# Modern Furan for Modern Castings

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**ABSTRACT**

Like Phenol ($C_6H_5OH$) and Urea $\{(NH_2)_2C=O)\}$, Furfuryl alcohol ($C_4H_3OCH_2OH$), a product of agricultural origin is capable of polymerization with Formaldehyde ($H_2C = 0$) under suitable PH conditions. However, usable polymers, at least as no bake for Foundry applications are obtained only when the condensations are carried out in association with Urea, Phenol or both. The series of resins obtained, having Furan ring ($C_4H_4O$) in chains, at different PH conditions and varying compositions are called Furan resins. These resins (binders) and acids (catalysts) make a two part no bake self-set system (popularly known as FNB in foundry terms) like Alkyd, Phenolic no bake (PNB), Urethane no bake (PUNB) and Alkaline Phenolic no bake (APNB) for binding sand particles for making moulds and cores in metal casting Industries.

With growth of Foundry industry, several self-sets have been introduced periodically for making molds and cores. Once the most popular inorganic Binder i.e. Sodium Silicate which make binder system with $CO_2$ gas or organic esters as curing agents has lost favor of Foundrymen because of its inherent drawbacks, main being poor de-coring property and unsatisfactory casting finish.

Other primitive binders like cement, molasses and many proprietory binders have largely been replaced by modern organic binders mentioned above, which meet requirements of faster productivity, better out of box and handling strength of molds and cores, rapid production cycle, better de-coring property and eventually better casting finish. This paper deals with evolution of Furan from introductory to modern stage, its advantages and disadvantages in comparison with other self-sets and its present market position and future trend, particularly in context to foundries based in India and Middle East.

## INTRODUCTION

FNB is a binder system comprising of two parts, both liquids. The resin, which is dark colored thin liquid acts as binder for sand particles and the catalyst or curing agent, is a solution of pure or mixture of organic, inorganic or organo inorganic acids in varying concentration.

Introduced in world market in 1958 along with PNB, it took long time at least in India to gain popularity.

Introduced in 1965 in world market, 3 Part Alkyd (no-bake and semi bake) was the most popular self-set in Indian Foundries in eighties.

PNB, which is also a two-part system, introduced in Indian Foundries in early eighties could not gain instant popularity mainly because of poor bench life of mixed sand, irritating smell of formaldehyde during mixing, limited storage life of binder etc. However, in introductory stage, the most important reason behind its non-acceptance was that the system did not have sufficient bench life of mixed sand suitable for use in batch mixers particularly in summer and in big jobs, which Alkyd could offer at ease.

Introduction of continuous mixers (CSM) in Indian Foundries in large scale in mid-eighties offered Foundries option to think about enhanced productivity and thus to go for faster setting systems beyond Alkyd, for mold and core making, as faster mixing and mold filling cycles did allow to work Foundrymen with lower bench life of mixed sand compared to Alkyd. Binder manufacturers also

started working on other short falls namely reduction of fume level, increase in shelf life, reduction of viscosity of binder and few more. In another two or three years, PNB was the first popular self-set introduced in Indian market as binder for CSM to produce flask- less molds in loop line with roll over strip and option for reclamation by attrition. In the process, alkyd started getting replaced by PNB for making repetitive moulds.

With success of PNB in CSM, some Indian Foundries started working with FNB, application of which match with PNB, mostly with imported ones and on advice of foreign collaborators in early eighties, when FNB was an established system in European and American Foundries. Experience was not sweet; as formulations developed abroad did not meet conditions of Indian Foundries, major being application temperature and sand quality.

Meanwhile, in mid-eighties, a new self-set called Alkaline Phenolic no bake (APNB) two part system was introduced in world market and also almost simultaneously in Indian market. This system with its unique three stage curing process and absence of N – S & P was found to produce castings of better quality than previous two. Steel Foundries wanted to take advantage of absence of said detrimental elements and CI foundries for over all casting quality and cleaner foundry environment.

PUNB introduced in Indian Foundries in eighties did not find mass application because of several shortfalls, which include inferior working environment and increased cost. Till date very few Foundries in India are continuing with this system. On positive side, it is fastest among self-sets.

Meanwhile APNB formulations got matured in India and Foundries, particularly steel ones started favoring this system in CSM with roll over strip for flask less moulds apart from big boxed moulds. Possibility for reclamation of used sand and control on bench life and strip time of mixed sand went in favor of the system over Alkyd.

FNB, with Indigenized formulations, when reintroduced in Indian Foundries, started gaining popularity by 2004. The FNB formulations available with Indian manufacturers today are most modern and are capable of meeting all requirements of Foundrymen for all Ferrous and Non-ferrous castings.

Today's FNB is altogether a different breed from those of 20$^{th}$ century and one of the two most widely used self-sets in Foundries, both Indian and abroad, other one being APNB (Table-1).

## MATURING OF FNB FORMULATIONS

With FNB, bench life of mixed sand in Indian Foundries in peak summer could be achieved up to as high as 20 mts, making it suitable for making giant moulds and cores for making heavy castings for wind mills, turbine components etc. In another extreme case, small moulds made with FNB can be stripped as fast as within 10 minutes, faster than other self-sets apart from PUNB. Low addition level and possibility of using high ratio of reclaimed: fresh sand (R: F) reduces gas content, improves shakeout properties, reduces adverse effect on environment, better economy and finally sound castings in case of modern FNB. Low S catalysts are available for SG iron castings. Safe storage life of six months for binder makes FNB a preferred one for export and use in hot countries.

FNB offers a series of formulations to be chosen from. This is true for binders as well as catalysts. Binder quality varies mainly depending on:

- Percentage of FA –usual range is 65 – 95% by weight of total mass
- Percentage of N – Usual range is Nil to 7% and
- Nature and % of other components present in binder

In broad sense, more the FA content and lesser the N content, better and costlier the product is.

In Catalyst, the variables are:

- Percentage purity of acid
- Percentage S in system
- Percentage P in system, if any

Selectivity of grade of FNB is very much metal specific. Whereas, in case of non-ferrous castings, high N systems don't have any adverse effect on casting quality, cost being reduced substantially, in case of steel castings, low or no - N FNB is a must to get castings free from pinhole defects.

**Table 1: Technical Details of PNB, APNB and FNB**

| COMPONENTS | PNB | APNB | FNB |
|---|---|---|---|
| Part 1 (Binder) Alcohol | Water borne Phenolic | Water borne Phenolic | Polymers based on Furfural |
| Part 2 (Hardner / Catalyst) | Solution of acid(s) | Organic ester(s) | Solution of acid(s) |
| Addition level in fresh sand (India) | 1.6-2.0 : 30-60 | 1.6-2.0 : 20-25 | 1.0-1.3 : 30-60 |
| Binder Viscosity as processed($B_4$, 30° C, Secs) | 30 - 60 | 20 – 35 | 15 – 25 |
| Min. Binder Storage life at room Temperature. (India), days | 45 | 90 | 180 |
| **Elements Presence** | | | |
| S | Yes | No | Yes |
| N | No | No | May or may not |
| P | No | No | May or may not |
| Reclaim ability (attrition) of used sand | Good | Fair | Excellent |
| Sensitivity to sand properties | ADV affects performance | Not much | ADV affects performance |
| Control over bench life and strip time of mixed sand and moulds | Fair | Very Good | Excellent |
| Out of box and handling strength of moulds | Good | Fair | Excellent |
| Effect of variation of Catalyst / Hardner addition level on curing properties within stipulated range | Appreciable | Not Much | Appreciable |
| Gas evolution at workable addition level | High | Low | Lowest |
| BTX evolution at pouring | Moderate | Low | Very low |
| Popularity in India and Middle East | Decreasing | Increasing | Increasing at Fast rate |

## MODERN FNB

Reintroduction of Furan Binder System in Indian Foundries at around 2004 started getting recognition initially slowly and then rapidly. It took time for Indian Foundrymen to forget bad experience with Furan of eighties. In last few years, growth of FNB market in India has increased at same fast rate, if not more than APNB. One of the reasons may be replacement of PNB by FNB is much easier than by APNB due to opposite PH reactions. Further, FNB has got several unique advantages over APNB. These are better flowability of mixed sand leading to better mold compaction, better out of box and handling strength of molds leading to rigidity and less breakage, workability at much less binder level, much better reclaimability of used sand, faster productivity of molds and castings.

Modern Furan offers excellent reclaim ability of used sand, by single attrition; there are examples of Foundries in India where reclaimability level is as high as 85% and addition level is 0.8: 30 – 50 in system sand of 85: 15. No other Binder system is workable at this low binder addition level.

Further, modern FNB can work over a wide room/sand temperature, which no other modern self sets can probably match. FNB has been found practically to work in temperature range of near zero to 55°C.

In case of ferrous metals, - N content in the system plays an important role dictating its selection on metal composition. It s a well documented fact that N in elemental form is dissolved in molten ferrous metal causing porosity in castings. Severity of effect is more in steel than CI castings. In CI castings also, section thickness of casting and its geometry decides the maximum allowed N in the FNB formulation to be allowed.

In general, maximum allowed - N content in FNB for various metals are as follows:

| Metal | % N allowed in Binder |
|---|---|
| Non-Ferrous | 5 or even more |
| CI and SG of low section thickness | 2 - 5 |
| Steel and SG of heavy section thickness | Nil – 2 |

It is more practical to go by N content of molding sand rather than that of Binder. Recommended allowable maximum N content in molding sand for different ferrous castings are as follows:

| Metal | % max N in system sand |
|---|---|
| CI and SG of low Section thickness | 0.15 |
| Steel and Heavy SG | 0.10 |
| Heavy Steel | 0.05 |

There is no chemistry behind difference in upper limit of % recommended - N content in CI and SG Iron. One answer may be the difference in allowance for soundness of casting between SG and CI; the former can be tested 100% for internal defects by ultrasound method but not later.

Again, not percent of - N, but its form in molding sand is of more importance for causing pinhole defects in ferrous castings. Nitrogen bearing elements, which decompose to produce elemental N, are utmost risky as the same is dissolved easily in liquid metal to give porosity defects. Ammonia cal Nitrogen comes under this category.

One classical example of above phenomenon is that PUNB, although it has N in structure of co- binder are being successfully used in steel Foundries, whereas N bearing FNB, shell system and hot box pose easy threat of pinhole formation.

## CONCLUSION

Although introduced in 1958 along with PNB as first synthetic binder systems in world market, FNB took long time to reach Indian Foundries, in fact much later than Alkyd and PNB.

Today's FNB (modern) formulations in India are not only capable of meeting all the requirements of Indian foundry men, both ferrous and non-ferrous, but also competing with global suppliers in Indian and Middle East market. Further, it can be said with confidence that modern FNB in India are not inferior to any of the formulations available globally.

Modern FNB in India is a complete foundry binder compatible with most of sand being used commercially and climatic conditions. ■