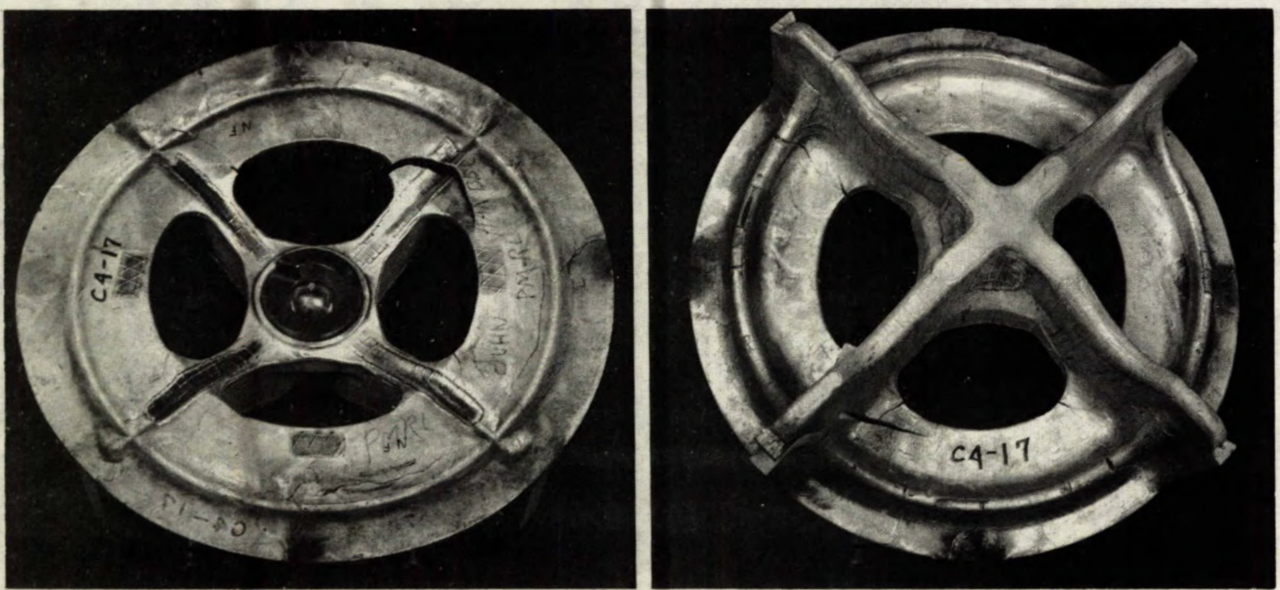


Figure 6. Mode of fracture with satisfactory soundness in the socket and reinforcing rib.

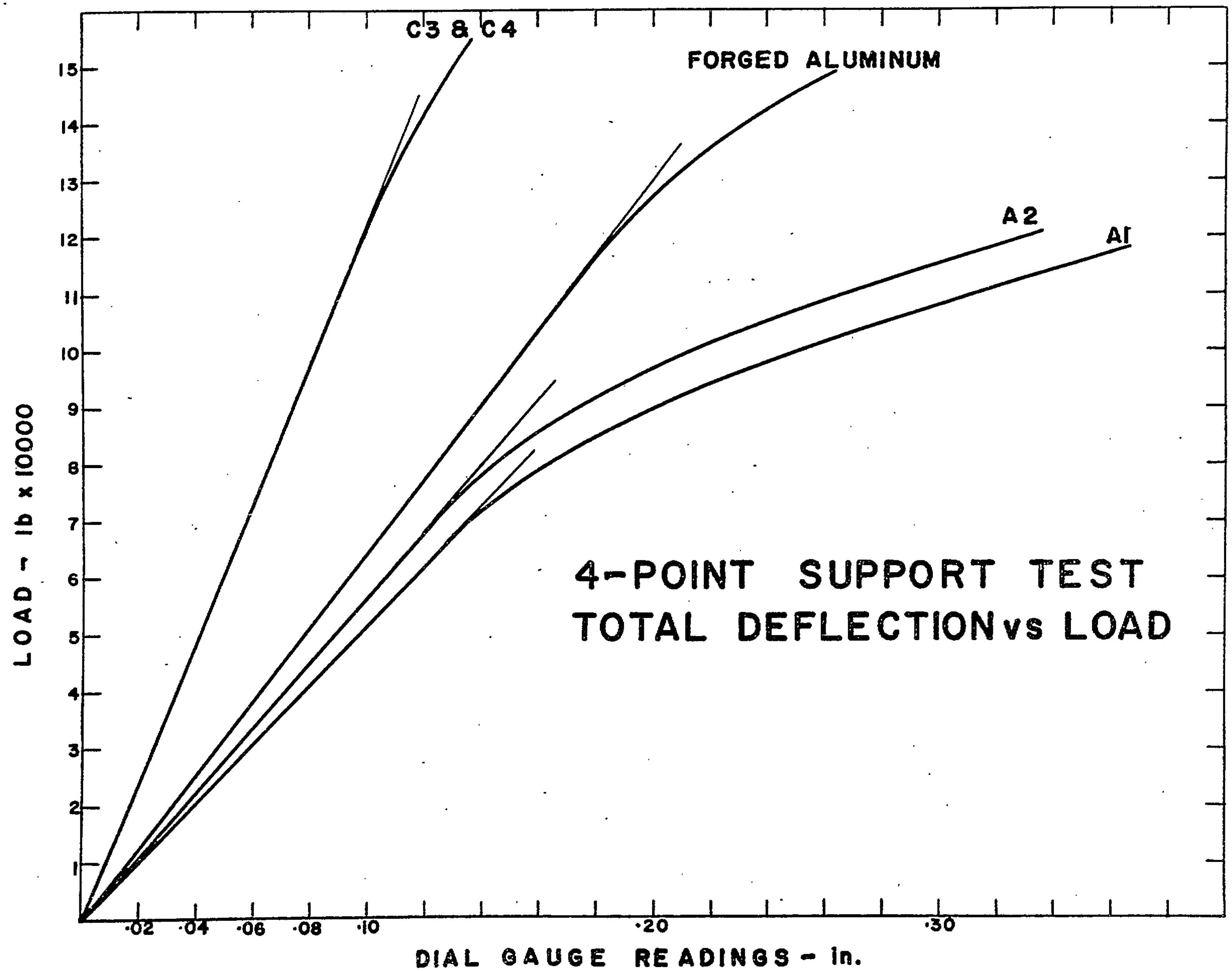

C3 & C4
FORGED ALUMINUM
A2
A1
4-POINT SUPPORT TEST
TOTAL DEFLECTION vs LOAD
LOAD ~ lb x 10000
DIAL GAUGE READINGS – in.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
·02
·04
·06
·08
·10
·20
·30

FIGURE 7

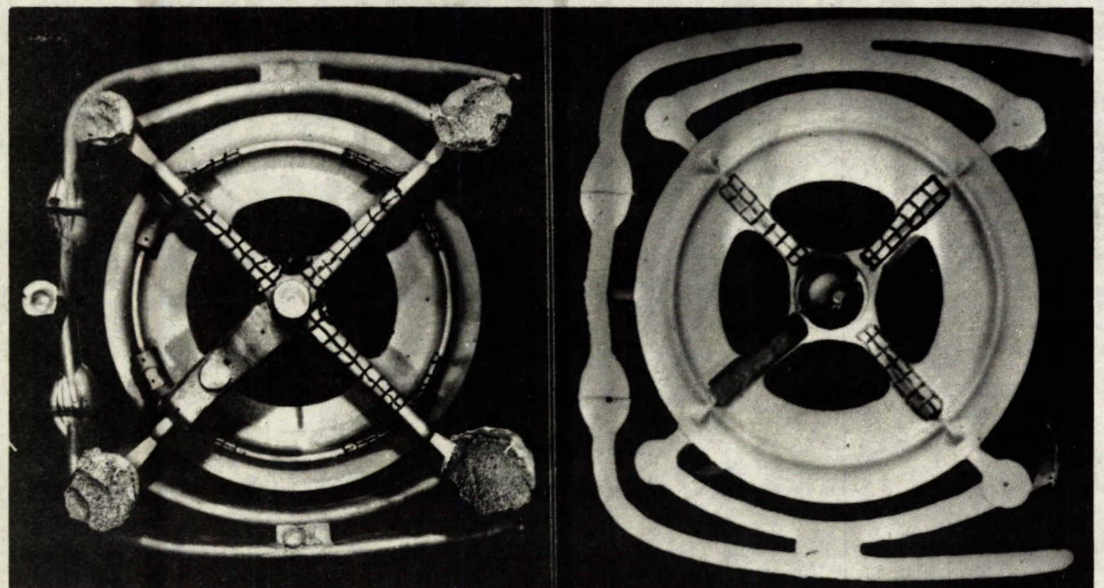


Figure 8. Moulding arrangement in commercial production of final design (A4).