INSTRUCTIONS

PATTERN SHOP

PRODUCTION OF

NEW PATTERNS

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CONTENT

1. INTRODUCTION

The pattern shop has to produce a pattern and all other involved tools that enable the foundry to produce a casting that is ñconformò to the customer (and foundry) requirements.

The pattern is a ñone-timeò cost where as the casting is a repetitive cost. So the cost of the pattern is less important if the casting will be lower cost, although most of the customer does always find the pattern cost too high.

To produce the pattern, the shop needs information. This information can be partly delivered by the customer, partly set after a discussion between engineering, production and pattern shop, partly from experience built files (shrinkage).
The information that is most important is the required pattern quality.

The pattern design will be made after intensive discussions with all departments involved and following by the company accepted rules.
The pattern design also includes the required and for quality reason interesting templates, which can be used by the operators.

The pouring system, including the sprue, runner, ingates and vents, and the riser and chill location also belongs to the responsibility of the pattern shop. Especially the dimensions and location must be set.

The best pattern is a result of the cooperation of all departments involved, which means engineering, production, inspection and pattern shop.

2. INFORMATION

The information is partly delivered by the customer and mentioned in the order, partly set by the foundry after discussions, partly filed experience information.

2.1 INFORMATION DELIVERED BY THE CUSTOMER

The information is present in:

1. drawing:
   - dimensions
   - tolerances (sometimes as cast and machined)
   - roughness
   - machining and dimension reference points.

2. order:
   - pattern quality
   - pattern lifetime (number of castings and or time limitation)
   - storage and or transport instructions.

2.2 INFORMATION DELIVERED BY FOUNDRY AFTER DISCUSSION

This information is present in the engineering sheet, which can partly refer to the company instructions.

1. split line
2. cores: design and number
3. dimension and location of risers (should be numbered)
4. dimensions and location of chills (should be numbered)
5. inventory list of risers and chills
6. pouring system (design, dimensions and location)
7. critical to quality items
8. required templates

2.3 INFORMATION FROM FILED EXPERIENCE

This information is very important because it provides rules that are valid all over the production, based on the standards, literature and experience of previous production.

1. metal shrinkage range and real data from similar parts
2. radius for all connecting sections
3. radius in splitline
4. draft of core and patterns
5. machining stock
6. type of pattern base: 2/2 pattern, 2 x ½ patterns on plate, core assembledé

3. PATTERN QUALITY

The customer never likes to pay very much for the pattern because it is a tool.

This tool is designed and produced by, or under the supervision of the foundry. The pattern has the design as that particular foundry did wish, which can be different from the opinion of other foundries. Therefore it can be difficult for the customer, who paid for the pattern, to move it to other foundries without an extensive cost for redesign or at least modifications.
If the pattern quality at that particular time (of transfer to another foundry) is too low compared to the standard of this other foundry, they will refuse to work with it.

The mould material also will lead to requirements for the pattern design and quality. Therefore patterns designed for use in green sand will not be usable in chemical bounded sand without extensive modifications.

The redesign or repair of a pattern will always decrease the quality. Thin layers of extra material, needed to correct the dimensions and or the surface quality, attached to the original pattern material will always tend to loose in a quick time or be damageable very easily.

For all this reasons, some of the national and international standards have described pattern quality in relation to the required number of castings and refer mostly to a type of moulding (and mould material). The pattern design is not taken in account because it is and always will be the responsibility of the foundry concerned.

One of the most common standards is DIN 1511, which describes:

1. Types of quality
2. Tolerances
3. Pattern draft
4. Colour codes.

In the future this standard will be replaced by an EN-standard.

The type of quality is described as follows (according to type of moulding and number of moulds to be produced):

Class	**Material**	**Suitable for**
H1a	Wooden	serial production
H1	Wooden	medium serial production
H2	Wooden	small serial production
H3	Wooden	badge production (single piece, eventually repeating)
M1	Metal	serial production
M2	Soft metal	medium serial production
K1	Plastic	medium serial production
K2	Plastic	small serial production
S1	Foam	several times usable pattern, smooth surface
S2	Foam	one time usable pattern, smooth surface
S3	Foam	one time usable pattern, no surface requirements

The tolerances are:

Dimensions From	till (mm)	Tolerances +/- H1a/H1	H2/H3	M1	M2	K1	K2	S1/S2	S3
0	18	0,2	0,4	0,10	0,15	0,15	0,25	0,4	0,6
19	30	0,2	0,4	0,10	0,15	0,15	0,25	0,5	0,8
31	50	0,3	0,5	0,15	0,20	0,20	0,30	0,5	0,8
51	80	0,3	0,6	0,15	0,25	0,25	0,30	0,7	1,1
81	120	0,4	0,7	0,20	0,30	0,30	0,45	0,7	1,1
121	180	0,5	0,8	0,20	0,30	0,30	0,50	0,9	1,5
181	250	0,6	0,9	0,25	0,35	0,35	0,60	0,9	1,5
251	315	0,6	1,0	0,25	0,40	0,40	0,65	1,1	1,8
316	400	0,7	1,1	0,30	0,45	0,45	0,70	1,1	1,8
401	500	0,8	1,2	0,30	0,50	0,50	0,80	1,4	2,2
501	630	0,9	1,4	0,40	0,60	0,60	0,90	1,4	2,2
631	800	1,0	1,6	0,40	0,60	0,60	1,00	1,6	2,5
801	1000	1,1	1,8	0,50	0,70	0,70	1,10	1,6	2,5
1001	1250	1,3	2,1	0,50	0,80	0,80	1,30	2,1	3,3
1251	1600	1,5	2,5	0,60	1,00	1,00	1,50	2,1	3,3
1601	2000	1,8	3,0	0,70	1,10	1,10	1,80	3,0	4,6
2001	2500	2,2	3,5	0,80	1,40	1,40	2,20	3,0	4,6
2501	3150	2,7	4,3	1,00	1,60	1,60	2,70	4,0	6,5
3151	4000	3,2	5,0	1,30	2,00	2,00	3,20	4,0	6,5

These tolerances are the minimum tolerances for the casting (as cast). The casting can never have smaller tolerances (range) than the pattern, which is used to produce the casting.

Colour coding of patterns
The colour code used for the pattern is mainly depending on the metal to be cast. This is to estimate the pattern shrinkage for the metal. The colours are:

Bleu	steel	Yellow	copper alloys
Purple (Lila)	ductile iron	Green	aluminium alloys
Red	grey (flake) iron		
Grey	malleable iron.		

Proposal for use (grey iron):

Weight Casting	Number of castings Total	Type of pattern
< 100 kg	< 500	H1a
	> 500	K2
	> 1.000	K2, M2
	> 5.000	M1
< 5.000 kg	1	S 1
	< 50	H 2
	< 100	H 1, H1a
	> 100	H 1a, K 2
	> 500	K 1
> 5.000 kg	< 50	H 1
	> 50	H 1a

4. PATTERN DESIGN

The pattern design concerns the splitline of the pattern (of any), the cores and core-assembly, the pattern draft, the radius (if any) of section connections (type L, T, Y, X and more complicated), the machining stock, location of risers and chills, transport tools (especially for cores), templates (for assembling, inspection) and last but not the least important the ñpattern shrinkageò(dimensional shrinkage of solid metal).

The pouring system is also part of the pattern and will be described in next chapter.

Of course not all these items are involved for all patterns, but a lot of foundries do forget very valuable parts of it affecting the quality of the casting: radius of section connections, transport tools and templates as well as a clear and permanent location marking for risers and chills.

4.1 SPLITLINE

The splitline (or parting line) is that plane where the pattern is split in two or more parts. It divides the mould in cope and drag mould. It is set after an extensive discussion between engineering (location of risers, chillsé), the production (easy and stable production possibility) and the pattern shop (complexity of pattern design, location of coreprints and cost of pattern).

Mostly one splitline is involved, sometimes none (simple shape castings) and sometimes two (for complicated castings). Sometimes a ñbroken splitlineòis used, which means that it is not in the same plane.

The splitline will decide the location of the sections: top, bottom or at the side. Mostly it is possible to reverse the pattern, if necessary (top becomes bottom), with few cost and without a decrease of quality.

The location of the splitline will anyhow influence the ñdraftò(slope of the side walls), the necessity for cores and the difficulty of radius at sections connected in the splitline. These items will be described in the next chapters.

4.2 CORES AND CORE ASSEMBLY

Cores will be used to:

1. produce an inside cavity
2. avoid draft at the side of the casting
3. to produce the total shape of the casting.

A core does need:

1. stable and rigid core-shoulder that refers to the core-print in the mould

2. stable and rigid core-shoulder that refers to the core-print in the core
3. very efficient venting
4. correct location towards the mould and other cores.

The cores must be assembled one to another and or in the mould in a unique way, assuring the repeating dimensional accuracy of the casting. Sometimes it can benefit or even being necessary to use steel bush and pin to assemble a core in another core. The best and most consistent result will be achieved with the use of templates.

4.3 PATTERN DRAFT

To be able to remove the pattern from the mould without damaging the pattern or mould, there is a need for a ñdraftòand all vertical planes. The more draft, the easier the removal will be, but the more extra material, which can not always be accepted by the customer.

Draft can be avoided by the use of a core.

Table: "Minimum draft" (in ° or mm) acc to the split or parting line (DIN 1511)

Height	Draft		Height	Draft
mm	**°**		**Mm**	**Mm**
- 10	**3°**		**400 ï 500**	**3,0**
10 ï 18	**2**		**500 ï 630**	**3,5**
18 ï 30	**1,5**		**630 ï 800**	**4,5**
30 ï 50	**1,0**		**800 ï 1000**	**5,5**
50 ï 80	**0,75**		**1000 ï 1250**	**7,0**
80 - 180	**0,50**		**1250 ï 1600**	**9,0**
180 ï 250	**1,5 mm**		**1600 ï 2000**	**11,0**
250 ï 315	**2,0**		**2000 ï 2500**	**13,5**
315 - 400	**2,5**		**2500 ï 3150**	**17,0**
			3150 ï 4000	**21,0**

For the small bosses, spotsé the minimum draft are:

till height of	70 mm	draft	5°
over height of	70 mm	draft	33°

This is also the draft to be used for coreprints!

4.4 RADIUS OF SECTION CONNECTION

The radius that is used to combine meeting sections is very important. For complex shaped connections, the radius is very important. The sections are L-, T-, Y, X- and even more complex ones.

The radius is depending on the connecting sections (wall thickness). It does not only involve the foundry but also the stress concentration during its use will depend on it.

If the drawing shows a radius that is not acceptable for the foundry, contact should be taken with the customer to request for modification.
Area that are machined can always be provided with the, for the foundry, best radius.

The most forgotten radius is the radius in the splitline (if a connection is present). This radius cannot be produced on the pattern due to the splitline. There is a need for a template and or tool to make it (always equal) after the pattern is removed from the mould. Never allow it to the operator producing it by hand.

4.5 MACHINING STOCK

The machining stock depends on several factors:

1. indication on the drawing or specification
2. location in the mould (top- or bottom plane)
3. risk for slag inclusions
4. size of casting
5. type of mould material.

In the standard ISO 8062 an indication of the minimum machining stock is given.

For a casting, especially a sand-casting, the minimum machining stock is in practice 3 mm for small castings and 6 mm for larger castings.
The machining stock on top of the casting (concerning location in the mould) shall always be 3 to 5 mm extra compared to the nominal machining stock due to the fact that all inclusions (sand, slag, dross) shall be located in this stock. This is especially valid for gas and slag and dross forming metals (ductile iron, high chromium iron, high chromium steelé).

Remark

It is not correct to increase the machining stock to compensate differences in linear shrinkage. If the process is under control, the dimensional shrinkage cannot differ very much.

4.6 LOCATION OF RISERS AND CHILLS

The location of the risers and chills is very important because they are calculated for a connection section (relation between modulus for the risers and section thickness for the chills) and a feeding length.

In most foundries, the location is marked by a ñmarkerò. Although this is not erasable, it will disappear after the providing of the coating (to ease the removal of the pattern from the mould). So all castings will have more or less a different figuration of risers and especially chills. The result concerning section quality (shrinkage) will also be different.

4.7 TRANSPORT TOOLS

The transport tools are mostly for transporting the pattern from and to the moulding shop and for transport of the cores.

The most important and most forgotten transport tools are these tools that enable the foundry to transport, store and dry as well as coat the cores without risk for deformation, cracking and or breaking. This tool should also be usable for removing core from the core box.

4.8 TEMPLATES

Because there is always a ñgapò between the core-shoulders and core-prints in the mould or in the other cores, there is a possibility to shift

4.9 PATTERN SHRINKAGE

The pattern shrinkage is indicated in a lot of literature, sometimes as one value or as a range. The latter is most correct.

The shrinkage depends:

1. mostly on the type of material
2. degree of hindering of shrinking (shape)
3. hot spots and cores (shape)
4. pouring temperature
5. strength of the mould material.

It is also important to realise that even for the same casting, different shrinkage rates can be applicable depending on the area of the casting.
For this reason, the foundry must file the real data of each type of casting, measured at the first casting and later confirmed by one out of the serial production.
This is a job for the pattern shop and engineering.

5. IMPORTANT RULES

This chapter will describe a number of important rules, which participate to success, taking in account that the pattern is a ñtoolò and not a target!

5.1 Concerning pattern

The split line or parting line is determining the location of the casting in the mould and will decide about the ñdraftò (or use of cores to avoid excessive draft).

The pattern can be mounted on a ñpattern plateò, which can be on one plate for a pattern without parting line or two plates for patterns with a parting line.
Especially for those on 2 plates, a good referencing system must be provided to assure correct assembling of the drag and cope part of the mould. This can be done with separate ñreference pinsò in sand, iron or steel. For smaller flasks (mould boxes) and serial production, the assembly referencing can be done by the mould flask system (pins and bushes).
A mismatching can lead to partly blocking of the pouring system, which leads to different section ratios and longer pouring time, to turbulent mould cavity filling and the production of slag and sand erosion.
Anyhow it is fact to check regularly the condition of the reference system.

What mostly is forgotten is the tooling to remove the pattern from the mould. This removing is the most common cause for pattern as well as mould damage.

5.2 Concerning ñLoose partsò of patterns

Too avoid the use of cores, especially for ñreverse draftò area on the pattern; ñloose partsò are applicable. These are parts of the pattern, loose from the pattern, which stay in the mould after removing the pattern from the mould. Later the loose part can be removed.

The problems are that they must:

1. be fixed correctly on the pattern
2. stay firmly on that area without shifting
3. be protected against damage and loss during transportation and storing of the pattern.

For these reasons, it is important that:

1. they are not small and thin (enlarge them to a larger part)
2. the connection is stable (long pins, V-slidesé)
3. the location is clearly indicated and measurable by a template.

5.3 Concerning cores and core boxes

A core is interesting to avoid an extensive draft and reverse draft area on the pattern. But it represents an extra cost and scheduling and transportation efforts.
The danger is that the cores must fit correctly with the pattern and other cores to make core-assemblies.

The following rules are commonly used:

1. reduce the number of cores to a minimum by combining them to larger ones
2. the connecting parts, core shoulders on the core and coreprints in the mould, must fit completely and within the required tolerances. The draft on the connection should be ñat leastò the draft for the pattern (DIN 1511), preferred even larger. The possibility to assemble without problems (damage of core or mould) must be present, not leaving to much gap to avoid the danger for large and thick grate. It should take in account the sealing and coating.
3. use templates and assembling instructions to locate the core to core and to mould in a unique way, within the required tolerances. It is preferred to provide the possibility to fill the gaps with sand after the assembly.
4. core boxes must be designed to be able to open the core box and to remove, even at low core material strength, the core from the core box without damage for the core and or the core box. Templates can be designed to remove and to transport and to assemble the core.
5. large cores as well as small complex shaped (thick and thin sections) cores must get ñdrying templatesò to avoid deformation during hardening.

5.4 Concerning templates

The use of templates to inspect the shape and dimensions of the cores and mould cavity and location of the cores to the mould cavity is under-estimated by most of the foundries. But it is the only guarantee for a, concerning dimensions, consistent casting performance.

5.5 Concerning ñparting lineò

The parting line is nearly always visible on a casting and will show any (even small) shift in the mould parts.

The most dangerous activity is the radius in the split line, which cannot be present on the pattern. The radius should be made, after removing the pattern, by the mould operator. To assure an equal and consistent radius, a template must be available.

5.6 Pattern marking

The location of the risers, chills, vents and ingates is very important. The pattern must have marks to locate all of them.

In most cases this is done by a ñmarkerò, which indication will be invisible after some use due to the covering with the pattern release agent (easy release of the pattern from the mould).

This can be solved by small ñlocation bossesò (some mm high), indicating location and size as well as shape of the feature concerned.

Another solution is the use of a picture file, indicating very clearly the location, size and shape. These pictures can be accompanied by templates to check the real location.

5.7 Engineering sheets

Together with the engineering department, sheets should be set, indicating at least the following:

1. type of pattern
2. number of core boxes
3. type and number of templates
4. type and number and location of risers
5. type and number and location of chills
6. type of pouring system
7. location and dimension of the sprue(s)
8. location and shape and dimensions of the runner
9. location and shape and dimensions of the ingates
10. location and shape and dimensions of the vents.

6. POURING SYSTEM

The pouring system consists of:

1. pouring box with stopper (plug) and or slag skimmer
2. sprue
3. runner
4. ingates
5. filters
6. vents.

The shape, dimensions and location of them are important. The calculation is different depending on the type of pouring system: pressurised or non-pressurised. It is preferred to use standardised shapes and dimensions.

6.1 Pouring box

The pouring box is mostly not considered as part of the pouring system, but it is. Although the pattern shop has nothing to do with it, it must recognise the relation to the sprue and total pouring weight.
Each pouring box must be characterised by a maximum diameter of ñsprueò for which it is usable. The sprue diameter determines the height of the siphon, which absorbs the slag of the metal surface and leads it into the mould cavity. It should be at least (3,5 times the sprue diameter + safety).
For larger castings (> 2.500 kg), the pouring ladle cannot (or can with some risk) deliver the metal in the short pouring time. Therefore the pouring box acts as a ñreservoirò, which should have minimum 25 to 35 % of the total poured metal.

6.2 Sprue

The sprue should be downwards tapered, with the bottom diameter and section as the calculated section (in both type of pouring systems).

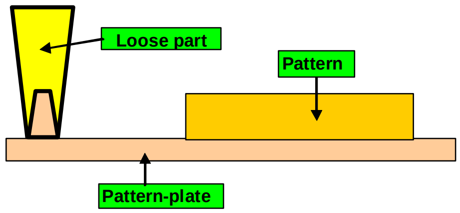
It is difficult to prepare standard sprues with this tapering, unless for one particular casting. For automatic moulding machines, it is even more difficult.

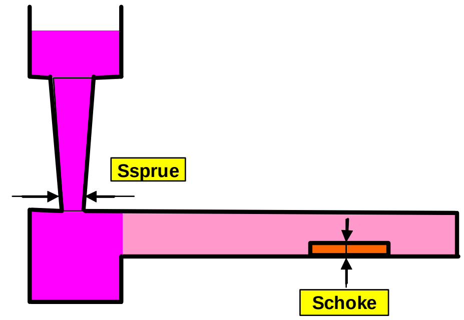
The solution is:

1. for large castings: use of ceramic pipes, equal in diameter top-bottom
2. for non-serial production: straight sprue pattern in wood
3. for serial production: straight sprue or use of an extra sprue-tap (see figure) or cut in the sand (can be done for the pouring box at the same time.

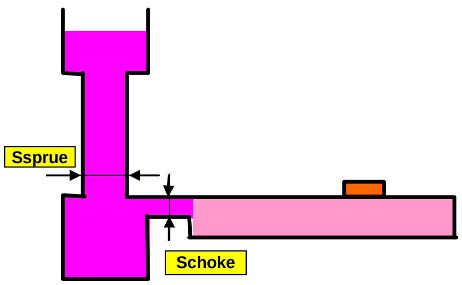
For the first two solutions, the connection between sprue and runner can be adapted as indicated in the next figure.
Never forget the sprue-pit.

The following figures do show this:

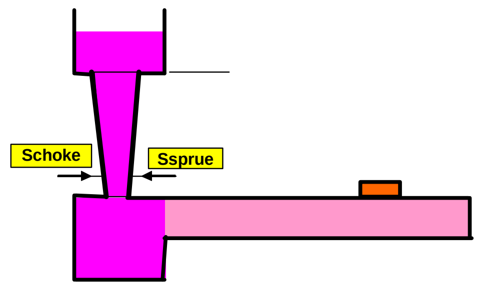




PRESSURISED POURING SYSTEM



NON-PRESSURISED POURING SYSTEM

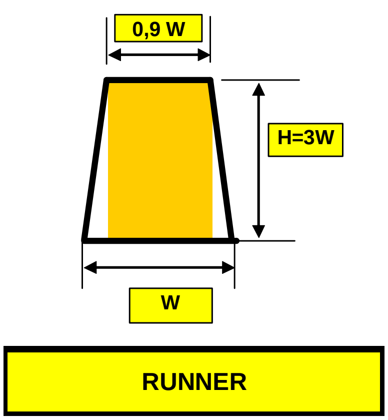


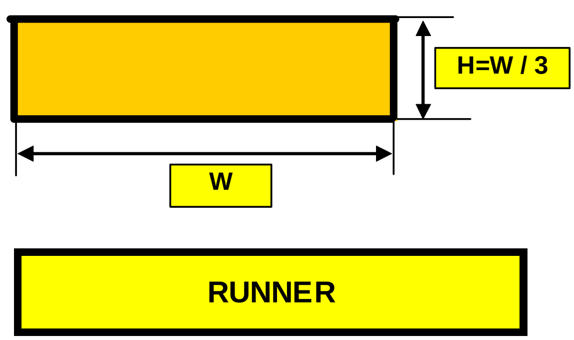
NON-PRESSURISED POURING SYSTEM

6.3 Runner

The runner is easy to standardise because it has no narrow dimensional range due to the fact that the section is mostly equal or larger than two times the choke section.

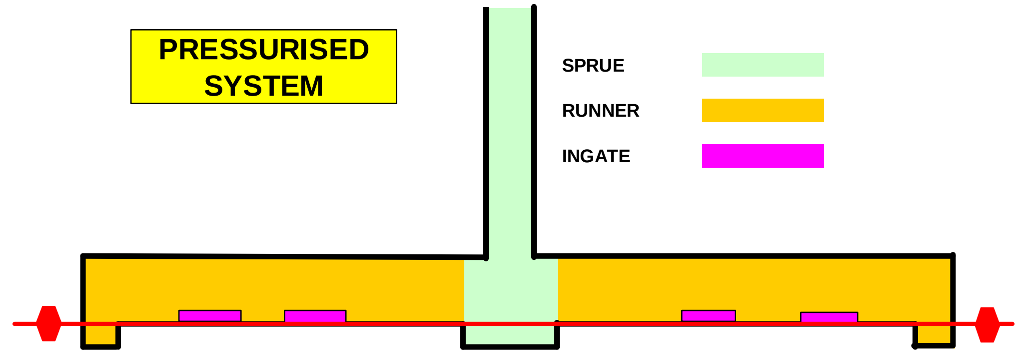
Pay attention that the shape is totally different for the pressurised and non-pressurised pouring system.

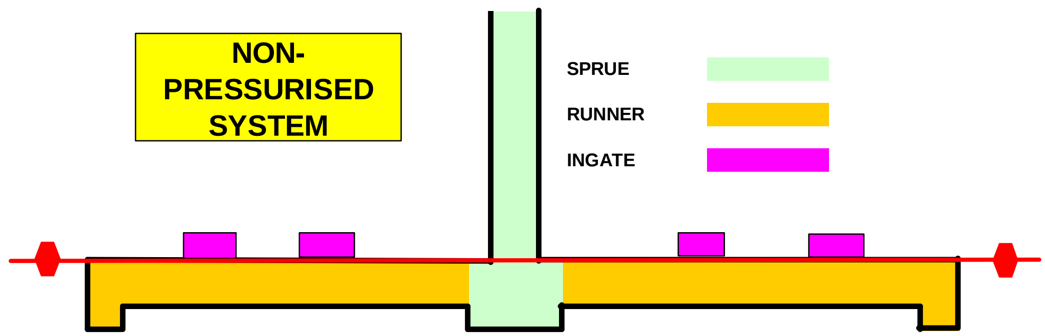




PRESSURISED POURING SYSTEM **NON-PRESSURISED POURING SYSTEM**

The runner for the pressurised system is located in the cope mould part and for the non-pressurised system in the drag part.





The runner-pit at the end of the runner is important. It can be used together with the slope at the end.

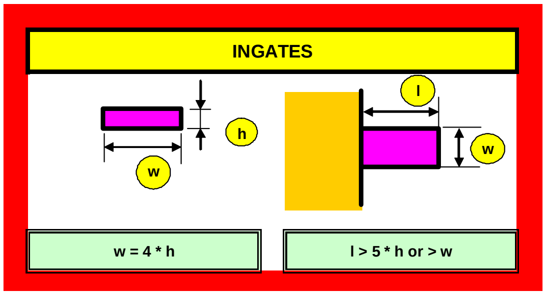
6.4 Ingates

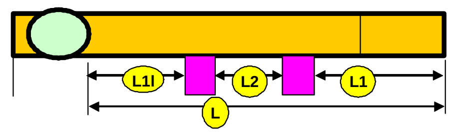
The ingates are more difficult to put on the pattern plate, due to the fact that the thickness (in case of pressurised pouring system, is very low. Take in account that the coating will decrease the thickness by 1 to 1,5 mm.

The fact that they are always located on the split line (above or below the splitline for the pressurised and above the split line for a non-pressurised pouring system) creates the difficulty to not damaging the shape (see figures above).

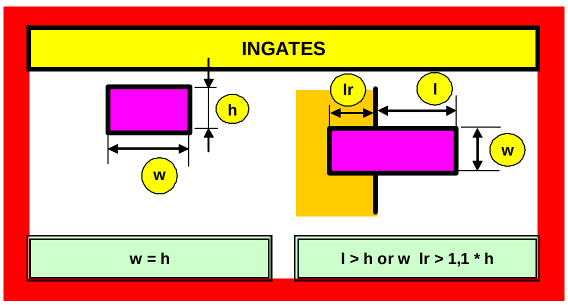
It is not possible to use loose ingate-patterns and it is dangerous to make the ingate by hand! The shape is different for pressurised and non-pressurised pouring system. This is illustrated in next figures.

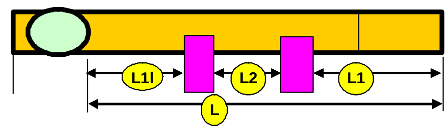
The distance from the ingate to the sprue bottom as well to the runner end and in-between the ingates is important. It is preferred to mark the location of the ingates and better, to use a template for producing them.





PRESSURISED POURING SYSTEM





NON-PRESSURISED POURING SYSTEM

Always check the modulus of the ingates compared to the modulus of the casting at the connecting location!

6.5 Filters

It is necessary to use the correct filter housing, which is prescribed by the supplier. A filter must be supported correctly and may not be able to move during pouring.

Never forget that the use of a filter requires a non-pressurised pouring system!

6.6 Vents

The vents are very important because they are needed for activating blind risers and to avoid gas (or air) inclusions. They are easy to standardise.

It is important to indicate the location on the pattern. Vents that are dislocated will have a lower effect.

Always check the modulus of the vents compared to the modulus of the casting at the connecting location!

7. NON-CONFORMITIES

There are a lot of non-conformities that appear due to incorrect ‟patterns", which means in terms of ‟process control", failing equipment. Some of the causes are primary (7.1 to 7.4), which means direct related, other are secondary (7.5 to 7.6), which means a result of.

7.1 Dimensions

The casting can have incorrect dimensions due to:

1. **an incorrect shrinkage**, which can be all over (incorrect for the metal concerned) or locally (incorrect estimation of the influence of the casting shape or mould and core material strength)
2. **shifting of mould halves** (drag and cope) or **core-halves** can lead to incorrect dimensions
3. **an incorrect fitting of core-mould** and or **core-core connection**.

7.2 Failing details

The casting can be incorrect due to:

1. **missing part** due to not using **loose part** of pattern or core box
2. **a missing core**, which was not well indicated.

7.3 Surface condition

The surface condition can be non-conform to the requirements due to:

1. **bad surface condition** of pattern and or core boxes
2. damage due to **incorrect draft pattern**
3. damage due to **incorrect set up of core boxes**
4. damage due to **incorrect repair** of lifting and transport tool devices
5. damage due to **incorrect repair** of broken mould or core

7.4 Grate

The grate, present on the casting, will require a lot of extra fettling and grinding, which in term will damage the visual appearance in the area.
Grate can be present due to:

1. **incorrect fitting of mould halves**: cope and drag
2. **incorrect fitting core-mould** and or **core-core**.

7.5 Inclusions

This is a secondary cause. Due to an incorrect pouring system, inclusions can come in the casting:

1. incorrect sections and or ratio of sections: slag, dross, oxides and sand
2. incorrect location of ingates: sand.

7.6 Porosity

Most of the foundries do think that the pattern has nothing to do with the presence of shrinkage, but this is incorrect. It can happen because of:

1. riser feeding fails due to an incorrect location of:
    - risers
    - chills
    - vents
    - ingates

2. incorrect pouring system:
    * sprue to close to the casting
    * modulus of ingates too large compared to the connection area
    * modulus of vents too large compared to the connection area
    * incorrect location of ingates

3. grate formation that blocks the feeding of risers

4. incorrect location of heavy section in mould (drag or cope).

8. CONCLUSION

The importance of patterns, including the riser and pouring system as well as necessary templates, is mostly underestimated by the customer as well as by the foundries.

The dimensions and the condition of the pattern will be the base for the dimensions and surface condition of the casting. The casting can never have a better quality, dimensionally and surface, as the pattern.

Because the pattern involves a lot of cost, especially for the batch and small serial production, it is important to take time for a deep estimation of all factors involved. For all castings, the experience should be filed for future use to avoid over and over experimental ñfirst part productionò.

The pattern and core boxes condition is subject to regular inspection and repair must be performed before incorrect (non-conform) casting are produced.

The pattern is the complexity of pattern (halves), core boxes, riser-patterns, vents, pouring system and indication of location of features like risers, chills, vents and ingates. The most important part is the group of templates that can be for inspection or transport or storage.

The lifetime of a pattern is set by the materials used and the handling and use by the moulding and pattern storage department. A good pattern is never cheap but can avoid a lot of non-conform castings that represent a high cost and a lot of troubles.