Evolution of the Modern Surge-Bin in Mineral Processing Plants with Highly Variable Feeds

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ABSTRACT

Mineral processing plants require a storage buffer to bridge differences in production rates between mining and processing. Where coarse ores are processed, such as coal or hard rock, this buffer may be an ore stockpile or silo.

For wet-mining processes, e.g. dredging or hydraulic mining, or where fine ores are slurried close to the mining face, a surge-bin is used to contain the plant feed and smooth out the variations in mining rates. These bins have gradually evolved from simple storage vessels to units that are now frequently part of the mineral separation process itself, such as providing a desliming function to remove deleterious ultrafine gangue. This feed conditioning is often essential to achieve the levels of plant performance required in times of declining ore grades and or where inherent ore characteristics make separations harder to achieve.

To achieve these dual roles requires careful consideration of bin design factors such as geometry and lining selection and increased use of instrumentation and advanced, or remotely supervised, control systems. All this ensures they provide capacity to smooth out variations in mining rates and guarantees that when conditioning ores or adjusting slurry densities ahead of the plant it is achieved without loss of valuable minerals.

This paper examines the evolution of the modern surge-bin from a simple, so called, constant density tank with its inherent mass-flow compromises, limited feed preparation and beneficiation abilities, and footprint penalty, to a current state of the art surge-bin, the LFCU, with a control system which provides demonstrable steady outputs, while conditioning and in some cases beneficiating the ROM material and all from a highly compact unit.

It further discusses their use in other applications around the world, for example providing the necessary security for long distant high-density pumping systems; constant high density, low water usage, tailings disposal pipelines and high capacity ultrafine iron ore beneficiation.

INTRODUCTION

In the mineral processing industry, even the simplest of processing units requires a method of introducing material into the process which bridges the different production rates between mining and processing. For coarse ores, typically greater than say 5 to 10mm the required buffer can be a stockpile or silo which are invariably dry or low moisture storage units. The stockpile or silo discharge can then be regulated to the desired feed rate and with water added to the required density provide the process plant with the optimum feed conditions.

For fine ores where wet mining is utilized, e.g., dredging or hydraulic mining, or where the ROM material is slurried close to the mining face and pumped to the processing plant, a surge bin is utilized to smooth out the mining rate fluctuations and provide a steady feed rate, in terms of solids rate and slurry density, to the process by varying its contained solids volume according to the balance between the input and output. That is the solids level in the bin will rise should the mining rate exceed the bin output rate and vice versa when the mining rate is less than the discharge rate. This type of surge bin is the subject of this paper.

PROCESS REQUIREMENTS

In the traditional sense the surge bin is designed to carry out two functions:

1. To smooth out variations in input flows so that stable output flows can be maintained which, in turn, allows downstream equipment to be adjusted to operate at optimum conditions; and
2. To provide a storage of material so that output flows can be maintained during short interruptions to input flows.

In the first instance, so long as input flows do not exceed the maximum design input flows to the extent, or for sufficient time, such that the amount of material added to the bin would exceed its capacity and overflow the surge bin, the surge bin can operate effectively providing steady output flows in perpetuity. The target range of the surge bin capacity or level in operation is therefore set by the degree of “safety margin” the operator wishes to maintain to avoid bin overflows in the event of occasional severe and short-term spikes.

Where long term input and outflows are reasonably matched and input flow spikes are reasonably infrequent, short-lived and/or not extreme, the bin level can be set at almost any level. In this scenario, residence or retention time is largely immaterial.

The more frequent, extreme and/or sustained are any input flow spikes, the more defensively the notional operational bin level may need to be set.

To fulfill its second duty then, the surge bin target operating level should be set close to the maximum design capacity so that, in the event of an unforeseen loss or reduction of input flow, downstream operation is maintained for as long as required before the input flow recommences and presumably catches up over time. If a known input flow downtime is approaching, the surge bin can be run to full design capacity just prior to the input flow interruption to maximise the volume retained in the bin and hence maintain downstream operation for as long as possible.

Clearly, maximum benefit from the surge bin is achieved when the input supply and output demands are reasonably matched over the medium or longer term and input spikes are not the result of very extreme flows or sustained operation above output flow rate.

Should the surge bin be setup with a continuous overflow it will provide additional de-sliming of the ROM feed material.

CONSTANT DENSITY TANK TO SURGE BIN

Perhaps the original slurry surge bin concept followed the dry storage silo principle where a volume of slurry was held at or marginally higher density than the discharge density required. This type of surge bin acted somewhat like a large transfer hopper and generally were typified by operating without an overflow. Without an overflow no additional de-sliming of the feed occurs.

In addition, the CD tank without overflow does not take advantage of the natural consolidation property of the material to optimise the solids surge volume that consequently limited the available capacity to smooth out input variations. For example (*Table **1***), at 800t/h bin discharge rate, a CD tank with some 250 m^3 bin surge volume a CD tank would provide 10 minutes of surge capacity. Compared to the modern surge bin, taking advantage of the consolidation properties of the feed material, would provide some 50% more surge time (15 minutes) for the same volume and although the modern surge bin has a conical bottom section and the CD tank is cylindrical, they would be similar in overall dimensions (~7m Ø x ~7m tall).

Table 1: CD tank versus Surge Bin

Parameter	Unit	CD Tank	Surge Bin
Discharge Rate	t/h	800	800
Surge Capacity	minutes	10	15
Surge Mass	t	135	203
Surge Material Density	% solids (w/w)	40	80
Surge Material Density	% solids (v/v)	20	30
Surge Material Slurry Volume	m^3	253	203
Surge Material Water Volume	m^3	253	51

As the material consolidates in the modern surge bin, an up-current of liquid occurs that reports to the bin overflow which carries with it slimes (ultra-fine material) in a process Mineral Technologies refers to as “autogenous” classification. This has the benefit of providing additional desliming of the feed to the downstream process and in some cases can replace a second stage of desliming hydro-cyclones.

It is noted that as the surge volume contained in the CD tank is very sensitive to all but relatively minor feed fluctuations, particularly in regard to feed density, its application in most mining operations and certainly for dredging operations is not recommended nor appropriate.

MAXIMISING CONSOLIDATION IN THE MODERN SURGE BIN

Conventional surge bins were design as large tanks, under the assumption that simply storing a large volume of feed would even out fluctuations in feed rate and feed density to downstream equipment (Lyons et al, 2009). Typically, these conventional surge bin had sidewall angles of around 45 degrees above the horizontal and designed without consideration of the flow properties of the material.

In the past, surge bins were not designed to promote mass flow and instead operated with funnel flow (Figure 1) with a rat-hole in the centre of the bin allowing the incoming feed to pass straight through the bin. Interruptions in feed caused the consolidated material hanging up on the bin sides to slough off, sending high density slugs forward to the processing plant (Lyons, et al, 2009).

To overcome some of these material flow problems, surge bins were designed with 60degree sidewall and agitation water was injected near the pump suction point to fluidise the material. In some later surge bins, system was added to draw water from the top of the bin and inject into the underflow pump suction point. Underflow density could be controlled by throttling the waterflow through this bypass using valves. These surge bins operated reasonably well within a narrow range of solids levels inside the bin, but outside this range the pressure differential between the slurry suction and the bypass suction made density control difficult (Lyons, et al, 2009).

A change of thinking started slightly more than 10 years ago: the slurry in the surge bin is considered as a consolidated bulk solid in saturated conditions instead of a viscous liquid. The surge bin is then designed more like a silo than a slurry tank.

It has been shown (Lecreps and Wiche, 2013) that Jenike’s design principles can be applied to the design of modern surge bins handling slurries if the test work is conducted in a submerged condition. In other words, when designing bins to treat water and mineral ore slurry mixtures, the mixture is should be considered a bulk solid under saturated conditions, rather than as a viscous liquid.

One major benefit of the modern surge bin design is the capability to handle very high density material (>80%w/w) by achieving mass flow through adherence to Jenike’s design principles. Storing the surge bin feed at higher density increases the solids storage capacity of the tank. Furthermore, the process of consolidating the feed displaces a large volume of liquid in a rising current that can be used to achieve a separation, or desliming step. In some cases, a beneficiation process can be achieved (Hasan, et al., 2021).

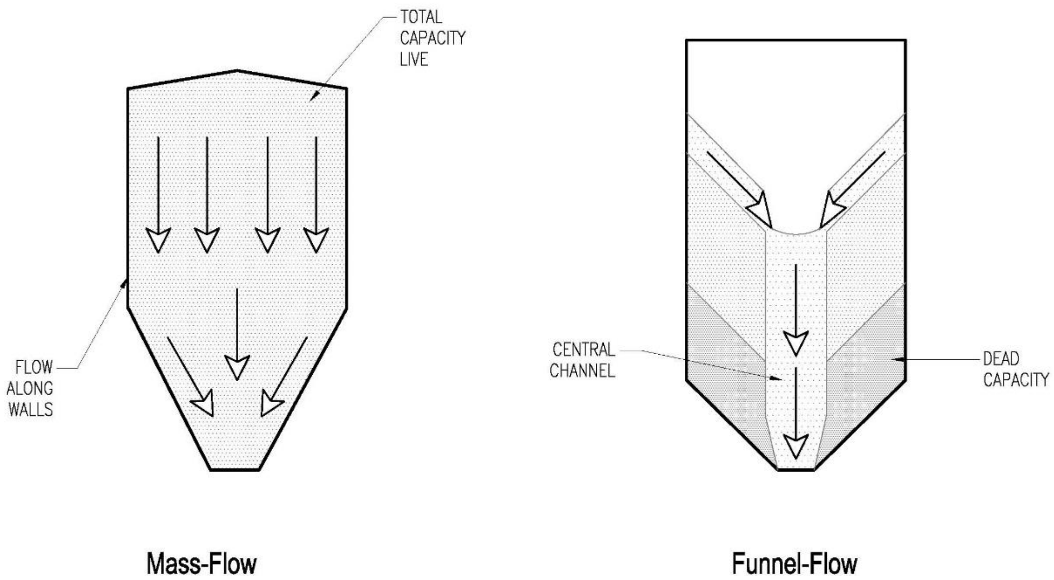

Figure 1: Mass Flow vs Funnel Flow

MODERN SURGE BIN OPERATING STRATEGY

By way of an extreme example demonstrating how the modern surge bin coupled with an optimised production strategy manages a highly variable mining operation (by a floating dredge) and provides a very stable and consistent feed to the wet plant, a simulation of an African mineral sands operation is presented below. The operation has a name plate design capacity of 500 t/h and consists of a floating dredge supplying a floating wet concentrator spiral plant.

Dredge Operation

The dredge in this operation would be considered somewhat oversized for optimum synchronisation between the dredge output rate and the WCP feed rate, which tends to make the output in terms of the solids rate extremely variable and difficult to regulate. This factor tests the surge bin operation and clearly demonstrates its effectiveness. It is noted that the dredge volume output is well regulated.

The dredge output for the simulation has been based on actual data gathered from the operation data logging system and is tabulated (*Table* ***2***) below.

Table 2: Dredge Output

Parameter	Unit	Value
Upper Push Rate	t/h	1200
Upper Reduced Rate	t/h	1000
Minimum Rate	t/h	10
Maximum Volume Rate	m^3/h	1600
Minimum Volume Rate	m^3/h	1400
Bin Level Reduced Rate Trigger	t	100
Bin Level Push Rate Trigger	t	50

The “Upper Push Rate” is the maximum instantaneous production rate derived from the plant SCADA system and is triggered when the surge bin reaches the minimum operational level, while the “Upper Reduced Rate” is a notional reduction or easing off in the maximum production rate which is triggered when the surge bin reaches the maximum operational level.

Surge Bin

The surge bin in this operation is primarily provided to stabilise the dredge output rate as feed to the WCP. The relevant surge bin design data and simulation parameters are tabulated (*Table* ***3***) below:

Table 3: Surge Bin Design Parameters

Parameter	Unit	Value
Total Maximum Live Capacity	t	125
Maximum Rougher Spiral Feed Rate	t/h	520
Minimum Rougher Spiral Feed Rate	t/h	480
Maximum RSF Volume Rate	m^3/h	880
Minimum RSF Volume Rate	m^3/h	860

Simulation

The simulation output is depicted in *Figure 2* below:

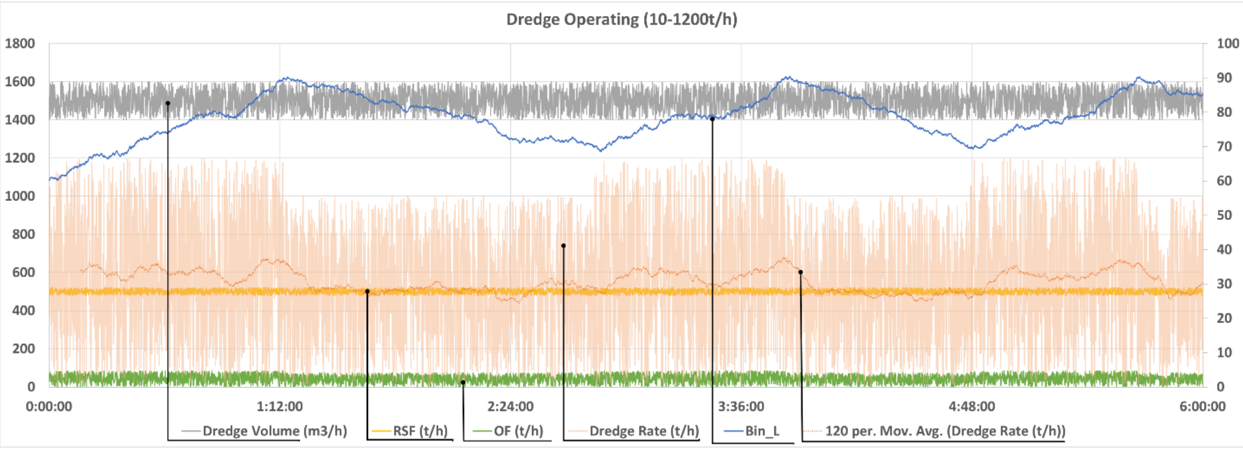

Figure 2: Simulation Output

Figure ***2*** clearly indicates that incorporating a push and reduced maximum dredge output rates (t/h) that are triggered by the minimum and maximum bin levels stable rougher spiral feed can be sustained.

Although this strategy has not been adopted it is useful to note that as depicted in *Figure* ***3*** below similar stability of the rougher spiral feed is being achieved.

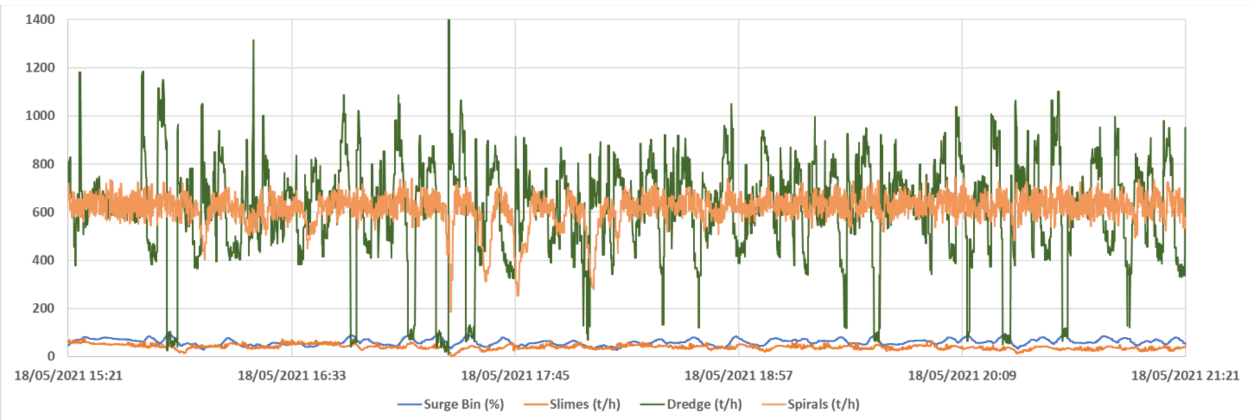

Figure 3: Actual Plant Trend Data

BENEFICIATION IN A MODERN SURGE BIN

Mineral Technologies (MT) worked with a prominent Australian iron ore producer over five years (starting in 2017) to implement gravity separation technology based on the modern surge-bin design for the beneficiation of ultrafine magnetite.

Extensive laboratory and pilot-scale test work has shown that, when well liberated, the magnetite can be efficiently separated from the gangue material using a modern surge-bin design referred to as Lyons Technology. Four Lyons Units, with a combined throughput capacity of 4500 t/h solids, reduce the SiO_2 content by a factor of approximately 2.2 (from 19.7% to 9.0%) whilst upgrading the magnetite Fe content by a factor of approximately 1.2 (from 53.7% to 63.6% Fe) (Hasan, et al, 2021).

Figure 4 and Figure 5 show these results graphically, whilst Figure 6 provides a qualitative visual illustration of the upgrade.

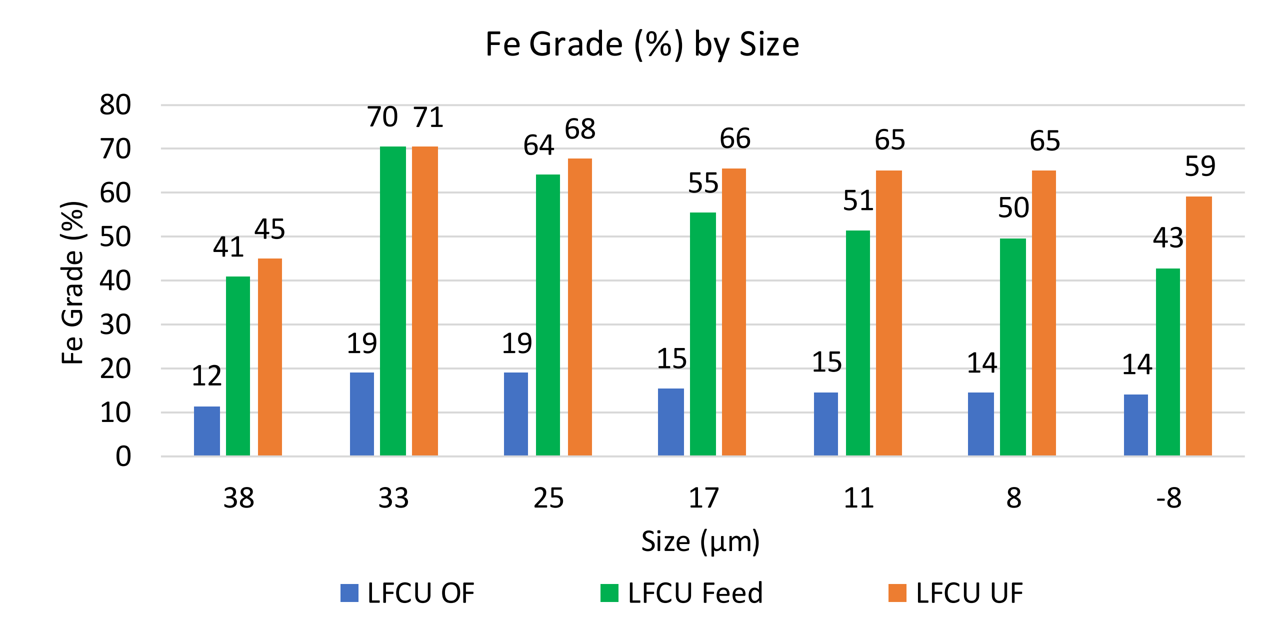

Figure 4: magnetite beneficiation results using modern surge-bin technology, Fe grade by size.

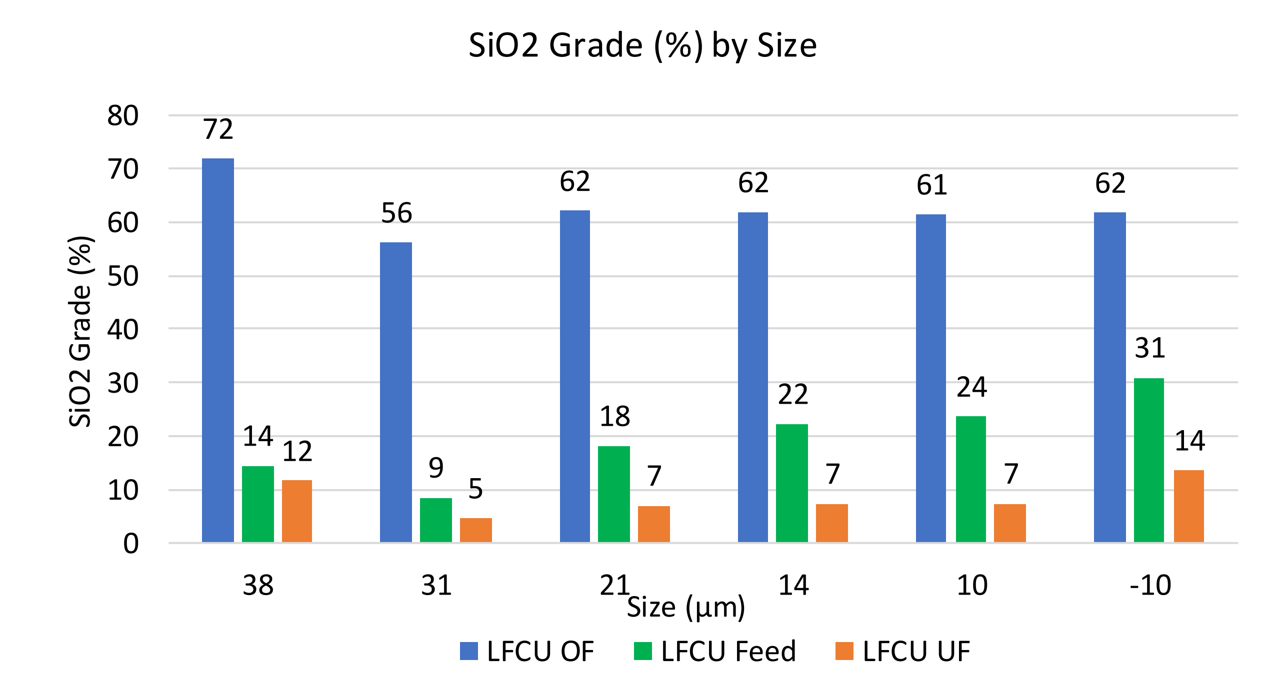

Figure 5: magnetite beneficiation results using modern surge-bin technology, SiO_2 grade by size.

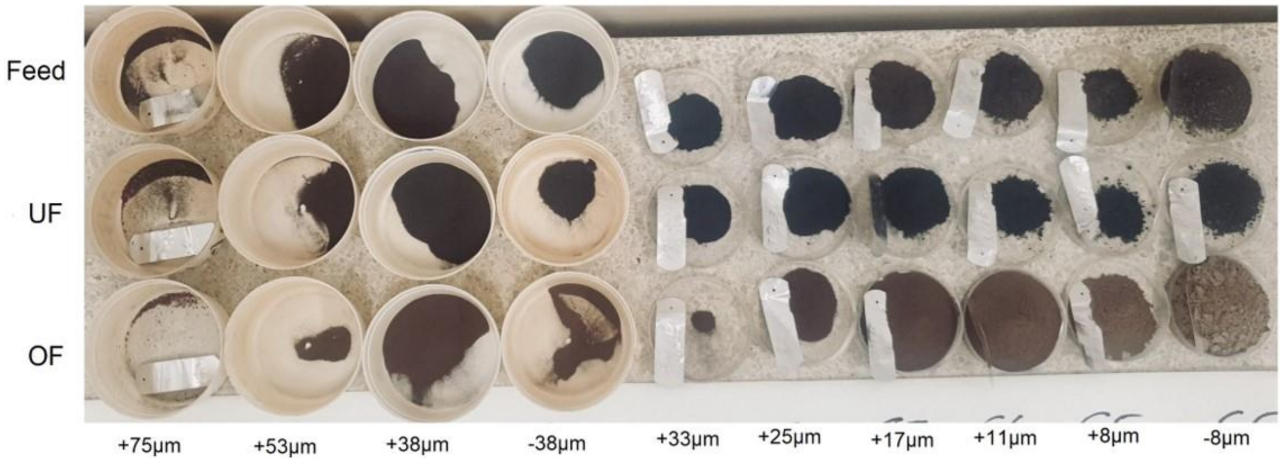

Figure 6: magnetite beneficiation results using modern surge-bin technology.

CONCLUSIONS

The modern surge bin:

- copes with extreme variations in mining rates
- provides the necessary stability of feed (rate and density) to down stream process stages to ensure they can operate optimally
- ensures continuity of feed to downstream processes during mining disruptions
- will provide additional de-sliming function
- can provide beneficiation of heavy values to the bin discharge.

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