Lead ISASMELT™ Operations at Ust-Kamenogorsk

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Abstract

Ust-Kamenogorsk Metallurgical Complex holds a prestigious role in the world of lead smelting, and has been home to many developments over the past 70 years. Famous among these developments was the design and practical demonstration of the world's first KIVCET furnace thirty years ago. The most recent development was brought to fruition in 2012 with the installation of the world's largest Lead ISASMELT™ furnace. The construction and commissioning of the new ISASMELT™ plant was an achievement of delicate 'brownfield' engineering, with multiple interfaces to the existing smelter. Despite the complexity of integrating the new plant into the smelter, no production time was lost on the pre-existing sinter machine and blast furnace flowsheet right up until the first feed was smelted in the Lead ISASMELT™ furnace. This paper includes a description of the engineering challenges, and some results of the subsequent plant operation.

Introduction

Ust-Kamenogorsk Metallurgical Complex (UKMC) is a venerable smelting site, which has maintained a leading position in the development and implementation of non-ferrous pyrometallurgy for over 70 years. Zinc production began in 1943, and lead production began in 1952. UKMC grew to become one of the largest zinc and lead smelting operations in the world. It was for many years the headquarters of zinc and lead metallurgical development within the USSR, and from its technical and operating expertise many processes were developed. Among the most famous is the KIVCET furnace for smelting lead concentrates, which has been adopted by smelters in Italy, Canada and China.

For the past two decades lead production has been exclusively through a sinter plant, of Lurgi design, with most equipment originally installed in 1974. From 2004 onwards the sinter machine gases have been treated by a Haldor-Topsoe wet sulphuric acid plant. Although the Haldor-Topsoe plant is designed to suit low-strength SO_2 gases that would be unsuitable feed for a contact process, the sulphur in gases from the tip end of the sinter machine has only been 50 % utilized. An estimated emission of 13,000 t/y SO_2 has been attributable to these gases in a normal production year.

In 2006 Kazzinc sought to change its lead smelting flowsheet to decrease SO_2 emissions into atmosphere, but with an aim to retain as much as possible of the existing infrastructure, and to continue running the sinter plant up with minimal disruption until the new technology was ready to operate. The new smelter would have myriad interfaces with the existing smelter, and management of these interfaces would require delicate ‘brownfield’ engineering with close cooperation between the smelter operating personnel and the project implementation team.

Lead ISASMELT™ Project

After careful evaluation of the process options Kazzinc chose to build an ISASMELT™ furnace, with the technology, some design services and equipment supplied by Glencore Technology.

Duty of Lead ISASMELT™ Plant

The lead ISASMELT™ plant was designed to treat 291,000 tonnes per year of new lead-bearing material (nett of any fluxes, fuel or dusts that may be generated by the process itself). The Kazzinc feed materials are comprised of three main types:

- Residues from the zinc plant
- Lead concentrates from Kazzinc’s mines
- Lead battery paste from Kazakhstan sources
- Precious metal concentrates, sometimes containing lead, from various sources across Kazakhstan and central Asia.

Depending on the ratio of these materials, which varies significantly across a year, the feed to the lead ISASMELT™ can contain anywhere between 20 - 60 %Pb. The design basis considered that the plant would treat new lead-bearing materials with an average composition as shown in Table 1, at the instantaneous rate of 40 t/h.

Table 1: Design feed blend for Lead ISASMELT™ Plant

Zn (%)	Pb (%)	Cu (%)	S (%)	Fe (%)	SiO_2 (%)	C (%)	As (%)	Sb (%)	H_2O (%)
10.5	42.9	2.4	17.2	9.1	5.6	0.0	0.4	0.20	14.8

During the design stage it was recognised that the ISASMELT™ operating mode would need to afford the operators at Kazzinc a great deal of flexibility in operation, in order to cope with the potential fluctuation in material types and compositions that were foreseen. For most of the range, an oxidative lead smelting operation, producing only lead-rich slag, is the most tolerant and robust processing option available. Consequently the plant design considered that the principle method of operation would be an oxidative lead ISASMELT™ furnace, followed by a reduction furnace. In

Kazzinc's case, the existing blast furnaces were to perform the reduction duty, creating an overall flowsheet reminiscent of the ISASMELT™ operation described for Qujing, China [1].

Integration with Surrounding Plant

The ISASMELT™ plant was designed to:

- Receive pelletised lead concentrate, directly from the existing pelletiser sitting astride the sinter machine;
- Supply cast ingots of lead-rich slag, directly to the existing bins for supply of sinter to the blast furnaces;
- Supply sulfur-rich gas directly to the existing Haldor-Topsoe sulfuric acid plant, via the same duct and through the same exhaust fans used by the sinter machine; and
- Remotely control, via DCS, the existing feed conveyors and flux bin feeders of the sinter machine, which had never been automated previously.

In combination, the engineering required to achieve these objectives was challenging and time-consuming. However, the careful execution of these four objectives was considered essential in order to minimize the shut down time associated with transition from the sinter machine operation to the Lead ISASMELT™ operation, and also to minimize interference with the upstream and downstream operations of a complex 'brownfield' site. A diagram of the Lead ISASMELT™ plant, and the main material transfer points, is shown in Figure 1.

A key feature of the layout in Figure 1, is the relatively small footprint of the plant. The footprint was defined by site infrastructure, and the engineering had to rise to meet the challenge. There was only one suitable location on the site of UKMC where the four integration objectives could reasonably be met, and that was the historic site of three dismantled sinter plants. The site was bounded by the:

- return sinter crushing building to the east;
- sinter skip hoist to the west;
- sinter machine feed conveyor gallery to the north; and the
- return sinter pan conveyor gallery to the south.

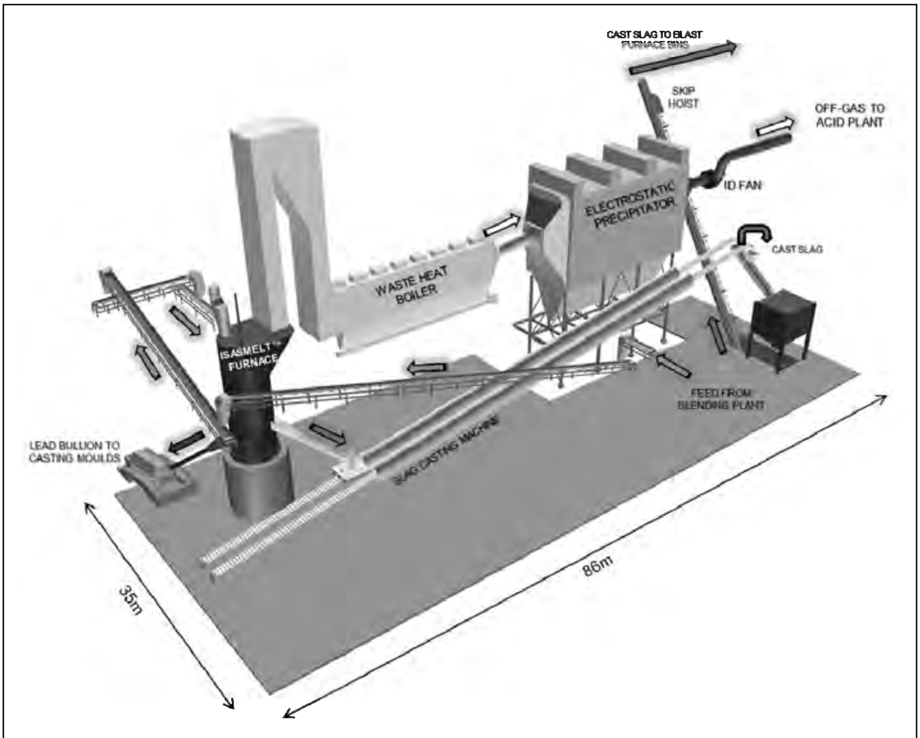

Figure 1: The Lead ISASMELT™ Plant at UKMC

Each of the surrounding unit operations had to continue operating throughout the construction and commissioning periods. Every spare metre of floor space was planned and used to fit the new smelting plant within an 86 m × 35 m footprint. The tightness of fit is illustrated by the artist's impression shown in Figure 2, in which the new (brown) building is contrasted against the old (light green) structures. Design of the compact plant layout, and cross-checking of site features, was performed largely by Kazzinc's in-house engineers with assistance by Engineering Dobersek GmbH.

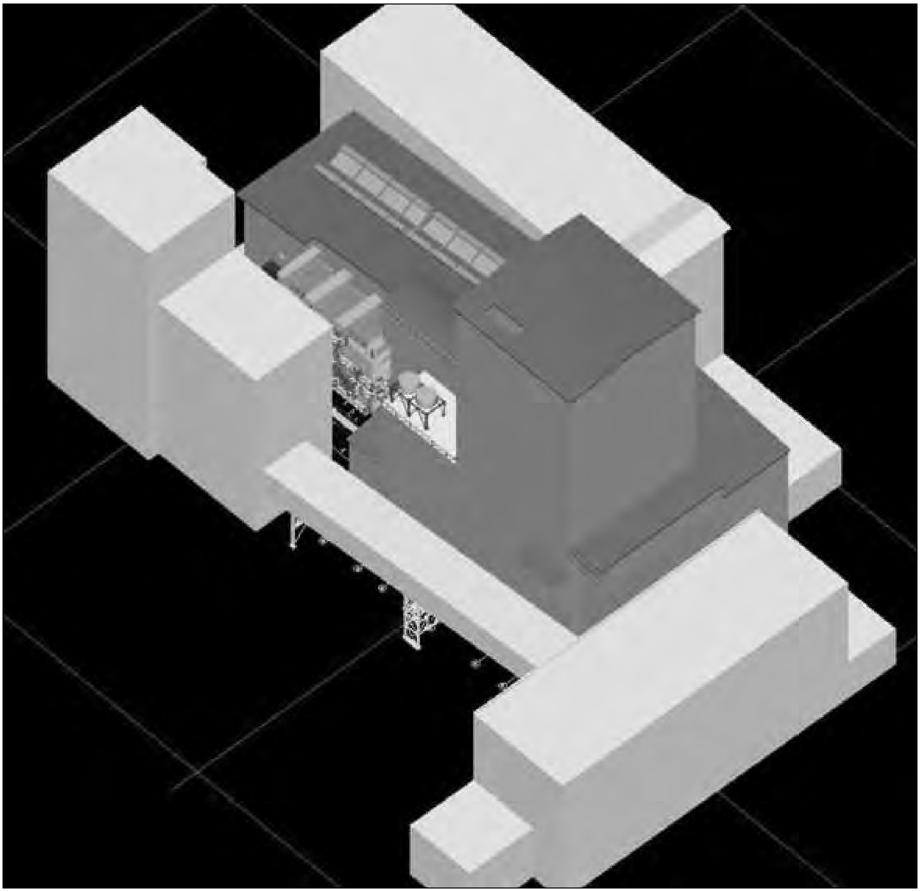

Figure 2: The Lead ISASMELT™ Plant at UKMC

Demolition and Restructure

The plant design took into account the complex task of 'brownfield' engineering, including the partial demolition of existing structures. The task would have been simplified if entire structures could have been demolished (see for example Figure 3) but this was not possible. Selective areas on upper floors of multi-storey buildings had to be supported and equipment kept in operation, while demolition of lower floors made way for new equipment. Careful, piece-wise demolition and reconstruction was required.

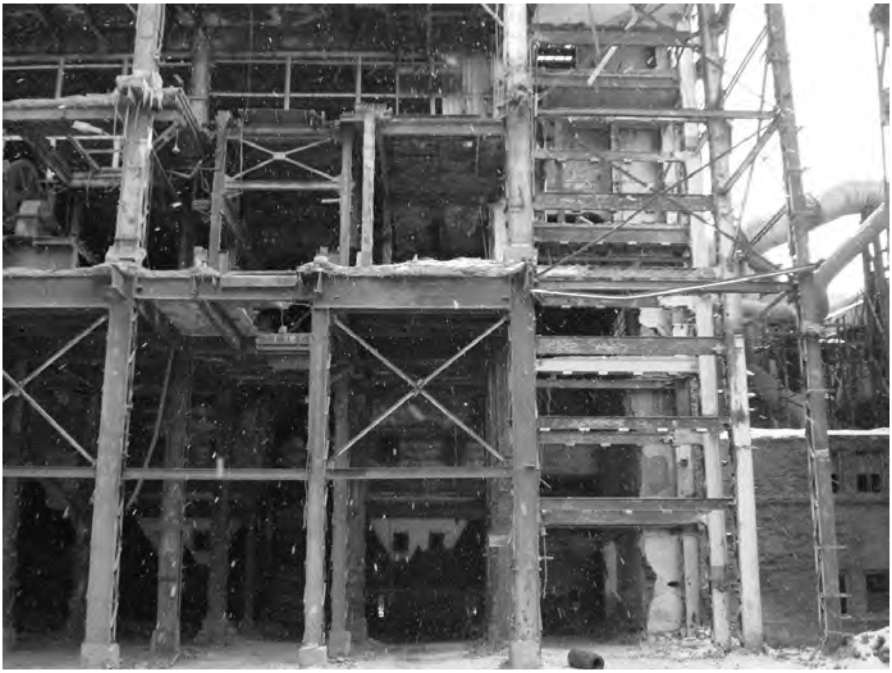

Figure 3: Construction site for the Lead ISASMELT™ Plant at UKMC

Erection

After partial demolition of the surrounding structures had cleared enough room, plant erection began delicately. Excavations to prepare new foundations were done with small machinery, sometimes manually, to enable maximum manoeuvrability around the footings of existing structures. The ISASMELT™ furnace foundation was among the first to be poured, and is shown in Figure 4, in which the partially-exposed footings of several other structures can also be seen at the periphery of the excavation.

Figure 4: Erection of the Lead ISASMELT™ Furnace at UKMC

Cut-in for Services and Materials Transport

The most challenging task in the Lead ISASMELT™ Plant project was to organise the cut-in for services and materials transport. The modernisation of the feed delivery system was a good example of the challenges that had to be met. The feed delivery system to the sinter plant was to be retained and reassigned for duty to the new Lead ISASMELT™ furnace. However, the sinter plant operation was engineered for local control of equipment units and the Lead ISASMELT™ Plant was engineered for automated remote control of equipment units. So each of the operating units in the lead sinter plant feed system had to be re-engineered and automated, ready for the new duty.

Approximately 3 months before the commissioning of the Lead ISASMELT™ Plant, all of the equipment in the lead sinter plant feed system (refer to Figure 5) had been automated, with the final electrical cut-in done during a planned 8-hour plant maintenance shutdown. From that point onwards, the equipment was run under the control of a remotely-situated operator, in what would soon become the Lead ISASMELT™ Plant control room.

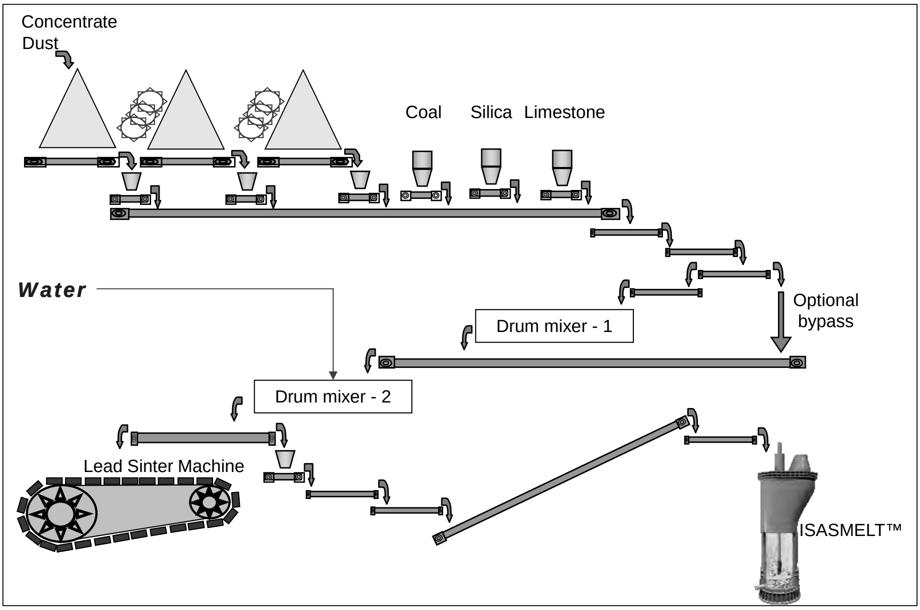

Figure 5: Common feed system of the lead sinter plant and the Lead ISASMELT™ Plant

Operator Training

Operators received both practical and theoretical training in advance of hot commissioning. Off-site training included stints of plant work at operating ISASMELT™ furnaces in Australia and the Peoples' Republic of China. On-site training included rehearsals of operating tasks, workplace safety procedures and plant theory tests.

An unexpected and useful benefit of the automation and early cut-in of the sinter plant feed system was that operators gained many weeks of experience in using the plant automated control system prior to the actual operation of the ISASMELT™ furnace.

Hot Commissioning

The furnace was heated ready for operation by the end of August 2012. Smelting began in September of the same year. There were some challenges to overcome in the following months of operation.

Feed for Start-up

As a result of the complex and time-consuming 'brownfield' engineering of the plant, the time of starting the ISASMELT™ plant was separated by some 6 years from the time of its initial design. Inside that 6 year gap Kazzinc had commissioned new lead mining assets, decommissioned old ones, altered a range of their internal plant recycle streams, and substantially changed the type of feed to be treated in the ISASMELT™ furnace. The combined feed materials (exclusive of fluxes and fuel) had a composition (averaged over the first 10 blended feed beds of 2500 t each) as shown in Table 2 at the time of starting the ISASMELT™ operation in September 2012.

Table 2: Start-up feed blend for Lead ISASMELT™ Plant

Zn (%)	Pb (%)	Cu (%)	S (%)	Fe (%)	SiO_2 (%)	C (%)	As (%)	Sb (%)	H_2O(%)
7.4	30.7	2.66	17.2	12.2	8.5	0.67	0.66	0.22	10.9

The major differences between the design feed composition in Table 1 and the actual feed composition in Table 2 were:

- The lead content was about 12 percentage points lower
- The arsenic content was about 0.3 percentage points higher
- The moisture content was about 4 percentage points lower
- Some organic carbon was present, where none had been expected

These differences contributed to the challenges of the subsequent operation period.

Ramp-up of Production

The first time that the ISASMELT™ plant achieved its design daily cumulative production was 5 weeks after smelting commenced. Maintaining the design production rate for periods longer than a few consecutive days was not possible until many months had passed, and the operation of some surrounding plant items had been optimised such as the slag casting machine, tilt bowl, waste heat boiler, electrostatic precipitator, feeding system, off-gas ducting, etc.

Tapping & Slag Casting Operations

The slag casting is a continuous operation, and requires a continuous feed of molten slag, which is achieved via the specially-designed ISASMELT™ tapping process. Tapped slag is distributed onto each strand of a twin-strand straight-line casting machine designed and supplied by Ormeto Yumz. The slag casting machine performance was found to be sensitive to the slag tapping temperature.

Owing in part to the lower lead grade of the incoming feed, the properties of the tapped slag were different from the vendor's expectations: the slag density was lower and the slag temperature was higher. This in turn meant that the slag casting machine was run at its maximum speed, raising the temperature of the slag briquettes at the discharge end of the casting machine. Some initial difficulty was experienced with reliably disengaging the slag briquettes from their moulds. Remedial actions included:

- Improvements to the design of the anvil that the mould trays impact near the head drum of the slag casting machine.
- Installation of a system for applying mould release agent to the tail end of the slag caster, upstream of where the tapped slag is received.
- Doubling the size of the cells containing the slag briquettes within each mould tray.

After these remedial actions were completed the disengagement of slag from the moulds became reliable.

Dust-handling Operations

The mass of dust collected from the ISASMELT™ furnace off-gas by the waste heat boiler (WHB) and electrostatic precipitator (ESP) was typically equivalent to about 7 % of the mass of the incoming feed materials. The typical dust particle has a diameter of about 10 - 20 µm, and accumulations of dust adhere strongly to steel surfaces. The WHB was sized to accommodate the expected inefficiency of heat transfer, and the sticky dust did not adversely affect the WHB.

However, the ESP operation was impaired by the accumulation of dust near the off-gas inlet, and the ineffectiveness of the rappers to dislodge the dust from this area. The removal of internal steel protrusions eliminated anchor points from which the dust accretions could accumulate. This action, combined with raising the temperature of the incoming off-gas by 50 °C, and improvements to the rapper design, were sufficient remedies for the ESP to attain full functionality.

The WHB was operating with a much reduced off-gas volume compared with design expectations. This is mostly the consequence of the actual feed having a moisture content 4 percentage points lower than design expectations, and therefore a much reduced requirement for combustion of fuel and generation of off-gas. In fact, the typical furnace operation was often autogeneous and the WHB received around 30 % less gas than it was designed for. WHB convection section evaporator bundles were progressively removed so that the optimum heat transfer could be achieved, to keep the ESP below its permissible maximum inlet temperature, but without approaching the acid dew-point.

Blast Furnace Operation

Kazzinc proceeded with the modernisation project assuming that the existing lead blast furnaces would be satisfactory for treating the slag produced in the Lead ISASMELT™ Plant, with little or no capital investment required. This assumption has since been validated. The instantaneous capacity of the ISASMELT™ furnace to generate slag is approximately twice the instantaneous capacity of a Kazzinc blast furnace to smelt slag, so two blast furnaces are in use most of the time.

The ISASMELT™ slag typically contains less CaO than is required to meet the slag chemistry target of the blast furnaces. Consequently, beginning with the introduction of ISASMELT™ furnace slag, the addition of limestone flux to the blast furnace charge has been introduced as a standard operating practice. This has not presented any significant operating difficulty.

One unexpected aspect of the project implementation was that the change-over of blast furnace operation from treating sinter to treating slag was not a one-off step change. The blast furnaces became adept at treating stockpiled material, from either source, and for many months they treated varying compositions of slag and sinter, with the mix varying from 0 - 100 %. This afforded a good opportunity to evaluate the furnace performance when using ISASMELT™ slag as feed, compared to using sinter as feed. The general findings were as follows:

- The blast furnace uses less coke per unit of charge when smelting slag, compared to smelting sinter. The reduction is equivalent to approximately 2 percentage points.
- Addition of a sulphidising agent to the blast furnace charge is necessary to ensure that the excess copper in charge reports to a matte phase, rather than to a less desirable speiss phase.

Post-Commissioning Period

Within a year of the Lead ISASMELT™ plant beginning operation, Kazzinc decided to determine the extent of the operating flexibility of their new furnace. They prepared a special blend of feed containing the approximate composition shown in Table 3. The objective of the trial was to compare the operation of the ISASMELT™ furnace when producing lead bullion and slag, versus production of only slag (which is the typical operation, according to the process described in [2]).

Table 3: Feed Blend for Trial Smelting Period

Zn (%)	Pb (%)	Cu (%)	S (%)	Fe (%)	SiO_2 (%)	As (%)	H_2O (%)
3.9	58.9	0.3	14.5	6.7	3.9	0.1	10.4

The trial was successful, and the lead bullion tapping and casting facilities were commissioned and evaluated against their design targets.

The first replacement of the brick lining occurred 24 months after the furnace was first heated. Good performance of the refractory was noted in most areas of the furnace, and some localised wear areas were identified with remedial actions adopted in advance of the second campaign.

There are ongoing efforts to optimize the material specifications for components of the re-used sinter plant off-gas system, where the introduction of ISASMELT™ off-gas (containing reduced volumes of gas and much stronger concentrations of SO_3) has resulted in accelerated acid corrosion compared with past experience.

Future Prospects

The installation of the ISASMELT™ technology at UKMC is merely the latest in a long line of developments that stretch back over the past 70 years of the venerable plant. Now that it has been successfully incorporated into the flowsheet at UKMC the next challenge is to consider what flowsheet improvements could be made at the blast furnaces, or whether their replacement by modern technology is economically attractive. Evaluation of the options is ongoing. It has been recognised that the presence of the Lead ISASMELT™ Furnace now opens up options for future development that did not exist previously.

Conclusions

A Lead ISASMELT™ Plant has been successfully introduced into the smelting flowsheet of Ust-Kamenogorsk Metallurgical Complex. The new plant was erected and commissioned in a 'brownfield' site with great care taken to optimise the production of the existing smelting assets. Operation began with feed that varied from the original design basis, but the smelting technology was not significantly impaired by this discrepancy. The plant has now treated feeds varying in lead content from 30 - 60 %Pb, at instantaneous operating rates exceeding the original design by 20 %. The introduction of ISASMELT™ technology is the latest in a long list of smelting developments at Kazzinc, and the company goes forward contemplating other technologies for further improvements.

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