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भारतीय मानक ब्यरो

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फाउंड्री और डाई कास्टिंग के लिए जिंक-एल्यूमीनियम मिश्र धातु सिल्लियों की विशिष्टता

(आई एस 713 का तीसरा पुनरीक्षण)

Draft *Indian Standard*

Specification of Zinc-Aluminium Alloy Ingots Intended for Foundry and Die Castings

(*Third Revision of IS 713*)

ICS 77.120.60

Ores and Feed Stock for Non-Ferrous (Excluding Aluminium and Copper) Industry, their Metals/ Alloys and Products Sectional Committee Sectional Committee, MTD 09	Last date for receipt of comments is 26/05/2025

FOREWORD

(*Formal clause of the foreword will be added later*.)

This standard was first published in 1955 and subsequently revised in 1966 and 1981. In the first revision, maximum limits for Thallium and Indium for zinc base alloys had been specified, the requirements for high purity zinc for making zinc base die casting alloys had been taken out as the same was covered in IS 209 to reduce the scope to cover only specification for zinc base alloy ingots for die casting. The assistance had also been taken from ISO Recommendation 437 "Recommendation for zinc alloy ingots", BS 1004: 1955 "Zinc alloys for die casting and zinc alloy die castings and ASTM B 86:1964 "Specification for zinc base alloy die casting" to revise the standard. In the second revision, maximum limit for iron in the alloys was reduced in line with ISO/R 301 'Zinc alloy ingots'. The alloy designation adopted in the revision was same as used in ISO/R 301, and replaced the former nomenclature of Alloy 1 and Alloy 2. The alloys ZnAl4 and ZnA14Cu 1 were almost identical in composition with Alloys 1 and 2, respectively.

The second revision of the standard was based on the manufacturing and trade practices followed in the country in this field .Assistance was been derived from the following:

ISO/R 301: 1963 Zinc alloy ingots. International Organization for Standardization.

BS 1004: 1972 Zinc alloys for die casting and zinc alloy die castings. British Standards Institution.

ASTM B 240:1964 (Reapproved 1971) Zinc alloys in ingot form for die &stings. American Society for Testing and Materials.

AS 1881: 1977 Zinc alloy ingots (for pressure die casting) and zinc alloy pressure die castings. Standards Association of Australia.

The current revision of the standard is being brought out to align with the latest developments taken place in the field of die casting ingots and newer alloys being developed. In this revision the title has been modified from 'Zinc Base Alloy Ingots for Die Casting' to 'Specification of Zinc-Aluminium Alloy Ingots Intended for Foundry and Die Castings'. In addition to these changes following major modification has been done:

a) Scope has been expanded to include alloys intended for foundry castings and thin wall die castings.

b) The clause on Terminologies has been incorporated.

c) Seven new grades have been added to the standard, including two additional conventional Zamak alloys (Zamak 2 and Zamak 7), three new ZA alloys with a nominal composition exceeding 4 percent, one new high-fluidity alloy (HF alloys) designed for thin-wall die castings, and one more grade, ACuZn5, developed by General Motors. The ACuZn5 alloy features a slightly higher copper content and offers improved tensile strength, hardness, and creep resistance compared to the Zamak alloys. Its strength, hardness, and wear properties are comparable to those of ZA-12.

d) Small compositional changes have been made in ZnAl4 (Zamak 3) and ZnAl4Cu1 (Zamak 5), including the removal of Indium and Thalium requirements in the composition to align with international standards.

e) A designation system of alloys has been included in the standard identical with ISO 301 except the fifth digit to demarcate difference between alloys of same nominal composition.

f) Colour coding has also been included as an optional requirement resting upon the discretion of the manufacturer.

g) Informative Annexes A, B, C, and D have been incorporated into the standard. Annex A delineates the relationship between the alloy designations specified in this standard and those employed in other international and national standards. Annex B provides a detailed overview of the nomenclature systems for zinc and zinc-aluminium alloys. Annex C offers comprehensive information regarding the development of advanced high-fluidity alloys, furnishes guidance on the selection of appropriate zinc alloys for specific applications, and elaborates on the role of various alloying elements in zinc alloys for die casting. Annex D includes information on the generally available composition of master alloys used with Zn99.995 and Zn99.99 grades of IS 209 for producing zinc alloy ingots for foundry and die casting applications.

The composition of the committee responsible for the formulation of the standard is given in Annex E.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis shall he rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Draft *Indian Standard*

Specification of Zinc-Aluminium Alloy Ingots Intended for Foundry and Die Castings

(*Third Revision of IS 713*)

1 SCOPE

1.1 This Indian Standard specifies the requirements for zinc alloys (Zinc-Aluminum) in ingot form for remelting for the manufacture of pressure die castings, foundry castings and continuous bar stock.

1.2 This standard also covers the requirements of a commercial zinc-aluminum alloy known as HF (High Fluidity) alloy, in ingot form for the manufacture of thin wall pressure die castings.

2 REFERENCES

The standards given below contain provisions which, through references in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of these standards:

IS No.	***Title***
IS 209 : 2024	Refined Zinc - Specification (Fifth Revision)
IS 1387 : 1993	General requirements for the supply of metallurgical materials (Second Revision)
IS 1817 : 1961	Methods of sampling non - Ferrous metals for chemical analysis
IS 2600 (Part 1) : 1988	Methods of chemical analysis of zinc and zinc base alloys for die castings: Part 1 Determination of copper, iron, nickel, tin and thallium by spectrophotometric method (First Revision)
IS 2600 (Part 2) : 1988	Methods of chemical analysis of zinc and zinc base alloys for die castings: Part 2 Determination of copper, iron, lead and cadmium by atomic absorption spectrophotometric method (First Revision)
IS 2600 (Part 5) : 2022	Method of chemical analysis of zinc and zinc base alloys for die casting: (Part 5) Analysis by inductively coupled plasma emission spectrometry (First Revision)
IS 2600 (Part 6) : 2022	Methods of chemical analysis of zinc and zinc base alloys for die castings: (Part 6) Determination of magnesium by atomic absorption spectrometric method (First Revision)
IS 2600 (Part 7) : 2022	Methods of chemical analysis of zinc and zinc base alloys for die castings: Part 7 Determination of aluminium by titrimetric method (First Revision)
MTD 34 (23421)	Methods of chemical analysis of zinc and zinc base alloys for die castings: Part 8 Analysis of solid samples by optical emission spectrometry
IS 18516 : 2023/ISO 20081 :2005	Zinc and zinc alloys − Method of sampling − Specifications

3 TERMINOOGIES

For the purposes of this standard, the following terms and definitions shall apply.

3.1 Zinc alloys — zinc with additions of one or more alloying elements, such as: Al, Mg, Cu

3.2 Ingot — cast product intended for remelting

3.3 Jumbo — large ingot, suitable for handling by mechanical equipment.

NOTE — Normally a jumbo weighs approximately one metric tonne.

3.4 Block — Large ingot with end notches suitable for handling by overhead hoist.

NOTE — Normally a jumbo weighs approximately one metric tonne.

3.5 Bundle — collection of ingots taken from one or more batches and secured, for example by banding, for the purposes of handling, shipment and storage

3.6 Cast — liquid metal which can be cast either by a non-continuous or a continuous casting process

3.7 Cast from non-continuous casting process/heat — product of one furnace, or crucible melt

3.8 Cast from continuous casting process — identified quantity of liquid metal.

3.9 Batch/Lot — number of ingots or blocks or jumbos, taken from a single cast.

3.10 Continuous Casting — a casting technique in which a cast is continuously withdrawn through the bottom of the mould as it solidifies, so that its length is not determined by mould dimensions; used chiefly to produce semifinished mill products such as billets, blooms, slabs etc ; also known as concast.

3.11 Die casting — a casting process in which molten metal is injected under high velocity and pressure into a metal die and solidified alternately known as pressure die casting ; also a product produced by such a process.

3.12 Foundry casting — it includes gravity die casting (also known as permanent mould casting) and sand casting; a casting process in which molten metal fills the mould cavity with the help of gravity and allowing it to solidify.

3.13 High fluidity alloy — a zinc alloy by nature of its composition is capable of producing die castings with thinner wall sections compared to the typical die cast alloys; often less than 0.3 mm in thickness.

3.14 Thin wall die castings — a die casting with wall sections that can be less than 0.3 mm in thickness.

4 SYSTEM OF DESIGNATION OF ZINC ALLOYS

4.1 General

Zinc alloys conforming to this Indian Standard are designated either by a symbol (*see* **4.2**) or by an alloy number (*see* **4.3**). For marking and labelling purposes only (*see* **10**), the short designation and/or colour code may be used (*see* **4.4** and Table 1).

4.2 Designation of Zinc Alloys by a Symbol

The designations shall be as given in Table 1.

Example: ZnAl4Cu1 designates a zinc alloy containing, nominally, 4 percent Aluminum and 1 percent copper.

4.3 Designation of Zinc Alloys by a Number

The designation by a number shall consist of the IS designation or active regional marking, i.e. two letters ZL (denoting zinc alloy), four numerals, and a letter having the following significance:

a) the first two numerals indicate the nominal aluminium content;
b) the third numeral indicates the nominal copper content; and
c) the fourth numeral indicates the nominal content of the next highest alloying element. If this is less than 1 percent, the fourth numeral shall be "0".
d) the fifth digit shall be a letter which differentiates between alloys of similar composition and can be omitted if similar compositions are not available.

4.4 Colour Code

The alloy colour code shall consist of two colours. The colours shall be as given in Table 1, in relation to the alloy symbols or alloy numbers.

> NOTE — The colour coding on the ingots does not form the mandatory part of this specification and may be done if agreed between the purchaser and the supplier.

5 MANUFACTURE

The zinc alloy shall be manufactured from:

a) Zinc ingots or liquid zinc conforming to grade Zn99.995 or Zn99.99 of IS 209 with the addition of appropriate alloying elements or using master alloys (*see* Annex D) of Zn-Al to meet the requirements of chemical composition of the alloys of this Indian Standard (*see* Table 1) , and/or
b) Identifiable casting-process returns, e.g. sprues, runners and overflows, and/or
c) Identifiable castings rejected from the foundry, or after secondary operations.

Materials that may cause contamination shall not be used.

6 SUPPLY OF MATERIAL

6.1 General requirements relating to the supply of zinc alloy ingots for foundry and die castings shall conform to IS 1387.

6.2 Zinc alloy ingots are typically supplied in the form of ingot bundles. The ingots can also be supplied in different shapes and masses like jumbos or blocks or any other shape at the discretion of the supplier unless a specific shape/size/mass is agreed between the purchaser and the supplier at the time of ordering**.**

7 CHEMICAL COMPOSITION

7.1 The zinc alloy ingots shall conform to the chemical composition as specified in Table 1 and the chemical analysis shall be done in accordance with the procedure given in **7.2**.

7.2 The chemical composition shall be determined either by the, combination of the methods specified in IS 2600 (Part 1), IS 2600 (Part 2), IS 2600 (Part 6) and IS 2600 (Part 7) so that the scope of the method of analysis shall fit into the chemical compositions scope of the product or by ICP-OES method specified in IS 2600 (Part 5) or spark OES method specified in IS 2600 (Part 8) (MTD/34/23421 under development) or any other established instrumental/chemical method as agreed between the purchaser and supplier. In case of dispute, the wet chemical analysis procedures using either classical wet chemical methods like gravimetric or volumetric methods or by wet chemical instrumental methods like ICP OES, AAS given in relevant parts of IS 2600 shall be used as a referee method.

NOTES

1 Optical emission spectrometry analysis of solid samples given in IS 2600 (Part 8) is recommended only for production control purposes and end-product certification and may be used in case of dispute, if agreed between purchaser and supplier.

2 The classical wet chemical analysis using EDTA method given in IS 2600 (Part 7) shall be the referee method in case of determining Al. The Al content in the referee method and otherwise shall be determined using this procedure only, when applying the classical wet chemical analytical procedure.

Table 1 Chemical Composition of Zinc Alloy Ingots

(*Clauses* 4.1, 4.2, 4.4, 5, 7.1 *and* B-1)

Common Name	**Traditional Name**	**Colour code**	**Alloy symbol**	**Alloy Number**	**Short Designations**	**Elements**								
						Al	**Cu**	**Mg**	**Pb**	**Cd**	**Sn**	**Fe**	**Ni**	**Zn**
Alloy 3	Zamak 3	white/yellow	ZnAl4	ZL0400A	ZL3	3.9 to 4.3	0.1	0.03 to 0.06	0.0040	0.0030	0.0015	0.035	–	Remainder
Alloy 7	Zamak7	White/brown	ZnAl4LM	ZL0400B	ZL7	3.9 to 4.3	0.1	0.010 to 0.020	0.0030	0.0020	0.0010	0.035	0.005 to 0.020	Remainder
Alloy 5	Zamak 5	white/black	ZnAl4Cu1	ZL0410	ZL5	3.9 to 4.3	0.7 to 1.1	0.03 to 0.06	0.0040	0.0030	0.0015	0.035	–	Remainder
Alloy 2	Zamak 2	white/green	ZnAl4Cu3	ZL0430	ZL2	3.9 to 4.3	2.7 to 3.3	0.025 to 0.05	0.0040	0.0030	0.0015	0.035	–	Remainder
ZA-8	ZA-8	white/blue	ZnAl8Cu1	ZL0810	ZL8	8.2 to 8.8	0.9 to 1.3	0.02 to 0.03	0.005	0.005	0.002	0.035	–	Remainder
ZA-12	ZA-12	white/orange	ZnAl11Cu1	ZL1110	ZL12	10.8 to 11.5	0.5 to 1.2	0.02 to 0.03	0.005	0.005	0.002	0.05	–	Remainder
ZA-27	ZA-27	white/purple	ZnAl27Cu2	ZL2720	ZL27	25.5 to 28.0	2.0 to 2.5	0.012 to 0.020	0.005	0.005	0.002	0.07	–	Remainder
HF Alloy	–	White/red or brown	ZnAl4**HF**	ZL0400C	–	4.4 to 4.7	0.035 Max	0.007 to 0.012	0.003 Max	0.002 Max	0.001 Max	0.03 Max	–	Remainder
–	ACuZinc / ACuZinc 5	White/Red	ZnAl3Cu6	ZL0360	–	2.8 to 3.3	5.2 to 6.0	0.035 to 0.050	0.004 Max	0.003 Max	0.002 Max	0.05 Max	–	Remainder

NOTES

1 Zinc Alloys Zamak 3, Zamak 7, Zamak 5 and Zamak 2 are used primarily for remelting in the manufacture of pressure die castings. ZA-8, ZA-12 and ZA-27 alloy ingots are used for remelting in the manufacture of both foundry and pressure die casting. HF alloy ingots are used for remelting in the manufacture of thin wall pressure die casting.

2 Zinc is determined arithmetically by difference.

3 The possible presence of other unnamed/incidental elements is not precluded. However, analysis shall regularly be made only for the impurities listed in the table. By agreement between manufacturer and the purchaser, analysis may be required and limits established for incidental/impurity elements like Cr, Ni, Si etc not specified in Table 1(except that nickel analysis for ZnAl4LM/ZL0400B/Alloy7/Zamak7 shall be made as being alloying element not an impurity).

8 SHAPE, SIZE AND MASS OF INGOTS

8.1 Zinc casting alloy ingots are typically supplied in ingot bundles. The ingots and bundles vary in size, shape and mass depending on the alloy and the supplier**.** The shape, size and mass of zinc alloy ingots shall be at the discretion of the supplier, unless a specific shape/size/mass is agreed between the purchaser and the supplier at the time of ordering**.**

NOTE — Usually the shape of the ingot is a rectangular trapezoid with a flat bottom or grooves/notches at the bottom, and with or without protruding ears/lugs at both ends (*see* IS 1817).

8.2 Zinc alloy casting ingots may also be supplied in the form of jumbos or blocks. The shape, size and mass of zinc alloy ingot jumbos or blocks shall be at the discretion of the supplier, unless a specific shape/size/mass is agreed between the purchaser and the supplier at the time of ordering**.**

9 SAMPLING

9.1 Sampling of zinc alloy ingots, for verification of compliance with the chemical composition requirements, shall be in accordance with IS18516.

9.2 If the sample prepared under **9** and tested for chemical composition as per **7.2**, fails to meet the requirements specified under 7.1, two further samples shall be taken from the same lot of metal and tested for chemical analysis as per **7.2**. If both the test results satisfy the relevant requirements, the lot shall be accepted. Should either of the re-tests fail, the lot represented shall be deemed as not complying with this standard.

10 MARKING AND LABELLING

10.1 Ingot

Each ingot shall be marked with the name or identification of manufacturer, grade designation by alloy symbol and/or short designation (*see* column 4 of Table 1). Additionally, each ingot may be marked with heat/batch/lot or cast number, the zinc alloy designation by alloy number, and/or colour code, and/or short designation (see column 4 of Table 1) as agreed between the manufacturer and the purchaser.

NOTE — If the ingots are permanently marked with the IS designation (by symbol and/or number) and are to be colour coded, then the first colour (white) may be omitted and only the second colour, as given in Table 1, is needed to identify the alloy.

10.2 Bundle and Jumbo

Each bundle of ingots, each bundle of small jumbos and each individually supplied jumbo shall be marked, or labelled, with the following minimum information:

a) name or identification of manufacturer;

b) the heat/batch/lot or cast number;

c) the zinc alloy designation, by alloy symbol, and/or alloy number, and/or colour code, and/or short designation (*see* **4** and Table 1);

NOTE— If the ingots are permanently marked with the IS designation (by symbol and/or number)and are to be colour coded, then the first colour (white) may be omitted and only the second colour, as given in Table 1, is needed in order to identify the alloy.

d) total net mass of the bundle and mass of each ingot, or the mass of each individual jumbo as applicable.

10.3 BIS Certification Marking

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the Bureau of Indian Standards Act, 2016 and the Rules and Regulations framed thereunder and the product(s) may be marked with the Standard Mark.

ANNEX A

(*Foreword*)

RELATIONSHIP BETWEEN THE ALLOY DESIGNATIONS USED IN THIS INTERNATIONAL STANDARD AND THE CORRESPONDING DESIGNATIONS PREVIOUSLY USED IN A NUMBER OF COUNTRIES

Table 2 National alloy designations and corresponding designations in this International Standard

Alloy symbol	Alloy number	ISO SYMBOL/NUMBER	Europe CEN EN 1774	Japan JIS H5301	Australia AS 1881	USA ASTM B 240	UNS (Unified Numbering System)
ZnAl4	ZL0400A	ZL0400/ZnAl4	ZnAl4	ZDC 2	ZnAl4	Alloy3/AG40A	Z33524
ZnAl4LM	ZL0400B	-	-	-	-	Alloy7/AG40B	Z33526
ZnAl4Cu1	ZL0410	ZL0410/ZnAl4Cu1	ZnAl4Cu1	ZDC 1	ZnAl4Cu1	Alloy5/AC41A	Z35532
ZnAl4Cu3	ZL0430	ZL0430/ZnAl4Cu3	ZnAl4Cu3	-	-	Alloy2/AC43A	Z35544
ZnAl8Cu1	ZL0810	ZL0810/ZnAl8Cu1	ZnAl8Cu1	-	-	ZA8	Z35637
ZnAl11Cu1	ZL1110	ZL1110/ ZnAl11Cu1	ZnAl11Cu1	-	ZnAl11Cu1	ZA12	Z35632
ZnAl27Cu2	ZL2720	ZL2720/ ZnAl27Cu2	ZnAl27Cu2	-	ZnAl27Cu2	ZA27	Z35842
ZnAl4HF	ZL0400C	-	-	-	-	HF Alloy	Z33511
ZnAL3Cu6	ZL0360	-	-	-	-	ACuZinc5/ ACuZinc	Z46540

ANNEX B

(*Foreword*)

NOMENCLATURE SYSTEMS FOR ZINC AND ZINC-ALUMINUM (ZA) ALLOYS

B-1 GENERAL

The information in this annexure does not constitute a part of this specification but is provided for information purposes only. The nomenclature covers commercial zinc-aluminum (ZA) alloys in ingot form for remelting for the manufacture of pressure die casting and foundry castings, as designated and specified in Table 1.

B-2 NOMENCLATURE SYSTEMS

B-2.1 General

Several different systems of nomenclature have evolved over the years to designate the zinc alloys used for castings as listed in Table 3.

Table 3 Nomenclature Systems for Zinc and Zinc-Aluminum (ZA) Alloys

Common Name	Traditional Name	IS Alloy Name	IS Alloy Number	ASTM Designations	UNS
Alloy 3	ZAMAK 3	ZnAl4	ZL0400A	AG40A	Z33524
Alloy 7	ZAMAK 7	ZnAl4LM	ZL0400B	AG40B	Z33526
Alloy 5	ZAMAK 5	ZnAl4Cu1	ZL0410	AC41A	Z35532
Alloy 2	ZAMAK 2	ZnAl4Cu3	ZL0430	AC43A	Z35544
ZA-8	ZA-8	ZnAl8Cu1	ZL0810	ZA8	Z35637
ZA-12	ZA-12	ZnAl11Cu1	ZL1110	ZA12	Z35632
ZA-27	ZA-27	ZnAl27Cu2	ZL2720	ZA27	Z35842
HF Alloy	-	ZnAl4HF	ZL0400C	HF Alloy	-

B-2.2 Common Names

Common names refer for the long established or conventional zinc casting alloys are designated by a suffix number based on their sequential development preceded by a prefix “Alloy”. Zinc-aluminum (ZA) alloys with a higher aluminum content than the conventional zinc die casting alloys, use the prefix “ZA” followed by their approximate percentage of the aluminum content. These terms are in common usage.

B-2.3 Traditional Names

Traditional names for the long established or conventional zinc casting alloys use the prefix “ZAMAK” which was devised based on the major elements present: zinc, aluminum, magnesium and kopper (copper). Zinc-Aluminum alloys use the prefix ZA followed by their approximate percentage of Aluminum content.

C-2.4 IS system for Alloy Names and Numbers

The alloy names constitute the chemical symbol of base metal Zinc (Zn); then by principal alloying element chemical symbol followed by its nominal percentage (after rounding off); then by second most significant alloying element followed by its nominal percentage (after rounding off). If the nominal percentage of an alloying element is less than 1 percent the same has to be omitted. The alloys having similar nominal composition of alloying elements are differentiated from it counterparts by using letters signifying specific characteristics of those alloys. For example LM in case of ZnAl4LM is similar in composition with ZnAl4; the word LM indicated low magnesium. Also, ZnAl4HF is having similar nominal composition as that of ZnAl4 but with slightly higher Aluminum content and lower magnesium content which enhances its fluidity properties and the word HF indicated High Fluidity.

The IS number designations are done as per **4.3**.

C-2.5 ASTM Designations

The ASTM designation are based on alloy chemistry. The first letter A, refers to the principal alloying element, aluminum. The second letter letter, G(magnesium) or C (Copper) refers to the second most significant alloying element. The first number, 4, refers to the nominal aluminum content. The second number refers to the nominal content of the second most significant alloying element. The last letter, A or B differentiates between the alloys of similar compositions.

C-2.6 UNS Designations

UNS numbers are established as a part of Unified Numbering System to provide a unique designation for each metal grade and alloy in use worldwide. Zinc alloys start with the prefix “Z” followed by five numbers. The first digit is based on major alloying element, the second digit provides further sub-classification based on secondary and tertiary alloying elements, the fourth digit designates the nominal concentration of the second most important alloying element, and the fifth digit allows a unique number to be established to differentiate between similar compositions.

ANNEX C

(*Foreword*)

GENERAL INFORMATION ON DEVELOPMENT OF NEW ALLOY AND SELECTION OF ALLOYS

C-1 BRIEF HISTORY OF HIGH FLUIDITY ALLOY DEVELOPMENT

A new generation of ultra-thin zinc die casting alloys has been developed that provides significant performance improvements compared to conventional zinc die casting alloys. Featuring a better fluidity, excellent surface quality, optimized mechanical properties and the ability to maintain close tolerances these alloys have the potential of saving material, energy and costs and creating new, innovative market opportunities. The density of zinc casting alloys is well known to be greater than that of aluminum or magnesium casting alloys. Because metals are normally sold on a per pound basis, the metal cost of a denser alloy can also make it disadvantageous on a per-part basis. An approach to overcoming these disadvantages with zinc has been to improve its fluidity, allowing for thinner casting sections, and therefore lighter weight castings to be produced. The first alloy that showed improved fluidity, compared with other existing alloys was Alloy 7. This alloy was developed by New Jersey Zinc Company who found that the absolute minimum level of Mg required to protect against effects of impurities, and provide the hardness needed to handle the castings in die casting plants was 0.005 percent. A Ni addition of 0.005-0.2percent was then added as a safety factor, and this quantity does not affect castability. Zamak 7 was granted US Patent 2,008,529 on July 16, 1935; however Alloy 7 was not marketed until 1960 when ample supplies of special high grade zinc, of the required purity, was assured. It was well known that the highest fluidity in the zinc-aluminum system was at the eutectic point of 5percent; however this composition was also associated with low fracture toughness. Therefore, efforts made since development of Alloy 7 have been on either side of the Zn-5percent Al composition. Beginning in 1992, Union Miniere, now part of Nyrstar, began development of its “Superloy” that was launched commercially in 1994 (until then Alloy 7 was the zinc die casting alloy with the highest fluidity). This alloy has a composition near the ternary eutectic, Zn-(6.4-6.8)percent Al-(3.2-3.6)percent Cu. Because of the higher aluminum and copper composition, Superloy, also called “GDSL” has improved impact strength, elongation and creep strength compared with conventional die casting alloys and equivalent values of tensile strength and hardness. Approximately 10percent lower injection pressure and plunger speeds are needed to make castings of equivalent thickness compared with conventional hot chamber alloys. A lower casting temperature and higher ejection temperature allow higher productivity to be achieved.

More recently, with the objective of minimizing the time and excess metal needed for alloy changeover, a new ultra-thin zinc die casting alloy has been developed using a composition closer to the conventional Zamak alloys. This new alloy, designated HF (High Fluidity) alloy has the same excellent castability of Superloy and GDSL and was developed by the International Zinc Association (IZA) in cooperation with the North American Die Casting Association (NADCA) and support from the US Department of Energy.

With their superior fluidity the Superloy, GDSL and the HF Alloy are best suited for casting parts with a section thickness of less than equal to 0.3 mm. They can also be used for casting parts that are difficult to fill or have high surface finish requirements.

The development of the ultra-thin zinc die casting alloys is based on two different approaches: The Superloy/GDSL Alloy identified a composition with higher aluminum and copper levels whereas the recently developed HF Alloy is based on the commonly used Zamak alloys but possesses the excellent castability of the Superloy/GDSL (*see* Table below). A laboratory fluidity test comparing the Superloy/GDSL and HF Alloy to Alloy 7, which is the most fluid of the conventional zinc die casting alloys, showed respectively a 42 percent and 40 percent greater fluidity of the ultra-thin zinc die casting alloys. The experimental results from the fluidity testing are reported in Figure 1.

Tests with the new HF Alloy have demonstrated that the alloy has comparable physical, mechanical and corrosion properties to Alloys 3 and 7 and exceeds minimum thickness targets allowing for casting parts with a wall thickness as thin as 0.25mm. Several industrial trials and evaluations have been carried out confirming the easy use and integration of the HF Alloy in existing die casting operations minimizing changeover time and increasing productivity.

HF Alloys (High Fuidity alloys) are hypo-eutectic (i.e. they contain less aluminum than the eutectic chemistry of 5percent Al) with a composition approximately 4.3 to 4.7 percent Al. Whereas Superloy / GDSL Alloys are hypereutectic with an aluminum content greater than the eutectic chemistry. All of the zinc casting alloys have dendritic/eutectic microstructures, however, the hypoeutectic alloys solidify with zinc-rich dendrites, whereas hypereutectic alloys solidify with aluminum-rich dendrites.

	Percentage m/m of elements present	
Element	*Superloy/GDSL*	*HF Alloy*
Aluminum	6.4 to 6.8	4.3 to 4.7
Magnesium	0.02 *Max*	0.005 to 0.012
Copper	3.3 to 3.6	0.035 *Max*
Iron	0.05 *Max*	0.03 *Max*
Lead	0.005 *Max*	0.003 *Max*
Cadmium	0.005 *Max*	0.002 *Max*
Tin	0.002 *Max*	0.001 *Max*
Zinc	Remainder	Remainder

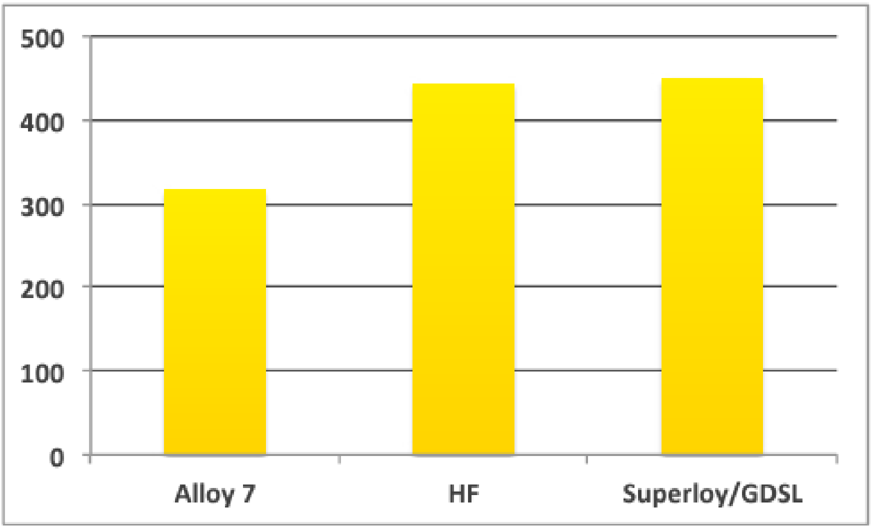

Figure 1:
Ragone fluidity distances of Alloy 7, the new HF Alloy and Superloy/GDSL, cast at 435°C (815F)

C-2 SELECTING THE BEST ZINC ALLOY FOR THE JOB

Zinc alloys have many unique benefits for the die casting process; they are strong, durable and cost effective. Their mechanical properties compare favorably with cast aluminum, magnesium, bronze, plastics and cast irons. These characteristics, together with their superior finishing capabilities and choice of casting processes make zinc alloys a highly attractive option for modern die casting. Zinc is also considered the most energy efficient of the engineering alloys by virtue of its low melting point and superior net-shape casting capability (which allows for reduced machining operations). Zinc alloys also offer the fastest production rates and longest tool life. It offers the following advantages:

a) Assembly operations are reduced – Entire assemblies can be cast as a single unit, eliminating the need for expensive manual assembly operations.
b) Less material is required – Zinc's superior casting fluidity, strength and stiffness permits the design of thin wall sections for reduced weight and material cost saving
c) Machining operations are reduced – Zinc alloys are castable to closer tolerances than any other metal or molded plastic. Zinc die casting can produce repeatability of less than ± 0.001 inch for small components, often rivaling machining tolerances. Few other processes can easily achieve the same net shape performance presenting the opportunity to reduce or eliminate machining. "Net Shape" or "Zero Machining" manufacturing is a major advantage of zinc casting.
d) Choice of low, medium and high production – A variety of casting processes are available to economically manufacture any size and quantity required
e) Eliminate bearings and bushings – Zinc's excellent bearing and wear properties allow greater design flexibility and reduce secondary fabrication costs by eliminating small bushings and wear inserts.
f) Faster production and extended tool life – Die casting production rates for zinc are much faster than for aluminum, or magnesium. Coupled with a tool life often exceeding 1 million parts, tooling and machine usage charges are dramatically reduced.

g) Dimensional Stability – Conventional zinc alloys, along with ZA-8 and ZA-12, have excellent dimensional stability characteristics in their ‘as cast’ condition. ZA-27, however, may require artificial aging treatment to minimize aging effects where exceptional tolerances are required. This is accomplished by heating the part to 95°C for 24 hours.

h) Zero Draft Angle Castability – Draft angle is the taper on the surface of a die required to facilitate removal of the cast part from the die cavity. Zinc alloys can be die cast with less draft angle than competitive materials. In fact, zinc components can sometimes be cast with zero draft angles which is a major advantage when producing parts in moving mechanical contacts such as gears. Zero internal draft permits net shape manufacturing resulting in lower cost production.

j) Joining – If required, the high ductility of zinc will allow parts to be distorted in a controlled manner to achieve a final desired shape, or be inexpensively joined to an adjacent component through bending, forming, spinning or heading. Threaded fasteners, along with flaring, riveting and crimping techniques are common low cost joining methods. Zinc alloys can also be joined using adhesive bonding or MIG and TIG welding, although welding is normally not an economical joining method for zinc die castings due to the high production volumes involved.

k) Thin Wall Capability – Exceptional casting fluidity is displayed by all conventional zinc and ZA alloys, which provides superior thin-wall castability, regardless of the casting process employed. Wall thicknesses of 0.15mm for die casting and 2.3mm for permanent mold casting are being produced. This thin-wall capability results in smaller, lighter, low cost components compared to other metals.

Weight is a major factor in reducing the energy efficiency of castings, especially since the energy savings achieved through weight reduction applies across the casting cycle life; from melting, casting, transport of finished parts, during use (e.g. vehicle applications) and end-of-life collection and recycling. Since castings are created to specific dimensions, the only way to reduce weight is to select the lowest density casting alloy (which may come with performance trade-offs) or use less material by reducing the thickness of the casting wall. The latter approach of reducing casting wall thickness brings the added benefit of reduced material handling, melting and scrap costs.

Thin section casting in all engineering alloys is limited by the casting properties of the liquid alloy, the thermal properties of the mould or die, the shape of the component to be cast and the design of the metal introduction system including gates and runners. Zinc alloys allow a thinner wall section as compared to most other metal alloys or casting processes because of zinc’s low melting point and its good fluidity during the casting process. Prior to the development of the new HF alloy, zinc castings were limited to a thickness of around 0.75 mm. The new alloy significantly improves zinc alloy fluidity to allow a reduction in casting section thickness to 0.3 mm or less.

The zinc alloys include the traditional Zamak (acronym for zinc, aluminum, magnesium and copper) group, Nos. 2, 3, 5, and 7, and the high-aluminum or ZA® alloy group, ZA-8, ZA-12 and ZA-27. The Zamak alloys all contain nominally 4percent aluminum and a small amount of magnesium to improve strength and hardness and to protect castings from intergranular corrosion. These alloys all use the rapid-cycling hot-chamber process which allows maximum casting speed.

Of all the zinc casting alloys, Alloy 3 is the most widely used, accounting for some 85percent of total zinc casting tonnage. Its excellent physical and mechanical properties, excellent castability, and long-term dimensional stability provide the basis for its broad usage. It can produce castings with intricate detail and excellent surface finish at high production rates. The ease with which it can be electroplated adds to the popularity of this alloy. The other alloys in the Zamak group are slightly more expensive and are used only where their specific properties are required. When properties comparable to or better than those of aluminum alloys are required, alloy ZA-8, ZA-12, or ZA-27 should be considered.

Zamak 2 and 5 have a higher copper content, which further strengthens and improves wear resistance, but at the expense of dimensional and property stability. Zamak 5 offers higher creep resistance and somewhat lower ductility and is often preferred whenever these qualities are required. Zamak 7 is a special high-purity alloy which has somewhat better fluidity and allows thinner walls to be cast.

ZA-8 is the only ZA alloy that can be cast by the faster hot-chamber process. It has the highest strength of any hot-chamber zinc alloy, and the highest creep strength of any zinc alloy, having a creep resistance three times that of Alloy 3. It is principally used in structural or highly-stressed applications. In spite of its relatively high aluminum content, it can be electroplated using conventional plating techniques.

Alloys ZA-12 possesses excellent castability in cold chamber diecasting machines and has a lower density and higher creep strength than Alloy3. ZA-12 is suitable for use with all casting processes, and can be electroplated. ZA-12 has superior wear properties which makes it possible to eliminate costly inserts in die castings which are otherwise required to provide bearing or wear surfaces.

Alloy ZA-27 is the strongest, hardest and lightest of all the zinc pressure diecasting alloys. It also has the best wear properties and is among the most creep resistant. Sand cast parts can be heat treated to increase ductility. Because of its higher melting range compared with the other zinc alloys, it requires longer casting cycle times, it is also the most difficult of the alloys to electroplate. ZA-27 is specified for high performance applications when conventional zinc or aluminum alloys are inadequate. In many cases either ZA-12 or ZA-27 may be substituted directly for aluminum alloys, using existing tooling. They can also be continuously and centrifugally cast for bearing and machine parts.

ACuZinc5 is the registered trade name of General Motors for the ZnA3Cu6 grade developed by General Motors and this alloy has improved tensile strength, hardness and creep performance compared to the conventional zinc alloys. ACuZinc5’s strength and hardness properties are comparable to ZA-12. Testing has also shown ACuZinc5 to have excellent wear characteristics. Although this alloy is a hot chamber die casting alloy, it is more difficult to die cast with a higher wear rate of the shot end components in the die casting machine.

C-3 ROLE OF ALLOYING ELEMENTS AND IMPURITIES IN ZINC ALLOYS

C-3.1 The function and influence of die casting zinc alloy elements:

C-3.1.1 Aluminium (Al)

a) Increase the fluidity of the alloy, refine the grain, and improve the strength and hardness.
b) Reduce the reaction ability of zinc to iron and reduce the erosion of ferrous materials, such as gooseneck, mold and crucible.

The aluminum content shall be controlled at 3.8 percent to 4.3 percent. The required strength and fluidity are mainly considered. Good fluidity is the necessary condition to obtain a complete, accurate size and smooth surface casting.

The fluidity reaches the maximum when the aluminum content is 5 percent and reduces to the minimum at 3 percent. The impact strength reaches the maximum at 3.5 percent aluminum content and reduces to the minimum at 6percent. When the aluminum content exceeds 4.3 percent, the alloy becomes brittle. If the aluminum content is lower than the specified range, resulting in difficult mold filling of thin-walled parts and the possibility of cooling fracture after casting.

The adverse effect of aluminum in zinc alloy is that it produces Fe_2Al_3 scum, resulting in the decrease of its content.

C-3.1.2 Copper (Cu)

a) Increase the hardness and strength of the alloy.
b) Improve the wear resistance of the alloy.
c) Reduces inter-granular corrosion.

The general composition content is controlled at 0.75 percent to 1.25 percent, and when the copper content exceeds 1.25 percent, the size and mechanical strength of die castings will change due to aging. It also reduces the elongation characteristics of the alloy.

C-3.1.3 Magnesium (Mg)

a) Reduce intergranular corrosion
b) Refine the alloy structure to increase the strength of the alloy
c) Improve the wear resistance of the alloy

When the content of general components is controlled at 0.03 to 0.06 percent, and the content of magnesium is > 0.08 percent, thermal embrittlement, toughness and fluidity will be reduced. It is easy to get oxidize and lose in the molten state of the alloy.

C-3.1.4 Impurity Elements — Lead (Pb), Tin (Sn), Cadmium (Cd)

When the impurity elements lead, cadmium and tin in the alloy composition exceed the standard, the intergranular corrosion of zinc alloy becomes very sensitive, which accelerates its intergranular corrosion in warm and wet environment, resulting in aging and deformation of castings.

When the workpiece is just die cast, the surface quality may be normal, but after it is stored at room temperature for a period of time (eight weeks to several months), the surface appears bubbling, or the volume expands, the mechanical properties, especially the plasticity, decrease significantly, and even break after a long time.

C-3.1.5 Impurity Element — Iron (Fe)

Iron reacts with aluminum to form fe2al3 intermetallic compound, resulting in loss of aluminum (poor fluidity) and formation of scum; Hard spots are formed in die castings, which affect post-processing and polishing; Increase the brittleness of the alloy.

ANNEX D

(*Foreword and Clause* 5)

SPECIFICATION FOR MASTER ALLOYS USED IN MAKING ZINC DIE CASTING ALLOY INGOTS

D-1 The specifications given in this Annex covers some of the aluminium base and zinc base master alloys used to make zinc die casting alloys. Alloy compositions specified for aluminium base master alloys (also called as hardeners are given in Table 3. Alloy compositions specified for zinc-base master alloys are given in Table 4.

NOTE —Hardeners are an aluminium base master alloys added to Zn 99.99 grade of IS 209 to produce a zinc alloy for die casting.

D-2 Aluminium alloy hardeners are added to Zn99.99 grade zinc of IS 209 in the proper alloying ratios, as shown in Table 3, to produce zinc alloy for die casting.

D-3 Zinc base master alloy is added to Zn99.99 grade zinc of IS 209 in the proper alloying ratio, as shown in Table 5, to produce zinc alloy for die casting.

D-4 Master alloys may be supplied in the form of shots, bars, ingots or jumbos as specified by the purchaser. Generally, the aluminium hardeners are supplied in the form of shots. Zinc base master alloys may be supplied as ingot or jumbo ingot form but is typically supplied as jumbo ingot. The weight of zinc master alloy jumbo ingots is important because they are added in a fixed ratio to Zn99.99 grade zinc jumbo ingots.

D-5 The material given in the annex may be manufactured by any suitable process.

D-6 The material covered by this annex shall be of uniform quality and shall be free of dross, flux, or other harmful surface contaminations, so that it does not affect the chemical composition and is not detrimental to the use of this material. Also if the materials is in the shot form , it shall be sound, uniform in size and free of heavily oxidized surface coatings, stringers and moisture.

Table 3 Chemical Requirements for Aluminum Base Master Alloys

Grade	Al, Min	Cu	Fe, Max	Si, Max	Mn, Max	Mg (see Note2)	Zn	Cr, Max (see Note2)	Ni, Max (see Note2)	Sn, Max (see Note2)	Pb, Max (see Note2)	Cd, Max (see Note2)	Usage
ABMA1	87.0	1.7 Max	0.8	0.7	0.7	0.65 to 1.05	6.5 to 7.5	0.20	0.20	0.02	0.020	0.010	1 part by weight of this alloy and 21 parts by weight of Zn99.99 grade to make zinc alloy ZnAl4/Alloy3/Zamak3 of this Indian Standard

NOTES

1 This note applies to all the specified limits in this Table. For determining the conformance with above specification, the observed values or calculated value from analysis shall be rounded off "to the nearest unit" in the last right hand figures used in expressing the specified limit, in accordance with rounding method given in IS 2.

2 Carried to one additional decimal place to ensure proper control in the final alloy.

Table 4 Chemical Requirements for Zinc Base Master Alloys

Grade	UNS Name (for information)	Al	Mg	Fe, Max	Cu	Pb, Max	Cd, Max	Sn, Max	Zn	Usage
ZBMA 1	Z33730	11.7 to 12.6	0.090 to 0.16	0.070	0.25 Max	0.005	0.004	0.003	Remainder	1 part by weight of this alloy (ZBMA1) and 2 parts by weight of Zn99.99 (as per IS 209) to make zinc die casting alloy ZnAl4/Alloy3/Zamak3 of this Indian Standard.
ZBMA 2	Z35740	11.7 to 12.6	0.090 to 0.16	0.070	2.1 to 3.3	0.005	0.004	0.003	Remainder	1 part by weight of this alloy (ZBMA2) and 2 parts by weight of Zn99.99 (as per IS 209) to make zinc die casting alloy ZnAl4Cu1/Alloy5/Zamak5 of this Indian Standard.

NOTES

1 Zinc base master alloys ZBMA1 and ZBMA2 used for producing zinc die casting alloys may contain nickel, chromium, silicon and manganese up to 0.02 percent, 0.02 percent, 0.035 percent, and 0.05 percent respectively. No harmful effects have ever been noted due to the presence of these elements in up to these concentrations and therefore analysis are not required for these elements, except that nickel analysis is required when producing die casting alloy ZnAl4LM/ZL0400B/Alloy7/Zamak7.

2 This note applies to all the specified limits in this Table. For determining the conformance with above specification, the observed values or calculated value from analysis shall be rounded off "to the nearest unit" in the last right hand figures used in expressing the specified limit, in accordance with rounding method given in IS 2.

ANNEX E

(*Foreword*)

COMMITTEE COMPOSITION

Ores and Feed Stock for Non-Ferrous (Excluding Aluminium and Copper) Industry, their Metals/Alloys and Products Sectional Committee, MTD 09

Organization	*Representative(s)*
CSIR -National Metallurgical Laboratory, Jamshedpur	DR ABHILASH **(*Chairperson*)**
Arya Alloys Private Limited, New Delhi	SHRI AMRENDRA K. JHA
BT Solders Private Limited, Bengaluru	SHRI S. RAMESH
Bombay Non Ferrous Metals Association Limited, Mumbai	SHRI SANDEEP VAKHARIA
CSIR -National Metallurgical Laboratory, Jamshedpur	DR. PRATIMA MESHRAM (*Alternate*)
Directorate General of Quality Assurance, Ministry of Defence, Ichapur	SHRI E SUMAN KUMAR
	SHRI RUPESH BANAIT (*Alternate*)
Eveready Industries India Limited, Kolkata	SHRI G. PRAHALATHAN
	SHRI SENTHIL R. PANDIAN (*Alternate*)
Exide Industries Limited, Kolkata	DR. SAGAR SENGUPTA
	SHRI SURAJIT CHANDRA DEB (*Alternate*)
Geological Survey of India, Hyderabad	SHRI VAMSHI KRISHNA PALLETI
Hindustan Zinc Limited, Udaipur	SHRI HIMMAT HADIYA
	SMT MANINEE MANASMITA NAYAK (*Alternate*)
Indian Bureau of Mines, Nagpur	DR. D. R. KANUNGO
	SMT JYOTI SHRIVASTAVA (*Alternate*)
Indian Institute of Technology , Roorkee	SHRI NIKHIL DHAWAN
	PROF UJJWAL PRAKASH (*Alternate*)
Indian Lead Zinc Development Association, New Delhi	SHRI K. SRIDHAR
	SHRI L. PUGAZHENTHY (*Alternate*)
Indian Rare Earths Limited, Mumbai	SHRI D. SINGH
	SHRI B. R. MISHRA (*Alternate*)
IZA India (International Zinc Association), New Delhi	DR. RAHUL SHARMA
	SHRI KENNETH DE SOUZA (*Alternate*)
Kothari Metsol Private Limited , Pune	SHRI VISHAL KOTHARI
MSME Testing Center, New Delhi	SHRI D. D. GAJBHIYE
	SHRI G.PRASAD (*Alternate*)
Malco Energy Limited, South Goa	SHRI S. SRIDHAR
	SHRI KAMALPREET SINGH (*Alternate*)
National Institute of Technology, Tiruchirapalli	PROF SANKARARAMAN SANKARANARAYANAN

National Mineral Development Corporation, Hyderabad	SHRI G. VENKATESWARA RAO
National Test House, Kolkata	SHRI D. RAJAGOPALA RAO
	SHRI SUHAS PINGALE (*Alternate*)
Phoenix Industries Limited, Masat	SHRI NITIN SALVI
	SHRI AMIT SANGAI (*Alternate*)
Power Grid Corporation of India, Gurugram	SHRI K. N. M. RAO
	DR. SATISH KUMAR (*Alternate*)
RITES Limited, Gurugram	SHRI V. K. DWIVEDI
	SHRI SANDEEP GUPTA (*Alternate*)
Research Designs and Standards Organization (RDSO), Lucknow	SHRI R. K. VIJAY
	SHRI ANOOP SINGH DAGUR (*Alternate*)
Saru Smelting Private Limited, Meerut	SHRI SHASHANK JAIN
	SHRI ARUN GUPTA (*Alternate*)
Southern Metals & Alloys Private Limited, Mumbai	SHRI VIVEK NORONHA
	SHRI VINOD NORONHA (*Alternate*)
Tata Steel Limited, Jamshedpur	DR. SOURAJYOTI DEY
	SHRI SUBRATA SADHU (*Alternate*)
BIS Directorate General	SHRI SANJIV MAINI, SCIENTIST 'F' AND Senior DIRECTOR AND HEAD (MTD) [REPRESENTING DIRECTOR GENERAL (*Ex-officio*)]

Member Secretary

SHRI SAAQIB RAAHI

Scientist 'C'/Deputy Director (MTD), BIS

Panel for Zinc Alloy Ingots and Die Castings, MTD9/P3

Organization	*Representative(s)*
IZA India (International Zinc Association), New Delhi	DR. RAHUL SHARMA **(*Convenor*)**
Indian Lead Zinc Development Association, New Delhi	SHRI K. SRIDHAR
Hindustan Zinc Limited, Udaipur	SHRI HIMMAT HADIYA
DST Industries Ltd, Haryana.	SHRI SANDEEP TANDON
Phoenix Industries Limited, Masat	SHRI NITIN SALVI
Indian Oil Corporation Limited, Mumbai	SHRI CHANDRAKANT GHATOL