

A PRIMER  
ON  
FERROUS FOUNDRY  
PRACTICE  
&  
METALLURGY

- G.M.RAJENDRA PRASAD. M.E., (I.I.Sc.)

*FORWARD NOTE.*

*As you read this book you will see voice of a person , who is eager to pass on the knowledge he has acquired, in his career to the young and old alike in a very simple –understandable language-and for those who had learnt metallurgy & foundry practice in their academics, a reading material which will rekindle their forgotten knowledge.*

*The gregarious knowledge outburst has been consolidated in such a short time and in a simple language for those who had forgotten Metallurgy and Material sciences.*

*To say a few things about the author Sri Rajendraprasad, who had joined our company as an enthusiastic youngster always seeking and exploring the knowledge of Material science and technology . He had a very keen analytical mind-never say never die attitude-and an excellent human being always keen to pass on the knowledge to others in simple terms. He is a great storey teller in Foundry practice and Metallurgy. He showed lot of interest and keenness in learning Methoding in Foundry and the feeding of castings.*

*We come across problems in FOUNDRY, which are challenging to a keen learner and from my point of view it is the only production practice to have innumerable variables, and a tricky mind teaser, each and every minute of our lives, through the industry.*

*Can you read this book with an open mind?*

*If so you will see the world of Metallurgy & Foundry, through the eyes of Mr Rajendra Prasad, and you may expand your mindset about Metallurgy in totality.*

*THIS BOOK IS FOR YOUR KNOWLEDGE BANK OF THE FUTURE.*

*Begur R Rao Niranjana*

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## **ACKNOWLEDGEMENT**

No Man is an island unto himself. Every human being is , what ever he is, because of Society.

The Members of this Society who have contributed to this book, directly or indirectly are :

My daughter, Ms Vasudha. Gulyam, who put the IDEA of writing a book, in me.

Mr.B.R.Niranjan , who in 1978, who not only introduced me to the fascinating field of METHODING of STEEL CASTINGS , lead me through.

Mr.T.Kumar , from whom I learnt a sense of Discipline in Life, particularly in Working Life, sense of Impartiality & Systemic Thinking.

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Mr Babu Sathian , who helped me in every thing .

I am eternally Grateful to the above People for EVERY THING .

**To  
THAT COSMIC FORCE, WHICH CONCEIVED  
THIS BOOK & HAD IT WRITTEN BY A CREATION OF HIS.**

## PREFACE

There is more than one reason for attempting to write this book.

At the outset, let me confess that I have never authored any thing before.

1) There is a severe man-power crunch in Foundry Industry, because of prevailing favourable job opportunities.(in other areas) In a situation like this, the foundries will have to make do with whoever is available.

In my 30 years of experience in various foundries, one thing that I have learnt is that in foundry you need **KNOWLEDGE,HUNCH and AT TIMES DIVINE INTERVENTION.**

As regards to the last point it may sound as a NON-SCIENCICAL SCIENCE.

But believe me it is true as I have had several experiences.

Let me tell you some thing with all the sincerity and the honesty that I can muster, **FOUNDRY SCIENCE** is a combination of several subjects ,which are often considered” Difficult.”

To name the subjects :FLUID MECHANICS.

HEAT TRANSFER.

SOLID MECHANICS.

MATERIAL SCIENCE.

It is a combination of Subjects from Mechanical engineering & Metallurgy.

Mechanical fellows are not comfortable with metallurgy and vice versa.

Hence ,it is time universities started a post of **PROFESSOR OF CASTING TECHNOLOGY**, instead of a mechanical or a metallurgy professor working on foundry.

This trend has started in **UNIVERSITY OF BIRMINGHAM**. I am very happy to note this change of perception.

Some people are likely to be offended by the above statement. For them I have only one answer “ **THOSE WHO MATTER DON’T MIND & THOSE WHO MIND DON’T MATTER.** Whole world is crying hoarse about pollution control **FOUNDRY** happens to be the second most polluting industry. Mining being the first one. But mining activity in Australia can’t be out-sourced to **INDIA**, but castings can be bought from Indian Foundries. Hence Foundry Industry is going to see a boom.

But to-day a Inter passed boy with a knowledge of English prefers to go to BPO. So Foundry industry will have to make do with who so ever is available.

( B.E, B.Sc, D.M.E’s have stopped considering a job opportunity in a Foundry )

In a situation like this it occurred to me as to why not share my 30 years of industrial experience with these boys, so that their awareness of foundry increases.( I am talking of boys who have come to foundry, as they had no option)

After my B.E( Met )( Honours) from R.E.C, Rourkela ( present day NIT ) and M.E.( FOUNDRY) from INDIAN INSTITUTE OF SCIENCE,BANGALORE in 1978,I have worked in several foundries for last 30 years. I started my career as a METHODS Engineer and subsequently went on to learn so many other things on my own initiative. In the process so many people have helped me.

In this world of ours nothing is permanent.

By the grace of GOD I have an enquiring mind and hence I don't take any body's statement as a WORD OF GOD till I am convinced about it. This statement may sound as though I am an ARROGANT fellow, but that does not bother me even a wee bit. My personal philosophy (?) has always been " I AM LIKE THIS, TAKE IT OR LEAVE IT"

In a situation like this, it occurred to me that whatever I think I know is not mine, it has come from a COSMIC FORCE and hence I have no MORAL right to carry it to my GRAVE. So I decided to share my knowledge with people who want to know about Foundry science.

Our ancient sages and seers did penance to appease GODS to get an ETERNAL KNOWLEDGE.I am no sage or seer nor I can give you an eternal knowledge.

Among people who seek the knowledge of foundry science are two types.

1) People who are working in foundries for several years but they do not know what is what. I have absolutely no qualms in saying this as I have met hundreds of such people.

2) Fresher's or New comers to foundry.

I would teach you the following PATTERN ,METHODING ,MELTING, MOULDING, FETTLING, HEAT TREATMENT,INSPECTION AND TESTING and finally some basic of METALLURGY which is relevant to you. Here I ask of you only one thing i.e. you must know ENGLISH. Rest you leave it to me. I will try, for all I am worth, to do justice so that your life in foundry becomes more cheerful and not drudgery.

I have yet another pre-requisite i.e.

THINK,THINK.THINK.THINK.THINK.THINK.THINK.THINK.THINK.THINK.

Animals have an INSTINCTIVE INTELLIGENCE and human being has an INTELLECTUAL INTELLIGENCE. Animals can't think and human being does not think. Do you find any big difference between animals and human beings ,tell me honestly .when I make this statement, it not is out of arrogance but with a deep sense of ANGUISH.

When I was studying an elective subject "NUCLEAR METALLURGY" in my final year B.E in 1975,I knew that India didn't have enough of Uranium, had plenty of Thorium .Even after 33 years we are going around the world begging for Uranium.

If this does not speak volumes about our scientific and thinking capability or lack of it ,what else can. That is the reason I am paying so much importance to

## THAT COMPONENT OF THINKING.

I am as much an INDIAN as all of you are, so do not jump to a conclusion that I am denigrating INDIA.I AM NOT.

Your parents sent you to school, when you were 5 years old. Why did they send you to school, because they knew that you didn't know any thing.( this includes me ).You know what is the maximum weight you can lift, you know how much you can eat, you know how far you can see with your naked eye, etc but do you know what your MIND can do or can't do. Your MIND is yours only, endowed to you by GOD almighty HIMSELF OR HERSELF OR ITSELF. When you don't use such a POWERFULL TOOL, are we not SINNING against GOD. Would it be wrong if GOD concludes HE OR SHE OR IT has made an "APATRA DHANA "i.e. giving a gift to an UNDESERVING FELLOW. So, my friends I request you ,beg of you to THINK. YOUR MIND IS YOUR BRAMHAstra,ICBM AND MIRV ALL IN ONE. I have said what I have said with a belief that CRITICISM IS AN ELEMENT OF FAITH AND NOT OPPOSITE OF FAITH.

This book will not be like a conventional book. This book will not be written in third person like other books. Instead this book will be interactive and conversational in nature and so read this book like you would read a novel.

Excepting the data and some diagrams, every thing is extempore. I will talk about the problems I faced and solutions I got. I will give you precautions and warnings to be adhered to in a foundry operation.

As I started my career as a METHODS engineer of STEEL castings, it is more likely than not that this book will show certain amount of bias towards STEEL. I have also worked in S.G Iron foundry, hence I will tell you about S.G. Iron making, and more importantly S.G. Iron FEEDING.

As regards to S.G Iron feeding many people think that S.G. Iron should be fed like STEEL, nothing is farther from TRUTH.

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## INTRODUCTION

I deliver lectures on the following topics for practicing foundrymen, design engineers and some engineering college teachers.

The topics I handle are:

- 1) Metallurgy for Non-Metallurgists.
- 2) Methoding of Steel and S.G. Iron castings
- 3) Steel and S.G. Iron foundry practice.

As is my wont I start my classes by asking a very ,very simple question.

“ WHAT IS ENTROPY” Believe me till date, in my last 35 years, I have not met a person who has given the CORRECT answer including most of my teachers. The word entropy has got philosophical overtones.

Invariably the answer given was / is ENTROPY IS DEGREE OF DISORDER Or ENTROPY IS DEGREE OF RANDOMNESS. As far as I am concerned they are not only silly answers but WRONG answers.

The word “ENTROPY” comes from 2<sup>nd</sup> law of Thermodynamics, which in turn had it's origin in Physics.

The above kind of answers are like saying that man is “SICK”. Sick of what ? Has got AIDS, cancer, arthritis, ulcer etc.

Above answers for ENTROPY are so slimy and slippery, you can never make use of it. Besides that Thermodynamics is a QUANTIFIABLE Science and not a QUALITATIVE SCIENCE.

If a Mechanical, Metallurgical and a Chemical engineer, who studies THERMODYNAMICS as a part of HIS course, is unable to define ENTROPY, properly, he is not an engineer worth his salt.

Before I explain ENTROPY to you, let me tell you categorically, in unambiguous terms, with out any vestige of doubt, ENTROPY decides your growth, development and progress. Man who taught me ENTROPY is not an ENGINEER or SCIENTIST but A FINANCE MAN by name JEROMY RIFKIN. JEROMY RIFKIN wrote a book entitled “ENTROPY—A WORLD VIEW.”

It is out of print now. Those of you who would want to get this book now, will have to look for those groups who are in the business of selling old books in USA.

(IT IS ORIGINALLY PRINTED BY BANTOM BOOKS,USA )

Let us get into explanation of ENTROPY.

In 1970-75, there was a motorbike called “ JAWA”, it used to give a mileage or Should I call it a kilometreage of 25km per litre of petrol.

There after came a motorbike called as ‘RAJDOOT’, which used to give us a mileage of 45 Km per litre of petrol.

Then came a motorbike called ‘YAMAHA-CRUX’ Which gives a mileage of

74 Km per litre of petrol.

Now let us look at it this way, in a matter of 15 years mileage went up from 25 Km to 74 Km per litre of petrol. HOW MUCH MORE IT CAN GO ?

Now a days there are vehicles which claim a mileage of 110 Km per litre.

Now we have come from 25 to 110 Km per litre of petrol. It is almost 4 times the Our first value of 25 Km per litre of petrol.

One litre of petrol has 9100 Kilocalories of heat energy. First law of thermodynamics states that energy can neither be created nor destroyed, it can only be converted from one form to another.

If we convert 9100 KCal of heat energy to work energy, for a weight of 150 Kg (100 Kg-motor-bike weight + 50 Kg is the man's weight ) One litre of petrol should give 180 Km per litre at 100 % efficiency.

Let us look at one vehicle after an other.

JAWA-----180—25 = 155 Km

Total available energy is 180 Km per litre of petrol.

What is made use of is only 25 Km.

Achievable energy – achieved energy = A MEASURE OF ENTROPY

180 Km –25 Km = 155 Km (unachieved energy) ENTROPY—JAWA.

180 Km –45 Km = 135 Km (unachieved energy)ENTROPY----RAJDOOT

180 Km –74 Km = 106 Km (unachieved energy)ENTROPY-----CRUX

180 Km –110 Km = 70 Km (unachieved energy) ENTROPY----PRESENT DAY VEHICLES.

If you look at the UNAVAILABLE ENERGY, it has come down from 155 Km to 70 Km. THIS IS ENTROPY.IS'T THIS A PROGRESS AND ADVANCEMENT. IT IS THIS ENTROPY,WHICH SETS US THE DIRECTION IN WHICH WE CAN PROGRESS.

IN OTHER WORDS,WHAT WAS HITHERTO UNAVAILABLE ENERGY IS CONVERTED TO AVAILABLE ENERGY.REDUCING ENTROPY IS EQUIVALENT TO IMPROVEMENT IN ENERGY EFFICIENCY.

Now do you understand that ENTROPY is not a slippery or a slimy term like DEGREE OF DISORDER OR DEGREE OF RANDOMNESS. It is a perfectly a quantifiable term.

IDEALLY SPEAKING IF ENTROPY BECOMES ZERO,SYSTEM CANNOT BE IMPROVED UPON FURTHUR.THAT IS THE DEAD-END.

Now let us talk of ENTROPY OF DEED. This is the difference between what You are capable of achieving and what are you actually achieving. If this happens to be negative, then there is ENTROY at play and you have ample scope to improve on your achievement. Thus reducing ENTROPY.

This can be partly achieved by employing the principles of “OPERATIONAL RESEARCH”, a subject in MANAGEMENT and MATHAMATICS. This is a

A case of “OPTIMISATION”

ENTROPY OF THOUGHT: Here you have no one to guide you, except your own EFFORTS towards SELF-IMPROVEMENT.

**Every day identify some thing about which you don't know anything.**

Animals can't do this, only HUMAN BEINGS can do it. Then, is it not the time you started? There is a saying “WHERE THERE IS A WILL, THERE IS A WAY”

You know as to how much weight you can lift.

You know as to how much you can eat.

You know as to how far you can see.

You know as to from how far you can hear.

BUT DO YOU KNOW AS TO WHAT YOUR MIND CAN DO OR CAN NOT DO ? HENCE THINK INTENSELY.

Now you will realise what is the POTENTIAL of MIND.

My dear friend you have only one OPTION, THINK—THINK INTENSELY.

To close this chapter, I will give you an other example on ENTROPY.

If you have a savings bank account in a bank with cheque facility, willy-nilly, you have to keep a minimum balance of Rs 1000. If you have a balance of Rs 20000 in your account, you can withdraw only Rs 19000 and leave Rs 1000 untouched. Don't you think that THIS Rs 1000 is ENTROPY as it is your money and yet it is not available to you.

Before I close, I want to tell you some thing.

Any subject ( CURRICULAM) will have about 15 chapters.---100 %

In examination they give about 8 Questions covering about 10 chapters—66 %

You are asked to answer 5 Questions, if all of which will fetch FULL MARKS

You will get 100 %-----for 33 % of the subject

If you are a just first class student ( 60 % )-----for 20% of the subject.

THINK & REFLECT ON IT.

## TOPICS COVERED

1. PATTERN
2. METHODING
3. MELTING
4. SAND PLANT
5. MOULDING
6. MOULD FINISHING
7. POURING
8. KNOCK OUT
9. FETTLING
10. HEAT TREATMENT
11. INSPECTION & TESTING
12. MANAGEMENT & LAYOUT
13. FERROUS METALLURGY

## ABBREVIATIONS USED

UTS	ULTIMATE TENSILE STRENGTH IN Kg / mm <sup>2</sup>
YS	YIELD STRENGTH IN Kg / mm <sup>2</sup>
%E	PERCENTAGE ELONGATION
%RA	PERCENTAGE REDUCTION IN AREA
BHN	BRINNEL HARDNESS NUMBER
Ra	ROCKWELL HARDNESS-A Scale
Rc	ROCKWELL HARDNESS-C Scale
Mc	MODULUS OF THE CASTING
Mf	MODULUS OF THE FEEDER
Mn	MODULUS OF THE NECK
B.C.C	BODY CENTERED CUBE
F.C.C	FACE CENTERED CUBE
B.C.T	BODY CENTERED TETROGONAL
DEGREES	DEGREES CENTIGRADE
M.P	MELTING POINT
Cp	SPECIFIC HEAT
L.H	LATENT HEAT
K	THERMAL CONDUCTIVITY
Dm	DECIMETRE ( 100 mm )
Psi	POUNDS PER SQUARE INCH
TOUGHNESS	HIGHER VALUES OF %E,%RA &IMPACT STRENGTH
IMPACT STRENGTH	STRENGTH OBTAINED ON HIGHER RATE OF LOADING
A	ANNEALING
N	NORMALIZING
AQ	AIR QUENCHING
OQ	OIL QUENCHING
WQ	WATER QUENCHING
T	TEMPERING

Metals can be Rolled, Forged & Cast.

When your mother takes a dough of wheat flour and water, gives a round shape with a wooden round piece, it is ROLLING

When a blacksmith heats a long piece of metal and hammers it, it is called FORGING.

During Christmas and Makara Sankranti, people distribute toy like things made of sugar to children. A slurry of sugar and water or milk is made and this slurry is poured into wooden dies (whose inside shapes can be a horse, elephant or any shape of your choice). This slurry is allowed to dry for while in the die itself for while till it attains some amount of strength for handling, there after it is dried in SUN LIGHT so that it becomes strong enough. Here a liquid sugar syrup has become solid.

Now let us see the differences between Rolling, Forging and Casting.

Rolling and Forging are the operations made **in solid state of Metal** to change the shape of the metallic piece into desired shape.

For example, your M.S. sheet is a Rolled product, the steel hammer you use for driving a nail into a wall is a Forged product. As these operations are done in solid state, you can't get complex shapes.

In casting, a metal is melted and poured into a container, whose shape it will take. Remember your horse, elephant made out of sugar syrup.

**In case of Casting, metal is melted and molten metal is poured into a container whose shape is pre-determined. This liquid metal is allowed to solidify to become solid in the container.**

Casting is an old art but a young Science. Even now there are several things **in castings about** which we don't know much.

**So it is very essential to keep your mind openly open and keep thinking**

When you keep your mind open and work, you will discover something every day. Your life becomes exhilarating. For a person with job satisfaction other things become insignificant.

Life is full of mysteries for a person who can think.

*IT IS BELIEVED THAT THERE ARE ONLY 26 DISEASES FOR WHICH EMPIRICAL CURE IS KNOWN. REST IS ALL GUESS WORK.*

*INCIDENTALLY DO YOU KNOW THAT EVEN TO THIS DAY WE DONOT KNOW THE EXACT CURE FOR "COMMON COLD"*

*THAT IS PROBABLY THE REASON FOR SAYING-----*

*COLD GETS CURED IN 7 DAYS TIME IF YOU TAKE MEDICINE,  
COLD GOES AWAY ON IT'S OWN IN A WEEK'S TIME EVEN IF YOU  
DONOT TAKE MEDICINE.*

## PATTERN

Patterns are replicas of component to be made with certain allowances. You should also remember that your casting can only be as good as your Pattern and certainly not better.

When you see a Brass tap ( a cast product) in your house, don't you marvel at it's complexity and elegance.

3000 years back, our fore-fathers made statues of DANCING NATARAJA out of metal, it was a cast product.

Patterns can be several types:

Solid pattern.

Split pattern.

Skeleton pattern.

Cored pattern

Cover cored pattern.

Patterns can be made of wood, metal polymer, plaster of Paris etc.

A pattern made by a pattern maker and a pattern designed by a Methods engineer may look totally different. I would like to state in no uncertain terms, that the fate and eventual cost of the casting, depends to a great extent on Pattern design.

A pattern maker is only concerned with taking the pattern out of the mould. ( mould—British English & mold---American English )

Whereas a Methods Engineer takes a holistic view. His goal is a good casting.

In the process a Method's Engineer's pattern may altogether look different.

A Methods Engineer can be compared to a GYNECOLOGIST; OBSTETRICIAN & PAEDIATRICIAN all packed in one.

Can you think of any of the above medical practitioners having a callous attitude towards pregnant mother, growing foetus, or the baby after birth.

Similarly a Methods engineer, worth his salt, must envisage all the phases a pattern or a casting goes through, identify probable problems which are likely to manifest at various stages of Foundry operation.

In other words I am calling a" METHODS ENGINEER " a complete foundry man.

For all I am worth, to the best of my ability with a dash of divine intervention, I hope I will able to do justice to the TASK on hand. Also familiarise you with all facets of a foundry operation.

Your are probably feeling bit heavy. So let us digress a bit. There is a saying " IT TAKES ALL SORTS TO MAKE A WORLD " How true. Remember you are not a nonentity. Do you know why ? With out you this world of ours will not be complete.

*I need to tell you a story now. There was an Indian scientist by name S.N.BOSE. He was a physicist and a young man. He wrote a paper on Theoretical physics. Like any youngster, he wanted second opinion from an other theoretical physicist. He sent his paper to none other than Einstein himself. At that time Einstein was still in Germany. He did not know English. A kind soul he was he got the paper translated to German. Read the paper, made some corrections and published a paper jointly in the name of BOSE & EINSTEIN. That paper was titled "BOSE-EINSTEIN STATISTICS" which is like a Bible for all Theoretical physicists even to this day. He identified a particle in the process and he named the particles as "BOSONS" after S.N.BOSE. What a commendable act of kindness.*

*Let us go to the other end of the Spectrum.*

*One Mr Chandrashekar ,again a physicist and a theoretical physicist. He went to LONDON and delivered a lecture on ASTROPHYSICS at ROYAL SOCIETY. In the audience there was PROF EDDINGTON. EDDINGTON was a NOBEL LAUREATE himself. He tore Chandrashekar into pieces.*

*A dejected, demoralised, demolished and depressed Chandrashekar left the shores of BRITAIN once for all. He went to UNIVERSITY OF CHICAGO in USA. Chandrashekar worked on Astrophysics. After full 50 years later Chandrashekar got a NOBEL PRIZE for the same theory he had proposed 50 Years earlier at ROYAL SOCIETY OF LONDON.*

*To day there is what is called "CHANDRASHEKAR LIMIT" in Astrophysics. Do you see the extreme contrast between EINSTEIN & EDDINGTON.*

*Now back to work.*

## METHODING OF CASTINGS

Methoding of castings is the HEART & SOUL of making a sound CASTING. As I have already told you Foundry is an old art but young science. Till 1939 castings were made by trial and error method. What we call FEEDERS now were called RISERS because workers used to see the way liquid metal was raising in the mould. The name RISERS got stuck, but to-day it is an inappropriate word. FEEDER is the appropriate word

Let us understand the word FEEDER. When we heat any thing it expands.

When a metal is melted, it takes the heat in 3 stages. 1) Solid state,  $\text{Mass} \times \text{Cp1} \times (\text{melting point} - \text{room temperature})$ -**Sensible Heat**, 2) Melting (Solid to Liquid)  $\text{Mass} \times \text{Latent Heat}$  At it's **Melting point**, this is called as **Latent Heat**, 3)  $\text{Mass} \times \text{Cp2} \times (\text{pouring temperature} - \text{melting temperature})$ -**Super Heat**. To give you an example, Pure Iron melts at 1539 degrees.

But you can not pour at 1539 degrees as it will become solid while pouring itself, so we give an additional heat to this liquid so that the metal remains above 1539 degrees till the cavity in the mould is filled & metal takes the shape of the casting. So we pour our metal at about 1640 degrees. As we all know when ever some thing is heated it expands, as we have put in 3 different heats namely Sensible Heat, Latent Heat & Super Heat-there is a great deal of expansion. While cooling, loss of Super Heat leads to Liquid - Liquid Shrinkage, the loss of Latent Heat leads to Solidification Shrinkage.

While loosing Sensible Heat, it occurs in Solid state, hence to counter the contraction the Pattern is made bigger to accommodate that contraction.

We need a **Reservoir of liquid metal** to compensate for other two shrinkages.

That comes from **FEEDERS**.

Imagine a CONE solidifying and a ROD solidifying. Would there be any difference. In a Cone solidification starts from the tip and gradually solidification moves towards the base of the cone. This pattern of solidification is called DIRECTIONAL SOLIDIFICATION. Where as in a ROD, there is a concurrent solidification taking place across the length of the rod. This kind of solidification that takes place in a rod is not conducive to a SOUND CASTING. Where as THE SOLIDIFICATION PATTERN that takes place in a CONE is conducive to a SOUND CASTING.

**SO THE METHOD OF MAKING ANY CASTING SOLIDIFY LIKE A CONE TOWARDS THE FEEDER, LEADS TO A SOUND CASTING.**

**IN ONE WORD THIS IS THE CRUX OF "METHODING"**

**This is achieved by making use of temperature gradients which result in Directional Solidification. By this we are making all the SHRINKAGE move out of the casting and go to feeder where a reservoir of liquid metal is available to compensate for the shrinkage which otherwise would have occurred in the casting itself. This process of taking this shrinkage**

from casting into a feeder is called **Directional Solidification. The Engineering of this is called METHODING.**

In 1939, one person by name CHEVERINOV came up with an equation, Called CHEVERINOV'S EQUATION. It looked like this:

$$t = 0.75 \times V^2 \times Q^2 \times S^2 / (SA)^2 \times T^2 \times k \times D \times Cp$$

Where t = Solidification time

V = Volume of the liquid metal

Q = Heat content of the metal

S = Density of the metal

SA = Surface area through which heat content of the liquid metal was lost to facilitate solidification

T = Solidification temperature

K = Thermal conductivity of mould material

D = Density of mould material

Cp = Specific heat of mould material

There are some terms which need further explanation.

Q-Heat content of Metal.

= Weight of metal x Specific heat (Cp1) x ( Melting point – Room temp ) ----1

= Weight of metal x Latent heat (at melting point )-----2

= Weight of metal x Specific heat ( Cp2) x( Pouring temp---Melting point )----3

The sum of 1+2+3 = Total amount of heat required till pouring temp

Specific heat is the amount heat required to raise the temp of a unit mass(weight) by 1degree centigrade—calories / gram/ degree C

This specific heat is not a constant figure.

Imagine that you are climbing 1000 steps to reach a temple, you will climb first 50 steps easily with out getting tired. There are after raising each and every step needs an extra effort. We human beings being intelligent we rest for a while and start climbing again. Even the people who built the steps provide what is called “LANDING” for resting.

But metals have no such advantage. The extra effort(heat) needed to raise the the temp by every 1 degree keeps raising.

For the most part, Cp of pure metals at room temp are available in

Physical constants tables. But Cp at higher temp are not available at all even for pure metals and for ALLOYS it is not available at all.

Then again we have Cp1 and Cp2.If Cp1 itself is not known properly what to talk of Cp2.

The atoms of the metal are BOUND or BONDED by a FORCE. For our

convenience sake ,let us assume that each atom of metal is BOUND BY A SPRING with another atom of metal. On heating the strength of the spring strength deceases. Here (1) is called SENSIBLE HEAT.

LATENT HEAT is the amount of heat required to CONVERT one unit mass of metal from SOLID TO LIQUID at it's MELTING TEMPARATURE.

For pure metals this data is available. Alloys do not melt at ONE temp rather OVER A RANGE OF TEMPERATURE. Here we do not know the Latent Heat. Now do you see in what sort of unchartered territory we are working in.

We virtually know nothing.

ON SEVERAL OCCASSIONS I HAVE FELT THAT WE METALLURGISTS OR FOUNDRYMEN ARE NEITHER SCIENTISTS NOR ENGINEERS.

When solid becomes liquid several bonds(springs in our case) are broken and hence liquid has a mobility which solids didn't have.

Information :Even in liquids all the bonds are not broken. That is the reason why it can be held in a container, but once you cross BOILING POINT all the bonds are broken and alloy becomes a GAS. Can you imagine holding a gas in an open container.

1) SENSIBLE HEAT- room temperature to melting point.

2)LATENT HEAT- at the melting point itself.

3) SUPER HEAT- from melting point to pouring temperature.

THE SUM OF 1+2+3 is the heat required to bring the metal to a temp where it can be poured into a container called MOULD.

Here I need to clarify a point, that is A SINGLE METAL (GOLD) is pure metal. But the moment we put some other element(ALL ELEMENTS ARE PURE) into a pure metal it becomes AN ALLOY.

Look at the RING you have on your finger, though we call it a GOLD RING, in actuality it is a GOLD ALLOY RING.

Pure Gold (24 carat ) is too soft and hence to give it some strength, we add small amount of COPPER or SILVER. Now your GOLD ALLOY RING is 22 carat.

Most of us have a misconception about the amount heat required to bring the metal to pouring temp.

For example Iron has a melting point of 1539° C

Copper-----do-----1083° C

Aluminium-----do-----660° C

Hence we conclude that heat required to melt one unit weight of Fe > that of Copper > that of Aluminium .

Nothing is farther from truth.

Let us say we pour our metals at a superheat ( melting temp + 100) degrees.

IRON AT 1539 +100 = 1639° C

COPPER AT 1083 + 100 =1183° C

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