

HICON/H₂[®] BRIGHT ANNEALING PROCESS TECHNOLOGY FOR COPPER AND BRASS STRIP AND WIRE COILS¹

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Abstract

In 1975, EBNER introduced and patented the HICON/H₂[®] bright annealing process for the heat treatment of brass, which revolutionized annealing technology and established itself as the world's leading bell annealer system. The deciding factors in this continued success have been the excellent quality of copper and brass strip coils annealed in 100 % hydrogen, paired with the shortest heating/cooling times and the lowest operating costs. The continuous, customer-oriented development of facility and process technology, the high-quality, precision fabrication of key components in EBNER's in-house workshops, and the resulting high levels of facility availability and economy are recognized throughout the world and form the basis for future development. The challenge for the future is to integrate the high-quality HICON/H₂[®] bell annealer facility, tailored to the latest market and product developments and providing the best price/performance ratio, into a customer's production sequence and to thereby make a meaningful contribution to the success of a customer's company.

TECNOLOGIA DE PROCESSO DE RECOZIMENTO BRILHANTE DE COBRE E LATÃO EM BOBINAS DE TIRAS E ARAME USANDO HICON/H₂[®]

Resumo

Em 1975, a EBNER introduziu e patenteou o processo HICON/H₂[®] de recozimento brilhante para o tratamento térmico de latão, que revolucionou a tecnologia de recozimento e se firmou como líder mundial de fornos tipo sino. Os fatores decisivos neste contínuo sucesso foram a excelente qualidade das bobinas de cobre e latão recozidos em uma atmosfera 100% hidrogênio, caracterizados ainda com os mais curtos tempos de aquecimento e resfriamento, e dos mais baixos custos operacionais. O desenvolvimento contínuo baseado nas necessidades dos clientes, tanto da instalação como da tecnologia de processo, a fabricação de componentes-chaves nas fábricas da EBNER, a disponibilidade e a economia são reconhecidos no mundo inteiro e formam a base para desenvolvimentos futuros. O desafio para o futuro é a integração da alta qualidade dos fornos sino HICON/H₂[®] adaptados aos últimos desenvolvimentos de mercado e produtos, com a melhor relação preço/produzibilidade dentro da seqüência de produção dos clientes e com isso contribuir significativamente para o sucesso das empresas dos clientes.

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1 INTRODUCTION

HICON/H₂[®] bell annealer technology was just EBNER's first step in advanced engineering to combine hydrogen process atmosphere with high-convection recirculation to achieve considerable improvements in quality and performance compared to conventional annealers.

In the early years, a mixed gas consisting of 25 % hydrogen, balance nitrogen was employed as process atmosphere, mainly for cost reasons. The current trend is to anneal in straight hydrogen. Due to the supply network that the process atmosphere suppliers have built up, the price - particularly of hydrogen supplied in cylinder batteries - has come down quite considerably.

Because of its high heat conductivity, using straight hydrogen as process atmosphere ensures rapid and uniform heating up and cooling of the charge, increasing the throughput of the heat treatment facility.

The power consumption of the workbase fan is reduced remarkably, by a ratio of 4:1. The energy costs won back with this process fully compensate for the higher cost of the hydrogen. In comparing two anneals where the cost factor is constant, an anneal in straight hydrogen yields an increase in throughput of 15 to 20 % during heating up and between 20 to 40 % during cooling.

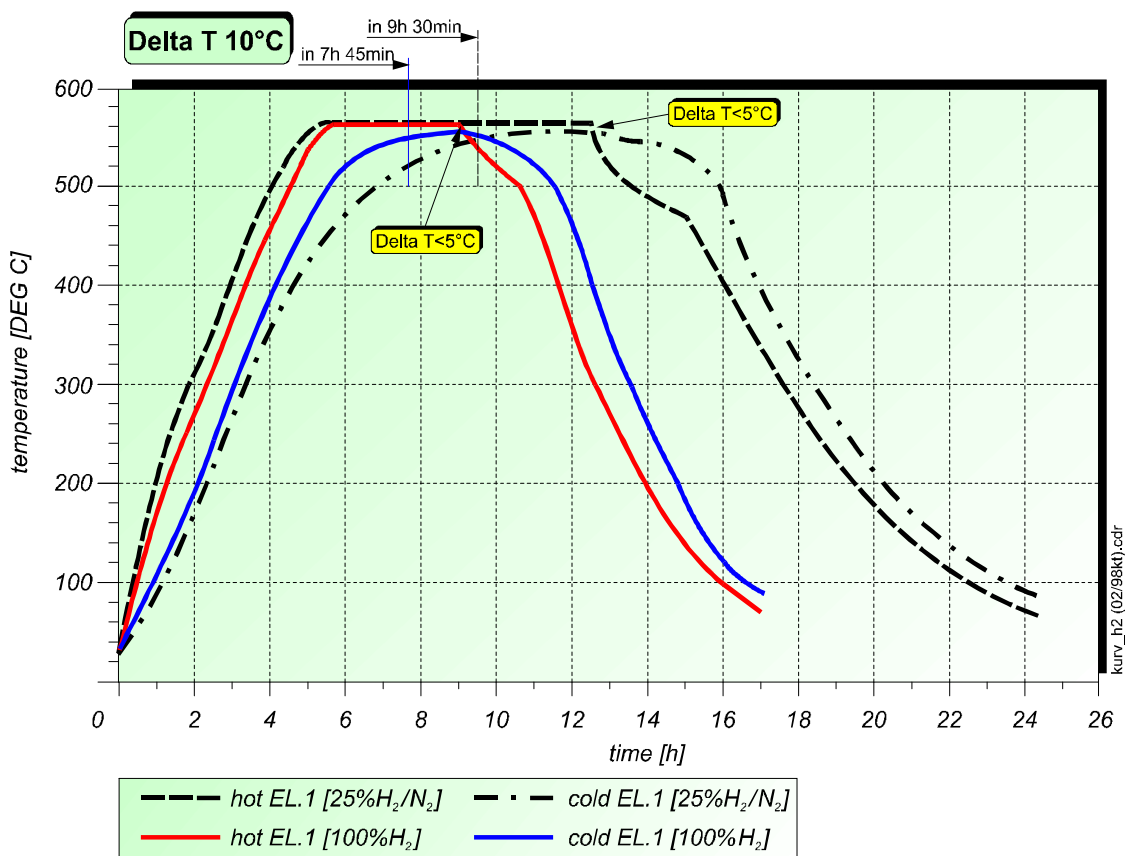


Figure 1: Annealing time comparison for two identical charges between 100% H₂ and 25% H₂/75% N₂.

Annealing can be carried out in straight hydrogen providing conditions prior to annealing allow it (e.g. deoxidized copper grades with very low or zero oxygen content). Compared to anneals carried out in standard process atmosphere

containing 0.5 to 5 % hydrogen, an anneal in straight hydrogen can achieve an increase in throughput of up to 50 %.

In addition to HICON/H₂[®] facilities drastically increasing throughput, using straight hydrogen dramatically reduces the noise level of the workbase fan motor.

Our experience with over 730 HICON/H₂[®] workbases annealing copper alloys is a result of guaranteeing these advantages.



Figure 2: overall view of facility / S&T Copper, Taiwan.

2 FACILITY COMPONENTS

Over the years the HICON/H₂[®] facility components have been subjected to ongoing development in order to maintain the following:

- ⇒ high throughput
- ⇒ low investment, operating and maintenance costs
- ⇒ best as-annealed mechanical and surface properties
- ⇒ maximum safety

Before newly developed components were released for incorporation in the HICON/H₂[®] concept, they were tested in our full-scale laboratory annealers, and were on trial for at least one year at selected customers' facilities.

Workbase

The heart of the HICON/H₂[®] facility is the workbase with its three key features:

- ⇒ high-convection fan, now with variable frequency drive and a rating of around 140 000 m³/h
- ⇒ sturdy, combined load plate with incorporated intake and outlet diffuser assembly for optimal fluid flow
- ⇒ all-metal encapsulated workbase insulation for absolute safety and lowest dewpoint

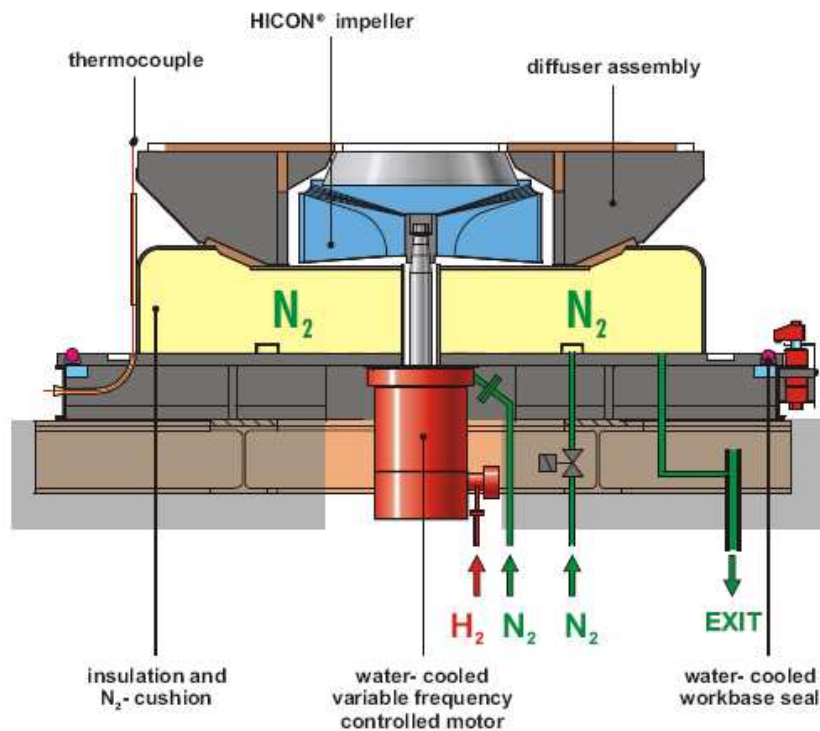


Figure 3: cross section of HICON/H₂[®] workbase.

Long service life is achieved for all our workbases and there has never been a safety problem nor an explosion.

Heating bell, combustion system and recuperator

Two-stage high velocity burners which do not require burner blocks are made of heat resistant steel castings, with the inner combustion chamber and primary air supply, and the flame outside where secondary air is fed in. This burner has a very long service life; the only wear parts are the ignition and ionization electrodes. Both the flame temperature and the NO_x output are reduced by splitting the combustion sequence into two stages. The velocity of the flame is still very high so as to create favourable circulation and convection around the outside of the inner cover.

The heating bell lining is entirely made up of fibre insulation blankets and modules, even around the burners. Due to the increase in convection within the workload space mentioned earlier, the connected supply per ton of material to be annealed, especially for medium size facilities, could be increased to such an extent that performance has increased by up to 25 %. At the same time though, energy

consumption has been reduced considerably due to the new design of burner and the large central recuperator.

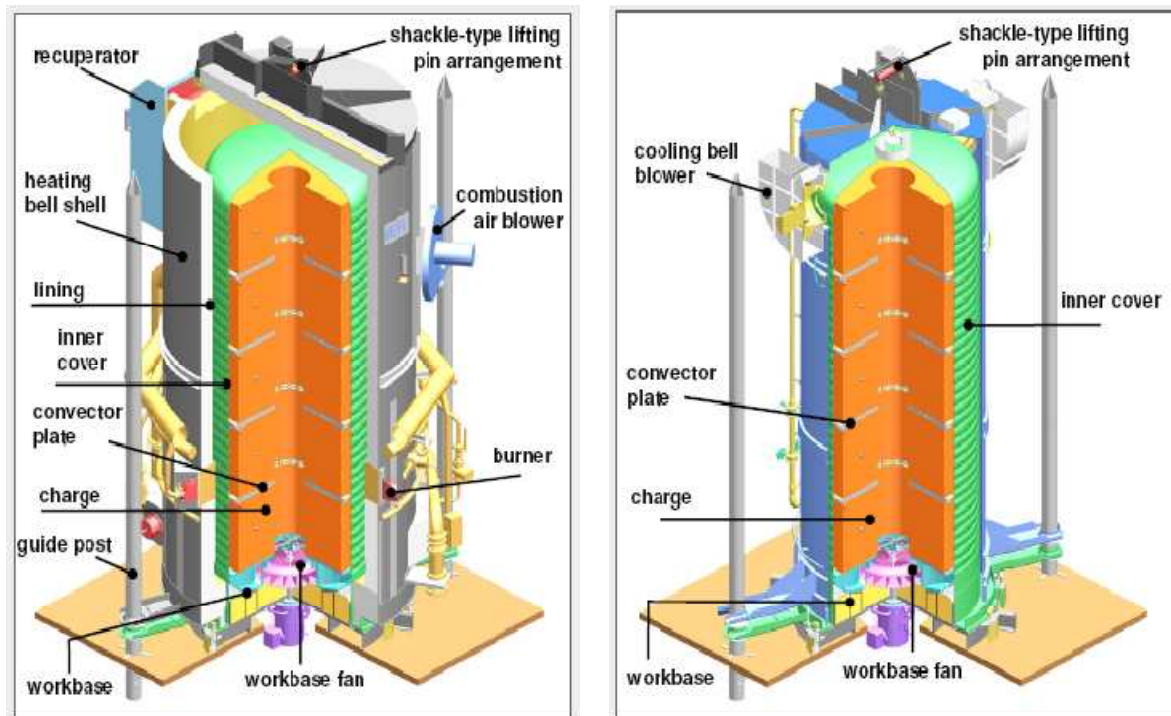


Figure 4: cross section through a HICON/H₂[®] bell annealer facility

Inner cover and cooling bell

The inner covers manufactured by EBNER of high alloyed heat resistant CrNi steel are corrugated on a special rolling machine developed in-house. A service life of over 1000 cycles is achieved with this specially manufactured inner cover when used with a combined air/water cooling system.

The service life of an inner cover depends not just on the way that it is manufactured, but also on the cooling process employed. At the end of air cooling the workbase fan must be switched off so that the temperature of the inner cover can be reduced further still before the water cooling system is switched on. We have developed a water spray system which completely covers the inner cover without bubbles forming. This system has proven highly successful worldwide over many years and achieves very short cooling times while maintaining the long service life of the inner covers.

3 DESCRIPTION OF BRIGHT ANNEALING PROCESS

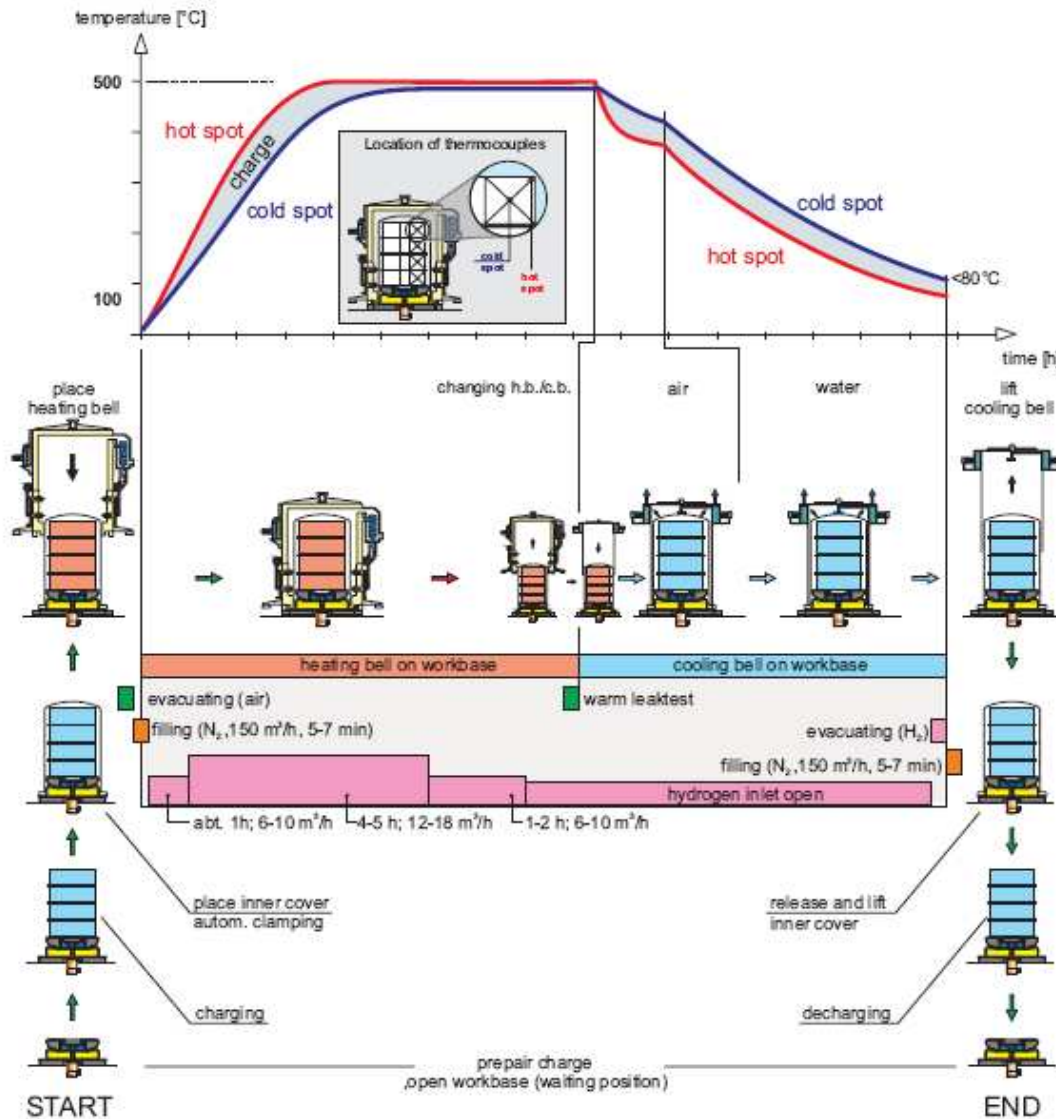


Figure 5: HICON/H₂[®] process sequence

Once a workbase has been charged with strip, with convecter plates sandwiched between or wire coils charged on coil carriers, an inner cover is placed on the workbase. Next, the inner cover flange is clamped down on the seal element in the workbase by a hydraulic clamping mechanism. After that, a vacuum pump removes the air in the workload space, which is then filled with nitrogen before purging with process atmosphere starts.

At this point, a heating bell can be placed on the workbase and a suitable annealing program, annealing temperature and soaking time depending on the alloy to be annealed, the mechanical properties desired, the condition of the material before annealing and the weight and dimensions of the charge can be selected and are transmitted to the workbase PLC before the operator can start the anneal.

The high-performance atmosphere recirculation system ensures that the coils are heated through uniformly, as a result of which exceptionally consistent mechanical properties and grain size are achieved through-out the entire charge.

At the end of the heating phase the heating bell is lifted off the workbase, a cooling bell is placed over the hot inner cover and the charge is cooled down to a core temperature of less than 100°C with a combined air/ water cooling system.

At the start of cooling the axial-flow blowers at the top of the cooling bell draw cold air up from below over the hot inner cover. This cools the cover surface down far enough to avoid any risk of thermal shock when water is then sprayed over it, extending its service life.

The initial air cooling phase also prevents excessive steaming when water is sprayed over the cover. Convection inside transfers heat to the inner cover, where the water flowing over it removes heat rapidly.

At the end of cooling, the workload space is vacuum purged and filled with nitrogen, the cooling bell and inner cover are lifted off, the charge is removed and the workload space made ready for the next anneal.

A PLC controls and supervises the annealing process. Digital data I/O is via remote electronic terminators at workbase and heating bell. Apart from charging and discharging the workbases and shifting the inner covers, heating and cooling bells, the whole process is controlled automatically.

The facility is operated from the central operating system (COS). From then until the end of the anneal, no further inputs or commands are required from the operator. Important information can easily be called up directly at the visualization system in order to obtain a good overview of the facility status. Manual interventions are possible to correct the automatic processing sequence without affecting any safety functions. Splitting the system up into sub-levels eliminates the possibility of commands being duplicated. For quality assurance purposes, every process step is logged automatically in chronological order and these records are then archived.

4 EXPERIENCE WITH THE BRIGHT ANNEALING PROCESS

Great attention must also be paid to the preparation of material to be annealed. The material can be optimally prepared for annealing by ensuring that there are no surface tool marks after milling, or other marks from cold working, that a clean lubricant (coolant) has been applied in the right quantities, and that the correct operating temperature and sufficient reduction have been achieved during rolling or drawing, at the correct speeds, that the coil has been formed tightly, with the lowest possible winding tension (without telescoping). If suitable charging aids are then used with compatible handling equipment, nothing else can stand in the way of a successful anneal (recrystallization anneal, temper, stress relieving anneal).

4.1 Strip

Experience has shown that it is almost impossible for a mill operator to optimally fulfill all the requirements made on the material before annealing as mentioned above. The reason for this is what I call the insecurity factor: the human being. Traditional thinking and methods that tend to find the easiest route make it difficult, in fact almost impossible, to ensure that the starting material conditions required can be achieved with a degree of repeatability. The second and at the moment most common reason for strips to have to undergo post anneal treatment (pickling), even if the visual appearance of the strip's surface finish is perfect, is that it is to be used in the electronics industry. This just means that strips which are final annealed in an EBNER annealer have to be pickled if the end product requires this process. This does not, however, apply to process annealed strip, the quality of which is much more straightforward to achieve.

This does not quite coincide with what we were saying 20 or even just 10 years ago. Humans being what they are and newly-developed methods of manufacturing the final product have however forced this step to be taken. However, the advantages of the HICON/H₂[®] system remain indisputable. The uniform mechanical properties and excellent surface finish, unobtainable by any other annealing process, combined with low running costs, make this the most cost-effective and flexible annealing system. The high flexibility of the HICON/H₂[®] annealer facility is displayed in particular by the fact that it is possible to anneal different alloys on different workbases simultaneously. This means that anything from standard copper grades through to special alloys (for example with high alloying elements such as Mn, Si or beryllium that have a high affinity to oxygen) can be annealed optically free of oxidation due to the high reduction potential of the process atmospheres that we use. The result is a surface finish which makes subsequent processing considerably easier and cheaper.

4.2 Wire

The difficulties in achieving a clean, oxide-free and spotless wire surface are similar to those of strip, although with wire, the drawing die itself is the best lubricant remover. Improved drawing lubricant and optimized drawing technology have solved the well known problems of nipping and rattling caused by insufficient lubricant, so that bright wire can be drawn trouble-free.

It is possible, and is standard practice, to draw wire with a diameter of 3 mm onto spools with a net weight of 2 tons, wire with a diameter of up to 1 mm onto spools with a net weight of 1000 kg, and wire with a diameter of up to 0.5 mm onto spools with a net weight of up to 500 kg, to ensure that subsequent bright annealing and further processing can be carried out without problems. This is of major significance for the final manufacturing step of the product that is to be made from this wire because the time between changing the feed coils at the automated cold heading machinery is greatly increased.

4.3 Economics

As we have seen in the previous diagrams, using 100% hydrogen increases input by around 20% for brass, or up to 50% for copper. The following table goes into greater detail on the comparison of the specific energy consumption costs for annealing in straight hydrogen, or a mixed gas consisting of 25% H₂, balance nitrogen.

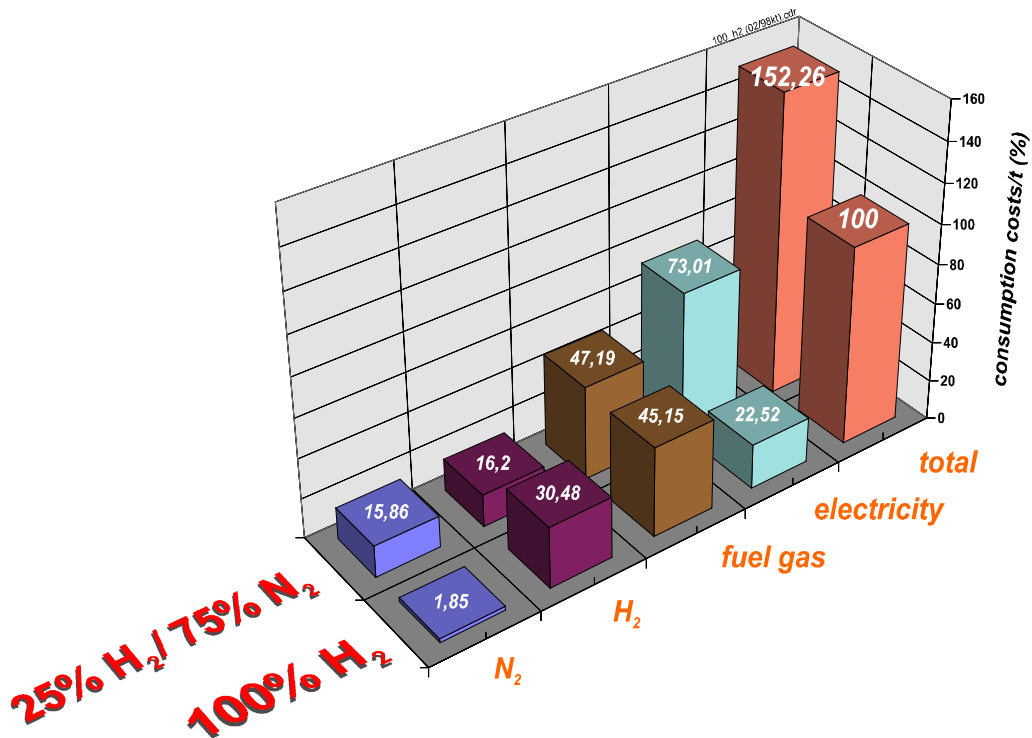


Figure 6: Energy costs comparison between 100%H₂ and 25%H₂/75%N₂

So the effective annealing costs are up to 50 % higher depending on exact energy costs and the alloy to be annealed. These are similar figures to those achieved in countries such as Germany or Japan. It is also worth mentioning the difference in investment cost due to the unnecessary process atmosphere mixing facility, and the savings due to the lower space requirements.

For copper anneals the difference between less than 5 % hydrogen and 100 % hydrogen is even greater, particularly regarding throughput.

4.4 Reducing environmental impact

Modifying or avoiding pickling means the expenditure of disposing utilities is reduced considerably or avoided totally.

The condensates that evaporate from the charge surface during heating up are vented with the hydrogen to an outburner in the heating bell where they are burnt off. Higher level hydrocarbons can still condense out however, and they are then collected in a condensate trap.

Lower energy consumption and two-stage high-velocity burners result in lowest CO₂ and NO_x emissions.

5 CONCLUSION

More than 30 years of experience have shown that the HICON/H₂[®] bell annealer is the most suitable annealing unit for the oxide-free heat treatment of copper and copper alloys.

It is also possible to fulfill the highest demands on mechanical properties of annealed wire due to the improved temperature control in high convection annealers processing in hydrogen.

It can also be claimed that annealing in hydrogen actually cleans the charge surface, because the contamination on the surface is considerably lower than for a nitrogen anneal. This is advantageous in the subsequent processing of the annealed wire.

The quality of the products can further be improved by fine-tuning the pre-anneal process steps.