CASE STUDY REPORT
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RAW MATERIAL STRATEGY

# RAW MATERIAL OPTIMIZATION FOR HIGH-ALLOY STEELMAKING

## Charge and Alloying Strategy Optimization from Melting to Casting

### BEYOND EAF CHARGE CALCULATION

Move beyond furnace-focused charge design and evaluate raw material decisions across the complete metallurgical route.

### DYNAMIC ALLOYING DECISIONS

Continuously balance scrap, ferroalloy costs, recovery rates and process conditions to determine the optimal alloying strategy.

### TOTAL ROUTE COST MINIMIZATION

Optimize raw materials, alloying additions and metallurgical processes to achieve final grade requirements at the lowest feasible cost.


# FOREWORD

In high-alloy and stainless steel production, raw material decisions have a much broader impact than the cost of the furnace charge alone. Valuable alloying elements such as chromium, nickel, molybdenum and manganese can enter the production route through different material streams and at different process stages. They may already be introduced through alloyed scrap in the electric arc furnace, or they may be added later by ferroalloys and other alloying materials in downstream metallurgical units such as AOD, VOD, RH or ladle furnace.

Both strategies can be technically feasible. However, they do not necessarily lead to the same total production cost. A charge that appears expensive at the EAF may reduce alloying demand later in the route. Conversely, a low-cost furnace charge may generate high downstream alloying requirements and therefore become more expensive when the complete route is considered.

This is why raw material optimization for high-alloy steelmaking must go beyond classical charge calculation. The relevant question is not only which materials should be charged into the furnace, but where and when alloying value should be introduced across the complete process route. This includes material cost, chemical composition, element recovery, oxidation and slag reactions, downstream alloying demand and the final casting specification.

Unlike low-alloy scrap optimization, the main challenge is not necessarily unknown or unstable raw material chemistry. Many stainless and special steel producers work with high-quality, well-sorted and well-analyzed raw materials. The complexity arises because the economic value of these materials depends on their effect across the full route. A high-chromium scrap grade, for example, cannot be evaluated only by its purchase price and chromium content. Its real value depends on the steel grade, the required chromium path, recovery rates, decarburization practice, slag chemistry and the price relationship between scrap and ferrochrome.

Therefore, raw materials must be evaluated by their route value rather than by their isolated material price. A material can be expensive per ton and still reduce total cost if it replaces more expensive downstream additions or improves recovery. Conversely, a cheaper material can increase total cost if it causes additional alloying demand, unfavorable process conditions or limitations later in the route.

The practical challenge is therefore not only to know the chemistry of each material, but to determine how this chemistry should be used most effectively across the route. This requires a model that connects raw material cost, chemistry, recovery, metallurgical reactions, process constraints and final specification in one integrated calculation.

**The central question is not which EAF charge is cheapest, but which combination of raw materials, alloys, fluxes, energy and process steps reaches the final casting specification at the lowest feasible total route cost.**

**Dr. Stefan Griesser**
Head of Sales at qoncept technology GmbH

qoncept

PIONEERING TECHNOLOGIES

# MAKING INTELLIGENT PRODUCTION A REALITY

Software and engineering solutions that increase process efficiency, optimize raw material use, and increase operator safety in steelmaking.

## GLOBAL FOOTPRINT

| 15+ | 5 | 60+ | 19 | 40+ | 9 |
|---|---|---|---|---|---|
| Software Projects | Countries Software | Equipment Projects | Countries Equipment | Consulting Projects | Countries Consulting |

## PRODUCT PORTFOLIO

### SOFTWARE & HARDWARE

**qontrol MAPS**
Raw material management & charge optimization

**qontrol L2**
Level 2 automation & digital twins

**qontrol MES**
Manufacturing execution system

**qontrol LMS**
Ladle management system

**qurve AI**
Operator terminals & camera systems

### EQUIPMENT & DEVICES

**qouplerG**
Automatic gas coupling system

**qouplerM**
Patented multi-media coupler

**qouplerD**
Automatic slide gate coupling, globally unique

**Bins & Silos**
Complete industrial silo systems

**Engineering Services**
Custom mechanical design & revamps

### CONSULTING & STUDIES

**Metallurgical Process Consulting**
Measurable improvements in melt shop operations

**Digitalization & Software Strategy**
Feasibility studies and transformation roadmaps

## COMPANY HISTORY

### 2018 — FOUNDATION

Founded in Leoben, Austria, by metallurgists with strong industrial backgrounds.

Establishment of the internal software architecture creating the scalable foundation for modular qontrol integration.

### 2020 — MARKET READINESS – qouplerM & FIRST PRODUCT DEPLOYMENT

qouplerM, an automatic multimedia coupler, reached market readiness and was patented.

Implementation of the first productive scrap tracking system, marking the transition to operational digital steel production.

### 2022 — PATENT AND FULL STEELMAKING INTEGRATION

Patent granted for the automatic slide gate coupling system qouplerD. This expanded the portfolio into automated slide gate actuation and signal integration.

Implementation of the first productive steel plan management system (Level 2) on full scope.

### 2024 — NORTH AMERICAN EXPANSION & PLATFORM SCALING

Establishment of qoncept Americas Inc. to support North American customers.

Functional specialization of the qontrol platform with dedicated modules for heat optimization, ladle tracking, and advanced scrap yard management.

### TODAY — 100+ PROJECTS WORLDWIDE

Active operations across Europe, the Americas, and Asia.

# CONTENTS





# 01 WHY EAF CHARGE OPTIMIZATION ALONE IS NOT ENOUGH

Traditional charge calculation usually focuses on the input materials required for the melting unit. It determines whether a selected raw material mix can meet a target chemistry at the EAF or tapping stage. This approach is useful, but it only represents one part of the economic decision.

For high-alloyed steels, the chemical and economic target is not reached at the EAF alone. The final product specification is achieved across a sequence of metallurgical steps. The route may include EAF melting, AOD, V(O)D or RH treatment, ladle furnace alloying and final adjustment before continuous casting. Each process step changes the chemical composition, the recovery of alloying elements, the slag composition, the energy demand and the cost structure.

This means that a locally optimized EAF charge may not be globally optimal. A low-cost charge can increase downstream correction cost. A higher-cost alloyed scrap mix can reduce ferroalloy additions later. A material that seems attractive from a purchasing perspective may lose value through oxidation, slag reactions or poor recovery. Therefore, raw material optimization must be evaluated across the complete route as indicated in **Figure 1**, not only at the first process step.

A heat that looks cost-optimized after the EAF can still become expensive before casting if downstream reactions, recovery losses and alloying demand are not considered.

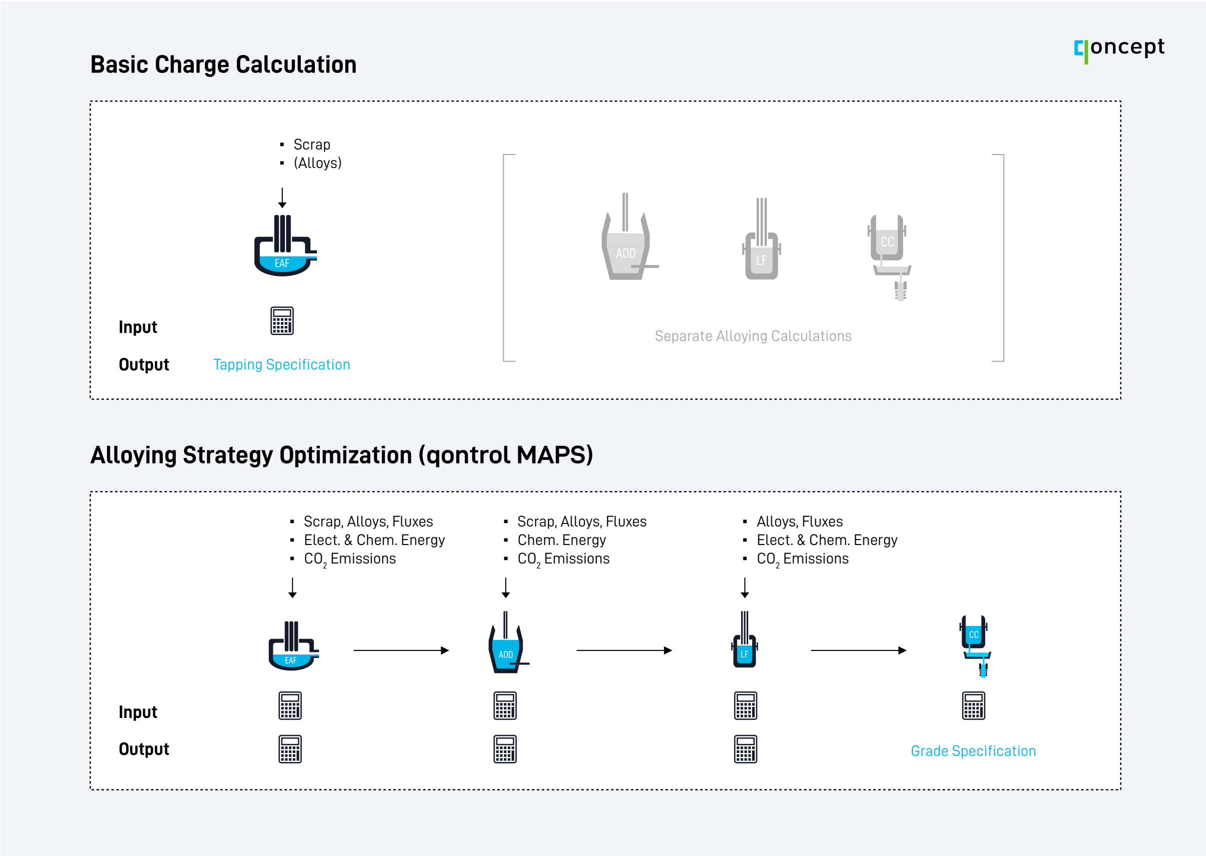


**Figure 1:** Schematic Comparison Between Traditional Charge Calculation and Combined Charge and Alloying Strategy Optimization.

This is particularly important for stainless and high-alloy steel grades, where small differences in chromium, nickel or molybdenum strategy can have a large economic impact. These elements are not only chemical components; they are major cost drivers. The optimization task is therefore not simply to meet a chemical target, but to decide where and how alloying value should be introduced into the process.

In practical production, a heat that looks attractive after the EAF may still be expensive by the time it reaches the final casting specification. The reason is that the route between melting and casting is not chemically passive. Decarburization, oxidation of accompanying elements, reduction reactions, deoxidation practice, slag carry-over and alloy recovery all influence how much of the charged alloying value finally remains in the steel. A production route wide model is required to account for these effects consistently.

# 02 CHOOSING THE IDEAL ALLOYING STRATEGY

High-alloy steel producers can usually follow two technically feasible alloying strategies. One option is to introduce a larger share of alloying elements through higher-alloyed scrap in the EAF charge. This may increase the initial furnace charge cost, but the melt already contains a significant share of the required chromium, nickel or molybdenum after melting, reducing downstream ferroalloy additions. The alternative is to use a lower-alloyed charge and add the required alloying elements later in secondary metallurgy. This may reduce EAF charge cost, but increases downstream alloying demand.

Neither strategy is generally superior. The economically best solution depends on the current boundary conditions, including scrap and ferroalloy prices, material availability, raw material analyses, oxidation losses, slag reactions, recovery rates, energy and $CO_2$-related costs, process constraints and final grade requirements. A material that appears expensive in the EAF charge can still reduce total route cost if it replaces more expensive downstream alloying additions or improves recovery. Conversely, a cheaper charge can become more expensive if it creates additional correction demand or unfavorable metallurgical conditions later in the route.

This makes alloying strategy optimization a dynamic problem. If alloyed scrap is available at attractive prices, it may be preferable to bring alloying value into the process early. If ferroalloys are cheaper or alloyed scrap is limited, the optimum may shift toward later alloying. The best strategy can therefore change from one grade to another, from one campaign to the next, or even from day to day as market prices, inventories and production constraints change.

Static recipes and isolated charge calculations cannot fully reflect this situation. They may be technically feasible, but they represent a historical compromise rather than the best decision under current conditions. This is particularly relevant in high-alloy steel production, where small changes in the strategy for chromium, nickel or molybdenum can have a significant impact on total production cost.

Route-wide optimization addresses this limitation by continuously recalculating the best raw material and alloying strategy based on the actual economic and metallurgical situation of the plant. It evaluates not only the EAF charge, but the complete route to the final specification, including material cost, recovery, reactions, downstream alloying demand and process constraints.

> The best alloying strategy is not fixed by recipe; it depends on the current balance between scrap value, ferroalloy cost, recovery, process constraints and final grade requirements.

# 03 COMBINED CHARGE AND ALLOYING STRATEGY OPTIMIZATION

Combined optimization of the charge and alloying strategy treats the complete production route as one connected metallurgical and economic system. Instead of calculating the EAF charge and downstream alloy additions separately, qontrol MAPS evaluates all relevant decisions together.

The optimization considers real-time data about raw materials, alloying materials, fluxes, energy input, $CO_2$-related costs, material availability, target chemistry, process limits and metallurgical reactions. These include oxidation reactions, deoxidation reactions, slag reduction reactions, element recoveries and process-specific losses. The result is not only a feasible EAF charge, but a complete raw material and alloying strategy for the full route.

The system can evaluate, for example, whether chromium should be introduced through alloyed scrap in the EAF or through ferrochrome additions later. It can also evaluate whether nickel-bearing scrap is more attractive than later nickel alloying, or whether a certain scrap mix creates additional downstream cost due to correction requirements.

The optimization target is therefore not the minimum raw material purchase cost of one process step. The target is the lowest feasible total cost to reach the final grade specification. This includes the cost consequences of all upstream and downstream decisions.

This changes the role of raw material optimization. It is no longer a preparation step for the furnace. It becomes a strategic decision model for the full melt shop route. The model supports production planning, metallurgical engineering and purchasing with one consistent economic and metallurgical view of the available material base.

In this context, qontrol MAPS acts as a connected raw material decision system. It can manage stock raw materials and virtual raw materials, consider current prices and availability, receive production orders, and calculate a charge and alloying strategy based on the actual requirements of the selected order. This enables the optimization to be linked directly to the production context rather than being performed as an isolated engineering calculation.

> Route-wide optimization does not calculate the cheapest furnace charge; it calculates the lowest-cost feasible path from raw material selection to final specification.

# 04 PRACTICAL EXAMPLE: EN 1.4307 / AISI 304L

A practical example was evaluated for the stainless steel grade EN 1.4307 / AISI 304L at a European stainless steel producer. Historical production data showed that the chromium content at the EAF varied significantly between individual heats. Each heat followed its own chromium path through the downstream route until the final specification was reached.

In conventional operation, these different paths were accepted as part of normal production practice. Some heats entered the downstream route with relatively high chromium content and required less additional alloying. Other heats started at lower chromium levels and required stronger correction later. All heats could eventually reach the final grade specification, but not at the same total material cost.

The production route wide optimization model evaluated the same production task with a different objective. Instead of only checking whether the route could reach the final chromium target, it calculated which combination of EAF charge and downstream alloying strategy would reach the target at the lowest feasible total material cost, as illustrated in **Figure 2**.

> Comparable chromium contents at the EAF can lead to significantly different material costs when the complete alloying path is not optimized.

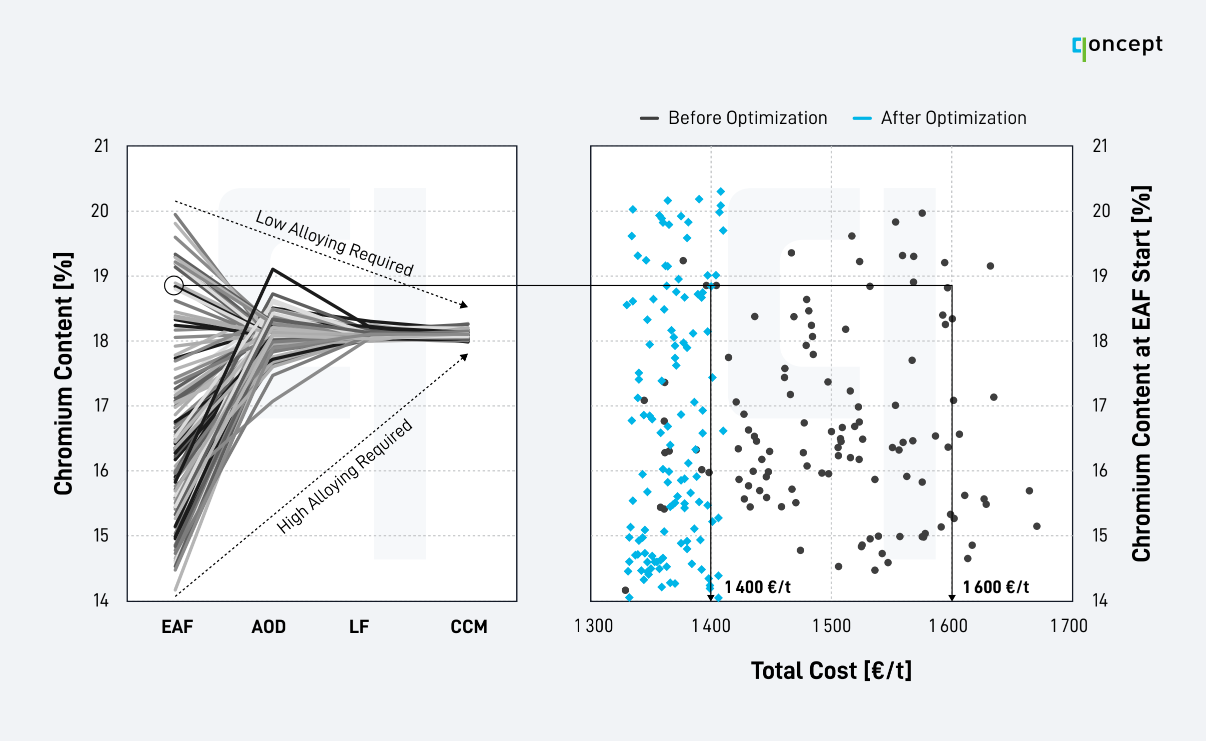


**Figure 2:** Chromium Paths and Total Material Costs for Individual Heats Before and After Optimization. Each Line on the Left and Each Data Point on the Right Represents an Individual Heat. Comparable Chromium Contents After the EAF Can Result in Large Cost Differences, Which Are Substantially Reduced by the Route-Wide Optimization Model.

The result showed a clear economic effect. In the historical operation, comparable chromium contents after the EAF could still lead to large differences in total material cost. In other words, two heats starting from a similar chromium level could end up with significantly different cost outcomes because the selected raw material and alloying strategy was not economically optimized across the full route.

After optimization, the same heats were concentrated in a much narrower cost window. This demonstrates that the model does not only reduce average cost. It also reduces cost scatter and makes the economic result of production more predictable.

This is one of the key advantages of route-wide optimization. It makes visible where cost variation is created and converts that knowledge into a more consistent operating strategy. The model does not simply replace one fixed recipe with another. It calculates the best alloying path for the actual situation, considering the cost and recovery implications of decisions made at each process step.

# 05 INDUSTRIAL IMPLEMENTATION AND IMPACT

Route-wide raw material and alloying strategy optimization creates the highest value if it is integrated into the daily production workflow. In industrial implementation, qontrol MAPS exchanges data with higher-level systems such as ERP, MES, production planning, material management, laboratory and automation systems. Typical input data include production orders, steel grades, target compositions, raw material master data, current stock levels, material prices, energy prices and available process constraints.

Once a production order is available, the system uses the current production context to calculate the cost-optimal raw material and alloying strategy. The optimization result includes detailed information about the type and quantity of all raw material additions, melt composition and temperature, slag mass and composition as well as energy consumption and $CO_2$ emissions for each production step along the complete production route. After review and confirmation, the result can be assigned directly to the production order and transferred to the operational execution level.

For the operator, the complexity of the process interactions is translated into clear and executable instructions. Instead of manually combining material availability, prices, target chemistry, recovery assumptions and downstream alloying demand, the user receives a structured recommendation that reflects the current technical and economic boundary conditions. This reduces manual planning effort and supports more consistent decisions across shifts, campaigns and changing market conditions.

The industrial impact is a shift from local cost minimization to total route optimization. The main benefits are lower total material cost, reduced alloying cost, better use of alloyed scrap, reduced cost scatter between heats, improved coordination between EAF and downstream metallurgy, and more transparent decision-making under changing plant and market conditions.

The system does not replace metallurgical expertise. It makes metallurgical expertise more effective by providing a structured calculation framework for complex interactions between raw material cost, chemistry, recovery, slag reactions, energy, process constraints and final product quality. The industrial value is therefore not only the calculated saving per heat, but the ability to make the right decision repeatedly and consistently under real production conditions.

> Industrial value is created when route-wide optimization is connected to real production orders, current material data and automatic data exchange with existing plant systems.

# 06 CONCLUSION

For high-alloy EAF steel production, the economically best raw material strategy cannot be determined by looking at the furnace charge alone. Alloying value moves through the complete production route. Chromium, nickel, molybdenum and other elements can be introduced at different stages, with different costs, recoveries and metallurgical consequences.

The cheapest EAF charge is therefore not necessarily the cheapest route to the final grade. The relevant optimization target is the lowest feasible total cost across the complete process route.

Route-wide raw material and alloying strategy optimization provides a method to solve this problem. It combines material prices, availability, chemistry, metallurgical reactions, process constraints, energy and $CO_2$-related costs in one connected model. The result is a dynamic decision basis that adapts to changing plant and market conditions.

The practical example for EN 1.4307 / AISI 304L shows that historical operation can lead to large cost variation even for comparable chromium levels after the EAF. By optimizing the complete route, this cost scatter can be substantially reduced.

The main conclusion is simple: in high-alloy steel production, cost leadership is not achieved by optimizing isolated process steps. It is achieved by optimizing the full metallurgical route from raw material selection to final grade specification.

> In high-alloy steelmaking, cost leadership is achieved by optimizing the full metallurgical route, not by optimizing isolated process steps.

# challenge us

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