**Light Metals 2014**
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## ALUMINUM REDUCTION TECHNOLOGY

## Environment II

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# Abart CDS - A New Compact Multi-Pollutant Pot Gas and Alumina Handling System

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## Abstract

A new modular Abart CDS has been developed that integrates silos, alumina handling, heat exchangers, fans, $SO_2$ scrubber and stack into a compact and efficient multi-pollutant pot gas treatment and recovery technology with incomparable footprint. The system is based on standardized modules that allows for short delivery time and early start-up. Each module includes an individual fan and optional $SO_2$ scrubber located directly on top of the module. This compact design reduces overall pressure drop and energy requirements for operation of the fans. This paper updates the previously reported experiences from the first full scale installation in Norway with new results on the integrated $SO_2$ scrubbers that were retrofitted in 2012/13.

## Introduction

Gas Treatment Centers (GTC) for aluminium smelter potlines are traditionally arranged in the courtyard between pot rooms and handle vast quantities of pot gas (3- 4 million $m^3$/h) in a large number of filter compartments (15-30) with demanding space requirements and challenging control of operation (see Figure 1).

For operational flexibility and gas and alumina flow considerations, the GTC is made up of a number of identical compartments that operate in parallel. The number of compartments could be as many as 30 or above which may be challenging to tune, operate and to detect failures or faults among the individual units.

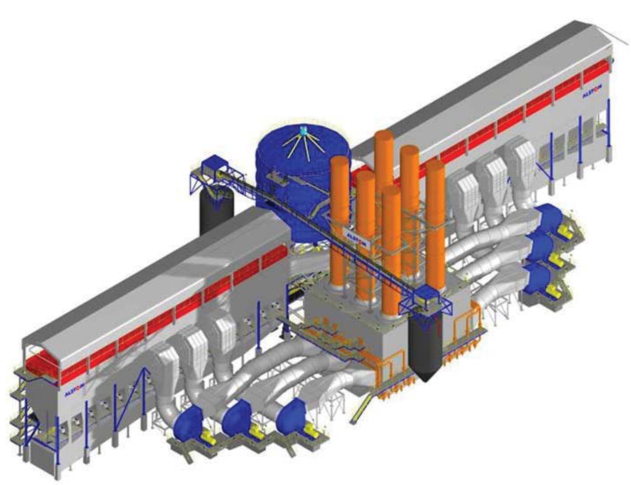

Figure 1. Traditional GTC arrangement for new smelters (including $SO_2$ scrubbing).

As specific pot production is boosted, often the pot gas temperature increases. Higher pot gas temperatures challenge the HF removal efficiency. Fluoride emissions from the GTC shows a sharp rise when pot gas temperatures exceed 110 °C [1]. The traditional way of cooling high temperature pot gas is bleeding-in ambient air to achieve an acceptable gas treatment temperature (110-115ºC). However, with an ambient temperature of up to 50°C, this method may increase the size of the GTC by more than 30% and increase the fan power requirement accordingly. The effect on the HF emission is moderate and sometimes inadequate. Also the additional filter bags increases maintenance costs. Installing a heat exchanger is an alternative solution that not only reduces the size of the GTC, but also results in large savings in the power consumption and reductions in total HF emissions. In addition, the value of the recovered energy alone often can justify the added investment cost of the heat exchanger.

Present GTC's demands more and more footprint. The space available often restricts how the different components may be arranged. Primary alumina silo, ducts, dry scrubber, fans, stack, secondary silo including air lift and pot feed system and sometimes wet scrubbers for sulphur dioxide abatement all demand footprint. In addition the ducting leading the gas from the pots to the GTC calls for efficient fluid dynamics design to minimize pressure drop.

## The Compact Abart-C Module

The compact Abart-C module was first introduced with the DDS-concept (Decentralized Dedicated Scrubber). This concept changed the thinking of incremental growth of potlines and GTC's [2]. The compact design of the DDS is based on the Abart-C module and one module integrates all components like fresh and enriched alumina storage, fresh alumina metering and transport, heat exchanger, reactor/filter, alumina recycling feeder, fan and stack and optionally wet $SO_2$ absorber (see Figure 2). The arrangement is very flexible, and can be adapted to specific customer demands, as the customer can select whether components are included or not. The integrated fan on filter top is a distinguishing feature of Abart-C

Many plants prefer the central GTC over distributed solutions for various reasons. Alstom therefore now introduces the centralized version of the Abart-C module, Abart CDS (Centralized Dedicated Scrubber). The Abart-C module is made in two basic sizes (Abart-C 308 or Abart-C 600) and each module is capable of treating between 50,000-110,000 $m^3$/h of pot gas. Each module is serving typically 5-12 pots, thus enabling an easy incremental growth of a smelter line.

The modules are arranged to fit the specific layout and duct arrangement of a specific plant. Based on customer requirements, a few Abart-C modules may be grouped together and arranged close to the pots for serving typically a section of pots (30-45 pots), i.e. an Abart DDS, or alternatively with 15-30+ modules in a centralized location, i.e. an Abart CDS serving more than 200 pots.

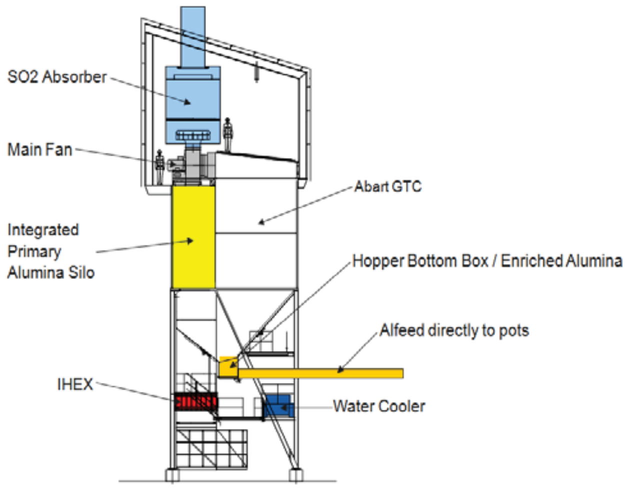


Figure 2. The integrated silo, $SO_2$ scrubber and fan on top, for one Abart-C module.

The Abart-C module features an improved gas flow control, which optimizes the filtration velocity and contributes to improved robustness. The HF emission performance of the modules is improved through the unique control of gas flow through each module by dedicated fan on top of each module. This allows five percent higher gas flow compared with the standard Abart.

The basic design of Abart-C is extremely adaptable with regard to transport and local site conditions. Components of this modular based design are preferably assembled in a workshop and delivered directly to site. Typical components are the filter, hopper, reactor, inlet duct, filter top, fan/motor assembly, $SO_2$ absorber and IHEX heat exchanger (Figure 2). This modular design and improved constructability gives shorter erection time and allows for early start-up of production pots.

The Abart-C technology includes a two stage counter current HF adsorption process, even though the stages internally operate in co-current mode. This process principle reduces the effects of moderate variations in upstream conditions, such as fluoride concentration as well as alumina flow and quality. The operating mode is as follows. Fresh alumina is injected into the gas in the filter stage, downstream of the patented reactor where the pot off-gases enter the Abart C module. The high capacity fresh alumina is therefore used at the tail end of the process, where the fluoride concentration is low. This dramatically increases the "driving force" for HF adsorption by the alumina, resulting in a stable low emission level. The alumina from the filter is led to the reactor, where it is blended into the incoming gas and recycled numerous times into recycled alumina.

**The Centralized Dedicated Scrubber - Abart CDS**

<u>The CDS concept</u>

As many smelters embrace the concept of a centralized GTC, Alstom used its experience of the DDS system to develop a centralized arrangement. The centralized GTC arrangement is called Centralized Dedicated Scrubber – CDS to distinguish it from the Distributed Dedicated Scrubber (DDS). Both systems are based on the same Abart-C module.

<u>Alumina Transport and Storage</u>

The alumina transport and storage can be significantly reduced and streamlined in a central dry scrubber by utilizing Abart-CDS.

The modules can be directly fed with fresh alumina by a pneumatic transport line from the central storage silo (see Figure 3). The traditional arrangement includes many silos that are maintained filled at 90-100% most of the time. With normal funnel flow silos, most of this storage space is never actively in use, and the material can harden after long term storage. The actual available material can be significantly less than the silo size indicates. Abart-CDS includes an integrated primary alumina silos large enough for 1-2 days of operation. They can be refilled quickly in case of stoppages. If more than 2 days of storage is needed, the integrated silos can easily be extended.

The need for enriched alumina storage is minimized since the primary alumina can be fed directly from the many integrated primary silos in case of emergency. This provides a very safe and efficient gravimetric filling of alumina with a reduced number of alumina transports as illustrated in Figure 3. Less alumina transports not only minimize particle degradation and segregation, in addition this reduces the number of critical equipment parts that can fail and prevent alumina to be transported to the pots. This concept is based on an overall balance of HF emission from the pots collected in the scrubber and directly returned to the pots, and therefore it is referred to as a "just in time" system.

However, to accommodate traditional storage philosophy, the Abart-C can also be delivered with traditional silos.

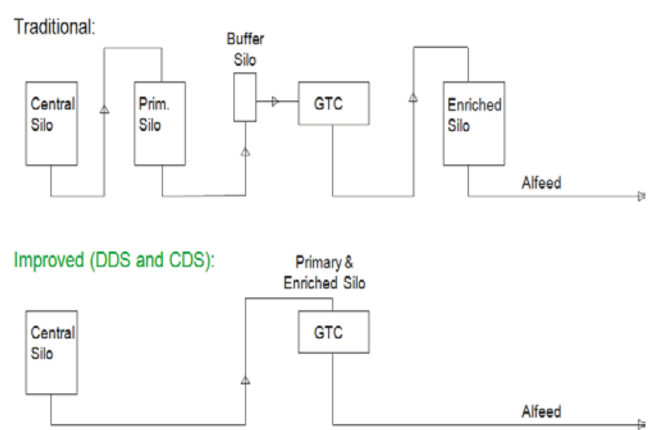


Figure 3. Alumina Flow schematics of a traditional GTC and the new CDS concept with integrated silos.

Fans and Energy Consumption

Main fans located on top of the filter is one of the main features of the Abart-CDS and will give a number of benefits such as:

a) Saving of ducting and pressure drop
b) Elimination of large concrete foundations required for a common fan system on the ground.
c) Only medium voltage (440 Volt) required with reduced cable and starter complexity.
d) No oversizing due to N-1 redundancy
e) Standard fan size and robust design
f) Improved fan efficiency
g) Easy fan maintenance and replacement
h) Reduced footprint

Of the above benefits the improvement in the overall fan efficiency should be emphasized. This is mainly a consequence of the large number of smaller fans running during normal operation in the Abart–CDS concept. With many fans (e.g. 30 fans) in operation it is not necessary to oversize the fans for the case that one fan is out of operation. Additionally with the traditional common fan arrangement on ground (typically 4-6 fans), each fan has to be oversized as much as 33% to handle the increased flow during N-1 operation.

This has serious consequences not only for the cost and size of the fan. For example, the motor and starter, etc has to be oversized correspondingly. In addition the overall fan efficiency of the traditional common fan arrangement suffers since not only must the fan in normal operation be heavily throttled, but also large compromises must be allowed for when selecting an optimal point of operation. This weakness may be partly dealt with if an N+1 fan design is chosen, but this is normally not done due to obvious cost issues and also due to the fact that all fans should be operating to avoid issues with bearings, etc.

In a typical Abart-C example, the gas volume from one module can be handled by a fan with 200 kW motor. With 32 compartments this equals 6.4 MW. By comparison, in a recent example a traditional GTC needs 6 motors, each approximately 1.5 MW, equal to a total of 9 MW.

In a typical example of traditional fan arrangement, an overall fan efficiency of only 70% was calculated, while for the same case the Abart-CDS standard fan gave an efficiency of more than 85%. This difference in efficiency gives a calculated electrical energy cost of approximately 35 million kWh/year for a project in the Middle East.

On top of the improvement in overall fan efficiency, the saving in pressure drop in the reduced fan inlet/outlet ducting in the Abart C module is in the order of 250 Pa. This equates to additional savings of 9 million kWh/year for the same project. With an energy cost in the range of 3 Euro cents per kWh, these two savings combined correspond to savings in the range of 1.3 million EUR per year.

Space / Area

The Abart-CDS is an extremely compact and efficient multi-pollutant control technology with incomparable footprint.

One example of a double line configuration of the Abart-CDS is shown in Figure 4. This fully utilizes the Abart-C module concept. There are several optional configurations that may be used such as a common central stack or a central $SO_2$ scrubber arrangement. Silos may be arranged at both ends or in the middle of the CDS plant.

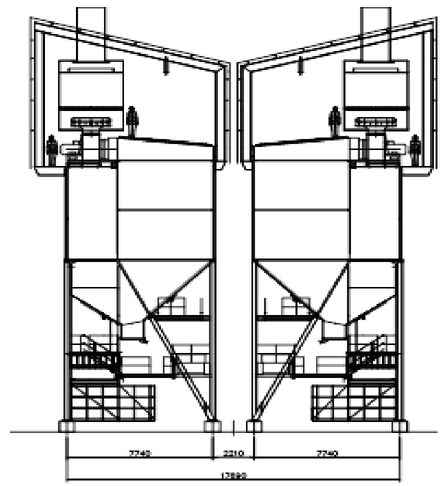

Figure 4. The CDS (A1) arranged in a double line configuration (including $SO_2$ scrubber).

The arrangement where only the fan on top is utilized, silos are located the traditional way and the stack is a common stack as demonstrated in Figure 5 below.

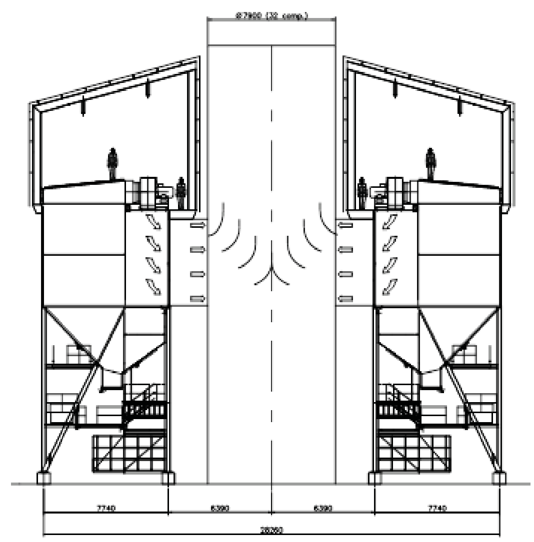

Figure 5. CDS (B2) with common stack and traditional independent silos without $SO_2$ scrubber

A footprint comparison of the CDS with and without $SO_2$ scrubbers is shown in Tables 1 and 2. Depending on the degree of integration and plant layout, the footprint can be reduced to as little as 25% if arranged as per Figure 4 above, or 64% for the arrangement in Figure 5, where both footprint percentages are compared to that of a traditional GTC layout as seen in Figure 1.

Table 1. CDS footprint needs relative to traditional GTC arrangements for systems including $SO_2$ scrubbers.

| Model | Type | Silo | $SO_2$ scrubber | Fan | Stack | Foot print (%) |
|---|---|---|---|---|---|---|
| GTC Abart | Single line | Indepe ndent | 6 | 6 | 1 | 100 |
| CDS - A1 | Single line | Integra ted | 32 | 32 | 32 | 22 |
| CDS-A1 | Double line | Integra ted | 32 | 32 | 32 | 25 |
| CDS-B1 | Double line | Indepe ndent | 8 | 32 | 1 | 47 |

Table 2. CDS footprint needs relative to traditional GTC arrangement, without $SO_2$ scrubbers.

| Model | Type | Silo | Fan | Stack | Foot print (%) |
|---|---|---|---|---|---|
| GTC Abart | Single line | Independent | 6 | 1 | 100 |
| CDS - A2 | Single line | Integrated | 32 | 32 | 30 |
| CDS - B2 | Double line | Independent | 32 | 1 | 64 |

HEX Integration

The high gas temperatures of new smelters make it challenging to meet the HF emission legislation. HEX technology is an efficient way to reduce the emission levels [1]. The Abart-CDS can effectively include Alstom's heat exchanger technology (IHEX) that is integrated in the reactors and filters. The integrated solution eliminates the need for additional bypass dampers, ducts, etc, and reduces the need for extra stairs and platforms.

The high level of integration and standardization brings the capital cost of the IHEX down to a level where it can compare with other cooling technologies that sometimes require less capital expenditure such as air dilution and water injection. One case that was investigated extensively was for Alba Line 4 [1] where it was demonstrated that the IHEX provided:

- Stable potgas flow through GTC
- Reduced footprint and size of GTC
- Reduced main fan power consumption
- Lower operation cost
- Possible utilization of 50 MW waste heat.

Water injection was not found to be cost effective especially since it could only provide cooling to 135C. At lower temperatures the calculations showed that the fine atomized water droplets did not get enough residence time to evaporate completely in the relatively short duct length available. In this case excessive corrosion and scaling is expected as well as significantly reduced lifetime of the filterbags due to increased hydrolysis.

Clogging of nozzles, stratification of the gas flows and coagulation of fine droplets were identified as additional issues as well as increased HF emissions due to regeneration of HF in the filtercake (this is documented in [4] and shown below in Figure 6).

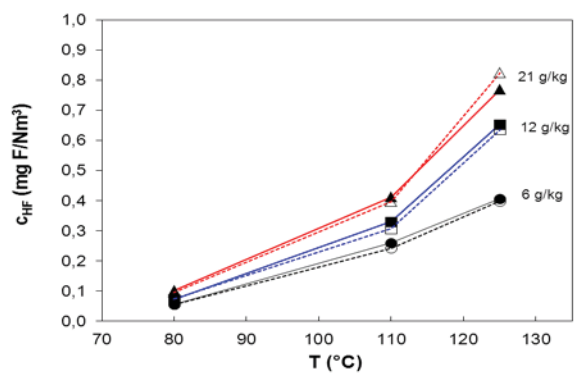


Figure 6: Chemical regeneration of HF in the filter cake as a function of water humidity and gas temperature as documented in [4].

For Alba line 4 it can be estimated that the operational costs is in the order of 0,5 to 1 million EURO lower with the IHEX technology compared to the other available technologies (such as air dilution and water injection). On top of this the IHEX technology gives the option to valorize in this case 50 MW of waste heat for e.g. adsorption cooling or desalination purposes. The valorization of low grade waste heat is a global challenge and has been studied extensively, and reasonable profits can be calculated for the aluminium smelter case [5]. This gives the aluminium industry the possibility to significantly and profitably reduce its $CO_2$ footprint.

Alfeed Integration

Alfeed is Alstom's system for feeding enriched alumina to the pots [3]. It can be efficiently integrated with the Abart–CDS, feeding enriched alumina by gravity directly into the Alfeed system. This eliminates the need for a separate enriched silo and additional alumina transports as discussed above. Alternatively, Alfeed can be fed from separate enriched silos as per the traditional way.

Integrated $SO_2$ Scrubber

The Abart-CDS can now also be delivered with integrated wet scrubbers for $SO_2$ abatement. The first full-scale installation of 5 such wet scrubbers was started in May 2013 and has shown good $SO_2$ removal as discussed later.

Traditionally wet scrubbers are built as several large concrete modules placed on the ground. Alstom wanted a more flexible solution in line with the philosophy behind the Abart-C module:

- Modularized
- Easy to install
- Standard components.

A new scrubber had to be developed and integrated with the filter and fan. With the new concept, the wet scrubber is placed directly above the fan as shown in Figure 2. No extra space, foundations or other provisions are needed except for the wet effluent handling system.

The new concept introduced several challenges that had to be overcome:

- Irregular gas flow distribution out of the fan
- Ensuring no water flows into the fan

In terms of utilizing the available space it is very advantageous to have the scrubber located above the fan. With such an arrangement it is also necessary to ensure that liquid from the scrubber cannot flow from the scrubber into the fan. The special gas inlet of the scrubber ensures that water cannot flow back into the fan. It also ensures easy draining of the scrubber. This design and the scrubber integration is a patent filed solution.

The gas flow distribution from a fan is irregular and the wet scrubber needs a homogenous gas flow distribution. Much effort was therefore put into a special scrubber inlet that homogenizes the gas flow, regains the fan pressure (low pressure drop) and ensures good wetting of the gas for $SO_2$ absorption.

Multi-phase Computer Fluid Dynamics (CFD) simulations were performed and compared with experimental lab trials of a scaled down model to arrive at an optimal scrubber geometry that addressed the various concerns. An example of such a CFD simulation is shown in Figure 7. The gas velocities in the inlet are very different, but the gas velocities in the scrubber part are homogeneous.

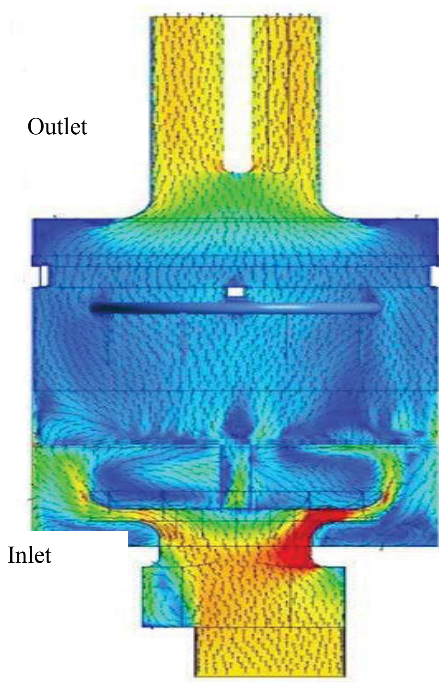


Figure 7. CFD analysis was used extensively in order to arrive at an optimum solution of the scrubber internals.

Each scrubber is sized for and treats the gas from one filter compartment (i.e. one fan) giving full N-1 operation.

The scrubber is made of lightweight GRP (Glass fiber Reinforced Plastic) and is installed directly above the fan, suspended from the roof structure. The advantages of the new scrubber are multiple compared to the traditional scrubber:

- No need for extra space or special concrete structures
- Can be used with any kind of liquid like NaOH (soda) or seawater.
- Easy to transport and install
- Based on a modular design and integrates with the filter within the space allocated
- Reduced costs compared with traditional wet scrubbers,
- Reduced fan power compared with traditional wet scrubbers
- No extra ducting
- No corrosion issues as it is made of GRP.

Figure 8. Abart DDS with wet $SO_2$ scrubbers installed.

Results of $SO_2$ Scrubber

Five new full scale wet scrubbers were recently retrofitted on a Abart DDS that has been in operation since 2007 [2]. This aluminium smelter is an inland plant and the scrubbing liquid used is NaOH. The scrubbers were put into operation in May 2013 and are now, after initial start-up, in full operation. The scrubber reduces the total $SO_2$ emission.

The full performance test data are not analyzed yet, but the preliminary analysis is shown below.

Each of the five scrubber modules treats up to 55,000 $m^3/h$. The gas from the pots contains between 200-300 $mg/m^3$ $SO_2$ depending on (among other things) the types of cells in operation and daily variations. The particle emission from the filter is very low, around 0.5 $mg/Nm^3$.

The table below shows results from one scrubber and two measurements on this scrubber.

Table 3. $SO_2$ removal efficiency

| | | |
|---|---|---|
| Incoming $SO_2$ from pots | 273 | $mg/Nm^3$ |
| Outgoing $SO_2$ after wet scrubber | 6 | $mg/Nm^3$ |
| Efficiency | 97.8 | % |

The results are similar for all the scrubbers, showing a reduction in $SO_2$ of more than 97% in average.

The dry scrubber recovers 99.8% of the fluoride in the gas. The fluoride content in the gas is therefore already extremely low, and the introduction of a wet scrubber further reduces an already low fluoride emission.

## Conclusion

The novel Abart CDS technology built on Abart-C modules is shown to have numerous advantages compared to the traditional GTC. The Abart-C compact version integrates silos, dry scrubber, fan, optional sulphur dioxide scrubber and stack into one unit. It offers an efficient multi-pollutant control system capable of meeting emission requirements at reduced power consumption.

It is shown that fan motor power can be reduced by more than 20%, by using smaller and more efficient fans. Shorter ducting also reduces the pressure loss, giving further reduced power consumption.

The design of Abart-CDS is very flexible with regard to sizing, extremely adaptable to local site conditions and the modules or components are easily transported to site. To keep up quality and speed up commissioning as well as startup, workshop fabrication can be used to the greatest possible extent.

The Abart-CDS gives a foot print as small as 25% compared with the traditional layout.

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