CANADA

PROPERTIES OF SAND-CAST MAGNESIUM ALLOYS

Part VI: Effect of Pouring Temperature and Holding Time

A. COUTURE & J. W. MEIER

DEPARTMENT OF MINES AND TECHNICAL SURVEYS, OTTAWA

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PROPERTIES OF SAND-CAST MAGNESIUM ALLOYS

Part VI: Effect of Pouring Temperature and Holding Time

by

A. Couture* and J.W. Meier**

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ABSTRACT

The influence of pouring temperature and holding time before pouring on the mechanical properties and chemical composition of several magnesium casting alloys has been investigated and the results, obtained on sand-cast four-bar moulds, are reported in the present report. The pouring temperature was varied from 700°C (1290°F) to 850°C (1560°F) and the holding time from 10 min to 2 hr at normal pouring temperature. Other melts were held at 700°C or 850°C for 30 min before pouring.

In general these various treatments did not adversely affect the chemical composition and mechanical properties to a pronounced extent. However, because alloy ZH62 tends to form dross when heated to 850°C, such a high temperature should be avoided if possible. The "insoluble" zirconium content of zirconium-containing alloys may be appreciably decreased by lowering the melt temperature to 700°C. The "soluble" zirconium and rare earth contents of alloy QE22, the rare earth content of alloy EZ33 and the thorium content of alloy ZH62 may be decreased by holding the melt at normal pouring temperature for an appreciable length of time.

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Direction des mines

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PROPRIÉTÉS DES ALLIAGES DE MAGNÉSIUM COULÉS EN SABLE

6e partie: Effet de la température de coulée et du temps de maintien à une température donnée

par

A. Couture* et J. W. Meier**

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RÉSUMÉ

Les auteurs ont étudié l'influence de la température de coulée, et du temps de maintien avant la coulée, sur les propriétés mécaniques et la composition chimique de plusieurs alliages au magnésium moulés, et les résultats pour des éprouvettes coulées en sable par grappes de quatre font l'objet du présent rapport. Ils ont fait varier la température de coulée de 700°C (1290°F) à 850°C (1560°F) et le temps de maintien de 10 minutes à 2 heures à la temperature normale de coulée. D'autres bains ont été retenus à 700°C ou à 850°C during 30 minutes avant la coulée.

De façon générale les divers traitements n'influent pas considérablement sur la composition chimique et les propriétés mécaniques. Cependant, parce que l'alliage ZH62 tend à s'encrasser si on le chauffe à 850°C, it faut tâcher d'éviter une température aussi élévée. La teneur en zirconium "insoluble" des alliages contenant du zirconium peut être grandement réduite en abaissant la température du bain à 700°C. Les teneurs en zirconium soluble et en terres rares de l'alliage QE22, la teneur en terres rares de l'alliage EZ33, et la teneur en thorium de l'alliage ZH62 peuvent être réduites en maintenant le bain à la température normale de coulée pour un période assez longue.

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INTRODUCTION

The enduring controversy over the usefulness of separately-cast test bars for the evaluation of the melt quality of castings was discussed in previous reports [1,2]. It was emphasized that separately-cast test bars are not intended to represent the properties of production castings and should be used only to check the melt quality, or the response to heat treatment, of the material from which the castings were made.

It should be particularly stressed that the full value of melt quality evaluation can be achieved only if the test bars are cast under standardized and strictly controlled conditions. The purpose of this report is to discuss certain important factors, connected with the thermal history of the melt, which affect melt quality, namely the maximum melt temperature, the holding time and the pouring temperature. These three factors are interdependent and could have a cumulative effect on the properties of the castings.

A search of the literature revealed that there are numerous papers mentioning the importance of the effect of one or other of the above factors (in most cases, the pouring temperature) on the mechanical properties of the casting. No systematic investigation of all three factors could be found, however, and it was therefore considered useful to record in this report the results of such a study begun some years ago in these laboratories.

Superheating, used in Mg-Al-Zn alloys for grain refinement, is not discussed in this report. Temperatures used in superheating are much higher (870-930°C, 1600-1700°F) than those used in this investigation. It is known that, to obtain a small grain size, it is necessary to cool the melt as rapidly as possible from the superheating temperature to the pouring temperature and to pour as soon as possible; holding the melt for any significant time at the lower temperatures may result in coarsening of the grain size.

GENERAL CONSIDERATIONS

Unlike most aluminum alloys, the highest mechanical properties of which are obtained at the lowest possible pouring temperature, magnesium alloys have an optimum casting temperature to produce a sound casting and highest mechanical properties. This temperature is considerably higher than the lowest possible casting temperature. According to published data and to general opinion, too low a pouring temperature tends to cause grain coarsening in some magnesium alloys, and higher pouring temperatures increase gassiness and iron-pickup.

Of particular interest is the effect of pouring temperature on the properties of test bars cast separately under closely controlled conditions, because some specifications require test bars to be cast at the same pouring temperature as the production castings. It is obvious that the choice of the pouring temperature, for any casting, depends on the casting's size and shape. Either high pouring temperatures, necessary for castings of complex and thin-sectioned shapes, or very low pouring temperatures, unavoidable at the end of pouring a number of castings, could therefore effect the properties of separately-cast test bars. To investigate this, a series of test bar castings was cast at pouring temperatures of from 700-850°C (1290-1560°F), a range most likely to be used in normal foundry production. The tensile properties of these bars were compared with those obtained on bars cast at "normal" pouring temperature used for the particular alloy, namely, 740°C (1365°F) for aluminum-containing alloys, and 760°C (1400°F) for zirconium-containing alloys.

The holding time, that is, the time of keeping the alloy in the molten state before pouring, has been claimed to be of critical importance for magnesium alloys. Published data on various Mg-Al-Zn alloys show that prolonged holding times cause grain coarsening and resultant decreased mechanical properties. Regarding zirconium-containing alloys, it has been inferred that longer holding times cause settling out of zirconium and, therefore, larger grain size and lower mechanical properties. In this investigation, holding times at the "normal" pouring temperatures were varied from the usual settling time of ten minutes to two hours (in some cases, up to almost four hours). Other experimental melts were held at low 700°C, 1290°F) and high (850°C, 1560°F) temperatures.

MELTING PROCEDURE

All the alloys studied in this investigation (Tables 1 and 2) were melted and prepared in steel crucibles.

AZ80, AZ91 and AZ92 alloys were obtained as follows: commercial ingots and/or scrap from previous melts were melted under a cover of Domal crucible flux, grain-refined with lampblack at a temperature of 720 to 740°C (1330 to 1365°F), degassed with chlorine for 10 min, and allowed to settle for 10 min before pouring.

The zirconium-containing alloys were prepared by melting high-purity "Domal" magnesium ingots, or appropriate scrap, under a flux cover consisting of barium and calcium chlorides and magnesium fluoride; when a temperature of 760°C (1400°F) was reached the alloying elements other than zirconium were added and this was followed by the introduction of zirconium in the form of fused salts, consisting of 50% $ZrCl_4$, 25% NaCl and 25% KCl, stirred manually into the melt for 10 min. Pouring was done after a 10-min settling period.

All test bars cast for this investigation were produced in a four-bar mould according to Canadian Standard CSA.HG. 1.5-1963, Figure 1 (similar to U.S. Federal Specifications QQ-M-56, p.6, Figure 1A).

SECTION I: INFLUENCE OF POURING TEMPERATURE

Casting Procedure

The alloys studied in this section of the investigation are listed in the first column of Table 3, and the casting procedure was the same for all the alloys. From the first melt, separately-cast test bars were poured at 740°C (1365°F) for the aluminum-containing alloys and at 760°C (1400°F) for the zirconium-containing alloys. The temperature was then raised to 850°C (1560°F), the melt was held for 10 min (except as mentioned below) at that temperature without stirring, and then another set of test bars was cast. This procedure was repeated at the successively lower temperatures of 800, 750 and 700°C (1470, 1380 and 1290°F). In the second melt, the pouring sequence was reversed: after casting a set of test bars at 740°C (1365°F) or 760°C (1400°F), the temperature was dropped to 700°C (1290°F) and then raised successively to 750, 800 and 850°C (1380, 1470 and 1560°F) and test bars cast at each temperature after a 10-min settling period. For alloys AZ80, AZ91, ZH62 and ZK61, two melts were prepared each way; in one case a 10-min holding period was allowed at each temperature and, in the second case, bars were cast immediately after reaching the pouring temperature. Only one melt of alloys AZ92, QE22, ZQ64 and ZQ91 was cast each way and, in all cases, the metal was held at temperature for 10 min before casting.

Experimental Results

Chemical Composition -

Samples for chemical analysis were drilled from the grip portion of the broken test bars, and the results (average results in the case of AZ80, AZ91, ZH62 and ZK61 as two melts were prepared for each pouring sequence) are presented in Table 3. In general, neither the pouring temperature nor the pouring order affected the chemical composition systematically, because the variations are inconsistent and are probably due to sampling and/or experimental variations. However, the "soluble" zirconium content of alloy QE22 decreases continuously the longer the metal is held in the molten state (as shown in the second half of Table 3) as does also, but to a lesser extent, the rare earths content of the same alloy. On the other hand, the "insoluble" zirconium content of ZQ91 is definitely decreased by holding this alloy at a temperature of 700°C (1290°F) and, when it has been reduced, it does not recover on subsequent reheating, as indicated by the second melt results. This reduction in "insoluble" zirconium is probably due to the precipitation between 750 and 700°C (1380 and 1290°F) and settling out of a zirconium phase which would otherwise have been reported as "insoluble" zirconium.

Mechanical Properties -

Average mechanical property results are presented in Tables 4 and 5 for aluminum-containing and zirconium-containing alloys, respectively. Results for AZ80, AZ91, ZH62 and ZK61 alloys are averages of four tests, other results are averages of two to four tests. In cases where two melts were prepared each way, i.e., one with and one without a 10-min holding period at each pouring temperature, the results from both melts were averaged because no significant differences were found.

Examination of Tables 4 and 5 does not reveal any pronounced effect of the pouring temperature on the tensile test results within the range of pouring temperatures investigated. There may be a slight tendency for the extreme temperatures of 700 and 850°C (1290 and 1560°F) to produce lower properties than the middle temperatures. This is more marked in AZ91, and especially in ZH62, than in other alloys. Casting ZH62 at 850°C (1560°F) produced a great number of flaws in the test bar fractures and this, in itself, may reduce the properties appreciably. Although the high pouring temperature per se may not be detrimental to the properties of alloy ZH62, it is certain that the greater likelihood of obtaining dross inclusions in castings cast at 850°C (1560°F) would make such a temperature undesirable. A noteworthy point is that, for all alloys, even if the tensile properties are reduced by casting at too low or too high a temperature, the properties of the melt can apparently be fully restored by using a more suitable temperature.

SECTION II: INFLUENCE OF PROLONGED HOLDING PERIODS AT NORMAL POURING TEMPERATURE

Casting Procedure

Melts of the alloys listed in the first column of Table 6 were held at a temperature of 740°C (1365°F) for the aluminum-containing alloys, and 760°C (1400°F) for the zirconium-containing alloys, for periods of 10, 30, 60 and 120 min without stirring before pouring. Three melts each of AZ80, AZ91, EZ33, ZH62 and ZK61 were prepared and two four-bar moulds were cast from each melt after each holding period. For alloys AZ92, QE22, ZQ64 and ZQ91, only one melt of each alloy was used and one four-bar mould cast after each holding period. One melt of AZ80 and AZ91 alloys was held at 740°C (1365°F) for 10, 40, 100 and 220 min and two four-test bar moulds cast in each case.

Experimental Results

Chemical Composition -

Samples for chemical analysis were drilled from the grip sections of the broken tensile test bars, and average results, in cases where more than one melt were cast, are presented in Table 6. In general, holding the molten metal for up to two hours at "normal" pouring temperature did not affect the chemical composition. However, a few slight trends cannot be ignored. The aluminum content of AZ92 alloy, the soluble zirconium of QE22 and the "insoluble" zirconium of ZQ91 were all slightly reduced when the melts were held for up to 2 hr. Although the differences are small it is felt that they are not accidental, because specimens taken directly from the melts (see Tables A, B and D of the Appendix) show the same trends. The thorium content of ZH62 might also be reduced by the same treatment.

Tables 9 and 10 indicate that the holding period can be as long as 220 min, at least for AZ80 and AZ91 alloys, without affecting the chemical composition and the iron pick-up.

Mechanical Properties -

Average mechanical property results are presented in Tables 7 and 8 for the main experiment and in Tables 9 and 10 for AZ80 and AZ91 alloys held at temperature for up to 220 min. In general, there appears to be a slight decrease in mechanical properties with increasing holding time, although, in the case of AZ91, keeping the metal for the excessively long period of nearly 4 hr did not have any effect. In spite of the apparent reduction of properties, the test bar properties remain far above the minima given in the specifications (Table 2).

SECTION III: INFLUENCE OF SHORT HOLDING PERIODS AT HIGH AND LOW TEMPERATURE

Casting Procedure

The alloys mentioned in the first column of Table 11 were cast as follows: test bars from two melts of each alloy were cast at 740°C (1365°F) for aluminum-containing alloys, and at 760°C (1400°F) for zirconium-containing alloys, after holding for 10 min at temperature; another set of test bars were cast at 850°C (1560°F) for the first melt and at 700°C (1290°F) for the second melt; and a third set was cast after returning to the normal pouring temperature. Two four-bar moulds were cast, in each case, from AZ80, AZ91, ZH62 and ZK61 alloys and one mould was cast from AZ92, QE22, ZQ64 and ZQ91 alloys.

Experimental Results

Chemical Composition -

Chemical analysis samples were drilled from the grips of the broken tensile test bars and results are reported in Table 11. Holding the molten metal at 850°C (1560°F) for 30 min did not affect the chemical composition of any of the alloys, with the possible exception of AZ80 and AZ91 alloys in which cases the aluminum content appears to have been reduced. There is possibly also a small loss of rare earths in QE22 and this would be consistent with results from the pouring temperature experiment.

The chemical composition of the aluminum-containing alloys was not affected by holding the melt at 700°C (1290°F) for 30 min. The "insoluble" zirconium content has been, however, markedly reduced by the low temperature holding period in all the zirconium-containing alloys, a conclusion which is consistent with that of the pouring temperature experiment. The other elements, with the possible exception of the rare earths in QE22, remained unaffected.

Mechanical Properties -

Average tensile test results are reported in Tables 12 and 13. The results of Table 12 suggest that the ultimate strength of aluminum-containing alloys may be lowered by holding the melt at 850°C or 700°C (1560°F or 1290°F) while the effect on the yield strength and elongation are even less pronounced. Grain size is appreciably increased.

The influence of holding at high or low temperature on the zirconium-containing alloys is as follows: QE22, ZQ64 and ZQ91 are not affected by that procedure; the properties of ZH62 after the 850°C (1560°F) treatment are appreciably reduced mainly due to the presence of numerous flaws in the test bar fractures and the ultimate strength might have been reduced by holding at 700°C (1290°F); the properties of ZK61-F and ZK61-T6 are not altered by holding at 850°C (1560°F) or 700°C (1290°F) respectively; the ultimate strength and elongation of ZK61-T6 are reduced by the high temperature treatment; whereas the ultimate and yield strengths of ZK61-F are lowered by holding at 700°C (1290°F).

In all cases, restoration of the pouring temperature to normal results in average properties which are also normal.

SUMMARY AND CONCLUSIONS

1. Melts of several magnesium alloys were cast at temperatures from 700°C (1290°F) to 850°C (1560°F), held for up to 2 hr at normal pouring temperatures, and for 30 min at 700°C (1290°F) or 850°C (1560°F), before pouring into four-bar moulds.

2. None of these treatments adversely affected the chemical composition and mechanical properties to a pronounced extent.

3. Because of the drossing tendency of alloy ZH62, a temperature of 850°C (1560°F) should be avoided, if possible.

4. The "insoluble" zirconium content of zirconium-containing alloys may be appreciably decreased by lowering the melt temperature to 700°C (1290°F).

5. Soluble zirconium and rare earths contents of alloy QE22 decrease with increasing holding time; a similar tendency may be found for rare earths in alloy EZ33 and thorium in alloy ZH62.

REFERENCES

1. J.W. Meier - "The Effect of Various Factors on the Mechanical Properties of Magnesium Alloy Castings" - Proc. 25th International Foundry Congress, Brussels, pp. 223-240 (1958).

2. J.W. Meier and A. Couture - "Effect of Casting Temperature on Aluminum Alloy Test Bar Properties" - Trans. AFS 68, 636-647 (1960).

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TABLE 1

Chemical Composition of Magnesium Alloy Castings[a]

Alloy	Al, %	Zn, %	Mn, %	Ag, %	R.E., %[b]	Zr, %	Th, %
AZ80	7.5-8.5	0.3-0.7	0.15-0.40	-	-	-	-
AZ91	8.3-9.3	0.4-1.0	0.15-0.40	-	-	-	-
AZ92	8.3-9.7	1.6-2.4	0.10 min	-	-	-	-
EZ33	-	2.0-3.1	-	-	2.5-4.0	0.5-1.0	-
QE22	-	-	-	2.0-3.0	1.8-2.5	0.4-1.0	-
ZH62	-	5.2-6.2	-	-	-	0.5-1.0	1.4-2.2
ZK61	-	5.5-6.5	-	-	-	0.6-1.0	-
ZQ64[c]	-	5.5-6.5	-	3.5-4.5	-	0.6-1.0	-
ZQ91[c]	-	8.4-8.8	-	0.8-1.2	-	0.6-1.0	-

(a) - According to CSA Specification HG.9-1963 or ASTM Designation B80-63.

(b) - In Alloy QE22, rare earths are in the form of didymium.

(c) - Experimental composition range (specifications are not yet available).

TABLE 2

Heat Treatment Used, and Minimum Properties Specified for Separately-Cast Test Bars[(a)]

Alloy (b) Designation	Solution Treatment			Ageing Treatment			Minimum Properties		
	Temperature		Time, hr	Temperature,		Time, hr	UTS, kpsi	0.2% YS, kpsi	El., % in 2 in.
	°C	°F		°C	°F				
AZ80-F	-	-	-	-	-	-	23	-	3
-T4	410	770	24	-	-	-	34	-	7
-T6	410	770	24	190	375	16	-	-	-
AZ91-F	-	-	-	-	-	-	20	10	-
-T4	410	770	24	-	-	-	34	12	7
-T6	410	770	24	200	390	16	34	16	3
AZ92-T6	415	780	20	190	375	16	34	18	1
EZ33-F	-	-	-	-	-	-	-	-	-
-T5	-	-	-	175	345	16	20	14	2
QE22-T6	525	975	8	200	390	8	35	25	2
ZH62-F	-	-	-	-	-	-	-	-	-
-T5A	-	-	-	180	355	16	35	22	5
-T5B	330	625	2	180	355	16	-	-	-
ZK61-F	-	-	-	-	-	-	-	-	-
-T6	500	930	2	130	265	48	42	26	5
ZQ64-T6	450	840	5	130	265	48	-	-	-
ZQ91-T6	385	725	16	130	265	48	-	-	-

(a) - According to CSA Specification HG.9-1963 or ASTM Designation B80-63.
(b) - According to CSA Codes H.1.1-1958 and H.1.2-1958.

TABLE 3

Effect of Pouring Temperature on Chemical Composition

Alloy[a]	Element %	Decreasing pouring temperature					Increasing pouring temperature				
		Normal[b]	850°C (1560°F)	800°C (1470°F)	750°C (1380°F)	700°C (1290°F)	Normal[b]	700°C (1290°F)	750°C (1380°F)	800°C (1470°F)	850°C (1560°F)
AZ80	Al	8.12	8.25	8.18	8.06	8.31	8.10	8.16	8.17	8.10	8.03
	Zn	0.44	0.41	0.42	0.42	0.42	0.42	0.42	0.43	0.42	0.42
	Mn	0.35	0.35	0.34	0.35	0.34	0.33	0.34	0.32	0.34	0.32
AZ91	Al	9.04	9.19	9.06	9.14	9.22	9.22	9.27	9.16	9.27	9.21
	Zn	0.66	0.65	0.68	0.67	0.64	0.66	0.65	0.67	0.66	0.68
	Mn	0.25	0.26	0.32	0.26	0.26	0.32	0.32	0.32	0.32	0.32
AZ92	Al	8.42	8.35	8.32	8.43	8.40	8.36	8.56	8.33	8.34	8.32
	Zn	2.23	2.23	2.33	2.25	2.25	2.30	2.27	2.27	2.27	2.30
	Mn	0.34	0.33	0.34	0.34	0.32	0.35	0.35	0.35	0.36	0.35
QE22	Ag	2.44	2.46	2.44	2.52	2.52	2.70	2.70	2.69	2.66	2.66
	R.E.	2.19	2.20	2.14	2.13	2.16	2.26	2.16	2.20	2.12	2.10
	Zr(s)[c]	0.54	0.51	0.51	0.48	0.44	0.49	0.47	0.44	0.41	0.36
	Zr(ins)[c]	0.07	0.06	0.06	0.06	0.05	0.07	0.04	0.05	0.07	0.06
ZH62	Zn	5.73	5.66	5.70	5.74	5.72	5.66	5.72	5.72	5.72	5.70
	Th	1.85	1.79	1.82	1.82	1.78	1.85	1.80	1.82	1.78	1.76
	Zr(s)[c]	0.82	0.83	0.82	0.84	0.83	0.82	0.82	0.82	0.83	0.80
	Zr(ins)[c]	0.14	0.13	0.14	0.11	0.08	0.12	0.08	0.06	0.09	0.10
ZK61	Zn	5.91	5.87	6.01	5.94	5.95	5.99	6.04	5.96	6.15	6.09
	Zr(s)[c]	0.76	0.76	0.76	0.78	0.71	0.76	0.75	0.74	0.72	0.74
	Zr(ins)[c]	0.11	0.12	0.13	0.11	0.09	0.10	0.08	0.06	0.10	0.09
ZQ64	Zn	6.54	6.48	6.42	6.58	6.56	6.66	6.45	6.66	6.53	6.64
	Ag	4.15	4.10	4.04	4.15	4.20	4.14	4.09	4.14	4.09	4.14
	Zr(s)[c]	0.75	0.73	0.72	0.70	0.66	0.84	0.78	0.78	0.78	0.76
	Zr(ins)[c]	0.06	0.07	0.07	0.06	0.02	0.06	0.06	0.06	0.09	0.06
ZQ91	Zn	9.15	9.15	9.13	8.92	8.65	9.18	8.92	8.97	9.18	9.02
	Ag	1.00	0.98	1.00	0.98	0.94	0.89	0.89	0.96	0.94	0.92
	Zr(s)[c]	0.67	0.66	0.66	0.65	0.69	0.68	0.63	0.63	0.65	0.66
	Zr(ins)[c]	0.32	0.33	0.32	0.30	0.15	0.31	0.16	0.14	0.13	0.13

(a) - According to CSA Code H.1.1-1958.

(b) - Normal pouring temperature is taken as 740°C (1365°F) for aluminum-containing alloys and 760°C (1400°F) for zirconium-containing alloys.

(c) - s and ins mean soluble and insoluble, respectively, in 1:2HCl:H_2O just brought to a boil for ZH62 and ZK61 alloys, and boiling for 5 min for silver-containing alloys.

TABLE 4

Influence of Pouring Temperature on Mechanical Properties of Aluminum-Containing Magnesium Casting Alloys

Alloy[a] Designation	Property[b]	Decreasing pouring temperature					Increasing pouring temperature				
		740°C (1365°F)	850°F (1560°F)	800°C (1470°F)	750°C (1380°F)	700°C (1290°F)	740°C (1365°F)	700°C (1290°F)	750°C (1380°F)	800°C (1470°F)	850°C (1560°F)
AZ80-F	UTS	26.5	27.2	27.9	28.0	27.0	28.0	27.9	27.0	27.8	27.7
	YS	14.3	15.2	15.2	15.3	15.0	15.1	14.3	14.7	15.3	15.1
	El, %	5.0	5.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	GS	4.0	5.0	4.0	4.0	5.0	4.0	6.0	5.0	4.0	5.0
AZ80-T4	UTS	39.3	38.8	40.1	40.2	38.7	40.3	39.4	39.1	40.5	40.2
	YS	13.5	13.1	13.8	14.8	13.6	13.0	12.9	12.2	13.4	13.1
	El, %	16.5	14.0	17.0	16.0	15.0	17.0	16.0	16.0	17.0	16.5
	GS	4.0	5.0	4.0	4.0	5.0	4.0	5.0	4.0	4.0	4.0
AZ80-T6	UTS	41.3	37.0	40.9	41.9	41.1	42.1	40.4	41.0	41.0	40.1
	YS	18.2	18.5	18.8	18.7	17.6	18.0	16.8	18.1	17.6	17.6
	El, %	7.0	4.5	6.5	8.0	8.0	9.0	8.0	8.0	8.0	7.5
	GS	4.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0	4.0	6.0
AZ91-F	UTS	25.8	25.6	25.8	26.0	24.7	25.8	25.0	25.2	25.5	24.7
	YS	15.1	16.0	16.0	16.4	15.2	15.4	14.8	15.2	16.2	15.4
	El, %	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0
	GS	4.0	5.0	4.0	4.0	5.0	4.0	6.0	5.0	5.0	6.0
AZ91-T4	UTS	42.1	39.8	41.5	42.0	40.7	41.8	40.4	41.3	41.5	39.7
	YS	14.4	13.9	14.4	14.1	14.0	14.6	14.4	13.9	14.2	13.7
	El, %	16.0	12.5	15.0	15.5	14.5	17.0	15.0	16.0	15.0	12.0
	GS	4.0	4.0	4.0	4.0	5.0	4.0	5.0	4.0	4.0	6.0
AZ91-T6	UTS	42.0	37.0	41.4	41.8	40.9	41.6	40.7	43.1	38.0	36.6
	YS	21.6	21.4	21.7	22.2	20.9	21.3	20.8	21.3	21.4	21.2
	El, %	5.0	2.0	3.5	4.0	4.0	3.5	4.0	5.0	2.5	2.0
	GS	4.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0	4.0	4.0
AZ92-T6	UTS	42.2	39.6	38.2	37.8	38.4	40.2	41.4	45.4	43.3	38.4
	YS	25.2	24.5	24.9	25.0	23.2	24.0	22.6	24.6	23.5	22.6
	El, %	2.5	2.0	2.0	3.0	2.0	4.0	3.5	4.5	4.5	1.5
	GS	3.5	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	4.0

(a) - According to CSA Codes H.1.1-1958 and H.1.2-1958.

(b) - UTS: Ultimate Tensile Strength in kpsi; YS: 0.2% Yield Strength in kpsi; El, %: Elongation in 2 in.; GS: Average Grain Diameter in 0.001 in.

TABLE 5

Influence of Pouring Temperature on Mechanical Properties of Zirconium-Containing Magnesium Casting Alloys

Alloy[(a)] Designation	Property[(b)]	Decreasing pouring temperature					Increasing pouring temperature				
		760°C (1400°F)	850°C (1560°F)	800°C (1470°F)	750°C (1380°F)	700°C (1290°F)	760°C (1400°F)	700°C (1290°F)	750°C (1380°F)	800°C (1470°F)	850°C (1560°F)
QE22-T6	UTS	39.2	39.3	39.4	38.4	38.3	38.8	39.0	38.8	38.5	35.5
	YS	30.0	29.8	29.3	28.4	29.2	29.6	30.0	29.8	29.9	29.0
	El, %	4.0	6.0	4.5	4.5	3.5	3.0	3.0	4.0	3.0	1.0
	GS	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.0
ZH62-F	UTS	39.7	35.4	38.8	39.5	39.8	36.0	38.4	38.3	38.2	36.3
	YS	22.5	23.2	22.0	23.2	21.9	21.5	19.9	20.0	22.4	22.3
	El, %	12.5	7.0	12.0	14.0	14.5	9.0	15.0	14.5	9.5	9.5
	GS	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
ZH62-T5A	UTS	40.0	38.2	41.8	41.6	40.6	39.0	37.9	39.3	40.4	37.2
	YS	26.7	26.4	25.8	26.2	25.8	24.1	22.9	23.9	25.3	24.9
	El, %	7.0	5.0	10.0	10.0	9.0	7.5	7.5	11.0	7.5	5.0
	GS	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
ZH62-T5B	UTS	41.4	37.8	40.2	42.6	41.8	39.6	40.4	40.0	41.0	38.5
	YS	27.6	26.5	27.1	26.8	27.3	27.4	26.8	25.7	26.7	27.3
	El, %	8.0	4.0	7.5	11.0	8.5	7.0	8.5	9.0	8.0	5.5
	GS	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
ZK61-F	UTS	39.6	39.8	39.0	39.8	38.7	38.8	37.5	39.8	40.7	38.5
	YS	22.7	22.6	22.7	21.8	21.9	23.1	22.6	21.9	22.4	21.6
	El, %	9.0	10.0	8.5	10.0	8.5	9.0	7.5	10.5	12.0	9.0
	GS	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
ZK61-T6	UTS	45.5	44.8	46.4	46.1	44.4	45.3	43.8	46.2	45.8	45.6
	YS	31.6	31.5	31.7	31.2	30.9	31.8	30.8	31.7	31.9	32.1
	El, %	9.0	8.0	10.0	11.0	7.0	8.0	7.0	13.0	10.5	6.5
	GS	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
ZQ64-T6	UTS	49.1	49.2	48.9	49.2	48.0	49.3	48.8	50.4	49.3	46.6
	YS	36.2	36.3	39.0	38.1	36.6	37.9	38.0	38.8	38.4	37.7
	El, %	5.5	5.5	3.0	5.5	3.5	6.5	5.0	5.0	5.0	3.0
	GS	3.0	3.0	2.5	3.0	3.0	3.0	2.5	3.0	2.5	3.0
ZQ91-T6	UTS	48.2	46.0	49.0	48.8	48.2	49.9	49.1	48.8	49.7	50.0
	YS	33.6	33.4	34.1	34.4	33.8	37.0	34.3	32.1	35.3	34.8
	El, %	6.5	5.0	8.0	7.0	6.5	11.0	8.0	5.5	7.0	10.5
	GS	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

(a) - According to CSA Codes H.1.1-1958 and H.1.2-1958.

(b) - UTS: Ultimate Tensile Strength in kpsi; YS: 0.2% Yield Strength in kpsi; El, %: Elongation in 2 in.; GS: Average Grain Diameter in 0.001 in.

TABLE 6

Influence of Holding at Normal[a] Pouring Temperature on Chemical Composition of Magnesium Casting Alloys

Alloy[b]	Element, %	Holding Time (min)			
		10	30	60	120
AZ80	Aluminum	8.38	8.26	8.23	8.31
	Zinc	0.41	0.45	0.43	0.41
	Manganese	0.34	0.34	0.33	0.35
AZ91	Aluminum	9.29	9.24	9.12	9.31
	Zinc	0.66	0.62	0.68	0.67
	Manganese	0.37	0.37	0.37	0.37
AZ92	Aluminum	8.38	8.32	8.34	8.16
	Zinc	2.23	2.23	2.23	2.20
	Manganese	0.35	0.34	0.35	0.33
EZ33	Rare earths	3.24	3.27	3.20	3.17
	Zinc	2.96	2.98	2.98	2.96
	Zirconium (s)[c]	0.64	0.63	0.62	0.62
	Zirconium (ins)[c]	0.04	0.03	0.04	0.03
QE22	Silver	2.55	2.57	2.51	2.57
	Rare Earths	2.24	2.25	2.19	2.04
	Zirconium (s)[c]	0.51	0.49	0.46	0.35
	Zirconium (ins)[c]	0.05	0.05	0.04	0.05
ZH62	Zinc	5.69	5.62	5.69	5.70
	Thorium	2.19	2.11	2.09	2.04
	Zirconium (s)[c]	0.84	0.85	0.85	0.85
	Zirconium (ins)[c]	0.14	0.15	0.13	0.11
ZK61	Zinc	5.89	5.91	5.97	5.96
	Zirconium (s)[c]	0.75	0.75	0.74	0.74
	Zirconium (ins)[c]	0.12	0.11	0.11	0.10
ZQ64	Zinc	6.50	6.50	6.50	6.53
	Silver	4.14	4.09	4.20	4.14
	Zirconium (s)[c]	0.80	0.80	0.80	0.78
	Zirconium (ins)[c]	0.06	0.06	0.05	0.05
ZQ91	Zinc	9.15	9.10	9.20	9.15
	Silver	1.01	0.99	0.99	0.97
	Zirconium (s)[c]	0.70	0.68	0.67	0.66
	Zirconium (ins)[c]	0.30	0.36	0.29	0.21

(a) - Normal pouring temperature is taken as 740°C (1365°F) for aluminum-containing alloys and 760°C (1400°F) for zirconium-containing alloys.

(b) - According to CSA Code H.1.1-1958.

(c) - s and ins mean soluble and insoluble, respectively, in 1:2:HCl:H_2O just brought to a boil for EZ33, ZH62 and ZK61 alloys, and boiling for 5 min for silver-containing alloys.

TABLE 7

Influence of Holding at Normal[a] Pouring Temperature on Mechanical Properties of Aluminum-Containing Magnesium Casting Alloys

Alloy[b]	Property[c]	Holding Time (min)			
		10	30	60	120
AZ80-F	UTS	28.4	28.3	27.8	27.2
	YS	14.8	15.4	15.3	15.1
	El, %	7.0	6.5	6.0	5.5
	GS	4.0	4.0	4.0	4.0
AZ80-T4	UTS	40.7	40.3	40.1	39.7
	YS	13.4	13.7	13.4	13.8
	El, %	17.5	17.0	17.5	16.5
	GS	4.0	4.0	4.0	4.0
AZ80-T6	UTS	41.2	42.2	40.9	39.8
	YS	19.2	19.0	18.6	18.5
	El, %	7.5	8.0	8.0	7.0
	GS	4.0	3.5	4.0	4.5
AZ91-F	UTS	25.9	26.2	26.0	25.3
	YS	16.9	17.1	16.4	16.5
	El, %	4.0	4.0	4.0	3.5
	GS	4.0	4.0	4.0	4.0
AZ91-T4	UTS	42.3	41.7	41.6	40.9
	YS	15.2	14.8	14.4	14.5
	El, %	16.5	15.5	15.5	16.0
	GS	4.0	4.0	4.0	4.0
AZ91-T6	UTS	41.5	41.1	42.3	41.5
	YS	22.5	21.9	22.1	21.7
	El, %	3.5	3.5	4.0	3.5
	GS	4.0	4.0	3.5	4.0
AZ92-T6	UTS	42.5	45.3	44.0	37.9
	YS	25.1	24.7	28.4	25.4
	El, %	3.0	5.5	4.5	2.5
	GS	3.0	3.5	3.5	3.5

(a) - Normal pouring temperature is taken as 740°C (1365°F).
(b) - See Table 5, footnote (a).
(c) - See Table 5, footnote (b).

TABLE 8

Influence of Holding at Normal[a] Pouring Temperature on Mechanical Properties of Zirconium-Containing Magnesium Casting Alloys

Alloy[b]	Property[c]	Holding Time (min)			
		10	30	60	120
EZ33-F	UTS	22.6	21.8	21.5	20.4
	YS	15.6	16.1	15.6	14.9
	El, %	4.0	3.0	3.0	3.0
	GS	3.0	3.0	3.0	3.0
EZ33-T5	UTS	22.5	22.6	21.5	21.1
	YS	15.9	16.6	15.9	16.0
	El, %	3.5	3.5	3.0	3.0
	GS	3.0	3.0	3.0	3.0
QE22-T6	UTS	39.7	39.7	39.3	38.2
	YS	30.4	30.9	31.1	30.4
	El, %	3.0	3.5	3.5	3.5
	GS	2.5	3.0	3.0	3.5
ZH62-F	UTS	38.2	37.4	37.9	37.3
	YS	21.2	20.6	21.4	20.4
	El, %	12.0	10.5	12.5	10.5
	GS	3.0	3.0	3.0	3.0
ZH62-T5A	UTS	38.6	38.9	39.6	38.1
	YS	25.2	23.8	24.8	22.8
	El, %	8.0	8.0	9.0	8.0
	GS	3.0	3.0	3.0	3.0
ZH62-T5B	UTS	39.9	39.8	39.4	40.2
	YS	26.3	27.2	27.5	28.3
	El, %	8.0	8.0	7.0	8.0
	GS	3.0	3.0	3.0	3.5
ZK61-F	UTS	39.3	39.1	39.0	38.6
	YS	23.4	22.8	23.2	23.6
	El, %	9.0	10.0	9.5	9.0
	GS	3.0	3.0	3.0	3.0
ZK61-T6	UTS	46.8	46.4	46.2	46.6
	YS	31.9	32.5	31.5	31.9
	El, %	10.0	11.0	10.0	10.0
	GS	2.5	2.5	2.5	2.5
ZQ64-T6	UTS	50.8	50.6	49.8	48.5
	YS	37.9	37.6	37.5	37.4
	El, %	6.0	6.5	6.0	5.0
	GS	2.5	2.5	2.5	2.5
ZQ91-T6	UTS	48.6	48.9	48.5	48.2
	YS	33.8	35.4	36.2	34.0
	El, %	8.5	7.0	7.0	6.0
	GS	4.0	3.0	3.5	5.0

(a) - Normal pouring temperature is taken as 760°C (1400°F).
(b) - See Table 5, footnote (a). (c) - See Table 5, footnote (b).

TABLE 9

Influence of Long Holding Time on AZ80 Alloy at 740°C (1365°F)
(All results are averages of 2 tests)

Alloy[a]	Property[b]	Holding Time (min)			
		10	40	100	220
AZ80-F	UTS	28.7	28.2	27.8	27.6
	YS	14.6	15.0	14.3	14.3
	El, %	7.0	6.5	6.0	6.0
	GS	4.0	4.0	6.0	6.0
AZ80-T4	UTS	40.0	39.6	39.5	39.4
	YS	13.4	14.4	14.1	15.1
	El, %	17.0	16.5	15.5	16.0
	GS	4.0	4.0	6.0	6.0
AZ80-T6	UTS	43.0	41.2	39.0	41.2
	YS	17.8	17.2	17.2	17.7
	El, %	11.0	9.5	8.0	10.5
	GS	4.0	4.0	4.0	4.0
Composition					
Aluminum, %		8.14	8.30	8.04	7.98
Zinc, %		0.43	0.43	0.43	0.43
Manganese, %		0.35	0.34	0.35	0.35
Iron, %		0.006	0.004	0.005	0.007

(a) - See Table 5, footnote (a).
(b) - See Table 5, footnote (b).

TABLE 10

Influence of Long Holding Time on AZ91 Alloy at 740°C (1365°F)
(F results are averages of 3 tests)
(T6 results are averages of 5 tests)

Alloy[a]	Property[b]	Holding Time (min)			
		10	40	100	220
AZ91-F	UTS	25.8	25.7	25.8	25.7
	YS	14.6	14.7	14.6	14.8
	El, %	4.5	3.0	3.5	4.0
	GS	4.0	4.0	4.0	4.0
AZ91-T6	UTS	40.8	42.0	41.3	41.3
	YS	20.6	20.4	20.8	20.7
	El, %	4.5	4.5	3.5	4.0
	GS	4.0	4.0	4.0	4.0
Composition					
Aluminum, %		8.90	8.90	8.88	9.02
Zinc, %		0.64	0.65	0.65	0.64
Manganese, %		0.30	0.29	0.28	0.28
Iron, %		0.003	0.003	0.004	0.006

(a) - See Table 5, footnote (a).
(b) - See Table 5, footnote (b).

TABLE 11

Influence of Holding at High or Low Temperature on Chemical Composition of Magnesium Casting Alloys

Alloy(a)	Element, %	High Temperature Holding			Low Temperature Holding		
		760°C (1400°F)	850°C (1560°F)	760°C (1400°F)	760°C (1400°F)	700°C (1290°F)	760°C (1400°F)
AZ80	Al	8.04	7.94	8.26	8.06	7.92	7.96
	Zn	0.45	0.39	0.38	0.44	0.45	0.44
	Mn	0.33	0.34	0.33	0.34	0.34	0.34
AZ91	Al	8.58	8.33	8.79	8.79	8.89	8.48
	Zn	0.69	0.64	0.69	0.69	0.69	0.69
	Mn	0.27	0.26	0.26	0.26	0.25	0.22
AZ92	Al	8.62	8.49	8.46	8.60	8.65	8.61
	Zn	2.30	2.28	2.35	2.27	2.35	2.30
	Mn	0.31	0.31	0.30	0.35	0.33	0.35
QE22	Ag	2.49	2.49	2.46	2.79	2.74	2.79
	R.E.	2.19	2.10	2.09	1.72	1.67	1.59
	Zr(s)(b)	0.52	0.50	0.46	0.41	0.36	0.34
	Zr(ins)(b)	0.05	0.06	0.06	0.13	0.09	0.14
ZH62	Zn	5.79	5.68	5.79	5.66	5.74	5.63
	Th	1.81	1.79	1.72	1.83	1.80	1.79
	Zr(s)(b)	0.76	0.74	0.76	0.74	0.76	0.74
	Zr(ins)(b)	0.14	0.16	0.13	0.15	0.04	0.06
ZK61	Zn	5.89	5.85	5.88	5.77	5.82	5.64
	Zr(s)(b)	0.76	0.76	0.74	0.71	0.71	0.69
	Zr(ins)(b)	0.10	0.13	0.13	0.14	0.03	0.06
ZQ64	Zn	6.53	6.63	6.53	6.51	6.56	6.59
	Ag	4.14	4.14	4.14	3.98	4.02	4.02
	Zr(s)(b)	0.84	0.84	0.84	0.76	0.73	0.73
	Zr(ins)(b)	0.07	0.07	0.07	0.08	0.04	0.04
ZQ91	Zn	9.10	9.20	9.32	9.20	9.20	9.15
	Ag	1.06	1.05	1.06	1.08	1.08	1.08
	Zr(s)(b)	0.63	0.67	0.65	0.66	0.63	0.61
	Zr(ins)(b)	0.39	0.29	0.25	0.25	0.15	0.17

(a) - See Table 6, footnote (b).
(b) - See Table 6, footnote (c).

TABLE 12

Influence of Holding at High or Low Temperature on Mechanical Properties of Aluminum-Containing Magnesium Casting Alloys

Alloy[a]	Property[b]	High Temperature Holding 740°C (1365°F)	850°C (1560°F)	740°C (1365°F)	Low Temperature Holding 740°C (1365°F)	700°C (1290°F)	740°C (1365°F)
AZ80-F	UTS	28.1	26.2	27.0	29.3	26.5	26.4
	YS	14.6	15.1	14.2	15.0	14.0	14.3
	El, %	6.0	5.0	6.0	7.0	6.5	6.0
	GS	6.0	8.0	7.0	4.0	7.0	6.0
AZ80-T4	UTS	40.1	39.6	38.8	41.0	37.2	39.8
	YS	13.5	13.0	12.6	13.0	11.2	12.3
	El, %	16.5	15.0	15.0	19.0	13.0	16.0
	GS	4.0	8.0	4.0	4.0	6.0	4.0
AZ80-T6	UTS	42.5	38.2	40.0	42.1	38.6	41.6
	YS	17.8	17.2	16.5	17.5	15.4	17.4
	El, %	10.5	6.0	9.0	8.5	9.5	10.0
	GS	4.0	7.0	4.0	4.0	7.0	4.0
AZ91-F	UTS	26.2	23.6	25.4	26.6	24.4	25.3
	YS	16.2	14.7	15.9	16.8	14.6	17.0
	El, %	4.0	3.0	3.0	4.0	4.0	4.0
	GS	4.0	10.0	5.0	4.0	6.0	5.0
AZ91-T4	UTS	41.3	37.8	40.4	43.0	39.5	41.8
	YS	14.3	13.2	13.4	14.6	13.4	13.4
	El, %	16.0	11.0	16.0	16.0	13.0	15.0
	GS	5.0	8.0	4.0	4.0	6.0	4.0
AZ91-T6	UTS	42.3	35.0	41.5	41.8	41.2	39.3
	YS	20.8	20.5	20.8	20.6	21.0	21.2
	El, %	5.0	3.5	4.0	4.0	5.0	3.5
	GS	4.0	8.0	4.0	4.0	4.0	3.5
AZ92-T6	UTS	44.8	42.7	45.1	44.6	41.5	44.4
	YS	25.2	24.6	25.2	24.9	26.5	24.6
	El, %	4.0	2.5	3.0	3.0	3.0	4.0
	GS	4.0	5.0	3.5	3.5	3.5	3.5

(a) - See Table 5, footnote (a).
(b) - See Table 5, footnote (b).

TABLE 13

Influence of Holding at High or Low Temperature on Mechanical Properties of Zirconium-Containing Magnesium Casting Alloys

Alloy[a]	Property[b]	High Temperature Holding			Low Temperature Holding		
		760°C (1400°F)	850°C (1560°F)	760°C (1400°F)	760°C (1400°F)	700°C (1290°F)	760°C (1400°F)
QE22-T6	UTS	40.4	40.3	39.8	41.0	41.5	42.1
	YS	32.0	31.4	30.2	30.7	31.0	30.9
	El, %	3.5	3.0	4.0	5.0	5.0	5.5
	GS	2.0	2.5	2.5	2.5	2.5	2.5
ZH62-F	UTS	41.0	32.4	39.8	40.6	37.5	37.8
	YS	24.8	23.3	24.0	22.4	19.6	19.8
	El, %	10.0	4.0	9.0	14.5	10.5	11.0
	GS	2.5	3.0	2.5	3.0	3.0	3.5
ZH62-T5A	UTS	40.1	36.9	42.0	40.8	38.2	38.3
	YS	27.3	28.0	27.3	25.8	23.1	23.0
	El, %	7.0	4.5	12.0	8.5	8.0	9.5
	GS	2.5	3.0	2.5	3.0	4.0	4.0
ZH62-T5B	UTS	41.5	36.3	41.8	41.1	40.0	38.3
	YS	29.0	25.6	31.4	25.0	22.6	23.0
	El, %	8.0	4.0	7.0	10.0	9.0	6.0
	GS	3.0	3.0	3.0	3.0	4.0	4.0
ZK61-F	UTS	39.8	39.6	39.6	38.2	36.1	39.0
	YS	22.2	21.7	21.4	22.0	18.2	22.9
	El, %	10.0	10.0	11.0	9.0	9.5	9.5
	GS	3.0	3.0	3.0	3.0	4.0	4.0
ZK61-T6	UTS	46.0	45.5	46.5	46.0	45.5	45.2
	YS	31.6	33.1	31.2	33.4	33.7	32.9
	El, %	10.0	5.5	12.5	13.0	10.5	8.5
	GS	2.5	3.0	2.5	3.0	4.0	3.5
ZQ64-T6	UTS	51.3	49.8	49.0	47.5	48.8	49.2
	YS	37.6	36.4	37.4	37.6	36.4	38.2
	El, %	9.0	6.5	5.0	3.5	5.5	6.0
	GS	3.0	3.0	3.0	2.5	3.0	2.5
ZQ91-T6	UTS	46.4	46.5	49.0	46.9	47.5	47.7
	YS	33.1	33.2	34.5	33.1	32.0	33.3
	El, %	5.5	5.5	8.0	6.5	7.5	7.0
	GS	4.0	3.5	3.0	4.0	6.0	6.0

(a) - See Table 5, footnote (a).
(b) - See Table 5, footnote (b).

APPENDIX

Comparison of Chemical Compositions of Melts and Separately-Cast Test Bars

Experiments [a] carried out after alloys AZ80, AZ91, ZH62 and ZK61 had been analysed chemically for the present investigation, showed marked segregation of zinc along ZK61 alloy test bars; additional work [b] revealed marked inverse segregation of the major alloying elements in all commercial magnesium casting alloys. It was therefore decided that, in the last part of the present investigation, the chemical analysis samples would be taken both directly from the melt and from the grips of separately-cast test bars. Individual and averaged results obtained are given in Tables A, B, C and D.

These tables show that the two sets of results are, in most cases, appreciably different. In all cases, where there is a difference the test bars are richer in alloying elements than the melt from which they were cast. In the test bars, the aluminum content of AZ92 is higher by 0.13% (absolute value), the zinc content of ZQ64 and ZQ91 by 0.4%, and the silver content by 0.3% in ZQ64, than in the melt. Differences of that order may appear insignificant but they are sufficient to put the melt outside the specification range at one end or the other. For example, AZ92 in which the difference is only 0.13%, out of twenty results some seven would be too low when the specimens are drawn from the melt and only one when the specimens are taken from the test bars.

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a) B. Lagowski and J.W. Meier - "Characteristics of Sand-Cast Magnesium - Zinc Alloys" - Trans. AFS 72, 561-574 (1964).

b) B. Lagowski and J.W. Meier - "Premium-Strength in Sand-Cast Magnesium Alloys" - Trans. AFS 72, 673-685 (1964); Mines Branch Research Report R 138, Department of Mines and Technical Surveys, Ottawa, Canada (1964).

TABLE A

Chemical Composition of AZ92 Melts and Separately-Cast Test Bars

Aluminum, %		Zinc, %		Manganese, %	
Melt	Test bar	Melt	Test bar	Melt	Test bar
8.56	8.42	2.26	2.23	0.35	0.34
8.37	8.35	2.21	2.23	0.33	0.33
8.35	8.32	2.21	2.33	0.33	0.34
8.32	8.43	2.18	2.25	0.33	0.34
8.26	8.40	2.24	2.25	0.32	0.32
8.56	8.36	2.21	2.30	0.36	0.35
8.08	8.32	2.16	2.30	0.35	0.35
8.11	8.34	2.18	2.27	0.36	0.35
8.26	8.33	2.23	2.27	0.34	0.35
8.20	8.56	2.13	2.27	0.35	0.35
8.19	8.38	2.31	2.23	0.32	0.35
8.25	8.32	2.25	2.23	0.33	0.34
8.16	8.34	2.28	2.23	0.32	0.35
8.06	8.16	2.28	2.20	0.32	0.33
8.40	8.62	2.25	2.30	0.28	0.31
8.36	8.49	2.28	2.28	0.28	0.31
8.31	8.46	2.28	2.35	0.28	0.30
8.35	8.60	2.23	2.27	0.35	0.35
8.37	8.65	2.26	2.35	0.38	0.33
8.33	8.61	2.23	2.30	0.35	0.35
$\overline{8.29}$	$\overline{8.42}$	$\overline{2.23}$	$\overline{2.27}$	$\overline{0.33}$	$\overline{0.34}$

TABLE B

Chemical Composition of QE22 Melts and Separately-Cast Test Bars

Silver, %		Didymium, %		Zirconium (s), %		Zirconium (ins), %	
Melt	Test bar	Melt	Test bar	Melt	Test bar	Melt	Test bar
2.46	2.44	2.12	2.19	0.53	0.54	0.05	0.07
2.87	2.46	2.13	2.20	0.51	0.51	0.06	0.06
2.46	2.44	2.11	2.14	0.50	0.51	0.05	0.06
2.46	2.52	2.13	2.13	0.48	0.48	0.04	0.06
2.39	2.52	2.09	2.16	0.46	0.44	0.04	0.05
2.66	2.70	2.14	2.26	0.49	0.49	0.05	0.07
2.66	2.66	2.07	2.10	0.38	0.36	0.03	0.06
2.67	2.66	2.09	2.12	0.46	0.41	0.01	0.07
2.66	2.69	2.09	2.20	0.46	0.44	0.02	0.05
2.66	2.70	2.14	2.16	0.50	0.47	0.02	0.04
2.49	2.55	2.24	2.24	0.52	0.51	0.06	0.05
2.48	2.57	2.25	2.25	0.50	0.49	0.04	0.05
2.49	2.51	2.22	2.19	0.47	0.46	0.03	0.04
2.53	2.57	2.11	2.04	0.37	0.35	0.04	0.05
2.43	2.49	2.17	2.19	0.55	0.52	0.04	0.05
2.43	2.49	2.18	2.10	0.53	0.50	0.05	0.06
2.43	2.46	2.18	2.09	0.50	0.46	0.05	0.06
2.80	2.79	1.72	1.72	0.51	0.41	0.07	0.13
2.80	2.74	1.68	1.67	0.44	0.36	0.06	0.09
2.77	2.79	1.60	1.59	0.40	0.34	0.04	0.14
$\overline{2.58}$	$\overline{2.59}$	$\overline{2.07}$	$\overline{2.09}$	$\overline{0.48}$	$\overline{0.45}$	$\overline{0.04}$	$\overline{0.07}$

TABLE C

Chemical Composition of ZQ64 Melts and Separately-Cast Test Bars

Zinc, %		Silver, %		Zirconium (s), %		Zirconium (ins), %	
Melt	Test bar	Melt	Test bar	Melt	Test bar	Melt	Test bar
6.10	6.54	3.78	4.15	0.78	0.75	0.01	0.06
6.12	6.48	3.86	4.10	0.65	0.73	0.02	0.07
6.12	6.42	3.81	4.04	0.70	0.72	0.01	0.07
6.13	6.58	3.81	4.15	0.65	0.70	0.02	0.06
6.04	6.56	3.81	4.20	0.69	0.66	0.04	0.02
6.17	6.66	3.75	4.14	0.79	0.84	0.09	0.06
6.18	6.64	3.81	4.14	0.73	0.76	0.10	0.06
6.22	6.53	3.78	4.09	0.76	0.78	0.07	0.09
6.17	6.66	3.81	4.14	0.79	0.78	0.04	0.06
6.20	6.45	3.81	4.09	0.80	0.78	0.04	0.06
6.14	6.50	3.86	4.14	0.80	0.80	0.11	0.06
6.17	6.50	3.86	4.09	0.80	0.80	0.10	0.06
6.13	6.50	3.86	4.20	0.80	0.80	0.10	0.05
6.07	6.53	3.80	4.14	0.75	0.78	0.12	0.05
6.20	6.53	3.91	4.14	0.88	0.84	0.08	0.07
6.17	6.63	3.87	4.14	0.80	0.84	0.13	0.07
6.17	6.53	3.91	4.14	0.84	0.84	0.08	0.07
6.17	6.51	3.82	3.98	0.85	0.76	0.05	0.08
6.17	6.56	3.88	4.02	0.78	0.73	0.03	0.04
6.12	6.59	3.88	4.02	0.75	0.73	0.07	0.05
6.15	6.54	3.83	4.11	0.77	0.77	0.07	0.06

TABLE D

Chemical Composition of ZQ91 Melts and Separately-Cast Test Bars

Zinc, %		Silver, %		Zirconium (s), %		Zirconium (ins), %	
Melt	Test bar	Melt	Test bar	Melt	Test bar	Melt	Test bar
8.76	9.15	0.92	1.00	0.71	0.67	0.33	0.32
8.66	9.15	0.92	0.98	0.73	0.66	0.31	0.33
8.66	9.13	0.92	1.00	0.69	0.66	0.35	0.32
8.71	8.92	0.89	0.98	0.69	0.65	0.29	0.30
8.68	8.65	0.93	0.94	0.71	0.69	0.14	0.15
8.60	9.18	1.15	0.89	0.70	0.68	0.35	0.31
8.68	9.02	0.92	0.92	0.73	0.66	0.12	0.13
8.58	9.18	0.94	0.94	0.68	0.65	0.16	0.13
8.46	8.97	0.92	0.96	0.68	0.63	0.16	0.14
8.56	8.92	0.92	0.89	0.68	0.63	0.18	0.16
8.70	9.15	0.92	1.01	0.71	0.70	0.33	0.30
8.67	9.10	0.91	0.99	0.71	0.68	0.32	0.36
8.65	9.20	0.92	0.99	0.66	0.67	0.33	0.29
8.65	9.15	0.93	0.97	0.75	0.66	0.17	0.21
8.80	9.10	1.00	1.06	0.73	0.63	0.32	0.39
8.93	9.20	1.01	1.05	0.80	0.67	0.19	0.29
8.85	9.34	1.00	1.06	0.78	0.65	0.15	0.25
8.81	9.20	1.01	1.08	0.67	0.66	0.28	0.25
8.78	9.20	1.01	1.08	0.69	0.63	0.12	0.15
8.76	9.15	1.03	1.08	0.65	0.61	0.13	0.17
$\overline{8.70}$	$\overline{9.10}$	$\overline{0.96}$	$\overline{0.99}$	$\overline{0.71}$	$\overline{0.66}$	$\overline{0.24}$	$\overline{0.25}$